The American Ceramic Society

12th International Conference on HTCMC and 3rd GFMAT for Sustainable Development

ABSTRACT BOOK

May 31 – June 5, 2026
San Diego, California, USA

Please note- this abstract book was up to date as of May 1, 2026. SThere may have been slight changes or withdrawn abstracts. It is always best to consult the on-line planner (coming soon) for the most up to date schedule.

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Introduction

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How to Use the Abstract Book

Refer to the Table of Contents to determine page numbers on which specific session abstracts begin. At the beginning of each session are headings that list session title, location and session chair. Starting times for presentations and paper numbers precede each paper title. The Author Index lists each author and the page number on which their abstract can be found.

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Monday, June 1, 2026

Plenary Session

Plenary Presentations

Room: Silver Pearl 1-3
Session Chairs: Mrityunjay Singh, Ohio Aerospace Institute; Tatsuki Ohji, Yokohama Kokuritsu Daigaku

8:45 AM

(PLEN-001-2026) Modernizing nuclear power with ceramic matrix composites (Invited)

C. A. Back*[1]

1. General Atomics Electromagnetic Systems Group, USA

Nuclear energy is at a crossroads. Aging technology from the 50s and the surging need for sustained, reliable power to feed the growing artificial intelligence demands are driving a reexamination of what it means to be a modern nuclear power plant. Faced with reactor plant retirements, the industry is taking advantage of new materials to extend and enhance the lifetime of current reactors. This path for current and advanced reactors is enabled by the powerful advances in modeling and simulation that are used in conjunction with prototyping and testing to efficiently adopt new materials in this highly regulated industry. In this plenary we will examine the advances underlying the customization of composites for nuclear energy applications. Using SiC composites for nuclear fuel rods as an example, the presentation will provide an overview of the fabrication methodology, advanced characterization methods, importance of engineered design, and prototypic testing necessary for efficient and informed adoption of ceramic matrix composites. From the harsh environments of a nuclear reactor to those in aerospace, hypersonic and space applications, CMCs can be engineered to play an expanding role because of their resistance to high temperature and high stress.

9:30 AM

(PLEN-002-2026) Advances in research and development of ceramic matrix composites: Current Japanese scenario (Invited)

Y. Kagawa*[1]

1. Tokyo University of Technology, Katayanagi Laboratory, Japan

This presentation provides an overview of recent advancements in the research and development of Ceramic Matrix Composites (CMCs) and Environmental Barrier Coatings (EBCs), with a particular focus on progress achieved in Japan. The discussion will address CMC systems for aircraft engines- such as SiC/SiC and oxide-oxide (Ox/Ox) composites- as well as SiC/SiC composites designed for nuclear applications. Significant developments include the emergence of next-generation SiC fibers and thermally robust Ox/Ox composites produced by Japanese manufacturers, which are approaching commercialization. In the area of manufacturing technologies, major domestic heavy industry companies have adopted distinct strategies to produce high-performance CMCs optimized for specific application environments. The presentation will also highlight key achievements from the Center for Ceramic Matrix Composites (CCMC) at Tokyo University of Technology. Additionally, the talk will introduce innovative experimental methodologies developed at the CCMC for reliability assessment, including advanced X-ray-based techniques, and will present new insights derived from their application. The presentation will conclude with an outlook on the future trajectory of CMC and EBC technologies, identifying technical challenges, emerging opportunities, and directions for further practical implementation.

10:35 AM

(PLEN-003-2026) Progress in the development of SiC CMC composites for extreme environments in Korea (Invited)

J. Park*[1]

1. Sewon Hardfacing Co. Ltd., Republic of Korea

SiC ceramics have emerged as a candidate material for a variety of applications in extreme environments characterized by high temperatures and high radiation. In particular, SiC_f reinforced composites are expanding their application as structural materials as they can compensate for the catastrophic failure. SiC_f composites are composed of fibers, interfaces, matrix, and coating layers, and therefore, various manufacturing processes can be attempted to obtain appropriate properties, which greatly influences the range of applications of the composite. In Korea, the development of SiC composites for use in high-temperature gas turbine engines and nuclear reactor core components has been ongoing for over 20 years, focusing on manufacturing process development. Composite matrix development, including CVI, LS(M)I, PIP, HP, and hybrid processes, has progressed to the point where it can be applied to actual shapes. The resulting EBC and TBC technologies, focusing on material development and coating processes, have also reached the stage of being applied to actual parts. This presentation will briefly summarize the technological progress, the current technological status, and future prospects in the development of SiC_f composites for use in extreme environments in Korea.

11:20 AM

(PLEN-004-2026) Advanced ceramics for stationary storage and CCU (carbon capture and utilization) technology (Invited)

A. Michaelis*[1]

1. Fraunhofer IKTS, Germany

Advanced ceramic materials offer enormous potential for innovations in the fields of energy conversion and storage as well as decarbonization. To cope with the fluctuation of renewable power (PV and wind) batteries (short term storage for arbitrage) and electrolysis (long term "seasonal storage) for green hydrogen production is needed. We present NaNiCl solid state batteries as a Li-free and safe technology for short term storage and latest results on SOE (solid oxide electrolysis) for green hydrogen production. Furthermore, SOE can be employed as a powerful technology for highly efficient CCU applications. For this, SOE is used in the co-electrolysis mode for the simultaneous production of H_2 and CO, so called syngas. In the co-electrolysis mode, CO_2 is actively removed from the environment and fed into the SOE system. By the Fischer Tropsch processes this syngas can be transferred to e-fuels (such as SAF: sustainable aviation fuel), higher alcohols, and even waxes. We present a fully integrated co-electrolysis Fischer Tropsch System combined with ceramic gas separation membranes for the extraction of CO_2 from different sources such as exhaust gas from lime industry or biogas. We also present examples using SOE for combined CCU and CDA (carbon direct avoidance) applications in green steel production. Applying this technology, even allows to produce CO_2 "negative" steel.

GFMAT-3 Symposium 1- Powder Processing Innovation and Technologies for Advanced Materials and Sustainable Development

GFMATS1- Particle and powder design and synthesis

Room: Shorebreak 2
Session Chairs: Satoshi Tanaka, Nagaoka University of Technology; Junichi Tatami, Yokohama National University

1:30 PM

(GFMAT-S1-001-2026) Design and Surface Characterization of Hollow Particles toward Functionalization (Invited)

C. Takai-Yamashita*[1,2]

1. Nagoya Kogyo Daigaku, Japan
2. Tohoku Daigaku, IMRAM, Japan

Hollow particles have attracted significant attention in powder and materials science due to their unique structural features. To fully exploit these advantages, an integrated framework combining structural design and surface characterization is essential. By controlling hollow structures at the powder design stage, we have demonstrated functional composite films exhibiting thermal insulation and optical transparency. This presentation introduces recent advances in hollow particle design focusing on multiscale structural control. While such structural parameters strongly influence material performance, structural control alone is not sufficient. Functionalization requires proper evaluation of surface physicochemical properties that directly interact with surrounding environments. In particular, the inner and outer surfaces of hollow particles play distinct roles and must be evaluated independently. Surface-sensitive characterization methods are therefore employed. In addition to conventional techniques, time-domain nuclear magnetic resonance (TD-NMR) provides non-destructive insights into surface affinity and interfacial dynamics, enabling differentiation of inner and outer surface contributions. By correlating structural and surface parameters, a clear design–characterization–function relationship can be established, guiding the development of functional powder materials.

2:00 PM

(GFMAT-S1-002-2026) Stimuli-Responsive Nanocarriers for Tumor Specific Accumulation (Invited)

S. Ilyas*[1]; S. Mathur[1]

1. University of Cologne, Institute of Inorganic and Materials Chemistry, Germany

The tumor microenvironment (TME) represents a highly complex barrier that fundamentally limits effective drug accumulation and therapeutic response. Tumor-specific accumulation of nanocarriers and on-demand drug transport, therefore, remains a major challenge medicine, particularly for hard-to-target diseases. This presentation focuses on how stimuli-responsive nanocarriers can be engineered to address these barriers and how surface conjugation strategies significantly enhance cellular uptake and tumor accumulation while remaining non-toxic to immune cells. Our data demonstrate that surface ligands, (e.g., folate and antibodies), enable receptor-specific binding and internalization with precise quantification and control of ligand density being critical for effective and selective targeting. The surface conjugation chemistry strongly influences drug release kinetics and pharmacological behavior, particularly for hydrophobic drugs that dominate current anticancer pipelines. In addition, biocompatible surface modifications and controlled polymer engineering (e.g., polyethylenimine (PEI) promote internalization and systemic stability while mitigating polymer-associated toxicity. Together, our data establish a chemical design framework for precision therapeutics with improved efficacy potential for diseases where standard managements options remain inadequate.

2:30 PM

(GFMAT-S1-003-2026) From high purity alumina to fully dense ceramics

J. Fourcade*[1]; A. Vivet[1]; J. Otto[1]

1. Baikowski SAS, France

Alumina is commonly used for the manufacturing of technical ceramics and composites. An in-depth review of ceramic manufacturers data sheets for alumina ceramics shows materials that range from 80% to 99.9% Al_2O_3. These materials have different densities, typically from 3.4 to 3.9 g/cc, and properties. In this work, we focused on alumina products with purity beyond 99.5% (2.5N) and we propose summarizing the physical, thermal and mechanical properties of these ceramics. Then we looked at the role played by alumina powders on these properties and how we can modify these powders to optimize densification, to better control grain growth and to tune material properties. We compare performances for different high purity alumina powders and introduce the role of some dopants such as MgO and ZrO_2. Finally, we will show how we can continue to manufacture great high purity powders with respect for the environment.

3:10 PM

(GFMAT-S1-004-2026) Ag^+ Superionic Conductors Derived from Silver Iodide and Silver Oxyacid Salts

Y. Matsushima*[1]; R. Kawanago[1]; K. Uchida[1]; M. Yamamoto[1]; C. Matsushita[1]; N. Oishi[1]; S. Yin[2]

1. Yamagata University, Applied Chemistry, Chemical Engineering, and Biochemical Engineering, Japan
2. IMRAM, Tohoku University, Japan

Solid electrolytes are promising materials for next-generation energy storage devices such as all-solid-state batteries. Among inorganic solid electrolytes, several silver compounds exhibit exceptionally high ionic conductivity reaching 10^{-1} S/cm at room temperature. Understanding such high-ion-conductivity materials provides crucial insights into designing new high-performance solid electrolytes. In this study, we systematically investigated the synthesis conditions of Ag^+ superionic conductors derived from AgI and silver oxyacid salts, including the AgI-Ag_2CO_3 and AgI-Ag_2SO_4 systems that we recently discovered, as well as the AgI-Ag_2WO_4 and AgI-$Ag_4P_2O_7$ systems previously reported in the literature. These Ag^+ superionic conductors were prepared by thoroughly mixing AgI and silver salts in a mortar or ball mill, followed by heating at a moderate temperature of 100-300°C. The crystallographic phases and crystallinity of the prepared samples depended on the synthesis conditions. Crystal structure analysis revealed that immobile anions (I^- and oxyacid ions) form rigid flameworks within the crystal structures, while Ag^+ ions exist in a “liquid-like” state within the spaces between the anion frameworks.

3:30 PM

(GFMAT-S1-005-2026) Intercalation-Assisted Massive Phase Transformation

P. Gouma*[1]

1. The Ohio State University, MSE, USA

The self-propagating high-temperature synthesis (SHS) reaction mechanism for the formation of Cu, Fe, and Ni-based Chevrel phases from binary intercalation compound precursors was systematically investigated through a series of experiments using compositions of 4Cu:2Mo:4MoS_2, 2Ni:2Mo:4MoS_2 and 2Fe:2Mo:4MoS_2 under varying temperatures and reaction durations. These studies revealed a remarkable phase transformation driven by the intercalation of the ternary metal cations into the layered MoS_2 structure. This transformation mechanism, characterized by its rapidity and occurrence at relatively low temperatures, is distinct and has been termed “Intercalation-Assisted Massive Phase Transformation.”

It enables the SHS reaction to initiate and propagate efficiently within a short time frame, offering a novel pathway for the synthesis of high temperature, complex ceramics and cluster compounds.

GFMAT-3 Symposium 4- Crystalline Materials for Semiconductor, Optical/ Scintillator and Dielectric Applications

GFMATS4- Phosphor and sensor

Room: Sandpiper C

Session Chairs: Kevin Anderson, U.S. Naval Research Laboratory; Tetsuo Tsuchiya, National Institute of Advanced Industrial Science and Technology (AIST)

1:30 PM

(GFMAT-S4-001-2026) Flexible Sensor Development Using Phosphor Films with Photo-MOD (Invited)

J. Nomoto[1]; Y. Uzawa[1]; T. Tsuchiya*[1]

1. National Institute of Advanced Industrial Science and Technology (AIST), Japan

We developed a novel flexible sensor technology utilizing luminescent materials through the Photo-MOD method. Since luminescent properties respond to temperature and chemical environments, this approach enables non-contact and highly accurate monitoring. The technology incorporates a temperature sensor that detects shifts in luminescent spectra and intensity with temperature changes, as well as an anti-corrosion sensor that monitors luminescent intensity variations caused by corrosion reactions. Compared to conventional electrochemical sensors, this method achieves long service life and low maintenance, contributing to the health assessment of infrastructure structures. Furthermore, optical readout allows remote monitoring, making this technology a promising solution for building smart infrastructure.

2:00 PM

(GFMAT-S4-002-2026) Design of Long-Wavelength Emitting LED Phosphors (Invited)

K. Toda*[1]

1. Niigata University, Japan

Long-wavelength (yellow and red) phosphors based on oxides, oxynitrides, and nitrides doped with Eu^{2+} or Ce^{3+} have attracted significant attention for white LED applications. Many researchers have claimed that the redshift of 5d-4f emission in nitride phosphors correlates with the strong covalent nature of the Eu(Ce)-N bond. This study proposes a novel strategy for designing red-emitting oxide phosphors. Symmetrical octahedral sites are well-suited for large splitting of the 5d bands of Eu^{2+} and Ce^{3+} ions. For example, the olivine-type $NaMgPO_4$:Eu^{2+} phosphor with symmetric octahedral coordination is efficiently excited by blue light irradiation and exhibits a red emission band centered at 628 nm. Therefore, this new strategy (octahedral coordination sites for Eu^{2+} or Ce^{3+}) could serve as a versatile and powerful tool in the search for red-emitting phosphors. Acknowledgements This work was supported by JSPS KAKENHI Grant Number 23K17955 (Grant-in-Aid for Challenging Research(Exploratory)) and KEIT "Development of new yellow phosphor and ink for high-tech IT products"

2:30 PM

(GFMAT-S4-003-2026) Sol-gel composite materials for high temperature ultrasonic sensor applications (Invited)

M. Kobayashi*[1]

1. Kumamoto Daigaku, Japan

The sol-gel composite technique, initially developed at Queen's University in Canada, integrates a sol-gel solution with ceramic powders to produce thick, crack-free films. Following deposition, the films undergo heat treatment to form porous thick layers, wherein the ceramic particles are mechanically and chemically bonded to each other and to the substrate by a sol-gel-derived matrix. Owing to this controlled porosity, when ferroelectric powders are employed, the ferroelectric material itself concurrently serves as an active piezoelectric phase and as an intrinsic backing layer that suppresses spurious vibrations and ringing effects. Furthermore, the porous structure effectively mitigates thermal shock and accommodates the mismatch in the thermal expansion coefficients between the film and substrate, facilitating stable operation as ultrasonic sensors at elevated temperatures. In particular, a $LiNbO_3$ powder–TiO_2 and $SrCO_3$ sol-gel composite thick film exhibited clear ultrasonic echoes even at 1000 °C, demonstrating an excellent signal-to-noise ratio and thermal robustness. The design concept, fabrication process, poling behavior of various sol-gel composite systems, and their high-temperature ultrasonic performance are demonstrated.

3:20 PM

(GFMAT-S4-004-2026) Synthesis of Phosphor Materials by the Water-Assisted Solid-State Reaction (Invited)

K. Toda*[1]

1. Niigata University, Japan

Water-Assisted Solid-State Reaction (WASSR) exhibits unique properties: the addition of trace amounts of water enables solid-state reactions to proceed at low temperatures. In many cases, reactions occur below 500 K, allowing the synthesis of high-performance ceramics such as YVO_4:Eu^{3+} and Ba_2SiO_4:Eu^{2+}. This reaction differs from conventional mechanochemical processes in that no mechanical stress is applied beyond initial brief mixing. HRTEM observations confirm that nanocrystals react directly to form products, supporting that this process is a solid-state reaction rather than solution-mediated. The reaction mechanism of WASSR can be explained as follows. The solid acidic/basic properties of the raw materials strongly influence reactivity. We observe that adding water alters these properties, promoting neutralization reactions. Adding a small amount of water to the raw material powder forms a thin film on the particle surface. This water layer induces acid-base reactions at the interface, accompanied by localized exothermicity. This technology is gaining attention as a novel soft chemistry approach bridging solution-based and solid-state methodologies. Acknowledgement This work was partly supported by a project from KEIT "Development of new yellow phosphor and ink for high-tech IT products"

3:50 PM

(GFMAT-S4-005-2026) Development of hybrid gas sensors using low-dimensional carbon nanomaterials and oxide ceramic nanostructures with MOD mathod (Invited)

T. Sugahara*[1]

1. Kyoto Institute of technology, Faculty of Materials Science and Engineering, Japan

We are developing the hybrid gas sensor that combines low-dimensional carbon nanomaterials and oxide ceramic nanostructures using the metal-organic decomposition method. The hybrid gas sensor exhibits special gas sensing properties for VOC gases such as ethanol and 1-propanol. In this presentation, we would like to explore the gas sensing mechanism of the hybrid gas sensor, discussing its sensing properties and behavior in the gate effect.

4:20 PM

(GFMAT-S4-006-2026) Synthesis of Silicate Phosphors Using a Novel Solid-Gas Hybrid Technology (Invited)

K. Toda*[1]; W. Hikita[1]

1. Niigata University, Japan

This presentation reports a novel solid-gas hybrid synthesis technology for silicate phosphors using SiO as raw material. SiO vaporization was performed from silica raw material (or SiO powder) at temperatures above 1673 K under an Ar/H_2 reducing atmosphere. Heating the silica raw material (or SiO powder) under a strong reducing atmosphere generates gaseous SiO, which reacts with other raw material powders on the downstream substrate. This method yields high-quality crystalline growth powders primarily in the micrometer size range due to relatively slow nucleation. $BaSrSiO_4:Eu^{2+}$ phosphor was synthesized at 1673 K using this method. High crystallinity and sufficient size enabled single-crystal XRD analysis to determine the crystal structure and Eu^{2+} incorporation sites of the $BaSrSiO_4:Eu^{2+}$ phosphor. This result demonstrates the usefulness of solid-gas phase technology for single-crystal growth of phosphor materials. Solid-gas hybrid technology is a versatile and powerful method for synthesizing silicate-based phosphors with good crystallinity and growth characteristics. To our knowledge, such a solid-gas synthesis process for producing silicate phosphors with good growth properties has not been reported previously. Acknowledgement This work was supported by Keit, R&D project number: RS-2024-00434047, R&D project name: Development of new yellow phosphor and ink for high-tech IT products.

4:50 PM

(GFMAT-S4-007-2026) Bottom-up design and fabrication of thermoelectric nanomaterials (Invited)

K. Anderson*[1]; B. L. Greenberg[1]; A. G. Jacobs[1]; J. Wollmershauser[1]; B. N. Feigelson[1]

1. US Naval Research Laboratory, USA

Thermoelectric materials uniquely exhibit the Seebeck effect, enabling direct conversion of thermal energy to electricity. Improving the power conversion efficiency of thermoelectric materials is a long-standing challenge that must be addressed through the innovative design and fabrication of high performance materials with new combinations of architecture and composition. In particular, nanostructuring offers a promising avenue for inhibiting thermal transport and maximizing thermoelectric efficiency. In this work, novel core-shell nanocomposite materials were fabricated via a unique method incorporating particle atomic layer deposition (pALD) on nanopowders and subsequent Environmentally Controlled – Pressure Assisted Sintering (EC-PAS) to produce bulk solids. These materials feature fully dense, percolated networks of nanoscale semiconductor and insulating phases, enabling tuning of electrical and thermal conductivity. The iterative design approach, novel processing methods, and resultant microstructures will be discussed, along with effects on relevant thermal and electrical properties.

GFMAT-3 Symposium 6- Advanced Batteries and Supercapacitors for Energy Storage Applications

GFMATS6- Li-ion batteries- Electrode Materials I

Room: Tidepool 1
Session Chairs: Naoaki Yabuuchi, Yokohama National University; Mickael Dollé, Université de Montreal

1:30 PM

(GFMAT-S6-001-2026) Toward high-energy-density and safe lithium-ion secondary batteries (Invited)

S. Seo*[1]

1. Semiconductor Energy Laboratory Co. Ltd, Japan

Lithium-ion secondary batteries have become increasingly ubiquitous in our daily lives. However, with the increasing demand for higher energy density, numerous battery fire accidents have occurred in recent years, posing a serious social issue. To prevent battery fire accidents, various new technologies, such as all-solid-state batteries, are being researched and developed. Nevertheless, it is not easy to immediately replace existing production facilities for lithium-ion secondary batteries using organic electrolyte solutions with production facilities for all-solid-state batteries. Therefore, enhancing the safety of lithium-ion secondary batteries using organic electrolyte solutions, which can be manufactured using existing equipment, is a pressing issue. In particular, it is essential to resolve this issue for lithium-ion secondary batteries with high energy density for mobile applications. Given these circumstances, our team has been working on developing high-energy-density and safe lithium-ion secondary batteries. We have successfully fabricated a battery with an organic electrolyte solution that achieves high energy density while reducing the risk of fires by using a new LCO-based cathode active material, and we report our findings.

2:05 PM

(GFMAT-S6-002-2026) Surface-Enhanced Nickel-Rich Layered Cathodes by Cation-Disordered Rocksalt (Invited)

J. Kim*[1]

1. Stevens Institute of Technology, Chemical Engineering & Materials Science, USA

Energy-dense Ni-rich layered oxide cathodes can enable Li-ion batteries to power electric vehicles for longer distance. Employing Ni-rich cathodes to integrate battery cells, however, faces challenges in stabilizing surface structures at high state of charge due to irreversible phase transformations and crack propagation. To address this challenge, strategies such as cation doping and/or surface passivation have proven effective for suppressing the surface degradation of the Ni-rich layered oxides at high voltage. To push the limit of Ni content in the layered oxide for reversible Li intercalation, we present a reactive formation of a thin cation-disordered rocksalt oxide (DRX) layer in interfaces of layered oxide primary particles and surface of their secondary particles. Our materials design hinges on controlling spatial distribution of cations for diffusion-limited nucleation of DRX and layered oxide phases. Extensive electron microscopy study confirmed uniform formation of DRX phases on the Ni-rich layered oxide particles. This interface-tailored Ni-rich cathode outperforms the pristine layered oxide cathode, demonstrating much improved high-voltage stability and capacity retention. We found that the overall synthesis involving DRX phases can promote protective passivation and dense packing of the primary particles, effectively suppressing oxygen loss and crack propagation at high state of charge.

2:35 PM

(GFMAT-S6-003-2026) Impact of fluorination on the structure and electrochemistry of Mn-rich disordered rocksalt cathodes

Q. Deville[1]; F. Weill[1]; B. Mortemard de Boisse[2]; M. Guignard[1]; D. Carlier*[1]

1. Institut de Chimie de la Matiere Condensee de Bordeaux, France
2. SAFT, France

Disordered NaCl-type materials using less critical elements like manganese offer a promising alternative for positive electrode materials for Li-ion batteries. hese disordered NaCl-type materials offer fast lithium diffusion, good electronic conductivity, and reversible capacities above 200 mAh.g^{-1}, but they suffer from irreversible oxygen oxidation at high voltage. Fluorination has emerged as an effective way to suppress this issue while maintaining high capacity. In this study, the influence of fluorination on $Li_{1.25}Mn_{0.5+y/2}Nb_{0.25-y/2}O_{2-y}F_y$ ($0 \le y \le 0.5$) synthesized by mechanosynthesis was investigated across multiple scales using 7Li/19F MAS-NMR, XRD, and PDF analysis. Although fluorination appeared uniform at the particle scale, higher fluorine contents altered the local cation distribution, reduced the lattice parameter, and created Li- and Nb-rich environments around F, as revealed by XRD, PDF, and NMR. The morphology remained unchanged. Electrochemically, Mn oxidation was followed by oxygen oxidation above 4.5 V, whose irreversible contribution decreased with increasing fluorination and disappeared for F contents ≥ 0.2. Compositions in this range showed the lowest polarization, good capacity retention, and capacities above 200 mAh.g^{-1} after 20 cycles.

3:20 PM

(GFMAT-S6-004-2026) The Earth-abundant Cathode Active Materials (EaCAM) consortium: Advancing manganese-rich oxides toward practical Application (Invited)

J. R. Croy*[1]

1. Argonne National Laboratory, USA

The rising demand for energy storage technologies has exposed deep concerns over the security of supply chains related to critical minerals. In particular, there is an urgent need for the development of Co-free/low-Ni cathodes that can compete with current NMC-type chemistries. In this regard, $LiFePO_4$ (LFP) has seen considerable success as a low-cost option. However, LFP supply chains and markets are almost fully controlled outside of the United States, and a more domestically-controlled supply chain is of interest. The most promising non-LFP options remain within the Mn-rich classes of cathode-oxides. These cathodes eliminate the use of Co, greatly reduce or eliminate reliance on Ni, and incorporate ~60% or more earth-abundant Mn. This presentation will present research and development efforts of the Earth-abundant Cathode Active Materials (EaCAM) consortium. Funded under the Vehicle Technologies Office of the U.S. Department of Energy, the EaCAM program focuses on the discovery, design, synthesis, characterization, and development of Mn-based cathodes as next-generation, non-LFP alternatives to current state-of-the-art chemistries. An overview of materials under development will be discussed along with experimental data and techno-economics assessing the progress of Mn-rich cell systems.

3:50 PM

(GFMAT-S6-005-2026) Calcination process design for layered oxide cathodes toward sustainable lithium ion battery (Invited)

H. Park*[1]

1. Korea University, Department of Materials Science and Engineering, Republic of Korea

Lithium transition metal layered oxides with nickel-rich or cobalt-less compositions have garnered particular interests as the most promising high-energy and sustainable cathode materials. However, those cathodes commonly suffer from rapid capacity decay along with structural and morphological degradation, aggravated by various structural defects, including internal void spaces, surface reconstruction layers, and intragranular nanopores. It still remains elusive how these defects are formed during synthesis though all of these layered oxide type cathodes are now produced by high-temperature solid-state calcination. Critical questions that require in-depth study include how the spatially inhomogeneous solid-state reaction begins at the interface of reacting precursors, propagates during the synthesis, and triggers the generation of defects. In this presentation, I will show the hidden synthesis mechanism of layered oxide materials using a combination of multi-length-scale analysis methods. The kinetic interplay in synthesis of layered oxide and its implications will be discussed in detail. Universal synthesis principle through comprehensive studies from conventional to high-nickel and cobalt-free layered oxide cathodes will be also covered. Based on mechanistic understanding, I propose a redesign of solid-state synthesis pathway to achieve structurally integrated layered oxide cathodes.

4:20 PM

(GFMAT-S6-006-2026) Metastable lithium-rich layered oxides for an enhanced structural stability (Invited)

M. Guignard*[1]; G. Zhao[1]; L. Castro[2]; P. Salles[3]; S. Belin[4]; D. Carlier[1]; C. Delmas[1]

1. ICMCB-CNRS, France
2. Toyota Motor Europe NV SA, Belgium
3. ESRF, France
4. Synchrotron SOLEIL, France

Lithium-rich materials with anionic redox are promising candidates for high-energy-density positive electrodes. Manganese-based compounds like Li_2MnO_3 offer advantages including low toxicity and abundant resources but suffer from poor rate capability due to irreversible oxygen loss and structural transformation. Here, we study an O_2-type layered oxide $LiMn_{0.75}O_2$, which shows significantly enhanced cycling stability. By combining electrochemical analysis with operando X-ray absorption spectroscopy and pair distribution function measurements, we provide a detailed picture of the material's structural and redox evolution. The first charge differs markedly from subsequent cycles, combining partially reversible bulk oxygen redox, irreversible Li extraction from surface regions and impurities with oxygen gas release. From the second cycle onward, reversible bulk oxygen redox process becomes progressively activated. Besides, no clear evidence of short O–O dimers was observed in PDF, suggesting a limited degree of oxygen dimerization during the oxygen redox. Overall, this work showcases the high-capacity potential of Mn-based Li-rich materials, deepens understanding of their redox behavior, and underscores the power of PDF-based operando techniques in probing local structural changes during cycling.

HTCMC-12/GFMAT-3 Joint Symposium-Additive Manufacturing Technologies and Applications

HTCMC -GFMAT- Joint Sym- Applications I

Room: Sandpiper B
Session Chair: Soshu Kirihara, Osaka University

1:30 PM

(Joint Sym-001-2026) Improvement in packing density of green body via binder jetting using binary powder mixing (Invited)

A. Shimamura*[1]; Y. Chung[2]; N. Kondo[2]

1. National Institute of Advanced Industrial Science and Technology (AIST), Japan
2. Sangyo Gijutsu Sogo Kenkyujo Chubu Center, Japan

Binder jetting (BJ) is an additive manufacturing technology in which parts are fabricated layer by layer with depositing a liquid binder in designated regions. Although this process enables the formation of complex ceramic geometries, the density of BJ-produced ceramics is

generally lower than that achieved by conventional forming methods such as mold casting or press molding. Therefore, powder preparation aimed at improving the packing density of BJ products is a key process. Bimodal powder mixing using particles of different sizes is a well-known approach to enhance powder packing density. In this study, alumina was used as a representative material, and three alumina powders of different particle sizes were mixed in various proportions with a coarse base powder. Green bodies were then fabricated from these mixtures, and their bulk density, microstructure, and pore-size distribution were evaluated. Incorporation of the binary powder significantly affected the powder-bed flowability and the resulting green-body density. The relative density of the green bodies increased compared with those produced without binary powder.

2:00 PM

(Joint Sym-002-2026) Fused filament fabrication of alumina and zirconia ceramics: Influence of infill architecture on microstructure and flexural strength

M. Ranaiefar*[1]; M. Singh[2]; M. C. Halbig[1]

1. NASA Glenn Research Center, USA
2. Ohio Aerospace Institute, USA

Additive manufacturing of structural ceramics enables lightweight, architected components with tailored mechanical response, yet the role of print architecture in mechanical performance remains underexplored. In this study, alumina and zirconia ceramics were fabricated using fused filament fabrication (FFF) with systematically varied infill percentages and infill patterns to investigate the influence of architectural design on microstructure and flexural strength. Printed green bodies underwent chemical de-binding followed by thermal sintering. Cross-sectional microstructural characterization was performed to quantify porosity content as a function of infill strategy. Flexural properties were evaluated using four-point bend testing. Results demonstrate clear relationships between infill architecture, porosity, and flexural strength, revealing both opportunities for performance tailoring and challenges associated with defect formation in FFF-processed ceramics. These findings provide practical guidance for infill design and process optimization toward reliable use of additively manufactured alumina and zirconia components in extreme-environment applications.

2:20 PM

(Joint Sym-003-2026) Micro-architected metamaterial composites by parametric optimization and additive manufacturing

M. Du[1]; C. Zheng[1]; H. Deng[1]; J. Tsai[1]; R. R. Kamath[1]; P. S. Chaugule[1]; C. A. Chuang[1]; D. Singh*[1]; M. C. Messner[1]

1. Argonne National Laboratory, USA

There has been an increasing demand for high-performance and high-energy efficiency lightweight composites to meet harsh-environment requirements in various application scenarios. In this study, a novel manufacturing route of an optimized two-phase metamaterial composite was proposed and tested to minimize the coefficient of thermal expansion (CTE) of an aluminum matrix with a periodic silicon carbide cellular lattice. The design was parametrically optimized to obtain the minimum dimensional structure of periodic cellular pattern and achieve a minimized coefficient of thermal expansion (CTE). The manufacturing was achieved via binder jetting additive manufacturing, followed by liquid aluminum infiltration. The cooling rate after infiltration was found to be critical for suppressing the reaction between the two phases and maintaining the silicon carbide phase. A comparable study found that a proactive cooling rate as high as 20 °C/min could maintain the phase of silicon carbide up to 12 wt.%, leading to minimized CTE values. The thermal cycling test validated the performance of the composite at high temperatures. This study explored the design-manufacturing-test route for a novel metamaterial composite and opened a wide research direction of advanced materials for harsh environments.

HTCMC-GFMAT- Joint Sym- Applications II

Room: Sandpiper B

Session Chair: Farid Akhtar, Lulea University of Technology

2:40 PM

(Joint Sym-004-2026) 3D printing technology for intelligent electronic medical devices (Invited)

S. Kang*[1]

1. Seoul National University, Materials Science and Engineering, Republic of Korea

Additive manufacturing for medical applications has advanced rapidly, enabling the fabrication of highly customized devices tailored to specific tissues and organs. While early efforts largely focused on printing structures that mimic biological morphology, recent developments have expanded toward functional printing that integrates electrical and mechanical capabilities. In this work, we present a 3D-printable biodegradable electronic ink engineered with optimized electrical performance and printability. The ink enables the creation of a wide range of passive and active components, as well as fully integrated three-dimensional circuits. As a representative demonstration, we fabricated a wireless bioelectronic implant capable of interfacing with neural tissue to deliver targeted electrical stimulation, validating the functional utility of the printed system. This approach establishes a pathway toward patient-specific, shape-conforming implantable medical devices, offering new opportunities for personalized therapeutic and diagnostic applications.

3:30 PM

(Joint Sym-005-2026) Stereolithographic additive manufacturing for fine materials components (Invited)

S. Kirihara*[1]; F. Spirrett[1]

1. Osaka University, Joining and Welding Research Institute, Japan

Stereolithographic additive manufacturing process had been developed to create metal or ceramic components with geometric structures. Micrometer-order scale propagated lattices, ordered cavities or emboss patterns were designed in a computer graphic space. The model data were converted into a stereolithographic format using polyhedral approximations. The ceramic nanoparticles were dispersed in photosensitive liquid resins to obtain thixotropic slurries. The highly viscous resin paste was fed using a controlled air pressure, and uniformly spread using a mechanical knife edge. Cross-sectional patterns were formed using laser drawing and micro-patterning. A high-resolution image could be achieved by using a finely focused laser beam. Solid components were built successfully by layer laminations. These precursors could be heat treated carefully to avoid deformation and cracking during dewaxing and sintering. The formed ceramic microstructures and part accuracies of geometric patterns were observed and measured by digital optical and scanning electron microscopy. Through the computer aided design, manufacture and evaluation, solid electrolyte micro pattern composed of lithium lanthanum titanate or zirconate were fabricated for useful application to all solid batteries.

4:00 PM

(Joint Sym-006-2026) Digital light processing of silica/chitosan inorganic/organic hybrids with open porosity (Invited)

J. Jones*[1]; H. Iqbal[1]; K. Lee[2]

1. Imperial College London, Department of Materials, United Kingdom
2. Imperial College London, Department of Aeronautics, United Kingdom

Inorganic/ organic hybrid materials can achieve properties superior to conventional composites because of the molecular scale interactions between the organic and inorganic conetworks. Examples are synergy of mechanical properties, such as toughness, and controlled biodegradation. Such properties are needed in packaging, structural foams and biomedical applications such as tissue scaffolds. Here, biomass sourced chitosan was used as the organic network.

The chitosan was functionalised to make it light curable before introducing it into the sol-gel process to produce a resin for digital light processing. The chemistry of the resin was optimised to allow printing of gyroid architectures that maximise porosity and mechanical properties.

4:30 PM

(Joint Sym-007-2026) Extrusion-based additive manufacturing of alumina foams and ammonia sorbents with tailored porosity and stability (Invited)

F. Akhtar*[1]

1. Lulea University of Technology, Division of Materials Science, Sweden

Hierarchical cellular ceramics and composite sorbent structures fabricated via extrusion-based additive manufacturing present new opportunities for energy and environmental applications. Tailorable alumina foams with low shrinkage and ~55–93% porosity were fabricated through a sustainable combination of aqueous-based viscoelastic pastes, sacrificial templating with lightweight hollow microspheres, and thermal treatment at 1200°C, yielding tunable multi-scale pore architectures with reduced CO_2 emissions. In parallel, novel ammonia sorbent structures were developed by rationally integrating strontium chloride ($SrCl_2$ with zeolite cages (SPZC) or bentonite clay using direct ink writing. These 3D-printed composites effectively accommodated $SrCl_2$ volume expansion, demonstrated stable NH_3 sorption–desorption over multiple cycles, and achieved enhanced kinetics compared to pure $SrCl_2$, with up to 488 mg/g storage capacity and 87.5% regeneration at 20°C. The results demonstrate that additive manufacturing enables precise structural control and rheological tunability for both ceramic foams and functional sorbents, advancing safe, efficient CO_2 and NH_3 management in energy and catalytic systems.

HTCMC-12 Symposium 3- Polymer Derived Ceramics and Composites

HTCMCS3- Preceramic Polymers and Polymer-Derived Ceramics I

Room: Sandpiper A

Session Chairs: Matthew Dickerson, Air Force Research Laboratory; Jordan Zackasee, Air Force Research Laboratory

1:40 PM

(HTCMC-S3-002-2026) Synthesis constituents and processing technologies for UHTCMCs (Invited)

T. Pruyn*[1]; M. B. Dickerson[1]; J. Delcamp[1]

1. Air Force Research Laboratory, Materials and Manufacturing Directorate, USA

Uncertainty in the performance of high-temperature structural materials remains a challenge to their development and implementation in extreme environments. Materials in these applications are often exposed to high heat-fluxes resulting in very high temperatures, steep temperature gradients, oxidation, and erosion. Ultra-high temperature ceramics (UHTCs; e.g., refractory carbides and borides) are being considered for these applications due to their high temperature capability and high thermal conductivity. However, UHTCs are prone to oxidation under flight conditions and have low fracture toughness, which increases the risk of using them in demanding structural applications. One way to mitigate these challenges is to utilize these UHTCs in a ceramic matrix composite (CMC), but challenges arise in the fabrication of a UHTC matrix in a CMC. This presentation will focus on our work in addressing these challenges via the synthesis of novel UHTC polymeric precursors, incorporating UHTCs in fiber reinforced composites, and improving our understanding of oxidation behavior via validation under relevant conditions. While the ultimate goal is to improve the extreme-environment performance of ultra-high temperature CMCs, the intermediate targets are the ability to control the content and distribution of the UHTC phase, and the evaluation of its impact on ablation performance for different distribution modalities.

2:10 PM

(HTCMC-S3-003-2026) Laser-induced graphene from polymeric materials and its application to microwave absorption (Invited)

S. Lee*[1]

1. Inha University, Mechanical Engineering, Republic of Korea

Modern fighters employ stealth technology to minimize their radar cross-section. This involves using frequency-selective surface-based radar-absorbing structure (FSS-RAS). Conventional method to fabricate FSS-RAS typically involves using conductive ink, which requiring several steps like dispersing conductive fillers into a polymer matrix, then applying this mixture through methods like bar-coating onto a dielectric substrate. These methods demand special metallic masks for pattern creation. Here, we introduce a novel method with Laser-Induced Graphene (LIG) transferred onto glass fabric prepreg to fabricate FSS-RAS. This method was applied to create an RAS featuring a Jerusalem cross FSS design. For LIG production, a polyimide (PI) film of 50μm thickness was used as a precursor. The PI film was laser-irradiated and the resulting LIG was then transferred to a glass fiber prepreg. The LIG covered PI film was removed, leaving only the LIG pattern on the glass fiber prepreg. This LIG-coated fabric was layered over glass fabric prepregs, and the composite RAS was fabricated using a vacuum-bagging process. We evaluated the performance of this LIG-transferred RAS with 2.9 mm thickness, which showed more than 90% radar absorption across the X-band frequency spectrum. This study has the potential for the scalability of our technique due to its straightforward and efficient process.

2:40 PM

(HTCMC-S3-004-2026) Architected ceramics from preceramic polymers: Powder bed fusion pathways to functional components (Invited)

A. Ortona*[1]

1. SUPSI, MEMTi, Switzerland

The polymer-derived ceramics (PDC) route provides unmatched flexibility to tailor the composition and microstructure of non-oxide ceramics at relatively low processing temperatures. When combined with powder bed fusion (PBF), microporous complex architectures can be directly printed and used as preforms for infiltration and pyrolysis. This strategy enables the fabrication of intricate lattices and triply periodic minimal surface (TPMS) structures with hierarchical porosity and controlled shrinkage. Further densification by reactive silicon infiltration or chemical vapor infiltration yields robust SiC- and SiOC-based components with high strength-to-weight ratios and tunable multifunctionality. In this talk, I will present recent advances in printing microporous PBF architectures and transforming them into ceramics via the PDC route, with emphasis on shape fidelity and shrinkage control during pyrolysis, microstructure–property correlations in architected networks, and opportunities for high-temperature applications in energy, environmental technologies, and ceramic matrix composites. By integrating computational design, polymer chemistry, and processing science, the PDC route emerges as a versatile platform for engineering next-generation ceramic components.

HTCMCS3- Preceramic Polymers and Polymer-Derived Ceramics II

Room: Sandpiper A
Session Chairs: Matthew Dickerson, Air Force Research Laboratory; Gurpreet Singh, Kansas State University

3:30 PM

(HTCMC-S3-005-2026) Mechanical characterization of 3D-printed polymer-derived ceramic composites at ambient and elevated temperature (Invited)

B. G. Compton*[1,2]

1. The University of Tennessee Knoxville Tickle College of Engineering, Mechanical and Aerospace Engineering, USA
2. The University of Tennessee Knoxville Tickle College of Engineering, Materials Science and Engineering, USA

This talk will discuss the results of two recent studies on a polycarbosilane-derived ZrB_2 composite and a polysilazane-derived SiC microfiber composite. The ZrB_2 composite was used to study the strength of printed microrods as a function of size and the presence or absence of aluminum oxide nanoparticle rheology modifier. Results show room temperature 3-pt flexure strength up to ~500 MPa for the smallest samples with a characteristic decrease in strength with increasing sample volume due to void formation in large-volume samples. Optical microscopy and Weibull analysis shows that the presence of nanoparticle alumina decreases void formation in larger samples and increases the Weibull modulus of the composites from ~5 to ~9. The SiC microfiber composite was used to study the evolution of 3-pt flexural strength at elevated temperature. Tests were conducted in air at room temperature and at 1200, 1400, 1500, and 1600 °C. Flexural strength increased from 97.8 MPa at room temperature to 367 MPa and 401 MPa at 1200 and 1400 °C, respectively. Strength decreased to ~184 MPa at 1500 °C and was not measurable at 1600 °C. Microscopy of fracture surfaces reveals evidence of degradation of the matrix phase above 1400 °C and x-ray diffraction reveals the formation of mullite above 1200 °C.

4:00 PM

(HTCMC-S3-006-2026) Straightforward design of 3D polymer-derived silicon carbide parts via extrusion-based 3D printing technology (Invited)

S. Bernard*[1]

1. CNRS, IRCER, France

There is a trend toward more performant or competitive materials with the objective to improve the efficiency of actual systems and to repel technological boundaries. Silicon Carbide (SiC) attracts strong interests due to its properties targeted for future materials and technologies especially in aerospace. Inherent difficulties to the traditional techniques for manufacturing such dense materials with a complex geometry can be overcome by the development of new manufacturing approaches and the deployment of synthetic paths where chemistry of materials and ceramic science are combined rationally. The Polymer-Derived Ceramics (PDC) route offers great opportunities in material sciences when combined with 3D printing. Here, the aim of this talk is to introduce a straightforward design approach consisting in tailoring the extrusion ability of polycarbosilanes to fit with a granule-based fused deposition modeling process and form after a two-step heat-treatment process at a relatively low temperature 3D stoechiometric SiC and derived composites parts.

4:30 PM

(HTCMC-S3-007-2026) Additive manufacturing of SiOC based monoliths as structured catalysts for CO_2 hydrogenation (Invited)

C. Salameh*[1]

1. Institut Européen des Membranes, France

The sustainable conversion of CO_2 into energy-rich molecules represents one of the central scientific and technological challenges in the transition toward a low-carbon economy. While significant progress has been achieved in catalytic CO_2 conversion, conventional catalyst architectures often suffer from limited stability, mass transport constraints, and poor scalability. Recent advances demonstrate that integrating materials chemistry with process-oriented design offers powerful opportunities to overcome these limitations. In this talk, I will show how polymer-derived ceramics shaped by additive manufacturing provide a versatile platform for the design of robust, architectured catalysts with finely tunable properties. By controlling composition, porosity, and macroscopic architecture, these structured ceramic systems enable improved efficiency, durability, and operational stability under CO_2 conversion conditions. Overall, this approach illustrates how the combination of novel chemistries and advanced fabrication strategies can accelerate the development of practical solutions for CO_2 utilization and renewable energy storage.

HTCMC-12 Symposium 4- Innovative Design, Advanced Processing and Manufacturing Technologies in Non-oxide and Oxide Composites

HTCMCS4- Innovative design

Room: Silver Pearl 1-3
Session Chair: Katsumi Yoshida, Institute of Science Tokyo

1:30 PM

(HTCMC-S4-001-2026) Progress on the "Matrix-First" paradigm for fiber-reinforced ceramic matrix composites (Invited)

A. Ortona*[1]

1. SUPSI, MEMTi, Switzerland

Fiber-reinforced ceramic matrix composites are usually processed by forming a fiber preform followed by matrix densification through PIP, CVI, RMI. While effective, these routes restrict architectural complexity and design freedom. We propose a matrix-first paradigm that inverts this sequence: a porous ceramic matrix scaffold is fabricated first by additive manufacturing, and fibers are then introduced. This decoupling allows computational design to be applied directly to the scaffold, enabling the digital design of pore networks, reinforcement pathways, and geometries for tailored architectures and multifunctional performance. Different porous ceramic scaffolds have been produced and characterized for porosity, microstructure, and mechanical integrity. Continuous fiber bundles have been integrated with controlled alignment and uniform distribution. Preliminary testing demonstrates improved toughness of reinforced scaffolds compared to unreinforced matrices. In addition, designed pore structures with fibers insertion have shown clear benefits in heat transfer, demonstrating the potential of this approach to couple thermal and mechanical performance. The matrix-first paradigm, supported by computational design, expands the design space for CMCs and provides a pathway toward architected composites with advanced functionality for aerospace and energy applications.

2:00 PM

(HTCMC-S4-002-2026) Development of LSIed C/SiC Components for Scramjet Engines in Korea (Invited)

S. Kim*[1]; I. Han[1]; H. Bang[1]; S. Kim[1]; Y. Seong[2]; S. Lee[1]

1. Korea Institute of Energy Research, Republic of Korea
2. Korea Institute of Energy Research(KIER), Energy Materials Laboratory, Republic of Korea

Air-breathing engines and hypersonic vehicles are being actively developed in Korea, and many programs are adopting ceramic matrix composites to enhance performance under extreme conditions. This presentation introduces ongoing domestic efforts to develop C/SiC components for scramjet engines, including a combustor, nozzle extension, and flame holder (cavity), all manufactured using the LSI process. The combustor and nozzle incorporate internal regenerative cooling channels, each produced with different fabrication approaches. A pin-fin channel structure was achieved for the combustor using pinning technology, while a linear cooling passage for the nozzle was formed through a damascene-based process. Metal fittings are applied at the fuel in/outlet, and geometric optimization and sealing methods were developed to prevent leakage under high-temperature and high-pressure conditions. The flame holder, which experiences severe ablation due to direct flame exposure, was redesigned using C/SiC with HfC and other ultra-high-temperature materials. Testing confirmed significantly improved ablation resistance compared with conventional metallic or C/SiC components. These developments are expected to expand the applicability of CMCs in future hypersonic vehicle systems.

2:30 PM

(HTCMC-S4-003-2026) Innovative design and testing of SiC/SiC composites for fusion devices (Invited)

A. J. Leide*[1]; D. Andrews[1]; J. Wade-Zhu[1]

1. UKAEA, Materials Division, United Kingdom

SiC fibre reinforced SiC composites have many desirable characteristics as a structural material for the breeder blanket or plasma facing components of fusion power stations including mechanical and microstructural stability under high temperature irradiation (~600–1000°C), low neutron absorption cross-section, and low induced activation. They are resistant to many corrosive environments and have low hydrogen isotope permeation. This presentation will include a variety of work undertaken by UKAEA and collaborators focussing on innovations in material design and test methods for assessing SiC/SiC performance. Fusion-grade materials require microstructures which are stable under intense high-energy neutron irradiation – in the case of SiC/SiC the interphase is considered the life-limiting factor of the composite structure. At UKAEA we have developed micromechanical test methods for evaluating composite interphases post ion irradiation and have investigated novel interphase designs including composition and microstructure variations. Fusion devices are large and complex requiring joining between a variety of components. Our latest progress on ceramic to ceramic joining methods will be presented with microstructural analysis. Ongoing developments in composite manufacturing will also be presented which are aimed at reducing costs for large and complex components.

3:20 PM

(HTCMC-S4-004-2026) Optimized local reinforcement of C/C-SiC structures using Fiber Patch Placement (Invited)

J. Riesner*[1]; D. Koch[1]

1. Universitat Augsburg, Germany

Fiber Patch Placement (FPP) enables highly flexible local reinforcement of composite structures, but current design and processing approaches focus almost exclusively on polymer matrix systems. This study presents a complete methodology for processing and optimizing locally reinforced C/C-SiC components manufactured via Liquid Silicon Infiltration (LSI). An inverse identification method is introduced to derive the anisotropic elastic properties of individual unidirectional patches from tests on cross-ply laminates, overcoming the limitations of direct UD processing in C/C-SiC. Based on these parameters, a gradient-based optimization framework using differentiable finite element analysis is developed to determine optimal patch placement and orientation. The approach is demonstrated on a center-holed plate and experimentally validated using a two-step curing process that preserves the designed patch architecture through the LSI route. Mechanical testing confirms a stiffness improvement of approximately 59% with only a 14% weight increase, in good agreement with simulation.

3:50 PM

(HTCMC-S4-005-2026) Development of refractory high-entropy ceramic matrix composites through the integration of computational thermodynamics and experiments (Invited)

Y. Arai*[1]; R. Inoue[1]

1. Tokyo University of Science, Japan

Hypersonic vehicles cruising at Mach 5-10 are considered as an innovative transportation system and have developed to enter service around 2040–2050. The components such as leading edges and nose corn are expected to exposed at 2000°C or higher in oxidizing atmosphere during hypersonic cruising owing to sever aerodynamic heating. Ultra-high temperature ceramics (UHTCs) and ultra-high temperature ceramic matrix composites (UHTCMCs) are attractive candidates for the component. However, the only oxidation-suppressing mechanism is the formation of SiO_2 formed by the oxidation of SiC, and its effectiveness becomes limited at temperatures above 1800°C. Thus, the objective of this study is to develop refractory high-entropy ceramic matrix composites (RHECMCs) as an advanced aerospace heat-resistant material. The matrix of RHECMCs has several refractory carbides and borides with complex composition and it is expected that complex oxides formed by the oxidation of complex matrix act as a barrier for oxidation at above 2000°C. To develop a design of material with complex composition, a material process with the combination of thermodynamic calculation and experiments also will be proposed.

4:20 PM

(HTCMC-S4-006-2026) Evaluation of mechanical and thermal properties of C/SiC using continuous composites CF3D technology

K. C. Bull*[1]; J. Gilder[2]; C. L. Cramer[3]; D. Gilmer[4]

1. The University of Tennessee Knoxville Tickle College of Engineering, Mechanical and Aerospace Engineering, USA
2. The University of Tennessee Knoxville Tickle College of Engineering, Aerospace, USA
3. Oak Ridge National Lab, Manufacturing Science Division, USA
4. The University of Tennessee Knoxville Tickle College of Engineering, Materials Science and Engineering, USA

Carbon Fiber-Silicon Carbide Matrix (C/SiC) composites are well suited for high-temperature aerospace and thermal protection system applications, yet conventional woven architectures often suffer from interlaminar weakness that limits performance under coupled thermal–mechanical loads. This work investigates C/SiC produced from Continuous Composites' proprietary CF3D preform architecture, which introduces a novel reinforcement pattern designed to modify load-transfer pathways and reduce interlaminar stress concentrations. The central hypothesis is that this engineered architecture will enhance interlaminar shear and tensile behavior, and that these improvements may also manifest as gains in thermal conductivity, thermal diffusivity, and oxidation resistance. Composites will be made with the CF3D process, pyrolyzed, PIP densified with carbosilane, characterized, and tested for thermal and mechanical properties.

4:40 PM

(HTCMC-S4-007-2026) Laser powder bed fusion of ceramic–regolith composites for lunar-analog cylinder fabrication under inert conditions

M. Feehan*[1]

1. Space Copy Inc., Canada

Laser powder bed fusion (LPBF) of ceramic–regolith composite feedstocks offers a promising pathway for in-situ resource utilization and the sustainable construction. This work investigates the processing behavior and mechanical performance of a ceramic-regolith matrix engineered by Space Copy Inc. in partnership with the University of Waterloo's Multi-Scale Additive Manufacturing Laboratory, and the University of Concordia Department of Mechanical Engineering. The goal of this study was to understand the challenges of creating uniform layers of regolith when manufacturing with the LPBF process. Cylindrical test articles were fabricated under inert atmospheric conditions designed to mimic low-oxygen lunar regolith chemistry and thermal gradients. Results demonstrate that controlled LPBF energy density enables partial melting and interparticle necking within the composite, producing dense, crack-limited structures capable of withstanding extreme thermal and mechanical loading. Microstructural analysis reveals a heterogeneous ceramic framework reinforced by sintered regolith particulates, indicating a viable route for additively manufactured pressure-bearing cylinders for future lunar infrastructure. These findings highlight the potential of LPBF-based ceramic matrix composites for sustainable off-world construction using locally sourced materials.

5:00 PM

(HTCMC-S4-008-2026) Effects of C-fiber tow counts on physical and mechanical behavior of the NITE-AXIOM SiC slurry Pre-preg sheets and their Laminate C/SiC Composites

H. Yun*[1]; A. Stanley[1]; W. Simpson[2]; E. Vargas[3]; A. L. Guevara[4]; K. Grijalva[5]; A. Garcia[5]

1. Axiom Materials Inc, USA
2. Axiom Materials Inc, Technical, USA
3. University of Southern California, Materials Science and Engineering, USA
4. Axiom Materials Inc, R&D, USA
5. Axiom Materials Inc, Sales, USA

CMC's including C/SiC are almost always constructed using woven fabrics or uni-directional architectures fabricated from multi-fiber tows typically with 500 to 12000 filaments (~7 to 14um diameter) per tow. AXIOM Materials has excelled in developing pre-preg sheets / tapes using continuous fibers of oxide-, carbon-, and silicon-carbide-based fibers. The concept of pre-preg on a fiber tow and combined tow fabric with the desired SiC-matrices in the upstream of CMC processing has two huge advantages, uniform infiltration into each fiber filament and single-step ceramic matrix formation. For the SiC matrix with a simple densification step, AXIOM has utilized NITE constituents with sintering additives, ~5w/o. In the present work, the effects of three types of C-fiber (heat-treated or pyC-coated) tow counts—3k, 7k, and 12k—are evaluated as prepreg sheets and fully densified C/SiC laminates. Handle-ability and tackiness of the pre-preg sheet, porosity level of laid-up / cured laminates, and flexural strengths of the final single-step densified C/SiC CMC will be discussed. The porosity level and matrix distribution (including pyC coatings) inside tows will be correlated by cross-sectional microscopy of the green and sintered laminates.

HTCMC-12 Symposium 7- Materials for Extreme Environments – UHTCs, MAX phases, and nanolaminates

HTCMCS7- Entropy stabilized compositionally complex UHTCs and MAX phases I

Room: Osprey
Session Chair: Miladin Radovic, Texas A&M University

1:30 PM

(HTCMC-S7-001-2026) Phase stability of compositionally complex UHTC transition metal carbides (Invited)

T. Davey*[1,2]; E. Zancan[1]; Y. Chen[2]

1. Bangor University, Nuclear Futures Institute, United Kingdom
2. Tohoku University, Graduate School of Engineering, Japan

High-entropy or compositionally complex ultra-high temperature ceramics (UHTCs) may have improved or tuneable properties such as melting point, hardness, ductility, and oxidation resistance. In particular, MC_{1-x} carbides have been the source of significant interest in recent years, but systematic experimental exploration of the entire composition space is prohibitively expensive and time consuming due to the number of components. Despite the individual group IV and V transition metal carbides having similar properties and behaviour on an atomic or electronic scale, the elemental differences result in complex local behaviour in the mixed cation carbides. At high temperatures, the configurational entropy in these is thought to overcome any opposing enthalpic effects inhibiting mixing, resulting in single solid solution phases. However, there remains significant distortion in the crystal structure and huge variations in bond strengths resulting from the local atomic environment. Although the thermodynamic stability can determine whether or not a mixture is a single phase at equilibrium, variations in the local structure may affect other features such as mechanical properties and oxidation rates. Therefore, this work uses first-principles calculations to understand the thermodynamics and local structural and bonding properties in MC_{1-x} (M=Ti,Zr,Hf,Nb,Ta) mixtures at different carbon stoichiometries.

2:00 PM

(HTCMC-S7-002-2026) Single-phase high-entropy carbide and boride UHTCs enabled by data-driven composition selection

A. F. Ornelas[1]; A. G. Castellanos*[1]

1. The University of Texas at El Paso, Aerospace and Mechanical Engr. Dept., USA

This study aims to experimentally validate the formation of bulk, single-phase high-entropy ultra-high temperature ceramics (HE-UHTCs) identified through data-driven composition screening. Candidate high-entropy carbide- and boride-based UHTC systems were first selected using machine-learning guidance, then processed by high-energy ball milling to homogenize the starting powders, followed by pressureless sintering under inert atmospheres to form bulk ceramics. Phase formation and microstructural homogeneity were assessed using X-ray diffraction, scanning electron microscopy, and energy-dispersive spectroscopy to evaluate phase purity, microstructural uniformity, and chemical homogeneity. The results show that several of the selected compositions form single-phase bulk ceramics with dense, chemically homogeneous microstructures and minimal secondary phases. Overall, this work demonstrates that data-driven composition selection, when combined with careful processing control, provides an effective route for synthesizing single-phase high-entropy UHTCs and supports their further development for extreme-environment applications.

2:20 PM

(HTCMC-S7-003-2026) Synthesis of zeta phase binary, mid-entropy, and high-entropy carbides exhibiting group IV and V metals

J. W. Wannenmacher*[1]

1. Missouri University of Science and Technology, Materials Science Engineering, USA

A major limitation of carbide ceramics is brittle fracture mechanisms that prevent widespread application in extreme environments. Zeta phases have been observed to improved fracture toughness in Tantalum Carbide (Ta_4C_{3-x}) due to stacking faults within lamellar microstructures redirecting propagating cracks through the materials. In literature, Ta_4C_{3-x} has been the only zeta phase carbide used to maximize fracture toughness values in monolithic ceramics. However, computational approaches have provided insight into the stability ranges of V_4C_{3-x} and Nb_4C_{3-x}. This research proposes direct synthesis of V_4C_{3-x}, Nb_4C_{3-x}, Ta_4C_{3-x} monolithic ceramics in addition to mid-entropy and high-entropy zeta phase carbides through a carbothermal reduction process using respective transition metal oxides (V_2O_5, Nb_2O_5, Ta_2O_5, TiO_2, and ZrO_2). Zeta phase materials will undergo strength and modulus measurements via 4-point bending on A-bars (ASTM C1161). This is followed by Vickers hardness indentations to directly measure indent dimensions for hardness values, and radial cracking for toughness values. Current synthesis processes in this study demonstrate that $VC_{0.66}$ exhibits 15.46±2.66 GPa at a load of 20 N and 7.94±1.87 $MPa(m)^{1/2}$ for Vickers hardness and direct crack fracture toughness. This talk will outline the synthesis, densification, and resulting processes of zeta phase carbide ceramics.

2:40 PM

(HTCMC-S7-004-2026) Lamellar microstructure engineering in tantalum, vanadium and niobium carbides for enhanced ceramic ductility

M. Lakusta*[1]; A. Emdadi[1]; J. Watts[1]; D. Lipke[1]; G. Hilmas[1]; J. Lonergan[1]

1. Missouri University of Science & Technology, Materials Science and Engineering, USA

Transition metal carbides offer exceptional ultrahigh-temperature performance but suffer from brittleness, limiting their structural applications. This study demonstrates a novel approach to induce ceramic ductility through the formation and control of zeta-phase nanodomains in tantalum, vanadium, and niobium carbide systems. Targeted compositions of TaCx, VCx, and NbCx (x=0.66) were prepared by ball milling commercially available transition metal carbide and metal powders, reacted and consolidated by hot pressing at 1650–1800°C under 32 MPa. XRD confirmed zeta-phase formation, and SEM revealed lath-like lamellar architectures composed of multiple intergrown carbide phases. Post-hot pressing thermal treatment at 1547–1700°C with cooling rates of 0.5–5°C/min produced additional phase transformations that refined and stabilized the lamellar structure. EDS verified the intended compositions with minimal oxide contamination. Vickers hardness testing revealed load-dependent strain-hardening behavior, with hardness ranging from 6 to 18 GPa, and improved mechanical stability following heat treatment. Fractography indicated a transition from purely brittle failure to pseudo-ductile behavior associated with deformation and interaction of the lamellar phases under indentation loading.

HTCMCS7- Entropy stabilized compositionally complex UHTCs and MAX phases II

Room: Osprey
Session Chair: Antonio Vinci, CNR - ISSMC

3:20 PM

(HTCMC-S7-005-2026) Toughening transition metal carbides through high entropy zeta phase nano domains (Invited)

J. Lonergan*[1]; M. Lakusta[1]; A. Emdadi[1]; J. Watts[1]; D. Lipke[1]; G. Hilmas[1]

1. Missouri University of Science and Technology, Materials Science and Engineering, USA

One of the principal barriers to broader adoption of transition metal carbide ceramics is their inherently brittle and often catastrophic failure behavior. Recently, the emergence of zeta-phase carbides, typically expressed as ζ-TM_4C_{3-x}, has drawn attention for their potential to enhance fracture toughness. These phases exhibit lamellar microstructures containing lath like stacking faults, which act as effective crack-deflection pathways and promote extrinsic toughening within the bulk ceramic. This research investigated synthesis of a mid ζ-$(Ta,Nb,V)_4C_{3-x}$ and high ζ-$(Ta,Nb,V,Zr,Ti)_4C_{3-x}$ entropy zeta phase carbide through super additions of transition metals (TM) to respective TMC powders to synthesize the individual zeta phases before reacting them to form a monolithic high entropy carbide. Post synthesis, annealing was performed to further modify the microstructure. Zeta phase materials will undergo strength and modulus measurement via four point bending as outline in ASTM C1161. Vickers hardness indentation was used to directly measure indent dimensions and produce radial cracking for fracture toughness measurements. This talk will discuss the processing, densification, and measured mechanical properties of mid and high entropy zeta phase carbide compositions.

3:50 PM

(HTCMC-S7-006-2026) Strategies for the controlled synthesis of compositionally complex MAX Phases (Invited)

M. Radovic*[1]; M. Dujovic[1]; C. Wang[1]; Z. Tan[1]; A. Srivastava[1]

1. Texas A&M University, Materials Science and Engineering, USA

Conventional synthesis of compositionally complex MAX phases withtwo or more transition metals on the M-site is challenging due to numerous intermediate reactions and the formation of multiple competing phases, some of which are stable and difficult to suppress during sintering. These complexities often hinder control over reaction pathways and result in limited phase and compositional uniformity. Recently, we developed a novel and controllable synthesis approach that employs pre-synthesized single M-element MAX phases as starting materials instead of elemental powders. This method enables diffusion-controlled reactions between structurally compatible layered precursors, significantly reducing the likelihood of forming unwanted intermediates and promoting homogeneous mixing on the M-site. Using this approach, a series of M_2AC (M = Cr, Ti, Ta, V, Nb, and their combinations) phases with two to five M elements were synthesized and systematically examined. Among the 26 compositions studied, only a few formed single-phase MAX phase solid solutions, while one showed spinodal decomposition. This synthesis route provides a generalizable and controllable pathway that can be extended to other MAX systems with different stacking sequences, such as M_3AC_2 and M_4AC_3, enabling broader exploration of compositionally complex layered ceramics and their compositional stability domains.

4:20 PM

(HTCMC-S7-007-2026) Microstructure and mechanical property correlation in high-entropy dual-phase (Ti,Zr,Ta,Hf) boride-carbide-based ultra-high-temperature ceramic

K. P. Singh*[1]; K. Balani[1]

1. Indian Institute of Technology Kanpur, Materials Science and Engineering, India

Ultra-High Temperature Ceramics (UHTCs), particularly borides and carbides of Zr, Ti, Ta, and Hf, are promising candidates for extreme environments; however, single-phase variants often lack the comprehensive performance required for such applications. To overcome these limitations, this study developed (Zr,Ti,Ta,Hf)-based dual-phase High-Entropy Boride-Carbide (HEB–HEC) ceramics and a 20 vol% SiC-reinforced HEB–HEC composite. Consolidated via Spark Plasma Sintering (SPS) at 2000 °C, all samples achieved near-theoretical density (~99%). Microstructural analysis revealed that secondary phases effectively inhibited grain growth via the pinning effect, significantly refining the grain size from 5.6 μm in single-phase HEB to 1.1 μm in the SiC-reinforced composite. This microstructural refinement led to a notable mechanical synergy. While the dual-phase HEB–HEC exhibited a flexural strength of ~460 MPa and fracture toughness of ~3.86 MPa.$m^{1/2}$, the SiC-reinforced composite demonstrated superior properties, achieving a flexural strength of ~565 MPa, fracture toughness of ~4.72 MPa.$m^{1/2}$, and microhardness of ~27.34 GPa. These results establish SiC-reinforced high-entropy dual-phase UHTCs as robust materials for demanding aerospace and hypersonic applications.

4:40 PM

(HTCMC-S7-009-2026) Development of Ultra-Hard UHTCS from MAX phases and boron carbide

W. Banas*[1]; D. D. Kozien[1]; L. Silvestroni[2]; S. Failla[3]; Z. Pedzich[4]

1. Akademia Gorniczo-Hutnicza im Stanislawa Staszica w Krakowie, Department of Ceramics and Refractories, Poland
2. Consiglio Nazionale delle Ricerche, ISSMC, Italy
3. National Research Council of Italy - Institute of Science, Technology and Sustainability for Ceramics, Department of Chemical Science and Materials Technologies (DSCTM), Italy
4. AGH University of Krakow, Department of Ceramics and Refractory Materials, Poland

Composites belonging to the ultra-high-temperature ceramics (UHTCs) group are characterised by high melting points, high hardness, good mechanical properties and the ability to operate at high temperatures. These materials include metal borides and carbides of transition metals and their production often involves the application of high temperatures or sintering aids, e.g. high pressure or electric current. A reactive sintering approach can significantly mitigate the sintering conditions and produce composites with a dense and fine-grained microstructure. The use of boron carbide and MAX phases as precursors has never been explored in the literature, but it shows considerable potential in terms of process and resulting properties. Here, UHTCs were obtained from B_4C and Nb_2AlC upon reactive spark plasma sintering (RSPS) in the 1800-2000°C temperature range, depending on the MAX volume fraction. X-ray diffraction and SEM-EDS analyses confirmed complete conversion of the MAX phase into ultra-fine NbB_2 grains and Al_4C_3, reaching microhardness about 30-32 GPa. The microstructure evolution process, preliminary mechanical properties and the overall energy balance are discussed.

HTCMC-12 Symposium 8- Testing and Evaluation of Ceramic Matrix Composites from Constituents and Coupons to Components, including EBCs

HTCMCS8- Mechanical characterization of ceramics and composites, techniques and equipment I

Room: Pelican
Session Chairs: Jeff Vervlied, Free Forms Fiber; Ryo Inoue, The University of Tokyo

1:30 PM

(HTCMC-S8-001-2026) Comparison of all-oxide ceramic matrix composites (OCMC) using Nextel, Nitivy and Vulcan Shield Global fabrics (Invited)

W. Pritzkow*[1]; V. Dosch[1]; T. Oberhofer[1]; K. Tushtev[2]; R. S. Almeida[2]; K. Rezwan[3]

1. Walter E.C. Pritzkow Spezialkeramik, Germany
2. University of Bremen, Advanced Ceramics Group, Germany
3. University of Bremen, Germany

The demand for materials for use at high temperatures in oxidizing atmospheres has driven significant research and development in the field of OCMC in recent years. Besides 3M™ Nextel™ fibers, which have been crucial to OCMC's success in a wide range of applications for over 30 years, Walter E.C. Pritzkow Spezialkeramik is exploring other alumina-based fiber fabrics that are currently being developed or are already on the market, aiming to produce new composites. This study focuses on the experimental fabrics Nitivy Alcelon DS-40 (85% Al_2O_3/15% SiO_2) and Nitivy Alcelon AS-40 (99% Al_2O_3), and the commercially available fabric WM-280 (99% Al_2O_3) from Vulcan Shield Global. A number of aspects of the new OCMCs are covered, including the property of the fiber fabrics, as well as the preparation, microstructure and mechanical performance of the composites. Tensile fiber bundles tests are performed to evaluate the fiber fabric properties in as-received condition and after thermal treatment at temperatures up to 1200°C. In plane and interlaminar properties of the composites are evaluated under tensile, compression, and flexural load at room and high temperatures. The results are discussed to provide researchers and users with insight into the future of OCMCs for low performance up to high-end applications, with a focus on thin-walled and lightweight structures.

2:00 PM

(HTCMC-S8-002-2026) Mode I interlaminar fracture behavior of ceramic composites at ultra-high temperature (Invited)

G. Jefferson*[1]; C. Popelar[2]; J. Pierce[3]; T. Jackson[3]

1. Air Force Research Laboratory, RXNC, USA
2. Southwest Research Institute, USA
3. University of Dayton, Research Institute, USA

Ceramic composites enable technologies for high-speed structural applications. Understanding the interlaminar performance of these materials at ultra-high temperatures (UHT) is critical for design and implementation. While methods for measuring interlaminar tensile and shear strengths at ultra-high temperatures have been established, a method for characterizing fracture toughness (G_{Ic}) at extreme conditions has not been demonstrated. This paper presents a methodology for determining the Mode I fracture toughness of ceramic composites at ultra-high temperatures up to 4000F. The UHT approach for fracture toughness is based on the ASTM D5528 and C1940 standards for room temperature evaluation of fiber-reinforced composites using a double cantilever beam (DCB) test configuration. Both standards rely on visual-based compliance vs. crack length measurements to determine fracture toughness, which is not feasible at temperatures of interest. To address this challenge,

an alternate compliance-based approach was developed that utilizes a single test interruption for a visual measurement. The resulting compliance is used to infer the instantaneous crack length and resistance curve (R-curve) measured from the DCB load-displacement history. DCB testing was then used to quantify UHT toughness in an inductively heated test specimen at temperatures up to 4000F.

2:30 PM

(HTCMC-S8-003-2026) Flexural strength of reinforced V shaped oxide/oxide composite specimen (Invited)

F. Guillet*[1]; R. Garcez[1]; A. Portal[1]; F. Laurin[2]

1. Commissariat a l'energie atomique et aux energies alternatives Siege administratif, France
2. ONERA, DMAS, France

The flexural strength of curved laminated composite parts is a subject of interest since such parts need to be integrated into various structures. This study focuses on the flexural response of a reinforced « V » shaped sample made of a oxide/oxide laminate composite with a quasi-isotropic stacking. The reinforcement takes place inside the sharp end of V as a circular plate going from one leg to the other. Each end of the plate is inserted into the legs through ply insertion. The samples were tested using a set of jaws which can rotate about an axis perpendicular to the displacement of the test machine and are clamped at each end of the sample legs. Displacement imposed by the test machine leads not only to a folding/unfolding of the legs but also a rotation of the jaws to accommodate the change in V-shape angle. The tests are heavily instrumented, incorporating image correlation (CIN), acoustic emission, local CIN in areas where delamination can initiate, and strain gauges. A finite element computation has been carried out on a numerical sample computed from CT imaging. This ensures that the FE model includes any imperfection and difference from to ideal CAD model. This FE model accurately describes the stacking of plies and their respective orientation, as well as ply insertion at both ends of the reinforcement. Full field kinematics of test samples are then compared with FE computations and discussed.

3:20 PM

(HTCMC-S8-004-2026) Enhanced deformability of off-stoichiometric TiC in Mo-Ti-C ternary composites (Invited)

S. Ida*[1]; E. Nakagawa[3]; V. Paul[3]; F. Tropper[3]; T. Ohmura[3]; K. Yoshimi[2]; T. Kimura[1]

1. Japan Fine Ceramics Center, Japan
2. Tohoku University, Japan
3. National Institute for Materials Science, Japan

We investigated the deformation behavior and mechanical properties of off-stoichiometric TiC using micropillar compression tests conducted in an in-situ scanning electron microscope, as well as nanoindentation tests. The samples were Mo–Ti–C ternary composites consisting of off-stoichiometric TiC in equilibrium with a solid solution phase with a BCC structure. Micropillar compression tests showed that off-stoichiometric TiC can accommodate over 10% plastic strain without fracture, unlike stoichiometric TiC, which fractures early in the deformation process. Slip systems on {110}<110>—as well as {111}<110>, and {100}<110>, which are typically inactive in stoichiometric TiC—were found to be activated during the plastic deformation of off-stoichiometric TiC. Both the yield stress measured by micropillar compression and the hardness obtained from nanoindentation increased with increasing shear stress. This suggests that these properties are influenced by Peierls stress. The critical shear stress required to initiate plastic deformation was proportional to the shear modulus, consistent with trends observed in various metals. These findings demonstrate that deformation in ductility-enhanced off-stoichiometric TiC is dominated by dislocation motion in the large-strain region, similar to metals.

3:50 PM

(HTCMC-S8-005-2026) High temperature digital image correlation for strain measurement of ceramic matrix composites

J. Shaw*[1]; M. Mordasky[2]; D. Collins[2]

1. Pratt & Whitney, USA
2. Raytheon Technologies Research Center, USA

Digital image correlation has been demonstrated to capture useful spatial strain fields at elevated temperatures. However, at temperatures exceeding 1200C the method breaks down due to challenges arising from speckle pattern stability and blackbody radiation. This talk presents methodologies that enable digital image correlation on SiC/SiC CMCs at temperatures exceeding 1400C. Building on previous strategies for mitigating heat haze, new approaches have been developed to mitigate loss of contrast due to blackbody radiation and to create a speckle pattern which remains stable for up to 100h at elevated temperatures.

4:10 PM

(HTCMC-S8-006-2026) Direct measurement of interlaminar tensile strength in CMCs at elevated temperatures using the Flex ILT method

Y. Zhou*[1]; K. Maxwell[1]; G. Gemeinhardt[1]

1. GE Aerospace, USA

Accurately measuring the interlaminar tensile (ILT) strength of ceramic matrix composites (CMCs) at high temperatures is complex. This paper presents a comparative evaluation of four ILT testing methods—flatwise tensile, curved beam flexure, flex ILT, and disc compression—for OX/OX and SiC/SiC CMCs. We identify key limitations in established techniques: flatwise tensile is room-temperature-limited and adhesive-sensitive; curved beam flexure requires complex fixtures and cannot provide constant-stress durability data; and disc compression requires correction for material anisotropy. The flex ILT method is highlighted as the most effective, enabling direct measurement of ILT strength at both room and elevated temperatures. Results demonstrate its utility in providing reliable property data for both CMC systems.

4:30 PM

(HTCMC-S8-007-2026) Condition assessment of SiC_f/SiC CMC via resonance testing techniques

Z. Quiney*[1]; J. Stephen[1]; G. Garcia Luna[4]; A. L. Chamberlain[2]; S. Jeffs[3]

1. Swansea University, Institute of Structural Materials, United Kingdom
2. Rolls-Royce North America Inc, USA
3. Swansea University, United Kingdom
4. Rolls-Royce plc, United Kingdom

Achieving lower emissions and higher efficiency in next-generation gas turbines requires weight reduction and the ability to operate at higher temperatures. Silicon carbide fibre-reinforced ceramic matrix composites (SiCf/SiC CMCs) offer the necessary thermal and mechanical properties to replace certain metallic components. However, as a relatively new material system, extensive testing, monitoring, and non-destructive evaluation are essential to understand damage initiation and progression, and its effect on performance and material life. Conventional monitoring methods such as acoustic emission, electrical resistance and X-ray computed tomography provide detailed insights under laboratory conditions but are impractical for more routine inspections, where relatively straightforward and cost-effective testing would be preferred. To investigate this, two resonance-based approaches were explored. The first method used impact-induced resonant response in a cantilever beam setup, and the second applied Process Compensated Resonance Testing (PCRT) where each are applied to batches of coupons at two stages: before and after testing. Test conditions included various degrees of axial mechanically loading and environmental degradation. Both resonance techniques demonstrated

sensitivity to material degradation across these conditions, providing a promising foundation for further development toward practical inspection.

4:50 PM

(HTCMC-S8-008-2026) Mechanical characterisation of unidirectional oxide/oxide ceramic matrix composite laminate

A. Garnier*[1,2]; C. Bouvet[1]; C. Morel[1]; T. Cutard[1]; G. Dusserre[1]; J. Malenfant[2]

1. Institut Clement Ader, France
2. Safran Ceramics, France

To improve the efficiency of aeronautical turbojet, engine manufacturers are considering oxide/oxide ceramic matrix composites (CMCs) for exhaust components. Their mechanical properties at high temperatures, their oxidation resistance and their low manufacturing cost make them a good candidate for these applications. In this context, a weak matrix CMC reinforced with 3M™ Nextel™ 610 fibres with a unidirectional technology has been developed by Safran Ceramics. This study presents the mechanical behaviour of five laminates based on mechanical tests, monotonic tensile and 4-point bending, instrumented with digital image correlation and acoustic emission. A highly linear behaviour followed by some damage is observed. A microstructural analysis characterises the initial state considering fibre volume fraction, porosity ratio and matrix cracks density depending on ply stacking sequence. The Classical Laminate Theory (CLT) and a finite element shear-lag model, estimating the stiffness loss due to matrix cracks density, have been used to identify the ply elastic properties. An analytical damage model has been developed, based on the CLT, defining an initiation criterion, an evolution law and a laminate failure criterion. An objective of this approach is to take into account the initial state of the material in the damage model and validate it on complex tests.

5:10 PM

(HTCMC-S8-009-2026) Tensile behavior and thermal analysis of an orthogonal 3D woven SiC-fiber/SiC composite under rapid temperature gradient heating

Y. Matsuda*[1]; N. Sugawara[1]; T. Ogasawara[1]; R. Inoue[2]; T. Aoki[4]; H. Sato[3]; Y. Kitamura[3]

1. Tokyo Noko Daigaku, Japan
2. Tokyo Rika Daigaku, Japan
3. Kabushiki Kaisha IHI, Japan
4. Uchu Koku Kenkyu Kaihatsu Kiko, Japan

In gas turbine engines, turbine blades and vanes that are being considered the application of SiC-fiber reinforced SiC matrix (SiC-f/SiC) composites, are subjected to thermal stresses caused by temperature gradients within the components. However, few studies have reported material evaluation tests under conditions involving a temperature gradient through the specimen thickness, and the influence of temperature gradients on mechanical behavior has not been clarified. The aim of this study is to establish an experimental method to evaluate the mechanical behavior of SiC-f/SiC composites under through-thickness temperature gradients, and to elucidate their thermal response, damage evolution, and fracture behavior. As a testing approach to impose temperature gradients, a localized and rapid radiant heating method using two infrared lamps with condensing mirrors was investigated. The digital image correlation (DIC) method was employed to capture the strain distribution under conditions where the front-surface temperature exceeded 1000 °C and the temperature difference between the front and back surfaces was 200–300 °C. In addition, thermal stress analysis was conducted to estimate the thermal strain and stress distributions in the specimens. As a result, the effect of thermal stresses on the fracture behavior of the SiC-f/SiC composites was demonstrated.

HTCMC-12 Symposium 10- CMC Applications I – Aerospace Propulsion and Structures

HTCMCS10- Processing and Properties of CMCs for Aerospace Applications I

Room: Shorebreak 1
Session Chair: Christopher Hawkins, Dstl

1:30 PM

(HTCMC-S10-001-2026) High-temperature characterization of CMCs in inert and oxidizing atmospheres (Invited)

M. Valle*[1]; L. Delledonne[1]; C. Gigante[1]; L. Malucelli[1]; A. Monzillo[1]

1. Petroceramics S.p.A., Italy

CMC combine distinctive properties (low weight, high thermal stability, resistance to thermal shock, and robustness in harsh environments) that are required for several aerospace applications. Liquid Silicon Infiltration (LSI)-Cf-CMCs process can meet these demands while also ensuring cost-effectiveness. Petroceramics has developed ISiComp®, OxyComp® and UHTComp®, each featuring a specific microstructure and designed for use under different operating conditions depending on mechanical loads, temperature, and external atmospheres. Measuring the physical and mechanical properties of these materials at high temperatures and in relevant environments is essential for the proper design of components and for exploring new application opportunities. Petroceramics has developed in-house two specialized facilities dedicated to advanced material characterization. The high-temperature dynamometer allows measurement of bending, tensile, and interlaminar shear strength, as well as elastic modulus, up to 2,700°C in inert atmosphere. The controlled-atmosphere furnace can expose materials to temperatures up to 1,800°C under various environments, including O_2, H_2O, CO, CO_2 and H_2 Here we present the main data obtained through extensive characterization of our materials, highlighting both their capabilities and limitations, and providing a solid basis for evaluating their suitability for new applications.

2:00 PM

(HTCMC-S10-002-2026) Current Tyranno Fiber® (SiC Fiber) developed by UBE Corporation and its applications (Invited)

T. Matsunaga*[1]

1. UBE Corporation, Specialty Products Division, Japan

UBE Corporation has developed several types of silicon carbide-based fibers which is called to “Tyranno Fiber®” for a few decades. The silicon carbide-based fibers are often used as a reinforcement materials for a silicon carbide fiber reinforced silicon carbide ceramic matrix composite (SiC/SiC-CMC). The SiC/SiC-CMC requires high-temperature capability because the SiC/SiC-CMC is expected to be utilized in various harsh environments such as a hot-section of turbine engine, a cladding rod of nuclear reactor, blanket of fusion reactor and so on. Besides since the silicon carbide fiber strongly governs to the SiC/SiC CMC, the higher temperature capability silicon carbide fibers are required accordingly. Thus, the high temperature capability, mechanical properties and so on of silicon carbide fibers has been improved. In the presentation, we would like to express some grades of Tyranno Fiber® developed by UBE Corporation and its Applications.

2:30 PM

(HTCMC-S10-003-2026) Damage-tolerant design for impact resistant ceramic matrix composites

A. Caporale*[1]; G. J. Janszen[1]; M. Ursic[2]; R. Passoni[2]; A. Airoldi[1]

1. Politecnico di Milano, Dept. of Aerospace Science and Technology, Italy
2. Brembo NV, Italy

This study investigates experimental methodologies for assessing impact tolerance and residual strength of ceramic matrix composites (CMC) thick drilled specimens taken from high-performance racing brake discs. The CMC is LSI C/SiC, with 3D long-fiber reinforcement in discs. A damage-tolerant approach was adopted, focusing on barely visible impact damage (BVID) and its effect on structural integrity. Low-velocity impact tests at varying energies identified visibility thresholds and damage mechanisms. Impact outcome showed repeatable damage modes and cracks shape. Post-impact evaluation employed a three-point bending test, proving the best compromise between simplicity and effectiveness. The effect of stress concentration of possible undesired anticlastic curvatures, typical of thick plates, and torsions were considered. These tests established relationships between impact energy, damage detectability, and residual strength. The results showed a relevant strength reduction (~30/40%) in specimens with hardly detectable damage. Fatigue tests under cyclic bending up to one million cycles on BVID specimen showed no stiffness loss or crack growth, confirming excellent fatigue resistance. The proposed methodologies provide a robust framework for defining BVID thresholds, assessing damage detectability, and establishing reliable design allowables for CMC components in safety-critical applications.

3:10 PM

(HTCMC-S10-004-2026) Hafnium-based ceramic nano composites: Near-zero ablation for hybrid rocket applications (Invited)

S. Lee*[1]; V. Nguyen[1]

1. Korea Institute of Materials Science, Republic of Korea

In hybrid rocket systems, the nozzle—particularly the throat—is exposed to extreme heat flux and shear from combustion gases, making it highly prone to ablation in oxidizing environments. Such degradation can reduce chamber pressure and specific impulse, highlighting the need for refractory, oxidation-resistant nozzle materials. This study evaluates the ablation resistance of hafnium-based ceramic composites and their influence on chamber performance. Hafnium carbide (HfC) and hafnium diboride (HfB_2) generate stable refractory oxides that provide excellent protection. High-purity HfC–SiC and HfB_2–SiC composites with ultra-fine microstructures were tested using a 250 N hybrid thruster operating on high-test peroxide and HDPE. Inserts of HfC–SiC, HfB_2–SiC, and graphite were fired without cooling at ~30 bar for 25 s, and the HfB2–SiC insert underwent an additional 102 s of cumulative firing to assess reusable survivability. Both HfC–SiC and HfB_2–SiC showed near-zero erosion, with only minor throat shrinkage from oxide-induced volume expansion. In contrast, the graphite throat diameter increased by over 111%. Consequently, chamber pressure and specific impulse remained nearly unchanged with hafnium-based inserts, whereas the graphite nozzle saw drops of ~39% and ~5%. Hafnium-based composites therefore provide stable performance and exceptional ablation resistance for hybrid rocket nozzles.

3:40 PM

(HTCMC-S10-005-2026) Advanced manufacturing and densification techniques for fabricating ceramic matrix composites (Invited)

D. Mitchell*[1]

1. University of Central Florida, Materials Science and Engineering, USA

Advanced/additive manufacturing (AM) techniques and densification processes relevant to fabricating ceramic matrix composites (CMCs) are surveyed. Current and potential future AM techniques are considered, including those applied to create both short and continuous fiber CMCs. Techniques to generate short fiber preforms, such as extrusion/direct ink write (DIW), binder jet (BJP), digital light processing (DLP) are elucidated. Advanced printing technologies that can create continuous fiber preforms are considered including desktop systems employing X-Y-Z gantry structures, filament winding and 3D robotic printing of continuous fiber and resin. The three primary net-shape densification processes will be reviewed, including reactive melt infiltration (RMI), polymer infiltration and pyrolysis (PIP), and chemical vapor infiltration (CVI), with advantages and disadvantages being discussed. Combining densification techniques will also be examined.

4:10 PM

(HTCMC-S10-006-2026) Polymeric ZrC precursors for ultrahigh-temperature ceramic matrix composites (Invited)

J. Hepp[1]; J. Williams[1]; I. Ivanov*[1]; C. Deck[1]; H. Khalifa[1]

1. General Atomics Electromagnetic Systems Group, Nuclear Technologies and Materials (NTM), USA

Ultrahigh-temperature ceramic matrix composites (UHTC CMC) enable operations in the extreme conditions encountered by hypersonic vehicles, beyond what is achievable with C/C and C/SiC CMC. Leveraging progress with pre-ceramic polymer prepreg and polymer infiltration and pyrolysis (PIP)-based processing, General Atomics Electromagnetic Systems (GA-EMS) has developed a series of polymeric precursors for ZrC based UHTC CMC materials. A series of polymeric ZrC precursors have been produced, including soluble solids and low-viscosity liquids, to identify an optimal precursor that balances CMC performance and fabrication efficiency.

4:40 PM

(HTCMC-S10-007-2026) SiC-based matrix densification and high-temperature mechanical properties with solid-state synthesized additives for CMC: Boron and titanium

M. Park*[1]; S. Jung[1]; W. Kwon[1]; W. Choi[1]; S. Lee[1]

1. Korea Institute of Materials Science, Extreme Materials Research Institute, Republic of Korea

SiC and SiC-based composites are prominent materials for harsh high-temperature environment applications, such as turbines and aerospace structures. Having a reliable structural material under these environmental conditions is crucial for system safety, performance, and efficiency. Over the past decade, SiC-based CMC has played a key role in commercial aviation engines and continues to expand its applications. However, significant efforts are being made to overcome inherent thermal limitations of commercialized SiC. Our group has been developing efficient strengthening techniques through factors related to filler compaction and precursor impregnation & pyrolysis (PIP), and has materialized high-strength carbon fiber-SiC CMC without additives (541 MPa in situ flexural strength at 2273K, inert). Moreover, we have been testing SiC filler for high-temperature atmospheric conditions with small amount of additives (usually below 1 vol.%), which result in beneficial behavior, strengthening while avoiding thermal degradation, and densification of the final product via solid-state processing. Additives containing boron (B) or titanium (Ti) have particularly caught our attention.

By controlling the initial packing density through the use of cold isostatic pressing (CIP), we have tested the contributions of additives before applying them to the CMC.

HTCMC-12 Symposium 11- CMC Applications II – Solar, Nuclear and Propulsion Systems

HTCMCS11- Coatings, integration, joining and machining

Room: Sandpiper D
Session Chair: John Holowczak, RTX Corporation

1:30 PM

(HTCMC-S11-001-2026) Development and assessment of SiC/SiC composite joints for containers in concentrated solar power systems (Invited)

V. Casalegno*[1]; C. Malinverni[1]; M. Salvo[2]

1. Politecnico di Torino, DISAT, Italy
2. Politecnico di Torino, Italy

Ceramic matrix composites (CMCs) offer superior high-temperature oxidation resistance compared to metallic alloys and higher fracture toughness than monolithic ceramics. Among them, silicon carbide fiber–reinforced silicon carbide matrix composites (SiC/SiC) combine excellent high-temperature thermo-mechanical properties with corrosion resistance, making them attractive for advanced thermal systems. In this work, a joining strategy tailored to SiC/SiC components was developed for their integration into containers used in concentrated solar power plants, where high-temperature metallic phase change materials (mPCMs) serve as thermal energy storage media. A key requirement is that both the composite and the joint region remain structurally sound and chemically stable when exposed to molten mPCMs, such as AlSi12 alloy and silicon. Two joining solutions—a SiC-based adhesive and a glass-ceramic system—were selected for their chemical compatibility with the storage media, suitable wetting behavior, and thermal expansion match with the composite. Joints were characterized by SEM and single-lap offset shear tests to evaluate microstructural integrity and apparent shear strength of butt and flat-faying geometries. Corrosion in molten mPCMs was investigated to assess durability under realistic conditions, comparing SiC/SiC substrates with and without a boron nitride coating.

2:00 PM

(HTCMC-S11-002-2026) The Joining and Fabrication of thin-walled ceramic composites with Embedded Wire Chemical Vapor Deposition

S. P. Shuster*[1]

1. Free Form Fibers, USA

As the field of aerospace materials advances so too does the need for more complex high temperature capable ceramic matrix composites (CMCs). One area CMCs still in need of advancements is in the area of joining. Current experimental options which include various forms of sintering, brazing, and super alloy approaches are often insufficient for various reasons. Embedded wire chemical vapor deposition (EW-CVD) can be offered as a sufficient alternative. EW-CVD is a manufacturing process developed in-house that can join existing CMCs homogenously, in addition to producing independent thin-walled ceramic matrix composites. From a conceptual standpoint the EW-CVD process works by utilizing a series of non-woven mattes consisting of high temperature ceramic fibers produced via laser driven chemical vapor deposition. A series of special resistive elements are passed through these mattes to heat the sample allowing the sample to act as its own heat source during the deposition and infiltration process. This process has demonstrated a unique control of composite microstructure, chemical identity, and thermal gradients while working off low power demands. For example, the energy required to fabricate Si_3N_4/Si_3N_4 composites is on the order of 100kW/kg. The composites fabricated in this work include (SiC/SiC) CMCs and silicon nitride (Si_3N_4/Si_3N_4) CMCs.

2:20 PM

(HTCMC-S11-003-2026) Design and manufacture of SiC/SiC joints by embedded wire chemical vapor deposition

B. W. Lamm*[2]; J. Pegna[1]; E. Cakmak[2]; W. Zhong[2]; T. Koyanagi[2]

1. Free Form Fibers, USA
2. Oak Ridge National Laboratory, Materials Science and Technology Division, USA

Ceramic joining – of monoliths and composites – has largely been restricted to brittle monolithic joints using dissimilar (heterogeneous) materials, similar to brazing in metals. This work presents the development of damage-tolerant joints using SiC fiber reinforcement. Tube work pieces (SiC fiber / SiC matrix composite) were joined by a nonwoven SiC fiber mat densified by embedded wire chemical vapor deposition (EWCVD) to create a fiber-reinforced weld-like joint by homogeneous joining. EWCVD minimizes thermal damage to surrounding composite workpiece material by using localized heating in the joint region specifically. The relative density, adhesion, and composition of joints were characterized by X-ray computed tomography (XCT). In-situ XCT during mechanical testing revealed crack deflections in the bonding layer, which indicated a toughening mechanism common in fiber-reinforced ceramic matrix composites. The novelty of the composite joining method and current technology challenges, including gas permeability, are discussed in comparison with traditional ceramic joints and materials.

2:40 PM

(HTCMC-S11-004-2026) Laser assisted joining of SiC/SiC for high temperature applications

M. Ferraris*[1,2]; K. Pandey[1,2]; A. Benelli[1,2]; M. De Maddis[3,2]

1. Politecnico di Torino, Department of Applied Science and Technology, Italy
2. J-Tech@PoliTO, Italy
3. Politecnico di Torino, DIGEP, Italy

Several technologies and materials have been proposed for joining of SiC/SiC components for high temperature applications. Among them, laser assisted joining seems to give promising results as a pressure-less, localized heating joining technology suitable for SiC/SiC. The present work reports on results on laser assisted joining of SiC/SiC; several joining materials have been used to join SiC/SiC by a diode laser (LDF 4000-40, Laserline GmbH) operating in the infrared (1020-1060 nm). Morphology, mechanical properties and micro-structure of joined SiC/SiC tubes will be discussed.
Acknowledgements Part of the research leading to these results has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101059511 - Project SCORPION (SiC Composite Claddings: LWR Performance Optimisation for Nominal and Accident Conditions)

HTCMCS11- CMC for energy systems
Room: Sandpiper D
Session Chair: Valentina Casalegno, Politecnico di Torino

3:20 PM

(HTCMC-S11-005-2026) Reflections on 40 Years of Structural Ceramics and CMCs for Nuclear, Turbine, and Heat Exchanger Applications (Invited)

J. E. Holowczak*[1]
1. RTX Corporation, Research Center, USA

The purpose of this talk is to provide a broad overview of the challenges encountered and solutions pursued over a 4 decade career in structural ceramics and ceramic matrix composites. It will span applications such as turbine engine hot section, nuclear fuel cladding, concentrated solar, armor, and heat exchanger applications. From early work in whisker toughened silicon nitride processing, to ceramic/metal interfaces, turbine silicon nitride pilot plant development, glass-ceramic matrix composite complex shape fabrication, lessons learned in application engineering of monolithic ceramics in small engines, cooled ceramics in industrial turbines, early environmental barrier coatings (EBC's), to analysis of and current work in development of fiber matrix interface coatings, much work has been accomplished. Additional challenges lie ahead, most notably production cost. The development of "hybrid" monolithic ceramic/CMCs, for applications in armor systems and turbine hot sections, are an approach to minimizing fiber content and raw materials cost. These are complex material systems where each aspect of fiber selection, interface application, matrix consolidation/bonding, and EBC coating processes must be carefully considered. The importance of continued government risk sharing, and the role if the United States Advanced Ceramics Association will be briefly discussed.

3:50 PM

(HTCMC-S11-006-2026) Ceramic Heat Exchanger for Solar Industrial Process Heat* (Invited)

D. Singh*[1]
1. Argonne National Lab, USA

Several high-temperature and high-pressure applications in power generation and manufacturing require heat exchangers (HXs) to transfer heat. One such application is in concentrated solar where a fluid is heated up using solar radiation and the heat is transferred to another fluid for potential use as process heat. For solar heat for industrial (chemical/materials manufacturing, etc.) processes, ceramic HXs need to operate above 700°C and up to 20 MPa fluid pressures for efficient heat transfer. At these temperatures and pressures, metal heat exchangers degrade in structural performance. To this end, heat exchangers based on advanced materials such as silicon carbide (SiC) are needed. In this presentation, design and development of a SiC-based heat exchanger will be discussed. Efforts related to process scale-up of the SiC HX will be highlighted. Finally, results on the performance testing will be presented. *This work was supported by the U.S. Department of Energy's (DOE) Office of Energy Efficiency and Renewable Energy (EERE) under the Solar Energy Technologies Office (SETO) Award Number 38479 at Argonne National Laboratory operated under Contract no. DE-AC02-06CH11357 by the UChicago Argonne, LLC.

4:20 PM

(HTCMC-S11-007-2026) Microscopic mechanical properties of Si_3N_4-based ceramics (Invited)

J. Tatami*[1]
1. Yokohama National University, Faculty of Environmental and Information Sciences, Japan

Silicon nitride (Si_3N_4) ceramics are typical engineering ceramics, and they have been applied to various fields, such as mechanical seals for nuclear equipment, and bearing balls, igniters, and tubes for aircraft engine and propulsion systems. In such applications, the thermal, mechanical, and chemical environments subjected to materials are increasingly severe conditions year after year. In order to ensure system reliability, understanding the degradation of mechanical properties of materials, particularly near the surface where they are highly affected by environmental influences. In this study, the objective was to clarify the microscopic mechanical properties of Si3N4 ceramic surfaces exposed to the environment through bending tests using microcantilever beam specimens. Exposure to acids or molten metals was found to change the chemical composition of the grain boundaries, resulting in a decrease in their strength. The degree of degradation depended on the type of sintering aid used. It was also revealed that the grain boundary strength on surfaces subjected to repeated stress similarly decreased. These findings are considered to result from stress concentration caused by dislocations generated in the β-Si_3N_4 grains near the surface.

Tuesday, June 2, 2026

GFMAT-3 Symposium 1- Powder Processing Innovation and Technologies for Advanced Materials and Sustainable Development

GFMATS1- Advanced characterization and analytical techniques for powder processing and materials
Room: Shorebreak 2
Session Chairs: Shaista Ilyas, Institute of Inorganic and Materials Chemistry; Chika Takai, Nagoya Institute of Technology

8:40 AM

(GFMAT-S1-006-2026) Sequential 3D characterization for structure understanding and defect control in alumina manufacturing (Invited)

S. Tanaka*[1]
1. Nagaoka Gijutsu Kagaku Daigaku, Japan

Three-dimensional (3D) observation is highly effective for understanding ceramic manufacturing. Continuous observation throughout the fabrication steps can significantly deepen our mechanistic understanding, particularly regarding defect formation. In this study, we utilize alumina as a model material to overview our findings. We introduce the 3D observation of bulk ceramics, focusing on molding through sintering, where granules are conventionally used. μ-X-ray CT was utilized to observe defect evolution. Our results clearly show that inter-granule gaps gradually increase during sintering. Furthermore, Liquid Immersion Microscopy, a simple optical method, also tracked the internal 3D structure. By combining continuous μ-Xray CT with the liquid immersion method, we comprehensively analyzed the mechanisms governing the formation and growth of large defects and their relationship to the overall sintering process. This presentation is based on results obtained from a project, JPNP22005, commissioned by the New Energy and Industrial Technology Development Organization (NEDO)

9:10 AM

(GFMAT-S1-007-2026) Geopolymerization of lunar and martian regolith simulants for space sustainability (Invited)

L. Santo*[1]; A. Proietti[1]; F. Quadrini[1]
1. Universita degli Studi di Roma Tor Vergata, Italy

In-Situ Resource Utilization (ISRU) and protection of astronauts and infrastructures from harsh environments are two relevant issues for the human settlements on the Moon and Mars considering Space sustainability. The use of local natural resources, instead of taking all needed supplies from Earth, enhances the capabilities of human exploration. Blocks for construction used to produce structural shields for the harsh space environment can be manufactured from regolith using different technologies. In this study, geopolymerization of regolith simulants of the Moon and Mars has been carried out. Regolith simulants of the Moon (LHS-1) and Mars (MSG-1, and JEZ-1) were provided by Space Resource Technologies (FL, USA). Tests have been performed in different conditions by mixing powders with a sodium hydroxide solution, compaction molding at room temperature, and subsequent high temperature drying. Flat samples for bending tests have been manufactured, and physical and mechanical tests have shown the possibility of this technical solution to build shielding blocks with sufficient strength. Results have been compared for different technological conditions. At the end, findings are discussed in the frame of Space sustainability.

9:40 AM

(GFMAT-S1-009-2026) Rheology and microstructural dynamics in ceramic processing (Invited)

T. Okazaki*[1]

1. Sangyo Gijutsu Sogo Kenkyujo Tsukuba Chuo Jigyosho, Japan

Understanding how ceramic microstructures evolve during processing is essential for achieving reliable and defect-controlled materials. This talk presents an overview of our recent studies on the rheology of aqueous slurries and the microstructural dynamics that occur during drying and sintering. We first show how variations in flow behavior, especially rheological hysteresis, influence the stability of particle networks and the onset of drying-induced cracking. Experimental analysis combined with machine-learning techniques reveals that hysteresis serves as a practical indicator of crack susceptibility and can be tuned to minimize defect formation. In addition, we introduce in situ observations of early-stage sintering using an environmental scanning electron microscope, which allow direct visualization of structural rearrangement and densification under controlled atmospheres. These results provide insights into mass transport and pore evolution that are not accessible by conventional methods. Acknowledgements: This work was based on results obtained from a project, JPNP22005, commissioned by the New Energy and Industrial Technology Development Organization (NEDO).

10:30 AM

(GFMAT-S1-010-2026) Isotropic graphite manufacturing process and product introduction (Invited)

H. Shirakawa*[1]

1. Toyo Tanso Kabushiki Kaisha, Japan

This presentation systematically explains carbon materials from fundamentals to applications, focusing specifically on the properties and manufacturing processes of isotropic graphite, as well as Toyo Tanso Co., Ltd.'s technological capabilities and global expansion. Regarding isotropic graphite, the concepts of anisotropy and isotropy due to differences in particle orientation are explained. The reasons for its artificial production, its high reliability, and the company's pioneering development achievements are introduced. The manufacturing process is detailed, covering the entire workflow from raw material grinding and mixing through pressing (Cold Isostatic Pressing), sintering, pitch impregnation, graphitization, high-purity treatment, coating, machining, inspection, and shipping. It specifically highlights high-purity processing, functionalization through various coatings (e.g., SiC, Pyrocoat), and application examples in the semiconductor and nuclear power sectors. Furthermore, it highlights diverse application examples where Toyo Tanso's products excel, spanning semiconductors, automobiles, railways, aerospace equipment, medical devices, renewable energy, industrial furnaces, continuous casting, and electrical discharge machining. Alongside its global market share leadership, it introduces the company's technological development framework and its capability to address customer challenges.

11:00 AM

(GFMAT-S1-011-2026) Internal structure evolution of silica slurry during drying observed by OCT - Influence of molecular weight of PEI used as dispersant-

J. Tatami*[1]; H. Kuroda[1]; M. Iijima[2]; T. Takahashi[3]

1. Yokohama National University, Japan
2. Yokohama National University, Graduate School of Environment and Information Sciences, Japan
3. Kanagawa Institute of Industrial Science and Technology, Japan

The effect of molecular weight of PEI added to an aqueous silica slurry on internal structural changes during drying was investigated by optical coherence tomography (OCT). OCT observations revealed that localized agglomeration occurred in the as-prepared slurry due to insufficient steric repulsion from low molecular weight PEI. Analysis of OCT images during the initial drying stage confirmed that agglomeration initiated from the surface as particle concentration increased, with an agglomeration transition region. In particular, the agglomeration transition in the low-molecular-weight PEI-added slurry occurred gradually due to agglomeration present in the as-prepared slurry. Furthermore, drying of the slurry containing low-molecular-weight PEI proceeded rapidly due to the inhomogeneous agglomeration regions. Moreover, as the molecular weight of PEI decreased, the thickness of the adsorption layer became smaller, resulting in an increase in particle concentration within the agglomeration regions. During the middle stage of drying, the deformation of the agglomerated regions varied depending on the thickness of the PEI adsorption layer. It was found that the final green density is controlled by the particle concentration in the agglomeration region during the initial stage and the deformation of the region during the middle stage.

11:20 AM

(GFMAT-S1-012-2026) Freezing behavior and spray freeze granulation drying of non-aqueous silicon nitride slurries with varying PEI molecular weights and OA contents

R. Yamazaki*[1]; J. Tatami[2]; M. Iijima[3]; S. Kawaguchi[4]; N. Kondo[5]

1. Yokohama Kokuritsu Daigaku, Graduate School of Environment and Information Sciences, Japan
2. Yokohama National University, Japan
3. Yokohama National University, Graduate School of Environment and Information Sciences, Japan
4. PRECI Co., Ltd., Japan
5. Kokuritsu Kenkyu Kaihatsu Hojin Sangyo Gijutsu Sogo Kenkyujo, Japan

Spray freeze granulation drying (SFGD) has been applied to reduce defects in ceramics, further improving their properties. In order to extend this technique for silicon nitride ceramics, a solvent mixture of tert-butyl alcohol and cyclohexane in a eutectic composition has been used as a dispersion medium. This approach confirmed the successful production of ceramics with a homogeneous structure. In this study, focusing on particle interface, slurries with varying molecular weights of polyethyleneimine (PEI) and contents of oleic acid (OA) in PEI-OA complex used as an organic additive were prepared. The effects of these parameters on the freezing behavior and the propertries of SFGD granules were evaluated. As a result, slurries with a higher content of OA or a larger molecular weight of PEI exhibited a lower freezing temperature due to better affinity between particles and the dispersion medium. Furthermore, it was also found that a higher OA content or a smaller PEI molecular weight showed the higher freezing rate, resulting in the formation of smaller pores of freeze-dried bodies.

GFMAT-3 Symposium 4- Crystalline Materials for Semiconductor, Optical/ Scintillator and Dielectric Applications

GFMATS4- Electronic material

Room: Sandpiper C
Session Chairs: James K C, University of Hyderabad; Kozo Fujiwara, Tohoku Daigaku

8:30 AM

(GFMAT-S4-008-2026) In-situ observation of solid-liquid interface phenomena in semiconductor materials (Invited)

K. Fujiwara*[1]

1. Tohoku Daigaku, Institute for Materials Research, Japan

Most bulk crystals of Si and other semiconductor materials are produced by the melt growth method. Various phenomena such as crystal defect formation and impurity segregation occur at the solid-liquid interface during crystal growth, and these phenomena significantly affect the quality of bulk crystals. The quality of bulk crystals in these semiconductor materials has been continuously improved over the years due to the development of crystal growth techniques. On the other hand, in the basic understanding of crystal growth, there are many phenomena whose theoretical interpretation is ambiguous due to lack of direct evidence of experimental facts. Our group has independently developed an "in-situ" observation system and has observed the solid-liquid interface of various materials, mainly Si. This system combines a compact horizontal crystal growth furnace with an optical digital microscope, enabling clear observation of crystal growth processes from the melt even at high temperatures near the melting point of Si (1687 K). In this presentation, several phenomena that occur in the unidirectional solidification process of Si and Si-Ge will be introduced. Specifically, we will focus on the solid-liquid interface morphology and discuss how crystal growth rate and impurities affect the solid-liquid interface morphology.

9:00 AM

(GFMAT-S4-009-2026) Interfacial control and device structures of van der Waals semiconductors on ferroelectric HfZrOx insulator toward flexible electronics (Invited)

N. Hiroshiba*[1]; K. Koike[1]

1. Osaka Kogyo Daigaku, Japan

This presantation provides our recent advancements in the design of device structures and fabrication processes of ferroelectric hafnium zirconium oxide (HZO) thin films deposited by the Facing Target Sputtering (FTS) method. HZO is one of key materials to realize the memory function and low voltage operations in conventional Si based CMOS circuit. However, the interfacial problems at Si/HZO interface are not ignored fatal point to the practical implementation and mass production. By moving from the conventional rigid, thermally unstable Si substrate to the vdW semiconductor/HZO heterostructure, we strategically bypass the fatal interfacial issues of the Si/HZO system. This approach exploits the clean, dangling-bond-free nature of the vdW interface, which is essential for achieving high-performance, low-voltage, and flexible ferroelectric devices. First, we focus on the solution-processed thienothiophene-based semiconductors grown on the HZO surface. We investigate the surface morphologies, crystallinity, and charge transport across the organic/HZO interface. Second, we discuss the fabrication process and device application of vdW graphene layer integrating on HZO insulators. The presented methodology provides crucial insights into the rational design and synthesis of functional hybrid systems based on vdW integration.

9:30 AM

(GFMAT-S4-010-2026) A process to make crystalline oxide ferroelectrics compatible with polymer or si substrates using expanded laser beam (Invited)

J. R. K C*[1]; A. TS[1]

1. University of Hyderabad, CASEST, School of Physics, India

There are phenomena like ferroelectricity which are exhibited only by crystalline state of the matter. For oxide ferroelectrics with good properties crystallization temperature is about 700°C, which is beyond the reach of polymers and nanoscale silicon. Hence non thermal crystallization processes are needed. A comfortable temperature is 250-300°C. It has been found that laser annealing is a suitable process to get these oxide films crystallized at these temperatures. Penetration depth related issues, makes the crystallization archived incomplete but good enough to exhibit their characteristic piezoelectric properties. The process requires extensive optimization owing to the many parameters involved. These studies were carried out primarily with the PLD grown films of $Ba_{0.5}Sr_{0.5}TiO_3$ (BST) and the studies were primarily in terms of their dielectric properties in the microwave range and their DC field dependence. The polymer substrate used is modified PTFE composite known by the trade name as RT Duroid. This process is significant considering the Semiconductor technology roadmap goal of integrating functional oxides with nanoelectronics in Si by 2028. This process is an alternate route to achieve this goal without the introduction of any chemical contaminants. Since this process use an expanded laser beam, it is possible to process whole wafers by this method.

10:20 AM

(GFMAT-S4-011-2026) Electrical properties of alkaline-earth hexaboride thin films doped with lithium

A. Hirales*[1]; V. R. Vasquez[2]; O. A. Graeve[1]

1. University of California San Diego, USA
2. University of Nevada Reno, USA

We explore how lithium doping influences the electrical behavior of alkaline-earth hexaboride thin films of CaB_6, SrB_6, BaB_6 synthesized via magnetron sputtering. Using a combination of radio frequency and direct current sputtering, lithium incorporation was systematically varied. Structural integrity was confirmed by X-ray diffraction, and film thickness was assessed via X-ray reflectometry. Electrical characterization through atomic and electrostatic force microscopy revealed a consistent decrease in the electrical bandgap and a marked enhancement in conductivity with increasing lithium content. X-ray photoelectron spectroscopy quantified lithium levels, directly correlating composition to electronic performance. These results demonstrate that lithium doping effectively tunes the electrical properties of hexaboride films, supporting their application in next-generation electronic devices.

GFMATS4- Transparent ceramic

Room: Sandpiper C
Session Chairs: Matthias Müller, Radiation Monitoring Devices Inc; Nobuya Hiroshiba, Osaka Kogyo Daigaku

10:40 AM

(GFMAT-S4-013-2026) Surface initiated densification of $MgAl_2O_4$ spinel driven by Ca concentration gradient (Invited)

H. Kim[1]; S. Cheon[1]; Y. Park*[1]; J. Ko[1]; J. Lee[1]

1. Korea Institute of Materials Science, Republic of Korea

We investigate the long-standing controversy regarding the role of calcium additives in the sintering of magnesium aluminate $MgAl_2O_4$ spinel, hypothesizing that spatial distribution is the decisive factor. Three specimens were prepared: undoped(SP), 800 ppm Ca homogeneously added via $CaCO_3$ powder(SP_P), and 800 ppm Ca surface-enriched via $Ca(NO_3)_2$ solution impregnation(SP_S).

Pressureless sintering at 1450°C revealed that SP_S achieved 95.7% relative density, whereas SP(89.4%) and SP_P(88.9%) didn't densify highly, confirming the critical role of the Ca gradient. EPMA, XRF, EDS analyses validated a Ca gradient in SP_S, confined within ~0.2 mm of the outermost surface. This led to a core-shell structure with a >99% dense shell and a ~91% dense core. After HIP treatment at 1450°C/180 MPa Ar/5 h, SP_S_1450H exhibited superior in-line transmittance of 78.62% at 300 nm and 85.73% at 800 nm, surpassing the compared samples owing to the lower amount of total porosity simulated according to Mie scattering theory. We propose a hybrid densification mechanism, (i) surface densification via Ca-rich eutectic liquid forming a shell, and (ii) stress-assisted solid-state densification of the core under compressive stress confirmed by X-ray. This self-enveloped sinter-HIP process enables full consolidation of a core with open porosity of ~91%, effectively lowering the conventional closed-pore threshold.

11:10 AM

(GFMAT-S4-014-2026) Optical and laser properties of sapphire/YAG bonding materials by pulsed electric current sintering (Invited)

H. Furuse*[1]; H. Uehara[2]; R. Yasuhara[2]

1. National Institute for Materials Science (NIMS), Japan
2. National Institute for Fusion Science, Japan

We have developed a simple and convenient bonding technique for sapphire, which has high thermal conductivity, and YAG ceramics, a representative high-power laser material, using pulsed electric current sintering (PECS). This method enables the fabrication of bonded materials with high optical quality, even between dissimilar materials with different thermal expansion coefficients, and improvements in laser properties have also been confirmed due to sapphire conduction cooling effect. In the presentation, we report on the fundamental optical characteristics of the sapphire/YAG bonded materials, such as in-line transmittance, birefringence, transmitted wavefront, and laser performance. Investigations into sandwich structures, scaling up to larger diameters, and interface microstructures, as well as future challenges and prospects for further increasing laser output, will also be discussed.

11:40 AM

(GFMAT-S4-019-2026) Laser purification and processing of quartz silica sand

S. Risbud*[1]; A. Naim[1]

1. University of California, USA

In collaboration with our industry partner we have developed rapid heating laser processes to purify raw quartz silica sand to make advanced materials for energy and technology applications. This environmentally friendly process leads to ultra-high purity levels (+99.99%) and is suitable primarily for high-end industrial applications such as semiconductors, LCDs, and optical glass. The process leverages femtosecond laser ablation, which eliminates the need for hazardous chemicals and energy-intensive mechanical methods traditionally used in silica purification. For example, writing silicon nanostructures inside silica for photonic devices is directly relevant to photonic chip interest. In this talk new will show how fast heating methods can make available ceramics and glasses in future applications.

GFMAT-3 Symposium 6- Advanced Batteries and Supercapacitors for Energy Storage Applications

GFMAT-S6- Battery Electrolyte and Interface Design

Room: Tidepool 1

Session Chairs: Dong-Hwa Seo, Korea Advanced Institute of Science and Engineering (KAIST); Yuki Orikasa, Ritsumeikan University

8:30 AM

(GFMAT-S6-008-2026) Unlocking the potential of non-aqueous battery electrolytes beyond conventional constraints (Invited)

I. Cekic-Laskovic*[1]

1. Forschungszentrum Julich GmbH, Helmholtz Institute Münster, Germany

In the domain of lithium-based battery systems, a holistic materials-science perspective is essential: cell performance, safety and lifetime depend not only on active materials, separators and inactive components, but on the complex interactions between them. Among these, the electrolyte plays a uniquely pivotal role: it bridges and interfaces with all other cell elements, governs redox reactions, dictates interfacial chemistry, and ultimately affects cost, stability and safety of each cell chemistry. The engineering of innovative non-aqueous electrolytes demands a careful balance of relevant properties, and represents both a formidable challenge and an exceptional opportunity. Comprehensive studies employing complementary electrochemical, analytical and spectroscopic techniques (including high-throughput workflows), alongside theoretical and machine-learning approaches, are indispensable. Integrating gained insights enables identification of critical parameters and processes within the cell, thereby driving the progression of battery technologies toward defined application benchmarks. This presentation invites you to explore the scientific design, development, and characterization of innovative electrolyte formulations by unlocking their full potential to elevate lithium- and sodium-based chemistries to unprecedented levels of performance, safety and application readiness.

9:00 AM

(GFMAT-S6-009-2026) Rational solvent design for advanced lithium-ion batteries (Invited)

Y. Yamada*[1]

1. The University of Osaka, SANKEN, Japan

An electrolyte for lithium-ion batteries (LIBs) has been traditionally composed of mixed organic carbonates including ethylene carbonate (EC), because they can form a stable solid electrolyte interphase (SEI) on graphite anodes. However, the carbonate-based electrolytes have some drawbacks such as high flammability and instability at high voltage and high temperature. To address this problem, various other solvents have been studied. For example, organic phosphates such as trimethyl phosphate (TMP) have been extensively studied as a co-solvent to reduce the flammability, but they cannot form a good SEI. Previously, we reported a fluorinated cyclic phosphate (TFEP) as a new solvent having both non-flammable character and good SEI-forming ability, but it is chemically and thermally unstable, preventing its widespread use as a main solvent. Here we design and synthesize a new solvent for LIB electrolytes by incorporating molecular-structural features of several solvents/salts. The new solvent has high chemical and thermal stabilities as well as both non-flammable character and good SEI-forming ability enabling reversible Li^+ intercalation at graphite anodes. Besides, the solvent can form a good cathode electrolyte interphase (CEI). We demonstrate excellent cycling performances of graphite anodes and high-voltage cathodes even at a higher temperature (70°C).

9:30 AM

(GFMAT-S6-010-2026) Renovating electrolytes for fast-charging and high-energy Li-ion batteries (Invited)

H. Lee*[1]

1. Yonsei University, Republic of Korea

Extremely fast-charging (XFC) in Li-ion batteries is often compromised when pursuing high-energy cell designs. This trade-off originates from interfacial dynamics involving Li^+ transport, desolvation kinetics, and solid-electrolyte interphase (SEI), all of which are dictated by electrolyte frameworks. This talk addresses the crucial role of electrolytes in achieving XFC capability in EV-targeted Li-ion cells. As a starting point, we revisit the high-concentration electrolyte (HCE) concept using linear carbonate (DMC) solvent, to effectively lower Li^+ desolvation energy barrier. For the SEI control, additive-guided engineering enables a thin, fluorinated 'Goldilocks' SEI formation, enhancing XFC cycling while suppressing Li plating Beyond DMC, highly conductive, low-viscosity ester-based HCE can guide smaller solvation clusters and serve as a molecular lubricant along Li^+ percolation pathway, boosting XFC capabilities over 10 C-rate (6-min charging) across all aspects, including solvation structures, interfacial kinetics, and bulk Li^+ transport. This electrolyte framework demonstrates outstanding XFC cycling at the pouch-cell level, and with extremely thick graphite (6.0 mAh cm^{-2}) and moderately thick Si-based anodes. This work provides an integrated design perspective for reconciling the trade-off between fast-charging and high-energy Li-ion batteries through electrolyte-driven interfacial control.

10:20 AM

(GFMAT-S6-011-2026) Interfacial reaction mechanisms governing battery kinetics and degradation (Invited)

Y. Orikasa*[1]; Y. Goto[1]; T. Hamada[1]; Y. Miyaura[1]; Y. Shiomi[1]

1. Ritsumeikan University, Department of Applied Chemistry, Japan

Lithium-ion batteries are required to exhibit various performance characteristics, including high energy density, high power capability, long cycle life, and safety. These factors significantly influence battery design specifications; therefore, identifying the key factors governing performance is of critical importance. In particular, degradation under high-temperature conditions is closely related to safety, and elucidating the underlying mechanisms is strongly demanded. In this study, we deepen the understanding of complex interfacial phenomena by analyzing reactions at the electrode–electrolyte interface. The solid electrolyte interphase (SEI) formed on the anode is known to play an essential role in enabling stable lithium plating and stripping; however, its reaction mechanisms remain highly complex. Previous studies have shown that the use of highly concentrated electrolytes promotes the formation of SEI layers rich in inorganic components, leading to improved Coulombic efficiency. In this study, we investigated lithium plating-stripping reactions and lithium intercalation–deintercalation into graphite under high-temperature conditions using highly concentrated electrolytes. The resulting electrode surface films were analyzed using hard X-ray photoelectron spectroscopy. Acknowledgement: This work was supported by JST, The Green Technologies for Excellence (GteX) Program, Grant Number JPMJGX23S3.

10:50 AM

(GFMAT-S6-012-2026) Three-dimensional mesoporous graphene for energy applications (Invited)

H. Nishihara*[1]

1. Tohoku Daigaku, Japan

Three-dimensional (3D) graphene-based materials have intensively explored. However, most of the reported materials face several challenges: (i) the presence of stacked graphene structures, (ii) the inclusion of graphene edges, and (iii) the presence of macropores. These issues result in (i) low specific surface area, (ii) poor oxidation resistance, and (iii) low volumetric energy density for battery-related applications, respectively. Our group has developed a novel synthesis pathway to create mesoporous graphene frameworks that avoid these problems. This method involves three steps: (1) uniform coating of oxide ceramic nanoparticles via chemical vapor deposition using specific surface catalysis, (2) template removal through chemical etching, and (3) high-temperature annealing to induce zipping reactions without collapsing the mesopores. The resulting material is termed graphene mesosponge (GMS). Due to its enhanced nanoporosity, oxidation resistance, high electrical conductivity, and unique mechanical flexibility, GMS exhibits exceptional functionality and performance in a wide range of applications, such as high-voltage supercapacitors, new type of heat pumps, durable Pt support for polymer electrolyte fuel cells, high-capacity sulfur support for Li-S batteries, and high capacity cathode with superior stability for $Li-O_2$ batteries.

11:20 AM

(GFMAT-S6-013-2026) Development of high performance Li-S batteries via the usage of scalable electrocatalysts (Invited)

A. J. Bhattacharyya*[1]

1. Indian Institute of Science, Interdisciplinary Centre for Energy Research, India

Sulfur stores energy via conversion chemistry and it's theoretical capacity is nearly an order higher than the best intercalation cathodes used in rechargeable Li/Na-ion batteries. In the context of metal-sulfur batteries using liquid electrolytes, a significant challenge is the leaching of higher-order polysulfides from the S-cathode, leading to anode poisoning, severe capacity fade, and poor energy density. We have previously demonstrated various chemical design-driven matrices targeted at achieving a high percentage of utilisable S-loading and efficient entrapment of polysulfides. An essential strategy is to use suitable electrocatalysts (or additives) embedded in the S-cathode. The role of the electrocatalyst is to trap S/polysulfides and facilitate the reversible S-conversion during charge and discharge. This strategy allows a high percentage of utilizable sulfur, and S-cathode assembly is comparatively simple. We discuss here electrocatalysts based on mono- and binary chalcogenides (oxides, sulfides, selenides), which enable high-performance coin- and credit-card-sized pouch Li-S cells. The talk highlights the importance of binders (aqueous vs. non-aqueous), the negative-to-positive electrode weight ratio, and the sulfur-to-electrolyte weight ratio on battery performance. Our work also highlights the critical role of operando studies in developing highly stable metal-S batteries.

11:50 AM

(GFMAT-S6-035-2026) Borate-Based Electrolytes Enabling Sustainable Sodium Batteries (Invited)

C. Ban*[1]

1. University of Colorado, Boulder, Mechanical Engineering, USA

The development of low-cost electrolytes is crucial for harnessing the full potential of sodium-ion batteries. Our research is focused on creating cost-effective sodium electrolytes and electrode materials, specifically aiming to eliminate fluorine from their formulations in order to reduce costs and minimize environmental impact. While fluorinated components are often deemed essential for maintaining interfacial stability in sodium metal anodes and sodium-ion cathodes, this study explores the feasibility of using fluorine-free electrolytes as a viable alternative. We critically assess whether fluorine-free interphases can provide sufficient stability to support reversible electrochemistry in both sodium-ion and sodium-metal systems. This presentation will discuss various electrode–electrolyte pairs and analyze how our borate-based electrolytes influence the formation and evolution of the solid-electrolyte interphase and the cathode–electrolyte interphase. Furthermore, we will examine how interfacial chemistry affects electrode performance and cycling stability. Overall, this talk highlights the challenges and opportunities associated with fluorine-free electrolyte systems, providing new insights into the impact of interfacial chemistry on battery performance.

HTCMC-12/GFMAT-3 Joint Symposium- Additive Manufacturing Technologies and Applications

HTCMC-GFMAT- Joint Sym- Applications III

Room: Sandpiper B
Session Chair: Hae-Jin Choi

8:30 AM

(Joint Sym-008-2026) Challenges and opportunities of ceramic additive manufacturing (Invited)

A. Michaelis*[1]

1. Fraunhofer IKTS, Germany

Additive manufacturing (AM) of ceramic materials is a powerful shaping technology offering completely new design possibilities. However, AM of ceramics is particularly challenging because the shaping process is embedded in a complex manufacturing scheme. In the case of multi-materials printing the thermal expansion behavior of the materials must be carefully adjusted for the co-sintering process. Know How from established 2D and 2,5 D multi-layer ceramic technologies such as LTCC (low temperature co-fired ceramics) or multi-component injection molding can be employed to address these issues. Examples of new additive manufacturing methods such as ceramic fused filament and ceramic 3D-thermoplastic printing are presented. An important demand for all AM technologies is the improvement of reliability and performance of the manufactured components. Due to the time-consuming manufacturing processes and the layer-wise building process it is necessary to control the quality of each layer in order to repair a defect layer or to stop the building process to avoid waste of time and expensive material loss. Therefore, it is important to access the quality of the printed parts as early as possible. This requires operando non-destructive evaluation methods. For this, we present new optical methods. For a further functionalization of the AM parts, 2D printing technologies are applied.

9:00 AM

(Joint Sym-009-2026) Multimaterial and composite printing: Ongoing efforts at Lawrence Livermore National Laboratory (Invited)

J. Schwartz*[1]

1. Lawrence Livermore National Laboratory, Materials Science Division, USA

Vat photopolymerization and direct-ink-write are facile techniques for fabricating polymer and composite structures, which can then be post-processed to ceramics, glasses, and functional materials. In many cases, however, progress is fundamentally needed in both engineering systems and chemistries to enable good shape fidelity and printability in these complex material systems. This talk will focus on ongoing efforts at Lawrence Livermore National Laboratory to push the boundaries of what is printable for complex, multimaterial, and multi-responsive structures. Highlighted results will include developments in microwave and light-based volumetric additive manufacturing of ceramics and glasses, vat photopolymerization of reinforced composites and battery materials, and direct-ink-writing of composites for diverse applications.

HTCMC -GFMAT- Joint Sym- Stereolithography

Room: Sandpiper B
Session Chair: Johanna Schwartz, Lawrence Livermore National Laboratory

9:30 AM

(Joint Sym-010-2026) Maturing ceramic additive manufacturing: Process–Structure–Property relationships in Vat photopolymerization (Invited)

K. Lee*[1]

1. Los Alamos National Laboratory, USA

Additive manufacturing (AM) of ceramics enables the fabrication of complex, high-performance components that are difficult to produce using conventional ceramic processing. Vat photopolymerization–based techniques, including stereolithography and digital light processing, offer high resolution, smooth surfaces, and geometric flexibility, but their use in functional applications remains limited by post-processing challenges, defect formation, anisotropic behavior, and qualification gaps. This invited talk presents recent advances in maturing ceramic vat photopolymerization through systematic investigation of process–structure–property relationships across silica-based ceramics, alumina, and mullite. Emphasis is placed on the role of debinding and sintering in controlling densification, shrinkage, feature resolution, and mechanical performance. Results show how thermal processing conditions, part geometry, and print orientation influence defect evolution and strength reliability. Purpose-designed test artifacts and statistically meaningful mechanical testing are highlighted as tools for quantifying geometric fidelity and performance limits. The talk concludes with emerging strategies for qualification and design enablement, including architected ceramic lattices, outlining a pathway toward predictable, application-ready ceramic AM.

10:20 AM

(Joint Sym-011-2026) Eliminating prolonged debinding in vat photopolymerization of ceramic materials: A photocurable suspension design approach (Invited)

M. Iijima*[1]; Y. Yamanoi[1]; F. Yokomori[1]; J. Tatami[1]

1. Yokohama National University, Japan

Vat photopolymerization has become a transformative technique for the on-demand 3D fabrication of ceramic components. However, most processes require prolonged debinding to prevent structural collapse originating from gas generation. Here, we introduce our recent achievements in designing photocurable suspensions which enable vat photopolymerization and rapid post processing (i.e. debinding and sintering). The suspension was formulated by dispersing ceramic powders into a mixture of acrylic monomers and solvents, facilitated by a multifunctional reactive polymer that serves both as a dispersant and as an active site for interparticle cross-linking. Upon UV irradiation, the designated suspension undergoes the formation of nanoscale polymer networks among the particles, thereby enabling efficient photocuring even under conditions of low acrylate monomer content. We demonstrate that the proposed suspension can be applied to DLP 3D printing, and that the printed parts can be rapidly fired without structural collapse. Further, owing to the high functionality of the polymer dispersants –including amphiphilic behavior and metal-ion complexation– the proposed suspension can be adapted to form Pickering emulsions and metal-doped systems, allowing the creation of porosity and additional properties in the printed parts while preserving rapid debindability.

10:50 AM

(Joint Sym-012-2026) Studies and characterization of 3D printed ceramic electrolytes for batteries

M. Faral*[1]; A. Laventure[1]; M. Dollé[1]

1. University of Montreal, Chemistry, Canada

Recent advances in additive manufacturing offer new possibilities for designing solid-state battery components and provide an effective way to study processing–performance relationships. In this context, 3D printing via direct ink writing (DIW) is investigated as an alternative forming technique for lithium-ion conducting ceramics such as LATP. Due to the limited information available in the literature, this work aims to establish the feasibility of printing LATP-based ceramics and to identify the main processing limitations associated with this system. Ceramic inks with 65 wt% solid loading and controlled rheology were developed, and printing and thermal parameters were optimized to ensure dimensional stability and reliable 3D-printed electrolytes. The effects of thermal treatments on densification, phase evolution, and microstructure were characterized using XRD, SEM, and profilometry. Geometrical deformations observed after sintering were examined to better understand structure–property relationships. To reduce these deformations, a pre-sintering step and adapted ceramic-blend compositions were developed, improving dimensional control without compromising ionic conductivity. The 3D-printed LATP remains dense, phase-stable up to 900 °C, and shows ionic conductivities comparable to conventional ceramics, confirming the relevance of DIW for solid-state electrolyte fabrication.

11:10 AM

(Joint Sym-013-2026) Optimized DLP-based 3D printing of porous ceramics and data-driven process modeling

I. Kim*[1]; H. Yun[1,2]

1. Korea Institute of Materials Science, Republic of Korea
2. University of Science and Technology, Republic of Korea

This study presents an integrated approach to optimizing porous ceramic additive manufacturing via vat photopolymerization (DLP), covering slurry preparation, DLP printing, and thermal post-processing. Major limitations—dispersion stability, light scattering–affected curing behavior, and shrinkage/pore evolution during debinding and sintering—are systematically addressed to improve printability, dimensional fidelity, and microstructural control. Slurry formulation effects on rheology, stability, and curing response are evaluated to define a robust processing window, showing that dispersant optimization enhances stability and printing reproducibility. Optical scattering during DLP exposure is investigated to clarify microstructure development with pore-forming agents, and results indicate that exposure-related parameters can be tuned to tailor interfacial characteristics and pore morphology. Finally, a tailored debinding/sintering protocol is developed, demonstrating that heating rate strongly influences dimensional accuracy, surface texture, and pore characteristics in the sintered ceramics. In addition, the experimental datasets and process knowledge established here provide a basis for lightweight AI-assisted modeling to predict formulation–property relationships and geometry-/process-dependent shrinkage, enabling more efficient process optimization with fewer trial-and-error experiments.

11:30 AM

(Joint Sym-014-2026) Preparation of a photocationic siloxane oligomer–Based hybrid binder for photopolymerization-based ceramic 3D printing

H. Park*[1]; S. Sakuragi[2]; S. Yang[2]; Y. Sohn[1]

1. University of Central Florida College of Engineering and Computer Science, USA
2. Changwon National University, Republic of Korea

In photopolymerization-based ceramic 3D printing, ceramic slurries are prepared by dispersing ceramic particles, photoinitiators, and additives in a photocurable resin. Although high solid loading is required to achieve desirable mechanical properties and dimensional accuracy after sintering, ceramic particles induce light scattering during exposure, resulting in non-uniform crosslink density within printed layers and leading to cracking, shrinkage, and distortion during sintering. In this study, a photocationic polymerizable siloxane oligomer was synthesized to fabricate green bodies with both high solid loading and uniform crosslink density. The oligomer was combined with silica starting particles, photoinitiators, and dispersants to produce a photocurable ceramic slurry with enhanced transparency and solid content. The printed photopolymers underwent additional thermal polymerization, improving interfacial bonding and crosslink uniformity. Crack-free sintered bodies without shape distortion were successfully obtained after heat treatment at 1000 °C. These results demonstrate that an organic–inorganic hybrid resin can simultaneously function as a photopolymer binder and an inorganic binder in ceramic 3D printing.

11:50 AM

(Joint Sym-018-2026) Analysis of mixing parameters on rheology and polymer stability in aqueous silicon carbide slurries

J. Feldbauer*[1,2]; C. L. Cramer[2]; T. Aquirre[2]; B. L. Armstrong[3]; R. Walker[5]; P. Snarr[4]; D. Gilmer[5]

1. The University of Tennessee Knoxville Tickle College of Engineering, USA
2. Oak Ridge National Lab, Manufacturing Science Division, USA
3. Oak Ridge National Lab, Material Science & Technology, USA
4. The University of Texas at Austin, USA, USA
5. The University of Tennessee Knoxville Tickle College of Engineering, Material Science and Engineering, USA

This work employs a Taguchi design of experiments framework to evaluate how mixing parameters influence the rheological properties and polymer stability of aqueous silicon carbide slurries. Using an L9 orthogonal array, the effects of mixing speed, mixing time, media amount, and container size were systematically studied for planetary mixing. Rheological measurements demonstrated that variations in shear intensity and mixing time strongly impacted viscosity and yield strength, while container size influenced dispersion uniformity. Gel permeation chromatography (GPC) was further used to understand the condition of the polymeric dispersant after mixing factors. By leveraging the Taguchi method, this study efficiently identified the dominant factors controlling slurry performance, reducing the experimental burden while providing insight into the balance between dispersion quality and polymer integrity. These findings establish a framework for tuning slurry preparation strategies in ceramic additive manufacturing and other aqueous-based processing systems.

HTCMC-12 Symposium 3- Polymer Derived Ceramics and Composites

HTCMCS3- Preceramic Polymers and Polymer-Derived Ceramics III

Room: Sandpiper A
Session Chair: Matthew Dickerson, Air Force Research Laboratory

8:30 AM

(HTCMC-S3-009-2026) Preparation and characterization of ceramic composites from hafnium and silicon oxycarbide hybrid precursor

A. Roy*[1]; G. Singh[2]

1. Kansas State University, Mechanical and Nuclear Engineering, USA
2. Kansas State University Carl R Ice College of Engineering, USA

We report on the preparation and characterization of HfOC/SiOC ceramic composite powders and fibermats using a polymer-pyrolysis route. The method employed a 1:1 mass mixture of 1,3,5,7-tetramethyl, 1,3,5,7-tetravinyl cyclotetrasiloxane (4-TTCS) and a commercial HfC precursor, with the latter dehydrated at 70 °C before blending and crosslinking between 160–400 °C. Three pyrolysis temperatures—800, 1000, and 1200 °C—were used under argon atmosphere. Composite evolution was analyzed via microscopy, diffraction, and spectroscopy, revealing the transformation from polymer to ceramic. Oxidation testing at 800 °C of fibermats treated at 1000 °C revealed superior stability in air compared to carbon-rich SiOC fibermats and total combustion of carbon-only mats under the same conditions.

8:50 AM

(HTCMC-S3-010-2026) Developing ceramic materials via preceramic polymer chemistry and a thorough understanding of structure-property relationships at the atomic scale (Invited)

N. Bedford*[1]

1. Idaho National Laboratory, USA

Polymer derived ceramics (PDCs) are attractive candidates for next generation high temperature materials (HTMs), leveraging established methodologies in processing, morphology and chemical control common to polymers and implementing them in ceramics processing. In this talk, efforts toward bridging this knowledge gap between coupling the chemistry and physical properties of preceramic polymers to their resulting PDCs will be discussed for a range of materials, including those consisting of non Si-based materials. Our efforts put an emphasis toward understanding structure/property relationships using in-situ synchrotron characterization techniques, where polymer to ceramic conversion processing can be monitored in-situ to provide new insights into formation processes. Additionally, this talk will describe ongoing efforts to make 3D printed materials consisting of preceramic polymers, wherein printing parameterization can be used tune materials properties, such as thermomechanical properties and porosity. Overall, our work showcases the promise of using PDC for a range of defense applications, including those beyond HTMs.

9:20 AM

(HTCMC-S3-011-2026) Polymer-derived TiC/SiC ceramics: Microstructural evolution and property enhancement (Invited)

K. Lu*[1]; M. Bidabadi[1]; S. Nemani[1]

1. University of Alabama at Birmingham, USA

This work examines the integration of MXenes into polymer-derived SiC ceramics to improve densification, microstructure, and structural and functional performance. MXenes are introduced into precursor systems to influence polymer crosslinking, carbon availability, and the formation pathways of TiC and SiC during pyrolysis. Spark Plasma Sintering (SPS) is then used to consolidate the powders at reduced temperatures, enabling rapid carbide crystallization and refinement of the final microstructure. The effects of MXene transformation, interphase development, and their catalytic or templating roles in SiC formation are analyzed to build a fundamental understanding of MXene–carbide interactions. The resulting composites show enhanced hardness and modulus due to interlocked TiC/SiC networks, as well as improved oxidation resistance associated with refined grain structures and stable surface layers. Electrical conductivity trends also reveal tunable pathways created by MXene-derived carbon domains and evolving carbide phases. These results demonstrate a viable approach for designing multifunctional TiC/SiC ceramics with improved mechanical, thermal, and environmental stability for extreme-condition applications.

HTCMCS3- Preceramic Polymers and Polymer-Derived Ceramics IV

Room: Sandpiper A
Session Chairs: Matthew Dickerson, Air Force Research Laboratory; James Ponder, Air Force Research Lab

10:10 AM

(HTCMC-S3-012-2026) From preceramic polymers to hBN 2D materials

C. Maestre[1]; C. Journet[1]; P. Steyer[2]; V. Garnier[2]; B. Toury*[1]

1. Universite Claude Bernard Lyon 1, Laboratoire des Multimatériaux et Interfaces, France
2. Materiaux Ingenierie et Science, France

Hexagonal boron nitride (hBN) is a key 2D material due to its outstanding properties. Beyond its thermal, chemical and mechanical stability, hBN shows high thermal conductivity, low compressibility, and a wide band gap (~6 eV), making it attractive for deep UV optoelectronics. Its excellent insulating behavior (dielectric constant < 2) and large bandgap, combined with diffusion barrier properties, make it promising for gate dielectrics, interconnects, and packaging. Vapor-phase processes like CVD enable large-scale coverage, but self-standing hBN crystals still provide nanosheets of unrivaled purity for demanding applications. To obtain large and high-quality hBN nanosheets (BNNSs), we investigate the Polymer Derived Ceramics route using polyborazylene precursors and different sintering processes. These approaches yield pure, well-crystallized single crystals exfoliable into BNNSs with lateral sizes over hundreds of microns. Structural analyses by TEM and Raman confirm excellent crystalline quality, with a record LWHM of 7.6 cm-1. Additional characterizations by cathodoluminescence and XPS evidence high structural and chemical purity. Finally, dielectric measurements reveal a constant of 3.9 and a strength of 0.53 V/nm, highlighting the potential of these BNNSs for electronic and optoelectronic applications.

10:30 AM

(HTCMC-S3-013-2026) Maximizing ceramic yields of polymer grafted nanoparticle via modification of polymer architecture and nanoparticle composition

J. Zackasee*[1]; A. Advincula[1]; J. Ponder[1]; J. Delcamp[1]; T. Pruyn[1]; M. B. Dickerson[1]

1. Air Force Research Laboratory, USA

Preceramic polymer grafted nanoparticles (PCP-GNPs) have emerged as a promising avenue to generate additively manufactured ceramics and ceramic matrix composites (CMCs). The potential utility of GNPs in these applications stems from their synthetic tunability, enhanced processability relative to ceramic powder slurries, and suppression of volumetric shrinkage. While GNPs offer desirable advantages over traditional CMC fabrication methods, current systems experience low ceramic yields due to corona materials lacking cross-linking functionality, leading to their degradation

during pyrolysis. In this work, we analyze the impact of polymer morphology and corona architecture on the ceramic yields and processability of PCP-GNP materials. The corona materials contain increased quantities of cross-linking groups within the polymer backbone, thereby encouraging polymer network formation during curing. Additionally, rheological experiments were performed to elucidate the relationship between GNP processability and corona composition. Furthermore, the final ceramic composition was modified through substitution of various ceramic nanoparticles and ceramic precursors. Overall, these PCP GNP systems exemplify the tunability that can be achieved with hybrid materials to enable enhanced ceramic yields, improved processability, and controlled ceramic nanostructures.

10:50 AM

(HTCMC-S3-014-2026) Metal nitride syntheses for dummies (Invited)

Z. Yi[1]; M. Aekka[1]; K. Osada[1]; J. Heron[2]; R. M. Laine*[1]

1. University of Michigan, Materials Science and Engineering, USA
2. University of Michigan, USA

We present here a very simple, low-temperature approach to the syntheses of single, and bimetallic nitride precursors and thereafter their respective nitrides wherein metal-nitrogen bond formation is driven by formation of Si-O bonds. The starting materials are metal carboxylates, and/or 2,4-diketonates and are reacted with hexamethyldisilazane, $Me_3SiNHSiMe_3$ or HMDS to from $M(MDS)_x$ monomers, oligomers and polymers. The resulting single and bi-metallic nitride precursors, $M(MDS)_x$ monomers and oligomers are for the most part fully soluble whereas polymeric versions are less so. However, even as complex mixtures on mild heating in an inert atmosphere transform to their respective nitrides at temperatures of ≥ 400 °C. Example syntheses include the single metal nitrides CoN_x, FeN_x, MgN, MnN, YN, bimetallic magnetic nitride materials including $FeCoN_x$, $FeNiN_x$ and $CoNiN_x$. Starting materials, silazane intermediates [$M(MDS_x$] and the nitride products were characterized by MALDI, FTIR, XRD and BET methods. A number of the resulting nitrides offer magnetic properties as assessed by coercivity measurements.

HTCMC-12 Symposium 4- Innovative Design, Advanced Processing and Manufacturing Technologies in Non-oxide and Oxide Composites

HTCMCS4- Advanced processing and manufacturing technologies I

Room: Silver Pearl 1-3

Session Chairs: Alberto Ortona, SUPSI; Daejong Kim, Korea Atomic Energy Research Institute

8:30 AM

(HTCMC-S4-009-2026) Comprehensive development of sustainable ceramic matrix composites (Invited) ***WITHDRAWN***

D. Koch*[1]; A. Thorenz[1]; D. Schüppel[1]; F. Halter[1]; L. Wietschel[1]; A. Schneller[1]

1. University of Augsburg, Institute for Materials Resource Management, Germany

Ceramic matrix composites CMC are mainly developed for high temperature application in severe environments. Generally the processing of these composites needs a lot of energy and resources. Therefore it is valuable to evaluate the manufacturing of CMC parts along the whole processing chain considering environmental aspects and therefore to develop a strategy to evaluate the environmental footprint of CMC. Here we focus on the liquid silicon infiltration (LSI) route. For this approach we establish first life cycle assessment (LCA) results on environmental impacts of the CMC production by correlating properties with environmental impacts during processing. The goal is to find a suitable tradeoff between individual properties and according manufacturing environmental impact. With this so-called Pareto-efficient correlation one can decide which process parameters lead to the best properties when environmental aspects are considered. This work is leading to the design of – how we call it – "Sustainable Ceramic Matrix Composites" (SCMC) where the issues of LCA and circularity of the CMC are taken into consideration. The presentation will explain the overall approach and will show how data collected during manufacturing are correlated with mechanical properties and can furthermore be crosslinked with life cycle assessment approaches for more sustainable manufacturing.

9:00 AM

(HTCMC-S4-010-2026) Agile CMC fabrication through continuous fiber 3D printing and on-head matrix impregnation (Invited)

D. King*[1]; D. Seymour[1]; B. Hill[1]; D. Young[1]; B. Garcia[1]

1. Weber State University, Miller Advanced Research and Solutions Center, USA

Fabrication of Ceramic Matrix Composites (CMCs) is often limited to artisan methods, like hand layup. While some automated methods, like pick-and-place, have received attention for the fabrication of CMCs, the development of methods, like continuous fiber 3D printing (CF3D), remains significantly behind when compared to polymer matrix composites (PMCs). For Ox/Ox CMCs, the development of suitable CF3D prepreg slit tapes has shown promise; however, other CMCs compositions remain elusive. In this work, CF3D is utilized for the fabrication of CMCs with varying fiber and matrix combinations through an on-head matrix impregnation method. Without the need to develop stable prepreg slit tapes, the same robot is utilized to fabrication Ox/Ox, C/SiC, and C/UHTC CMCs. Understanding of the processability, microstructure, layup architectures, and mechanical properties of these CMCs will be presented.

9:30 AM

(HTCMC-S4-011-2026) Fluidized bed chemical vapor deposition – A versatile technique for the preparation of ceramic composites (Invited)

A. El Mansouri[1]; T. Da Calva[1]; A. Guette[1]; N. Bertrand[1]; G. Chollon[1]; H. Plaisantin[1]; S. Couthures[1]; G. L. Vignoles*[1]

1. University Bordeaux, LCTS - Lab for ThermStructural Composites, France

Ceramic composites contain by definition reinforcing phases dispersed in a matrix. One of the sensitive issues of these materials is the compatibility between reinforcements and matrix, during processing and during usage, usually at high temperatures. It is therefore highly desirable in general to provide some protection to the reinforcing phase by a coating. In the case of powders or discontinuous fibers, among other methods, Fluidized-Bed Chemical Vapor Deposition (FB-CVD) is very attractive. Indeed, it is rather versatile and easy to scale up, once it has been suitably controlled. Here we will display some aspects of process engineering necessary for a correct operation of this process, including thermal engineering and the study of fluidization and fluid transfer; then, examples of deposition of several coatings on powders and discontinuous fibers will be shown, characterized and discussed.

10:20 AM

(HTCMC-S4-012-2026) AI image diagnosis of damage cracks in ceramic matrix composites

M. Kotani*[3]; M. Yagai[2]; Y. Tanaka[1]; Y. Kagawa[1]

1. Tokyo University of Technology, Japan
2. Research Institute of Systems Planning, lnc., Japan
3. Japan Aerospace Exploration Agency, Japan

This study investigated an automated diagnostic technology using AI image analysis aimed at ultra-high-speed evaluation of the integrity of ceramic matrix composites (CMCs). A two-stage approach was employed: (1) selecting potential crack locations using deep learning-based AI image analysis software, and (2) determining whether each selected location is a crack and counting its number, based on images of unidirectionally strengthened composite specimens with cracks captured by an X-ray interferometer. For crack feature identification, "gLupe" from System Planning Laboratory Co., Ltd. was selected as a software candidate capable of building a machine learning model with fewer sample data. A dedicated auxiliary tool was newly created for crack detection and counting. At first, optimal annotation conditions were explored for the AI image analysis software to identify crack features with higher accuracy. Next, to more appropriately determine cracks from the resulting identification images, the optimal conditions for each parameter of the auxiliary tool were explored using experimental design methods. Through these systematic studies, we were able to quantitatively evaluate damaged cracks to some extent, not only in images taken under load that caused the cracks to open, but also in images taken after the load was removed when the cracks were closed.

10:50 AM

(HTCMC-S4-013-2026) Application of pulsed DC electrophoretic deposition process to interphase formation for SiC_f/SiC composites (Invited)

K. Yoshida*[1]; D. Sakakibara[1]; A. Gubarevich[1]; M. Kotani[2]

1. Institute of Science Tokyo, Japan
2. Japan Aerospace Exploration Agency (JAXA), Japan

Silicon carbide fiber-reinforced silicon carbide (SiC_f/SiC) composites have been expected as next-generation highly reliable heat-resistant materials for aerospace industries, nuclear and fusion applications. Currently carbon or hexagonal-boron nitride (h-BN) has been applied as the interphase for SiC_f/SiC composites, and they have been commonly formed by CVD method. The present authors proposed the novel interphase formation process for SiC_f/SiC composites by electrophoretic deposition (EPD), and it is demonstrated that SiC_f/SiC composites with the interphases formed by EPD showed excellent mechanical properties as well as SiC_f/SiC composites with these interphases formed by CVD. In our EPD process, water is used as the dispersion medium for the suspension used for EPD. To increase the deposition on SiC fibers within short time by EPD, applied voltage should be higher. However, higher EPD voltage would affect the quality and properties of the interphase due to bubble generation by water electrolysis. Therefore, this study focused on the application of pulsed direct current (DC) electric fields for EPD process, EPD process was optimized to form dense and high-quality BN interphase on SiC fibers within short time. Furthermore, SiC_f/SiC composites using SiC fibers with BN interphase formed by pulsed DC EPD were fabricated, and their mechanical properties were evaluated.

11:20 AM

(HTCMC-S4-014-2026) Advances in the processing of ceramic matrix composites (CMCs) by polymer infiltration and pyrolysis (PIP)

M. B. Dickerson*[1]; Z. D. Apostolov[1]; L. M. Rueschhoff[1]; M. Cinibulk[1]; J. Delcamp[1]; C. Kassner[1]; T. Pruyn[1]

1. Air Force Research Laboratory, USA

High- and ultra-high-temperature ceramic matrix composites (CMCs) are essential materials in aerospace applications, primarily due to their high service temperature, oxidation resistance, and low ablation rate. The materials community is actively developing and utilizing numerous processing methods to synthesize dense, non-oxide composites. While techniques such as reactive melt infiltration (RMI), chemical vapor infiltration (CVI), and hot-pressing each offer advantages, the Air Force Research Laboratory (AFRL) Ceramics Research Team has focused its efforts on advancing polymer infiltration and pyrolysis (PIP)-based processing of CMCs. This presentation will provide an overview of AFRL's advancements in PIP-based CMCs, with a specific emphasis on processing CMCs using commercially available polycarbosilanes. A key focus will be a detailed discussion of the chemistry, processing, structure, and property relationships inherent in PIP-based CMCs.

11:40 AM

(HTCMC-S4-015-2026) The influence of key processing parameters on porosity in CMCs fabricated using CVI

O. Brandt*[1]; R. Steadman[2]; V. Venkatachalam[2]; T. Shoulders[3]; L. Backman[1]; J. Binner[4]

1. US Naval Research Laboratory, Spacecraft Engineering Division, USA
2. University of Birmingham, Metallurgy and Materials, United Kingdom
3. Technology Assessment and Transfer Inc, USA
4. University of Birmingham, Ceramic Science & Engineering, United Kingdom

Fabricating dense ceramic matrix composites (CMCs) without introducing closed porosity remains a significant challenge. Traditional processing approaches relying on a single method such as polymer infiltration and pyrolysis (PIP), reactive melt infiltration (RMI), or chemical vapor infiltration (CVI) for densification. The PIP process effectively fills inter-bundle porosity but struggles to uniformly infiltrate intra-bundle porosity, particularly after multiple cycles. Conversely, CVI uniformly coats fibers and fills intra-bundle porosity, but is inefficient for inter-bundle porosity filling. This study investigates the impact of radio-frequency CVI (RF-CVI) and isothermal CVI (I-CVI) parameter variations (e.g., temperature, pressure) on porosity evolution in CMCs. The resulting composites were characterized via density measurements, microscopy and image analysis to quantify the open and closed porosity fractions. Results reveal a correlation between infiltration pressure, densification rate and the onset of closed porosity. Furthermore, a novel hybrid processing approach combining high-pressure CVI, PIP, and low-pressure CVI will be discussed to leverage the individual strengths of each method for achieving dense CMCs with minimal closed porosity. The successful of this hybrid process would lead to the fabrication of CMCs with improved mechanical properties and high-temperature performance.

HTCMC-12 Symposium 7- Materials for Extreme Environments – UHTCs, MAX phases, and nanolaminates

HTCMCS7- Novel processing methods for bulk, coatings, thin films, fibers, and/or composites

Room: Osprey
Session Chair: Diletta Sciti, CNR-ISSMSC

8:30 AM

(HTCMC-S7-010-2026) Enhanced high temperature protective performance of hybrid composite fibers (Invited)

S. Moon*[1]; S. Yun[1]; W. Kim[2]

1. Korea Institute of Science and Technology, Republic of Korea
2. Korea Institute of Ceramic Engineering and Technology, Aerospace&Defense R&D Group, Republic of Korea

This study presents the synthesis and comprehensive characterization of ultra-light Cf/SiC composite fibers engineered for high-temperature applications. High-purity SiC coatings were fabricated via a carbon-reduction reaction in a SiC-rich gaseous environment combined with chemical vapor reaction (CVR) heat treatment. Modulation of the reaction parameters enabled precise control over the crystallinity and thickness of the deposited SiC layer, thereby enhancing oxidation resistance and thermal stability. Microstructural analyses revealed that the reaction conditions exerted a significant influence on the preferential growth of specific SiC crystallographic planes. These results demonstrate that deliberate tailoring of processing parameters facilitates the optimization of Cf/SiC composites for use in extreme thermal environments. Overall, the findings underscore the potential of these composites as lightweight, thermally robust materials suitable for aerospace components and other high-temperature systems requiring reliable thermal protection and oxidation resistance.

9:00 AM

(HTCMC-S7-012-2026) A novel processing route for near-net-shape Cf–ZrB_2 CMCs using 3D-printed fiber preforms

J. Park*[1,2]; H. Choi[1]; S. Lee[1]

1. Korea Institute of Materials Science, Extreme Materials Institute, Republic of Korea
2. Pusan National University, Republic of Korea

Carbon fiber–reinforced ZrB_2 ceramic matrix composites are promising candidates for thermal-protection components above 1800 °C. However, conventional lay-up and hot-pressing routes are restricted to simple geometries and require extensive post-machining, limiting the fabrication of complex near-net-shape structures. In this study, we present a novel processing route that integrates a 3D-printed carbon-fiber perform, a high-solid-loading ZrB_2 slurry, and an all-in-one near-net-shape mold. A multilayered 2D fiber architecture is produced by filament-type 3D printing and placed inside a refractory mold approximating a nose-cone geometry. An aqueous ZrB_2 slurry(>50 vol% solids) is formulated by optimizing dispersant content and mixing conditions to secure viscosity and sedimentation stability for pressure-assisted infiltration. Organic binders are removed through a controlled debinding, followed by heat treatment and polymer-infiltration-and-pyrolysis(PIP) cycles to densify the matrix. Microstructural analysis confirms homogeneous matrix distribution across the fiber bundles and the formation of a continuous load-transfer network. This processing route demonstrates that near-net-shape Cf–ZrB_2 CMC components and be fabricated with significantly reduced machining and highlights the potential of 3D-printed fiber-preform strategies for other ultra-high-temperature ceramic-based CMC systems.

9:20 AM

(HTCMC-S7-013-2026) Kinetic study and reaction mechanisms of C/ZrC composite in molten chloride salt

A. El Melhoufi*[1]; L. Maillé[1]; J. Braun[1,2]; F. Rebillat[1]

1. University of Bordeaux - Laboratory for Thermostructural Composites (LCTS), UMR 5801, France
2. CEA, France

Zirconium carbide (ZrC) is a promising ultra-high temperature ceramic for extreme environments. Although recent studies have investigated ZrC synthesis in molten chloride salts, none has used metallic Zr as a precursor. This work investigates the kinetics and reaction mechanisms of ZrC formation from metallic Zr in molten chloride salt. Its formation is followed on carbon fibers and within fibrous 2.5D preforms. Time-resolved syntheses combined with quenching experiments under various conditions revealed transient species and stepwise ZrC evolution. Dissolution tests of Zr metal alone in molten salt identified the initial chlorination step and formation of reactive chlorozirconate complexes ($[ZrCl_6]^{2-}$). Complementary characterizations (SEM, EDS, Raman, XPS) enabled the confirmation of a two-stage mechanism: (1) rapid chlorination of Zr leading to the formation of soluble chloride complexes, and (2) interfacial reaction with carbon yielding ZrC. Infiltration experiments using 2.5D carbon preforms with Zr powder in molten NaCl demonstrated the successful formation of a homogeneous ZrC coating throughout the porous architecture, validating scalability for composite manufacturing. This study provides a fundamental understanding for optimizing molten salt synthesis and establishes a framework for rational design of UHTC composites.

HTCMCS7- Processing-microstructure-property relationships of UHTCMCs

Room: Osprey

Session Chair: Jason Lonergan, Missouri University of Science and Technology

9:40 AM

(HTCMC-S7-014-2026) Recent advances on ceramic matrix composites obtained by sintering (Invited)

A. Vinci*[1]; L. Zoli[1]; M. Mor[1]; D. Sciti[1]

1. CNR - ISSMC, Italy

Ceramic matrix composites (CMCs) are conventionally processed through matrix-specific routes, such as liquid silicon infiltration (LSI) for SiC-based systems, polymer infiltration and pyrolysis (PIP) or chemical vapor infiltration (CVI) for carbon matrices, and slurry- or infiltration-based approaches for oxide-oxide composites. While these methods are well established, they often result in multiphase or partially amorphous matrices or low melting residues, which can limit thermo-mechanical stability at elevated temperatures. In contrast, sintering enables the formation of dense, phase-pure ceramic matrices with superior refractoriness and high-temperature strength. Building on the established expertise of ISSMC-CNR in the sintering of UHT-CMCs for extreme environment applications, this processing strategy was extended to CMCs with different matrix chemistries. In this work, we present the processing and characterization of CMCs fabricated by sintering, demonstrating the versatility of this approach across a broad range of matrix chemistries. Composites based on UHTC matrix (ZrB_2, HfB_2), non-oxide matrices (SiC and Si_3N_4), and oxide matrices (ZrO_2 and Al_2O_3) were successfully produced via slurry infiltration and sintering using carbon fibres as a common reinforcement. The resulting microstructures and mechanical properties are analyzed and compared, and the potential applications are explored.

10:30 AM

(HTCMC-S7-015-2026) Investigation and modelling of the mechanical response of UHTCMC materials (Invited)

A. Airoldi*[1]; A. Caporale[1]; L. Zoli[2]; P. Galizia[2]; A. Vinci[2]; R. Savino[3]; D. Sciti[2]

1. Politecnico di Milano, Dept. of Aerospace Science and Technology, Italy
2. CNR - ISSMC, Italy
3. Universita degli Studi di Napoli Federico II, Italy

The design of UHTCMC structural elements requires a comprehensive understanding of their mechanical response and appropriate numerical approaches. The orthotropic non-linear response of Cf-ZrB_2/SiC UHTCMCs was investigated through tensile, bending, and impact tests, highlighting peculiar anelastic mechanisms in the fibre direction, which were attributed to residual thermal stress. More complex stress states have been applied through ring-on-ring tests, showing a combination of intralaminar and interlaminar damage. A first modelling approach was developed based on bi-phasic material law to delve into the mechanism of non-linear response and explain the role of residual stress. A second, more pragmatic approach was developed for cross-ply specimens based on a modified Hill plasticity, including a pressure-dependent term. Such an approach was successfully applied to model tensile and bending response and was combined with a Cohesive Zone Model to capture the response of ring-on-ring tests. Finally, the mechanical response of bars subjected to three-point bending tests was investigated and simulated before and after exposure to plasma of dissociated air at 2200°C. Overall, the results highlight the most significant characteristics of Cf-ZrB_2/SiC UHTCMCs and provide the guidelines and tools to design real-world structural components with more complex geometries for extreme temperature applications.

11:00 AM

(HTCMC-S7-016-2026) Effect of composition and fiber orientation on the thermal conductivity and emissivity of ultrahigh temperature ceramic matrix composites

E. S. Golightly*[1]; H. B. Schonfeld[1]; P. E. Hopkins[2]; D. Sciti[3]; A. Vinci[3]

1. University of Virginia, Mechanical and Aerospace Engineering, USA
2. University of Virginia, USA
3. CNR - ISSMC, Italy

Hypersonic vehicles require leading edge components to withstand extreme heat flux, driving the need for materials to operate above 2500°C. The next generation systems depend on developing new materials and accurately measuring their properties at relevant conditions. However, techniques for evaluating thermal behavior at such temperatures face limitations, including contact resistance, long measurement times, and known emissivity. Ultrahigh-temperature ceramic matrix composites (UHTCMCs) are strong candidates for these applications due to superior thermal shock resistance compared to ultrahigh temperature ceramics. Our work introduces a method that bypasses stated constraints and enables characterization at relevant temperatures. Using modulated laser heating, thermal imaging, and hyperspectral radiative pyrometry, we obtain temperature and emissivity data from 500-1700nm. Thermal conductivity is found using a heat equation model with radiative boundary conditions through steady state temperature differential radiometry (SSTDR). We investigate how composition and fiber orientation influence the thermal conductivity and emissivity of UHTCMCs. Compositions of ZrB_2-SiC, LaB_6-SiC, HfC-HfB_2-SiC, and SiC are tested with in-plane and through plane fiber orientations to provide insight into critical property trends for hypersonic applications.

HTCMC-12 Symposium 8- Testing and Evaluation of Ceramic Matrix Composites from Constituents and Coupons to Components, including EBCs

HTCMCS8- Mechanical characterization of ceramics and composites, techniques and equipment II

Room: Pelican

Session Chairs: Udayakumar Andi; Takuya Aoki, Japan Aerospace Exploration Agency

8:30 AM

(HTCMC-S8-010-2026) Real time X-ray tomography imaging of cracks initiation and propagation in CMCs above1000°C (Invited)

D. Liu*[1]

1. University of Oxford, Engineering Science, United Kingdom

Ceramic-matrix composites have complex microstrucutre therefore in-situ imaging technqiues are needed to investigate their deforamtion, crack initation and propagation in 3D. This work will showcase the range of CMCs, with and without coatings, studied using in-situ X-ray computed tomography with loading at elevated temperatures up to 1200°C. The loading configurations include short-beam flexural testing, C-ring compression and notched flexural testing. The tests were carried out over a range of temperatures and the impact of temperature on the mechanical behaviour of the different types of CMCs designs will be reported. Post-test data analysis inlcudes 3D image segmentation as well as digital volume correlation for 3D strain distribution to identify the 3D failure strain, strain localisation, crack initiation and propagation. The toughening mechanisms in the materials systems will be presented.

9:00 AM

(HTCMC-S8-011-2026) Development of a fully articulated graphite flexure fixture for high temperature testing

W. M. Carty*[1,2]; J. Castle[1]; H. Lee[1]

1. New York State College of Ceramics at Alfred University, Ceramic Engineering, USA
2. Materials Research Furnaces, LLC, Research & Development, USA

High temperature flexure testing fixtures are a critical element to the evaluation of high temperature mechanical properties of advanced materials. Following the recommendations of ASTM C1161 and C1211, two fully-articulated testing fixtures were designed and built, the first of sintered SiC and the second of graphite, and were used to generate strength data for sintered SiC from ambient to 1800°C. The SiC fixture generated flexure strength data that was consistent with published strength values but would often break load pins and fixture components after specimen failure indicating a fixture design problem. To address this problem the design was corrected and a new fixture, constructed of isotropic graphite, was fabricated incorporating Woodruff rockers and tighter tolerances. The redesigned fixture has eliminated fixture component failure but the elevated temperature strength data was statistically different than the data generated using the SiC fixture but with similar Weibull modulii. Comparison of the results to ambient temperature strength data suggests that the SiC data is potentially erroneous, as the data from the graphite test fixture aligned well with the data obtained at ambient temperature. These results suggest that the elastic modulus of the test fixture may not be of significant importance when designing test fixtures.

9:20 AM

(HTCMC-S8-012-2026) Damage detection in heat-resistant composites using synchrotron radiation CT and deep learning-based image segmentation

H. Taniguchi*[1]; G. Okuma[2]; Y. Arai[1]; T. Tsunoura[3]; H. Tsuruta[3]; H. Kakisawa[2]; R. Inoue[1]

1. Tokyo Rika Daigaku, Japan
2. Busshitsu Zairyo Kenkyu Kiko, Japan
3. Kabushiki Kaisha IHI, Japan

In the present study, in-situ tests were conducted for four types of unidirectional SiC fiber-reinforced SiC model composites (UD-SiC/SiC) with interfacial coatings of different thicknesses to evaluate their mechanical properties. An experimental setup was established to perform in-situ tensile testing using a universal X-ray CT system and synchrotron radiation CT systems at SPring-8 and NanoTerasu. Deep learning-based image segmentation was applied to the imaging results. The results showed that the microstructure of the model composites was distinguished, and the thickness of the interfacial coating and damage were visualized and quantified in three-dimensional. These results showed that matrix cracks were periodically distributed, and that the periodic spacing increased with increasing interfacial coating thickness. In addition, the crack density obtained from the segmentation results was expressed as a function and visualized for comparison among the different interfacial coating thicknesses. Furthermore, Digital Volume Correlation (DVC) analysis was also applied to imaging results, and the internal tensile strain fields were successfully visualized. These results suggested that the interfacial coating thickness influences the initiation and propagation of damage, providing important insights into the damage mechanisms of the composites.

9:40 AM

(HTCMC-S8-013-2026) Development of an experimental-numerical dialogue for the identification of a damage initiation threshold under combined loadings in a SiC/SiC CMC

V. Herbert*[2]; F. Laurin[2]; T. Archer[2]; A. DeBarre[2]; T. Vandellos[1]

1. SAFRAN Ceramics, France
2. DMAS, ONERA, Université Paris-Saclay, France

Reducing the carbon footprint of air traffic involves, in particular, increasing engine operating temperatures. With this aim, silicon carbide (SiC) based ceramic matrix composites are developed due to their low density and high mechanical properties. If the mechanical behavior at room and homogeneous temperatures is well known, the impact of thermal gradients and combined loadings needs to be improved. For these reasons, ONERA developed a laser-based test bench, coupled with a tensile testing machine in an environmental chamber. A rich set of instrumentation technics (DIC, IR imaging, AE) is used in order to maintain a good understanding of the tests while getting closer to in-flight conditions. The presentation focuses on the analysis of thermomechanical tests in order to identify damage threshold and mechanisms. To this end, a test-simulation dialogue is set in addition to microstructural observations to fully connect the actual stress state to the experimental results. Various tests were conduced (i.e monotonic, interrupted and loading/unloading) in order to gain a better understanding of the CMC's behavior under combined loadings. Furthermore, a damage model is then used to study the propagation of damage until failure of the specimen.

10:20 AM

(HTCMC-S8-031-2026) Radiation and h2 durable nuclear thermal propulsion fuel element mxene insulator (Invited)

J. H. Lalli*[1]

1. NanoSonic, Inc., USA

NASA Glenn and Marshall Space Flight Center have identified a need for new higher-temperature fuel element insulators for fission-based, H2 fueled, Nuclear Thermal Propulsion (NTP) engines. While NTP reactors offer a specific impulse of ~ 900 seconds, more than twice that for state-of-the-art chemical rocket engines such as the Saturn V, weight reductions are still needed. Space nuclear propulsion (SNP) and doubled fuel efficiency may cut current transit time to Mars of 6-months by half, as well as astronauts' exposure to galactic cosmic radiation (GCR) and supplies needed. NanoSonic has developed new low thermal conductivity nanoporous ceramic insulators based on MXenes layered with high-Z carbines to increase thermal stability up to ~4,000 °C. In this talk, radiation shielding, durability, thermal conductivity, H2 durability-morphology and XRD for new nanolaminates shall be presented. Initial nanolaminate results include combined RF shielding (EMI SE -93 dB over 2 – 10 GHz) with a 23% enhancement (to -114 dB) upon both High Energy Laser (HEL) exposure and 100 rads of 1 GeV Fe. Thermal protection was observed upon 17 kW laser HEL Exposure whereby panels retained a low < 125 °C back side upon > 1500 °C front side exposure. The high temperature performance shall be increased to >2727 °C with a corresponding low thermal conductivity using the layered nanoporous HfC-SiC MXene ceramics.

10:50 AM

(HTCMC-S8-015-2026) Mechanical behavior of a sandwich structure based on carbon fibers geopolymer matrix composites

D. Habans*[1]; P. Reynaud[1]; É. Prud'homme[1]; T. Cutard[2]; G. Dusserre[2]; G. Fantozzi[1]; N. Godin[1]

1. Institut National des Sciences Appliquees de Lyon, MATEIS, CNRS UMR5510, France
2. Ecole Nationale Superieure des Mines d'Albi-Carmaux, ICA, CNRS UMR5312, France

Few structural applications have emerged for geopolymers outside of civil engineering despite their great polyvalence and their potential for sustainability. In this work, we present an innovative sandwich structure made of a geopolymer matrix composite as external layers, and of a geopolymer foam as the core. The composites are made by impregnating continuous inorganic fibers with a geopolymer matrix. The geopolymer foam suspension is poured between two composite layers to form a sandwich by consolidating in-situ. We assessed the mechanical behavior of the structure using mainly four-point bending tests assisted with digital image correlation (DIC). A plane strain finite element model (FEM) of the structure was also built based on a concrete damage plasticity (CDP) behavior. Results show that cracks appear in the foam before propagating to the composites or being deviated at the foam/composite interface. As is prominently displayed by both DIC and FEM, damage originates from shear strains. The CDP behavior simulates adequatly the damage initiation and propagation. In further investigations, we will be using acoustic emission to track damage initiation and propagation, as well as testing the structure in tensile mode. The results orient the optimization process towards the improvement of the foam and the reinforcement of the structure with respect to shear.

11:10 AM

(HTCMC-S8-016-2026) Ablation behavior of C_f/ZrB_2-SiC CMCs fabricated with high concentration slurry using an HVOF torch

J. Lee*[1]; Y. Zou[1]; S. Lee[1]

1. Korea Institute of Materials Science, Extreme Materials Institute, Republic of Korea

Carbon fiber-reinforced ZrB_2–SiC ceramic matrix composites (Cf/ZrB_2–SiC CMCs) were fabricated by infiltrating a high solid-loading ZrB_2 slurry into carbon fiber preforms, followed by densification to form a ZrB_2–SiC matrix. Ablation under severe localized heat flux was evaluated using a high-velocity oxy-fuel torch for 60 s. The surface temperature rose within 1 s and stabilized at ~1720°C, giving a quasi-steady state. Surface profilometry revealed a concentrated erosion pit with a peak recession rate of 5.46×10^{-3} mm/s and radial microcracks induced by thermal shock. X-ray diffraction and SEM/EDS identified a stratified oxidation scale consisting of an outer borosilicate-rich glass and an inner ZrO_2-rich region above the unreacted composite. The development of porous, microcracked ZrO_2, associated with thermal-expansion mismatch and the tetragonal-to-monoclinic transformation, governs oxygen transport and local stress fields. Delayed stress-corrosion cracking and spontaneous fragmentation of the ablated region after ambient storage indicate water-assisted degradation of the glass/oxide scale and subcritical crack growth. Overall, the results show that high-concentration slurry processing yields C_f/ZrB_2–SiC CMCs that withstand intense HVOF flame, while oxidation-scale instability and time-dependent damage are critical for hypersonic thermal protection.

11:30 AM

(HTCMC-S8-017-2026) Test for rapid assessment of interface coating performance

B. Callaway*[1]; J. Shaw[1]

1. Pratt & Whitney, USA

Processing time for the manufacture of ceramic matrix composites via chemical vapor infiltration can be measured in weeks. That lead time prevents timely feedback on development of the material. This talk presents a test methodology for assessment of interface coating function within days after coating deposition. Specimen preparation, test methodology, and interpretation of results will be discussed. Correlations indicating strong agreement between rapid-assessment results and performance of fully processed panels will be shown.

11:50 AM

(HTCMC-S8-018-2026) Automated fiber push in measurements for fiber coating evaluation in CMCs

A. Badran*[1]; E. Maillet[1]; G. Zorn[1]; Y. Zhou[1]

1. GE Aerospace Research, USA

Automating workflows for evaluating fiber coatings in SiC-SiC Ceramic Matrix Composites (CMCs) is a critical step for enhancing material performance and manufacturing efficiency. Traditional qualitative push-in methods are time consuming, limited in data, and lack the detail needed for rigorous assessments. This approach integrates a Quantitative Microscopy Interactive Visualization Overlay tool for precise fiber selection from microscopy images with an automated fiber push-in measurement system. This system provides the indenter preselected fibers to capture force-displacement data. A model evaluates frictional sliding stress from valid curves, providing statistically significant data on fiber coating mechanical behavior. The automation of this method offers improved statistical analysis and detailed visual insights. The method facilitates efficient material testing, supports raw material qualification, and improves the accuracy of microstructure evaluations, appealing to both experimentalists and modelers by providing robust data for material property enhancements.

HTCMC-12 Symposium 10- CMC Applications I – Aerospace Propulsion and Structures

HTCMCS10- Processing and Properties of CMCs for Aerospace Applications II

Room: Shorebreak 1

Session Chairs: Jon Binner, University of Birmingham; Marc Bouchez

8:30 AM

(HTCMC-S10-008-2026) Oxide ceramic matrix composites for aeronautical applications: Relationships between materials, processes, properties and thermomechanical behavior (Invited)

T. Cutard*[1]

1. Ecole Nationale Superieure des Mines d'Albi-Carmaux, Institut Clément Ader - UMR CNRS 5312, France

OCMCs are materials that combine several advantages for thermostructural applications at temperatures between 400°C and 1000°C in oxidizing atmospheres. This talk gives an overview of results obtained during more than 10 years of research activities on OCMCs conducted by the ICA's Composite Materials and Structures research group, often as part of collaborative projects. These activities focus in particular on aeronautical applications, notably engine outlet plugs. The first area of activity deal with the processes to elaborate such materials, with the aim of establishing relationships between materials, processes and properties, particularly mechanical ones. It addresses the key stages of suspension formulation, the study of their rheological behavior, consolidation, the elimination of organic additives and sintering. The case of OCMC repair is also considered. Alumina matrices and alumina-silica matrices are considered. A second area deal with the mechanical and thermomechanical behavior of such composites. The considered approaches combine experimentation, modelling and numerical simulation. Specific testing methodologies are developed and used to obtain the data necessary for a good knowledge and understanding of these behaviors and also to obtain the data necessary to establish predictive numerical simulation methodologies.

9:00 AM

(HTCMC-S10-009-2026) Advances in materials and processing for cost-effective, scalable Ox–Ox CMCs (Invited)

W. Simpson*[1,2]; E. Vargas[1,3]; K. Dincer[5]; M. G. Simpson[4]; S. Fast[4]; H. Yun[1]

1. Axiom Materials Inc, Research and Development, USA
2. University of California Irvine, Material Science & Engineering, USA
3. University of Southern California, Materials Science and Engineering, USA
4. 3M Company, Advanced Materials, USA
5. Axiom Materials Inc, Process Engineering, USA

Oxide–oxide ceramic matrix composites (Ox–Ox CMCs) are established materials for low-density, high-temperature components in aerospace, advanced energy, and industrial applications requiring high thermostructural performance. However, their broader adoption has been constrained by high cost and limited process scalability. This study evaluates cost-reduction approaches through characterization of the material properties and processing behavior of a 10,000-denier Nextel™ 610 semi-unidirectional fabric Ox–Ox CMC prepreg and a unidirectional Ox–Ox slit-tape compatible with automated fiber placement (AFP). The study further includes a comparative cost analysis of these materials relative to baseline commercial Ox–Ox CMC prepreg systems.

9:30 AM

(HTCMC-S10-010-2026) Angle-dependent erosion and microstructural damage in oxide-oxide ceramic matrix composites and polycrystalline nickel alloy

A. Wright[4]; K. Young[3]; V. Heng[2]; A. Ghoshal*[1]

1. US Army Combat Capabilities Development Command Army Research Laboratory Aberdeen Proving Ground, USA
2. The Boeing Company Defense Space and Security Huntington Beach, USA
3. The Boeing Company, USA
4. SURVICE Engineering Company LLC, USA

This study evaluates the erosion response of Inconel 625 and three oxide/oxide ceramic matrix composites (Ox/Ox CMCs) reinforced with Nextel™ 312, 610, or 720 fibers under alumina jet impingement at 650 °C. Erosion experiments spanning impingement angles of 5° – 15° revealed angle- and material-dependent scar morphologies and degradation modes. Inconel exhibited ductile ploughing with discoloration from oxidation, whereas the CMCs showed brittle matrix removal and fiber fragmentation. Using exposure-normalized data, maximum wear depth versus impingement angle followed a power-law over 5° – 15°; however, invariance of depth wear rate across exposure was observed only for Inconel and N720. Elliptical contour fitting of profilometry maps enabled evaluation of a volume-to-surface area metric that plateaued at approximately 28 % of the maximum depth across materials. Scanning electron microscopy imaging revealed that Inconel's erosion morphology varied strongly with impingement angle, while the CMCs displayed anisotropic fracture features governed by fiber orientation. These results provide a quantitative baseline for comparing composite and metallic materials and support the feasibility of Ox/Ox CMCs as potential erosion-resistant alternatives to conventional alloys in exhaust systems.

HTCMCS10- Design and Testing of CMC Components for Aerospace Applications I

Room: Shorebreak 1
Session Chairs: Richard Jones, Pratt & Whitney; Jared Weaver, GE Aerospace

10:10 AM

(HTCMC-S10-011-2026) An overview of CMC application development at IHI (Invited)

F. Watanabe*[1]

1. Kabushiki Kaisha IHI, Japan

IHI operates across a wide range of fields, including aero-engines, space, defense, and energy. In these sectors, the development of ceramic matrix composites (CMCs) has been pursued for several decades as one of the key solutions to meet societal demands and enhance customer value. IHI has focused on the design, prototyping, and testing of CMC components for high-temperature applications, such as turbine blades, vanes, and shrouds in aircraft and industrial gas turbine engines, tail cones and other exhaust parts, as well as thruster nozzles for space applications. This presentation provides an overview of CMC application development at IHI. Our approach involves close collaboration among materials, manufacturing, and design engineers to maximize the benefits of CMCs for each application. Comprehensive evaluations are conducted, from material system selection (including fiber, matrix, and fiber architecture) to component and system design. Technical confidence is built through a stepwise testing process, including material coupon tests, element tests, component tests, and full-system tests, which inform the development, revision, and validation of design methods and criteria. This presentation introduces IHI's experiences and insights gained from these activities in CMC application development.

10:40 AM

(HTCMC-S10-012-2026) Development and industrial deployment of high-temperature CMC technologies in Korea (Invited)

H. Shin*[2]; K. Kim[2]; D. Im[1]

1. DACC Co Ltd, R&D Center, Republic of Korea
2. DACC Carbon Co., Ltd, Republic of Korea

Ceramic Matrix Composites (CMCs) were developed in the 1970s for space and defense applications requiring resistance to extreme thermal and mechanical environments, particularly in rocket propulsion systems. Compared with metallic superalloys, CMCs enable operation at higher temperatures while providing improved damage tolerance relative to monolithic ceramics. Due to their low density, thermal stability, and resistance to oxidation and wear, CMCs have expanded into industrial applications such as transportation systems, combustion environments, and high-temperature heat-treatment equipment. Advances in material system design and processing technologies have supported their adoption in demanding service conditions. In Korea, DACC Carbon has accumulated more than three decades of experience in the development and industrial application of CMC technologies, including brake systems, propulsion-related components, and structural elements for high-temperature industrial systems. This invited presentation will present Korea's CMC development with emphasis on material systems, processing technologies, and application-driven requirements, while also addressing recent progress in polymer-derived SiC fibers and SiCf/SiC composites as representative examples of ongoing technological evolution.

11:10 AM

(HTCMC-S10-013-2026) CMCs for the aerospace market: Recent high-impact applications

L. Cavalli*[1]; Y. Akram[1]; M. Arnoldi[1]; M. Boiocchi[1]; M. Cantù[1]; F. Giacometti[1]

1. Petroceramics, Italy

ISiComp®, OxyComp®, and UHTComp® are three high-temperature Cf-CMC material systems developed by Petroceramics via Liquid Silicon Infiltration (LSI) and engineered to meet the challenging requirements of high temperature aerospace applications. These materials combine low density, high thermal stability, resistance to severe thermal shocks and long-term durability in oxidizing and combustion environments. Despite sharing similar processing steps, the three materials exhibit distinct properties. Precise control over the evolution of the fiber–matrix interface throughout manufacturing enables the tailored microstructures of Cf-CMCs, which in turn determine their different thermo-mechanical behaviors in service. Representative applications include Thermal Protection Systems (TPS) for re-entry vehicles based on ISiComp®, other aerospace components utilizing OxyComp®, and leading edges for hypersonic vehicles manufactured from UHTComp® The three systems are at different stages of maturity. ISiComp® has reached TRL 6, with Space Rider TPS flight-model production ongoing following successful qualification. Full-scale OxyComp® components have been fabricated, and extensive testing under relevant conditions is in progress to advance their TRL. UHTComp® materials are currently at lower TRL, but plasma wind tunnel testing at small scale has demonstrated their strong potential for hypersonic flight.

11:30 AM

(HTCMC-S10-015-2026) Multidisciplinary approach to designing and validating CMC components, testing and simulation pyramid at SAFRAN (Invited)

S. Denneulin*[1]

1. Safran SA, CERAMICS, France

Ceramic matrix composites (CMCs) for high-temperature applications, such as aeronautical parts, especially for civilian use, require a thorough understanding of their behavior from the constituent scale up to the component level, under complex mechanical and thermal loadings. In addition, a high level of confidence and strong control over variability are needed. This presentation will address the testing and simulation pyramid. It will present a multidisciplinary approach to designing and validating CMC components, including tests on CMC and EBC coupons (such as tensile, bending, shear, fatigue, and corrosion testing), as well as burner rig tests with and without environmental conditions. Instrumentation methods such as digital image correlation, acoustic emission, and infrared cameras will also be described. Establishing an effective feedback loop between testing and simulation is essential to make the best use of the collected data.

HTCMC-12 Symposium 11- CMC Applications II – Solar, Nuclear and Propulsion Systems

HTCMCS11- UHTC CMC materials

Room: Sandpiper D
Session Chair: Zbigniew Pedzich, AGH University of Krakow

8:30 AM

(HTCMC-S11-08-2026) Interface-engineered ceramic composites for extreme temperatures (Invited)

S. Ren*[1]

1. University of Maryland, USA

Carbon composites exhibit exceptional mechanical strength, low density, and high thermal conductivity, yet their rapid oxidation above ~500 °C severely limits their performance in high-temperature. Conventional ceramic matrix provides only partial protection due to non-uniform coverage, thermal expansion mismatch, and microstructural defects. Here we present an interface-engineered dual-layer ceramization (IEDC) strategy that couples in-situ preceramic conversion to achieve conformal, adherent, and durable oxidation resistance. During pyrolysis, a dense nanocrystalline ceramic shell evolves from the preceramic precursor at the interface, forming robust chemical bonds that block oxygen ingress and mitigate high-temperature erosion. This nanocrystalline interlayer acts synergistically with the outer ceramic barrier, preserving structural integrity under extreme thermal flux. Thermogravimetric and high-temperature tests demonstrate that IEDC-treated composites retain nearly full mass after exposure to ultrahigh temperature, indicating oxidative and thermal stability. Infrared thermography further reveals a pronounced thermal-barrier effect, with a surface-to-backside temperature differential exceeding 300 °C under localized heating. This work establishes a scalable route for nanoscale ceramization, enabling oxidation-resistant composites for next-generation extreme environment applications.

9:00 AM

(HTCMC-S11-010-2026) Novel ultra-high temperature ceramic matrix composites for high temperature applications (Invited)

P. Tatarko*[1]; H. Ünsal[1]; S. sahin.ates@tubitak.gov.tr[2]; F. Valenza[3]; R. Kumar[4]; I. Dlouhy[5]

1. Institute of Inorganic Chemistry, Slovak Academy of Sciences, Department of Ceramics, Slovakia
2. Tubitak Marmara Arastirma Merkezi, Turkey
3. Istituto di Chimica della Materia Condensata e di Tecnologie per l'Energia Consiglio Nazionale delle Ricerche Sede di Genova, Italy
4. Indian Institute of Technology Madras, Metallurgical and Materials Engineering, India
5. Ustav fyziky materialu Akademie ved Ceske republiky, Czechia

Ultra-High-Temperature Ceramic Matrix Composites (UHTCMCs) are promising materials for extreme environments due to their superior thermal and mechanical stability. The first part of the presentation will deal with the development of UHTCMCs by reactive melt infiltration process (RMI). The ZrSi2 infiltrated into the Cf/SiC composites, where it reacted with SiC matrix and C fibres to form ZrC or with B4C-infiltrated SiC matrix to form ZrB_2-ZrC-SiC. The second part of the presentation will focus on the preparation of ZrB_2-based ultra-high-temperature ceramic (UHTC) coatings to enhance oxidation/ablation resistance of C_f/C and C_f/SiC ceramic matrix composites (CMCs). The coating was applied via a room-temperature deposition process and cured at 200°C in multiple layers. Ablation performance was evaluated through an oxyacetylene torch test at surface temperatures of ~2300°C for C_f/C and ~2050°C for C_f/SiC, with real-time temperature monitoring via optical pyrometry. The results demonstrated a significant reduction in mass ablation rates, with the coated and annealed samples exhibiting up to 50% improvement in ablation resistance compared to uncoated counterparts. This work was supported by the Slovak Research and Development Agency under the Contract no. APVV-SK-CN-23-0015. The support of the project SAS-TUBITAK/JRP/2023/807/HiTemCom (No. 720464) and CNR-SAS-2024–03 is also acknowledged.

HTCMCS11-Novel materials, processing, manufacturing, design, and qualification for energy applications

Room: Sandpiper D
Session Chair: Tatsuya Hinoki, Kyoto University

9:30 AM

(HTCMC-S11-027-2026) SiC as bulk ceramics for harsh environment applications (Invited)

P. Sajgalik*[1]; O. Hanzel[1]; M. Hicak[1]; A. Kovalcíkova[1]

1. Institute of Inorganic Chemistry, Slovak Academy of Sciences, Ceramic Department, Slovakia

Freeze-granulated silicon carbide powder was densified to the full density without any sintering aids by rapid hot-pressing at temperatures from 1850 °C to 1900 °C. The static oxidation (parabolic rate constant) at 1450 °C for 204 h was 4.9×10^{-5} mg^2/cm^4h, which is almost negligible in comparison to the parabolic rate constant 7.0×10^{-2} mg^2/cm^4h of the LPS sintered SiC materials. In the dynamic regime the ceramics sustained 1900 °C for 60 s without substantial damage, weight loss was only 0.2 %. When the oxidation was prolonged to 300 s the damage was visible but still not crucial, weigh loss was 8.8 %. Comparison with commercially available CVD SiC showed that CVD sample at these conditions had 0.6 wt. % of weight loss, while the bulk SiC ceramics had weight loss almost 9 wt. %. Ablated crater of dense SiC sample is changed to porous SiAlOC glass. Thermal conductivity is radically changed from 145 W/mK for SiC to 0.4 W/mK for porous SiAlOC glass. This change of the materials chemistry in the crater centre is responsible for the substantial decrease of thermal stress resistance. The consequence is crack formation, which is limitted just for the crater centre. This work was financially supported by the Slovak Research and Development Agency under the Contract No. APVV-24-0442.

10:20 AM

(HTCMC-S11-011-2026) Reactive sintering of UHTC materials as a method for tailoring their composition and properties (Invited)

Z. Pedzich*[1]; D. D. Kozien[1]; W. Banas[1]; A. Gubernat[1]; A. Wojteczko[1]; E. Durda[2]; C. Balazsi[3]

1. AGH University of Krakow, Department of Ceramics and Refractory Materials, Poland
2. AGH University of Krakow, Department of Physical Chemistry and Modelling, Poland
3. Centre for Energy Research, Centre of Excellence of Hungarian Academy of Sciences, Hungary

The presented work concerns the preparation of dense composite sinters containing a boride phase (ZrB_2 or TiB_2) and carbide phases. The method involves a simultaneous synthesis and densification process. The initial mixtures contain boron carbide as a boride precursor, and silicide, intermetallic, or MAX phases as a source of zirconium, titanium, and/or silicon. The use of different techniques from the FAST methods family allows for the production of highly densified composites with fine and homogeneous microstructure. Depending on the precursor phases used, the reactions occurring during sintering take place at different speeds and in different temperature ranges, which results in different final properties. By controlling the proportions of the initial phases and the process conditions, the final microstructure can be designed and optimized

for mechanical or thermomechanical properties as illustrated by the examples presented in the paper. Acknowledgemets: The work was carried out in the frame of “Excellence Initiative - Research University” IDUB Programme by the AGH University of Krakow, projects IDs: 12418 and 9886.

10:50 AM

(HTCMC-S11-012-2026) Environmental barrier coatings based on rare earth silicates (Invited)

J. Maier*[1]; C. Eckardt[1]; J. Vogt[1]; A. Konschak[1]

1. Fraunhofer-Zentrum fur Hochtemperatur-Leichtbau HTL, Germany

Environmental barrier coatings (EBC) play a crucial role in protecting oxide and non-oxide ceramic matrix composites (CMCs) used in aerospace and power generation applications. Rare earth silicate-based materials are particularly promising for this purpose based on their good thermodynamic stability. However, to achieve a functional coating, these materials must meet a variety of important requirements. Key criteria include an appropriate coefficient of thermal expansion, chemical compatibility with the substrate, temperature and phase stability, as well as environmental durability. To address these challenges, different bond coat and top coat materials and combinations have been evaluated. This presentation will focus on the adaptation of these materials for their use on oxide and non-oxide CMCs, utilizing simple slurry application methods. By optimizing the properties of the coatings, we aim to enhance the performance, longevity and reliability of CMCs in demanding environments. The thermal properties, phase composition and microstructure of the coating materials will be presented, demonstrating the potential for tailored EBC solutions that can be specifically customized to CMCs with different properties.

11:20 AM

(HTCMC-S11-013-2026) The influence on used FAST techniques on microstructure and phase composition of reactively sintered UHTC materials (Invited)

D. D. Kozien*[1]; W. Banas[2]; D. Salamon[3]; P. Tatarko[4]; M. Hicak[4]; O. Hanzel[5]; K. Pasiut[1]; P. Nieroda[7]; Z. Pedzich[6]

1. Akademia Gorniczo-Hutnicza im Stanislawa Staszica w Krakowie, Department of Ceramics and Refractory Materials, Poland
2. Akademia Gorniczo-Hutnicza im Stanislawa Staszica w Krakowie, Department of Ceramics and Refractories, Poland
3. Central European Institute of Technology, Brno University of Technology, Czechia
4. Institute of Inorganic Chemistry, Slovak Academy of Sciences, Department of Ceramics, Slovakia
5. Ustav anorganickej chemie Slovenska akademia vied, Slovakia
6. AGH University of Krakow, Department of Ceramics and Refractory Materials, Poland
7. AGH University of Krakow, Department of Inorganic Chemistry, Poland

This study examines formation mechanisms and oxidation resistance of ultra-high-temperature ceramic (UHTC) in the Ti–Al–B_4C system. The composites were synthesized using boron carbide and Ti–Al intermetallic nanopowders through SPS and SHS. Materials underwent thermal ablation between 1800 - 2000°C. X-ray Absorption Spectroscopy (XAS) confirmed formation of key phases, including TiB_2 and a protective Al_2O_3 layer. This oxide scale suppressed oxygen diffusion, ensuring structural integrity at oxidative environments. Elemental mapping revealed minimal migration, validating the protective oxide barrier. Rapid Acoustic Ceramic Sintering (RACS) enabled homogenization through acoustic activation, while Ultrafast High-temperature Sintering (UHS) provided rapid thermal cycling and microstructural control. Composites with excellent phase stability and oxidation resistance at ultra-high temperatures were manufactured through optimization. These findings demonstrate the potential of Ti–Al–B_4C systems as next-generation UHTCs. Acknowledgemets: This research was supported by National Center for Research and Development (LIDER XIII; 0024/L-13/2022, “Excellence Initiative - Research University” IDUB Programme by the AGH University of Krakow, projects IDs: 12418,12256,9886,9679 and National Science Centre, SONATA-20, 2024/55/D/ST11/02206.

11:50 AM

(HTCMC-S11-014-2026) Enhancement in the joining sections of nuclear cladding materials through the use of embedded wire chemical vapor deposition

S. P. Shuster*[1]

1. Free Form Fibers, USA

The field of nuclear cladding continues to be an area of interest as alternative forms of energy are being explored on a global scale. While impressive advancements have been made in the past decade, there still remain gaps in progress, such as in joining and end-capping of nuclear cladding materials. Currently Free Form Fibers has developed and continues to innovate with an in-house technique, embedded wire chemical vapor deposition (EW-CVD). The process leverages the use of resistive elements and in-house ceramic fibers developed through laser chemical vapor deposition to “weld” reinforced joining sections on similar or dis-similar cladding materials. This EW-CVD process has demonstrated a unique control of the joining area composite microstructure and a high degree of control of thermal gradient behavior during the deposition process. The materials used in the EW-CVD cladding focused procedure have also been sent out for testing under different radiation environments. An in-depth review of these materials will be discussed in this presentation in terms of joining materials microstructure, experimental conditions, alongside performance of materials in cladding environments.

GFMAT-3 Symposium 1- Powder Processing Innovation and Technologies for Advanced Materials and Sustainable Development

GFMATS1- Nanostructure and microstructure control

Room: Shorebreak 2
Session Chairs: Loredana Santo, Universita degli Studi di Roma Tor Vergata; Takashi Shirai, Nagoya Institute of Technology

1:30 PM

(GFMAT-S1-013-2026) Sintering of transparent nanocrystalline tetragonal zirconia without stabilizers (Invited)

M. Yoshida*[1]

1. Gifu Daigaku, Japan

Tetragonal zirconia is widely used as grinding media, wear-resistant components, and dental materials due to its high strength, toughness, and chemical stability. However, its strong optical anisotropy causes substantial light scattering at grain boundaries, making polycrystalline tetragonal zirconia opaque and difficult to render transparent. Overcoming this limitation and successfully fabricating transparent tetragonal zirconia would enable new applications as an optical material. To enhance optical transparency, we used a tetragonal zirconia nanoparticle dispersion with an average particle size of approximately 5 nm as the starting material. This dispersion consisted of pure, unstabilized tetragonal zirconia nanoparticles with a high-aspect-ratio morphology. The calcined sample exhibited optical transparency, and its type I adsorption isotherm confirmed a microporous structure. XRD analysis revealed a small amount of monoclinic phase in the compact; however, the tetragonal phase was dominant. The calcined samples were subsequently sintered at temperatures ranging from 500 °C to 1200 °C. As the sintering temperature increased, the relative density increased while the specific surface area decreased. At 900 °C, the sample achieved a relative density of 94.7% and maintained its optical transparency.

2:00 PM

(GFMAT-S1-014-2026) Refining of ATZ mechanical properties by reactive sintering process (Invited)

Z. Pedzich*[1]; M. Grabowy[2]; A. Kluczowska[2]; M. Gromada[2]; D. D. Kozien[3]; W. Banas[3]

1. AGH University of Krakow, Department of Ceramics and Refractory Materials, Poland
2. Institute of Power Engineering - Research Institute, Ceramics Division Cerel, Poland
3. Akademia Gorniczo-Hutnicza im Stanislawa Staszica w Krakowie, Department of Ceramics and Refractory Materials, Poland

The work concerns the development of ATZ composites containing different alumina content. The selected ATZ composites compounds were fabricated by means of reactive sintering of the mixture of powders composed of precipitated zirconia differing in yttria content. The ATZ specimens had a hardness of 13.8 GPa, flexural strength higher than 1 GPa and fracture toughness exceeding 10 $MPam^{1/2}$. The ATZ composites were tribologically tested using the ball-on-disc method. The results proved that material had significantly improved wear susceptibility, especially at a range between 350 and 500 °C due to the presence of pseudoplastic surface layer, which strongly decreased degradation by limiting of single grains removal. The effects of hydrothermal aging were systematically studied. Highly transformable ZrO_2 grains gives the material high resistance to fracture, while making the material very susceptible to hydrothermal aging. The studies confirm that the ATZ material manufactured by the proposed technique had a distinctly improved properties. The investigated ATZ products possess strong potential to be used for reliable machinery parts working in the sliding regime at elevated temperatures, next generation bioceramics for medical devices, high-performance structural elements. Acknowledgment: This work was financed by the National Centre for Research and Development under the project FENG.01.01-IP.01-A03U/23-Z-CER

2:30 PM

(GFMAT-S1-015-2026) Improving dispersion of hollow silica nanoparticles in polymer composites via melt kneading

T. Ogiya*[1]; K. Ishii[1]; Y. Sato[2]; Y. Takagi[3]; M. Ishihara[1]; M. Fuji[1]

1. Nagoya Institute of Technology, Japan
2. Tokyo City University, Japan
3. Tokyo University of Science, Japan

Recent advances in AI and the growing information-driven society have greatly increased the need for high-speed data transmission. As a result, electronic materials must offer low dielectric loss and efficient thermal management to save energy. Polymer-based composites combine the electrical insulation and easy processing of polymers with the functions of fillers, making them a promising solution. To improve these properties, various functional fillers can be added to polymer matrices. Among them, hollow silica nanoparticles (HSNPs), with internal nanoscale voids, reduce dielectric loss and improve thermal insulation. In this study, HSNPs were dispersed in poly(lactic acid) (PLA) via melt kneading. HSNPs were synthesized by a sol–gel method using a template and a silica precursor. Subsequently, sheets were fabricated by hot pressing, and the dispersion state of HSNPs was examined using scanning transmission electron microscopy (STEM). The results show that HSNP morphology strongly affects its dispersion in the polymer, giving insights into how to improve filler distribution during melt processing. Acknowledgements: This work was partially supported by JSPS KAKENHI Grant Number 23H01801 and JST SPRING, Grant Number JPMJSP2112.

GFMAT-3 Symposium 4- Crystalline Materials for Semiconductor, Optical/ Scintillator and Dielectric Applications

GFMAT-S4- Scintillator

Room: Sandpiper C
Session Chairs: Kenji Toda, Niigata University; Ha-Neul Kim, Korea Institute of Materials Science

1:30 PM

(GFMAT-S4-015-2026) Development of halide ceramics processing methodologies to achieve transparency requirements for optical applications

T. Rudzik*[1]; N. Cherepy[2]; S. A. Payne[1]

1. Lawrence Livermore National Laboratory, USA
2. Lawrence Livermore National Lab, Chemistry and Materials Science, USA

Halide ceramics have promising applications in scintillators and laser gain media with many potential advantages over single crystals, such as easier scalability, spatial control of doping and enhanced fracture toughness, but have seen severely limited application thus far due to the difficulties of reducing optical scatter to acceptable levels. Over multiple years of iterative improvements to our fabrication methodology, we have successfully developed procedures, including treatments of powder feedstocks, hot press sintering, and post-sinter annealing, to repeatably produce SrF_2 ceramics of the scale 1 cm^3 with thickness >1 cm and optical scatter of <1 %/cm. Additional work has shown these procedures can be adapted to other halides (BaF_2) and demonstrated control of the location and concentration of doping (Nd) within SrF_2 ceramic samples.

1:50 PM

(GFMAT-S4-016-2026) Transparent ceramic scintillators fabricated into pixelated arrays via Direct-Ink-Write

A. Kostogiannes*[1]; N. Cherepy[1]; S. A. Payne[1]

1. Lawrence Livermore National Laboratory, Materials Science Department, USA

Direct-ink-write (DIW) has been shown to be a viable route to fabricate transparent pixelated arrays of GLO, $(GdLu)_2O_3$: Eu, for x-ray imaging. Engineering a pixelated geometry has shown to improve imaging efficiency and spatial resolution. In this work, we extend the DIW technique for fabrication of $(GdY)_3(GaAl)_5O_{12}$: Ce ceramic arrays to be utilized for gamma-ray spectroscopy. Pixel size, length, fill factor and material composition can all be engineered to improve scintillator imaging screen properties, while offering potential for scalable manufacturability.

2:10 PM

(GFMAT-S4-017-2026) Garnet ceramics for radiation detection (Invited)

M. Müller*[1]

1. Radiation Monitoring Devices Inc, Ceramics, USA

Scintillators convert ionizing radiation, such as X-rays, γ-rays, and neutrons, into ultraviolet or visible light making them the centerpiece of modern radiation detectors. Single crystals, such as $CdWO_4$, $Bi_2Ge_3O_9$, $Lu_2SiO_5:Ce^{3+}$, and $NaI:Tl^+$, are commonly used materials for γ-detection, while Li containing materials, including $LiI:Eu^{2+}$ and $LiCs_2YCl_6:Ce^{3+}$, are typically used for the detection of neutrons. However, these scintillators come with a set of drawbacks, including low light yield, hygroscopy, and in some cases high fabrication costs. Scintillators made from transparent ceramics are promising alternatives to single crystals due their lower production temperatures, shorter processing cycles, and consequently lower costs. Garnets are optimal candidates for the development of ceramic scintillators not

only due to their excellent properties, such as high density, high Z_{eff}, chemical inertness, mechanical strength, high radiation hardness as well as high light yield and good energy resolution, but also due to virtually boundless freedom to tune their composition. This talk explores how the compositional flexibility of the garnet structure can be leveraged to develop novel scintillator materials. In more detail, it outlines the development of scintillator ceramics for radiography and neutron detection applications using entropy-based approaches as well as Li-stuffing of garnets.

2:40 PM

(GFMAT-S4-018-2026) $Y_{1-x}Tb_xTaO_4$ single crystals as scintillators for X-ray detection (Invited)

K. Shimamura*[1]; E. G. Víllora[1]; Y. Zhou[1]; D. Nakauchi[2]; T. Kato[2]; N. Kawaguchi[2]; T. Yanagida[3]

1. National Institute for Materials Science (NIMS), Japan
2. Nara Sentan Kagaku Gijutsu Daigakuin Daigaku, Japan
3. Nara Institute of Science and Technology, Japan

Single-crystal scintillator that is free from toxic elements and has scintillation properties comparable to commercial $CdWO_4$ (CWO) in terms of light yield, afterglow, and stopping power, has been demanded since long. In this work, transparent and colorless $Y_{1-x}Tb_xTaO_4$ (YTTO) mixed single crystals have been grown by the floating-zone (FZ) technique and investigated as scintillators. The optimum scintillation performance was found for 15% Tb concentration: the light yield was about 1.5 times that of CWO, while the density, the stopping power, and the afterglow were comparable. These results demonstrate the potential of $Y_{0.85}Tb_{0.15}TaO_4$ single crystals as an environmentally friendly alternative to CWO ones for high-energy X-ray radiography.

GFMAT-3 Symposium 6- Advanced Batteries and Supercapacitors for Energy Storage Applications

GFMATS6- Advanced Battery Materials

Room: Tidepool 1
Session Chair: Dany Carlier, Institut de Chimie de la Matiere Condensee de Bordeaux

1:30 PM

(GFMAT-S6-035-2026) Accelerating battery materials development with autonomous labs and AI: From disordered rocksalt cathodes to electrolytes

D. Seo*[1]

1. Korea Advanced Institute of Science and Engineering (KAIST), Republic of Korea

Autonomous laboratories combined with artificial intelligence are changing how battery materials are developed by making experiments faster, more systematic, and more data-driven. In this talk, I will present our recent efforts to accelerate battery materials development using autonomous platforms. We first developed a robotic Joule-heating synthesis system for Mn-based disordered rocksalt cathodes, where rapid heating and cooling help control short-range order and improve Li-ion transport. Based on this cathode platform, we further expanded the autonomous workflow to the development of solid electrolytes by combining automated synthesis, structural characterization, and property measurements with active-learning-guided experiment planning. Finally, I will also introduce our self-driving platform for liquid electrolyte research, which autonomously formulates and evaluates electrolyte compositions. These examples show how autonomous labs and AI can be extended across different battery material systems.

2:00 PM

(GFMAT-S6-015-2026) Safety assessment of lithium metal batteries: From reactive materials to advanced diagnostics (Invited)

M. Bertrand[1]; N. B. Johnson[2]; C. Saint-Antoine[1]; M. Dollé*[1]

1. Université de Montréal, Chemistry, Canada
2. Sandia National Laboratories, Power Sources R&D, USA

Lithium metal batteries are considered a key technology for next-generation high-energy storage systems, yet their widespread deployment remains limited by critical safety challenges. Among these, the intrinsic reactivity of lithium metal toward both electrolytes and cathode materials raises severe concerns under abuse or failure conditions. In particular, thermite-type reactions can lead to rapid heat release, gas generation, and catastrophic cell failure. This contribution reviews recent experimental insights into these reactions, highlighting their thermodynamic drivers, and implications for cell-level and system-level safety. In parallel, this work will also present the development of a computer-vision-based methodology to quantitatively determine the flash point of liquid and gel-polymer electrolytes. By combining high-speed imaging with automated image analysis, the proposed tool enables objective, operator-independent detection of ignition events that are difficult to capture using conventional techniques. This approach improves measurement repeatability. Together, these studies illustrate how coupling fundamental reaction analysis with advanced diagnostic tools can contribute to a more comprehensive safety assessment of lithium-based batteries, supporting the rational design of safer materials and testing protocols for high-energy electrochemical systems.

2:30 PM

(GFMAT-S6-016-2026) Defect-enginnered and practical lithium insertion materials for Li storage applications (Invited)

N. Yabuuchi*[1]

1. Yokohama National University, Japan

Ni-rich layered oxides such as $LiNiO_2$ are attractive positive electrodes, but suffer from capacity degradation at high voltages due to Ni migration. Recent studies show that non-stoichiometry and antisite defects play a critical role, and defect engineering enables highly reversible pure Ni-based layered materials without metal substitution. In parallel, Co-/Ni-free Mn-based electrodes are important for cost-effective electric vehicles. While typically synthesized by energy-intensive milling, nanostructured $LiMnO_2$ with high energy density (~800 W h kg^{-1}) has recently been obtained through conventional calcination, demonstrating scalability. For safety, solid electrolytes are promising, but electrode volume changes complicate interface stability. Dimensionally invariable cation-disordered rocksalt oxides address this issue, achieving excellent reversibility with solid electrolytes. Overall, defect-engineered and nanostructured lithium insertion materials are central to the development of safe, high-energy, and practical Li-ion batteries.

HTCMC-12/GFMAT-3 Joint Symposium- Additive Manufacturing Technologies and Applications

HTCMC-GFMAT- Joint Sym- Integration of Artificial Intelligence

Room: Sandpiper B
Session Chair: Motoyuki Iijima, Yokohama National University

1:30 PM

(Joint Sym-015-2026) Predicting composite material properties from images using a multi-input deep learning framework (Invited)

M. Kim[1]; H. Choi*[1]

1. Chung-Ang University, Mechanical Engineering, Republic of Korea

Composites are widely used in thermal management applications, but nonuniform filler distributions often lead to localized thermal hotspots, making accurate prediction of effective thermal conductivity challenging. Conventional theoretical models and numerical simulations rely on simplified assumptions or high computational costs, limiting their applicability to realistic microstructures. In this study, an image-based multi-input deep learning framework is proposed to predict the effective thermal conductivity of composite materials. Microstructural images generated from three-dimensional statistical volume elements are used to train a multi-input convolutional neural network that integrates global and local structural features. The proposed model achieves high predictive accuracy, with an RMSE of 0.066 and an R2 of 0.932, demonstrating its capability to directly predict composite properties from microstructural images. This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korean government (MSIT) (No. NRF-2022R1A2C2003), and by the Technology Innovation Program – Industry Technology Alchemist Project (No. 20025702, Development of smart manufacturing multiverse platform based on multisensory fusion avatar and interactive AI) funded by the Ministry of Trade, Industry and Energy (MOTIE), Republic of Korea.

2:00 PM

(Joint Sym-016-2026) Industrialising ceramic AM with artificial intelligence and automation

A. Hovsepyan*[1,2]; E. Louradour[1]; R. Gaignon[1]

1. 3DCeram Sinto, 3DCeram Sinto, USA
2. Additive Plus, USA

Ceramic additive manufacturing has reached a level of technological maturity that raises a new challenge: industrialisation. For large ceramic components and series production, process stability, repeatability, and cost control remain the main barriers to adoption. This presentation will share an industrial perspective on how artificial intelligence and end-to-end automation can address these challenges and enable the transition from prototyping to production-ready ceramic AM. AI is used as a process intelligence layer, supporting parameter optimisation, material behaviour management, and real-time adjustments during printing based on in-situ data. Rather than replacing expertise, it assists operators in controlling complex ceramic processes and improving consistency. Automation complements this approach by structuring the workflow—from preparation and printing to monitoring and post-processing—reducing variability, limiting waste, and improving overall productivity. The combination of AI and automation proves particularly relevant for large-scale ceramic parts and repeatable series manufacturing, where manual intervention becomes a limiting factor. This presentation illustrates how AI-driven automation contributes to more robust, scalable, and cost-efficient ceramic additive manufacturing processes, opening new opportunities for advanced ceramic applications requiring complex geometries and high performance.

2:20 PM

(Joint Sym-017-2026) A domain-specialized AI agent for photopolymer composite AM: Process and material recommendation, optimization, feedback control

S. Han*[1]; L. Geonhwi[1]; H. Choi[1]

1. Chung-Ang University, Department of Mechanical Engineering, Republic of Korea

Photopolymerization-based AM delivers high resolution; however, composite printing is highly sensitive and the quality is inconsistent because the formulation and process parameters are closely coupled, which makes empirical tuning a time-consuming process. We propose a domain-specific Large Language Model (LLM) agent that consolidates literature, datasheets, machine specifications and process logs into a structured knowledge base. The agent uses Retrieval-Augmented Generation (RAG) to make evidence-based, reliable decisions. Based on user-defined targets and constraints, the agent performs PSPP-guided inverse design to recommend feasible material–process combinations and optimized parameters. An adaptive monitoring–feedback loop uses in-process state signals to detect issues and update key process parameters, thereby improving robustness, suppressing defects and accelerating development cycles. Acknowledgment This work was supported by the National Research Foundation of Korea(NRF) grant funded by the Korea government(MSIT) (No. NRF-2022R1A2C2003) and also supported by the Technology Innovation Program - Industry Technology Alchemist Project (20025702, Development of smart manufacturing multiverse platform based on multisensory fusion avatar and interactive AI) funded by the Ministry of Trade, Industry & Energy (MOTIE, Korea)

2:40 PM

(Joint Sym-018-2026) A review of Additive Manufacturing Technologies for designing polymer matrix composites (PMCs)

S. Gupta*[1]

1. University of North Dakota, Mechanical Engineering, USA

Additive Manufacturing (AM) has emerged as as important manufacturing process for manufacturing polymer matrix composites (PMCs). Some of the important processes are, Fused Deposition Modeling (FDM), Selective Laser Sintering (SLS), Stereolithography (SL) etc. Each of these processes have their own merits and demerits. In this presentation, I will present a review accompanied by case studies to understand and document the advantages and disadvantages of these processes. It is expected that this presentation will be helpful for manufacturing engineers for designing novel materials via AM based processes.

HTCMC-12 Symposium 3- Polymer Derived Ceramics and Composites

HTCMCS3- Preceramic Polymers and Polymer-Derived Ceramics V

Room: Sandpiper A
Session Chairs: Matthew Dickerson, Air Force Research Laboratory; Kathy Lu, University of Alabama at Birmingham

1:32 PM

(HTCMC-S3-015-2026) Wrinkled SiOC ceramic surfaces via UV–thermal dual curing of novel polysiloxane precursors

M. Sobczak*[1]; T. Li[1]; K. Song[1]

1. University of Georgia, Mechanical Engineering, USA

Surface wrinkling in ceramics offers a powerful strategy to engineer micro- and nanoscale patterns with tunable functionality, yet achieving such morphologies on hard, high-temperature materials remains a challenge. In this work, we report a novel preceramic

polymer route to fabricate wrinkled ceramic coatings via a polysiloxane (PSO) precursor containing dual crosslinkable functional groups that enable both UV-induced and thermal curing. This dual-curing strategy enhances ceramic yield and structural fidelity during pyrolysis, allowing the generation of well-defined wrinkled morphologies directly on rigid substrates. The resulting surfaces exhibit hierarchical features and excellent mechanical and chemical stability. By controlling the curing conditions and ceramic conversion, the wavelength and amplitude of the wrinkles can be systematically tuned. These patterned ceramic surfaces have promising applications in energy and defense systems, where controlled surface topology can influence drag reduction, light scattering, and thermal or chemical protection.

1:52 PM

(HTCMC-S3-016-2026) Light-driven transformations of polymers to ceramics (Invited)

R. Hickey*[1]; B. Stovall[1]; A. Katona[2]; T. Coutinho de Carvalho[1]; A. Ul Hosna[3]; A. van Duin[3,1]; J. Maria[1]; B. Lear[2]

1. The Pennsylvania State University, Materials Science and Engineering, USA
2. The Pennsylvania State University, Chemistry, USA
3. The Pennsylvania State University, Mechanical Engineering, USA

Polymer derived ceramics are a critical class of materials that have led to advances in the production of ceramic fibers and coatings. The chemical diversity of the polymer precursors (i.e., preceramic polymers) before conversion into ceramics is an exciting handle to tailor specific chemical compositions. Although the compositional variability is desirable, traditional pyrolysis methods to convert polymers to ceramics are energy intensive and time demanding. Thus, it is desirable to convert polymeric precursors to high-temperature ceramics at low bulk temperatures in a single step, ideally via light. Here, we show that it is possible to convert a preceramic polymer containing boron functional groups to boron carbide (B_4C) via laser irradiation. B_4C films of 400 mm^2 are synthesized within seconds, highlighting the processing speed and efficiency. The conversion is hypothesized to be a photothermal process that drives the transformation. This hypothesis is supported by our computational chemical analysis, which indicates that this conversion is initiated by H_2 release from the decaborane, followed by exothermic formation of a boron-cluster, which assists in thermal decomposition of the hydrocarbon polymer backbone. Photothermal heating is shown to provide spatially resolved ceramic features that are dictated by the laser settings, whereas conventional heating leads to bulk ceramic materials.

2:22 PM

(HTCMC-S3-017-2026) Formulation and filler effects on the printability and properties of polymer-derived ceramic lattices (Invited)

M. Jakubinek*[1]; H. Yazdani Sarvestani[2]; A. Kulkarni[2]; T. Lacelle[1]; C. Nojavan[2]; A. Robitaille[3]; B. Ashrafi[2]

1. National Research Council Canada, Division of Emerging Technologies, Canada
2. National Research Council Canada, Aerospace Research Centre, Canada
3. Defence Research and Development Canada, Valcartier Research Centre, Canada

Ceramics are known for their high compressive strength and high thermal and chemical stabilities, which make them the only material option for some of the most extreme environments; however, traditional ceramics are also prone to brittle failure and exhibit low damage tolerance. The toughness of ceramics can be improved through use of architecture, as is observed in nature, and additive manufacturing methods now enable the production such bioinspired structures, lattices, and other complex geometries that are challenging or impossible to produce by other methods. The combination of 3D printing with preceramic polymers can also provide greater versatility in ceramic compositions. Here we describe the development of photopolymerizable formulations for polymer derived ceramics, which are patterned by digital light processing (DLP) 3D printing to produce gyroid lattices and pyrolyzed at high temperature. The properties and compositions of the resulting ceramic lattices are tailored through the precursor polymer, filler particles and post-processing, and the resulting parts are evaluated for their composition, temperature stability and performance in compression.

HTCMC-12 Symposium 4- Innovative Design, Advanced Processing and Manufacturing Technologies in Non-oxide and Oxide Composites

HTCMCS4- SiC-based composites I

Room: Silver Pearl 1-3
Session Chair: Alex Leide, UKAEA

1:30 PM

(HTCMC-S4-016-2026) Material design of the novel metal-SiC hybrid composites (Invited)

T. Hinoki*[1]

1. Kyoto University, Japan

Silicon carbide (SiC) composites are promising materials for aerospace and nuclear applications due to engineered toughness by fiber reinforcement and due to intrinsic features of SiC including very high temperature mechanical performance and exceptional irradiation stability. However fracture strain is limited by SiC fiber elongation. Low thermal conductivity especially at high temperature may cause significant additional stress. Tungsten is a candidate material for the plasma facing material for nuclear fusion. However embrittlement under neutron irradiation and recrystallization at high temperature are significant issues. The novel metal-SiC composites were designed to improve ductility and thermal conductivity of SiC composites and to improve ductility of a tungsten material. Tungsten and molybdenum were selected to combine SiC due to high melting point. The SiC fibers and the metal wires were woven. The novel metal-SiC composites were fabricated successfully.

2:00 PM

(HTCMC-S4-017-2026) Advanced lightweight ceramic composites with short fiber reinforcement for aeronautical applications (Invited)

M. Bechelany*[1]; E. Bouillon[1]

1. Safran SA, Safran Ceramics, France

Meeting aerospace weight reduction goals has encouraged the advancement of ceramic matrix composites (CMCs), which provide high temperature stability and low density. To better suit small and complex-shaped components, new materials have been developed using short silicon carbide fibers embedded in optimized ceramic matrices. With short fibers, the composite can be processed using various shaping methods, which offers enhanced manufacturing flexibility for the production of complex structures. However, challenges remain in properly controlling fiber lengths, effectively coating them with a suitable interphase, and achieving a ceramic composite that ensures non-brittle behavior. Through careful management of these factors, a short fiber CMC material has been obtained, showing improved mechanical properties, including a flexural strength of up to 500 MPa, a Young's modulus around 300 GPa, and a fracture toughness close to 8 $MPa.m^{1/2}$. Thermal and mechanical tests, including flame exposure, validate the robustness of these materials under demanding conditions. The improved performance of short fiber reinforced CMCs creates new opportunities for their integration into next-generation lightweight aeronautical components.

2:30 PM

(HTCMC-S4-018-2026) Development of SiC core material for LWR (Invited)

T. Nishimura*[1]; M. Ukai[1]; S. Suyama[2]; T. Takada[1]; S. Kuboya[1]; M. Akimoto[1]; R. Kojima[1]

1. Kabushiki Kaisha Toshiba, Japan
2. Toshiba Energy Systems & Solutions Corporation, Japan

Toshiba Energy Systems & Solutions Corporation (Toshiba ESS) has been developing core material of Silicon Carbide (SiC) composite for a candidate of accident tolerant fuel (ATF) since 2012. Even though SiC has several desired properties for ATF, it is necessary to develop fabrication and manufacturing technologies. Our SiC/SiC composite core material are made by means of braiding SiC fibers and CVD/CVI process. In addition to developing fabrication process of SiC/SiC composite, other manufacturing technologies which are necessary to use the composite as ATF core materials also have to be developed. From this point of view, Toshiba ESS has been developing SiC/SIC core material as LWR accident-resistant material and succeeded in building manufacturing process of SiC/SiC composite which meets the performance and function requirement for practical use in Light Water Reactors (LWR). SiC/SiC composite to be applied to core material should meet the performance requirement, such as mechanical strength, airtightness or corrosion resistance. These principal results of the various examinations and the current issues about our research and development shall be presented.

HTCMC-12 Symposium 7- Materials for Extreme Environments – UHTCs, MAX phases, and nanolaminates

HTCMCS7- Response of UHTCs/UHTCMCs in Extreme Environments I

Room: Osprey
Session Chair: Elizabeth Golightly, University of Virginia

1:30 PM

(HTCMC-S7-018-2026) Aerothermal response of leading edge prototypes made of Pan or Pitch based Cf – reinforced UHTCs

D. Sciti*[4]; A. Vinci[4]; L. Zoli[4]; A. Airoldi[1]; A. Caporale[2]; M. De Stefano Fumo[3]

1. Politecnico di Milano, Dept. of Aerospace Science and Technology, Italy
2. Politecnico di Milano, Italy
3. Centro Italiano Ricerche Aerospaziali, Italy
4. Consiglio Nazionale delle Ricerche, Italy

Thermal protection materials for space vehicles must endure extreme temperatures, chemical environments, and rapid thermal changes. UHTCMCs (ultra-high temperature ceramic matrix composites), combine UHTC-rich matrices with carbon fibers, improving damage tolerance and ablation resistance above 2000°C. In this talk we show the recent advancements in the manufacturing of UHTCMCs leading edge prototypes and their mechanical and environmental testing. Two manufacturing approaches were evaluated: machined composites from sintered manufacts and near-net shape prototypes via polymer infiltration and pyrolysis. Six prototypes, three from each technology were placed in a customized sample holder and exposed to a high enthalpy flow in the Scirocco plasma wind tunnel facility. Notably, the two types of prototypes, due to different manufacturing processes, exhibited distinct compositions, leading to variations in thermal behavior. The temperature for sintered samples gradually increased to around 1900°C, while for polymer-based samples, the temperature immediately rose to 2000°C with a constant profile. Following three minutes of stable flux conditions, the samples were cooled down to room temperature, undergoing a slight weight change. Microstructural analyses and mechanical tests were conducted to assess oxidation and strength degradation from these extreme conditions.

1:50 PM

(HTCMC-S7-019-2026) High-enthalpy testing of UHTCMC leading edges under hypersonic flow conditions

L. Baier*[1]; M. Friess[1]; N. Hensch[1]; O. Hohn[1]; J. Schukraft[2]

1. Deutsches Zentrum fur Luft- und Raumfahrt DLR, Germany
2. Deutsches Zentrum fur Luft- und Raumfahrt DLR, Ceramic composites and Structures, Germany

In the ongoing development of hypersonic technologies, material innovations are essential to meet the extreme thermo-mechanical demands of high-speed flights. Ultra-High Temperature Ceramic Matrix Composites (UHTCMCs) combine load-bearing fibre architectures with high-temperature-stable ceramic matrices that exhibit excellent oxidation and erosion resistance. These properties qualify UHTCMCs for applications exceeding 2000 °C, enabling use at temperatures beyond the limits of conventional CMCs. At the German Aerospace Center (DLR), a UHTCMC material based on carbon fibres and a zirconium diboride (ZrB_2) matrix is being developed using Reactive Melt Infiltration (RMI), a three-stage process consisting of preform fabrication, pyrolysis, and subsequent melt infiltration. To evaluate the suitability for hypersonic applications, leading edges were manufactured and subjected to hypersonic flow conditions in an arc-heated wind tunnel. These tests reproduce the coupled thermo-chemical and thermo-mechanical loads experienced during atmospheric entry or sustained hypersonic flight, to make a prediction of surface degradation, oxidation behaviour, and structural response. It was demonstrated that the tested UHTCMC leading edges are free of degradation.

2:10 PM

(HTCMC-S7-020-2026) High temperature ablation resistance of C_f/ZrC-SiC UHTCMCs formed by electrophoretic co-deposition

M. J. Ammendola*[1,2]; N. Tran[2]; C. Mosebey[3,2]; A. Ghoshal[2]; D. E. Wolfe[1]

1. The Pennsylvania State University, Materials Science and Engineering, USA
2. US Army Combat Capabilities Development Command Army Research Laboratory Aberdeen Proving Ground, USA
3. SURVICE Engineering Company LLC, USA

Electrophoretic deposition (EPD) is a colloidal processing method in which an applied electric field is used to deposit particles out of a fluid suspension. Despite EPD's long tenure for forming near-net shape ceramic green bodies, the technique is largely unexplored for ultra-high temperature ceramics (UHTC) and ceramic matrix composites (UHTCMCs). This work approaches EPD as a low-cost, high-throughput solution to UHTCMC processing, compared to conventional approaches with lengthy processing cycles. By manipulating the wet chemistry environment, the particle charge of high temperature carbides like ZrC and SiC is tailored to enable effective deposition onto 2D carbon fiber weaves. Green bodies are then stacked in a layup fashion and consolidated by two distinct methods: (1) polymer infiltration and pyrolysis (PIP) using a carbon forming resin, and (2) field-assisted sintering technology (FAST) with an applied pressure. The ablation resistance is then tested by oxyacetylene torch exposure, where composites experience temperatures exceeding 2000 °C in an oxidizing environment. Sample behavior is evaluated by electron microscopy, x-ray diffraction, and volumetric material loss analysis. The PIP and FAST processes are compared with respect to their samples' ablation performance as well as each technique's capacity to effectively consolidate EPD green bodies.

2:30 PM

(HTCMC-S7-021-2026) Surface erosion resistance of carbon fiber reinforced ultra-high-temperature ceramic matrix composites in harsh environments

A. Nishikawa*[1]; Y. Arai[1]; R. Inoue[1]

1. Tokyo University of Science, Japan

Carbon fiber reinforced ultra-high temperature ceramic matrix composites (C/UHTCMC) were fabricated by melt infiltration (MI) into cross-ply carbon/carbon (C/C) composites using Zr-Ti (ZT) binary, Zr-Si (ZS) binary and Zr-Ti-B (ZTB) ternary alloys. Microstructural observations showed UHTC matrix was formed into transverse cracks in C/C laminates. Oxy-hydrogen burner tests for C/UHTCMC specimen showed that the surface temperature and temperature increasing rate were increased as the radius of curvature of specimen decreased. Recession resistance for C/UHTCMC was also significantly suppressed compared with C/C composite. Furthermore, C/C composites infiltrated ZS and ZTB alloy formed a dense, thick oxide scale on their surfaces. ZS specimen showed the smallest change in the radius of curvature among all specimens. These results suggested that the ZS alloy improves the infiltration characteristics due to its superior wettability and could be realized high recession resistance. In addition, a coupled thermal and ablation analysis considering localized heat flux and material recession was conducted using COMSOL Multiphysics, which provided quantitative knowledge for the experimental results.

HTCMC-12 Symposium 8- Testing and Evaluation of Ceramic Matrix Composites from Constituents and Coupons to Components, including EBCs

HTCMCS8- Environmental effects, thermo-mechanical creep, fatigue performance and tribology

Room: Pelican
Session Chairs: Ken Goto, Japan Aerospace Exploration Agency; George Jefferson, USAF

1:30 PM

(HTCMC-S8-019-2026) Retained strength of SiC/SiC CMC after exposure to combustion environment (Invited)

C. Smith*[1]; A. S. Almansour[2]; M. J. Presby[3]; R. I. Webster[1]

1. NASA Glenn Research Center, USA
2. NASA Glenn Research Center, Mechanical Engineering, USA
3. NASA Glenn Research Center, Environmental Effects and Coatings Branch, USA

The durability of ceramic matrix composites (CMCs) with environmental barrier coatings (EBCs) is affected by oxidation in combustion environments. Oxidation studies of these materials typically focus on the buildup of thermally grown oxide and the effect it has on EBC adherence. This study explores how the combustion environment affects CMC durability. CMC samples with an EBC were exposed to natural gas/ oxygen combustion environment at temperatures up to 2700°F for up to 300 hours. After exposure, the samples were tensile tested at room temperature. Retained strength and matrix cracking stress will be compared to pristine samples.

2:00 PM

(HTCMC-S8-020-2026) Behaviour of SiC/SiC composites under thermomechanical stress combining flame and tensile testing

E. Perret[1]; A. Bernardot[1]; S. Denneulin*[2]; V. Herb[2]; J. Mateo[2]

1. Institut de Recherche Technologique Antoine de Saint-Exupery, Ceramix Matrix Composites Division, France
2. Safran SA, CERAMICS, France

The development of SiC/SiC ceramic matrix composites (CMCs) for high-temperature applications requires understanding their behaviour under complex mechanical and thermal loadings. This study presents a multidisciplinary approach to design, and validate CMC component performance. Fully instrumented flame tensile tests, including Digital Image Correlation (DIC) and infrared cameras, and accoustics emissionsswere conducted. Experimental results show that thermal loading significantly influences the mechanical response of CMCs at temperatures above 1000°C, leading to changes in failure mode and location. These findings contributes to the understanding of the high-temperature behaviour of CMC structures and provides a design and validation approach for SiC/SiC components in extreme environments. Further work will focus on improving the Knowledge accuracy by investigating damage mechanisms and their temperature-dependent behaviour.

2:20 PM

(HTCMC-S8-021-2026) Oxidation behavior through cracks of unidirectional ceramic composites in dry and wet air (Invited)

S. Kanazawa*[1]; F. W. Zok[2]

1. IHI Corporation, Japan
2. University of California Santa Barbara, USA

Oxidative degradation of SiC/SiC composites has been attributed to deterioration of fiber coatings due to internal oxidation. In this study we investigated the internal oxidation behavior of unidirectional SiC/BN/SiC minicomposites at elevated temperature in dry and wet air. We employed high-resolution scanning electron microscope and energy dispersive X-ray spectroscopy analyses of both pristine and pre-cracked specimens to examine the evolution of interfacial oxidation as a function of BN coating thickness, crack opening, and environmental water content. The study reveals oxidation-induced closure occurs through multiple mechanisms, governed by crack width and environmental conditions and four distinct closure pathways were identified. These findings suggest new insight into the governing processes of interfacial degradation and help establish a framework for lifetime prediction in SiC/SiC composites.

2:50 PM

(HTCMC-S8-022-2026) Demonstration of a new test method for evaluating fatigue crack growth in SiC fiber/SiC matrix composites at elevated temperatures in air

N. Ikegami*[1]; T. Ogasawara[1]; T. Aoki[2]

1. Tokyo Noko Daigaku - Koganei Campus, Japan
2. Japan Aerospace Exploration Agency, Advanced Composite Research Center, Institute of Aeronautical Technology, Japan

This study examined a test method for evaluating the fatigue crack growth behavior of an orthogonal 3-D woven SiC fiber/ carbon interphase / SiC matrix (SiC-f/SiC) composite under cyclic tensile loading at 1100 °C in air. A new compact tension specimen was designed based on the conventional geometry specified in ASTM E399, and it was employed for fracture-mechanics-based fatigue testing. Finite element analysis was used to derive the relation between the specimen compliance and the crack length, as well as the relation between the crack length and the mode I stress intensity factor (K_I). Based on these results, a system was developed that enables real-time measurement and control of both crack length and K_I from the compliance measured in each cycle during fatigue loading. Using the developed experimental system, fatigue crack growth tests were conducted on SiC-f/SiC specimens under K_I

control mode. The fatigue test was intermittently interrupted, and the crack length was directly measured at room temperature using a scanning electron microscope and X-ray computed tomography. The crack lengths estimated from the specimen compliance showed good agreement with those obtained from the SEM and X-ray CT measurements, demonstrating the effectiveness of this method for evaluating fatigue crack growth in the SiC-f/SiC composite at 1100 °C in air.

HTCMC-12 Symposium 10- CMC Applications I – Aerospace Propulsion and Structures

HTCMCS10- Design and Testing of CMC Components for Aerospace Applications II

Room: Shorebreak 1
Session Chairs: Jared Weaver, GE Aerospace; Richard Jones, Pratt & Whitney

1:30 PM

(HTCMC-S10-014-2026) CMCs components development for aero-turbine, in Safran (Invited)

E. Bouillon*[1]

1. Safran SA, Safran Ceramics, France

SiC/SiC CMC and Oxide CMC, are becoming a major leading alternative for the design and manufacturing of the next gas turbine engines components as airfoils, shrouds, combustion chambers and exhaust. These materials offer higher temperature capability than the current state-of-the-art metallic superalloys. The growing interest in CMC technologies is directly linked to the new short-term engine design constraints, namely an increase of functioning temperature and an increase of mass saving, a drastic decrease of community noise and air polluting emissions and a specific fuel consumption decrease. During the last fifteen years, substantial research efforts have been devoted to evaluating a wide range of CMC and manufacturing routes. Available experiences, in term of sub-element rig tests and engine ground and flight tests, confirmed the expected gains and provided significant lessons in field service. Furthermore, design tools and tests methods have been optimized for fine understanding of behaviour, damage tolerance, design criteria and certification approach. The aim of this presentation, is to illustrate these different aspects, through different examples of Safran experiences, including different types of CMC associated to different type of component.

2:00 PM

(HTCMC-S10-016-2026) CMC turbine vane subelement testing and validation (Invited)

K. Rugg*[1]

1. Pratt and Whitney, USA

Stress concentrations are common inside the tight radius of the trailing edge of a hollow turbine vane. The local stress in the structural model can greatly exceed the durability limit established from coupon testing. To clear a ceramic matrix composite material for engine testing, a series of subelement tests were conducted first establishing the strength of trailing edges cut from full-scale vanes and then performing durability tests to demonstrate adequate life. A durability model that includes oxidation and delamination mechanisms correlates well with the subelement results providing a path for analytical validation.

HTCMC-12 Symposium 11- CMC Applications II – Solar, Nuclear and Propulsion Systems

HTCMCS11- SiC CMC for nuclear applications I

Room: Sandpiper D
Session Chair: Peter Tatarko, Institute of Inorganic Chemistry, Slovak Academy of Sciences

1:30 PM

(HTCMC-S11-015-2026) Development of SiGA® Silicon Carbide Composite Cladding Technology for the Light Water Reactor Fleet (Invited)

S. Gonderman*[1]; S. Oswald[1]; L. Borowski[1]; A. Giles[1]; W. Mcmahon[1]; R. Haefelfinger[1]; D. Kuebler[1]; L. Hunter[1]; A. Moore[1]; G. Lovelace[1]; A. Langevin[1]; A. Sathrum[1]; C. Deck[1]; G. Jacobsen[1]; H. Khalifa[1]

1. General Atomics Electromagnetic Systems Group, Nuclear Technologies and Materials, USA

General Atomics – Electromagnetic systems (GA-EMS) is developing SiGA® composite technology, a silicon carbide (SiC) fiber reinforced SiC matrix ceramic matrix composite cladding. This multi-layered, engineered structure is designed to provide safe and economically competitive nuclear power in light water reactor (LWR) applications. The high temperature mechanical and irradiation stability of SiC composites positions SiGA® cladding to deliver improved performance during normal operational and enhanced safety in accident conditions. Recent progress on the demonstration of SiGA® cladding will be reported, including separate effects testing (supporting quantification of operational benefits), irradiation in representative fission reactor environments (including test data from MITR, HFIR and ATR), and advancements in fabrication scale-up. SiGA® composite cladding is now being fabricated as full length fuel rods (~4m long) meeting tight dimensional, thermal/mechanical, and sealing requirements of nuclear fuel cladding. Parallel efforts are underway to deploy manufacturing efficiencies to reduce fabrication costs of nuclear grade SiC/SiC composites. These developments are part of a comprehensive effort to advance the technology toward commercial lead rod testing and subsequent deployment.

2:00 PM

(HTCMC-S11-016-2026) Metal/SiC interactions in SiC/SiC composites: Diffusion-driven reaction kinetics and implications for Generation IV reactor applications

F. Bourlet*[1]; C. Lorrette[1]

1. Commissariat a l'energie atomique et aux energies alternatives Siege administratif, France

Interactions between SiC/SiC ceramic matrix composites (CMCs) and metallic materials were first investigated for pressurized water reactors (PWRs), where selected metals ensured hermetic sealing in advanced and breakthrough SiC/SiC cladding concepts. With the transition toward Generation IV systems, CMCs are now explored for their high-temperature capability, irradiation tolerance, and low neutron absorption. In these next-generation environments, CMC components will interface with various structural metals, making the understanding of their mutual interactions essential. This work examines the compatibility of SiC/SiC composites with candidate metals for Generation IV applications, focusing on interfacial reactions, degradation mechanisms, and their impact on component integrity. Reaction kinetics governing interfacial layer formation were analyzed using a diffusion-controlled model described by Fick's law. This approach enables comparison of reaction rates across different metal/SiC systems by linking reaction-layer thickness to time–temperature parameters, thus identifying metals most compatible with SiC at high temperatures. Electron microprobe analysis (EPMA) along concentration profiles, combined with elemental mapping, provides insight into the phases formed in the reaction zone and clarifies diffusion pathways and reaction mechanisms.

2:20 PM

(HTCMC-S11-017-2026) Mechanical characterization and scaling of SiC composite nuclear fuel cladding

J. Quan*[1]; S. Gonderman[1]; R. Haefelfinger[1]; S. Oswald[1]; L. Borowski[1]; A. Giles[1]; G. Jacobsen[1]; H. Khalifa[1]

1. General Atomics Electromagnetic Systems Group, NTM, USA

General Atomics Electromagnetic Systems (GA-EMS) is developing SiGA® cladding, a silicon carbide (SiC) fiber reinforced ceramic matrix composite (CMC) nuclear fuel cladding, to provide enhanced safety and operation benefits to the nuclear industry through high-temperature stability and irradiation resilience. To meet performance needs of SiGA® cladding at commercial length, GA-EMS has developed characterization methods to provide mechanical, dimensional, and gas-tightness data on full-length rods. Using these methods, full-length SiGA® rods have shown <5% axial variation in mechanical properties and meet gas-tightness specifications for reactor use. Large-scale testing has been coupled with low length mechanical testing and in-situ leak measurements to capture composite behavior under relevant reactor loads. Data from in-situ testing shows SiC composite layers ability to arrest microcracking and preserve gas-tightness. This out-of-pile characterization is being acquired along with irradiation data to ensure nuclear performance. Details on developed characterization techniques and performance data will be presented in the context of how this testing fits in a comprehensive framework for evaluating failure modes, correlating microstructural behavior with macro-scale performance, and scaling this performance to commercial length to support the qualification of next-generation CMC cladding systems.

2:40 PM

(HTCMC-S11-018-2026) Irradiation effect on constituents of SiC composites

T. Hinoki*[1]; Y. Zhong[1]; J. Lee[1]; S. Kondo[2]

1. Kyoto University, Japan
2. Tohoku University, Institute for Materials Research, Japan

Silicon carbide (SiC) composites are promising materials for nuclear applications due to engineered toughness by fiber reinforcement and due to intrinsic features of SiC, including low activation, chemical and environmental inertness, exceptional irradiation stability, and very high temperature mechanical performance. Highly crystalline SiC is required to avoid significant dimensional change due to crystallization under irradiation. However each highly crystalline SiC constituent may have additional phase and impurities depending on fabrication methods. The objective is to understand irradiation effect on the constituents to discuss the design window of fluence and temperature ranges of various type of highly crystalline SiC composites. Neutron irradiation and relating hot lab works have been performed by SCK CEN in the framework of SCK CEN-Tohoku Univ. collaboration.

Posters

Room: Corals Ballroom 3, 4, 5

5:30 PM

(Poster001-2026) Design of multi-elemental oxides for thermal barrier coatings using first-principles molecular dynamics and machine learning potential

R. Masuda*[1]; T. Kurata[1]; R. Inoue[1]; Y. Kogo[1]; Y. Arai[1]

1. Tokyo Rika Daigaku, Japan

Yttria-Stabilized zirconia (YSZ) has long been the conventional material of thermal barrier coatings (TBCs) for gas turbine engines. Recently, high-entropy oxides (HEOs) are attractive candidates for advanced TBCs to improve their performance. However, the enormous number of potential compositions makes traditional experimental screening too slow and difficult for effective material development. Furthermore, without fundamental insight into the atomic-scale mechanisms, it is impossible to reliably predict or optimize material properties. The objective of this study is to establish an advanced data-driven system for material processes by the combination of first-principles calculations, molecular dynamics and machine learning potential. By this integrated approach, it becomes possible to establish a materials processing capable of proposing optimal compositions for unexplored material systems from a quantum-mechanical perspective. As an important property for TBCs, coefficient of thermal expansion (CTE) is estimated by this integrated approach. The relationship between calculated structures and CTE will be discussed in the presentation.

(Poster002-2026) Advanced manufacturing of ceramic materials via novel compositions

M. Sobczak*[1]; T. Li[1]; D. Patil[1]; A. Ramanathan[1]; S. Thummalapalli[1]; K. Song[1]

1. University of Georgia, Mechanical Engineering, USA

Advanced manufacturing enables new approaches to process ceramics with tailored geometries, compositions, and surface features that are unattainable through conventional methods. This work highlights two strategies that demonstrate the versatility of additive and polymer-derived routes for next-generation ceramics. In the first, highly loaded silica inks are formulated for direct ink writing (DIW) to produce dense, low-shrinkage components with excellent shape fidelity, expanding the design space for structural and thermal applications. In the second, a novel polysiloxane-based preceramic polymer with dual crosslinkable functionality is synthesized to create wrinkled SiOC ceramic coatings via UV and thermal curing. These wrinkled surfaces exhibit controllable hierarchical morphologies and exceptional chemical and thermal stability. Together, these efforts underscore the potential of combining ink-based and preceramic-polymer-based approaches to advance the processing, performance, and functionality of modern ceramic materials for demanding applications in energy, aerospace, and defense.

(Poster003-2026) Controlling cracking behavior of preceramic polymers via manipulation of gelation conditions

I. Fisher*[1]; J. Wiggins[2]

1. University of Southern Mississippi, USA
2. University of Southern Mississippi College of Arts and Science, Polymer Science and Engineering, USA

Polymer-derived ceramics (PDCs) are a class of materials with major significance in high temperature applications, such as aerospace composite materials, due to their molecular diversity, high oxidation and corrosion resistance, thermal stability, and creep resistance at extreme temperatures, ~2000 °C. While PDCs are widely used as both fibers and matrices for composite applications, the resulting ceramic composites have long manufacturing times due to the polymer infiltration and pyrolysis cycles required to achieve desired density. Cracks provide pathways for material to fill voids during infiltration; however, literature pertaining to the influence of green-body formation on cracking remains poorly understood. In crosslinked polymer networks, internal stress develops with each subsequent bond formed after gelation. Once local stress exceeds a maximum, deformation occurs in the form of cracking. This research aims to control the cracking behavior of polysiloxane green-body networks via manipulation of gelation conditions. Several polysiloxane blends were subjected to various curing conditions to understand the influence of ramp rate, cure temperature, and hold time on green-body cracking and thermal stability. The blends were analyzed for their conversion via near-infrared spectroscopy, thermal stability via thermogravimetric analysis, and mass loss during cure for each protocol.

(Poster004-2026) The effect of oxygen and excess carbon on the densification behavior of polycrystalline SiC fibers stabilized by electron beam irradiation

H. Lee*[1,2]; T. Kim[1,2]; Y. Jeong[2]; K. Cho[1]; Y. Joo[1]

1. Korea Institute of Ceramic Engineering and Technology, Republic of Korea
2. Pusan National University College of Engineering, Republic of Korea

Silicon carbide (SiC) fibers and fabrics have been proposed as reinforcements in ceramic matrix composites (CMCs) for aerospace applications due to their excellent mechanical properties, such as tensile strength (≥2.45 GPa) and tensile modulus (220 GPa) even at high temperatures (>1200°C). In this study, the effects of low oxygen and excess carbon on the conversion of amorphous SiOC fibers to crystalline SiC fibers during the fabrication of polymer-derived SiC fibers were observed. The oxygen content was controlled to 2-4 wt% by electron beam irradiation, and the excess carbon was controlled to a C/Si ratio of 1.7-3.5 by hydrogen heat-treatment. The amorphous SiOC fibers were prepared by heat treatment at 1000, 1100, 1200, and 1300°C for 1h in a H_2+Ar atmosphere, and converted to polycrystalline SiC fibers by pyrolysis at 1600°C for 0.5 to 1h in Ar atmosphere. The grain growth of crystals and mechanical strength of polycrystalline SiC fibers were improved by controlling the excess carbon in amorphous SiOC fibers. However, when the carbon content was excessively adjusted, bulk SiC grain and porous cross-sections were observed on the fiber surface. The fracture surface of SiC and SiOC fibers were analyzed by FE-SEM, and the elemental content were traced by EDS, ONH, and XPS.

(Poster005-2026) Thermal and radiative heat transport in $Gd_2Zr_2O_7$ for thermal barrier coating applications: A first-principles study

M. Harish*[1]; K. Sasihithlu[1]

1. Indian Institute of Technology Bombay, Energy Science and Engineering, India

Rare-earth pyrochlores such as $Gd_2Zr_2O_7$ have emerged as leading candidates for next-generation thermal barrier coatings (TBCs) due to their structural disorder, excellent phase stability, and intrinsically low thermal conductivity. In this work, we present a comprehensive first-principles investigation of heat transport in $Gd_2Zr_2O_7$ aimed at understanding its suitability for high-temperature TBC applications. Lattice thermal conductivity is computed over 300-1500 K by solving the phonon Boltzmann transport equation Both three-phonon and four-phonon scattering processes are explicitly included, revealing strong higher-order anharmonicity that further suppresses phonon transport at elevated temperatures. Radiative thermal conductivity is evaluated using infrared optical properties calculated in the 1-50 μm wavelength range and incorporated through the Rosseland diffusion model. Results indicate that while lattice thermal conductivity remains extremely low across the full temperature range, radiative heat transport becomes increasingly significant above ~1200 K- an important consideration for TBCs operating in turbine environments. The combined analysis highlights the interplay between anharmonic phonon scattering and radiative transfer, providing a realistic assessment of the total thermal conductivity of $Gd_2Zr_2O_7$ under service-level temperatures.

(Poster007-2026) Scale-dependent Tg in amorphous PEKK nanocomposites from structural and thermomechanical analysis

C. R. Dixon*[1]; J. Wiggins[2]

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The glass transition temperature (T_g) marks the onset of large-scale polymer chain mobility and plays a critical role in the thermomechanical behavior of nanocomposites. However, the characteristic length scale of motion probed by different T_g measurement techniques is not well established. Here, the T_g of amorphous polyether ketone ketone-graphitic nanoplatelet (PEKK-GNP) nanocomposites were measured using DSC, TMA, and in-situ XRD to capture thermodynamic, thermomechanical, and structural responses. For DSC and TMA, measurements at multiple heating rates were extrapolated to zero ramp rate to determine equilibrium T_g while minimizing kinetic effects. In TMA and XRD, T_g was identified from the inflection point of thermal expansion, where the coefficient of thermal expansion approximately doubled above T_g. TMA yielded the highest T_g, due to the large-scale mobility required to permit viscoelastic deformation under load. DSC gave an intermediate T_g, indicating the equilibrium thermodynamic transition, and XRD detected the lowest T_g, reflecting that changes in local interchain packing (d-spacing) preceded bulk dimensional response. These results demonstrate how complementary techniques can deconvolute scale-dependent confinement effects and provide a multiscale understanding of T_g, informing the design of thermomechanically stable PEKK nanocomposites.

(Poster008-2026) Oxygen flow rate as a parameter for UHTC's oxidation behaviour under oxyacetylene flame

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During atmospheric re-entry, thermal protection materials are subjected to severe environments under high heat fluxes. At hypersonic velocities, the aerodynamic heating experienced by spacecraft leading edges can reach temperatures above 2000 °C for several minutes. In this framework, interest is focused on the description of the behaviour in such environmental conditions of ceramic materials selected as thermal and chemical protection systems at ultra-high-temperatures. In this study, to investigate this behaviour, aging conditions under different atmospheres are required on the same material. High flux oxyacetylene flame is used as an oxidation method. Correlation to NASA chemical equilibrium code (CEA) allows to extract the impact of the oxygen flow rate on the oxidation kinetics of the material. The kinetics were identified in regard to the dominant mechanisms operating within the material, depending on oxygen flow rate. As a function of the range of experimental conditions (temperature, flow rate, time), microstructural analysis allows to highlight differences in: (i) densification, (ii) oxide layer thickness, (iii) SiC depletion thickness and (iv) quantity of consumed material.

(Poster010-2026) Effects of filler composition on the joint properties of SiC joined by Si-C reaction bonding

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Silicon carbide (SiC) is widely used for various applications due to its excellent mechanical properties and stability under extreme conditions. However, the strong covalent bonding and low self-diffusivity of SiC lead to the fabrication of simple shape only, making the joining of multiple components essential for fabricating complex component for practical applications. In this study, an optimal filler composition for SiC joining via Si–C reaction bonding was examined with the aim of minimizing residual Si to achieve a reliable SiC joint. SiC blocks were joined under vacuum at 1430 °C for 20 min using 25 μm-thick filler tapes composed of SiC/C ranging from 10/90 to 90/10 wt% by molten-Si infiltration. The effects of SiC/C weight ratios on the joint microstructure and strength were examined, and an effort was made to correlate them with the degree of Si–C reaction and resulting phases. Moreover, the reason for joining failure with carbon-rich filler was explained by Si-C reaction mechanism. A SiC/C ratio of 60/40 wt% was chosen as an optimal composition, which revealed the highest joint strength of 400 MPa.

(Poster011-2026) Irradiation-condition dependence of heavy-ion-induced flow for surface damage recovery in oxide ceramics

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Oxide ceramics are widely used in aerospace components, environmental barrier coatings, nuclear reactors, and fusion systems, where exposure to energetic particles is unavoidable. Understanding their fundamental irradiation responses is therefore essential. Recent observations indicate that some oxide ceramics exhibit pronounced flow under heavy-ion irradiation, enabling partial healing of surface defects. However, the dependence of this behavior on irradiation conditions and material system remains unclear. This study investigates how surface trenches deform through irradiation-induced flow and examines the influence of ion energy, fluence, dose rate, and temperature. Controlled trenches of varying widths were introduced by FIB, and YAG, mullite, alumina, and 10YSZ were irradiated with 3 MeV Si ions. Post-irradiation analyses showed substantial trench closure in YAG and mullite, with trenches up to ~4 μm and ~5 μm, respectively, fully closing. Distinct flow features also appeared from sample edges, whereas alumina and 10YSZ showed no detectable deformation. Dose-rate dependence was clear in mullite: 8.3×10^{-3} dpa/s produced ~5 μm of flow, while 2.8×10^{-3} dpa/s yielded ~2.5 μm, indicating that higher damage rates enable larger net flow. These findings clarify key factors governing flow behavior in oxide ceramics under particle irradiation.

(Poster012-2026) Degradation of mechanical properties of single-crystal 8YSZ – Effects of point defects from reduction treatment in vacuum at high temperature –

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Degradation mechanism of 8YSZ ceramics used as solid electrolytes in SOFCs is crucial for reliable system development. This study aims to clarify the effect of point defects generated during reduction treatment of single crystal 8YSZ, an ideal crystalline grain, on its near surface mechanical properties. Microcantilever beam specimens approximately 12 μm long were fabricated on the surface of single-crystal 8YSZ reduced at 1500 °C or 1600 °C for 30 min under vacuum. Bending tests were carried out using a nanoindenter. The result showed a significant decrease in bending strength and Young's modulus after treatment. Furthermore, EPMA revealed a decrease in surface oxygen concentration after treatment. XPS analysis showed that only the O1s spectrum of the treated sample showed a peak bulge at high energy, suggesting an increase in oxygen vacancies. This decrease in the number of Zr-O bond due to increased oxygen vacancies should result in the degradation in mechanical properties. Furthermore, a lower valent Zr peak was observed in the Zr3d spectrum, and a peak related to the tetragonal ZrO_2 was found in the Raman spectrum after treatment. These changes also presumably have contributed to the mechanical property degradation.

(Poster013-2026) In-situ OCT visualization of internal structure evolution in alumina slip casting: Roles of mold geometry and dispersant content

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Understanding consolidation behavior, namely the internal structure evolution, is one of the key issues to fabricate better ceramics by slip casting. This behavior should be influenced by mold shape and by dispersant. Optical coherence tomography (OCT), which has been developed for inspection of inside of human body, is one of the candidates to observe the internal evolution during slip casting. In this study, in-situ OCT visualization of internal structure evolution during slip casting of alumina slurries with 0.4 or 3.0 mg/m^2 of polycarboxylic acid was conducted using a porous alumina mold with flat or semicylindrical surface. After pouring the slurry into the mold, the OCT images changed over time, forming a consolidated body. Time variation in the OCT images was evaluated as the motion fraction analyzed by a frame subtraction method. The motion fraction of the slurry with 0.4 mg/m^2 dispersant decreased after casting and then increased over time, suggesting partial collapse of agglomerated particle networks. In contrast, the slurry with 3.0 mg/m^2 dispersant showed only a slight increase in the motion fraction for the semicylindrical mold. They indicate that dispersant content and mold shape affect particle mobility and internal structural evolution during slip casting.

(Poster014-2026) Reduced-order modeling of gas-solid flows with heat transfer via a frequency-based approach

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Reduced-order models (ROM) have been developed for accelerating coupled computational fluid dynamics and discrete element method (CFD-DEM) simulations of solids handling equipment. The ROMs are often created using highly elaborate machine learning model architectures, which capture the irregularity of gas-solid flows but can be difficulty to fine-tune due to the large number of hyperparameters and long training times. In this study, we introduce the frequency-based ROM as an alternative to machine-learning based ROMs. A full-order model (FOM) of a heated fluidized bed is formulated as a case study. Afterward, proper orthogonal decomposition (POD) is applied to decompose the FOM snapshots into POD modes and time-varying coefficients. The frequency-based ROM then identifies the peak frequencies in the coefficients, which is the only step that requires parameter tuning. The identified frequencies are subsequently used to reconstruct and extrapolate their values over time. The extrapolated coefficients are then combined with the modes to generate the extrapolated snapshots. The ROMs could replicate the spatiotemporal characteristics of the FOM while also generating results order-of-magnitudes faster. The frequency-based ROMs also took only a few seconds to train and involved minimal parameter tuning, which allows for much faster prototyping than machine learning-based approaches.

(Poster015-2026) Synthesis of Na-A zeolites from coal residual fractions for agronomic application as slow-release ammonium carriers

WITHDRAWN

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This study investigated the synthesis of Na-A zeolites from residual fractions generated during coal beneficiation, aiming at their use as slow-release ammonium carriers in agricultural fertilizers. Based on the premise that silica- and alumina-rich mining residues can be transformed into value-added zeolitic materials, the approach aligns with circular-economy principles and helps mitigate environmental liabilities. Residual coal fractions collected at different beneficiation stages were thermally treated and characterized for chemical composition, mineralogy, thermal behavior, and morphology. Zeolites produced through alkaline activation (CWZ-A and CWZ-B) exhibited high microporosity, large specific surface area, and elevated cation-exchange capacity, properties that governed their performance in soil incubation assays. A polyurethane-coated urea formulated with CWZ-A reduced cumulative nitrogen volatilization from 54.3% to 0.8% over 14 days, demonstrating efficient controlled nutrient release and significant mitigation of N losses. Life-cycle assessment indicated lower carbon footprint and energy demand relative to conventional nitrogen fertilizers. Overall, the results show that coal-mining residues are effective precursors for zeolites and offer a technically and environmentally sustainable strategy for soil fertility management.

(Poster016-2026) Fabrication and structural analyses of $Hf_xZr_{1-x}O_2$ gate insulators by chemical slution deposition method

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$Hf_{0.5}Zr_{0.5}O_2$ (HZO) thin films with the orthorhombic phase are insulating films that exhibit high-dielectric constant properties and demonstrate ferroelectricity even in ultrathin films less than 10 nm. Consequently, HZO is one of promising device materials for applications in memory devices and as the gate insulator in low-voltage-driven Ferroelectric Field-Effect Transistors (FeFET). HZO films are widely investigated using vacuum-based deposition technique, primarily including Atomic Layer Deposition (ALD). However, such established processes suffer from drawbacks, including high cost and long fabrication time. Therefore, our research aims at the fabrication of HZO films via a solution process, which offers the advantages of low cost, shorter processing time, and energy-efficient, vacuum-independent fabrication. The fabrication of the films was carried out via the spin-coating method. Two different precursor solutions were employed: a sol-gel solution based on metal salts and a Metal Organic Decomposition (MOD) solution derived from organometallic compounds. The fabricated samples were characterized by evaluating their surface morphology and crystallinity. Finally, we systematically discuss the electrical properties and film quality in this presentation.

(Poster017-2026) Electrochemical performance of Silicon oxy-carbide (SiOC) in ionic liquids (ILs) for high temperature adaptable Li-ion batteries

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Technological advancements in the military, aerospace, and data infrastructure are increasing demand for high-temperature-tolerant and high-capacity energy devices. However, the degradation of the active material and the decomposition of the organic electrolyte at high temperatures hinder the development of high-temperature-tolerant rechargeable batteries. To develop high-temperature-adaptable rechargeable batteries, it is crucial to investigate high-temperature-stable electrodes and electrolytes for Li-ion batteries (LIBs). Polymer-derived ceramics (PDCs) are promising electrode materials because of their high-temperature stability and good cycle life stability towards LIBs. Ionic liquids are promising electrolytes for high-temperature-tolerant rechargeable batteries because of their thermal stability. To develop a deeper understanding of the electrochemical properties of PDC in ionic liquid electrolytes, we are investigating the performance of silicon oxy-carbide (SiOC) in LIBs for high-temperature applications.

(Poster018-2026) Grain-scale fracture resistance in silicon nitride ceramics measured using microcantilever specimens

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Silicon nitride (Si_3N_4) ceramics exhibit excellent mechanical properties, such as high strength and high fracture toughness, mainly due to crack bridging by elongated grains behind the crack tip. While fracture toughness and R-curves have traditionally been measured using macroscale notched bending specimens, microscale techniques such as microcantilever bending now allow evaluation at submicron scales. This study investigated rising R-curve behavior during crack extension of several hundred nanometers using single-edge notched microcantilever beams. Si_3N_4 ceramics were prepared by adding Y_2O_3 and Al_2O_3 (5:3:92 wt%), followed by sintering and HIP at 1700 °C. The average grain size was 459 ± 286 nm. FIB-fabricated beams (1.5 × 2.5 × 12 μm) contained a 250 nm-deep sharp notch. KI was determined from compliance changes estimated by FEM. The load–displacement curves exhibited nonlinear drops caused by repeated crack propagation and arrest. The R-curve showed that 459 nm of crack growth increased fracture toughness by 1.4 MPa $m^{1/2}$, approximately one grain size. The calculated maximum crack-bridging stress reached 1.8 GPa and increased more rapidly with crack extension than previously reported.

(Poster020-2026) Three-dimensional continuum damage-based constitutive model for C/C–SiC composites fabricated via liquid silicon infiltration

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A three-dimensional, nonlinear constitutive model was formulated to characterize the mechanical response of carbon/carbon–silicon carbide (C/C–SiC) ceramic-matrix composites fabricated via liquid-silicon infiltration using carbon fabrics. The model is based on a continuum damage mechanics framework suitable for integration into a finite-element solver. The model aims to capture inelastic strain accumulation and the progressive change in elastic properties due to damage development. Furthermore, the 3D formulation accounts for the coupling of damage mechanisms across different loading modes including cyclic tension-compression and crack closure. The constitutive formulation was implemented as a user-defined material subroutine (UMAT) within the Simulia-Abaqus finite element software. The material parameters were calibrated using three representative experimental datasets. Subsequently, the calibrated model was employed to simulate a series of uniaxial tensile and Iosipescu shear tests across various off-axis orientations and prepreg stacking sequences, thereby providing comprehensive validation of the proposed model.

(Poster021-2026) In-situ high-temperature fracture behavior of polymer-derived SiC fibers under thermal shock in air

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Silicon carbide (SiC) fibers are widely used as reinforcements for ceramic matrix composites (CMCs) in aerospace applications owing to their high tensile strength at elevated temperatures. However, conventional high-temperature tensile evaluations are typically performed at room temperature after thermal exposure, which does not adequately represent extreme environments. In this study, an in-situ high-temperature tensile measurement method was employed to investigate the fracture behavior of polycrystalline SiC fibers under rapid thermal shock in air. Tensile strength was measured during direct exposure to thermal shocks at 1273~1773 K, with exposure times up to 120 min. The tensile strength of SiC single-filament decreased immediately from 3.0 GPa to 1.5 GPa after thermal shock at 1773 K, respectively, and further declined to 0.87 GPa after 120 min at 1773 K. Also, in-situ stress–strain curves exhibited a three-stage response consisting of thermal expansion, elastic deformation, and ductile deformation. Microstructural analyses confirmed the retention of β-SiC crystallinity up to 1773 K, while oxidation and residual carbon-induced defects promoted ductile fracture. These results demonstrate that in-situ high-temperature tensile testing more accurately simulates extreme environments and provides critical insights for the design of advanced SiC fibers for HT-CMC applications.

(Poster022-2026) Development of reaction bonded alumina short fiber reinforced oxide ceramic matrix composites based on an injection molding process

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Ceramic oxide fiber-reinforced oxide matrix composites (OCMCs) offer exceptional temperature stability, corrosion resistance, and a degree of quasi-ductility compared to monolithic ceramics. However, their broader application is still limited by inherent brittleness and uncontrolled sintering shrinkage. While monolithic ceramics typically exhibit isotropic yet substantial dimensional changes during sintering, OCMCs show anisotropic shrinkage and often require complex post-processing steps. Ceramic injection molding (CIM) can be adapted for OCMC fabrication, providing a simple and cost-effective route for large-scale production. To mitigate sintering shrinkage, the reaction-bonded alumina oxidation (RBAO) process can be utilized. During this process, the volumetric expansion associated with aluminum oxidation compensates for shrinkage occurring during sintering. This paper describes the manufacturing of OCMC materials by incorporating various aluminum-containing additives into the CIM process, followed by thermal treatment (debinding and sintering). In addition to analyzing shrinkage behavior, microstructural characterization and mechanical testing were performed. The results demonstrate that the RBAO process can substantially reduce shrinkage and, when combined with CIM, enables near-net-shape manufacturing suitable for high-volume production.

(Poster023-2026) New alumina matrix for high performance oxide CMC

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The matrix part in oxide CMC typically represents 50 to 60 vol% of the total CMC and the matrix porosity ranges from 20 to 40 vol%. Based on that, we can estimate that alumina matrix is 40 to 50wt% of the oxide CMC. As the whole (aeronautic) industry is trying to reduce its direct and indirect carbon emissions it seems essential to engage raw materials with minimal environmental impacts, to decrease temperature for oxide CMC manufacturing and to enhance composites performances et lifetime. This work focuses on the role played by alumina powders to adjust the matrix formulation in order to better control low temperature densification, leading to homogeneous pore size distribution. Oxide CMC are typically designed to operate at temperature between 700 and 1000°C for extended periods. It is also well known that oxide fibers mechanical performances decrease rapidly when they are exposed to temperatures greater than 1200C for extended periods. It is therefore essential to maintain the sintering temperature as low as possible and to limit exposure above 1200°C to a minimum. In addition, dopants such as MgO and ZrO_2 can also be added to further limit grain growth for both the matrix and the fibers and therefore increase composite mechanical strength and creep resistance.

(Poster024-2026) Textured ZrB_2 ceramics self-reinforced by aligned elongated grains via strong magnetic field alignment

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Zirconium diboride (ZrB_2) is widely considered as a promising ultra-high-temperature ceramic owing to a unique combination of high melting point (>3000 °C), relative low density and good strength, making it suitable for thermal protection systems in aerospace. However, its poor fracture toughness and poor sinterability limit practical applications. Considering the recent studies reporting the enhancement of fracture behaviour in ceramics by anisotropic reinforcement, this work designs using rod like ZrB_2 grains as self- reinforcement. Their alignment among ceramic was achieved through strong magnetic field alignment (SMFA) followed by spark plasma sintering. Refined ZrB_2 powders were employed as the matrix, and 0.1 vol% carbon nanotubes (CNTs) were introduced to promote densification at 1720 °C and helped maintain the elongated grain morphology during sintering. The obtained ceramics displayed distinct grain alignment and pronounced anisotropic fracture toughness, reaching 5.7 MPa $m^{1/2}$ perpendicular to the rod axis due to crack deflection. The addition and alignment of elongated grains also contributed to a high flexural strength of 789.5 MPa. This study provides a feasible approach to fabricating self-reinforced textured ZrB_2 ceramics with anisotropic fracture toughness via magnetic-field-assisted grain orientation.

(Poster025-2026) Ultra-high temperature (UHT) processing of refractory metal borides and carbides at 2500°C

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Ultra-high temperature ceramics are used for the leading edge of hypersonic vehicles, engines and turbines which experience temperatures exceeding 2000°C. A liquid Hf-Nb-Ti-Ta alloy was infiltrated into a B_4C/C packed bed at 2500°C to investigate the phase equilibria and form a boride-carbide composite. A low oxygen partial pressure (< 10^{-32} atm) was maintained by using a pseudo-isopiestic technique with low-temperature region (~1000°C) containing a Y-Al/Y_2O_3-Al_2O_3/carbide mixture to prevent the formation of oxides at 2500°C. Microstructural and phase formation acquired by SEM/EDS and XRD are discussed with thermodynamic calculation toward the formation of Hf-Nb-Ti-Ta diborides and monocarbides at 2500°C.

(Poster026-2026) Ablation behavior of ZrB_2-SiC composites: Evaluation of bulk and joined materials

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This research presents an integrated study on the ablation characteristics and joining performance of $ZrB_{2}-SiC$ based ultra-high temperature ceramics for extreme thermal environments. The high-temperature stability of $ZrB_{2}-SiC$ sintered bodies was first evaluated using a kerosene-oxygen flame test. Results indicated that a dense ZrO_{2}-based oxide scale formed at temperatures above 2500°C serves as an effective protective barrier, suppressing oxygen diffusion and protecting the bulk material. To enable the fabrication of large-scale and complex-shaped components, five distinct joining processes—Reactive Brazing, Liquid-Phase Sintering Bonding, Solid-State Sintering Bonding, Direct Diffusion Bonding, and Reactive Sintering Bonding—were investigated. The joined assemblies were subjected to the same flame conditions to evaluate their interfacial stability and resistance to thermal shock-induced cracking. By correlating the base material's ablation resistance with the performance of various joining configurations, this study aims to identify the optimal mechanism for ensuring structural integrity under severe conditions. These findings offer a critical technical foundation for high-reliability thermal protection systems by establishing an ablation database and optimizing joining processes for next-generation aerospace applications.

(Poster027-2026) In-SEM single-fiber-push-out tests of ceramic matrix composites – Fiber-matrix-bonding distribution within a whole fiber bundle

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Within the most studies a single or few fibers were characterized, when it comes to determine the fiber matrix bonding (FMB) by push-out tests. The reason for that drawback is the high sophisticated preparation. Only small parts of a sample resp. a bundle can be prepared, and it is doubtful, whether the obtained values are representative for the composite. To overcome this challenge, we introduce an alternative sample preparation, that allows to measure the FMB of every fiber within one fiber bundle and the over the whole cross section of a 10 x 3 mm^2 and 100 μm thin sample. The presented poster shows the details of the in-SEM nanoindentation test bench based on a Bruker Hysitron PI 89 SEM PicoIndenter which was used, to test C/C-SiC manufactured by the Liquid Silicon Infiltration technique. The material is based on a CFRP with a phenolic matrix and HT-fibers (3k, HTA-Tenax, Teijin Co.) with UD-fiber reinforcement. After the pyrolysis > 1000 °C the C/C-samples were infiltrated with liquid silicon > 1420 °C under vacuum. The results from the push-out tests show whether the FMB is changing from CFRP over C/C to the C/C-SiC state. Furthermore, the FMB-distribution within a single bundle will be studied for the first time. The impact on the fracture toughness and mechanical behavior of the composites is discussed.

(Poster028-2026) Accessing the high-temperature thermophysical and mechanical properties of C/C-SiC materials with varying fiber volume contents up to 1350 °C

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This study aims at revealing the interdependence between the material composition, the microstructure, the anisotropic high-temperature thermophysical and the high-temperature mechanical properties of carbon fiber reinforced silicon carbide (C/C-SiC). 2D reinforced composites with varying fiber volume fractions (35, 45, 55%) were manufactured via the liquid silicon infiltration process and investigated using light microscopy, SEM, XRD, dilatometry, DSC (c_p), LFA (λ), 3 and 4-point bending tests, tensile tests, compression tests and the determination of the interlaminar shear strength. The study presents a near complete dataset of the thermophysical and mechanical properties up to temperatures of 1350 °C. Clear correlations between the fiber volume content, the phase composition and the resulting thermophysical as well as mechanical properties were found. The young's modulus in bending and tensile tests is directly connected to the fiber volume fraction of the samples and can easily be modelled. The bending strength as well as the tensile strength are only partially proportional to the fiber volume content. Surprisingly, the compressive strength is barely dependent on the fiber volume fraction and fiber orientation and can be considered an isotropic property of C/C-SiC. This underlines the complexity of structure property relations for CMC.

(Poster029-2026) Diffusion-Induced grain boundary migration during sintering of a Gd_2O_3–ZrO_2 composite for burnable absorber application in small modular reactors

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Small modular reactors (SMRs) have attracted much attention as next-generation nuclear power reactors, owing to their high stability based on passive systems and low power output. Among these, light-water SMRs have been studied worldwide because of their significant compatibility with current nuclear reactor systems. To realize their full potential, a high-performance burnable absorber is one of the critical elements for boron-free operated SMRs—to control reactor reactivity. Gd_2O_3, known for its excellent neutron absorption capability. However, Gd_2O_3 must be stabilized at high density, which requires enhanced densification during sintering. In this study, we selected a 20 mol% Gd_2O_3–80 mol% ZrO_2 composite as a promising composition for attaining higher density, and then analyzed grain-growth behaviours over the temperature range of 1400 °C to 1600 °C for up to 8 h. As a result, a high relative density up to 96.6% TD. Meanwhile, the grain boundaries appeared with abnormally curved shapes, a typical characteristic of diffusion-induced grain-boundary migration (DIGM). Considering that grain-growth was accompanied by DIGM, it is essential to understand and control the DIGM phenomenon beneficially in the Gd_2O_3–ZrO_2 composite. This study provides experimental evidence of DIGM and a possible way of controlling it.

(Poster030-2026) Irradiation test of neutron absorber pellets for control rod of light water reactors

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This paper presents the post-irradiation examination (PIE) results of novel oxide-based neutron absorber pellets irradiated in the HANARO research reactor. These advanced materials were developed to extend control rod lifetime and enhance safety by minimizing irradiation swelling, gas generation, and low-melting-point eutectic phase formation, all while maintaining neutron absorption capability. The irradiation campaign comprised sixteen absorber rods, including fourteen Eu- and Dy-oxide variants and two commercial B_4C reference rods, which were irradiated for 241.2 effective full-power days (EFPDs). Following discharge and transfer to the Irradiated Material Examination Facility (IMEF), the specimens underwent non-destructive X-ray imaging, followed by dimensional and density measurements and optical microscopy. Dimensional analysis indicated excellent stability for most candidate pellets, with volumetric swelling remaining below 1%. Microstructural observations confirmed that the compositional homogeneity of the as-fabricated pellets significantly influenced post-irradiation evolution. Ultimately, the Dy-Zr-O compositions demonstrated the most favorable irradiation performance, characterized by minimal swelling and the maintenance of sound microstructural integrity.

(Poster031-2026) Synthesis and photocatalytic activity of TiO_2 nanoparticles for the degradation of the drug N-(4-hydroxyphenyl)ethanamide (paracetamol)

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Titanium dioxide (TiO_2) is widely recognized as one of the most efficient semiconductors used in heterogeneous photocatalysis due to its stability, low cost, and strong activity under UV radiation. In Brazil, however, commercial TiO_2 is mostly imported, which increases costs and restricts broader application. This study aimed to develop a direct inorganic route for synthesizing TiO_2 nanoparticles without prolonged thermal treatment, focusing on their use in the photocatalytic degradation of the pharmaceutical Paracetamol. The synthesis was carried out through controlled precipitation using $TiOSO_4$ and NH_4OH, with variations in precursor ratios, addition sequence, dripping times, and reaction solvents. The obtained materials were characterized by XRD, FTIR, BET/BJH, SEM/EDS, EPR, DRS, Raman spectroscopy, HPLC, and MS. The results confirmed the formation of anatase-phase TiO_2 with properties suitable for photocatalysis. Sample M1C15 showed the best performance, presenting a surface area higher than commercial P25 and achieving 80% Paracetamol degradation under UV irradiation in 180 minutes. Under visible light, it reached 18.2% removal, demonstrating photocatalytic activity beyond the UV range. Therefore, the proposed synthesis route is viable, low-cost, and promising for treating water contaminated with pharmaceutical residues.

(Poster032-2026) Thermal analyses of zeolite/polylactide filaments for additive manufacturing of the flowing islands

M. T. Sitarz*[1]; J. Marchewka[2]

1. AGH University of Science and Technology, Faculty of Materials Science and Ceramics, Poland
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Floating islands are passive systems used to adsorb pollutants from water reservoirs. Their chemical composition must ensure their durability during operation and maximize the efficiency of the adsorption processes. The 3D geometry of the islands must enable them to float on water while providing a sufficiently large specific surface area. Additive manufacturing technologies, such as fused deposition modelling (FDM), are ideal for fabricating these components, as they enable the obtaining of complex 3D structures that precisely replicate pre-designed virtual models. Selecting appropriate process parameters in additive manufacturing is crucial to achieve the desired quality of 3D structures such as floating islands. Since FDM utilizes thermoplastic polymer-based materials, the key task of the project was to determine the appropriate thermal processing parameters. These were selected based on results from thermal analysis (STA 449 F3 Jupiter analyzer, Netzsch, Germany). Moreover, high-temperature processing of materials can induce structural changes, particularly polymers degradation. Therefore, emphasis was placed on structural investigations using FT-IR spectroscopy (Vertex 70v spectrometer, Bruker, USA). This research was funded by the National Science Centre, Poland, grant no. 2024/55/B/ST10/02896.

(Poster033-2026) The development status of SiC heating elements in Korea

Y. Seong*[1]; I. Han[1]; D. Seo[1]; H. Hwang[1]; S. Lee[1]; S. Kim[1]; S. Kim[1]; H. Bang[1]

1. Korea Institute of Energy Research, Republic of Korea

The urgent demand to reduce greenhouse gas emissions necessitates a transition to electrification processes or the use of zero-carbon fuels as substitutes for fossil fuels. Especially for achieving carbon neutrality in key energy-intensive industries such as the steel and petrochemical sectors, it is essential to shift from combustion-based heating methods using hydrocarbon fuels to renewable energy-based electric heating methods, alongside increasing the availability of renewable energy. Silicon carbide (SiC) resistance heating elements, offering long-term durability at a maximum heating temperature of 1600°C, are currently widely used in Korea, both for laboratory and industrial electric furnaces. However, there are no research cases on SiC heating element development in Korea, and no production companies domestically. Consequently, Korea relies entirely on imported products mainly from abroad (Sweden, Japan, China, India, etc.). Therefore, the development of domestic SiC heating element technology in Korea is imperative. This study aims to first compare and analyze the status and characteristics of SiC heating elements, followed by introducing the process of domestic SiC heating element development in Korea.

(Poster035-2026) Dielectric and magnetic properties of the FE-$Y_2DyFe_5O_{12}$ ceramic composites

D. Brzezinska*[1]; D. Bochenek[1]; M. Zubko[1]; A. Chrobak[1]

1. University of Silesia in Katowice, Faculty of Science and Technology, Institute of Materials Engineering, Poland

The work presents the technology and microstructural, structural, dielectric, and magnetic properties of the FE-YDF ceramic composites. In the ceramic composites, the matrix was a ferroelectric (FE) material (90%), while the magnetic phase was $Tb_{0.3}Dy_{0.7}Fe_2O_{4.5}$ (10%). Three compositions of ceramic composites were obtained with the following chemical compositions: (i) 0.9 ($Pb(Zr_{0.51}Ti_{0.49})O_3$+0.2%at.$Bi_2O_3$+0.03%at.$Nb_2O_5$+0.06%at.$MnO_2$) – 0.1 ($Y_2DyFe_5O_{12}$) (PZT1-YDF), (ii) 0.9 ($Pb_{0.90}Ba_{0.10}(Zr_{0.53}Ti_{0.47})O_3$+2%at.$Nb_2O_5$) – 0.1 ($Y_2DyFe_5O_{12}$) (PZT2-YDF), (iii) 0.9 ($BaTiO_3$) – 0.1 ($Y_2DyFe_5O_{12}$) (BT-YDF). In the microstructure of FE-YDF composites, the magnetic grains of the YDF material are surrounded by grains of the ferroelectric matrix component and are randomly distributed within the matrix. BT-YDF ceramic composite exhibits intermediate permittivity values. In contrast, the PZT1-YDF and PZT2-YDF compositions exhibit higher permittivity values at the phase transition. Dielectric loss values are also higher than those of the BT-YDF composite, at RT 0.084, and 0.127, respectively. The magnetic properties of the FE-YDF ceramic composites are typical for ferroelectro-ferromagnetic composite materials. The research demonstrated that the FE-YDF ceramic composite exhibits excellent dielectric and magnetic properties, making it suitable for micromechatronic applications.

(Poster036-2026) Fabrication and mid-infrared optical properties of transparent Er:Sc_2O_3 ceramics

Z. Xu[2,1]; H. Furuse*[1]; T. S. Suzuki[1,2]

1. National Institute for Materials Science (NIMS), Japan
2. Waseda Daigaku, Japan

In this study, we report on Er^{3+} doped Sc_2O_3 sesquioxide transparent ceramics for mid infrared laser materials. The homogeneous powders with different Er doping concentrations of 1, 5, and 10 at.% were synthesized using a co-precipitation method. And the as-synthesized powders were densified at 1450 °C under uniaxial pressure via spark plasma sintering (SPS) technology. As a result, the powders and ceramics have a cubic structure without any secondary phases. Meanwhile, the Er:Sc_2O_3 ceramics exhibit high in-line transmittance of 80% at the wavelength of 2.8 μm which coincides with the emission of Er^{3+} ion due to $^4I_{11/2} \rightarrow {}^4I_{13/2}$ electron transition. Microstructure analysis reveals that the densely packed fine grains with diameters below 300 nm effectively suppress the formation of residual pores. We believe that the heavy doping Er:Sc_2O_3 ceramics with high optical quality have the potential for effective laser materials in the mid-infrared region.

(Poster037-2026) Influence of rare-earth elements on the functional properties of BZT–BCT ceramics

J. Makowska*[1]; M. Adamczyk-Habrajska[1]; B. Wodecka-Dus[1]

1. Uniwersytet Slaski w Katowicach, Poland

The study investigates the effect of rare-earth elements on the structural and functional characteristics of $Ba(Zr_{0.2}Ti_{0.8})O_3$ - $Ba_{0.7}Ca_{0.3}TiO_3$ (BZT–BCT) ceramics. Microstructural features were analyzed using scanning electron microscopy, allowing assessment of grain development, size variability, and structural homogeneity resulting from the introduced modifiers. X-ray diffraction analysis was employed to examine the crystal structure and assess the impact of rare-earth addition on the phase composition of the ceramics. The dielectric response of the ceramics was characterized through measurements of dielectric permittivity and loss factor across broad temperature and frequency intervals. The obtained results indicate that

the presence of rare-earth ions leads to significant changes in both microstructure and dielectric behavior, contributing to improved stability and lowered dielectric losses. Overall, the study highlights rare-earth modification as an effective strategy for adjusting the functional performance of BZT–BCT ceramics intended for dielectric and electromechanical applications.

(Poster038-2026) Technology and properties of multi-component multiferroic ceramic composites PMN-PT-PS-Ferrite

D. Bochenek*[1]; D. Brzezinska[1]; M. Zubko[1]; A. Chrobak[1]

1. University of Silesia in Katowice, Faculty of Science and Technology, Institute of Materials Engineering, Poland

The paper presents the technology of multi-component multiferroic composites (PPP-F) sintered by the free (pressureless) sintering method (1100 °C/8 h) and their structural, microstructural, dielectric, ferroelectric, and magnetic properties. In the ceramic composites, the matrix was the ferroelectric phase, comprising 90% of the material, while the magnetic phase was nickel-zinc ferrite (F), accounting for 10%. The ferroelectric component was (1-y)((1-x) $Pb(Mg_{1/3}Nb_{2/3})O_3$–$xPbTiO_3$)–$yPbSnO_3$ (x from 0.25 to 0.4, y = 0.1), while the magnetic one was $Ni_{0.64}Zn_{0.36}Fe_2O_4$. In the microstructure of PPP-F composite samples, larger grains of the ferroelectric component surround smaller grains of the magnetic component, which are randomly distributed in the matrix. The dielectric study of the PPP-F composite samples showed high permittivity values, small dielectric loss values and preservation of the ferroelectric properties. The magnetic properties are typical for ferroelectro-ferromagnetic composite materials, characterized by narrow magnetic hysteresis loops. The dielectric measurements indicated that the magnetic subsystem influences the dielectric properties of the composite materials. The presented research showed that the PPP-F ceramic composite has good dielectric, magnetic, and ferroelectric properties, which predisposes this type of material to specific applications in microelectronics.

(Poster039-2026) Synthesis, microstructural evolution and dielectric properties of BLT ceramics modified with a special glass admixture

B. Wodecka-Dus*[1]; J. Makowska[1]; M. Adamczyk-Habrajska[1]

1. Uniwersytet Slaski w Katowicach, Faculty of Science and Technology, Poland

Ceramic materials with a tetragonal perovskite structure of Ba1-xLaxTi1-x/4O3 (x = 0.004) were synthesized via a conventional solid-state reaction from simple oxide precursors. To control densification and grain growth, a lead–borosilicate special glass was introduced into the BLT matrix, resulting in materials with a homogeneous and well-developed microstructure. Simultaneous thermal analysis was performed to examine the thermal behaviour of the powder precursors. The phase composition and crystal structure of the sintered ceramics were analysed by X-ray diffraction, while SEM and EDS techniques were used to characterize the microstructure and confirm the elemental stoichiometry. The addition of glass significantly modified the dielectric response, causing a reduction in dielectric permittivity and an enhancement of frequency dispersion. Temperature-dependent dielectric measurements revealed a first-order ferroelectric–paraelectric phase transition, analogous to that observed in pure BLT ceramics. The transition temperature exhibited a slight upward shift with increasing glass content, indicating subtle changes in phase stability. These results demonstrate that controlled glass modification provides an effective route for tailoring the microstructure and functional dielectric properties of lanthanum-doped barium titanate electroceramics.

(Poster040-2026) Interfacial control for accelerating charge transfer in secondary batteries

T. Teranishi*[1,2]; A. Kishimoto[1]

1. Okayama University, Japan
2. Insitute of Science Tokyo, Japan

Interfaces govern the rate performance of both liquid- and solid-electrolyte batteries. In liquid-electrolyte lithium-ion batteries, Li adsorption, desolvation, and subsequent charge transfer at the cathode surface constrain high-rate operation. We previously showed that insulating dielectric layers with optimized permittivity or surface charge state enhance these steps by lowering the activation energy for Li adsorption, as supported by DFT-based molecular dynamics and nanoscale force measurements. In oxide-based all-solid-state batteries, performance instead suffers from resistive interphases formed during co-sintering. We addressed this by applying nonequilibrium 24 GHz millimeter-wave irradiation to engineer solid–solid interfaces. The high-frequency field drives ion-selective migration via the ponderomotive force, suppressing specific cation diffusion that leads to interphase formation. This process both prevents interfacial reactions and improves electrolyte densification, resulting in markedly reduced interfacial resistance and enhanced electrochemical performance.

(Poster041-2026) Effect of E-Glass Powder Addition on Characteristics of Blast Furnace Slag-Based Glass Marbles

J. Lee*[1]

1. Korea Institute of Ceramic Engineering and Technology (KICET), Republic of Korea

This study investigates the vitrification of blast furnace slag (BFS) by adjusting the content of steel slag and the added amount of E-glass. SaEb glasses were prepared with a composition of x wt% BFS and (100-x) wt% E-glass (x = 10, 20, 30, 40, and 50). Each composition was melted in a platinum crucible under atmospheric conditions at 1,500 °C for 2 h, and transparent glasses with a transmittance exceeding 75 % were fabricated. All SaEb glasses exhibit an amorphous pattern, indicating successful vitrification. We also analyzed their optical, thermal, and physical properties, including Fourier transform infrared spectroscopy (FT-IR), glass transition temperature (Tg), and x-ray pattern. As the E-glass content increased, the glass transition temperature of blast furnace slag-based glass decreased from 765 °C to 734 °C due to the weakening of the SiO4 unit structure. In all compositions, the glass transition–crystallization temperature difference exceeded 220 °C, confirming the glasses stability for slag fiber applications. The blast furnace slag-based glass exhibits potential for application in slag fiber production, and is expected to provide fundamental data for future studies on related materials.

(Poster042-2026) Chemical robustness of aqueous quasi-solid-electrolyte (3D-SLISE) and their batteries

Y. Shiratori*[1]; S. Yasui[1]

1. Tokyo Kagaku Daigaku, Japan

We developed a borate-based aqueous quasi-solid electrolyte (3D-SLISE). Lithium salt insertion within the slime-like reaction layer formed at the borate interface enables three-dimensional expansion of the Li+ conduction pathway. 3D-SLISE can be prepared under ambient conditions and, being water-soluble, is suitable for direct recovery of active materials. The quasi-solid-state battery (QSSB) using 3D-SLISE exhibits a cycle life exceeding 2,000 cycles at a stack pressure of 30 MPa, 27 °C, 3C rate under cathode-excess conditions, however only 70 cycles at a 1:1 cathode-to-anode capacity ratio and 0.2C rate. We report the physicochemical properties of 3D-SLISE, the decomposition mechanism of QSSB, and the current status and countermeasures for upcycling cathode active materials.

Wednesday, June 3, 2026

GFMAT-3 Symposium 1- Powder Processing Innovation and Technologies for Advanced Materials and Sustainable Development

GFMATS1- Low-cost and energy-saving processing of advanced ceramics and ceramic composites, including smart recycling of materials for sustainable development

Room: Shorebreak 2
Session Chairs: Takamasa Mori, Hosei Daigaku Seimei Kagakubu; Wenwu Xu, San Diego State University

8:40 AM

(GFMAT-S1-017-2026) Development of functional materials using interfacial reaction fields by powder technology (Invited)

T. Shirai*[1]

1. Nagoya Kogyo Daigaku, Advanced Ceramics Research Center, Japan

We are focusing on the development of new ceramic processes by local reaction field control using microwave (MW) heating and mechanochemical (MC) effects based on particle surface characterization and nanoscale particle surface design. In particular, in recent years, we have developed new oxidation catalysts using heat-induced radical formation of apatite hydroxyl acid (HAp), cement substitute materials using MC treatment technology, and visible light application catalysts and functional optical materials by MW heating to circulate resources and energy and use energy with high efficiency. It is promoting a series of research and development leading to the synthesis and application of functional materials that contribute to the SDGs, such as new energy creation technologies. In this lecture, we will introduce research cases related to the development of functional materials using surfaces as reaction fields, and discuss the future of ceramics / powder processes and manufacturing.

9:10 AM

(GFMAT-S1-018-2026) Reaction sintering synthesis of tungsten tetraboride at relevant scale via electric field assisted sintering

A. Preston*[1]; J. Rufner[2]

1. Idaho National Laboratory, USA
2. Idaho National Lab, Materials Science and Manufacturing, USA

Tungsten tetraboride (WB4) is a novel material which has been of interest for its extremely high hardness, which has been demonstrated to be over 40 GPa (Vickers) in laboratory scale samples. Relevant scale synthesis has proven challenging, however, and this material has not transitioned to widespread use in real-world applications. The Idaho National Laboratory is developing a novel method of solid-state reaction sintering of tungsten and boron powders, which enables fine control of the process, and will enable large scale articles to be produced. The current work covers the reaction sintering investigation, and the resultant material properties. Preliminary results regarding nanoparticle doping mechanisms (to further increase hardness) will be covered, along with a novel method of intimately joining this material to more common structural materials.

GFMATS1- Particle dispersion control in liquid or polymers

Room: Shorebreak 2
Session Chairs: Koji Morita, National Institute for Materials Science (NIMS); Arin Preston, Idaho National Laboratory

9:30 AM

(GFMAT-S1-019-2026) Dispersion of conductive nanomaterials in structural adhesives for easy disassembly using high-voltage electrical pulses (Invited)

H. Kamiya*[2,1]; M. Inutsuka[2]; K. Matsuo[3]; Y. Okada[4]; S. Yamashita[4,5]; M. Kubo[6]; T. Saito[6]; C. Tokoro[2]

1. Tokyo University of Agriculture and Technology, Institute of Engineering, Japan
2. Waseda University, Japan
3. Waseda Daigaku Riko Gakujutsuin, Japan
4. Institute of Agriculture, Japan
5. Tokyo Noko Daigaku, Japan
6. Tohoku Daigaku, Japan

Large structures, such as automobiles, consist of multi-material systems including metals and carbon fiber reinforced plastics (CFRP) bonded with high-strength adhesives. However, such robust bonding often hinders dismantling and resource circulation. While we previously reported that disassembly can be achieved via high-voltage electrical pulses by dispersing conductive nanomaterials within the adhesive, the effects of base material types and nanomaterial-specific aggregation on disassembly behavior have not yet been fully understood. This study investigates the influence of the dispersion behavior and characteristics of nanomaterials in epoxy resin adhesives on high-voltage pulse disassembly, employing silver nanoparticles with distinct synthesis processes and surface modifications. By comparing these with commercial silver nanoparticles of different sizes and carbon black with varying specific surface areas we aimed to elucidate how aggregation states and interfacial structures affect internal discharge characteristics and dismantlability. Specifically, we evaluated the effects of conductive nanomaterial dispersion within the adhesive through a combination of experimental analysis and multi-scale simulations.

10:20 AM

(GFMAT-S1-020-2026) Do slurries decide density?— Flow or packing: What really controls it? — (Invited)

T. Mori*[1]

1. Hosei Daigaku Seimei Kagakubu, Japan

Many devices that support modern society, such as multilayer ceramic capacitors and lithium-ion battery electrodes, are produced by wet-forming using slurries. To control product properties, it is essential to design and manage slurry characteristics, which requires appropriate evaluation. Density is a key property of wet-formed bodies. Better particle dispersion generally leads to higher density, and various methods have been used to evaluate slurry dispersion. Because slurries typically have high solid loadings, techniques such as particle size distribution after dilution, as well as rheology and sedimentation tests that directly assess concentrated slurries, are commonly applied. We have studied correlations between slurry evaluation results—mainly for aqueous slurries—and the density of bodies formed by tape casting and slip casting. We found that, in tape casting, the deposition packing ratio from sedimentation tests correlates best with green sheet density, while in slip casting, the cake packing ratio from constant-pressure filtration shows the strongest correlation. These findings indicate that, as particle concentration increases during wet forming, it is necessary to evaluate not only the initial dispersion state but also how it evolves with concentration or forming time. In this presentation, we discuss the key slurry evaluation indicators for controlling the density of wet-formed bodies.

10:50 AM

(GFMAT-S1-021-2026) Structural and physical property evaluation of multi-component slurries for sheet-forming processes

K. Kitamura*[1,2]; T. Mori[3,2]

1. Hosei Daigaku, Chemical Science and Technology, Japan
2. Hosei Daigaku, Hosei University Research Institute for Slurry Engineering, Japan
3. Hosei Daigaku Seimei Kagakubu, Japan

The performance demands of modern devices have increased the use of multi-component slurries containing diverse particles and additives. Because particles differ in size and surface properties and interact with binders and dispersants, evaluating dispersion is difficult, especially at high solid concentrations where viscosity or sedimentation alone cannot represent the true dispersion state. This study examines anode, cathode, and all-solid-state battery slurries to clarify how dispersion governs forming behavior and final properties. In graphite anode slurries, the mixing sequence of CMC and SBR alters particle adsorption, affecting dispersion, viscosity, sediment packing, and electrode resistivity. In cathode slurries, conductive-additive networks govern flow and sedimentation; combined rheology and hydrostatic sedimentation quantify network strength, with normalized sedimentation time serving as a practical evaluation indicator. For all-solid-state battery cathodes, dispersion and particle-network formation depend on concentration. Relative viscosity, yield stress, and sheet-formed structures show that good rheology does not ensure dense packing, requiring an optimal balance between dispersion and networking. Overall, multi-component slurry evaluation demands an integrated, multi-technique approach.

11:10 AM

(GFMAT-S1-022-2026) Hollow silica nanoparticle-polymer composite films and their thermal insulation properties

K. Ishii*[1]; Y. Yoshida[1]; R. Ichihara[1]; M. Fuji[1]

1. Nagoya Institute of Technology, Japan

Hollow silica nanoparticles (HSNPs) have a core-shell structure consisting of a void core and a silica shell. Due to their unique structure, HSNPs have various characteristics. By using HSNPs as fillers in composite materials, the properties can be imparted or improved to the matrix. In the template hollow particle synthesis method, template particles for forming the hollow core are dispersed, the dispersed particles are coated with silica for the shell, and then the template particles are removed. When emulsion droplets are applied to template particles, the core template components can be removed simply by washing with water. Furthermore, by encapsulating a dispersant within the droplets, it is possible to synthesize highly dispersible hollow particles. In this study, HSNPs were synthesized using a polyacrylic acid-ammonium solution emulsion system; composite membranes were prepared with cellulose nanofibers, and the thermal insulation properties of the composite materials were evaluated.

GFMAT-3 Symposium 6- Advanced Batteries and Supercapacitors for Energy Storage Applications

GFMATS6- All-solid-state Batteries I

Room: Tidepool 1

Session Chairs: Saneyuki Ohno, Kyushu Daigaku; Kentaro Yamamoto, Nara Women's University

8:30 AM

(GFMAT-S6-017-2026) NASICON-based materials: A wonderful "crystal-chemistry" playground (Invited)

J. Chotard*[3]; N. Subash[3]; P. Cabelguen[1]; F. Fauth[2]; C. Masquelier[3]

1. Umicore, Belgium
2. CELLS-ALBA Synchrotron, Spain
3. Laboratoire Reactivite et Chimie des Solides, France

NaSiCon-based materials have a regain interest in the last decade. Originally known for their high ionic conductivity, their chemical versatility allows them to be used as electrode materials as well as as coating materials for different battery technologies (Li-ion, Na-ion, multivalent-ions and all-solid-state batteries). Indeed, the NaSICon crystal structure allows a wide range of chemical substitutions. Among them, the vanadium phosphate $Na_3V_2(PO_4)_3$ is of particular interest because of its fantastic rate capacity and thermal stability, with a theoretical capacity of 117.6 mAh/g and an energy density of 396 Wh/kg and can be used both as an anode or a cathode. They have also proven to be among the best solid electrolyte material for sodium All-Solid-State-Batteries (ASSBs). As an example, $Na_{3.4}Zr_2Si_{2.4}P_{0.6}O_{12}$ attains ionic conductivity as high as 10 mS/cm with 3D diffusion path. Because of those electrochemical properties, their chemical stability and compatibility, NASICON-type are perfectly matching for building ASSBs. On the anode side, Ti and Nb based NaSICon materials, allow to play with several redox couples from Nb +V to +III as well as Ti +IV to +III with really interesting charge and discharge mechanisms investigated via XRD Operando measurements. I will discuss the diversity of the crystal chemistry of the NASICON materials mostly studied through operando X-Ray Diffraction as well as its use in ASSBs.

9:00 AM

(GFMAT-S6-018-2026) Comprehensive safety evaluation of solid-state batteries compared to lithium-ion (Invited)

N. B. Johnson*[1]

1. Sandia National Laboratories, Power Sources R&D, USA

Ceramic solid-state batteries represent a promising technology for next-generation energy storage, promising high energy density through lithium metal anodes and enhanced safety by replacing flammable liquid electrolytes with non-combustible solids. Yet, safety in this emerging field has often been assumed rather than rigorously examined, as electrolyte flammability is only one aspect of the broader issue of battery safety. Critical hazards—including explosion, deflagration, reignition, toxic gas release, ejecta, and metal fires—remain largely unexplored for solid-state systems. In this presentation, we adopt a holistic perspective to evaluate the safety of ceramic solid-state batteries beyond electrolyte flammability. We identify potential failure mechanisms, compare them with conventional lithium-ion batteries, and analyze how eliminating liquid electrolytes alters thermochemical pathways and associated risks. Early recognition of these hazards is essential to guide material development, enabling safer cell designs and accelerating the commercialization and public adoption of next-generation battery chemistries.

9:30 AM

(GFMAT-S6-019-2026) Challenges of transport limitations in solid-state Li–S batteries (Invited)

S. Ohno*[1]

1. Tohoku Daigaku, Institute of Multidisciplinary Research for Advanced Materials, Japan

The utilization of sulfur as an earth-abundant and cost-effective material for energy storage has been investigated for more than 60 years. However, it has not yet become commercially viable, mainly due to the dissolution of reaction intermediates into the electrolyte. The recent development of solid-state batteries has brought sulfur-based active materials back into the spotlight, as solids can physically eliminate the dissolution. While solid-state Li-S batteries have the potential to address several issues inherent to traditional Li-ion batteries with liquid electrolytes, the use of solid electrolytes also introduces unique challenges. In particular, the ionically and electronically insulating active materials must be composited with solid electrolytes and electron-conductive additives to ensure sufficient ion and electron supply at the triple-phase boundary. However, this compositing process can make the transport pathways for charge carriers highly tortuous and requires careful optimization to achieve the maximum attainable energy density. Additionally, the need for a high interfacial area density can lead to pronounced degradation of the solid electrolytes, and the formation of less-conductive interphases further decreases the overall transport within the composites. In this talk, we present our recent work on transport analysis and strategies to overcome transport limitations in solid-state Li–S batteries.

10:20 AM

(GFMAT-S6-020-2026) Mechanisms of ion-transport and interfacial stability in argyrodite electrolytes for solid-state lithium batteries (Invited)

B. Narayanan*[1]; V. Shreyas[1]; S. Gupta[1]

1. University of Louisville, Mechanical Engineering, USA

Halogen-doped derivatives of argyrodites have emerged as a lucrative class of electrolytes for solid-state lithium batteries (SSLBs) owing to their high Li-ion conductivity, and good mechanical properties. Nevertheless, they remain far from commercialization owing to poor interfacial stability against Li, and limited routes to improve it without compromising ion transport. Here, we integrate ab initio molecular dynamics (AIMD), and machine learning (ML) to demonstrate how doping argyrodites with dual halogens can simultaneously improve Li-ion conductivity and interfacial stability. Analysis of our AIMD trajectories using graph-based ML methods indicate that dual-doping Li-argyrodites with F and another halogen (e.g., Cl) flattens the energy landscape of Li-ion hops, primarily due to tetrahedral arrangement of Li around F. This, in turn, opens up several 3-D pathways for long-range Li-diffusion, yielding ~50% increase in Li-ion conductivity in $Li_6PS_5F_{0.5}Cl_{0.5}$. Concomitantly, F also improves its stability against Li-anode owing to formation of a stable solid-electrolyte interface containing conductive species (Li_3P), alongside LiCl and LiF, consistent with X-ray photoelectron spectroscopy and electrochemical cycling experiments. These results will be discussed in the context of accelerating design of novel solid-state electrolytes for high-performance SSLBs.

10:50 AM

(GFMAT-S6-021-2026) Interface design for all-solid-state lithium metal batteries operable at room temperature and low pressure (Invited)

W. Zhang*[1]

1. Nanyang Technological University, Electrical and Electronic Engineering, Singapore

All-solid-state lithium metal batteries (ASSLMBs) are a promising platform for high-energy, safe energy storage, yet their practical application is limited by low lithium reversibility, electrode loading, and the need for elevated temperature and pressure during operation. These limitations stem from both the bulk properties of solid-state electrolytes (SSEs) and unstable electrode–electrolyte interfaces. Inorganic SSEs, unlike liquid electrolytes, lack compositional flexibility, making it difficult to design stable interphases. Meanwhile, intrinsic defects and grain boundaries provide pathways for dendrite growth. Here, we present a molecular interface engineering strategy that leverages reductive electrophiles to modify SSE surfaces. These molecules spontaneously form a lithiophobic, electron-insulating interphase, the solid reductive-electrophile interphase (SREI), which suppresses dendrite propagation and stabilizes both the interfaces and bulk. Using this strategy, ASSLMBs exhibit high lithium Coulombic efficiency (≈99.7%), long-term cycling at room temperature (30 °C), and low stack pressure (2.5 MPa) under high loading. The approach establishes a general, composition-independent framework for interface design in solid-state batteries.

11:20 AM

(GFMAT-S6-022-2026) How can glass help us to discover new materials

C. Chenier*[1]; M. Serhane[1]; D. Chartrand[1]; G. Foran[1]; S. Rousselot[1]; M. Dollé[1]

1. Universite de Montreal, Chemistry, Canada

This work explores how glass matrix can help us discover new materials, one example being inside the $Li_2O–B_2O_3–Al_2O_3–GeO_2$ system. Using a glass synthesis-based approach, we focused on achieving a glass matrix to recrystallized and obtain crystalline inclusions. We achieved to identify a new crystalline phase isotype to γ-$LiAlO_2$ with a composition of $Li_{0.7}Al_{0.7}Ge_{0.3}O_2$. Thorough structural characterization and study of ionic conduction mechanism were conducted on $Li_{0.7}Al_{0.7}Ge_{0.3}O_2$ to explore its electrical properties. The activation energy of the ionic conduction of γ-$LiAlO_2$ was previously reported in the range of 0.7–0.9 eV, depending on the measurement method and the disorder present. Our results reveal a significant decrease in activation energy of 0.413 eV, attributed to a change in the ionic conduction pathway, yielding an ionic conductivity of 2.25×10^{-6} S/cm at room temperature. It is likely that glass disordered structure, owing to glass synthesis and resulting from its thermal treatment, could impact the ionic conductivity. Experimental and computational evidence for the formation and properties of this new material is then provided through in situ X-ray diffraction and thermal analysis during crystallization and further supported by single-crystal X-ray diffraction, and simulations of ionic conduction in order to understand the origin such improvement.

GFMAT-3 Symposium 10- Materials Recycling for Energy and Environment Applications

GFMATS10- Disassembly and recycling solutions for end-of-life batteries, fuel cells

Room: Sandpiper C
Session Chairs: Kenta Iyoki, Tokyo Daigaku Daigakuin Shinryoiki Sosei Kagaku Kenkyuka; Asako Narita, Waseda University; Surojit Gupta, University of North Dakota

8:30 AM

(GFMAT-S10-001-2026) Sustainable synthesis of zeolites and their applications (Invited)

K. Iyoki*[1]

1. Tokyo Daigaku Daigakuin Shinryoiki Sosei Kagaku Kenkyuka, Environment Systems, Japan

Zeolites, microporous ceramics, are widely used as catalysts, adsorbents, and ion exchangers. While hydrothermal synthesis is employed for their production, recycling methods for both synthesis feedstocks and the zeolites themselves remain unestablished. This presentation introduces efforts to develop sustainable zeolite synthesis methods aimed at reducing environmental impact. Among zeolite applications gaining attention in recent years are the direct removal of carbon dioxide from the atmosphere (direct air capture) and the development of catalysts to convert captured carbon dioxide into hydrocarbons via combination of CO2 hydrogenation catalysts. For these applications, precise control over the zeolite's microstructure, defects, and atomic arrangement is required. This presentation also covers studies aimed at modification of zeolite properties and applied research contributing to carbon neutrality.

9:00 AM

(GFMAT-S10-002-2026) Separation of lithium-ion batteries from small appliances using high-voltage electrical pulses - aiming for both safety and resource circulation - *WITHDRAWN*

A. Narita*[3]; T. Kirihara[1]; C. Tokoro[3,2]

1. Waseda Daigaku, Graduate School of Creative Science and Engineering, Japan
2. Tokyo Daigaku, Faculty of Engineering, Japan
3. Waseda Daigaku Riko Gakujutsuin, Japan

Lithium-ion batteries (LiBs) embedded in small appliances are difficult to recycle because of the lack of standardization, difficulty of removal, and limited economic feasibility. In addition, fires caused by LiB breakage during mechanical crushing have been increasing, making the application of conventional crushing-based treatment difficult from a safety standpoint. We have previously reported the effective separation of multi-material components using a high-voltage electrical pulsed discharge. This method is applicable to underwater operations, enabling the non-contact application of forces for crushing without relying on metal contact. In this study, we conducted a case analysis of the removal of LiBs from small home appliances and clarified the underlying mechanisms. For a mobile fan commonly used in Japan, the plastic housing rapidly fractured and separated from the embedded LiB by underwater pulsed discharge. Even after discharge, the LiB retained its shape without any sudden heating or ignition. The metallic battery casing acts as a robust discharge path, and the impact force generated by the pulsed discharge selectively fractures the surrounding plastic housing of the battery pack. These findings indicate that the electrical pulse method can simultaneously ensure safety and promote resource circulation in LiB recycling.

9:20 AM

(GFMAT-S10-003-2026) Recovery of carbon fibers from unidirectional CFRP laminates using direct electrical pulsed discharge

K. Sato*[1]; M. Inutsuka[2]; C. Tokoro[3]

1. Waseda Daigaku, Graduate School of Creative Science and Engineering, Japan
2. Waseda Daigaku, Waseda Center for a Carbon Neutral Society, Japan
3. Waseda Daigaku, Faculty of Science and Engineering, Japan

Carbon fiber–reinforced polymer (CFRP) is widely used in various products, although it is difficult to dismantle and dispose of CFRP waste because of its high specific strength. An efficient method for separating carbon fibers (CF) from CFRP is required for the sustainable use of CFRP. Although conventional thermal and chemical methods can selectively decompose resins, these processes impose substantial environmental burdens. In this study, we investigated CF separation using a direct electrical pulsed discharge, which applies a high voltage instantaneously. A CFRP model sample composed of a single CF in epoxy resin was subjected to pulsed discharge, and the separation mechanism was examined using SEM observation and finite element analysis. The results revealed that the thermal decomposition of the interfacial resin caused by Joule heating in the CF played an important role in the separation mechanism. In another experiment, by applying pulsed discharge to unidirectional CFRP, we successfully separated CF from the resin. SEM observations confirmed the presence of particulate resin residues on the recovered CF surfaces, while the recovered CFs retained 90–95% of their original tensile strength. These findings demonstrate that direct electrical pulsed discharge is an effective technique for separating CF from CFRP and is useful as a pretreatment for thermal or chemical methods.

GFMATS10- Life cycle analysis and techno-economic analysis of the technologies

Room: Sandpiper C
Session Chair: Motoyuki Iijima, Yokohama National University

9:40 AM

(GFMAT-S10-016-2026) Design and development of next generation biomass based recycling technologies

S. Gupta*[1]

1. University of North Dakota, Mechanical Engineering, USA

Biomass is a critical resource for designing novel materials. It is enriched with components like lignin, cellulose and hemi-cellulose. Novel methods are needed for recycling these materials. In this presentation, I will report progress in two different types of recycling processes, namely (a) bioplastics design by using biomass, and (b) pyrolysis. These two processes will be discussed in detail. Detailed microstructural, physical characterization and commercialization potential of these technologies will be presented.

10:20 AM

(GFMAT-S10-005-2026) Improving high temperature ceramic composites for sustainable energy applications

G. Kimotho*[1]

1. University of Nairobi, Research, Kenya

High temperature ceramic matrix composites are materials that can withstand extreme heat and stress, making them important for energy and industrial systems. They are widely used in turbines, reactors, and other equipment where normal materials fail. This study explores simple ways to improve the strength, durability, and heat resistance of these composites by using advanced fibers and optimized processing methods. Samples were prepared in the laboratory and tested under high temperatures and mechanical stress. Measurements focused on mechanical strength, thermal stability, and resistance to cracking. The results show that adding

selected fibers and using careful processing improves performance and reduces defects. These improved composites can enhance the efficiency and safety of energy systems while supporting sustainable development by saving energy and reducing material waste. The study also identifies areas for future research, including testing different fiber types and layering methods to further improve performance. This research helps industries understand how simple material and process improvements can produce more reliable and sustainable high temperature composites. Using such materials can support technological innovation, energy efficiency, and long-term sustainability in critical industrial applications.

10:40 AM

(GFMAT-S10-006-2026) LCA driven recycling of yttrium disilicate: Towards a circular economy for environmental barrier coatings

C. Augeard*[1,2]; G. Sonnemann[2]; C. Aymonier[1]

1. Institut de Chimie de la Matiere Condensee de Bordeaux, France
2. Institut des Sciences Moleculaires, CyVi, France

Environemental Barrier Coatings (EBC) have provided a tailored technical solution to a major problem : the volatilization of SiC/SiC ceramic matrix composite (CMC). EBCs are manufactured from highly critical materials : rare earth elements. The production of ytterbium and yttrium embodies major global challenges—geopolitical, environmental, social, and humanitarian. Recycling these critical materials is a way not only to circumvent the geopolitical tensions surrounding them but also to reduce the environmental impact of their production, which is far from negligible. This work will be based on both an experimental approach and a standardized environmental impact quantification method : life cycle assessment (LCA). We therefore propose to conduct an initial "very early stage" LCA at the laboratory scale to select the most environmentally favorable acid. The results will guide experimental choices, from which a parametric study of the mineralization kinetics of yttrium disilicate will be derived. This study aims to investigate the stability of yttrium disilicate under acidic conditions. The conclusion will provide answers both technically and sustainability by performing a comprehensive LCA of the process to estimate the environemental impact of recycling on the product life cycle.

11:00 AM

(GFMAT-S10-007-2026) Fabrication and detailed study of novel MoAlB/Cr2AlC waste glass composites (Invited)

M. Dey*[1]; E. Sofowora[2]; E. Oloo[1]; J. Zhang[1]; S. Gupta[1]

1. University of North Dakota, Mechanical Engineering, USA
2. University of North Dakota, Chemical Engineering, USA

Sustainability and circular economy have evolved from textbook definition to a lifesaving pathway recently. In this novel research work, waste glass was used to fabricate glass-ceramic composites, using MAX and MAB nanolayered non-oxide ceramics as the reinforcement material. Interestingly, both porous (~25% relative density) and densified composites (~85% relative density) could be fabricated in this work by primarily altering the type of filler and their loading in the glass matrix composites. Densification additives further strengthened dense Cr_2AlC MAX phase reinforced composites. However, MoAlB MAB phase reinforced composites showed a different trend where MoAlB acted as a sintering aid, showing denser composites than their Cr_2AlC counterparts. Additives instead reduced relative density and mechanical strength of the MoAlB based composites. Partial deintercalation of Al leading to Al diffusion from the ceramics to the glass matrix could also be detected. This effect was more prominent in the smaller ceramics particulates than the larger ones. Detailed study using SEM, XRD, X-ray Tomography, micro-vicker's hardness, crack propagation and thermal shock study showed the potential of these materials in multifunctional applications. This novel study shows the methods of fabricating these high valued glass-ceramic composites along with detailed characterization, revealing their material properties.

11:30 AM

(GFMAT-S10-008-2026) Effect of multi-directional fiber architecture on the microstructure and mechanical properties of C_f-SiC_m composites

S. Roy*[1]; A. Mahato[2]; S. Mondal[1]; M. Thangarasu[1]; S. K. Sahoo[1]; A. Meena[1]

1. Indian Institute of Technology Kharagpur, Materials Science Center, India
2. Indian Institute of Technology Kharagpur, School of Nanoscience and Technology, India

Carbon fiber reinforced Silicon Carbide matrix (C_f-SiC_m) composites offer promising solutions for aerospace applications due to their capacity to endure extremely high temperature. Present study introduced non-crimped fabrics (NCFs) as the starting material for the fabrication of C_f-SiC_m composites due to their absence of out of plan orientation defects. Afterwards, multi-directional (1D, 2D, 3D, 4D) C_f-SiC_m composites were fabricated through liquid silicon infiltration (LSI) method. The composites were characterized for microstructure evolution by optical and scanning electron microscopy while X-ray micro computed tomography (μ-CT) was employed to quantify internal fiber architecture as well as porosity within various composites. The effect of fiber orientation on various mechanical properties were evaluated through static (tensile, compression, flexural and fracture toughness) and dynamic (DMA) tests at both room and high temperature. Under uniaxial tensile and compressive loading, strength decreases in the order 4D> 3D> 2D>1D while flexural strength in the order 1D > 2D > 3D > 4D and fracture toughness remains comparable for 2D, 3D, and 4D composites. Detailed fractographic analysis of ailed test specimens reveal underlying failure mechanisms.

Young Professionals Forum

HTCMC-GFMAT- YPF- Ceramic-Based Composites I

Room: Sandpiper B
Session Chairs: Nico Langhof, University of Bayreuth; Dong Liu, University of Oxford

8:30 AM

(YPF-001-2026) Thermoset injection molding as shaping possibility for C/C-SiC production (Invited)

J. H. Stiller*[1]; D. Nestler[1]; L. Kroll[1]

1. Technische Universitat Chemnitz Fakultat fur Maschinenbau, Department of Lightweight Structures, Germany

The industrially established process for manufacturing C/C-SiC ceramic matrix composites is based on infiltrating porous, carbonaceous preforms with liquid silicon. Established processing methods for composite materials can be used to shape these preforms, with injection molding offering particular advantages for large-scale, automated production. Phenolic resins meet the requirements of the LSI process due to their high carbon yield and dimensional stability during pyrolysis and were therefore used as the matrix system in this work. Processing carbon fiber reinforced phenolic resins necessitated further development of compounding and thermoset injection molding. The aim was to elucidate the interrelations between material, process, microstructure, and resulting properties. The focus lay on the influence of fiber length and orientation as well as the rheological and structural changes along the process chain. The flow and filling behavior were characterized, fiber length was increased by adding chopped fiber bundles, and the resulting crack network was affected. The results demonstrate the suitability of injection molding for manufacturing reproducible, structurally defined preforms for the LSI process and provide a technological basis for reliable series production of complex ceramic matrix composite components.

9:00 AM

(YPF-002-2026) The detrimental role of the fiber volume content in reactive melt infiltrated C/C-SiC Processing–Microstructure–Property correlations (Invited)

F. Wich*[1]; F. Ebrahimi[1]; N. Langhof[1]; S. Schafföner[1]

1. University of Bayreuth, Chair of Ceramic Materials Engineering, Germany

This study aims at closing the gap in understanding the interconnections between material composition and anisotropic thermophysical and mechanical properties of C/C-SiC. 2D reinforced composites with varying fiber volume fractions (35, 45, 55%) were manufactured via the liquid silicon infiltration process and investigated using light microscopy, SEM, XRD, dilatometry, DSC (c_p), LFA (λ), 3 and 4-point bending tests, tensile tests, compression tests and determination of the interlaminar shear strength. Clear correlations between the fiber volume content, phase composition and the resulting thermophysical as well as mechanical properties were found. The acquired data suggests that the young's modulus in bending and tensile tests is directly connected to the fiber volume fraction of the samples and can therefore easily be modelled. Bending strength as well as tensile strength on the other hand are only partially proportional to the fiber volume content and are most likely influenced by a pyrolysis shrinkage induced entanglement of ply layers which appears only in samples with higher fiber volume fractions. Surprisingly, the compressive strength is barely dependent on the fiber volume fraction and fiber orientation and can be considered an isotropic property of C/C-SiC ceramics underlining the complexity of structure property relations for CMCs.

9:30 AM

(YPF-003-2026) Silica-carboxymethyl cellulose macrobeads as scalable templates for metal–organic framework growth (Invited)

P. K. Kimani*[1]; C. Takai-Yamashita[1,2]; M. Fuji[1]

1. Nagoya Kogyo Daigaku, Advanced Ceramics Research Institute, Japan
2. Tohoku Daigaku, Institute of Multidisciplinary Research for Advanced Materials, Japan

Metal–organic frameworks (MOFs) offer exceptional porosity and tunability, yet their translation into practical remediation systems remains limited by challenges in scalability and handling. This work presents a simple, sustainable route to overcome these constraints by engineering macroscopic bead templates composed of silica and carboxymethyl cellulose (CMC) through a dropping technique. The hybrid macrobeads combine the mechanical stability of silica with the renewability and metal-ion–binding capacity of CMC, enabling uniform metal loading and controlled MOF nucleation throughout the bead structure. We demonstrate that the silica–CMC beads support the growth of copper-based high-surface-area MOFs under room temperature conditions, producing robust, porous composites in a sustainable way. Structural characterisation confirms successful MOF integration and preservation of bead integrity, while preliminary performance tests show strong potential for applications such as emerging contaminant degradation. This scalable platform provides a versatile pathway for fabricating MOF–biopolymer macrostructures designed for sustainable and scalable real-world environmental remediation.

HTCM-GFMAT-YPF- Ceramic-Based Composites II

Room: Sandpiper B

Session Chair: Meelad Ranaiefar, NASA Glenn Research Center

10:20 AM

(YPF-004-2026) Prepreg-based oxide fiber composites – Processing influences, repeatability, and properties (Invited)

G. Puchas*[1]; L. Wagner[1]; F. Lindner[1]; A. Held[1]; S. Schafföner[1]; W. Krenkel[1]

1. University of Bayreuth, Chair of Ceramic Materials Engineering, Germany

The damage tolerant fracture behavior of oxide fiber composites (OFCs) is ensured by a weak, i.e. highly porous, matrix. OFCs exhibit excellent thermomechanical behavior at high temperatures and offer lightweight construction potential. Prepreg (pre-impregnated fiber preform) processes are an industry-oriented fabrication method for composites, which also have been established for OFCs over the last ten years. However, these are mostly proprietary processes about whose processing influences, robustness and repeatability very little information is available. Our prepreg process is already well documented in the literature and uses the addition of glycerol to the slurry in order to obtain a defined processing state. We've investigated the influence of processing parameters such as fiber filament count, used powders, glycerol content and conditioning humidity on the microstructure and flexural strength of Nextel™ 610/Al_2O_3-ZrO_2 OFCs. Glycerol contents of 16 wt.% and 26 wt.% were used for further comparative tests regarding the slurry viscosity and the effects of drying and remoistening as well as storing on prepregs containing these slurries. Investigations of process repeatability and reproducibility yielded similar mean flexural strengths in excess of 350 MPa, but distinctive differences in the Weibull moduli of the strength distributions.

10:50 AM

(YPF-005-2026) Manufacturing and application of HTCMCs for space application at the German Aerospace Center (DLR) (Invited)

L. Baier[2]; I. Petkov[2]; T. Reimer[1]; G. Di Martino[1]; C. Rauh[1]; D. Hargarten[3]; A. Gülhan[4]; H. Weihs[1]; J. Schukraft*[2]

1. Deutsches Zentrum fur Luft- und Raumfahrt DLR, Space System Integration, Germany
2. Deutsches Zentrum fur Luft- und Raumfahrt DLR, Ceramic Composites and Structures, Germany
3. Deutsches Zentrum fur Luft- und Raumfahrt DLR, MORABA, Germany
4. Deutsches Zentrum fur Luft- und Raumfahrt DLR, Supersonic and Hypersonic Technologies, Germany

Fabricating CMC components as thermal protection systems (TPS) for use in high-temperature space applications is critical due to their exceptional thermal stability, low density, and high-temperature resistance. Manufacturing techniques significantly influence the performance and suitability of these components because they acquire their material properties during fabrication. Therefore, structural design and manufacturing are crucial for the application of these parts. At the German Aerospace Center (DLR) different polymer composite fabrication technologies, such as filament winding, resin transfer molding (RTM), and autoclave processing of prepreg woven fabrics followed by subsequent pyrolysis and liquid silicon infiltration (LSI), are used to tailor the properties of HTCMC materials and optimize their structural design. Successful flight experiments were carried out to validate the application of TPS with tailored HTCMC materials, and the results will be presented.

11:20 AM

(YPF-006-2026) Ceramic to metal joining for high temperature oxygen separation applications (Invited)

S. De La Pierre*[1]; P. Fedeli[2]; F. Smeacetto[1]; F. Drago[2]; M. Ferraris[1]

1. Politecnico di Torino, DISAT, Italy
2. Ricerca sul Sistema Energetico RSE SpA, Italy

The integration of Oxygen Transport Membranes (OTMs) in industrial processes can lead to energetic and economic advantages. Still, proof of concept membrane modules are highly necessary to demonstrate the feasibility of this technology. This study identifies innovative materials to be used to join ceramics to metals, with a specific focus on joining materials for the integration of OTMs in metallic modules for high temperature applications. In this work is presented the development and high temperature characterization carried out on glass-ceramic sealants selected to join ceramic membranes to the metallic part. First of all the glass ceramics have been produced and analyzed to evaluate their thermal properties as sealant materials for the application. Then glass-caramic pastes have been developed and tested, to be employed with robocasting and tape-casting deposition techniques. Furthermore the thermomechanical compatibility of the selected sealants, with the ceramic membrane and the metallic case, has been tested, after joining, with X-ray thermography analysis and SEM observation of the interfaces. The produced joints have been subjected to relevant condition ageing tests (800-950°C, 1 to 3 weeks) and microstructurally analyzed afterward. In the end, gas tightness tests of the joints and scale-up to a final module configuration have also been performed.

HTCMC-12 Symposium 3- Polymer Derived Ceramics and Composites

HTCMCS3- Preceramic Polymers and Polymer-Derived Ceramics VI

Room: Sandpiper A
Session Chairs: Matthew Dickerson, Air Force Research Laboratory; Timothy Pruyn, Air Force Research Laboratory

8:30 AM

(HTCMC-S3-018-2026) Structure modification of preceramic polymer grafted nanoparticles for tunable preceramic processability and polymer derived ceramic composition (Invited)

J. Ponder*[1]; A. Advincula[1]; J. Zackasee[1]; J. Delcamp[2]; T. Pruyn[2]; M. B. Dickerson[2]

1. AV Inc., USA
2. Air Force Research Laboratory, Materials and Manufacturing Directorate, USA

Polymer derived ceramics (PDCs) suitable for high temperature environments have become increasingly important for various aerospace applications, ranging from aircraft brakes to atmospheric re-entry shielding. Commercially available silicon carbide-yielding preceramic polymer (PCP) formulations (e.g., SMP-877 or PZ20) have been utilized to produce the PDC matrix phase in ceramic matrix composites (CMCs). Due to their relatively low viscosities, capacity for thermal cross-linking to produce cured polymer networks, and moderate ceramic yields, PCPs can be used effectively in polymer-infiltration-pyrolysis processes. Despite the rapidly emerging commercial applications of PDCs, many scientific questions remain regarding structure-property relationships in these materials. In this study, we investigate the role of PCP structural changes in the context of both neat PCPs and corona materials in polymer grafted nanoparticles (GNPs). Corona-to-core ratios, degrees of branching, and different cross-linking moieties were investigated. Various characterization methods have been utilized to not only determine the properties of the PCP and composition of the resulting PDC, but also the specific chemical species volatilizing away during pyrolysis. From these results, PCPs can be better designed for commercial and developing applications.

9:00 AM

(HTCMC-S3-019-2026) Multi-step kinetic modeling of polysilazane pyrolysis *WITHDRAWN*

J. Fischer*[1]; R. Walker[1]; J. Efferson[2]; D. Gilmer[1]

1. The University of Tennessee Knoxville Tickle College of Engineering, Materials Science and Engineering, USA
2. The University of Tennessee Knoxville Tickle College of Engineering, Nuclear Engineering, USA

Preceramic Polymers (PCPs) offer a versatile route to advanced structural materials for extreme environments through the formation of Polymer Derived Ceramics. One such PCP, Durazane, a polysilazane based polymer, provides excellent high-temperature resistance, high hardness, good corrosion resistance, and strong chemical stability once converted to the binary SiN or ternary SiCN system by pyrolysis. While pyrolysis conditions such as atmosphere, peak temperature, heating rate, gas flow rate, and residence time clearly influence the microstructure and properties of the resulting ceramic, the mechanisms by which these parameters modify the polymer-to-ceramic conversion are not yet fully understood. Further insight is needed into the degradation dynamics and the coupled chemical and physical processes that govern this multistep transformation. In this work, we combine thermal analysis techniques, including differential scanning calorimetry (DSC) and thermogravimetric analysis (TGA), with mechanistic and structural characterization to investigate the kinetic behavior and evolution of molecular structure during pyrolysis. By linking pyrolysis conditions with the final ceramic structure, this work reveals how kinetic behavior drives phase transformation pathways and microstructural evolution during thermal decomposition.

9:20 AM

(HTCMC-S3-020-2026) Design of tailored polymeric precursors enabling high-performance UHTCs via the PIP route

J. So*[1]; K. Lee[1]; H. Hwang[1]; J. Choi[1]; S. Lee[1]

1. Korea Institute of Materials Science, Republic of Korea

Ultra-high-temperature ceramics (UHTCs) are vital materials in aerospace and defense due to their exceptional heat and ablation resistance. However, their extremely high melting points, exceeding 2000°C, create challenges in shaping and sintering, necessitating effective densification methods. One promising technique is the polymer infiltration and pyrolysis (PIP) method. This process involves introducing a low-viscosity polymeric precursor into a matrix and converting it into ceramics through high-temperature pyrolysis, enabling the densification of various ceramics and near-net shape fabrication. The success of the PIP method relies on using liquid polymer precursors with low viscosity for efficient matrix infiltration and high yield for effective ceramization. Our research group has extensively studied the PIP process and developed tailored synthetic strategies to create suitable ceramic precursors. Specifically, we focus on precursors for producing (Zr, Hf, Si)-based ceramic. In this presentation, we will share our precursor synthesis methods and examine how applying these precursors through the PIP process impacts UHTC properties, highlighting advancements in their fabrication and practical application.

9:40 AM

(HTCMC-S3-021-2026) Evolution of C/SiC fiber/matrix microstructure under field-assisted sintering technique (FAST)

S. Kusdono*[1]; S. Nutt[1]

1. University of Southern California, Mork Department of Materials Science and Chemical Engineering, USA

In this work, evolution of the fiber and matrix structure of a C/SiC composite processed via field-assisted sintering technique (FAST) is documented, and observed trends are linked to fiber-matrix interfacial strength. C/SiC composites were first processed by 6 cycles of polymer infiltration and pyrolysis (PIP), followed by FAST post-processing steps at different sintering temperatures. Transmission electron microscopy (TEM) samples were prepared via focused ion beam (FIB). Increasing FAST sintering temperature led to rapid SiC grain growth in the matrix and into C-fibers/coating. Different regions with distinct levels of packing, orientation, and size of SiC grains were observed depending on proximity to C-fibers. Increasing FAST temperature also led to increased texturing of carbon in both fibers and coating. In conclusion, the evolution of grain growth in a polymer-derived matrix was mapped, contributing to understanding of processing-structure-property relationships in FAST-produced CMCs.

10:20 AM

(HTCMC-S3-022-2026) Processing and performance of fiber-reinforced polymer-derived CMCs for harsh environment applications

A. Moore*[1]; G. Lovelace[1]; L. Hunter[1]; A. Langevin[1]; J. Hepp[1]; J. Williams[1]; A. Sathrum[1]; I. Ivanov[1]; N. Pacheco[1]; C. Deck[1]; H. Khalifa[1]

1. General Atomics Electromagnetic Systems Group, NTM, USA

Fiber-reinforced, polymer-derived ceramic matrix composites (CMC) can leverage processing efficiencies and tailorable formulations to produce high performance CMCs for harsh environment applications. General Atomics Electromagnetic Systems (GA-EMS) has demonstrated that pre-ceramic polymer prepreg and polymer infiltration and pyrolysis (PIP)-based processing of CMCs can reduce process duration and process energy consumption by 75% or more compared to alternative methods, such as chemical vapor infiltration. Different formulations of preceramic polymer slurries allow for a range of preforming methods, including conventional prepreg lay-ups and automated fiber placement (AFP) techniques, which can enable more complex structures and reduce waste. These routes are being used to fabricate SiC/SiC materials for fission and fusion applications, including accident tolerant nuclear fuel cladding and fusion blanket and structural components, supported by recent testing showing that SiC/SiC can survive fusion plasma exposure. Alternative pre-ceramic polymer formulations have also been developed to enable processing of ultra-high temperature CMCs, including composites with polymer-derived ZrC matrices. Properties and performance of these fiber-reinforced, polymer-derived CMCs will be reported.

10:40 AM

(HTCMC-S3-023-2026) Microstructural and defect evolution in polytitanoxane-derived titanium carbide systems for next-generation CMCs ***WITHDRAWN***

K. Y. Wickramathilaka*[1]; S. L. Suib[1]

1. University of Connecticut, USA

Titanium carbide (TiC) is emerging as a lightweight, high-temperature alternative to traditional UHTCs for next-generation ceramic matrix composites (CMCs). Although TiC can be synthesized from preceramic polymers, the microstructural and defect evolution during processing remains poorly understood. This study analyzes three polymer-derived TiC systems synthesized from acetylacetone and tert-butyl titanate precursors at varying ratios. X-ray diffraction (XRD) was used to confirm phase formation, assess crystallite size, and evaluate stacking fault density. Raman spectroscopy provided insight into carbon structure, with I(D)/I(G) ratios used to quantify graphitic ordering. High-resolution TEM and aberration-corrected STEM enabled direct imaging of defects such as stacking faults, dislocations, and grain boundary twisting formed during polymer-to-ceramic conversion. X-ray photoelectron spectroscopy (XPS) was used to probe bonding environments and identify residual Ti–O species. These multimodal analyses offer a comprehensive understanding of structural evolution in polymer-derived TiC, informing the design of optimized TiC matrices for advanced CMCs and hypersonic applications.

HTCMCS3- Preceramic Polymers and Polymer-Derived Ceramics VII

Room: Sandpiper A

Session Chairs: Timothy Pruyn, Air Force Research Laboratory; Jordan Zackasee, Air Force Research Laboratory

11:00 AM

(HTCMC-S3-024-2026) Process parameters – mechanical properties relationships for metakaolin geopolymers used in continuous fiber composites and chemical foams

D. Habans*[1]; É. Prud'homme[1]; P. Reynaud[1]; T. Cutard[2]; G. Dusserre[2]; G. Fantozzi[1]

1. Institut National des Sciences Appliquees de Lyon, MATEIS, France
2. Ecole Nationale Superieure des Mines d'Albi-Carmaux, ICA, CNRS UMR5312, France

Few structural applications have emerged for geopolymers outside of civil engineering despite their great polyvalence and their potential for sustainability. Therefore, we explored the potential of an innovative sandwich structure made of a carbon fibers geopolymer matrix composite as external layers, and of a geopolymer foam as the core. In this work, we focus on the process parameters – mechanical properties relationship of the constituents of this structure, namely the composite and the foam. The composites are made by impregnating continuous inorganic fibers with a geopolymer matrix. The geopolymer foam is obtained via chemical foaming using aluminium powder and a surfactant. We used tomography and scanning electron microscopy to investigate the resulting microstructures. Compression tests were conducted on samples of geopolymer matrix and foam, while tensile tests were conducted on composite samples. Results for the foams show mostly spherical porosities, the size of which can be controlled by adjusting aluminium content and paste viscosity. Curing and drying conditions are also optimized for enhanced mechanical properties. Results for the composite show that finer particle size of the metakaolin powder influence considerably its mechanical properties. Preserving the castability of the suspension is crucial to properly coat the fibers.

11:20 AM

(HTCMC-S3-025-2026) Radio frequency transparent materials based on geopolymers

A. El Khomsi*[1]; A. Gharzouni[1]; E. Martinod[2]; S. Rossignol[1]

1. Institut de Recherche sur les Ceramiques, UMR-CNRS-7315, France
2. XLIM - UMR CNRS 7252, France

Radomes protect communication systems while allowing electromagnetic signal to pass through. Traditional radome materials, such as fiberglass-reinforced composites and ceramics, often face challenges related to high production costs, environmental concerns, and thermal stability. In recent years, geopolymers have emerged as a promising class of inorganic polymer materials, offering a more sustainable alternative. Characterized by their thermal resistance, mechanical strength, and low environmental impact, these materials can be tailored to exhibit low dielectric properties suitable for radome applications. Thus, the aim of this study is the shaping of geopolymer Radome for radio frequency application. To achieve low dielectric losses and permittivity, metakaolin based geopolymers

curred in different consolidation temperatures were tested. The consolidated materials were characterized by dielectric and signal gain measurements showing low relative permittivity and dielectric loss. These formulations were shaped into radomes by casting, and successfully withstood freeze-thaw cycles (-20 to +20°C) and water immersion tests. The signal gain measurements showed similar performance between the geopolymer and the classical polymer radome, indicating that the material didn't attenuate the signal. This study highlights the potential of geopolymers as a sustainable, functional alternative for advanced technological applications.

11:40 AM

(HTCMC-S3-026-2026) The effect of dopants and controlled cooling rates on solar thermal properties of fayalitic slags

G. Alkan*[3]; P. Mechnich[3]; D. Schneider[2]; F. Flucht[3]; B. Kölsch[1]; B. Friedrich[2]

1. Deutsches Zentrum fur Luft- und Raumfahrt DLR, Germany
2. Rheinisch-Westfalische Technische Hochschule Aachen, Germany
3. DLR - German Aerospace Center, Institute of Frontier Materials on Earth and in Space, Germany

Metallurgical slags are considered as promising secondary raw materials to prepare ceramic granules to be used in concentrated solar thermal technology (CST) as high-temperature stable heat absorptance and storage medium. In this study, adaptive smelting process was conducted on fayalitic slags from copper industry with controlled crystallization rate and nucleation agents such as titania, alumina and calcium oxide. Firstly, the effect of cooling rate on the crystal quality and phase formation mechanisms of as-received slags were examined. Afterwards, the effect of nucleation agents on crystallization behavior and mineral products in as-received slags were elucidated. After revealing material properties, the influence of chemistry, crystal quality and phase composition on CST related functional properties such as heat capacity, solar absorptance and high temperature stability was studied. The controllability of material properties by adaptive smelting and heat treatment, and their effect on CST related properties is discussed.

HTCMC-12 Symposium 4- Innovative Design, Advanced Processing and Manufacturing Technologies in Non-oxide and Oxide Composites

HTCMCS4- SiC-based composites II

Room: Silver Pearl 1
Session Chair: Sea-Hoon Lee, Korea Institute of Materials Science

8:30 AM

(HTCMC-S4-019-2026) C/C-SiC sandwich structures for optical benches (Invited)

B. Heidenreich*[1]; D. Boban[2]; O. Simane[2]; M. Berrill[3]

1. German Aerospace Center, Germany
2. Thales Alenia Space Cannes la Bocca, France
3. European Space Research and Technology Centre, Netherlands

In a close cooperation of DLR and Thales Alenia Space, France (TAS-F), a C/C-SiC sandwich optical bench demonstrator (600 x 600 x 60 mm) has been developed and validated. C/C-SiC materials are based on carbon fibers embedded in carbon (C) and silicon carbide (SiC) matrix. Most important for ultrastable optical benches, the combination of carbon fibers and SiC matrix leads to a very low coefficient of thermal expansion (CTE), close to zero. Since there is no polymer at all in the material, also outgassing is not an issue and a high stability in space environment is expected. Based on the heritage of DLR and TAS-F, a sandwich design with a grid core and representative interfaces were selected. A novel interface concept was developed and tested in screw tightening and out of plane tension of representative coupons. The interface components were also made of C/C-SiC, in order to ensure similar coefficients of thermal expansion of interface and sandwich structure, and finally to avoid internal stresses and even minimal structural deformation. A material and structural model was developed, which was used to define representative coupon geometries as well as the demonstrator design. Thereby, it could be shown that the real structural behavior of the demonstrator in thermal and vibration tests was reproduced closely. This presentation will be focused on the manufacture and testing of the coupons and the optical bench demonstrator.

9:00 AM

(HTCMC-S4-020-2026) Deposition of porous carbon via C_xH_y-based CVD for liquid silicon infiltrated SiC_f/SiC composites

D. Kim*[1]; J. Lee[1,2]; W. Kim[3]

1. Korea Atomic Energy Research Institute, Materials Safety Technology Research Division, Republic of Korea
2. Hanyang University, Republic of Korea
3. Korea Atomic Energy Research Institute, Republic of Korea

LSI SiC_f/SiC composites exhibit excellent thermal stability, high specific strength, and resistance to oxidation and creep, making them promising materials for high-temperature structural components. To ensure high-temperature mechanical reliability, it is essential to minimize the residual carbon and silicon remaining in the matrix after the LSI process. Achieving this requires the formation of a porous carbon body with appropriate density and uniformly distributed carbon within the fiber preform, as this directly determines the uniformity of the SiC matrix and the composite quality. Conventional carbon-filling approaches, including phenolic-resin pyrolysis, are advantageous for large or complex-shaped preforms but suffer from high residual silicon content and compositional non-uniformity. In this study, SiC fiber preforms were fabricated using Tyranno SA-grade fibers, and the carbon deposition behavior was investigated with respect to differences in fiber architecture. To control carbon nucleation and growth, a porous-carbon deposition process was developed using acetylene (C_2H_2) combined with C_xH_y mixed gases, enabling tailored carbon formation inside the preform. After forming the porous carbon layer, molten silicon was infiltrated to produce the LSI composite. The distribution of residual silicon and the mechanical strength of the composite was evaluated.

9:20 AM

(HTCMC-S4-021-2026) Advanced manufacturing and characterization of high-purity, stress-free SiC/SiC CMCs for high-temperature applications

A. Palumbo*[1]; L. Montgomery[1]; W. Fischer III[1]

1. Advanced Silicon Carbide Materials, USA

SiC/SiC CMCs are pivotal for next-generation high-temperature systems. However, conventional fiber-reinforced CMCs are often constrained by interlaminar shear vulnerability, residual porosity, and anisotropic thermal/mechanical responses, hindering industrial scalability. ASCM has developed an advanced chemical vapor composite (CVC®) manufacturing method that produces 100% dense, ultra-high purity (< 5 ppm), stress-free SiC/SiC CMC, using SiC particles entrained within a CVD SiC matrix. This approach departs from traditional fiber-reinforced CMCs and enables near-net-shape manufacturing of complex geometries, demonstrated up to 1.5 m in diameter and 75 mm in thickness. The CVC® CMC equiaxed grain structure overcomes the performance limitations of conventional CVD SiC, as a stress-free SiC/SiC with isotropic thermal/mechanical properties. Advanced metrology and high-precision finishing are further employed to validate surface form and grain integrity for demanding applications. This work details breakthroughs in the manufacturing scalability and characterization of particle reinforced SiC/SiC composites, engineered for extreme thermal, radiological, and chemically corrosive environments. The demonstrated near-net-shape precision at scale positions this innovative manufacturing process as a transformative pathway for the industrial adoption of next-generation CMCs.

9:40 AM

(HTCMC-S4-022-2026) Matrix development for non-oxide ceramic matrix composites based on the weak matrix concept

G. Puchas*[1]; F. Schwedler[1]; L. Wagner[1]; S. Schafföner[1]

1. University of Bayreuth, Chair of Ceramic Materials Engineering, Germany

Ceramic Matrix Composites (CMCs) offer a combination of outstanding properties of ceramics, such as high temperature strength and high stiffness, with a damage tolerant fracture behavior. Non-oxide CMCs mostly rely on a weak fiber/matrix-interface to ensure this damage tolerance. C/C and SiC/SiC with a porous matrix are produced via a costly chemical vapor infiltration process. We investigated the fabrication of porous, powder-based SiC and Si_3N_4-SiC matrices for a carbon fiber reinforced CMC with a weak matrix. This provides a very cost-efficient way to obtain matrices in less than five hours at 1250 °C-1400 °C. By varying the amount of reactive powders, the reaction temperature and the reaction time in a design of experiments approach, the in-situ formation of silicon carbide based on a gas phase was studied. The microstructural analysis using SEM in combination with the determination of flexural strength, Young's modulus and porosity enabled the identification of process-microstructure-property correlations of these matrices. The reaction between pitch-based carbon fibers and the silicon containing gas phase was studied using different fiber pre-treatments. Finally, C/SiC and C/Si_3N_4-SiC CMCs were manufactured using the developed matrices and analyzed regarding their mechanical properties and microstructure.

HTCMCS4- Advanced processing and manufacturing technologies II

Room: Silver Pearl 1
Session Chair: Seyoung Kim, Korea Institute of Energy Research

10:20 AM

(HTCMC-S4-023-2026) Advanced CVI processing of next-generation high temperature composite structures (Invited)

V. Papageorgiou*[1]; N. Djordjevic[1]; H. Strakov[1]

1. IHI Bernex AG, Switzerland

Chemical Vapor Infiltration (CVI) enables precise deposition of ceramic interfacial layers and serves as a key technology for producing high-performance ceramic composites. Beyond its established use on ceramic fibers to control fiber / matrix adhesion through BN, PyC or SiC coatings, CVI is now applied to complex additive-manufactured (AM) ceramic structures. These 3D-printed architectures offer customized aperture rates and CVI provides the required densification, oxidation resistance and mechanical performance that conventional fabrication routes cannot achieve. A novel heat-exchanger concept couples a SiC-infiltrated AM ceramic core with a fiber-reinforced ceramic sheath equipped with tailored CVI interfacial layers. The SiC-treated core exhibits significantly improved high-temperature stability and mechanical robustness, while the coated fiber-based sheath contributes thermal-shock tolerance and structural integrity. Recent advances in CVI process engineering, including modular reactor designs and optimized gas-phase chemistries, enable higher infiltration yield, improved uniformity and scalable deposition of multiple ceramic materials. Such developments demonstrate how the combination of CVI and AM can produce compact, mechanically resilient, and thermally efficient ceramic components for extreme-temperature environments.

10:50 AM

(HTCMC-S4-024-2026) Development of high-temperature protective coatings for ceramic matrix composites using the aerosol deposition method (Invited)

M. Hasegawa*[1]

1. Yokohama National University, Graduate School of Engineering Science, Japan

Ceramic matrix composites (CMCs), such as C/C, C/SiC, and SiC/SiC, are expected to be used as high-temperature structural materials. However, the surface temperatures of the nose cones and leading edges of hypersonic aircraft are believed to exceed 2000°C during operation. CMCs cannot be directly applied to these regions due to insufficient heat resistance and oxidation resistance at such temperatures. ZrB_2 is an ultra-high-temperature ceramic (UHTC) that has attracted attention for its high melting point, relatively low density, and excellent oxidation resistance. It is also known that adding SiC to ZrB_2 can enhance its oxidation resistance. Using brazing or spray coating to join UHTC to CMC requires extremely high temperatures, which can degrade the CMC substrate. The aerosol deposition (AD) method can produce dense, crystalline coatings at room temperature. This technique forms coatings via so-called room-temperature impact solidification, where solid particles fracture and deform plastically upon collision with the substrate. Consequently, it is believed that this process will not damage the CMC substrate. This presentation highlights recent progress in developing UHTC coatings on substrates at room temperature using the AD method and discusses the microstructure and oxidation properties of the resulting coatings.

HTCMC-12 Symposium 5- Advanced Thermal and Environmental Barrier Coating – Processing, Properties, and Applications

HTCMCS5- Ceramic Coatings

Room: Silver Pearl 2/3
Session Chair: Peter Mechnich, DLR - German Aerospace Center

8:30 AM

(HTCMC-S5-001-2026) Mechanisms of CMAS interactions with rare earth monosilicates (Invited)

E. Opila*[1]; C. Miller[1]

1. University of Virginia, USA

Rare earth monosilicates (REMS) are proposed for top layers of environmental barrier coatings due to their thermodynamic stability with combustion gases. REMS surface reactions with calcium magnesium aluminosilicates (CMAS) present in the environment are also of interest. In this study REMS reactions with CMAS were systematically studied at 1300°C for exposure times up to 24h, varying RE cation selection in REMS across the lanthanide series. Mechanisms of CMAS reaction were identified. Large cation REMS formed RE-containing apatite phases without calcium (Ca) as a barrier layer toward further reaction. The formation reactions of Ca-RE apatite phases from intermediate sized cation REMS were limited by dissolution since the apatite phase readily precipitates. The formation reactions of Ca-RE apatite phases from the small cation REMS, however, have less thermodynamic driving force and are therefore limited by the precipitation reaction providing overall better behavior than the intermediate size RE cations in REMS.

9:00 AM

(HTCMC-S5-002-2026) Enhanced CMAS resistance of EBCs using yttrium-silicon-iron oxide APS coating

C. Y. Guijosa Garcia*[1]; E. Garcia Granados[2]; P. Mechnich[1]; V. Venkatachalapathy[2]; S. Sampath[2]; U. Schulz[1]; R. Naraparaju[1]

1. DLR - German Aerospace Center, Institute of Materials Research, Germany
2. Stony Brook University, Center for Thermal Spray Research, USA

Environmental barrier coatings (EBCs) are proven to protect SiC-based materials against recession under water vapor at high temperatures. The state-of-the-art EBCs for CMCs consist of a Si bond coat and an ytterbium disilicate ($Yb_2Si_2O_7$) top coat. However, $Yb_2Si_2O_7$ is known to be susceptible to degradation by molten calcium-magnesium-aluminum-silicate (CMAS) deposits, which would compromise the durability of the SiC-based components. The magnetron sputtered multi-phase yttrium-silicon-iron oxide (YSiFe-O_x) coating has been proved its excellent CMAS resistance by enabling a quick reaction with CMAS, forming a reaction layer consisting of apatite+garnet with a minimum of consumption of the coating. This study aims to develop the multi-phase YSiFe-O_x coating using atmospheric plasma spray (APS) for the first time on top of an APS EBC system (SiC+Si+YbDS). This investigation involved the morphological, chemical, and phase characterization of YSiFe-O_x powder and its coatings. The implementation of YSiFe-O_x as a top coat layer on YbDS required a study of its crystalline behavior (HT-XRD), thermal conductivity (LFA), and coefficient of thermal expansion (dilatometry). Finally, the performance of YSiFe-O_x against CMAS corrosion was evaluated through infiltration experiments y the formation of the reaction products.

9:20 AM

(HTCMC-S5-003-2026) Microstructural and chemical analysis on multilayered sample with PDC coating for high temperature application

I. S. Nurak*[1]; A. Pundt[1]; Y. Eggeler[2]

1. Karlsruher Institut fur Technologie, IAM-WK, Germany
2. Karlsruher Institut fur Technologie, LEM, Germany

The main focus of this work is to gain a fundamental understanding of the structural and chemical evolution of composite materials, depending on the specific synthetic routes used and the additional thermal treatments to tailor the intrinsic properties. Therefore, different electron microscopy techniques will be applied to (i) polymer-derived ceramic nanocomposites coatings, (ii) ultra-high temperature structural silicides MoSiTi substrate and (iii) Cr bond coat layer. In this present work MoSiTi-Cr-Si(Hf, Ta)BCN(O) multilayer system will be investigated. The samples are heat treated at 1200°C and 1400°C in air and argon atmosphere. All materials studied will be first imaged via SEM and conventional TEM techniques to study interface structure and local nanocrystalline precipitates. The authors acknowledge the funding of Deutsche Forschungsgemeinschaft (DFG) in the frame of the MatCom-ComMat project (GRK 2561).

9:40 AM

(HTCMC-S5-004-2026) Next-generation sol-gel protective coatings against high-temperature oxidation for aeronautic applications

B. Toury*[1]; L. Lager[3]; S. BENAYOUN[2]; J. Delfosse[3]; S. Senani - de Monredon[3]

1. Universite Claude Bernard Lyon 1, Laboratoire des Multimatériaux et Interfaces, France
2. école centrale de Lyon, France
3. Safran SA, France

Environmental barrier coatings (EBCs) are essential for protecting CMCs in HT environments, particularly in the context of next-generation aircraft engines. Extending this technology to metallic substrates, such as titanium alloys, offers an opportunity to enhance their HT performance while laying the groundwork for future adaptation to CMCs. In this study, we designed and synthesized a HT anti-oxidizing coating using a sol-gel process, focusing on titanium alloysubstrates, commonly used for engine parts, and that suffer a significant reduction in mechanical properties, due to oxide layer formation when used at HT without any protection. This approach enables the direct deposition of sol onto complex-shaped substrates, with precise control over the coating's stoichiometry. The main issue encountered is linked to the formation of cracks within the coating. To improve their mechanical integrity, an extensive investigation was conducted. Two complementary strategies were explored: (i) tailoring the sol viscosity to reduce internal stresses during gelation and densification and (ii) optimizing the surface preparation of the substrate via activation or specific texturing routes to enhance adhesion and minimize stress concentrations. Initial oxidation tests demonstrated the promising protective behavior of these coatings and their potential for applications in HT environments.

10:20 AM

(HTCMC-S5-005-2026) Alumina-titania-based coatings for oxide/oxide ceramic matrix composites

P. Mechnich*[1]

1. DLR - German Aerospace Center, Institute of Frontier Materials on Earth and in Space, Germany

Protective coatingy play a crucial role for the application of oxide ceramic matrix composites in demanding, harsh environments. Thermal as well as mechanical loads, such as erosion and wear, can substantially attack oxide/oxide CMC with porous matrices. As manufactured CMC typically exhbit inhomogeneous surfaces with free-standing fibers and mattrix-rich areas in-between. In particular the porous matrix areas are prone to mechanical attack e.g. by particle erosion. In a conceptual study, oxide/oxide CMC based on woven fabrics were manufactured by accuum-assisted slurrry infiltration. After firing, model wear-resistant coantings in the system Al2O3-TiO2 were deposited on CMC surfaces by thermal spraying processes. Key coating/CMC properties auch as microstructures, adhesion, interface properties are analyzed and the potential for protection oxide/oxide CMC system is discussed.

10:40 AM

(HTCMC-S5-006-2026) Deposition of ultra-high temperature ceramics by hybrid aerosol deposition (Invited)

K. Shinoda*[1]; T. Ghara[1]; T. Nagoshi[1]; S. Kuroda[1]

1. National Institute of Advanced Industrial Science and Technology (AIST), Core Manufacturing Technology Research Institute, Japan

Ultra-high temperature ceramics (UHTCs) have melting points exceeding 3000 °C, which can cause some issues such as sublimation, oxidation, and composition drift during rapid heating when they are deposited by conventional methods such as plasma spraying. Meanwhile, solid-state particle kinetic spray deposition, such as aerosol deposition and hybrid aerosol deposition (HAD), potentially enables deposition unaffected by these factors because heating of the raw material particles is limited. Therefore, this study investigated the feasibility of UHTC coating formation using an HAD process. As the UHTC materials, ZrB_2 and ZrC were sprayed and deposited by HAD. The results will be compared with SiC deposition by HAD. Further comparison with UHTC coatings sprayed by conventional plasma spray deposition will also be discussed.

HTCMCS5- Interface phenomena, adhesion and interfacial properties

Room: Silver Pearl 2/3
Session Chair: Peter Mechnich, DLR - German Aerospace Center

11:10 AM

(HTCMC-S5-007-2026) Mechanisms controlling the failure resistance of high entropy alloys to static and cyclic oxidation conditions (Invited)

J. Liu*[1]

1. University of Alberta, Canada

Will the vast compositional space of high entropy alloys (HEAs) be designed so as to achieve excellent failure resistance under extreme thermo-mechanical-environmental conditions? Transition-metal HEAs have been found to have comparable oxidation mass gain rates as Fe and Ni superalloys, but are better than refractory HEAs. Nevertheless, when subjected to cyclic oxidation conditions, they suffer the same, if not worse, susceptibility to rumpling or debonding induced failures of the thermally grown oxide (TGO) layer. As the first hypothesis, it is anticipated that tuning the Cr-to-Al ratio can lead to the formation of "stress domains" in TGO, thus relaxing the growth stress and delaying the rumpling or debonding failure. The second hypothesis bridges the static/cyclic conditions to a substrate stress field that arises from the coupling among creep, oxidation, and diffusion processes. Using a model transition metal HEA, Fe20Co20Ni20Cr20Cu20-xAlx (at. %; x=0,5,10), under 900 and 1000 °C, we have identified the systematic change of failure modes with respect to x and isothermal vs thermal cycle (1 hr hold time) conditions. These experimental findings agree favorably with our theoretical analyses of rumpling, debonding, and stress domains, which help delineate a "failure mechanism map".

11:40 AM

(HTCMC-S5-008-2026) Evaluation techniques of interface toughness for environmental barrier coatings on ceramic matrix composites (Invited)

H. Kakisawa*[1]

1. Busshitsu Zairyo Kenkyu Kiko, Japan

Techniques for evaluating interface toughness for environmental barrier coatings (EBCs) on ceramic matrix composited (CMCs) are introduced. Considering the weak interlaminar shear and tensile strength in CMC substrate and the phase angle expected at the interface crack tip in EBC/CMC systems, two interface toughness tests of tension-rich and shear-rich ones are designed so that little load can be applied to CMC substrate in the interlaminar direction for avoiding substrate fracture prior to the intended interface fracture. For the tension-rich test, asymmetric double cantilever beam specimen is prepared and a notch machined along the interface is opened by inserting a wedge in it. For the shear-rich test the CMC substrate is embedded in a support jig and only the coating is shear-loaded by a punch. Examples of application of the tests to the evaluation of changes in EBC/CMC interface toughness during the heat exposure are also shown.

HTCMC-12 Symposium 7- Materials for Extreme Environments – UHTCs, MAX phases, and nanolaminates

HTCMCS7- Processing-microstructure-property relationships of existing or new systems I

Room: Osprey
Session Chair: Yoonjoo Lee, Korea Institute of Ceramic Engineering and Technology

8:30 AM

(HTCMC-S7-022-2026) Mechanistic insights in shear, delamination and kinking in MAX phases (Invited)

M. Radovic*[1]; A. Srivastava[1]; M. Dujovic[1]; H. J. Rathod[1]; Z. Zhan[1]; S. Celik[1]

1. Texas A&M University, Materials Science and Engineering, USA

MAX phases challenge the conventional description of ceramics because of their unusual and highly attractive combination of properties. This broad class of over 350 compounds shares the chemical formula $M_{n+1}AX_n$ (n = 1–3; M is an early transition metal, A is typically a group 13–16 element, and X is C or N) and features a distinct nanolayered crystal structure in which strongly bonded $M_{n+1}X_n$ layers alternate with relatively weakly bonded A layers. This layered architecture—unique among ceramics—enables a combination of metal-like and ceramic-like behavior, including machinability, thermal shock resistance, and exceptional damage tolerance. TThis lecture will provide mechanistic insights into delamination along basal planes as well as deformation by shear and kink-band formation—processes that govern the complex mechanical response and exceptional damage tolerance of MAX phases. Our recent results on anisotropic deformation and failure mechanisms in MAX single crystals will be highlighted, together with micromechanical testing of micropillars and cantilevers oriented along different crystallographic directions relative to the applied load. The implications of these findings for the mechanical behavior and remarkable damage tolerance of polycrystalline MAX phases will also be discussed.

9:00 AM

(HTCMC-S7-023-2026) High-fidelity 3D microstructural characterization of ZrB_2 during hot-pressing

R. Swanson*[1]; M. Chapman[3]; Y. Zhou[2]; A. Hilmas[3]; L. M. Rueschhoff[4]; M. D. Uchic[3]; W. Fahrenholtz[2]; S. J. McCormack[1]

1. University of California Davis, Materials Science and Engineering, USA
2. Missouri University of Science & Technology, Materials Science and Engineering, USA
3. Air Force Research Laboratory Materials & Manufacturing Directorate, USA
4. Air Force Research Lab, Materials and Manufacturing Directorate, USA

Manufacturing of ultra-high-temperature ceramics (UHTCs) such as ZrB_2 often produces components with widely varying properties, particularly mechanical performance. This variability stems from an incomplete understanding of how processing affects microstructure and how microstructure influences properties. To address this gap, an Integrated Computational Materials Engineering (ICME) framework is being developed to use existing data for improved modeling and accelerated material development, but high-fidelity microstructural data for ZrB_2 remain limited. This work provides detailed 3D microstructural and crystallographic characterization of fully dense ZrB_2 using EBSD mechanical polishing serial sectioning. The results reveal a plate-like grain morphology that becomes more pronounced with increasing grain size, with the shortest-to-longest axis ratio converging to ~0.4. Grain growth occurs orthogonally to the [0001] direction and is independent of applied load. Neighbor grain misorientation angles follow a random distribution. Grain boundary characteristics and the influence of different processing routes on microstructural variation are also presented. These datasets enable more realistic synthetic microstructures for ICME integration and reveal previously unrecognized processing–microstructure relationships, improving the accuracy of multiscale models and guiding more informed processing strategies.

9:20 AM

(HTCMC-S7-024-2026) Low-temperature synthesis of high purity ZrC with controlled carbon stoichiometry

H. Gross*[1]; A. Emdadi[1]; J. Lonergan[1]

1. Missouri University of Science & Technology, Materials Science and Engineering, USA

Emerging interest in hypersonic technologies will require the use of materials able to withstand the extreme temperatures generated during flight (3000°C+). Ultra-high temperature ceramics (UHTCs) are prime candidates for hypersonic applications due to their extremely high melting temperatures (3000°C+). Only certain UHTCs are capable of retained strength for structural applications above 3000°C, among those being ZrC. Traditionally, it has proven difficult to achieve nominally fully dense ZrC. When this feat is achieved, it requires high pressures (50+ MPa) and temperatures (2000°C+) to do so, which may be unattainable in most sintering setups. This work uses a synthesis method that involves a solid-state reaction of zirconium hydride with carbon to form ZrC. Upon sintering, nominally fully dense samples are formed at temperatures as low as 1700°C. A mathematical model will be employed to elucidate the densification mechanism governing this reaction-based processing route. Densification behavior along with intrinsic mechanical and thermal properties will be presented and compared with the values in the literature using other synthesis methods. The separate effects of carbon stoichiometry, oxygen content, and other impurities will be examined.

(HTCMC-S7-025-2026) Synthesis and evolution of ζ-phase vanadium carbide microstructures ***WITHDRAWN***

W. Rubink*[1]

1. Lawrence Livermore National Laboratory Physical and Life Sciences Directorate, Materials Science Dept, USA

Production of high phase fraction ζ-Vanadium Carbide (VC) has proven to be challenging for analysis of bulk properties. It is our intent to develop a process to reliably produce bulk ceramic components of this phase by Spark Plasma Sintering. The nano-lamellar structure of ζ-VC (V_4C_{3-x}) may offer enhanced fracture toughness compared to other vanadium carbide phases, typically in the range of 3–7 MPa√m. Achieving both high strength and fracture toughness at elevated temperatures is important for many applications where metals may be insufficient. To identify conditions that favor ζ-VC as the predominant phase, we evaluated various vanadium and vanadium carbide powders from multiple suppliers, exploring a range of stoichiometries and processing parameters. Continued refinement and optimization of these factors show promise for producing ceramic bodies with a higher fraction of ζ-VC.

HTCMCS7- Processing-microstructure-property relationships of existing or new systems II

Room: Osprey

Session Chair: Sook Young Moon, Korea Institute of Science and Technology

(HTCMC-S7-026-2026) Fabrication of seamless 3D woven ceramic matrix composites via continuous through-thickness architecture (Invited) ***WITHDRAWN***

W. Yu*[1]; J. Yang[1]; Y. Oh[1]

1. Seoul National University, Republic of Korea

Ceramic Matrix Composites (CMCs) reinforced with three-dimensional (3D) woven architectures offer exceptional structural integrity and damage tolerance for extreme environments. However, several challenges remain in the fabrication of 3D woven structures, partic-ularly the difficulty of producing complex geometries without seams and the inherent weaving limits of brittle SiC fibers. Conventional methods for manufacturing complex composites, such as stitching and laminate assembly, often cause fiber breakage, stress concentra-tion, and weak interlaminar strength at joints. To overcome these issues, we developed a 3D weaving process with continuous z-direction fibers that cross seam regions, enabling a seamless, integrally woven structure without secondary joining. By optimizing fiber-path archi-tecture and mold geometry, the preform achieves near-net-shape formation close to final geometries. Nevertheless, the inherent brittleness and low abrasion resistance of SiC fibers hinder their weavability, complicating the fabrication of complex 3D preforms. To address this, a specialized weaving methodology tailored for SiC fibers was established, combined with a protective sizing treatment applied as a pre-processing step. This improves fiber durability and continuity, offering a practical route to seamless SiC 3D woven CMC structures with enhanced mechanical reliability.

9:40 AM

(HTCMC-S7-027-2026) Transformation and crystallization behavior of $HfC_{1-x}N_x$ in a polymer-derived SiC matrix (Invited)

Y. Lee*[1]

1. Korea Institute of Ceramic Engineering and Technology, Republic of Korea

In this study, we prepared a hybrid precursor by copolymerizing polycarbosilane (PCS) with a previously developed hafnium-containing precursor. This approach allows for molecular-level mixing of hafnium species within a silicon-based polymer network. The hafnium precursor, derived from amines, is designed to form a hafnium carbide (HfC) phase during pyrolysis. Meanwhile, the PCS component converts into a carbon-rich silicon carbide (SiC) matrix, creating a chemically homogeneous environment that facilitates phase evolution. During thermal treatment, the hafnium precursor initially produces a cubic $HfC_{1-x}N_x$ phase, attributed to nitrogen from the amine groups. As the temperature increases, the carbon-rich SiC matrix encourages nitrogen depletion and the incorporation of carbon into the hafnium-based phase. This process drives the compositional evolution toward stoichiometric HfC and promotes concurrent crystallization. Thus, this work elucidates the transformation and crystallization behavior of $HfC_{1-x}N_x$ within a polymer-derived SiC environment and examines how these heterogeneous phases influence crystal growth.

10:30 AM

(HTCMC-S7-028-2026) Optimisation of the impregnation slurry for the development of Ultra-High-Temperature Ceramic Matrix Composite (UHTCMC)

F. Courjault*[1]; J. Petit[1]; A. DeBarre[1]; A. Julian Jankowiak[1]; N. Brard[2]

1. Office National d'Etudes et de Recherches Aerospatiales, DMAS, France
2. MBDA Holding SAS, France

Propulsion, atmospheric re-entry and hypersonic applications require materials that can withstand temperatures over 2273K in an oxidizing atmosphere. In collaboration with MBDA, ONERA works on the development of an Ultra-High Temperature Ceramic Matrix Composite (UHTCMC) combining the good properties of UHTC ceramics with the damage tolerance required in a composite structure. In order to enhance the mechanical properties and the oxidation resistance of the material, it is necessary to improve the impregnation slurry. To achieve this, the grain size of the HfB_2 powders and the slurry must be optimised. Various grinding cycles have been tested and the grain size of the powders during grinding was monitored to achieve a D_{50} under 1μm. An in-depth study of aqueous slurries has been carried out using different solid loading of Polyethyleneimine (PEI) dispersant and different solid loading of HfB_2 powder. During the impregnation, the slurry's stability and viscosity impacts the infiltration effect. Poor slurry stability reduces the uniformity of the impregnation while high slurry viscosity causes the ceramic particles to accumulate in the surface layer of the fibres. To prevent processability issues, the infiltration of the slurry at the fibre core have been observed by SEM analysis.

10:50 AM

(HTCMC-S7-029-2026) Dynamic oxidation resistance and thermal properties of additive-free SiC ceramics and CVD-SiC

O. Hanzel*[1]; M. Tatarkova[1]; Z. Netriová[1]; M. Hicak[1]; P. Sajgalik[1]

1. Ustav anorganickej chemie Slovenska akademia vied, Slovakia

Fully dense (t. d. > 99 %) SiC ceramics without traditional sintering additives were successfully prepared by combination of freeze granulation of SiC powder, annealing of granulated powder and subsequent rapid hot pressing at 1900°C with dwell time from 5 to 80 minutes under a uniaxial pressure of 70 MPa in vacuum. Thermal properties and microstructure of additive-free SiC with various α/β content has been investigated. The thermal diffusivity of SiC ceramics increased from 47.3 to 68.4 mm^2/s with increasing holding time at sintering temperature and therefore increasing α-SiC content from 63 to 94 % as well as increasing grain size. The highest thermal conductivity (λ=165 W/m.K) among the SiC ceramics sintered at temperatures T ≤ 1900°C was achieved for additive-free SiC sintered at 1900°C under vacuum for 80 minutes. In addition, such prepared materials were tested in oxy-acytelene torch at 1700°C, 1800°C and 1900°C for 300 seconds. In the dynamic regime the additive-free SiC ceramics survived 1900 °C for 5 minutes. For comparison, as a benchmark, CVD bulk SiC samples were dynamically oxidized/ablated at the same conditions. It seems that these materials are suitable for ultra-high-temperature applications. Acknowledgments This work was financially supported by the VEGA Project No. 2/0094/25 and by the Slovak Research and Development Agency under the Contract No. APVV-24-0442.

HTCMC-12 Symposium 8- Testing and Evaluation of Ceramic Matrix Composites from Constituents and Coupons to Components, including EBCs

HTCMCS8- Fracture mechanics, failure analysis and fractography

Room: Pelican
Session Chairs: Takuya Aoki, Japan Aerospace Exploration Agency; Sung-Min Lee, Korea Institute of Ceramic Engineering and Technology (KICET)

8:30 AM

(HTCMC-S8-023-2026) Cf–SiC composites for high-temperature structural and hypersonic applications (Invited)

U. Andi*[1]

1. CSIR National Aerospace Laboratories, Materials Science Division, India

Carbon fibre Reinforced silicon carbide (Cf/SiC) composites are widely used in advanced applications such as space vehicle components, hypersonic structures, thermal protection systems and braking systems for aircraft and high-speed transport due to their high specific strength and modulus, excellent high temperature mechanical performance and favourable tribological properties. Chemical Vapour Infiltration (CVI) generated Cf/SiC composites suffer from limitations such as thickness constraints, residual porosity and high costs. To address these challenges, hybrid processing routes combining CVI with Polymer Impregnation and Pyrolysis (PIP) and Liquid Silicon Infiltration (LSI) have been developed. Cf/SiC composites produced via CVI and hybrid routes were characterised for their mechanical, thermal, thermomechanical and tribological behaviour and the results are presented. To enhance robustness and reliability, a multi-level protective architecture was developed, comprising a multilayer interphase, a self-healing Si–B–C matrix and an external SiC seal coating. The oxidation resistance and mechanical performance of these composites at elevated temperatures were evaluated and discussed. In addition, 2.5D Cf/SiC composites coated with ultrahigh-temperature ceramics (UHTCs) such as TaC and ZrB2 were investigated under hypersonic erosion conditions and the key findings are presented.

9:00 AM

(HTCMC-S8-024-2026) Analytical model for the static tensile behavior of cross-ply ceramic matrix composites

D. Haruyama*[1]

1. IHI Corporation, Japan

The increasing application of ceramic matrix composites (CMCs) in aircraft engine components has contributed to enhanced fuel efficiency. Accurate prediction of structural strength and a comprehensive understanding of failure mechanisms require precise modeling of the microscopic structure and micro-damage in CMCs, along with reliable estimates of their mechanical behavior. In this study, cross-ply CMCs were investigated, aiming to accurately characterize material responses such as stress-strain behavior and crack growth. An analytical model was developed to describe matrix crack accompanied by fiber-matrix interfacial debonding, as well as transverse crack growth. The random crack growth calculations were performed using Monte Carlo simulations. Consequently, the model demonstrated a high degree of similarity with the crack density observed in experimental tests. Furthermore, an analytical model was constructed by combining a periodic crack growth model, which is equivalent to the random crack growth model, with a fiber fracture model. The stress-strain relationships calculated with this model showed good agreement with experimental results, thereby validating the proposed modelling approach and underscoring its practical applicability.

9:20 AM

(HTCMC-S8-025-2026) Temperature-dependent fracture toughness of monolithic alumina evaluated by the disk-compression method *WITHDRAWN*

N. D. Parolini*[1]; A. K. Singh[1]

1. Baylor University, Baylor University, Waco, TX, US, academic, Mechanical Engineering, USA

The disk compression test method is used for the evaluation of mode I and mode II fracture toughness of densified monolithic alumina. A central crack was introduced in the disk, with tests for the different fracture toughness modes performed by changing the orientation of the disks. Fracture toughness tests were performed at temperatures ranging from room temperature to 1200 degrees Celsius. In-situ digital image correlation was used to acquire full field displacement and strain data for tests under all the temperature conditions. Since alumina is resistant to oxidation, the observed material response trends are based on purely thermal effects. Post-test fractography was performed using state-of-the-art microscopy techniques to evaluate the traversing path of fracture through the material. Numerical simulations were performed and validated with experimental results. The paths of fracture were consistent with the mode of fracture toughness test and thus validated the test method. A reduction in fracture toughness was observed with increasing temperature, potentially due to the combined effects of residual stress and thermal expansion. The numerical simulation results corroborated well with the experimental predictions.

9:40 AM

(HTCMC-S8-026-2026) Fabrication conditions to enhance mechanical properties and high-temperature oxidation resistance of FB-SiC/SiC composites

S. Teshima*[1]; T. Kondo[1]; S. Inoue[1]; Y. Kubota[2]; M. Uda[2]; K. Abe[3]; K. Kishimoto[4]; A. Hosoi[1,5]; H. Kawada[1,6]

1. Waseda University, Japan
2. KENQ, INC., Japan
3. IHI AEROSPACE Co.,Ltd., Japan
4. Trade Service Corporation, Japan
5. Kagami Memorial Research Institute for Materials Science and Technology, Japan
6. Kanazawa Institute of Technology, Japan

SiC/SiC composites are lightweight and highly heat-resistant; however, conventional matrix fabrication methods require long processing times, resulting in high manufacturing costs that limit their wider application. This study examines the effects of fabrication conditions on the mechanical properties and microstructure of SiC/SiC composites fabricated by the film boiling method, enabling shorter processing times and lower costs. We call this material FB-CMC. Results show that controlled heating and cooling cycles form a layered matrix structure, improving mechanical properties via crack deflection. Furthermore, appropriate interfacial treatment was found to be essential for achieving sufficient mechanical strength. To enhance the applicability of FB-CMC in high-temperature environments, high-temperature oxidation resistance was examined. Cosmo Coat composed of multi-element metal oxides was applied as a thermal/environmental barrier coating (T/EBC), effectively suppressing oxygen ingress and interfacial degradation, thereby reducing the degradation of mechanical properties. In addition, Cosmo Coat systems incorporating inorganic modifiers were also designed. Arc wind tunnel tests were conducted to evaluate protective performance under extreme environments, providing insight into oxidation behavior and optimization of fabrication conditions.

HTCMCS8- Testing and Evaluation of Ceramic Matrix Composites

Room: Pelican

Session Chairs: Dong Liu, University of Oxford; Gerard Vignoles, University Bordeaux

10:20 AM

(HTCMC-S8-027-2026) Boron nitride nanotube modified ox-ox cmcs: Processing, microstructure, and physical properties (Invited)

E. Vargas[4]; W. Simpson*[1,2]; L. R. Scammell[3]; M. G. Simpson[5]; S. Fast[5]; T. Henneberg[3]

1. Axiom Materials Inc, Technical, USA
2. University of California Irvine, Material Science & Engineering, USA
3. BNNT Materials, Applications, USA
4. University of Southern California, Materials Science and Engineering, USA
5. 3M Company, Advanced Materials, USA

Oxide-oxide ceramic matrix composites (Ox-Ox CMCs) are increasingly used in aerospace and thermal protection applications due to their oxidation resistance and damage tolerance. These composites typically rely on porous matrices and weak fiber-matrix interfaces to deflect cracks and prevent brittle failure. However, many applications, such as TPS face sheets, RF windows, and combustor liners, require not only mechanical resilience but also tailored thermal conductivity. Recent studies have shown that thermal conductivity in Ox-Ox CMCs can be directionally tuned through matrix composition and fiber architecture. The addition of boron nitride nanotubes (BNNTs) offers a pathway to modify heat flow while maintaining structural integrity. This work investigates BNNTs as processing additives in an aluminoborosilicate fiber-aluminosilicate matrix system. BNNTs were dispersed in isopropyl alcohol and directly added in varying volume percent ratios to a solvent-based slurry to affect the thermal and mechanical behavior of Ox-Ox CMCs. By establishing a processing-microstructure-property relationship, we aim to provide a framework for designing application-specific thermal management solutions. A compact Taguchi L9 design varied total solids, solvent volatility, plasticizer balance, and particle ratio to decouple dispersion, drying stresses, and packing effects from BNNTs.

10:50 AM

(HTCMC-S8-028-2026) Damage evolution during mechanical loading of oxide composites by X-ray tomography, acoustic emission and machine learning

R. S. Almeida*[1]; J. Horvath[1]; K. Tushtev[1]; K. Rezwan[1]

1. University of Bremen, Germany

Ceramic matrix composites (CMCs) show enhanced fracture toughness due to different damage mechanisms, such as: matrix cracking, fiber debonding, fiber breakage and fiber pullout. Thus, understanding these mechanisms is crucial for the further development of these composites. In this work, we investigate crack propagation in an oxide CMC using in-situ X-ray microscope computer tomography (XRM-CT) and acoustic emission monitoring (AE). XRM-CT scans were performed at different stress stages while AE monitoring was performed continuously during tensile testing. In order to quantify the different types of damage, XRM-CT scans were segmented using an U-net deep learning model, whereas AE signals classification was performed by a supervised machine learning model. AE signals are detected at early stages of loading, indicating that damage starts at low stresses. However, significant increase in crack volume is only observed at higher stresses. As loading progresses, different crack patterns along matrix and fiber regions are observed in the XRM-CT scans and are associated with the aforementioned mechanisms. While XRM-CT provides important information such as damage location, crack patterns and total crack volume, AE can be used to quantify the time development, frequency and intensity of each damage mechanism.

11:10 AM

(HTCMC-S8-029-2026) Enhancing CMAS corrosion resistance of ytterbium-aluminum garnet by secondary phase addition

N. Yamazaki*[1]; T. Nakamura[1]; S. Kitaoka[2]; M. Tanaka[2]; t. Yamamoto[3]

1. IHI Corporation, Japan
2. Japan Fine Ceramics Center, Japan
3. Nagoya Daigaku, Japan

In the aerospace industry, improving fuel efficiency in aircraft engines is crucial due to climate change and the need to reduce greenhouse gas emissions. Advanced heat-resistant materials like Ceramic Matrix Composites (CMCs) are important because of their durability and high-temperature performance. However, developing reliable Environmental Barrier Coatings (EBCs) to protect CMCs from corrosive high-temperature environments remains a challenge. A major threat is degradation from CMAS, which enters engines as sand, volcanic ash, or dust, melts on hot components, and reacts with EBCs, causing rapid deterioration and damage. This study focused on garnet crystal structures, which can incorporate CMAS into their lattice, suggesting garnet-type materials could improve EBC durability. We investigated oxide materials that form garnet upon reacting with CMAS and tested if adding a secondary phase accelerates garnet formation during CMAS exposure. The hypothesis was that faster garnet formation would consume CMAS more effectively and enhance resistance to corrosion. Our results showed that the developed materials had excellent resistance to CMAS attack. Even after prolonged exposure at high temperatures, corrosion and degradation were minimal. These findings demonstrate that promoting rapid garnet formation is highly effective in mitigating CMAS-induced damage.

11:30 AM

(HTCMC-S8-030-2026) EBC coated ceramic matrix composite (CMC) thermal mismatch parametric study via combined DIC and finite element analysis

A. Abdul-Aziz*[2]; M. Onifade[2]; R. I. Webster[1]

1. NASA Glenn Research Center, USA
2. Kent State University, Aerospace, USA

Environmental Barrier Coating (EBC) systems enable ceramic matrix composites (CMCs) to function in high-temperature aerospace environments; however, thermal expansion mismatch between multilayer coatings and CMC substrates drives residual stress, crack initiation, and spallation. This study analyzes the thermo-mechanical response of a ten-layer EBC–CMC system using a three-dimensional ANSYS finite element model of an EBC-coated dogbone specimen. Layer-wise, temperature-dependent material properties were incorporated. A uniform thermal cooldown from 1482 °C to 38.7 °C simulated residual stresses associated with processing and service. Stress metrics evaluated include in-plane stresses related to vertical cracking, out-of-plane (peel) stresses, interfacial shear stresses governing delamination, and maximum principal stresses controlling tensile crack initiation. Predictions were validated against full-field surface strain measurements obtained via digital image correlation (DIC), showing strong agreement in strain evolution and localization. A secondary cooldown at 1427 °C produced comparable stress distributions, confirming robustness. Results demonstrate that thermal mismatch–induced stress concentrations dominate durability and highlight the effectiveness of an integrated DIC–FE framework for multilayer EBC durability assessment and optimization.

HTCMC-12 Symposium 10- CMC Applications I – Aerospace Propulsion and Structures

HTCMCS10- Design and Testing of CMC Components for Aerospace Applications III

Room: Shorebreak 1

Session Chair: Sungbo Shim, Rolls-Royce plc

8:30 AM

(HTCMC-S10-017-2026) Thin walled and light weight all oxide ceramic matrix composites (OCMC) structures for a novel propulsion system- a long development story (Invited)

W. Pritzkow*[1]; V. Dosch[1]; F. Wehner[1]; A. Evulet[2]

1. Walter E.C. Pritzkow Spezialkeramik, Germany
2. Jetoptera Inc, USA

Jetoptera has developed a Fluidic Propulsion System (FPS®) for Unmanned Aerial Vehicles (UAVs) for vertical take-off and landing (VTOL). This system uses augmenting thrusters, connected to a gas generator producing up to 800°C exhaust gas. These thrusters become very light when constructed of low density of OCMC, at 2.8 g/cm^3. Weight and temperature needs make OCMC the only option with parts using a wall thickness of less than 2mm. Since 2017, Walter E.C. Pritzkow Spezialkeramik began developing propulsion thrusters for Jetoptera from OCMC, with all structures being thin walled and as light as possible, resulting in several successful flights on three different aircraft, currently used by Jetoptera as a Flight Test Beds. The 2025 DARPA LIFT Challenge aims to prove a VTOL can lift a payload twice its weight. The challenge requirements include a weight of less than 25kg and a mission is to carry a payload of 50kg for 4 nautical miles with payload and an additional 1 nm without payload. The requirements mean that the engine system must weigh less than 4,5 kg excluding the gas generator and manifold valving. The only option is to combine all previous developments and build an extremely complex large OCMC manifold and thrusters system with wall thicknesses of less than 1mm. We are presenting our results.

9:00 AM

(HTCMC-S10-018-2026) Towards Space Rider Flight Readiness: Development, qualification, and production of C/SiC based thermal protection system (Invited)

M. De Stefano Fumo*[1]

1. Centro Italiano Ricerche Aerospaziali, Italy

SPACE RIDER is a program led by the European Space Agency aimed at developing a cost-effective, independent, and reusable space transportation system, enabling regular access to and from Low Earth Orbit. Following its orbital mission, the vehicle is designed to re-enter the atmosphere and land safely on a precise spot, where it can be unloaded and refurbished for subsequent flights. To enable these capabilities, the spacecraft requires a Thermal Protection System (TPS) capable of withstanding the extreme thermal and mechanical loads encountered during atmospheric re-entry. The Ceramic TPS, designed by the Italian Aerospace Research Centre (CIRA), is based on the proprietary C/SiC composite, ISiComp®, developed in partnership with Petroceramics Spa. CIRA is responsible for all steps of development, manufacturing, testing, and final integration of TPS components onto the flight vehicle. The SPACE RIDER program is presently at the end of the qualification phase, and the manufacturing of the flight models is ongoing. This talk summarizes the development steps, manufacturing routes, and qualification activities for all TPS components, including the status of flight model manufacturing towards integration onto the spacecraft for system qualification activities and the maiden flight foreseen by the end of 2027.

9:30 AM

(HTCMC-S10-019-2026) Feasibility evaluation of a SiC/SiC stand-off thermal protection system

Y. Kubota*[1]; K. Abe[2]; T. Kondo[3]; K. Kishimoto[4]; M. Uda[1]; H. Kawada[3]

1. KENQ, INC., Japan
2. Kabushiki Kaisha IHI Aerospace, Japan
3. Waseda Daigaku, Japan
4. Trade Service Corporation, Japan

SiC/SiC ceramic matrix composites (CMCs) are used in aircraft-engine hot sections and are promising for reusable thermal protection systems (TPS). Unlike many stand-off TPS studies centered on C/C–SiC or C/SiC, we assess SiC-fiber-reinforced SiC/SiC for improved oxidation-tolerant reusability. A 1D transient heat-conduction model with hot-face radiation and cold-side convection compares a tile TPS and a stand-off concept with a CMC skin, quantifying the thermal-resistance shares of the skin, insulation, and cavity and confirming thermal feasibility under the same reentry-like heat-flux history. Using the tile TPS as a baseline, target system areal density and life-cycle cost are estimated under stated assumptions and used to gauge feasibility of a SiC/SiC stand-off architecture, including manufacturing and process considerations. To support the reuse assumption, film-boiling-processed SiC/SiC coupons with a carbon interphase, with and without a protective coating (Cosmo Coat), were exposed twice in an arc-heated wind tunnel at 1.3 MW/m^2 for 30 s each. Post-test flexural strength showed no degradation relative to unheated references. Although the number of thermal cycles remains limited and further testing is required to resolve coating effects, the results demonstrate the absence of strength degradation after repeated short-duration high-enthalpy exposures.

HTCMC-12 Symposium 11- CMC Applications II – Solar, Nuclear and Propulsion Systems

HTCMCS11- SiC CMC for nuclear applications II

Room: Sandpiper D

Session Chair: Benjamin Lamm, Oak Ridge National Laboratory

8:30 AM

(HTCMC-S11-019-2026) Revolutionizing nuclear safety: SiC ceramic matrix composites research and development at Idaho National Laboratory (Invited)

P. Xu*[1]; S. Gonderman[2]; S. Oswald[3]

1. Idaho National Lab, USA
2. General Atomics, USA
3. General Atomics Electromagnetic Systems Group, Nuclear Technologies and Materials, USA

Silicon Carbide (SiC) ceramic matrix composites (CMCs) are at the forefront of next-generation accident-tolerant fuel (ATF) technologies for light water reactors. Their exceptional high-temperature oxidation resistance, irradiation tolerance, and robust performance under accident scenarios make them a transformative solution for enhancing nuclear fuel safety and maximizing power outputs. Idaho National Laboratory (INL), in partnership with General Atomics, is leading a comprehensive R&D program to accelerate the deployment of SiC-based ATF. Our work integrates advanced irradiation testing, post-irradiation examination (PIE), and cutting-edge characterization to elucidate SiC CMC behavior under both nominal and extreme conditions. These results are critical for validating in-core performance, informing the design of Lead Test Rods (LTRs), and enriching the data ecosystem that supports high-fidelity modeling, predictive analytics, and AI-driven fuel design. This presentation will highlight key findings from our ongoing R&Ds and discuss the implications for the future of nuclear fuel innovation. This work represents a pivotal step towards safer, more economical and resilient nuclear energy systems.

9:00 AM

(HTCMC-S11-020-2026) Effect of outer coating thickness on the deformation and fracture of a SiC-based nuclear-fuel cladding at 1200°C

G. Yuan[2]; E. J. Lahoda[4]; M. Ukai[5]; T. Takada[5]; P. Xu[3]; D. Liu*[1]

1. University of Oxford, Engineering Science, United Kingdom
2. University of Bristol, Physics, United Kingdom
3. Idaho National Lab, USA
4. Westinghouse Electric Company LLC, USA
5. Toshiba Energy Systems & Solutions Corporation, Isogo Nuclear Engineering Centre, Japan

Nuclear-grade continuous SiC fibre reinforced SiC matrix composites (SiC_f-SiC_m CMCs) coated with SiC outer coating are widely considered as a possible design of accident-tolerant fuel (ATF) cladding material in advanced light water reactors. In this work, the mechanical behaviour of a SiC_f-SiC_m cladding material with a dual-layer outer SiC coating and 2D fibre braided SiC CMC substrate was investigated at room temperature (RT) and 1200°C in an inert gas (argon) environment under C-ring compression loading. The failure processes were studied by in situ X-ray micro-computed tomography (XCT) scans captured at increasing loading steps. The variation of local properties across coating thickness is investigated. The outcomes of this study can be used to optimise the design of SiC CMC-based ATF cladding materials.

9:20 AM

(HTCMC-S11-021-2026) Extrusion-based processing of high-purity silicon carbide for nuclear applications

S. Kondo*[1]; D. Miura[2,1]; H. Yu[1]; Y. Ogino[1]; R. Kasada[1]

1. Tohoku University, Institute for Materials Research, Japan
2. Tohoku Daigaku, Department of Quantum Science and Energy Engineering, Graduate School of Engineering, Japan

Silicon carbide fiber–reinforced silicon carbide (SiC/SiC) composites are regarded as promising structural materials for advanced nuclear systems, including reactor fuel structures and fusion blanket components. In particular, high-temperature gas-cooled reactors and compact fusion concepts require components with complex geometries, which place strong constraints on both processing routes and material purity. In this study, we have developed an extrusion-based processing route for the fabrication of dense, high-purity SiC without the use of sintering aids or post-infiltration treatments. Using this approach, laboratory-scale prototype components of monolithic SiC were fabricated while maintaining a high level of chemical purity, which is a critical requirement for irradiation environments. Furthermore, this processing route was extended to SiC/SiC composites by incorporating short SiC fibers into the SiC-based feedstock. The feasibility of extrusion-based processing for producing dense, high-purity SiC/SiC composite structures is demonstrated, and representative results obtained from this material system are reported. This processing strategy offers a potential pathway toward the fabrication of complex-shaped SiC-based components for nuclear applications.

9:40 AM

(HTCMC-S11-022-2026) Advancing SiC composite tube processing and non-destructive evaluations for nuclear applications

T. Koyanagi*[1]; D. Richardson[1]; A. Rogers[1]; B. W. Lamm[2]; E. Cakmak[2]; J. D. Arregui-Mena[3]

1. Oak Ridge National Laboratory, USA
2. Oak Ridge National Laboratory, Materials Science & Technology Division, USA
3. Oak Ridge National Lab, Nuclear Materials Science & Technology Group, USA

A hollow tube structure of a SiC fiber-reinforced SiC matrix composite has been proposed for subcomponents of core structures in advanced nuclear fission and fusion energy systems. Fabricating high-quality components for these applications requires precise

dimensional control, cost-effective manufacturing, and process consistency, while still meeting thermo-physical property requirements. To advance current processing technologies to meet these needs, this work explores the application of advanced manufacturing and characterization methodologies. The composite system consisted of crystalline, near-stoichiometric SiC fibers, a pyrolytic carbon interphase, and a SiC matrix deposited via chemical vapor infiltration. SiC fiber winding on an additively manufactured SiC tube substrate enabled a smooth inner surface finish and precise control of the inner diameter. Newer grades of SiC fibers were evaluated to enhance the ultimate strength of the composites. AI-assisted X-ray computed tomography analysis of the tube materials reduced turnaround times for detecting processing-induced cracks and microporosity, as well as for assessing dimensional accuracy in manufacturing. Finally, an optimization framework for SiC tube processing is discussed.

HTCMCS11- Effects of operating environment on microstructure, physical and mechanical properties

Room: Sandpiper D
Session Chair: Takaaki Koyanagi, Oak Ridge National Laboratory

10:20 AM

(HTCMC-S11-023-2026) Neutron-induced radioactivity and response to atomic displacement damage of CB/BN particles dispersed SiC fabricated by liquid-phase sintering (Invited)

B. Huang*[1]

1. Sun Yat-Sen University, China

Advantages inherent in SiC such as high strength and chemical inertness at high temperatures, exceptional stability in high-radiation environments, low induced-activation, low after-heat properties, along with greatly increased damage tolerance offered by SiC fiber-reinforced SiC composites (SiCf/SiC composites), making SiCf/SiC composites extremely attractive for future nuclear energy systems. Basically weak fiber/matrix interphase materials such as carbon (C) or boron nitride (BN) is required for SiCf/SiC composites. Precise control of the interphase material, however, is a critical issue in terms of large scale production and material cost. In addition, the interphase material is the weakest point for the environmental effects. To overcome these problems, the carbon black (CB) and hexagonal boron nitride (h-BN) particles dispersed silicon carbide (SiC) composites without interphase materials have been developed and have displayed promising mechanical properties and oxidation resistance. In this study, neutron-induced radioactivity and response to atomic displacement damage of CB/BN particle dispersed SiC materials prepared by liquid-phase sintering (LPS) will be reported.

10:50 AM

(HTCMC-S11-024-2026) Effects of high dose neutron irradiation at light water reactor-relevant temperatures on the mechanical properties of SiC/SiC composites

Y. Jimba*[1]; T. Koyanagi[1]; Y. Katoh[1]

1. Oak Ridge National Laboratory, USA

Neutron irradiation effects on thermomechanical properties of SiC/SiC composites are critical for assessing their feasibility and lifetime in accident-tolerant core structures of light water reactors (LWRs). A knowledge gap currently exists regarding the transitional processes in radiation-induced thermomechanical degradation at high neutron doses. To capture the processes and identify the underlying mechanisms, grades of nuclear grade chemical vapor-infiltrated SiC/SiC composites with different interface microstructures were irradiated up to 30 displacements per atom (dpa) at the High Flux Isotope Reactor at Oak Ridge National Laboratory. Flexural testing, dimensional measurement, and thermal diffusivity analysis showed irradiation-induced changes saturated over the dose range of 2–30 dpa for certain composite materials. However, the retention of mechanical properties differed from degradation behavior reported in the literature for similar SiC/SiC composites. The discrepancy is discussed based on numerical analysis on irradiation-induced stress evolution informed by Raman spectroscopy analysis of carbon interphase in the as-fabricated composites. Finally, radiation-resistance interphase microstructure will be discussed. This work was supported by US DOE Office of Nuclear Energy, Advanced Fuels Campaign.

11:10 AM

(HTCMC-S11-025-2026) Spatially-resolved microscale thermal conductivity measurements of ion-irradiated SiC/SiC CMCs for fusion applications

D. M. Cogbill*[1]; A. J. Leide[2]; J. Pomeroy[1]; A. Sarua[1]; J. Wade-Zhu[2]; D. Liu[3]

1. University of Bristol, School of Physics, United Kingdom
2. UKAEA, Materials Division, United Kingdom
3. University of Oxford, Department of Engineering Science, United Kingdom

Silicon carbide fibre reinforced silicon carbide ceramic-matrix composites (SiC/SiC CMCs) are a leading candidate material for fusion reactor structural components, due to their superior thermo-mechanical and radiation-tolerant properties at high temperature (≤1000°C). This work comprises the first spatially-resolved microscale thermal conductivity mapping measurements of ion-irradiated SiC/SiC CMCs, allowing individual fibre measurements to be performed within an ion-irradiated layer and compared to the unirradiated state, via time-domain thermoreflectance (TDTR). Finite-element modelling indicates that the sub-fibre radius resolution of the TDTR measurements avoided fibre-matrix interface boundary effects in all cases. The mean thermal conductivities of Hi-Nicalon Type S and Tyranno-SA4 fibres decreased by eight times following C+ irradiation to 1.1 DPA at 800°C. The mean thermal conductivities of SiC matrices fabricated via the NITE and CVI processes likewise decreased by an order of magnitude. Microstructural analysis via Raman spectroscopy showed a significant increase in residual stress and breakdown of crystalline order post-irradiation. These results show potential for improved material design strategies based on ion irradiation and micro-thermal measurements. Future work will evaluate further ion irradiated SiC/SiC specimens as a function of temperature.

11:30 AM

(HTCMC-S11-026-2026) Irradiation-induced mechanical response of polymer-derived SiC: Linking defect formation to hardening

H. Singh*[1]; D. Gilmer[1]; K. Hattar[1]

1. The University of Tennessee Knoxville Tickle College of Engineering, Material Science & Engineering, USA

Ceramic Matrix Composites which utilize polymer-derived ceramics (PDCs) to form SiC matrices are promising candidates for hypersonic and radiation-intensive environments. However, the evolution of their defect landscape and mechanical response under irradiation remains unclear. This work explores whether polymer-derived SiC develops distinct, defect-driven mechanical behavior compared to conventional SiC exposed to similar conditions. To establish this baseline, C/SiC coupons with PDC SiC were pyrolyzed and crystalized and then irradiated with Au ions to 1, 10, and 100 dpa. Literature reports increase in hardness upon low-dose irradiation that define the post-formation defect response of polymer-derived SiC, and we expect Raman spectroscopy and nanoindentation to reveal similar trends in our samples. Building on this baseline, upcoming in-situ nanoindentation and low-fluence irradiation studies will track the earliest stages of defect generation and mechanical change in real time, capturing when and how the material first begins to harden. The broader impact is the potential to develop ceramics inherently suited for the extreme thermal loads of hypersonic flight and the radiation environments relevant to advanced energy systems.

Thursday, June 4, 2026

GFMAT-3 Symposium 1- Powder Processing Innovation and Technologies for Advanced Materials and Sustainable Development

GFMATS1- Novel shaping, forming, and sintering technology, including additive manufacturing

Room: Shorebreak 2
Session Chairs: Eugene Olevsky, San Diego State University; Hui-Suk Yun, Korea Institute of Materials Science

8:30 AM

(GFMAT-S1-023-2026) Electro-Nano-Pulsing: New manufacturing paradigm (Invited)

E. Olevsky*[1]

1. San Diego State University, College of Engineering, USA

This presentation outlines Electro-Nano-Pulsing (ENP), a novel field-assisted materials processing method that enables nanoscale engineering of grain boundaries using ultra-intense, high-frequency electrical pulses. ENP employs sub-microsecond pulsing at extremely high current densities, generating highly localized Joule heating, strong electric fields, and pronounced electron wind effects. Together, these coupled mechanisms promote controlled alteration of grain boundary geometry, dislocation formation, nanocoating development, and electromigration-driven precipitation, while largely maintaining the integrity of grain interiors. Experimental observations supported by computational modeling demonstrate the distinctive capabilities of ENP, including grain boundary roughening, nanoscale melting, and the formation of thermodynamically stable intermetallic precipitates. In contrast to conventional thermomechanical processing, ENP enables near-instantaneous control of microstructure with unprecedented spatial and temporal precision. This technique holds significant promise for the targeted tuning of material properties across structural, electronic, and energy-related applications. Its broader impact includes improved fatigue and corrosion resistance, enhanced thermal management, and superior electrochemical performance in demanding environments such as aerospace systems, semiconductor technologies, and advanced energy platforms.

9:00 AM

(GFMAT-S1-024-2026) Effect of electric field and current on high-temperature processing of 8Y-CSZ (Invited)

K. Morita*[1]

1. National Institute for Materials Science (NIMS), Japan

Various external field effects have been attracted many attentions in sintering processing. In particular, electric field/current effects reported in spark-plasma-sintering (SPS) and flash sintering have been utilized to realize effective powder densification at lower temperatures and shorter processing times. However, the details of the electric field/current effects remain unclear and are still under discussion. One of the reasons that make it difficult to clarify the effect of the electric field/current on the sintering is that the powder densification is accompanied with dramatic microstructure change from powder to bulk states. Recently, it is reported that the electric field/current is effective not only in the powder sintering, but also in other high-temperature processes of bulk materials, such as deformation, joining and crack healing. The high-temperature processes of the bulk materials are relatively stable rather than the powder sintering. Therefore, the clarification of the current effects on the high-temperature processes of bulk materials enable to understand the current effects on the sintering of ceramics. In order to clarify the field/current effect on the high temperature processing, therefore, the present study was carried out to examine the electric field/current effects on grain growth behavior of zirconia ceramics (8YSZ) under the DC/AC current conditions.

9:30 AM

(GFMAT-S1-025-2026) Flash sintering of YSZ from atomistic modeling and experiment: Mechanisms and grain growth (Invited)

W. Xu*[1]; S. Soltero[1]; C. Delaney[1]; T. Norris[1]

1. San Diego State University, Mechanical Engineering, USA

Flash sintering (FS) of yttria-stabilized zirconia (YSZ) offers an ultra-rapid, energy-efficient route to ceramic densification. This talk integrates molecular dynamics (MD) and controlled FS experiments to elucidate sintering mechanisms and grain growth behavior in 8 mol% YSZ (8YSZ). MD quantifies field-enhanced diffusivity and accelerated neck formation beyond purely thermal effects, guiding the interpretation of measured microstructures. Experimentally, dog-bone compacts flash-sintered at 850°C under about 120V/cm exhibit thermal runaway within about 5s, with temperature ramp rates on the order of 50-60 K/s; thermoelectric analyses indicate sample temperatures near 1,650~1,700K during the flash. A grain growth model at ~1,675K yields an exponent $p \approx 3$ and an activation energy on the order of 190~200 kJ/mol, consistent with rapid boundary controlled coarsening. Electron microscopy reveals heterogeneous and anisotropic growth, amplified near the anode, vacuum conditions suppress flash initiation and promote electrolytic reduction, underscoring the critical role of oxygen. Taken together, these MD-experiment comparisons support a coupled electrothermal-electrochemical picture in which Joule heating, field-accelerated diffusion, and local chemistry jointly govern densification and microstructure.

10:20 AM

(GFMAT-S1-026-2026) Advanced modeling strategies for digital twins in powder processing: Challenges and opportunities (Invited)

M. Sakai*[1]

1. Tokyo Daigaku, Japan

Fine ceramics are essential functional materials widely used in industrial products. Their production quality relies on powder processing operations. Numerical simulation plays an important role as an engineering tool for rational process design and optimization, reducing reliance on costly trial-and-error approaches. However, industrial ceramic manufacturing involves large numbers of particles, complex equipment geometries with moving components, and strong solid–fluid interactions, which pose significant challenges for conventional simulation methods. To address these challenges, our research group has developed advanced numerical models for industrial-scale powder processing. Particle motion is described by the Discrete Element Method (DEM), including a coarse-grained DEM framework. We have also introduced a scalar-field-based boundary model that enables robust treatment of moving walls. In addition, we have developed an artificial-intelligence-based reduced-order model that significantly reduces computational cost while maintaining high accuracy. This presentation shows application examples in fine ceramic manufacturing processes and discusses their potential for future digital twin implementation.

10:50 AM

(GFMAT-S1-027-2026) Approaches for selecting sustainable raw materials in ceramic additive manufacturing (Invited)

H. Yun*[1,2]

1. Korea Institute of Materials Science, Republic of Korea
2. University of Science and Technology, Republic of Korea

Additive manufacturing (AM) enables the layer-by-layer fabrication of complex 3D ceramic structures directly from digital designs without the need for part-specific tooling. Among ceramic AM

technologies, stereolithography stands out for its ability to produce highly accurate and precise components by curing photo-curable polymer slurries embedded with ceramic particles. Despite significant advancements, challenges remain in optimizing raw materials to achieve sustainable, high-quality ceramic parts. Selecting sustainable raw materials requires careful consideration of their physical and chemical properties, including density, refractive index, color, and compatibility with post-sintering thermal treatments. Additionally, managing the shrinkage behavior of multiple materials is critical to prevent defects such as cracks, delamination, or separation during processing. This presentation explores various approaches to raw material selection focused on sustainability, addressing the balance between material performance, environmental impact, and process compatibility to advance sustainable ceramic additive manufacturing.

11:20 AM

(GFMAT-S1-028-2026) Study on the 3D printing of zirconia and silicon nitride by stereolithography (Invited)

J. Zhang*[1]

1. Shanghai Institute of Ceramics Chinese Academy of Sciences, China

Stereolithography is an attractive technique for the fabrication of complex-shaped ceramic components with high dimensional accuracy. The materials used in stereolithography are the blend of photocurable monomer, resin, ceramic powders and photoinitiator etc, which can be solidified under a certain amount of radiation. Presently, alumina, silica and zirconia powder have been successfully prepared by stereolithography method with high accuracy. However,there are still quite a lot problems in term of solid loading, the curable thickness and printing accuracy that need to be well resolved. In this study, two ceramic powder were studied for Stereolithography. The dispersion of ceramic powder in photocurable resin and the slurries properties were intensively investigated. The selection of dispersant, and the slurry properties were studied based on the adsorption, FTIR, rheological and contact angle etc. measurements. The factors that influence the curable thickness and the printing accuracy were investigated. The binder removal, sintering and the final properties of the ceramics were also characterized. Finally, the optimized composition, the processing parameter for the development of high performance ceramics through stereolithography were presented.

GFMAT-3 Symposium 3- Novel, Green, and Strategic Processing and Manufacturing Technologies

GFMATS3- Novel, Green, and Strategic Processing and Manufacturing Technologies I

Room: Sandpiper D
Session Chairs: Tatsuki Ohji, Yokohama Kokuritsu Daigaku; Ivar Reimanis, Colorado School of Mines

8:30 AM

(GFMAT-S3-001-2026) How sintering mechanisms impact novel sintering methods (Invited)

S. J. Dillon*[1]

1. University of California, Irvine, USA

The drive to make sintering less energy intensive, faster, and more efficient has driven the development of many novel sintering techniques. Examples include a variety of high heating rate methods employing novel energy input (light, current, induction, microwaves, etc.), two step sintering, cold sintering, deformable punch sintering, etc. Explanations for the efficacy of these approaches have not typically emerged clearly from classical models for sintering. These models have been built on largely unjustified assumptions about grain boundary strain mechanisms. Quantitative in situ transmission electron microscopy-based creep experiments reveal the importance of strain mediating grain boundary defects and suggest their incorporation into analytical models is critical. Using these insights models are formulated that predict well observations from high heating rate sintering, cold sintering, two step sintering, and hot pressing. This talk will discuss these new insights.

9:00 AM

(GFMAT-S3-002-2026) Operando observation using an OCT-TG-FTIR-MS combined system for understanding dewaxing process and green manufacturing (Invited)

J. Tatami*[1]; F. Kimura[1]; M. Iijima[2]

1. Yokohama National University, Japan
2. Yokohama National University, Graduate School of Environment and Information Sciences, Japan

Although approaches such as extremely slow heating rates has been employed to avoid cracking and deformation of the green bodies due to removing the organic compounds in ceramic powder process, they were not sufficient. For a greener dewaxing process, it is important to identify the point at which cracking and deformation occur and elucidate the mechanism. In this study, operando observations were carried out using a combined system of OCT, which enables high-speed, high-resolution observation of the internal structure of opaque bodies even at high temperatures, together with TG, FTIR, and MS for gas analysis. This enabled understanding and control of the dewaxing process. The samples used were alumina green bodies with PVB added as a binder. At approximately 200 °C, gas generation commenced, primarily composed of water and acetaldehyde, resulting from the thermal decomposition of the side chains of the PVB used as a binder. OCT observation confirmed deformation occurring within this temperature range. Based on these results, a temperature holding step at 180 °C was implemented, significantly reducing deformation. These findings provide valuable insights into optimal temperature control during the ceramic dewaxing process, contributing to improved product quality and manufacturing efficiency.

9:30 AM

(GFMAT-S3-003-2026) Optical single crystals, growth and characteristics (Invited)

K. Shimamura*[1]; E. G. Víllora[1]

1. National Institute for Materials Science (NIMS), Japan

Electro-optical technology progress in a wide range of applications, and still demands the further development. Our intention is to explore novel single crystal materials for diverse applications, and to implement them in the industrial use. New concept of HB white LEDs based on yellow Ce:YAG single crystal phosphors is proposed. SCPs demonstrated high internal quantum efficiency (QE_{int}) (over 95%), outstanding thermal stability of QE_{int} in the temperature range 25-300°C, and quit low temperature increase under high blue irradiation, which contrast with the performance of conventional phosphor powders. $Tb_3(Sc_{1-x}Lu_x)_2Al_3O_{12}$ (TSLAG) single crystals have been designed for high-power laser machinery. It showed a higher visible transparency and a larger Faraday rotation than the conventional $Tb_3Ga_5O_{12}$ (TGG). In 2013, mass production has started. For the UV-VIS region a completely different approach was adopted. The envisaged objective was achieved with the well-known scintillator crystal CeF_3. A drastic enhancement of the light yield of Ce:$Li_6Y(BO_3)_3$ (LYBO) single crystals by ~600% is achieved. Ce:LYBO could be of interest as efficient, low-cost, and stable solid-state materials for portable thermal neutron detection.

10:20 AM

(GFMAT-S3-004-2026) Fabrication of high-nitrogen-content silicon oxynitride glasses and their physical properties (Invited)

H. Segawa*[1]

1. Busshitsu Zairyo Kenkyu Kiko, Japan

Silicon oxynitride (Si-O-N) glass is a promising material for advanced applications, but its fabrication with high nitrogen content remains a challenge. To address this, we employed a two-step process: silica powder was systematically nitrided via ammonolysis at various temperatures, and the resulting powders were consolidated into dense bulk samples using Spark Plasma Sintering (SPS). The nitridation temperature was found to be a critical parameter. An optimized temperature window yielded a fully dense, optically transparent, and amorphous bulk glass with a very high nitrogen content. The material's properties showed a clear, positive correlation with nitrogen concentration; both Young's modulus and thermal conductivity increased substantially with higher nitrogen incorporation. Interestingly, the crystallized composites exhibited lower thermal conductivity, a phenomenon attributed to enhanced phonon scattering at the glass-crystal interfaces. This work demonstrates a viable pathway for fabricating high-performance Si-O-N glass, validating its potential for demanding thermomechanical environments.

10:50 AM

(GFMAT-S3-005-2026) The industrial relevance of advanced sintering technology: Field assisted sintering

J. Rufner*[1]; A. Gorman[1]; X. Zhang[1]; A. Preston[1]

1. Idaho National Lab, Materials Science and Manufacturing, USA

Advanced sintering technology is increasingly crucial for industrial manufacturing of advanced materials. Among these technologies, field-assisted sintering is notable for reducing processing times, creating materials with specific properties, and applying unique processing stresses. These improvements not only cut manufacturing costs but also enhance energy efficiency. It can be a powerful tool to enable the production of materials that are difficult to manufacture through conventional means by increasing throughput and reducing development cycles. Historically, these materials have long lead times and are confined to small-scale research settings due to the absence of sufficiently large systems for industrial-scale production. This talk will provide perspective on the evolution of field-assisted sintering over the past few years, advancements that are transitioning it from a research tool to an industrial platform, and areas believed to need focus to further accelerate its industrial adoption.

11:10 AM

(GFMAT-S3-006-2026) Controlled crystallographic orientation and fabrication of transparent lanthanum silicate apatite phosphor using high magnetic field and SPS

T. S. Suzuki*[1]; H. Ariga[2]; A. Kawamura[2]; K. Kobayashi[1]; H. Kiyono[2]

1. National Institute for Materials Science, Optical Ceramics Group, Japan
2. Shibaura Kogyo Daigaku, Japan

High-brightness phosphors are essential for improving image quality in displays. For high-power excitation like laser lighting, transparent bulk phosphors are preferable over resin encapsulants with low heat resistance. Lanthanum silicate oxyapatite (LSO) is a promising material when activated and offers high chemical stability, but densifying and making bulk samples translucent is difficult. In non-cubic LSO, light scatters at grain boundaries due to birefringence, so crystal orientation control is needed to improve transmission. This study focused on enhancing LSO transparency using colloidal processing in a magnetic field and examined how grain size and orientation affect transmittance. Eu-doped LSO was also fabricated to study Eu's effect on orientation. LSO powder was synthesized by solid-state reaction. The powder was dispersed in water with dispersant, consolidated by slip casting in a magnetic field, and sintered by SPS. Smaller grain size led to higher transmittance because it reduced Rayleigh scattering. Undoped LSO had its c-axis aligned parallel to the magnetic field, while Eu-doped LSO had the c-axis perpendicular to the magnetic field. These results demonstrate that controlling grain size and crystal orientation enables fabrication of transparent LSO phosphors.

11:30 AM

(GFMAT-S3-007-2026) Recent progress of silicon nitride ceramics

T. Ohji*[1]; J. Tatami[1]

1. Yokohama National University, Japan

Silicon nitride is one of the most widely used engineering ceramics for a variety of structural applications because of their excellent mechanical properties. During the last four decades, a great deal of research effort has been devoted for tailoring the microstructures through innovative sintering process and enhancing the properties, leading to tremendous progress of silicon nitride. Particularly, in recent years, a lot of attention has been collected to studies on small or thin parts of silicon nitride ceramics because of their expanding application field. This paper gives an overview on such recent progress of silicon nitride ceramics, focusing on the processing (or sintering)-structure-properties relationship, with some examples of how a unique processing route generates a novel microstructure, which brings enhanced properties in turn. Particular emphasis is placed on microstructural elements, including grains, pores, particles, and interfaces at different scale levels, as well as their effects on the mechanical and thermal properties. This work was supported by JST, CREST Grant Number JPMJCR2192, Japan.

GFMAT-3 Symposium 6- Advanced Batteries and Supercapacitors for Energy Storage Applications

GFMATS6- Na-ion battery and Supercapacitor

Room: Tidepool 1

Session Chairs: Bruce Dunn, UCLA; Matteo Bianchini, Universitat Bayreuth Fakultat fur Biologie Chemie Geowissenschaften

9:00 AM

(GFMAT-S6-024-2026) Development of positive and negative electrode materials Na-ion batteries (Invited)

M. Xu[1]; G. Gammaitoni[1]; M. Bianchini*[1]

1. Universitat Bayreuth Fakultat fur Biologie Chemie Geowissenschaften, Germany

The Bianchini group investigates sodium-ion battery materials within the ERC project 4SBATT and the BMBF-funded SIB:DE consortium. I will report on our recent advances both on cathode and anode materials development. For cathodes, layered oxides (Na_xTMO_2) with P2 structure are explored. While P2 phases offer superior Na^+ conductivity, they suffer from low Na content and irreversible P2–O2 transitions at high voltage. Li-doping strategies ($Na_{5/6}Li_yNi_{5/12-3y/2}Mn_{7/12+y/2}O_2$) mitigate these issues by stabilizing structure, suppressing phase transitions, and tuning O-redox activity. Among tested compositions, $Na_{0.745}Li_{0.164}Ni_{0.238}Mn_{0.599}O_2$ exhibited minimal O-redox, reduced volume change, and enhanced cycling stability. Our recent results on the role of polymorphism and particles morphology will also be reported. For anodes, hard carbon's low volumetric capacity is addressed via HC/Sn composites synthesized by spray drying. These are carefully analyzed through spectroscopic, scattering, and electrochemical techniques. Limited amounts of Sn improve specific and volumetric capacity, thanks to the higher density of the composite. Operando XRD and SAXS confirm phase evolution and morphology, while electrochemical tests demonstrate superior gravimetric and volumetric performance compared to hard carbon, positioning these materials as promising candidates for next-generation Na-ion batteries.

9:30 AM

(GFMAT-S6-025-2026) Development of cost-effective and high-energy cathodes for sodium-ion battery (Invited)

H. Kobayashi*[1]

1. Hokkaido University, Japan

Iron oxide-based materials are attractive cathodes due to their earth-abundant nature, and there have been efforts made for a long time to utilize Fe^{4+}/Fe^{3+} redox reactions at cathodes. Even in well-known layered-type oxides such as $LiFeO_2$ and $NaFeO_2$, the utilization of Fe^{4+}/Fe^{3+} one-electron redox is still challenging; excess oxidation leads to O_2 evolution. Herein, we introduce a new material of Na-Fe binary oxides, Na_5FeO_4, for a sodium-ion battery cathode. The sodium-superrich Na_5FeO_4 is composed of tetrahedral FeO_4 units, which is different from $NaFeO_2$ (composed of octahedral FeO_6 units). It delivers a two-electron redox reaction to achieve a high reversible capacity of 228 mAh g^{-1}. X-ray absorption spectroscopy suggests that during the two-electron redox, a cationic Fe^{5+}/Fe^{3+} redox with no O_2 evolution proceeds, holding the tetrahedral FeO_4 local structure.

10:20 AM

(GFMAT-S6-026-2026) Sodium-Ion electrodes based on induced pseudocapacitive behavior (Invited)

Q. Nguyen[1]; A. Zambotti[1]; B. Dunn*[1]

1. UCLA, Materials Science and Engineering, USA

Pseudocapacitive materials are characterized by reversible redox reactions which occur at or near the surface of an electrode material at rates similar to those of a carbon-based electrical double-layer capacitor, but with significantly higher capacity. As a result, these materials have attracted considerable attention because of the prospect of achieving high energy density at high rates of charge and discharge. This presentation reviews our recent findings in which sodium-ion insertion into crystalline TiO_2 (anatase) produces pseudocapacitive properties with excellent Na^+ capacities at high rates. Na^+ insertion induces the formation of amorphous layers of 3 to 5 nm thick in the initial anatase material and stores charge from Ti^{4+}/Ti^{3+} redox reactions. When the size of the TiO_2 nanoparticle is reduced to 10 nm or less, the entire particle becomes amorphous and Na^+ insertion now extends throughout the entire particle. The resulting electrodes prepared from these nanoparticles exhibit Na^+ capacities in excess of 200 mAh/g operating at rates of 3C. These results underscore the prospect that short range order may be an important consideration in the design of high performance. Na^+ electrode materials.

10:50 AM

(GFMAT-S6-027-2026) Systematic phase modulation in $Na_{0.8}$(Mn-Fe-Ni)O_2 system for high energy density & structural stability

S. Saxena*[1]; N. Dagar[1]; S. Kumar[1]

1. Indian Institute of Technology Indore, India

The growing demand for sustainable energy storage positions Na-ion batteries as cost-effective alternative to Li-ion technology. This study examines the impact of phase engineering on structural and electrochemical behavior in $Na_{0.8}$(Mn-Fe-Ni)O_2 system, harnessing the outstanding performance of layered oxide cathodes. Samples calcined at 700°C, 800°C, 900°C, and 1000°C display diverse phase compositions, including P and O-type phases. Rietveld refinement of X-ray Diffraction (XRD) data shows that higher Ni content resulted in reduced Na-O layer spacings, compromising rate performance. P2/O3-$Na_{0.8}Mn_{0.53}Fe_{0.14}Ni_{0.33}O_2$, calcined at 900°C, achieved highest discharge capacity (~139 mAh g^{-1}), followed by $Na_{0.8}Mn_{0.53}Fe_{0.25}Ni_{0.22}O_2$, calcined at 800 °C(~134 mAh g^{-1}) at 0.1C. For constant Fe content, decreasing the Ni/Mn ratio results in sloping charge-discharge curves, indicating reduced honeycomb ordering during cycling. $Na_{0.8}Mn_{0.64}Fe_{0.14}Ni_{0.22}O_2$ demonstrates the best overall performance, retaining over 88% of its initial capacity after 50 cycles at 0.2C. Operando Synchrotron XRD analysis reveals a minimal (~-1.6%) change in c parameter during cycling, correlating with exceptional capacity retention. This work emphasizes the critical role of phase composition, metal ratios, and synthesis temperature in optimizing $Na_{0.8}$(Mn-Fe-Ni)O_2 based cathodes for high-performance Na-ion batteries.

GFMAT-3 Symposium 10- Materials Recycling for Energy and Environment Applications

GFMATS10- Recycling

Room: Sandpiper C
Session Chairs: Madhusoodana C D, Bharat Heavy Electricals Limited; Maharshi Dey, UbiQD, Inc.; Shibayan Roy, Indian Institute of Technology Kharagpur

8:30 AM

(GFMAT-S10-009-2026) Next-generation photovoltaic module recycling via selective interfacial heating and design-for-disassembly (Invited)

C. Tokoro*[1]

1. Waseda University, Japan

End-of-life photovoltaic modules are increasing, and low-energy recycling methods are needed. This study examined three approaches matched to different module structures. For conventional crystalline silicon modules, we applied electrical pulsed discharge as a preprocessing step without overall heating. Rapid vaporization of the silver grid lines generated a volume expansion that ruptured and lifted the encapsulant sheets. This promoted mechanical separation and enabled recovery of silver and copper with the encapsulant resins, although intact silicon wafer recovery remained difficult. To improve recoverability, we proposed a honeycomb-structured silicon module designed for disassembly. Selective microwave heating softened only the adhesive surrounding the silicon cells and allowed intact wafer recovery while maintaining rigidity and reducing weight. We also examined film-type perovskite modules where control of encapsulant release and safe handling of lead-containing materials were required. Electrical pulsed discharge was evaluated to assist dismantling without bulk heating. These results indicate that recycling strategies must be selected according to module structure and that design for disassembly is essential for photovoltaic circularity.

9:00 AM

(GFMAT-S10-010-2026) Recycling DLP-3D printed green bodies: Disassembling and powder reusage to photocurable suspensions (Invited)

M. Iijima*[1]; Y. Hiroshige[1]; N. Morimoto[1]; J. Tatami[1]

1. Yokohama National University, Japan

Additive manufacturing using photocurable suspension has become one of indispensable processes to enable on-demand structing of ceramic components having complex geometries. While many studies have been focused on 3D structuring and structure related property designing, recycling process of 3D printed green bodies, which should be important in terms of resource circulation using powder with rare elements, has not been established so far. Here, using silica as a model system, we propose a design of photocurable suspension which can be implemented to DLP-3P printing followed by disassembling into powders, and powder reusage to photocurable suspension. The suspension design was based on our recently reported system, which the suspension can be photocured through interparticle photo-cross-linking reaction using minimum amount of monomers. Owing to the unique microstructure of the photocured bodies which the particles were crosslinked with nano-scaled polymer networks, the photocured bodies can be disassembled into primary particles by a mild reaction in aqueous solution. Further, the disassembled powders were found to be processable into photocurable suspension and DLP-3D printing associated with rapid heating for debinding and sintering.

9:30 AM

(GFMAT-S10-011-2026) Polymer-derived ceramic coatings on zirconia microspheres via rotating flow fluid dynamics and pyrolysis (Invited)

K. Lu*[1]; N. Ravi[1]; K. Behera[1]

1. University of Alabama at Birmingham, USA

In this study, polymer-derived ceramic (PDC) technology is employed to fabricate carbon–silicon carbide (C–SiC) coatings on zirconia kernel spheres designed for advanced nuclear fuel systems. A rotating-flow fluid deposition process is used to achieve uniform precursor distribution and conformal coating of the spherical kernels, providing a controllable and scalable route analogous to early-stage TRISO (tristructural-isotropic) coating processes. The coated particles are subsequently pyrolyzed at multiple temperatures under an argon atmosphere to convert the polymeric precursors into a dense C–SiC ceramic layer. The work focuses on understanding how interfacial chemistry and pyrolysis temperature govern the polymer-to-ceramic conversion pathway and the resulting coating adhesion, densification, and microstructure. Detailed characterization—thermal analysis, spectroscopy, and electron microscopy—is carried out to probe crosslinking reactions, the evolution of carbon-SiC phases, and changes in coating morphology during pyrolysis. These findings offer critical insight into the microstructural development and thermal behavior of PDC-derived C–SiC coatings on high-density ceramic kernels. The work demonstrates the potential of PDC routes as a versatile and tunable method for producing robust, high-temperature-stable coating layers for next-generation nuclear fuels.

10:20 AM

(GFMAT-S10-012-2026) Novel low-temperature chemical densification process for ceramics considering material recycling (Invited)

Y. Yamaguchi*[1]

1. National Institute of Advanced Industrial Science and Technology (AIST), Japan

Ceramic-based materials require a process called “sintering,” where they are fired at high temperatures to make dense structures. This process typically involves heat treatment at temperatures exceeding 1000 °C, requiring significant energy and emitting large amounts of CO_2. Furthermore, the ceramic materials obtained through this high-temperature heat treatment are characterized by their stability, which makes them difficult to decompose and recycle. In this research, we developed a unique low-temperature manufacturing technology called the Acid-Base Chemical Densification (ABCD) process. This process utilizes the synthesis reaction of the target complex oxides to create bulk ceramics, and we have successfully produced ceramics with a relative density exceeding 90% using this method. Furthermore, by controlling the conditions of the chemical reaction, we have also developed a technology to convert the bulk material into powdered material.

10:50 AM

(GFMAT-S10-013-2026) Chemithermal pulverization: A potential technique for ceramics recycling (Invited)

H. Segawa[2]; N. Ohashi*[2,1]

1. Institute of Science Tokyo, MDX Research Center for Elemental Strategy, Japan
2. National Institute for Materials Science (NIMS), Japan

Chemothermal pulverization (CTP) is a new phenomena/techinique found by the authors. The dense ceramics and bulk crystals can be crushed into nano-sized powder by thermal treatment in the gas mixture of ammonia and oxygen, that is CTP. Typical appearance of CTP is that well-sintered barium titanate ceramics are pulverized, not mechanically but chemothermally, by heating them at 1000deg.C or higher in the gas mixture of ammonia and oxygen (air). The resultant pouwder looks nano-size, around 100nm in diameter. The other oxides, such as YSZ single crystals. can also be crushed by CTP. As CTP is not mechanical pulverization, we do not need to afraid of contamination from the mill. The mechanism of CTP is not revealed completely but it is evident that CTP is not achieved by decomposition but pulverization, as crystalline phases are not changed by CTP. The mechanism of CTP will be discussed in the session.

11:20 AM

(GFMAT-S10-014-2026) Enhancing citric acid solubility and mitigating heavy metal contamination in sewage sludge incineration ash for high-quality fertilizer production

H. Kamiya*[1]; X. Hao[1]; Z. Kun[1]; S. Oleszek[1]; H. Iwai[1]; M. Ito[2]; K. Fujimori[2]; Y. Iwai[2]; R. Tsujibayashi[2]; C. Tokoro[1]

1. Waseda University, Japan
2. Sanki Engineering Co Ltd, Japan

Sewage sludge incineration ash (SSIA) contains high concentrations of phosphorus and is a promising candidate for agricultural fertilizer. However, key challenges remain, including the mitigation of heavy metals such as arsenic that exceed regulatory limits, and the enhancement of citric acid solubility to improve nutrient availability and fertilizer functionality. Furthermore, the effects of mineral components—such as Ca, Al, and Fe, introduced during raw sludge and sewage treatment—on citric acid solubility are not yet fully understood. In this study, we demonstrated that heavy metal concentrations can be reduced below regulatory standards through a low-cost, energy-efficient method that separates fine particles containing high concentrations of arsenic. We verified the effectiveness of this remediation using cyclone separation, a common industrial powder separation technique. To evaluate the impact of mineral phases on solubility, we developed model ash by mixing, drying, and heat-treating Ca and P precursors. By incorporating Al and Fe into these models, we investigated the relationship between the resulting compounds and their citric acid solubilities.

11:40 AM

(GFMAT-S10-015-2026) A novel interfacial separation method for rubber–metal composites recycling using liquid nitrogen cooling and its mechanism

M. Sayama*[3]; A. Narita[1]; T. Nishioka[2]; A. Mase[2]; C. Tokoro[1,4]

1. Waseda University, Faculty of Science and Engineering, Japan
2. Sumitomo Riko Companny Limited, Japan
3. Waseda University, Graduate School of Creative Science and Engineering, Japan
4. The University of Tokyo, Faculty of Engineering, Japan

Rubber–metal composites are extensively used in the transportation and construction industries. Recovering and recycling rubber from these composites are important for securing raw material supply and reducing environmental impacts. However, separating rubber from metal remains challenging because of the strong vulcanization bonding at the interface. This study proposes a non-thermal separation method for natural rubber–iron composites using liquid nitrogen and discusses the underlying mechanism through experiments and finite element thermal-stress analysis. The plate specimens bonded by vulcanization were immersed in liquid nitrogen. Specimens with rubber layers above a threshold thickness exhibited abrupt interfacial separation approximately 60 s after immersion, leaving a characteristic residual rubber pattern on the iron surface. High-speed imaging and microscopy indicate that separation typically initiates near the interface corners and then propagates along the interface. Finite-element analysis of the elastic strain energy density revealed a localized energy concentration at the interface corners owing to a thermal contraction mismatch between the rubber and iron. These findings demonstrate that cryogenic cooling can induce debonding in rubber–iron joints and may serve as a nonthermal separation approach for recycling polymer–metal composites.

GFMAT-3 Symposium 11- Ceramics and Glasses for Bio-Medical Applications

GFMATS11- Ceramics and Glasses for Bio-Medical Applications

Room: Sandpiper A
Session Chair: Katalin Balazsi, Centre for Energy Research HAS

10:20 AM

(GFMAT-S11-001-2026) Respiratory infection single exhale (RISE) breath test (Invited)

P. Gouma*[1]

1. The Ohio State University, MSE, USA

Dr. Gouma's recent breakthrough in ceramics for sensors technology is an electronic olfaction device based on four rmetal oxide sensors that are specifically sensitive to the biomarkers of interest (METHOD FOR DETECTING AND MONITORING EXHALED BREATH", patent granted US12,016,671 B2, 06/25/2024, Inventor: Pelagia I. Gouma). A single-exhale, breath testing device consists of an array of gas sensors, each of which satisfies the following stringent conditions: high sensitivity to the target gas, high selectivity, stable response over extended periods of time and rapid response. The concentration of a target gas over a selective sensor is quantified by measurement of the sensor resistance. The Department of Defense (DIU/DTRA) funded the accelerated development of this technology for its potential distribution to the military under the program "Exhale".

10:50 AM

(GFMAT-S11-002-2026) Decomposition of luminescent hydroxyapatite scaffolds in simulated body fluid (Invited)

O. A. Graeve*[1]; F. Martinez-Pallares[1]; M. Herrera[2]

1. University of California, San Diego, Mechanical and Aerospace Engineering, USA
2. Universidad Nacional Autonoma de Mexico, Centro de Nanociencias y Nanotecnologia, Mexico

We present a luminescence study investigating the dissolution of rare-earth doped hydroxyapatite scaffolds in simulated body fluid (SBF), aiming to assess the luminescence stability of Tb-, Ce-, and Eu-doped scaffolds over time. Our findings reveal a consistent decrease in luminescence emission intensity across all samples over a four-week period in which the scaffolds were immersed in the SBF. In addition, energy dispersive spectroscopy confirms a decrease in rare-earth ion concentration in the scaffolds with respect to time, whereas fluorescence spectroscopy shows the presence of rare-earth ions in the SBF, indicating the partial dissolution of the scaffolds over time. The use of rare-earth ions as luminescence markers provides insights into the mechanisms of apatite formation in hydroxyapatites. Thus, these scaffolds may find wider use in regenerative medicine, particularly in targeted drug delivery systems, where their luminescent properties have the potential to non-invasively track drug release.

11:20 AM

(GFMAT-S11-003-2026) DNApatite: An elastic apatite with sub-nanometer scale organo–inorganic structures (Invited)

J. Lee*[1]

1. Sungkyunkwan University, Advanced Materials Science & Engineering, Republic of Korea

Hydroxyapatite (HA) is a renowned bioceramic material for its exceptional biocompatibility, bioactivity, osteoconductivity, and inherent anti-inflammatory properties. Despite extensive research into pure HA, ion-doped HA, and HA-polymer composites, significant challenges such as brittleness persist. In this study, we present the first realization of an elastic-ceramic material, 'deoxyribonucleic apatite (DNApatite)', a newly synthesized material incorporating both ceramic (represented as Hydroxyapatite, HA) and polymeric elements (represented by single-stranded DNA, ssDNA) at a sub-nanometer scale to overcome the limitations of conventional ceramics. DNApatite is synthesized through the self-crystallization of polymeric single-stranded deoxyribonucleic acid (ssDNA) without additional phosphate ions. The resulting DNApatite, with the composition DNA1Ca2.2(PO4)1.3OH2.1, exhibits a unique dual-phase structure comprising inorganic HA crystals and amorphous organic ssDNA at the sub-nanometer scale, organized into nanorods. This novel material demonstrates markedly improved mechanical properties, including enhanced toughness and elasticity, and a Young's modulus comparable to that of natural bone. Therefore, this ceramic represents a non-composite material that achieves synergistic effects from the integration of ceramic and polymer characteristics.

Young Professionals Forum

HTCMC-GFMAT- YPF-Novel Ceramic Processing I

Room: Sandpiper B
Session Chairs: Alex Leide, UKAEA; Yuki Nakashima, National Institute of Advanced Industrial Science and Technology (AIST)

8:30 AM

(YPF-007-2026) Developing a hybrid route for next-generation ceramic matrix composites (Invited)

V. Venkatachalam*[1]; J. Binner[2]

1. University of Birmingham, Metallurgy and Materials, United Kingdom
2. University of Birmingham, Ceramic Science & Engineering, United Kingdom

The next generation of ceramic matrix composites (CMCs) demands processing strategies that can balance performance, structural integrity, and manufacturability. Amongst the near net-shape processing routes widely used for making CMCs, polymer infiltration & pyrolysis (PIP) and chemical vapour infiltration (CVI) have been promising in terms of engineering both matrices and interfaces. However, whilst both processes have distinct advantages they currently also bring challenges in terms of scale-up, particularly where the numbers of components to be made might restrict the ability to achieve economic viability. In order to address these issues, this work describes the hybrid approach of combining a polymer-derived ceramic (PDC) route with a subsequent chemical vapour infiltration (CVI) step with a view to overcoming the limitations of each individual method. By leveraging carbon fibre preforms with engineered architectures – ranging from 2D to 3D woven and needled structures – a hierarchical framework has been established that promotes efficient infiltration, controlled densification and tailored interfacial bonding. The PDC phase serves as an early-stage pore-sealing and compositional tuning step, whilst subsequent RF-heated CVI cycles enhance matrix continuity and microstructural refinement. This hybrid approach results in CMCs with superior properties through a faster and more energy-efficient process.

9:00 AM

(YPF-011-2026) Effect of cellulose-nano-fiber addition on the rheology properties of ceramic paste for extrusion-based additive manufacturing (Invited)

Y. Chung*[1]; A. Shimamura[1]; N. Kondo[1]; M. Hotta[1]

1. National Institute of Advanced Industrial Science and Technology (AIST), Japan

In additive manufacturing of ceramic materials, extrusion-based techniques such as direct ink writing (DIW) have received increasing attention due to their simple equipment design and broad applicability to various materials. In this method, a highly concetrated paste-like ceramic slurry is extruded through a nozzle and deposited layer by layer to form three-dimensional structures. The ability to flow during extrusion and the ability the retain shape after deposition are critical requirements for the prepared paste and are usually evaluated by rheological properties. Carboxymethyl cellulose (CMC) is one of the commonly used thickening agent to control the rheological properties, but its low solubility in aqueous solution decreased the flexability of adusting rheological properties of ceramic slurries. On the other hand, celluose nano fibers (CNFs) that are produced from fibrillating cellusoe fibers with nanoscale diameters of 10-50 nm, is found to reinforce the strength of green bodies and prevent drying cracks of ceramics made by slip casting. Therefore, whether CNFs is possible to strengthen wet paste came to our insterest. The present study investigates the effect of CNFs on the rehological properties of ceramic pastes and evaluates its applicability for DIW.

9:30 AM

(YPF-009-2026) Unlocking the potential of microwave heating for advanced ceramics and composites processing (Invited)
WITHDRAWN

R. D'Ambrosio*[1]; A. Cintio[1]; A. Lazzeri[2,1]; G. Annino[3]

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2. University of Pisa, Department of Civil and Industrial Engineering, Italy
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This contribution presents recent advances in microwave (MW) processing of advanced ceramics and composites, highlighting its potential within the current energy transition framework. The exploitation of MW benefits, as a volumetric, rapid and selective heating method for high-T ceramic materials treatment, will be discussed based on practical examples as a part of IPCF-CNR's research activities. The approach combines high-T dielectric characterization with multiphysics simulation to guide the design and optimization of MW-assisted reactors. The results demonstrate that accurate dielectric data and reliable modelling enable the definition of optimal cavity design and heating strategies, leading to high energy efficiency and tailored sample temperature profiles. Still, the achievement of a uniform material temperature profile remains a major challenge when moving from lab to industrial component sizes. However, the effective combination of optimized applicator design with MW solid-state sources significantly reduces heating non-uniformities and supports the transition to pilot-scale operation. These findings confirm that MW processing is a viable route for manufacturing advanced ceramic components with reduced energy consumption, faster cycle times, and improved material properties. The demonstrated methodologies provide a framework for further technology scaling and industrial deployment.

HTCMC-GFMAT-YPF- Novel Ceramic Processing II

Room: Sandpiper B
Session Chair: Yuki Nakashima, National Institute of Advanced Industrial Science and Technology (AIST)

10:20 AM

(YPF-010-2026) Advanced metal oxide nanoparticles with hierarchical nanostructures: Novel synthesis and applications in catalysis and sensors (Invited)

T. Fuchigami*[1]

1. Sangyo Gijutsu Sogo Kenkyujo Tsukuba Chuo Jigyosho, Japan

Single-nanoscale (<10 nm) metal oxides exhibit significantly enhanced performance compared to their bulk counterparts (>100 nm). However, their widespread industrial implementation remains limited due to challenges such as low durability, poor dispersibility, and difficulties in handling. Metal oxide nanoparticles with hierarchical nanostructures—such as sea urchin-like architectures—offer a promising solution, combining high surface activity, structural stability, excellent dispersibility, and facile recoverability. In solution-based synthesis of hierarchical nanostructures, non-classical crystal growth mechanisms employing organic molecules as structure-directing agents have attracted increasing attention. Building on this concept, we have developed a novel solution process utilizing cross-linking agents to fabricate and functionalize diverse nanoarchitectures. In this work, we present the formation mechanisms, mesocrystal structures, crystallographic orientation, and surface functionalization strategies of niobium oxide and cobalt oxide nanoarchitectures, with a particular focus on their applications in catalysis and sensing.

10:50 AM

(YPF-008-2026) SiC_f/SiC composites made by conventional and particle enhanced polymer infiltration pyrolysis (Invited)

C. Akaoglu[1]; J. Lao[1]; Q. Zhang[2]; P. Withers[1]; P. Xiao[1]; D. Scotson*[1]

1. The University of Manchester, Materials, United Kingdom
2. University of Bristol, Physics, United Kingdom

The inclusion of fine silicon particles (SiC_p) into the precursor during polymer infiltration pyrolysis (PIP) has been shown to enhance the density and crystallinity of (SiC_f/SiC) ceramic matrix composites in an approach termed particle enhanced polymer infiltration pyrolysis (PEPIP). In this work we have compared the microstructure and properties made in this way with the conventional PIP method. The SiC_p appear to break up the precursor aggregates during pyrolysis creating finer pore channels between the fibres. This refines the microstructure, accelerating the decomposition of SiC_xO_y phase and thereby increasing the amount of SiC which increases the crystallinity and density of the matrix over conventional PIP material. Processing parameters on control microstructure of CMCs are examined. The mechanical properties of CMCs are also determined in relation to the microstructure of CMCs. The processing-microstructure-properties relationship is going to be established.

11:20 AM

(YPF-012-2026) Wet filament winding of non-oxide ceramic matrix composites

P. Patel*[1]

1. University of Bristol, United Kingdom

Hypersonic flight, next-generation gas turbine components and nuclear fusion demand non-oxide ceramic matrix composites (CMCs) but costly manufacturing techniques limit industrial adoption. Filament winding (FW) is an automated manufacturing process suited to the cylindrical geometries common in the fusion and defence sectors. It enables significant cost reductions through high levels of automation and material waste minimisation. Wet FW includes a ceramic-slurry bath and infiltration stage with simultaneous lay-up and matrix introduction; the slurry properties must encourage

retention of the matrix to produce a high ceramic density in the component. This work presents a comparison between water and solvent based non-oxide ceramic slurries to create green state materials using wet FW. The rheological properties of the slurry system, tack, sedimentation and microstructure were all assessed. Infiltration trials with carbon fibre tows demonstrate manufacturing practicality. The solvent-based system showed a higher density of ceramic particles, despite non-uniform distribution and interlayer macroporosity. The water-based system proved more stable, therefore, development to improve the deposition of ceramic particles would be valuable, alongside full optimisation for the FW process. The trials show that FW is promising for use with non-oxide CMCs to produce green state preforms with a high density of ceramic particles.

HTCMC-12 Symposium 2- Fibers, Preforms, and Interphases

HTCMCS2- The Effects of Fiber and Preform Properties on the Thermal Behavior of CMCs

Room: Shorebreak 1
Session Chair: Jonathan Maier

8:30 AM

(HTCMC-S2-001-2026) High-temperature performance of SiC fibers and the role of interphases in ceramic-matrix composite fracture (Invited)

K. Shimoda*[1]; H. Katsui[2]

1. National Institute for Materials Science (NIMS), Research Center for Structural Materials, Japan
2. National Institute of Advanced Industrial Science and Technology (AIST), Multi-Material Research Institute, Japan

SiC-based ceramic fibers are essential reinforcement materials, typically produced via organic-to-inorganic conversion of precursor fibers. Industrial fibers are manufactured from polycarbosilane (PCS) following the method developed by Yajima et al., evolving from first-generation amorphous, carbon-rich fibers to nearly stoichiometric, polycrystalline third-generation products. This study evaluates the in-situ thermal stability of five commercial SiC fibers across three generations, focusing on elastic modulus and electrical conductivity up to 1800 °C under high vacuum, using a single-fiber tensile system (MacaSiC) for continuous monitoring during heating and cooling. Fibers exposed to 1200–1900 °C for 10 min were further assessed for tensile strength retention and correlated with crystallinity and microstructural changes. Third-generation fibers show superior thermal stability, with strength degradation linked to SiC grain growth and carbonization from Si depletion at the fiber surface. Additionally, we examined conditions promoting pseudo-ductile fracture in C/SiC and SiC/SiC ceramic-matrix composites, highlighting the critical role of the interphase between fibers and matrix. This work was partially supported by ATLA, Grant Number JPJ013268.

9:00 AM

(HTCMC-S2-002-2026) Effect of through thickness Stitching of 2D preforms on the thermomechanical properties of C/SiC composites (Invited)

C. Sauder*[1]; t. courtellemont[1]; M. Bornert[2]; p. aimedieu[2]

1. Commissariat a l'energie atomique et aux energies alternatives Centre de Saclay Bibliotheque, SRMA, France
2. Ecole nationale des ponts et chaussees, France

Stitching process is well-known for joining or reinforcing 2D preforms in trough thickness direction, especially to enhance interlaminar shear strength. A lot of studies were dedicated to the influence of this process on Polymer Matrix Composites (PMCs) properties and especially on Carbon fiber reinforced polymer (CFRP) composites. A clear conclusion of benefits of stitching is not clear from all these studies. The difficulties come from a variety of factors (type of composite, stitching conditions, loading conditions, …) that could influence properties. In this study it is proposed to evaluate the thermomechanical properties of 2D stitched carbon fiber reinforced ceramic matric composites (CMC). Results of in plane and out of plane mechanical characterizations are proposed and discussed. No degradation of in plane mechanical properties is observed. Enhancement of interlaminar shear strength (ISS) and thermal through thickness diffusivity is clearly observed with dependance of stich spacing. This first study clearly demonstrates the benefit of stitching on the thermomechanical properties of 2D C/SiC composites even if the influence of all stitching conditions needs an evaluation to understand all the factors that could influence composite properties.

9:30 AM

(HTCMC-S2-003-2026) Emerging SiC fiber and mini-composite with superior thermal stability and creep resistance

M. Sumino*[2]; T. Matsunaga[1]

1. UBE Kabushiki Kaisha, Specialty Products Division, Japan
2. UBE Kabushiki Kaisha, Research & Development, Japan

UBE Corporation has developed several types of silicon carbide fiber known as "Tyranno Fiber®" over many years. Silicon carbide fiber is widely used as a reinforcement material in silicon carbide fiber-reinforced silicon carbide ceramic matrix composites (SiC/SiC-CMC). SiC/SiC-CMC is expected to be used in extreme conditions, such as the hot sections of turbine engines, so high heat resistance is required. In addition, SiC fiber strongly influences the properties of SiC/SiC-CMC, so fibers with higher heat resistance are necessary. For this reason, the heat resistance and mechanical properties of silicon carbide fibers have been improved. In this study, we present a new fiber with excellent creep resistance and high thermal conductivity. We also fabricated a mini-composite CMC using this fiber, which demonstrated outstanding high-temperature strength and high creep resistance. These results are also presented in this work.

9:50 AM

(HTCMC-S2-004-2026) Effects of matrix composition on the thermal stability and grain growth kinetics of alumina-based fibers

R. S. Almeida*[1]; K. Tushtev[1]; K. Rezwan[1]

1. University of Bremen, Germany

Thermal stability is the main limitation of oxide fibers as grain growth and strength loss occur at temperatures above 1000°C. This is an important issue since these temperatures are easily reached during the lifetime of the fibers, e.g. during composite processing or in-field application. Furthermore, oxide fibers can also interact with the surrounding matrix at those temperatures. The objective of this work is to study the effect of matrix composition on the microstructure evolution of alumina-based fibers. For that, minicomposites were produced by embedding Nextel 610 and Nextel 720 fibers in matrices with different compositions (alumina, MgO-doped alumina, alumina-zirconia and mullite-alumina) and evaluated before and after different thermal exposures. Results show that fiber grain growth kinetics are strongly influenced by matrix composition, especially at the fiber-matrix interface. Higher grain growth is observed for fibers in a pure alumina matrix, whereas fiber grain growth is slower in mullite matrices. These changes are associated with the diffusion of elements that can inhibit fiber grain growth at high temperatures. Therefore, doping an alumina matrix with oxides such as MgO is another good alternative to hinder fiber grain growth. Lastly, the effect of these microstructural changes on the mechanical properties of the minicomposite is discussed.

HTCMCS2- Properties and New Developments in Interfaces/Interphases

Room: Shorebreak 1
Session Chair: Cédric Sauder, CEA

10:30 AM

(HTCMC-S2-005-2026) In-situ observation of micro-cracking in SiC/SiC ceramic matrix composites (Invited)

T. Sekigawa*[1]; Y. Tanaka[1]; M. Takeda[1]

1. Tokyo University of Technology, Japan

Multiple matrix cracking during loading is the most important mechanism for ensuring reliability in the design of component damage tolerance. Mechanical characterization of the nonlinear behavior of ceramic matrix composites (CMCs) under tensile loading demonstrated that the inelastic strains can be attributed to permanent strain caused by multiple matrix cracking. Developing methodologies capable of detecting micro-damages and linking these damages to macroscopic stress-strain behaviors of constituent materials is necessary. Detecting multiscale damage evolution processes and understanding their relationship with macroscopic characteristics through nondestructive evaluation is one of the challenging research topics. Talbot-Lau X-ray interferometry (TLI), combined with a mechanical loading device, enables direct observation of matrix crack initiation and propagation in CMC using small scattering contrast (SSC) image, at low magnification in a short time. In this study, the evolution of matrix cracks in a melt-infiltrated SiC/SiC CMC under tension loading was examined using TLI system. Additionally, crack propagation under loading was observed using an optical microscope, and the interfacial properties were measured by the push-in test to investigate the damage mode at the interphase.

11:00 AM

(HTCMC-S2-006-2026) The evolution of the fiber matrix bonding strength during CMC processing – Single fiber push-out tests in CFRP, C/C and C/C-SiC state

F. Wich*[1]; N. Langhof[1]; S. Schafföner[1]

1. University of Bayreuth, Chair of Ceramic Materials Engineering, Germany

The mechanical properties of ceramic matrix composites (CMC) are vastly determined by the strength of interactions between fibers and matrix. The key knowledge and challenge in acquiring high-performance CMC materials oftentimes lies in tailoring the fiber-matrix interphase. However, the evolution of the fiber-matrix bonding strength along the processing chain of CMC is oftentimes not understood due to complications in sample preparation and measurement of the highly-porous CMC intermediates. This study presents preparation methods for thin-sections of porous composite samples as well as the results of in-situ single fiber push-out tests using an SEM picodenter. Values of the fiber-matrix bonding strength along the processing chain for melt infiltrated carbon fiber reinforced silicon carbide (C/C-SiC) are presented. Furthermore, micromechanical mechanisms such as crack initiation and propagation, delamination and push-out are presented in unprecedented detail using the combination of in-situ testing and high-magnification SEM analysis. Time-correlated force-displacement curves as well as direct observations of samples via videos of the push-out tests deliver new insights on the micromechanical deformation mechanisms of CMC. The presented methods and results strongly contribute to a deeper understanding of the mechanical behavior of CMC materials.

11:20 AM

(HTCMC-S2-007-2026) CVI-controlled growth and characterization of a 3D-architectured BN interphase

A. Mounérat*[1]; H. Plaisantin[2]; S. Jacques[3]; G. Chollon[3]

1. SAFRAN Ceramics, LCTS, University of Bordeaux, France
2. SAFRAN Ceramics, LCTS, France
3. CNRS, LCTS, University of Bordeaux, France

sp^2-BN synthetized by chemical vapor deposition or infiltration (CVD, CVI) is commonly used as interfacial layer in ceramic SiC/SiC composites. While BN grown at low temperatures by CVD is usually poorly structured, 3D architectures occasionally appear within the interphase by infiltration (CVI) as an assembly of sp^2-BN nanowalls. No clear explanation nor growth mechanism has been proposed to date to justify these particular forms of BN. In this study, model channel pores have been fabricated to simulate CVI conditions, allowing the controlled growth of 3D-architectured-BN films from BCl_3/NH_3 gas mixtures. Advanced structural and physico-chemical characterizations have been performed on the films to investigate the solid at different scales. Following this, SiC/BN/SiC microcomposites have been prepared with such architectured-BN interphases, to evaluate their interfacial properties through micromechanical tests. The use of model channel pores has demonstrated the key role of CVI processes in the growth of the 3D-architectured BN interphases. The structural analyses have revealed that nanowalls tend to grow vertically and consist of pure highly structured sp^2-BN, which is unusual given the low deposition temperature. Micromechanical tests on microcomposites with architectured interphases evidenced original properties compared with typical disordered BN interphase.

11:40 AM

(HTCMC-S2-008-2026) Tailored interphases and UHTC coatings by laser-assisted chemical vapor deposition

H. Katsui*[1]; K. Shimoda[2]; M. Hotta[1]

1. National Institute of Advanced Industrial Science and Technology (AIST), Multi-Material Research Institute, Japan
2. National Institute for Materials Science (NIMS), Research Center for Structural Materials, Japan

The development of durable fiber-reinforced ceramic composites for extremely harsh environments requires advanced fiber interphases and robust environmental barrier coatings. This study introduces a unified strategy that utilizes rapid chemical vapor deposition (CVD) of alkylamino-based precursors within a localized reaction field generated by laser irradiation to fabricate both interphases and ultra-high-temperature ceramic (UHTC) coatings. Using laser-assisted CVD, boron carbonitride (BCN) interphases were deposited on SiC monofilaments with turbostratic structure at rates up to 6.1 nm/s, achieving uniform thicknesses ranging from 91 to 1093 nm and tunable interfacial shear strength (93.8-11.4 MPa), which is critical for fiber–matrix debonding control in SiC/SiC composites. Meanwhile, SiC-TaCN nanocomposite coatings exhibited a nanometric mosaic architecture, combining high hardness with moderate elastic modulus, thereby significantly improving erosion resistance under zirconia slurry impact. Both processes exploit localized laser activation for rapid, homogeneous deposition, offering a versatile route to enhance durability, damage tolerance, and functionality of fiber-reinforced composites. This work was partially supported by the Acquisition, Technology and Logistics Agency (ATLA), Grant Number JPJ013268.

HTCMC-12 Symposium 4- Innovative Design, Advanced Processing and Manufacturing Technologies in Non-oxide and Oxide Composites

HTCMCS4- Oxide-based composites

Room: Silver Pearl 1
Session Chair: Matthew Dickerson, Air Force Research Laboratory

8:30 AM

(HTCMC-S4-027-2026) Fracture mechanism of oxide fiber reinforced oxide matrix composites at room temperature and high temperature (Invited)

H. Kakisawa*[1]

1. Busshitsu Zairyo Kenkyu Kiko, Japan

Fracture mechanism of oxide fiber reinforced oxide matrix composites (Ox/Ox composites) at room temperature and high temperature of 1000°C are investigated. Ox/Ox composites with porous matrix and 2D woven oxide fabric are fabricated by a vacuum-assisted slurry infiltration molding method at a final sintering temperature of 1100 °C and loaded in tension at 25°C and 1000°C. Cross-section of the specimen is observed during the loading by an originally developed optical observation system for high temperature in which UV light is used for illumination while the thermal radiation is cut off by a optical filter. Tehe obtained images are analyzed with digital image correlation to measure strain distribution. At both temperature accumulation of new matrix cracking due to the loading does not occur; matrix cracks induced during the process are opened at the early stage of loading and then interlaminar debonding is induced followed by sliding of the debond interface and fiber pull-out. Differences of strength and elongation deepening on the temperature are discussed based on the in-situ observed fracture behavior and the measured stress distribution.

9:00 AM

(HTCMC-S4-028-2026) Blind machining of a 2D woven oxide-oxide ceramic matrix composite using abrasive waterjet process

M. Latour*[1]; L. Crouzeix[1]; C. Morel[1]; G. Dusserre[1]; R. Zitoune[1]; T. Cutard[1]; J. Malenfant[2]

1. Institut Clement Ader, France
2. Safran Ceramics, France

The machining of ceramic matrix composites (CMC) presents a significant challenge in the manufacturing of structural components due to their high brittleness and heterogeneous microstructure. Abrasive Water Jet (AWJ) is an understudied but highly promising machining solution, as it significantly limits the structural degradation of the machined material. This study investigates the feasibility of AWJ blind machining on an Oxide CMC (OCMC) and attempts develops an empirical model to control and predict both the machining depth and surface quality. An experimental plan was performed to examine the impact of water jet pressure, scan step, and abrasive flow rate on the machined depth as well as on pre-selected roughness criteria. Several characterization steps were carried out, including confocal and scanning electron microscopy, followed by image analyses. The proposed procedure validated the feasibility of machining an OCMC using AWJ and led to the development of a predictive model for machining depth with an error below 10%. Additionally, a qualitative approach regarding surface condition was undertaken. From topographical micrographs classified according to their depths, the consequences of material removal mechanisms were analyzed. As a conclusion, the surface quality depends on the machining parameters and on the local fiber/matrix ratio of the OCMC.

9:20 AM

(HTCMC-S4-029-2026) Thermal control of slurry infiltration and tow impregnation in oxide ceramic matrix composites

E. Valenzuela-Heeger*[1]; J. Binner[2]

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2. University of Birmingham, Ceramic Science & Engineering, United Kingdom

Control of slurry temperature during matrix infiltration offers a potential route to improve impregnation quality and reliability in oxide ceramic matrix composites. Here, the effect of an integrated thermal control step applied to both slurry and tooling during infiltration was examined through temperature-dependent rheology, controlled processing trials, quantitative microstructural analysis of inter- and intra-tow impregnation, and mechanical testing. Increasing infiltration temperature altered slurry viscosity and therefore yield behaviour, promoting differences in tow penetration and a controllable matrix distribution without slurry reformulation. Statistical analysis of micrographs revealed a significant reduction in impregnation variability with lower viscosity temperatures, while mechanically tested composites showed increased strength and improved Weibull modulus relative to baseline processing. The study demonstrates that thermal regulation represents a robust processing parameter for controlling infiltration pathways and improving the mechanical reliability of oxide ceramic matrix composites.

HTCMCS4- Advanced processing and manufacturing technologies III/ SiC-based composites III

Room: Silver Pearl 1
Session Chair: Gerard Vignoles, University Bordeaux

9:40 AM

(HTCMC-S4-030-2026) Effect of membrane pressure application timing on slurry transfer molding of SiC/SiC parts

M. Dias[1]; N. Eberling-Fux[2]; L. Laberge Lebel*[1]

1. Polytechnique Montreal, Canada
2. Safran Ceramics, France

Slurry transfer molding (STM) is a manufacturing process used to fill SiC fiber preforms with SiC particles, in the form of a cake. The preform is placed into a mold where a SiC slurry is supplied on one face of the fiber preform and filtered on the opposite face. This slurry supply face has poor surface finish due to the slurry distribution network engraved into the mold. We propose to improve the surface finish of the slurry supply face by placing a membrane conforming to the preform surface when an inflation pressure is applied. The objective of this study is to evaluate the impact of the pressure application time during STM. Flat preforms are 3D printed to replicate the porosity of SiC fiber preforms. The preforms are placed into a mold equipped with a membrane with 1 mm gap above the preform to facilitate slurry circulation during STM. The inflation pressure causes the membrane to conform to the preform. The time of pressure application is varied from T0% (cake construction start), T25%, T50%, T75% and T100% (cake construction end). The total time of cake of construction is measured based on slurry injected volume. The resulting infiltrated preforms are inspected using X-ray tomography to evaluate intra-cake porosities and surface finish. The T100% has the lowest construction time and lowest porosities due to the regularity of the slurry supply during cake construction.

10:20 AM

(HTCMC-S4-031-2026) Hybrid post-processing to suppress porosity growth during crystallization of PIP-derived C_f/SiC

K. T. Nguyen*[1]; S. Nutt[3]; E. J. Pope[2]

1. University of Southern California, Aerospace Mechanical Engineering, USA
2. MATECH, USA
3. University of Southern California, USA

This study demonstrates the use of field-assisted sintering (FAST) as a post-processing step to modify the microstructure of polymer infiltration and pyrolysis (PIP)-processed carbon fiber–SiC (C_f/SiC) composites. Composite panels produced by PIP were FAST-sintered for 10–15 minutes at peak temperature, and the resulting microstructural evolution was analyzed to assess matrix crystallization, porosity, and interface structure. FAST processing produced a polycrystalline SiC matrix while preventing the porosity growth typically associated with high-temperature crystallization of PIP-derived SiC. Carbon at the coated-fiber surface underwent partial graphitization, forming a pyrolytic graphite (PyG) interface layer. Fractography of consolidated samples revealed fiber pullout and crack deflection, attributed to the PyG layers at fiber–matrix interfaces. The results demonstrate that a FAST post-processing step can restructure the PIP-derived matrix and interface structure within a short processing window, providing a hybrid processing route for producing dense C_f/SiC composites while retaining the scalability of PIP fabrication.

10:40 AM

(HTCMC-S4-032-2026) High-solid-loading ceramic slurry infiltration process for high-temperature structural ceramic composites

S. Jung*[1,2]; M. Park[1,2]; W. Kwon[1]; S. Lee[2]

1. Korea Institute of Materials Science, Republic of Korea
2. Korea Institute of Materials Science, Extreme Materials Research Institute, Republic of Korea

Ceramic matrix composites (CMCs) are promising materials for high-temperature use due to their strength and thermal stability. This study investigates a fabrication route that combines high-solid-loading ceramic slurry infiltration with the Precursor Impregnation and Pyrolysis (PIP) process to improve densification and promote matrix formation inside fiber bundles. Woven carbon and SiC fibers were used as reinforcement, and ultra-high-temperature ceramic (UHTC) matrices were prepared from milled ZrB_2 powders. Aqueous slurries with solid loadings of 55 vol% (ZrB_2) and 64 vol% (SiC) were formulated by adjusting dispersants and pH for stability. The slurries were infiltrated into fiber bundles under vacuum–pressure or vacuum–ultrasonic conditions, then dried to form prepreg sheets. Additional densification was achieved through repeated PIP cycles using SiC precursors. SEM observations confirmed matrix penetration into fiber bundles, with partially uninfiltrated regions remaining due to the rapid drying behavior of high-solid-loading aqueous slurries. The combined slurry infiltration–PIP method offers a practical approach for producing dense CMCs for high-temperature structural applications.

11:00 AM

(HTCMC-S4-033-2026) Development of pre-impregnated carbon fiber tapes using PVA and PVA-PEG aqueous solutions

J. Gilder*[1,2]; A. Capehart[3]; C. Clarkson[2]; K. E. Copenhaver[4]; A. Hubbard[2]; E. Krist[2]; C. L. Cramer[4]; D. Gilmer[3]

1. The University of Tennessee Knoxville Tickle College of Engineering, Aerospace, USA
2. Oak Ridge National Laboratory, USA
3. The University of Tennessee Knoxville Tickle College of Engineering, MSE, USA
4. Oak Ridge National Lab, Manufacturing Science Division, USA

Automated Tape Placement (ATP) is a process experiencing rapid growth as a method of preform manufacturing for many composite industries, including the production of CMCs, because it eliminates hand layup variability, improves the speed and cost effectiveness of preforming, and enables the manufacturing of various geometries. Many feedstocks use thermoplastic pre-impregnated (prepreg) tapes, but the ability to make new feedstock is limited. Additionally, thermoplastic prepreg is difficult to make. By making tapes with water dissolvable thermoplastic, formulations can easily be made, manipulated, and prepregged in liquid state. This study explores the use of aqueous PVA-based solutions as a polymer matrix to circumvent some of the processing issues in thermoplastic prepregs, such as wetting, dispersion, and void formation. PEG was also added to further lower the combined Tg of PVA system providing the potential for low temperature preforming. Rheology of the liquid prepreg as well as dried and melted prepreg material was measured. DMA and Lap shear were measured on the prepregged and dried tapes. The study results indicate that PVA + PEG based aqueous solutions are a promising candidate for low temperature ATP preforming of CMCs.

11:20 AM

(HTCMC-S4-034-2026) Drying control for scaling aqueous ceramic slurry material extrusion geometries

A. Gourley*[1,2]; C. Wyckoff[3,1]; J. Kaufman[3,1]; J. Hardin[1]; L. M. Rueschhoff[4]

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2. National Academies of Sciences Engineering and Medicine, USA
3. UES, Inc., USA
4. Air Force Research Lab, Materials and Manufacturing Directorate, USA

While slurry-based material extrusion of high-performance ceramics and ceramic matrix composites achieves high densities relative to other additive manufacturing, balancing flowability with post-extrusion shape retention often hinders fabricating larger, more complex structures. Water-based inks with high solids loadings perform especially well for bulk structures, but they cannot leverage techniques such as curing to increase strength during fabrication. Although uncontrolled drying creates defects such as cracking, warpage, and nozzle clogging, the effective increase in solids loading improves static properties, offering strategies to address structural failure. This work investigates the effects of atmospheric and temporal control using an aqueous carbon-fiber reinforced silicon carbide (SiC) slurry to increase part scale. Drying tests allowed for calculations of drying rate, providing geometry-independent values for quantifying the loss of moisture over time. Experimental builds with varying print speeds and humidity levels determined the maximum achievable height of builds, demonstrating an increase in build stability with greater drying. Through the strategic control of drying behaviors and print speeds, tall and thin-walled ceramic structures exceeding 140 mm in height could be extruded, demonstrating a promising path toward fabricating larger-scale ceramic components via material extrusion.

11:40 AM

(HTCMC-S4-035-2026) Advanced routes for manufacturing high performance CMCs

C. Akaoglu*[1]; A. Dobosz[1]; G. Jones[1]; V. Rubio[1]

1. Lucideon Ltd, Advanced Materials, United Kingdom

The manufacturing route chosen for CMCs, including UHTCMCs, is fundamental to achieving the required properties and performance. Tight control of key parameters; porosity and its distribution, fibre orientation, reinforcement architecture, matrix, interphase, is essential throughout the multistep processing chain. Optimising each stage, from powder preparation to infiltration, pyrolysis, sintering, and densification, is critical to delivering the mechanical and thermal behaviour needed for demanding environments. Lucideon has developed strong capabilities to design, refine, and scale CMC and UHTCMC manufacturing routes. The AMRICC Centre offers controlled atmosphere furnaces, high temperature and isostatic presses, and flash sintering, enabling tailored consolidation and densification strategies. These are complemented by powder processing, slurry formulation, green body forming, and consolidation via presses and autoclaves, all aligned with specific component requirements. Extensive characterisation, from elemental analysis to dimensional stability assessments, including flatness, deformation, and shrinkage, supports process optimisation. Together, these resources enable the development of Ox/Ox, C/SiC, SiC/SiC, UHTCMCs, and C/C materials for aerospace, space, defence, and nuclear applications. The AMRICC Academy further addresses industry skills gaps through targeted training in advanced ceramics and composites.

HTCMC-12 Symposium 5- Advanced Thermal and Environmental Barrier Coating – Processing, Properties, and Applications

HTCMCS5- Thermal and environmental barrier coatings for CMCs

Room: Silver Pearl 2/3

Session Chair: Elizabeth Opila, University of Virginia

8:30 AM

(HTCMC-S5-009-2026) Advanced design of high-temperature-stable and radiation-efficient T/EBC systems using machine learning (Invited)

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Thermal and environmental barrier coatings (T/EBCs) enable the use of ceramic matrix composites in high-pressure turbine environments by providing excellent thermal-cycling durability and protection. These coatings typically use multilayer designs in which the top coat is a low-thermal-conductivity oxide that improves insulation but also increases surface temperature, promoting steam volatilization and CMAS attack. Increasing the emissivity of the top coat can mitigate this temperature increase and enhance thermal barrier effectiveness, as shown by heat-transfer calculations considering optical properties. Yb_2TiO_5, with lower thermal conductivity than YSZ and excellent CMAS resistance, is a promising next-generation top-coat candidate. Its radiation performance would be further improved by substituting Yb sites with various rare-earth (R) elements to exploit the excitation energies of R^{3+} ions, though high-temperature phase stability depends on the chosen element combinations. This study applied machine learning to predict temperature dependent of crystal phases for arbitrary equimolar R-element mixtures and to rank their radiation performance. Thin films of the predicted compositions were deposited on YSZ-TBCs via EB-PVD, and burner rig testing was used to evaluate their thermal barrier performance and surface-temperature-reduction effects.

9:00 AM

(HTCMC-S5-010-2026) Dense and pure ytterbium disilicate environmental barrier coating as protection of SiC against oxidation

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In the latest generation of SiC/SiC composites, ytterbium disilicate (YbDS) has become one of the main materials used for environmental barrier coating (EBC). β-YbDS is particularly suitable due to: its coefficient of thermal expansion close to the CMC, its phase stability during temperature changes, and its efficient barrier properties against the diffusion of oxidizing species. Current EBCs are multilayered, with YbDS as the top coat deposited on a silicon bond coat. However, the latter is detrimental to new-generation composites that have to endure temperatures up to 2700°F. EBCs are commonly deposited by thermal spraying, but this method produces defects such as cracks network, porosities or phase impurities. Recent development in EBC design have allowed producing dense, thin, homogenous, and fully crystallized YbDS coatings. Substrates are silicon wafers covered with a CVD SiC layer that simulates the absence of a silicon bond coat. The obtained coatings are tested in an oxidation furnace during up to 500 hours at 1300 °C under atmospheric pressure (50 kPa H_2O/10 kPa O_2/40 kPa N_2) and a gas velocity about 30 $cm.s^{-1}$. Buckling delamination occurs during the initial stage of oxidation tests. However, the crystal structure of the EBC remains stable. Low formation rate of thermally grown oxide are noted on CVD SiC after oxidation in areas without buckling.

9:20 AM

(HTCMC-S5-011-2026) Characterising boron diffusion into silicon bond coats for environmental barrier coatings

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Environmental barrier coatings are the facilitating technology for the introduction of SiC CMCs into gas-turbine engines. However, there is concern over boron's role in accelerating the oxidation rate of the silicon bond coat. Here, for the first time, the diffusion kinetics of boron from a reaction-bonded SiC substrate into a silicon bond coat is determined by Raman spectroscopy mapping and NanoSIMS. Using these characterisation techniques maps the diffusion of boron to the oxidising interface of the silicon bond coat within 100 hours of steam exposure at 1350 °C. Consequently, this highlights boron's potential to accelerate silicon oxidation in gas-turbine environments.

9:40 AM

(HTCMC-S5-012-2026) Ultrafast fabrication of high-temperature resistant Si–Al–C–N ceramic coatings from single-source precursors

A. D. Camacho Ramirez*[1]; M. Boroojerdi[1]; L. Korell[2]; G. Falcão[3]; M. C. Galetz[2]; M. Heilmaier[3]; E. Ionescu[4]; R. Riedel[1]

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4. Fraunhofer-Gesellschaft zur Forderung der angewandten Forschung eV, Fraunhofer Research Institution for Materials Recycling and Resource Strategies IWKS, Germany

In this work, a single-source precursor for Si–Al–C–N ceramics was synthesized through the chemical modification of a commercial organopolysilazane (Durazane 1800) with an aluminum amide complex. The incorporation of aluminum into the polymer backbone was confirmed by NMR, FTIR, and elemental analysis. The thermal behavior of the modified polymer was evaluated. The resulting preceramic polymers were spin-coated onto silicon wafers and Al pack-cemented eutectic Mo–20Si–52.8Ti (at%) substrates yielding crack-free, submicrometer amorphous Si–Al–C–N coatings with excellent adhesion. To enable the formation of thicker coatings, an ultrafast multilayer deposition process was developed, producing filler-free, crack-free coatings exceeding 10 μm in thickness. Their high-temperature oxidation resistance at 1200–1400 °C revealed excellent structural integrity. Furthermore, during rapid thermal cycling with DT: 1250 °C, the coatings showed no visible damage after ten cycles, demonstrating remarkable thermal shock resistance. These results highlight the potential of the synthesized Si–Al–C–N coatings as environmental barrier coatings (EBCs) for ultra-high-temperature ceramic (UHTC) applications and components exposed to severe thermal environments. The authors acknowledge the funding of the Deutsche Forschungsgemeinschaft (DFG) within the MatCom-ComMat project (GRK 2561).

10:20 AM

(HTCMC-S5-013-2026) Porosity dependence of molten sand wetting and infiltration in oxide ceramics

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The role of porosity in governing the interaction between molten sand and oxide substrates remains poorly understood. Here, we systematically investigate the effect of porosity on CMAS wettability, infiltration, and reactivity across 3 mol.% yttria stabilized zirconia (3YSZ), Gd_2O_3, and $(Y_{1/2}Yb_{1/2})_2Si_2O_7$ (YYbDS) by coupling high temperature contact angle experiments conducted at 1260 °C for 30 min with microscopy, elemental, and phase analyses. In 3YSZ, increased porosity promoted deeper infiltration but suppressed lateral spreading. Gd_2O_3 showed the opposite trend in that greater porosity enhanced CMAS spreading that was attributed to its reactivity. For YYbDS, despite being chemically reactive, showed reduced spreading with increased porosity. Linear regression revealed strong correlations between porosity and a few wetting parameters depending on the reactivity regime. These findings reveal that porosity dependence on CMAS interactions with a substrate are coupled with reactivity and provide an approach to forecast CMAS behavior with novel materials.

HTCMCS5- Advanced testing and non-destructive evaluation methodologies

Room: Silver Pearl 2/3
Session Chair: Elizabeth Opila, University of Virginia

10:40 AM

(HTCMC-S5-015-2026) Optical diagnostics of CMAS infiltration into environmental barrier coatings with spectroscopic ellipsometry and high temperature spectral pyrometry

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Jet turbine engines are susceptible to intaking environmental particles such as dust and ash which are represented in laboratories as calcium-magnesium-aluminosilicate (CMAS). Once the CMAS reaches the hot, ceramic matrix composite (CMC) turbine blades, CMAS will form a molten, corrosive species that degrades barrier coatings protecting turbine blades from the extreme, high temperature environment. Environmental barrier coatings (EBCs) aim to serve as an additional layer of protection to defend against CMAS infiltration. This work investigates optical diagnostic approaches to improve understanding and detection of CMAS infiltration in EBCs. The first approach employs spectral pyrometry at temperatures near engine operating conditions (~1400°C) to examine changes in emissivity caused by CMAS infiltration, providing insight into its impact on radiative heat transfer during operation. The second approach uses spectroscopic ellipsometry to measure polarization changes upon reflection, enabling extraction of optical properties such as absorption behavior and dielectric function. Correlating these optical signatures with CMAS infiltration depth supports the development of a nondestructive technique for assessing EBC health and predicting degradation.

HTCMC-12 Symposium 7- Materials for Extreme Environments – UHTCs, MAX phases, and nanolaminates

HTCMCS7- Response of UHTCs/UHTCMCs in Extreme Environments II

Room: Osprey
Session Chair: Theresa Davey, Bangor University

8:30 AM

(HTCMC-S7-030-2026) Eutectics observed in Group (IV,V) binary transition metal diboride (Invited)

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This work presents direct experimental evidence of invariant eutectic reactions in all investigated binary (Group IV – Group V) transition metal diboride Systems [$(Ti,Nb)B_2$; $(Ti,Ta)B_2$; $(Zr,Nb)B_2$; $(Zr,Ta)B_2$; $(Hf,Nb)B_2$; $(Hf,Ta)B_2$]. Published phase diagrams for these systems previously did not include the invariant eutectic reactions. Eutectic microstructures were achieved through laser heating and cooling from the melt. In addition, the existence of a eutectic in the $(Zr,Ta)B_2$ binary system is further verified with calorimetric measurements

of excess enthalpies and a preliminary updated phase diagram is presented for the $(Zr,Ta)B_2$ binary system. These results highlight that phase diagrams presented for these transition metal diborides need to be updated to reflect the observed eutectic reactions.

9:00 AM

(HTCMC-S7-031-2026) Uncovering the spectral emissivity of transition metal carbides at ultrahigh temperatures

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Ultrahigh temperature ceramics are candidates for hot structures in hypersonic and space vehicles, where radiation becomes significant above 2500 K. Yet the temperature dependence of emissivity remains largely unquantified from first principles. We address this by combining measurements with finite-temperature electronic structure modeling across single-cation carbides (ZrC, TaC, HfC, TiC, NbC) and a high entropy carbide, (ZrTaTiHfNb)C, from 0-4000 K. Spectral emissivity is measured via high-power localized laser heating and hyperspectral pyrometry using the direct radiance method from 500–1000 nm and above 1500 K; a band that coincides with the blackbody peak at ultrahigh temperatures. On the theory side, interband optical properties are computed from DFT, incorporating equilibrium thermal displacements, quasi-harmonic lattice expansion and electronic smearing. Intraband response is obtained with EPW pipelines, capturing electron-phonon limited transport and the Drude contribution to the complex dielectric function. Direct comparison resolves the competing roles of free carriers and interband transitions and clarifies how electron-phonon scattering, thermal disorder, and composition shape emissive trends. We report validated spectral emissivity trends, mechanism-specific signatures across composition, and implications for designing next-generation UHTC thermal protection systems.

9:20 AM

(HTCMC-S7-032-2026) Influence of the state and quantity of oxygen on the oxidation mechanisms of a ZrB2-ZrC-SiC system under high flux conditions

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4. Office National d'Etudes et de Recherches Aerospatiales, France

During atmospheric re-entry, thermal protection materials are subjected to severe environments under high heat fluxes. At hypersonic velocities, the aerodynamic heating experienced by spacecraft leading edges can reach temperatures above 2000 °C for several minutes. In this framework, interest is focused on the description of the behaviour in different environments of monolithic ceramic materials selected as thermal and chemical protection systems at ultra-high-temperatures. In this study, to investigate such a response, various aging tests under different atmospheres are required on the same material. Different oxidation methods under high thermal flux were used to extract the impact of the oxygen partial pressure and its state on the oxidation kinetics of the material. The kinetics were identified in agreement with the dominant mechanisms operating within the material, depending on Po2 and the involved oxygen species. As a function of the range of experimental conditions (temperature, pressure, time), microstructural analysis allows to highlight differences in: (i) densification, (ii) oxide layer thickness, (iii) SiC depletion thickness and (iv) quantity of consumed material.

HTCMCS7- Response of UHTCs/UHTCMCs in Extreme Environments III

Room: Osprey
Session Chair: Scott McCormack, University of California Berkeley

9:40 AM

(HTCMC-S7-033-2026) Recent developments and characterization of ultra-refractories for harsh environments

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UHTC are good candidates to fulfil the harsh requirements of hypersonic and propulsion applications (nose, leading edge and air intakes of hypersonic vehicle, combustion chamber, nozzle and injector for propulsion system, etc.). Under these severe conditions of use, materials are subjected to numerous stresses: temperatures exceeding 2000°C, high mechanical loads, corrosive and oxidizing atmospheres, erosion due to high-speed flow, etc. As a result, for several years, ONERA has been involved in the development of this family of materials. Our work focuses on both monoliths and composites, and testing is carried out from specimen to prototypes representative of the application. Within this framework and depending on the programs, research is conducted to develop UHTC compositions, test manufacturing processes (for UHTCMC materials, functionally graded materials, etc.), and develop specific test benches to better understand degradation mechanisms. The presentation will cover ongoing developments. These include HT oxidation resistance evaluations of new diboride-based UHTC compositions using dedicated laser benches. We will also discuss exploratory developments in additive manufacturing of UHTC and UHTCMC parts, and, depending on their level of maturity, protective UHTC coatings for composites. Furthermore, if available, the latest prototype tests currently in preparation will be included.

10:20 AM

(HTCMC-S7-034-2026) From prediction to proof: Zirconium carbonitrides with near-record melting temperatures

H. B. Schonfeld*[1]; Q. Hong[2]; I. M. Hawthorne[3]; S. Ryu[1]; D. Fisher[2]; J. Matteucci[4]; S. Ushakov[4]; A. CampBell[2]; H. Xu[4]; P. E. Hopkins[1,3]; E. J. Opila[3,1]; A. Navrotsky[4]

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Ultrahigh temperature ceramics (UHTCs) enable hot structures in hypersonic and space vehicles, where temperatures exceed 2500 K. By definition, UHTCs must melt above 3273 K, yet only a small subset of known ceramics meet this criterion, motivating discovery of new compositions whose thermal and mechanical properties can be tailored for such extremes. Here we present an integrated computational-experimental strategy to discover and validate refractory materials in the Zr-C-N system. A machine learning model rapidly screens melting points to propose nitrogen-rich zirconium carbonitrides, which we then assess with ab initio molecular dynamics. The calculations predict exceptional thermal stability, with melting points up to ~4100 K, within a few hundred kelvin of record-holding hafnium carbonitrides. We validate these predictions with laser-based, containerless melting experiments utilizing hyperspectral pyrometry, which locally melt candidate compositions and confirm the simulated melting behavior. This ML-AIMD-experiment pipeline provides a generalizable framework for accelerating discovery of the next-generation UHTCS, with Zr(C,N) emerging as a high-performance, earth-abundant candidate.

10:40 AM

(HTCMC-S7-035-2026) Synthesis and characterization of 2.5D C/SiC composites with SiC/ZrB2/SiC modified matrix for ultra high temperature applications

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2. CSIR National Aerospace Laboratories, Materials Science Division, India

Ultra-high-temperature ceramic matrix composites (UHTCMCs) are promising for extreme-environment applications such as turbine engines, rocket nozzles, thermal protection systems (TPS) in hypersonic vehicles, and nuclear systems. Carbon fiber–reinforced silicon carbide (C/SiC) composites offer excellent dimensional stability, high-temperature strength, and oxidation resistance. In this study, 2.5D C/SiC composites (1.8–2.0 g/cc) were fabricated using isothermal chemical vapor infiltration (ICVI) with an MTS–H2 precursor and characterized for thermal, mechanical, and microstructural performance. Zirconium diboride (ZrB2), an ultra-high-temperature ceramic (melting point ~3200 °C), provides high thermal conductivity, strength, and ablation resistance. To improve oxidation behavior above 1300 °C, 30 wt.% SiC was added. In the final CVI stage, a ZrB2/SiC-modified matrix was introduced via phenolic formaldehyde impregnation, followed by pyrolysis, heat treatment, and liquid silicon infiltration (LSI). The resulting SiC/ZrB2/SiC-modified C/SiC composites were evaluated for thermo-mechanical and tribological properties. The ZrB2 addition markedly enhanced high-temperature stability, making the material suitable for hypersonic use. Leading-edge components coated with ZrB2/SiC were tested under hypersonic erosion, and key performance results are presented.

11:00 AM

(HTCMC-S7-036-2026) Effect of SiC content on the densifiction, mechanical properties, and ablation response of HfC-SiC-TaC UHTCs

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Placeholder This study investigates the evolution of protective oxide layers in HfC-SiC-TaC ultra-high-temperature ceramics (UHTCs) subjected to prolonged oxyacetylene ablation at ~2400 °C. Building upon prior work optimizing TaC reinforcement, this phase examines the effects of decreasing SiC content (5-20 wt.%) on oxide formation mechanisms and long-duration ablation performance. Composites were fabricated via pressureless sintering and exposed to extended ablation durations of up to 25 mins to monitor the progressive evolution of surface chemistry, morphology, and stability. Microstructural and compositional characterization revealed the development of dense, multilayered oxide scales composed of $HfSiO_4$, $Hf_6Ta_2O_{17}$, and SiO_2-rich amorphous regions, with fine Ta_2C nanoparticles embedded near the surface. As SiC content decreased, the oxide network exhibited greater compositional uniformity and adherence, suppressing SiO volatilization and minimizing spallation. The stable and continuous oxide layer effectively restricted oxygen ingress and preserved the underlying microstructure under extreme thermal flux. These findings demonstrate the critical role of SiC variation in governing oxide-scale chemistry and thermal protection efficiency, establishing a framework for compositional optimization of HfC-based ceramics in next-generation hypersonic and re-entry environments.

GFMAT-3 Symposium 2- Functional Nanomaterials for Sustainable Energy Technologies

GFMATS2- Metal oxide nanostructures for sensing, batteries, and water splitting applications

Room: Sandpiper C

Session Chair: Donglu Shi, University of Cincinnati

1:30 PM

(GFMAT-S2-001-2026) Plasma-driven engineering of functional oxides for photonic and energy applications (Invited)

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This presentation explores plasma-based methods for producing advanced oxides for next-generation photonics and for environmental and energy uses such as water purification and green hydrogen. The focus is on Pulsed Laser Deposition (PLD) to grow undoped and doped VO_2 and TiO_2 thin films. VO_2 is notable for its sharp, reversible metal–insulator transition (MIT) near 68°C, causing large changes in resistivity and IR/THz reflectivity. The work examines how W, B, N, and Cr dopants influence the MIT, phase stability, and optical properties, supported by Density Functional Theory. It also highlights the combined roles of W-doping and interfacial strain from (001) rutile TiO_2 substrates, and introduces a low-temperature, large-area PLD route enabling high-quality VO_2 films on flexible polymers. PLD-grown TiO_2 photocatalysts are also presented. A six-layer nitrogen-gradient TiO_2 with multiple homojunctions shows superior photocatalytic performance and photocurrent generation thanks to its 1D structure and strong internal fields. Finally, $BiVO_4$ on black TiO_2 nanotube arrays enables efficient visible-light degradation of a persistent antibiotic, demonstrating strong potential for environmental remediation.

2:00 PM

(GFMAT-S2-002-2026) Hybridization of graphene and molybdenum oxide with the field-effect transistor for volatile organic compound gas sensing

O. Okanishi*[1]; A. Katsura[1]; Y. Hirose[1]; N. Nagamura[3]; T. Ono[2]; T. Uemura[2]; T. Sugahara[1]

1. Kyoto Kogei Sen'i Daigaku, Japan
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3. Busshitsu Zairyo Kenkyu Kiko, Japan

Sensing of volatile organic compounds (VOCs) in exhaled human breath are enabled the early detection of the serious illnesses and, disease, etc. The VOCs sensing with high sensitivity and simplicity is expected to be used as future technology for human health care. VOCs sensors based on metal oxide semiconductor (MOS) have attracted significant attention for their robustness, compactness, and high sensitivity. However, MOS sensors face challenges such as high impedance and significant power consumption. Our research group have developed the hybrid gas sensor with integrating the graphene and molybdenum oxide nanorod-array thin film (MoO_x). The hybrid gas sensor achieves low electrical resistance from integrating highly conductive graphene. The hybrid sensor was able to maintain high gas response sensitivity as incorporating nanostructured MoO_x with the large specific surface area. In this study, we fabricated the hybrid gas sensor with the field-effect transistor (FET) structure, and performed the detailed investigation as the gas sensing characteristics with influence of the field effect into the various VOCs such as Ethanol, 1-propanol, 2-propanol, etc.

GFMATS2- Nanomaterials for energy conversion, storage, and catalysis

Room: Sandpiper C
Session Chair: Giovanni Fanchini, University of Western Ontario

2:20 PM

(GFMAT-S2-003-2026) Rational Design of Perovskite Oxide Catalysts for Efficient CO_2 Methanation (Invited)

B. Koo*[1]

1. Sungshin Women's University, School of Chemistry and Energy, Republic of Korea

Among the various carbon reduction technologies, CO_2 methanation can contribute to reducing CO_2 emissions by chemical reaction with hydrogen (H_2). However, it is necessary to develop catalysts with high catalytic activity and durability in order to maintain methane production for a long time. Exsolution process is a synthetic technique of metal nanoparticles, in which metal ions doped in B-site of perovskite oxide (ABO_3) lattice escape from the lattice and form well-distributed metal nanoparticles on the oxide surface. It has been reported to perform as an active and stable catalyst by anchoring metal nanoparticles with oxide supports in high-temperature catalysis. Accordingly, this study aims to apply an isovalent doping effect in perovskite-type oxide to promote the exsolution of Palladium (Pd), which is known as a representative active catalyst for CO_2 methanation reaction. Barium (Ba) is added in Strontium (Sr) sites in perovskite oxide for controlling on Pd-O bond length in the $SrTiO_3$ as a model oxide support. The catalytic activity and durability of Pd exsolved $SrTiO_3$ catalysts by Ba doping in Sr sites against CO_2 methanation are evaluated. Pd-excess can be remarkably accelerated by the isovalent doping effect, improving the catalytic activity and long-term stability of the perovskite surface.

3:10 PM

(GFMAT-S2-004-2026) Solar photothermal energy generation through multiple transparent Fe_3O_4–$Cu_{2-x}S$ thin films for building utility heating (Invited)

D. Shi*[1]; M. Gandharapu[1]; A. Katepalli[1]; A. Harfmann[2]; M. Bonmarin[3]; J. Krupczak[4]

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3. ZHAW Zurcher Hochschule fur Angewandte Wissenschaften, Engineering, Switzerland
4. Hope College, Engineering, USA

We present a Photothermal Solar Tunnel Radiator (PSTR) that uses multiple Transparent Photothermal Glass Panels (TPGP) to provide energy-neutral heating for built environments. A lab-scale Photothermal Solar Box (PSB) demonstrates the concept, heated entirely by sunlight converted through glass panels coated with Fe_3O_4–$Cu_{2-x}S$, which offer both transparency and strong solar absorption. We also evaluate a related Photothermal Solar Tunnel (PTST), a simplified solar-thermal system that converts sunlight directly into heat without the complex components required in photovoltaic-based heating. Experiments on the University of Cincinnati campus tested performance across different weather conditions, including subzero temperatures. Under ambient temperatures of minus 5 to minus 7°C, the photothermal panels increased surface temperatures to 30.9°C and raised internal tunnel air temperatures to 22.8°C with minimal insulation. The system also retained heat during intermittent sunlight. These results show strong potential for greenhouse heating, sustainable building design, and off-grid thermal applications. Further gains could be achieved with improved insulation, optimized airflow, and thermal storage. Overall, the findings confirm that photothermal panel-based heating is a practical, scalable, and cost-effective approach for renewable thermal energy.

GFMATS2- Transition metal chalcogenides, carbon nanostructures, 2D materials

Room: Sandpiper C
Session Chair: Alberto Vomiero, Lulea University of Technology

3:40 PM

(GFMAT-S2-007-2026) How to not make high temperature ceramics: The curious case of 2D auxetic semicarbides (Invited)

G. Fanchini*[1]

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2D materials exhibiting auxeticity at the molecular level, defined as a positive response strain normal to applied strress, have been receiving tremendous interest in recent years. This unusual behavior can be quantified in terms of negative Poisson's ratio, $v<0$. Giant auxetics are metals in which the density-of-electronic states at the Fermi level increases upon stretching. Many 2D semicarbides have been predicted to be giant auxetics, but their realization is elusive as attempts to synthesize them had so far relied on techniques operating under thermodynamic equilibrium, even if many of such materials are known to form only at irrealistically high tempera-tures. For example, 2D tungstensemicarbide (W_2C) was predicted to exhibit giant auxeticity, but had yet to be synthesized because the full carbide ceramics counterpart (2D-WC) is energetically favored under equilibrium conditions in chemical vapor deposition (CVD) reactors customarily used to grow 2D MXene ceramics. Here, we review the state of the art on auxetic materials and present a remote plasma enhanced CVD reactor specially designed by our research group to grow 2D giant-auxetic carbides out of thermodynamic equilibrium with well-tuned ratios of molecular precursors. (1) Our 2D-W_2C crystals exhibit the strongest auxetic behavior observed to date, in agreement with theoretical reports. (2) Stocek et al Mater Horizons 11 (2024) 3066

GFMAT-3 Symposium 3- Novel, Green, and Strategic Processing and Manufacturing Technologies

GFMATS3- Novel, Green, and Strategic Processing and Manufacturing Technologies II

Room: Sandpiper D
Session Chairs: Tohru Suzuki, National Institute for Materials Science; Shen Dillon, University of California, Irvine

1:30 PM

(GFMAT-S3-008-2026) Clay-based ceramics for hydrogen production and gas separation (Invited)

I. Reimanis*[1]; O. Olaleye[1]; R. McGinnis[1]; S. Ricote[2]; G. Coors[3]; R. Marder[4]; W. D. Kaplan[4]

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2. Colorado School of Mines, Mechanical Engineering, USA
3. Hydrogen Helix, USA
4. Technion - Israel Institute of Technology, Dept. of Materials Science and Engineering, Israel

Kaolinite-based clay exhibits a very porous microstructure with high surface area. When bisque fired it retains the desirable morphology and is ideal for use as a catalyst support as well as for gas separation due to naturally forming porous microchannels. Recent experiments with Ni-infiltrated bisque-fired kaolinite have demonstrated that hydrogen can be produced from ethanol (ethanol steam reforming, ESR) at rates that are of high commercial interest. Additionally, the high surface area and fine pore channels lead to excellent gas separation performance. The talk will describe the processing, including rheological aspects, microstructure evolution, and mechanical integrity of kaolinite-based ceramics in the context of ESR and gas separation.

2:00 PM

(GFMAT-S3-009-2026) Immobilization of laccases on CuO and ZnO nanoparticles: Enhanced stability and catalytic performance for water bioremediation applications (Invited)

O. A. Graeve*[1]; F. Suarez[1]; R. Vazquez-Duhalt[2]

1. University of California, San Diego, Mechanical and Aerospace Engineering, USA
2. Universidad Nacional Autonoma de Mexico, Centro de Nanociencias y Nanotecnologia, Mexico

Laccases are enzymes capable of oxidizing a large variety of organic compounds, including textile dyes for water bioremediation applications. However, laccases show low stability under industrial conditions that decrease their applicability. Thus, the search for options to stabilize these enzymes is of critical importance, with laccase immobilization a particular methodology that can be optimized. In this study, we immobilized laccases on CuO nanoparticles and ZnO nanoparticles by covalent attachment. The activity and stability of the immobilized laccase was measured using UV-Vis spectroscopy under different conditions such as temperature, pH, and the presence of laccase inhibitors. Results demonstrate an increase in the catalytic activity and stability of immobilized laccase, as compared to the free laccase. Inductively coupled plasma mass spectrometry showed a direct relationship between the stability of laccase and the release of copper ions from the CuO nanoparticles. These findings highlight the potential of nanoparticles in enhancing laccase performance and their broader application in water bioremediation efforts.

2:30 PM

(GFMAT-S3-010-2026) Lignin-based polymer precursors for advanced ceramic systems (Invited)

D. Gilmer*[1,2]; R. Walker[1]; J. Fischer[1]; J. Brown[1]; T. Nelson[3]; D. Harper[1]

1. The University of Tennessee Knoxville Tickle College of Engineering, Material Science and Engineering, USA
2. Oak Ridge National Laboratory Energy Science and Technology Directorate, USA
3. University of Tennessee Oak Ridge Innovation Institute, USA

Compositionally complex ceramics (CCCs) consist of multiple ceramic species with high nano- and atomic-scale disorder, which can result in superior thermal, mechanical, and chemical performance compared to traditional single-phase ceramics. Carbide, boride, and nitride CCCs are promising for extreme environments, but their synthesis is limited by the difficulty of achieving atomic-level mixing before high-temperature diffusion becomes restricted. This work investigates a polymer-derived ceramics (PDC) route that utilizes functionalized methanol-fractionated lignin as a bio-derived and low-cost carbonaceous precursor for CCC synthesis. Methanol-fractionated lignin is modified with (3-aminopropyl)triethoxysilane (APTES), introducing a silicon-containing functional group terminated with a primary amine capable of coordinating metal-acetylacetonates. The motivation of this functionalization is to explore new and potentially viable precursor pathways toward CCC formation while contributing to the long-standing industrial and academic interest in lignin valorization. This research aims to assess whether lignin-based PDCs can generate non-oxide ceramics with properties suited for extreme operating environments while establishing lignin as a credible precursor material for advanced ceramic systems.

3:20 PM

(GFMAT-S3-011-2026) 3D printable ceramics from glass and pre-ceramic polymers: From molecular design to additive manufacturing (Invited)

M. Sobczak[1]; K. Song*[1]

1. University of Georgia, Mechanical Engineering, USA

This work presents a unified approach to 3D-printable ceramics based on low-temperature glass formulations and polymer-derived ceramic (PDC) precursors. UV-curable polysiloxane (UV-PSO) systems are synthesized through controlled HEA functionalization and optimized UV/thermal crosslinking to yield SiOC ceramics with high ceramic yield and exceptional dimensional stability. These precursor-designed PDCs are compatible with SLA and enable patterned surface wrinkling that remains stable after pyrolysis. Complementary glass-ink development provides inorganic printable feeds that sinter into transparent or opaque glass-ceramic components. Using direct ink writing (DIW), silica-based glass inks are co-printed to create hybrid structures with tailored interfaces, packing factors, mechanical properties, and high-temperature performance. Our SLA and DIW platforms demonstrate precise microstructural control from molecular design through pyrolysis and sintering, enabling new ceramic architectures for thermal management, microfluidics, lightweight structures, and functional coatings.

3:50 PM

(GFMAT-S3-012-2026) Binder Jet additive manufacturing of recycled glass to form trim tools

T. Prum*[1]; D. Gilmer[1]; A. Stiles[2]; R. Walker[1]

1. The University of Tennessee Knoxville Tickle College of Engineering, Materials Science and Engineering, USA
2. Vitriform3D, USA

This study investigates the use of recycled glass powder as a sustainable feedstock for binder jet additive manufacturing (BJAM) of tooling used in carbon fiber composite molding. The goal is to evaluate whether post-processed glass-based tooling could achieve the surface finish, dimensional accuracy, and thermal stability required for high-temperature composite forming. Recycled soda-lime glass was processed to 153-206 μm, then processed via binder jetting using a Concre3de Armadillo Green printer. The printed parts were infiltrated with Pro-Set INF-114 epoxy and bismaleimide to enhance mechanical properties. The findings indicate that recycled glass offers a viable and environmentally responsible material option for producing complex, reusable tooling via BJAM.

4:10 PM

(GFMAT-S3-013-2026) Hydrothermal processing of nanostructured oxide coatings for self-cleaning surfaces

J. Cho*[1]

1. Binghamton University, Mechanical Engineering and MSE, USA

Surface and air contamination by harmful pollutants and pathogens pose significant risks to public health, necessitating frequent disinfection and cleaning. Ceramic coatings composed of metal oxides offer a promising solution by enabling surface reactivity for the decomposition of organic contaminants and microorganisms, thereby providing self-cleaning and antimicrobial functionality. Achieving these properties requires ceramic surfaces engineered with highly crystalline nanostructures. In this study, we utilized low-temperature hydrothermal processing to tailor a range of nanostructures based on TiO_2, ZnO, and their hybrid nanocomposites. These nanostructures exhibit antimicrobial properties through photocatalytic reactions under UV or visible light, as well as contact-based inactivation even without light illumination. Our findings highlight key ceramic design principles for developing nanocomposite coatings with self-cleaning and antibacterial performance. Additionally, the low-temperature, low-energy processing protocol demonstrated here offers a pathway toward more sustainable technologies and holds potential for applications in water and air purification and the effective removal of organic and biological contaminants.

4:30 PM

(GFMAT-S3-014-2026) Design at nanoscale of thermostable hybrid sol-gel bondlayer to functionalize aeronautical CFRP by thermal spray

S. Senani - de Monredon*[1]; L. Rozes[2]; A. Joulia[3]; G. Penvern[4]

1. Safran Electronics & Defense Massy, Head of Operations Dpt, France
2. Sorbonne Universite, LCMCP, France
3. Safran Tech, PFX, France
4. Safran Tech, Composites, France

Composite Fibers Reinforced Parts are widely used in aeronautic since more than 40 years to decrease the aircrafts environmental footprint. Indeed CO_2 and NO_x emissions have been considerably decreased by lightweighting correlated to significate fuel consumption reduction. To go further and reach the new ambitious target of 20% reduction for the next aircraft engine, functionalization of CFRP is mandatory to extend them to more aggressive use cases. To reach this goal, thermal spray coatings are widely studied, even if it remains very complex to implement. Metallization of CFRP by coldspray is favored by numerous teams, with interesting results but not sufficient to fit performance required for aeronautic qualification. Our approach aims to design a thermostable sol-gel hybrid bondcoat. We will discuss how we succeed to control the nanostructuration and the nature of the substrate/bondlayer/topcoat interfaces to influence the thermomechanical bondcoat's properties and thus the building and the thickness increase of the thermal sprayed topcoat layer linked to the adhesion of the stack. Understanding the relation between nanostructuration of the hybrid sol-gel layer and their thermomechanical properties is essential to optimize the whole system. Finally, this will widely open the variety of materials reachable to functionalize CFRP part and allow new use cases.

GFMAT-3 Symposium 6- Advanced Batteries and Supercapacitors for Energy Storage Applications

GFMAT-S6- New and Emerging Electrochemisty

Room: Tidepool 1

Session Chairs: Vallabha Rao Rikka, Underwriters Laboratories Inc; Palani Balaya, National University of Singapore

1:30 PM

(GFMAT-S6-029-2026) High-capacity intercalation-type cathode materials using anionic redox for all-solid-state fluoride-ion batteries (Invited)

K. Yamamoto*[1]

1. Nara Women's University, Japan

All-solid-state fluoride-ion batteries, which use fluoride-ions as carriers, are attracting attention as the next-generation batteries due to their theoretical high energy density and safety. Although simple metal/metal fluorides such as Cu/CuF_2 have been developed as conventional cathode materials, these cathode materials have disadvantages of the power density and cyclability due to the large volume change during charging/discharging. To solve these problems, intercalation-type cathode materials, similar to the cathode materials applied in lithium-ion batteries, have been developed. The intercalation-type cathode materials exhibit superior rate performance and cyclability to the simple metal/metal fluorides whereas they have the disadvantage of relatively small capacity due to the heavy formula weight. In this presentation, high-capacity intercalation-type cathode materials by using anionic redox was developed. When the charge compensation by anion redox occurs, molecular formation originating from anions has been observed within the cathode materials. In this presentation, the detailed reaction mechanism will be discussed.

2:00 PM

(GFMAT-S6-030-2026) Accelerating the development of high-performance battery materials through human-in-the-loop active learning and generative design (Invited)

I. Park*[1]

1. Daegu Gyeongbuk Institute of Science & Technology, Department of Energy Science and Engineering, Republic of Korea

The rapid advancement of secondary battery technologies is essential for sustainable energy solutions, yet the traditional material development cycle remains slow and resource-intensive due to the high-dimensional design space of chemical compositions and processing parameters. This presentation discusses strategies to accelerate this cycle by integrating advanced artificial intelligence into the experimental workflow. We explore the implementation of human-in-the-loop frameworks that combine researcher intuition with active learning and generative modeling. By utilizing closed-loop optimization, we demonstrate how significant improvements in material performance, such as discharge capacity and microstructural control, can be achieved with a substantially reduced number of experiments. Specific focus is placed on overcoming the gap between fundamental laboratory discovery and industrial-scale fabrication through automated image analysis and physics-informed diagnostics. These component technologies enable a more efficient exploration of process-dependent properties, ultimately fostering a self-improving loop for the discovery of next-generation energy storage materials. This integrated approach offers a significant opportunity to streamline the development of high-performance materials essential for next-generation energy storage technologies.

2:30 PM

(GFMAT-S6-031-2026) Electrolyte design for Li metal batteries: Toward improving cycle stability (Invited)

M. Kim*[1]

1. Kwangwoon University, Republic of Korea

To develop high–energy-density lithium-ion batteries, significant efforts have been devoted to the design of advanced electrode materials. However, as the energy density increases, large structural changes often occur during cycling, leading to poor reversibility and limited cycle stability. While approaches such as doping and surface coating have been explored to address these issues, this study focuses on enhancing stability through electrolyte engineering, which directly influences the interfaces with active materials (both cathode and anode). Moreover, for next-generation conversion-type electrodes that generally require lithium metal as the anode, the development of optimized electrolytes is even more critical. In this presentation, we discuss the mechanisms and results of improved cycling stability achieved through tailored electrolyte formulations in lithium metal battery systems.

3:20 PM

(GFMAT-S6-032-2026) Binder-enabled solvation control suppresses SEI invasion in silicon anodes (Invited)

V. Rikka*[1]; W. Tang[1]; J. Jeevarajan[1]

1. Underwriters Laboratories Inc, Electrochemical Safety Research Institute, USA

Silicon anodes promise high gravimetric capacities, yet their deployment remains constrained by extreme volume changes and progressive inward growth of the solid–electrolyte interphase (SEI), which infiltrates the electrode interior and electrically isolates active silicon. While most binder designs focus on accommodating mechanical expansion, the role of the binder in regulating ion transport and interfacial solvation to arrest SEI invasion remains unclear. Here we report a Li-ion activated, 3D supramolecular binder based on carbonyl-functionalized β-cyclodextrin that couples adaptive mechanics with solvation control. The macrocyclic scaffold provides multivalent anchoring, while carbonyl groups dynamically coordinate Li-ion and partially displace solvent molecules at the electric double layer, lowering desolvation barriers and suppressing electrolyte reduction. Reversible imine crosslinks integrate these interactions into a tough yet viscoelastic network that accommodates silicon expansion while establishing continuous Li-ion pathways. As a result, silicon anodes exhibit reduced SEI thickness, stabilized interfacial impedance, preserved electronic connectivity, and sustained capacity retention during extended cycling. This work identifies binder-enabled solvation engineering as a strategy to suppress SEI invasion and enable durable, high-capacity silicon anodes for long-life lithium-ion batteries.

3:50 PM

(GFMAT-S6-033-2026) Phosphorus doping led improvement on the electrochemical property of rGO with SiO_x composite as anode material for lithium-ion battery (Invited)

J. Huang*[1]

1. National Cheng Kung University, Materials Science and Engineering, Taiwan

Wen-Feng Lin, Yu-Min Shen, Jow-Lay Huang Department of Materials Science and Engineering, National Cheng Kung University, Tainan 70101, Taiwan Lithium-ion batteries (LIBs) are among the most promising energy storage technologies due to their high energy density, large capacity, and lack of a memory effect. In this study, we investigate non-stoichiometric silicon oxide (SiOx, $0 < x < 2$) as a potential anode material due to its relatively lower volume expansion compared to pure silicon. we incorporate reduced graphene oxide (rGO) and phosphorus (P) to enhance the electrochemical performance of SiOx. The two-dimensional layered structure of rGO facilitates lithium-ion and electron transport, while its carbonaceous nature improves electrical conductivity. Additionally, phosphorus doping, introduced using phosphoric acid followed by post-annealing, modifies the structural and electronic properties of rGO, creating additional lithium storage sites and improving the initial coulombic efficiency (ICE).

4:20 PM

(GFMAT-S6-034-2026) Ceria-carbonate heterostructure reinforced PBI composite membranes for enhanced performance and durability in high-temperature PEM fuel cells (Invited)

P. Singh*[1]

1. Indian Institute of Technology(BHU), Physics, India

High-temperature proton exchange membrane fuel cells (HT-PEMFCs) require electrolytes that combine high proton conductivity, thermal robustness, and long-term electrochemical stability under anhydrous conditions. In this work, a ceria-based heterostructure composite (CHC) consisting of CeO_2 integrated with a eutectic mixture of Li_2CO_3/Na_2CO_3 (CLNC) was incorporated as an inorganic functional filler into a polybenzimidazole (PBI) matrix to fabricate a mixed-matrix membrane for HT-PEMFC applications. The CLNC powder was synthesized via solid-state ball milling followed by thermal treatment, and 5 wt% filler was dispersed into PBI using solution casting to obtain PBI/CLNC composite membranes. Structural and morphological characterizations (XRD, FTIR, SEM–EDX) confirmed the formation of a fluorite-phase ceria framework with amorphous carbonate distribution and homogeneous dispersion of the composite within the polymer matrix. Phosphoric acid (PA) doping revealed a ~17% lower acid uptake in the composite membrane compared to pristine PBI, resulting in reduced swelling and improved dimensional stability. Enhanced proton conductivity for the PA-doped PBI/CLNC membrane (42.3 mS per cm at 180 °C) was obtaimed compared to pristine PBI (36 mS per cm), with reduced activation energy (9.31 kJ mol^{-1}).

GFMAT-3 Symposium 11- Ceramics and Glasses for Bio-Medical Applications

GFMATS11- Ceramics and Glasses for Bio-Medical Applications

Room: Sandpiper A
Session Chairs: Pelagia-Irene Gouma, The Ohio State University; Cristina Balagna, Politecnico di Torino

1:30 PM

(GFMAT-S11-004-2026) Design of calcium phosphate invert glasses for biomedical applications (Invited)

S. Lee*[1]

1. National Institute of Advanced Industrial Science and Technology (AIST), Japan

Inorganic ions can stimulate cellular activity at proper concentrations, enhancing adhesion, proliferation, and differentiation, whereas excessive amounts may inhibit functions or cause cytotoxicity. Our research group focuses on bioactive phosphate glasses that control ion release. Phosphate glasses, more acidic than silicate ones, have attracted interest for their diverse inorganic ion contents. To regulate release behavior, our group studied phosphate invert glasses incorporating intermediates such as TiO_2, Nb_2O_5, ZnO, and MgO into the glass network. TiO_2, Nb_2O_5, and ZnO improve glassification and chemical durability, while MgO enhances glassification but reduces chemical durability. Based on these findings, phosphate glasses containing large amounts of MgO and ZnO were designed to consist mainly of orthophosphate units. These glasses showed good glassification and higher ion release, making them promising as carriers for therapeutic ions in bone regeneration. Recently, we succeeded in synthesizing bioactive phosphate invert glasses at room temperature via a liquid-phase method. The glasses feature a novel chain-like structure, $(–O–P–O–P–O–Ti/Nb–O–)_n$, formed by pyrophosphate units bridged with TiO_x/NbO_y. This chain structure has not been reported in conventional melt-quench-derived phosphate glasses, representing a new development in glass science with potential biomedical applications.

2:00 PM

(GFMAT-S11-005-2026) Sustainable antimicrobial composite coatings for air filtration and biomedical applications (Invited)

C. Balagna*[1]; A. Luceri[2]; F. Gattucci[2]; M. Donalisio[4]; D. Lembo[4]; M. Ferraris[3]

1. Politecnico di Torino, Dept. Applied Science and Technology, Italy
2. Politecnico di Torino, DISAT, Italy
3. Politecnico di Torino, Department of Applied Science and Technology, Italy
4. Universita degli Studi di Torino, Italy

This work presents nanostructured glass/ceramic composite coatings embedding silver nanoparticles, developed also within the EU-funded NANOBLOC project to enhance health and environmental protection. These coatings provide durable antimicrobial and antiviral activity for air filtration systems and potentially for biomedical surfaces. Two eco-friendly fabrication routes were explored: magnetron co-sputtering and pre-ceramic polymeric precursors. Co-sputtering enables thin, homogeneous films with silver nanoclusters uniformly distributed in SiO_2 or ZrO_2 matrices, ensuring controlled and prolonged silver-ion release. The coatings exhibit strong efficacy against bacteria, fungi, and viruses, including influenza and SARS-CoV-2, and maintain biocidal performance after repeated thermal sterilization. The pre-ceramic route allows low-temperature processing and minimal waste generation, supporting energy-efficient and sustainable manufacturing. The combination of tailored composition, scalability, and robust antimicrobial performance makes these coatings suitable for integration into air filtration systems, clinical environments, and high-touch public surfaces. This research demonstrates the potential of engineered glass and ceramic materials as multifunctional, sustainable solutions for infection control and improved air quality.

2:30 PM

(GFMAT-S11-006-2026) Ceramic-polymer composites – different manufacturing approaches but the same goal to regenerate bone and osteochondral tissue defects (Invited)

E. Pamula*[1]

1. AGH University of Krakow, Faculty of Materials Science and Ceramics, Department of Biomaterials and Composites, Poland

Bone and osteochondral injuries are challenging clinical tasks that require a personalised approach and the application of medical devices to support regeneration. Such devices can be made of ceramic-polymer composites that mimic the native extracellular matrix to provide the appropriate signals to cells. In our group, we are using different approaches to biomaterial design and manufacturing, but we have one aim, improved tissue healing. We produce scaffolds made of bioglass or TCP particles embedded in resorbable polymers, and their degradation kinetics is correlated with tissue healing. The other approach is based on the application of hydrogels of polysaccharide/protein origin, which we can mineralise with calcium phosphates (CaP) by enzymatic means. We can also produce osteochondral scaffolds by 3D indirect printing, with the use of sacrificial moulds, in which the hydrogel is poured and after setting the mould is dissolved. Concomitantly, if soaking is carried out in CaGP, a fully or partially-mineralized scaffold can be produced suitable for osteochondral defects. Our composite materials are cytocompatible with osteoblasts, macrophages, and mesenchymal stem cells and histocompatible, as shown by in vivo tests. This study was supported by the HORIZON-MSCA- 2023-SE-01-01 EngVIPO project (ID: 101183041).

3:20 PM

(GFMAT-S11-007-2026) Coacervate–hydroxyapatite hybrids for bone repair (Invited)

J. J. Chung*[1,2]

1. Seoul National University Hospital, Transdisciplinary Medicine, Republic of Korea
2. Seoul National University College of Medicine, Medicine, Republic of Korea

Currently, no single material fully satisfies the requirements for repairing critical-sized and congenital bone defects. An ideal bone repair material should provide sufficient mechanical stability, stimulate osteogenic cell activity, promote mineralized bone formation, and biodegrade as host tissue regenerates. Coacervates have previously been developed to protect growth factors from rapid degradation and limited biological half-lives. Coacervates formed from fucoidan and poly-L-lysine arise from electrostatic interactions between oppositely charged polyelectrolytes until a near charge-neutral state is achieved. This presentation introduces a coacervate–hydroxyapatite hybrid material for bone repair applications. The incorporation of dopamine-functionalized coacervates enables encapsulation of bioactive agents and promotes interfacial interactions with hydroxyapatite, while the bioactive ceramic phase supports osteoconductivity and mineralization. This organic–inorganic hybrid provides a bone putty–like material suitable for bone regeneration.

3:50 PM

(GFMAT-S11-008-2026) Evaluation of amorphization mechanism of β-tricalcium phosphate by bead milling

Y. Tsuji*[1,2]; M. Sakurai[2]; T. Kasuga[3]; F. Nagata[1]; S. Lee[1]

1. Sangyo Gijutsu Sogo Kenkyujo Chubu Center, Japan
2. Chubu Daigaku, Department of Applied Chemistry, Japan
3. Nagoya Kogyo Daigaku, Japan

β-tricalcium phosphate (β-TCP) is a bioresorbable material widely used in orthopedic fields. In some cases, its bioabsorbability requires improvement, and increasing its solubility can be one of the effective approaches. Recently, our group reported partially amorphized β-TCP by bead milling, improving its solubility compared to β-TCP. In this work, the amorphization process was evaluated to clarify the mechanism. ^{31}P MAS-NMR spectra showed that the area ratio of amorphous phases increase with milling time. Furthermore, the powder composed of only the amorphous phase can be obtained in the present method. β-TCP consists of several phosphate sites (P (n), n = 1-3) in its crystal structure. The peak areas of P (2) and P (3) more significantly decreased compared to that of P (1). The mechanism of amorphization during bead milling was considered as follows: first, P (2) and P (3) are preferentially broken by mechanical forces, since their PO_4 tetrahedra face each other in the crystal structure, which may be weak points of β-TCP. Subsequently, all of the β-TCP crystal structures are broken, leading to amorphization. The bead milling method can be a novel process to prepare amorphous material for biomedical applications.

4:10 PM

(GFMAT-S11-009-2026) Cytocompatibility evaluation of PVDF-$(Na,K)NbO_3$ composite fibers for neural tissue engineering applications

T. Nafis*[1]

1. Indian Institute of Technology BHU Varanasi I-DAPT HUB Foundation, CERAMIC DEPARTMENT, India

Peripheral nerve injuries often lead to incomplete recovery due to limited neuronal regeneration and the absence of biomimetic scaffolds. Piezoelectric materials offer a promising route to electrically stimulate axonal growth. In this work, electrospun fibers of poly(vinylidene fluoride) blended with 10 vol.% $(Na,K)NbO_3$ were developed and assessed for neural tissue engineering. PVDF was dissolved in DMSO at high temperature, mixed with NKN particulates, electrospun, and corona poled. FT-IR analysis confirmed alpha, beta, and gamma phases, with a marked increase in the electroactive beta phase after NKN incorporation and poling. Primary embryonic mouse neurons showed improved adhesion, neurite extension, and axonal elongation on poled composites compared to unpoled controls. The enhanced cellular response is attributed to improved surface charge distribution and electromechanical cues generated by the piezoelectric fibers. These findings highlight PVDF-NKN composites as promising candidates for self-powered nerve guidance scaffolds aimed at supporting peripheral nerve repair.

Young Professionals Forum

HTCMC-GFMAT-YPF- Non-destructive testing

Room: Sandpiper B

Session Chairs: Jing Liu, University of Alberta; N. Ahmad

1:30 PM

(YPF-013-2026) Real-time monitoring of ceramic sintering and high-temperature behavior via the impulse excitation technique (Invited)

P. Springer Simonova*[1,2]; E. Gregorova[2]; W. Pabst[2]; N. Langhof[1]; S. Schafföner[1]

1. University of Bayreuth, Chair of Ceramic Materials Engineering, Germany
2. University of Chemistry and Technology, Prague, Department of Glass and Ceramics, Czechia

The impulse excitation technique (IET) is a standard non-destructive method for characterizing elastic and anelastic behavior of ceramics and other brittle materials. The technique is based on a light mechanical impact to the sample using a small projectile, recording the resulting acoustic response, and applying fast Fourier transformation to obtain resonant frequencies and associated elastic properties. IET can be integrated into a high-temperature furnace, which enables real-time monitoring of temperature dependence of elastic moduli and damping during heating and cooling. These measurements can reveal characteristic hysteresis loops, reversible phase transitions, and other thermally induced changes that would otherwise require thermal analysis or dilatometry. Compared with these techniques, IET can additionally detect structural and microstructural changes, making it a powerful tool for monitoring sintering processes and high-temperature behavior of materials. In this contribution, the method will be outlined and demonstrated on oxide, non-oxide, and silicate ceramics. Real-time observations of densifying and non-densifying sintering, sintering accompanied by phase transformations, temperature dependence of elastic properties, thermal cycling and its impact on microstructure stability, and softening of amorphous phase will be presented on different types of ceramics.

2:00 PM

(YPF-014-2026) Synchrotron X-ray multiscale tomography for revealing heterogeneous microstructures and defects in ceramics (Invited)

G. Okuma*[1]

1. Busshitsu Zairyo Kenkyu Kiko, Japan

Synchrotron X-ray multiscale tomography, combining micro- and nano-tomography, enables high-resolution 3D imaging of heterogeneous microstructures and defects in ceramics across multiple length scales. In multilayered and high-purity alumina ceramics, strength-limiting defects originate from powder inhomogeneities, layer interfaces, and particle rearrangements during tape casting and sintering. Complex interconnected pores and flake-like micro-sheets form through particle transformation and self-assembly. Fracture analysis and mechanical modeling confirm that these defects govern strength. These results demonstrate that controlling powder heterogeneity and processing conditions is key to designing high-reliability ceramics.

HTCMC-12 Symposium 1- Computational Modeling and Design of New Materials and Processes

HTCMCS1- Computation of mechanical, thermal and thermomechanical properties I

Room: Osprey
Session Chairs: Frank Zok, University of California Santa Barbara College of Engineering; Dong Liu, University of Oxford

1:30 PM

(HTCMC-S1-001-2026) Spatial autocorrelation of fiber fracture in ceramic composites: Theory and practice (Invited)

F. W. Zok*[1]; N. Han[2]

1. University of California Santa Barbara College of Engineering, Materials, USA
2. UCSB, Materials, USA

Micromechanical models of ceramic composites typically assume global load sharing (GLS), where load from broken fibers redistributes uniformly. However, experimental evidence suggests local load sharing (LLS) often dominates, producing break clusters that reduce strength. Quantifying spatial patterns on fracture surfaces is essential for distinguishing these mechanisms. This study employs geostatistical methods for characterizing spatial autocorrelation of fiber breaks: Global Geary's C (for overall correlation), semivariograms (for correlation strength and range), and Local Geary's C (for identifying localized clusters). Simulated fracture surfaces with prescribed autocorrelation are used to (i) evaluate method effectiveness across varying fiber counts and correlation ranges, (ii) establish guidelines for applying these techniques to experimental measurements, and (iii) demonstrate their utility and limitations in diagnosing spatial fracture patterns. Applied to several SiC fiber-based composites, the methods reveal varying levels of spatial autocorrelation––depending on fiber arrangement and processing history–– and strong correlations with composite strength. These tools enable assessment of load-sharing behavior and identification of features promoting damage localization.

2:00 PM

(HTCMC-S1-002-2026) A subvolume homogenisation framework to determine thermo-mechanical properties of SiC/BN/SiC CMCs

A. Soni*[1]; P. Foster[1]; V. Dubey[1]; L. Kawashita[1]; G. Allegri[1]; S. Hallett[1]

1. University of Bristol, Civil aerospace and design engineering, United Kingdom

Ceramic Matrix Composites (CMCs) represents a modern class of materials that combines the excellent thermal properties of ceramics with high strength and toughness of fibre reinforced composites. Subvolume homogenisation offers a computationally efficient way of representing the interactions between the microstructural constituents at the continuum level. First, the tow level properties are obtained using RVE based computational homogenisation, which takes into account the tow architecture and the volume fraction of different constituents. A subvolume mesh is then defined where each elements consists of fiber tow and matrix phases. The material properties of each element of a subvolume mesh are determined using Chamis homogenisation which takes into account the fiber volume fraction in each element, thus representing the microstructural makeup of the composite at continuum levels. These elements are mapped on a coarser macro level mesh and the material properties of each element of the macro level mesh is the numerical average of the properties of subvolume elements contained in that element. The thermo-mechanical properties thus obtained are then compared with those in literature and are found to be in close agreement.

2:20 PM

(HTCMC-S1-003-2026) Characterization of CVI-SiC CMC microstructures using xCT CNN segmentation

B. Lenz*[1]

1. Pratt & Whitney, USA

X-ray micro-computed tomography (xCT) is an effective non-destructive evaluation method for characterizing 3D volumetric microstructures of chemical vapor infiltration (CVI) ceramic matrix composites (CMC). One difficult challenge of executing quantitative analysis of this xCT data is performing a clean segmentation of the silicon carbide (SiC) fibers from the CVI-SiC matrix, due to similarity in greyscale intensity that causes traditional thresholding to produce undesirable results. To solve this problem, the CMC development program at Pratt & Whitney (P&W) has invested in training a convolutional neural network (CNN) deep learning model using Comet Dragonfly software to produce high-performing constituent segmentation of xCT data of CMC microstructures. This talk will discuss the key steps of training, validating, and testing a CVI-SiC CMC xCT CNN segmentation model, as well as showcasing some results and applications of the model and its impact on the CMC development program. Developing this segmentation capability has been a key enabling technology for characterizing CMC phase distributions, elucidating sources CVI process variability, and building links between microstructure and properties. The team currently deploys this model for evaluating CVI-CMC microstructures and continues to improve segmentation capabilities for future work.

2:40 PM

(HTCMC-S1-004-2026) Determination of the mechanical properties of 2D woven plies in ultra-high temperature ceramic composites

T. Rumen*[1,2]; A. Este[1]; M. Montemurro[3,5]; A. Cosculluela[1]; M. Bouchez[4]; A. Catapano[6,2]

1. Commissariat a l'energie atomique et aux energies alternatives Centre d'etudes scientifiques et techniques d'Aquitaine, France
2. Institut de Mecanique et d'Ingenierie, France
3. Ecole Nationale Superieure d'Arts et Metiers, France
4. MBDA France SAS, France
5. Institut Universitaire de France, France
6. Bordeaux INP, France

This study aims at determining the mechanical properties of Ultra-High Temperature Ceramic Matrix Composites (UHTCMCs), specifically a 2D woven C/C laminated infiltrated with ZrB_2, at the scale of the woven ply. To achieve this goal, a multi-scale material model is developed. First, at the microscale level, the elastic properties of the tow are determined using a numerical finite element (FE)-based method combined with analytical approaches. In particular, the elastic properties of the tow cross-section plane are determined using a semi-realistic statistically representative volume element with periodic boundary conditions. Then, at the meso-scale level, the elastic properties of the 2D woven ply are obtained using an analytical model, based on classical laminate theory and now generalised to first-order shear deformation theory. The results show that UHTCMC properties are sensitive to key parameters at the tow scale, identified through a Monte Carlo analysis. These parameters, such as ZrB2 infiltration, in turn, affect the ply properties. Eventually, obtained ply properties are compared with literature case studies and a 3D FE model. In conclusion, the multi-scale model provides an effective tool for understanding UHTCMC materials, highlighting the influence of tow-scale parameters. The findings have important implications for the design of UHTCMC future structures.

HTCMCS1- Computation of mechanical, thermal and thermomechanical properties II

Room: Osprey
Session Chair: Frédéric Laurin, ONERA

3:20 PM

(HTCMC-S1-005-2026) An embedded-fiber approach to modeling the non-linear behavior of ceramic-matrix composites (Invited)

G. Couégnat*[1]; A. Vassalié[1,2]; C. Le Bras[1]; S. Denneulin[2]

1. Laboratoire des Composites Thermostructuraux, France
2. Safran SA, CERAMICS, France

Ceramic-matrix composites (CMC) enable higher service temperatures in aircraft engines, yet their complex non-linear behavior, resulting from multi-scale coupling between microscale damage and mesoscale load transfer, remains challenging to predict. Traditional multiscale homogenization-based approaches fail to capture the full damage process due to limited scale separation and material variability. We introduce a unified mesoscale approach where constituents, damage mechanisms and load transfer are treated simultaneously. The method combines discrete element concepts with mesh superposition: fibers are modeled as trusses embedded in the matrix, both exhibiting quasi-brittle behavior. A specially developed non-linear interface user-element restores kinematic coupling while introducing interfacial damage and friction, extending classical embedded methods to complex non-linear behavior. Applied to SiC/SiC composites, this approach successfully reproduces damage evolution and mechanical response up to failure for architectures ranging from unidirectional laminates to 3D woven preform. Validation against fully instrumented tensile tests demonstrates that characteristic CMC behaviors emerge naturally without the need of additional fitting parameters. This offers a promising pathway for deeper understanding and optimization of CMC materials.

3:50 PM

(HTCMC-S1-006-2026) In situ CT-Scan observation and modelling of damage in oxide/oxide composites (Invited)

F. Laurin*[1]; T. Drouin[2]; F. Guillet[2]; A. Sauvet[2]; G. Couegnat[3]

1. ONERA, Paris-Saclay University, DMAS, France
2. Commissariat a l'energie atomique et aux energies alternatives Siege administratif, CEA Le Ripault, France
3. Laboratoire des Composites Thermostructuraux, France

Ceramic Matrix Composites are lightweight materials with excellent mechanical properties at high temperatures, making them promising candidates for various advanced applications. 2D woven oxide/oxide (Ox/Ox) laminates are particularly relevant for moderate thermomechanical loadings. However, these materials sustain damage even at low load levels. Determining a constitutive damage law, that can describe the complex loadings encountered in composite structures, requires a precise understanding of their mechanical behaviour at the ply level, as well as rigorous observation and measurement of their damage mechanisms. Therefore, the aim of this study is firstly to establish the damage scenario in Ox/Ox through tensile and torsion tests on different lay-ups at room temperature. These tests are highly instrumented (using acoustic emission and digital images correlation) and some have been conducted using a CT-scan to analyse the damage and failure patterns. Secondly, based on the experimental tests, a damage law has been developed and identified at the ply scale on 0/90 and -45/45 tensile specimens. The model predictions were successfully compared with experimental data obtained on another laminate. Furthermore, torsion tests have been performed and the in-plane shear behaviour was consistent with that obtained from tensile tests on -45/45 laminate, and well predicted with proposed damage model.

4:20 PM

(HTCMC-S1-007-2026) Benchmark of 2D woven carbon-fiber composites constitutive models with respect to notched plate tests

M. Guiho*[1]; J. Bénézech[2]; C. Léger[2]; A. Derrien[1]; J. Maire[2]; F. Laurin[2]

1. MBDA Holding SAS, France
2. Office National d'Etudes et de Recherches Aerospatiales, DMAS, ONERA, Université Paris-Saclay, France

Carbon/Carbon Ceramic Matrix Composites offer a unique combination of high stiffness-to-weight ratio and thermal resistance, making them ideal for demanding aerospace and defense structural applications. MBDA has developed, via the PIP process, a 2D woven composite with carbon fibers and a weak ceramic matrix. The material is available in two density grades: one exhibiting a quasi-brittle damage behavior with higher strength, and the other one offering a progressive damage development with lower strength. Despite extensive research on 3D and 4D C/C composites, 2D woven C/C composites remain lowly documented. Existing macroscopic damage models for other CMCs or 3D C/C composites are not directly applicable. The scientific gap motivates the main objective of this work: to benchmark constitutive laws with respect to a structural-detail test: a notched plate 0/90. The ultimate objective of this work is to develop a constitutive law tailored to 2D C/C woven composite, and to validate numerical predictions against an industrially relevant demonstrator. This work is an intermediate step, required to refine the material constitutive model, before targeting a structural scale component. The relevance of the proposed modelling framework will be assessed by confronting numerical predictions and detailed multi-instrumented experimental data.

4:40 PM

(HTCMC-S1-008-2026) A multiscale modelling framework for mechanical, temperature and oxidation-dependent behaviour of SiC/BN/SiC CMCs

V. Dubey*[1]; P. Foster[1]; A. Soni[1]; L. Kawashita[1]; G. Allegri[1]; S. Hallett[1]

1. University of Bristol, Aerospace Engineering, United Kingdom

Recent advancements in ceramic matrix composites (CMCs) manufacturing must be complemented by reliable predictive modelling of material behaviour under different conditions. Given the complex and costly fabrication process, numerical modelling is crucial during early design. CMCs exhibit complex microstructures with phenomena occurring at multiple length scales; therefore, characterization and simulation across these scales are necessary to capture their behaviour accurately. At the microscale, MicroTool is developed to generate high-fidelity RVEs of SiC tow microstructures and obtain homogenized mechanical, thermal, and electrical properties. A Mori–Tanaka based damage model is implemented and validated against minicomposite tests. At the mesoscale, the SimTex tool models the woven SiC fabric, converting it into a finite element mesh with constituent volume fractions and orientations. Homogenization-based and continuum damage models are applied to simulate tensile tests on dogbone and open-hole specimens, validated against experiments. At the macroscale, a stress and oxidation-induced damage model for SiC/BN/SiC composites is developed. It includes temperature-dependent properties, variations in constituent volume fractions, and oxidation-driven degradation. The framework captures both on- and off-axis behaviour and is validated against experimental data.

5:00 PM

(HTCMC-S1-009-2026) Pyrolytic carbons: Structure-mechanical properties relationships studied by modeling and experiments

J. Leyssale[2]; B. Farbos[1]; M. Lalanne[5]; F. Polewczyk[2,3]; P. Aurel[2]; P. Weisbecker[5]; J. Da Costa[4]; P. Lafourcade[3]; A. Bident[1]; G. Chollon[5]; S. Jacques[5]; S. Jouannigot[5]; G. Couégnat[5]; G. L. Vignoles*[1]

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4. Bordeaux Sciences Agro, IMS - Insitute from Materials to Systems, U. Bordeaux, France
5. CNRS, LCTS, France

Pyrolytic carbons are used in several high-tech applications – nuclear energy, ceramic-matrix composites, electrodes, etc …; they have a great versatility of multi-scale structural/textural organization, which greatly impacts their mechanical properties. The relationships between them are by far not easy to grasp; hence, research projects have been conducted bith experimentally and numerically. A great variety of pyrocarbons has been produced and characterized by numerous techniques; in parallel, modeling tools based on Molecular Dynamics have been developed to address the nanoscale – in particular, Image-Guided Atomistic Reconstructions either from HRTEM or from XRD data. From hundreds of molecular models in 12.4 nm edge size cubes, with efficient MD simulations and the use of a supervised machine learning algorithm, it has been shown that elastic constants can be accurately predicted using only 3 experimentally accessible descriptors. Their evolution with temperature has also been followed, showing a moderate decrease, as for graphite. We also show how softening occurs in an indentation / compression situation, thanks to a multi-scale approach mixing MD and finite element simulations. CEA and DGA are acknowledged for their financial support to F.P.'s PhD. ANR is acknowledged for funding through projects "PyroMaN" (ANR-2010-BLAN-0929) and "CoMéCA" (ANR-23-ASTR-0004).

HTCMC-12 Symposium 2- Fibers, Preforms, and Interphases

HTCMCS2-New Developments in Oxide and Non-Oxide Ceramic Fibers

Room: Shorebreak 1

Session Chair: Kazuya Shimoda, National Institute for Materials Science (NIMS)

1:30 PM

(HTCMC-S2-009-2026) Development of a pyrolysis method for SiC fibers with protection against oxygen exposure (Invited)

T. Goto*[1]; K. Hofuku[1]; R. Iuchi[1]

1. Kabushiki Kaisha Kureha Chuo Kenkyujo, New Business Development Department, Japan

Silicon carbide (SiC) fibers are key components for ceramic matrix composites (CMCs), which are widely adopted in aerospace applications due to their excellent mechanical strength and thermal stability derived from high crystallinity and purity. Conventional production of high-quality SiC fibers rely on costly processes such as electron beam irradiation for curing polycarbosilane (PCS), significantly increasing manufacturing expenses. Furthermore, conventional PCS precursors often contain oxygen atoms at molecular ends, which are incorporated during pyrolysis and degrade fiber quality. In our previous work, we developed a novel, cost-effective method for producing high-quality SiC fibers without electron beam curing, successfully achieving properties comparable to conventional SiC fibers such as Hi-Nicalon TypeS. However, during pyrolysis, high-temperature treatment aimed at improving thermal stability, such as creep resistance often cause oxidative degradation, reducing mechanical strength of the fiber. To address this issue, we propose a new pyrolysis method designed to protect SiC fibers from a trace amount of oxygen exposure. The resulting SiC fibers exhibit low oxygen content, excellent mechanical strength, and superior thermal properties.

2:00 PM

(HTCMC-S2-010-2026) General atomics SiGA™ SiC fiber overview

J. Brown[1]; D. Wegrzyn[1]; H. Park[1]; S. Fan[1]; J. Hepp[1]; I. Ivanov*[1]; H. Khalifa[1]

1. General Atomics Electromagnetic Systems Group, Nuclear Technologies and Materials (NTM), USA

General Atomics Electromagnetic Systems (GA-EMS) is a global leader in the development of SiC-SiC ceramic matrix composite (CMC) based fuel cladding for nuclear energy generation - SiGA® cladding. SiC fiber, the enabling material behind SiGA® cladding and all SiC-SiC CMCs, is prohibitively expensive and lacks a domestic supply chain, impeding the commercialization of SiGA® cladding. To overcome these barriers, GA-EMS initiated a ground-up SiC fiber development effort with a domestic supply chain to onshore this critical material. The GA-EMS process is inherently more efficient, scalable, and lower cost than currently used processes. We will present development progress of SiGA™ SiC fiber at our end-to-end fiber facility and the enhancement of critical fiber properties for extreme environment applications.

2:20 PM

(HTCMC-S2-011-2026) Integrated development of oxide and nonoxide ceramic fibres from precursor to pilot scale at Fraunhofer ISC Center HTL (Invited)

J. Maier*[1]

1. Fraunhofer-Zentrum fur Hochtemperatur-Leichtbau HTL, Germany

Fraunhofer ISC Center HTL advances ceramic fibre development across oxide systems (Al_2O_3 SiO_2 ZrO_2 Y_2O_3) and non oxide systems (SiC, SiBNC), as well as leached SiO_2 fibres, via a scalable process chain. Sol gel precursors and spinning dopes are tuned for dry and melt spinning with targeted rheology and stability. Development spans laboratory rigs (1 to20 filaments), technical scale lines (500 filaments), and a preindustrial fibre pilot line with 4 × 500 parallel filaments, enabling rapid translation of formulations into continuous fibres that are calcined/pyrolysed and continuously sintered. We optimise precursor chemistry, fibre forming, and thermal windows to control phase composition, porosity, and grain growth, achieving uniform diameters, high strength, thermal stability, and oxidation resistance. Microstructural control through yttria stabilisation and SiO2 content tuning suppresses crystallisation and creep at high temperature. Inline monitoring and feedback reduce defects and increase throughput, ensuring reproducible manufacturing. Performance is validated by tensile, creep, and oxidation testing and thermomechanical analysis at service relevant temperatures. Results demonstrate a robust, scalable route to ceramic fibres for high temperature composites, thermal insulation, and filtration, bridging materials design and near industrial production.

2:50 PM

(HTCMC-S2-012-2026) Metal oxide nanowires, nanofibers, and 3D non-woven mats by high-throughput electrospinning

P. Gouma*[1]

1. The Ohio State University, MSE, USA

The electrospinning process involves the electrostatic drawing of fibers from solutions. Blend electrospinning utilizes sol-type precursors and carrier polymers to form ceramic fibers. Our research group has demonstrated single crystal nanowires of transition metal oxides and 3D self-supported mats of yttria and alumina, as

well as non-oxide fibers (amyloids, cellulose acetate, etc.). We have developed a turn-key high-throughput electrospinning system which allows for a wide range of precursors and solvents and can be used for svalable fiber manufacturing. Specific collectors are also presented for aligned and random fiber mats. These advances are expected to revolutionize the manufacturing of both oxide and non-oxide fiber processing.

HTCMCS2- Performance of Interfaces/Interphases in Extreme Environments

Room: Shorebreak 1
Session Chair: Elizabeth Opila, University of Virginia

3:30 PM

(HTCMC-S2-013-2026) Performance of crystalline, amorphous, and Si-doped BN coatings in steam environments (Invited)

F. W. Zok*[1]; V. Christensen[1]

1. University of California Santa Barbara College of Engineering, Materials, USA

Boron nitride (BN) fiber coatings enable damage tolerance in SiC/SiC composites but are susceptible to oxidation and volatilization in water vapor environments. This study systematically compares three coating types: crystalline BN, amorphous BN, and Si-doped amorphous BN. High-resolution characterization following oxidation at 1000°C in 20 vol% water reveals fundamental differences in recession mechanisms. Crystalline BN volatilizes directly at a rate of 25-50 μm/h without forming protective borosilicate glass, as carbothermal reduction from concurrent SiC oxidation prevents liquid boria formation. Amorphous BN oxidizes more rapidly (50-100 μm/h) to form borosilicate glasses that progressively seal recession channels as boria volatilizes and silica precipitates. Si-doped BN exhibits the fastest oxidation and most complete gap sealing. Coating thickness critically determines sealing behavior: thin coatings (<0.25 μm) form short oxide plugs (~15 μm), while thicker coatings produce longer plugs (>200 μm). These findings establish that coating selection must balance the competing requirements of maintaining interface compliance versus providing environmental barrier protection, with amorphous/Si-doped coatings favored for rapid self-sealing in aggressive environments.

4:00 PM

(HTCMC-S2-014-2026) Corrosion of BN/SiC coated SiC fibers in a silicon melt infiltration process

J. Schmidt*[1]; A. Konschak[1]; J. Maier[1]

1. Fraunhofer-Zentrum fur Hochtemperatur-Leichtbau HTL, Germany

The melt infiltration (MI) of pure silicon into porous SiC fiber preforms offers the possibility to generate a highly dense matrix for SiC/SiC composites. As the melt is very aggressive, the challenge is to protect the SiC fiber and its functional fiber coating from the degradation reaction during the MI process, which is a prerequisite to achieve a high strength and high strain of the CMC. The purpose of this study is to develop a deeper understanding of the reaction mechanisms during the attack of the aggressive silicon melt. In our study we used single fiber tows with BN/SiC coating to investigate critical parameters of the MI process. We prepared the CMC by infiltration of SiC based matrix slurries and performed a low temperature MI by using an atmosphere controlled Thermo Optical Measurement System. Parameters such as holding time, fiber length and particles were varied. The microstructure was investigated by light and electron microscopy and the element distribution by line-scan. It will be demonstrated that with an adjusted coating and optimized furnace parameters a large number of SiC filaments survive the process. Coating degradation can be observed hand in hand with a grain growth of SiC particles within the matrix. It can be concluded that the silicon attack of the coating and fiber can be reduced by adjusting the matrix composition and choosing appropriate SiC particles and carbon content.

4:20 PM

(HTCMC-S2-015-2026) Use of silicon alloys to preserve BN-SiC interphases in SiC/SiC mini-composites processed by liquid silicon infiltration

K. Postler*[1]; J. Moosburger-Will[1]; D. Koch[1]

1. Universitat Augsburg, Institute of Materials Ressource Management, Germany

Production of SiC/SiC ceramic-matrix composites (CMC) by liquid silicon infiltration (LSI) can degrade the BN-SiC interphases between fibers and matrix, resulting in strong fiber-matrix bonding and a loss of damage tolerance. Alloying silicon offers a route to lower the infiltration temperature and to moderate melt reactivity, thereby protecting the interphase. This study compares near-eutectic SiB_8, $SiZr_9$, $SiHf_8$, and $SiMo_{3.7}$ alloys with pure Si to identify compositions that do not damage Hi-Nicalon Type S fibers with BN-SiC interphases. Differential scanning calorimetry quantifies the exothermic heat of the $Si + C \rightarrow SiC$ reaction, revealing distinct reductions in heat release for alloyed systems. Depending on the alloy system, mini-composites fabricated using the novel Pipette Sliding Infiltration Process (PipSliP) can exhibit dense SiC matrices with reduced residual Si and well-preserved interphases. The findings establish a correlation between alloy composition, reaction thermodynamics, and interphase stability, demonstrating that use of silicon alloys can mitigate interphase degradation and thermal overstress during LSI. The work contributes to understanding how alloy composition governs fiber-matrix interactions in SiC/SiC CMCs and supports the design of damage-tolerant materials for high-temperature applications.

4:40 PM

(HTCMC-S2-016-2026) Intermediate temperature oxidation of SiC/BN/SiC CMCs

S. Holles*[1]; E. Opila[1]

1. University of Virginia, USA

Silicon carbide ceramic matrix composites (SiC CMC) are proposed for use in high-temperature aeroturbine components. In this application, SiC CMCs are exposed to oxygen and water vapor which is a byproduct of fuel combustion. Silica growth occurs at peak application temperatures of 1300°C while more rapid degradation is observed between 600 and 800°C. In this temperature range, SiC CMCs with boron nitride fiber interphase coatings form silica, boria, and borosilicate glasses and are vulnerable to degradation due to formation and volatilization of boria and borosilicate glass. Thermogravimetric analysis was used to study oxidation behavior of the CMCs. The material was exposed to flowing oxygen or 50% water vapor/50% oxygen for 1- and 50-hours at 600, 700, and 800°C. SEM/EDS was used to study elemental distribution before and after exposure. Inductively coupled plasma optical emission spectroscopy was used to accurately quantify the borosilicate glass composition. In both wet and dry oxygen at 600°C the material showed mass loss volatilization. In dry oxygen the oxide is boria rich, transitioning to a more silica rich oxide as temperature increases. At 800°C the material showed mass gain oxidation with more weight gain occurring in wet oxygen than dry. Understanding these oxidation reactions and mechanisms in dry and wet oxygen are crucial to drive design decisions for SiC CMCs.

HTCMC-12 Symposium 4- Innovative Design, Advanced Processing and Manufacturing Technologies in Non-oxide and Oxide Composites

HTCMCS4- Characterization and damage assessment

Room: Silver Pearl 1
Session Chair: Masaki Kotani, Uchu Koku Kenkyu Kaihatsu Kiko Koku Gijutsu Bumon

1:30 PM

(HTCMC-S4-036-2026) Material properties of high temperature resistant CMC (Invited)

T. Nakamura*[1]; N. Yamazaki[1]; H. Hirano[1]

1. IHI Corporation, Japan

IHI began research and development of CMCs in the early 1990s, focusing mainly on turbine components (shrouds and nozzles) for aircraft engines. The current development target is 1400°C. To achieve this, IHI has been investigating matrices, interfaces, and environmental barrier coatings (EBC). In previous studies, third-generation SiC fibers were utilized, and a BN interface coating was applied using a continuous process to enhance heat resistance. A new matrix with improved oxygen resistance was also developed. This matrix incorporates a rare-earth silicates on the outside of the SiC CVI phase, combining the mechanical strength of SiC CVI with the oxidation resistance of rare-earth silicates. A novel melt infiltration method was adopted for impregnating rare-earth silicates. Strength tests including tensile, low cycle fatigue, and creep tests, as well as material property evaluations for stiffness and thermal performance, confirmed that the developed material system shows excellent properties at 1400°C. Additionally, a new EBC with CMAS resistance at temperatures above 1400°C was developed. The top coat consists of a Yb2O3-Al2O3-HfO2 system, while the undercoat uses Yb2Si2O7, considering the thermal expansion difference with the CMC. The use of an oxide matrix enabled good adhesion with the Yb2Si2O7 undercoat, eliminating the need for a Si bond coat. This EBC system demonstrated outstanding CMAS resistance at 1400°C.

2:00 PM

(HTCMC-S4-037-2026) Ultra-high and high temperature ceramic matrix composites aimed for hypersonic applications (Invited)

L. Baier[2,1]; M. Friess*[2,1]; I. Petkov[2,1]; O. Schatz[2,1]; O. Hohn[2]

1. DLR - German Aerospace Center, Institute of Structures and Design, Germany
2. Deutsches Zentrum fur Luft- und Raumfahrt DLR, Germany

Materials and structures for aerospace applications applied at very high temperatures (hypersonic, re-entry vehicles, propulsion systems) demand on extremely challenging requirements regarding corrosion resistance as well as sufficient thermomechanical performance and damage tolerance in changing atmospheric conditions. Therefore, only fibre-reinforced ceramic materials are a viable way to proceed. For short term applications carbon fibre-reinforced composites with silicon carbide matrix are the first choice due to their easy access for matrix built-up via liquid silicon infiltration as well as formation of a passive protection layer of SiO_2 under oxidation conditions during "mild" hypersonic flight conditions. However, under severe hypersonic or harsh re-entry conditions this passive oxidation protection layer is no longer formed, moreover, active oxidation takes place on the aerodynamically exposed surfaces leading to mass loss as well as enhanced material recession and structural degradation. Either, this limitation is taken into account of the intended flight profile or, alternatively new material systems have to be developed based on materials with pre-dominant active oxidation of Zr-compounds to ZrO_2 with extended thermal resistance and regarding thermochemical and -mechanical behaviour. In addition, wind tunnel testing under hypersonic conditions is reported.

2:30 PM

(HTCMC-S4-038-2026) Ultra-fine and ablation-resistant UHTC composites for rocket nozzle applications (Invited)

S. Lee*[1]; K. Kim[2]; V. Nguyen[1]

1. Korea Institute of Materials Science, Republic of Korea
2. Korea Advanced Institute of Science and Technology, Republic of Korea

To fabricate dense ultra-high temperature ceramic (UHTC) compacts using conventional pressureless or hot pressing methods, high sintering temperatures and pressures, or the addition of sintering aids, are typically required. However, both approaches often promote grain growth, leading to degradation in mechanical properties. In particular, the use of sintering additives can deteriorate the high temperature mechanical performance of UHTCs. We introduce a sintering method that achieves densification under relatively low temperature and pressure conditions, while suppressing grain growth and avoiding the formation of secondary phases that could reduce high-temperature performance after sintering. The resulting material exhibited a uniform and ultra-fine grain structure. The sintering process was carried out at 1800 °C under 20–40 MPa. The fabricated UHTC–SiC composites formed a dense microstructure consisting of uniformly distributed UHTC and SiC grains with an average size of ~300 nm. The sintered composites were applied to rocket nozzles to evaluate their ablation resistance under extreme conditions. When applied as a nozzle material in a bipropellant hybrid rocket, the composite demonstrated remarkable ablation resistance. The HfB2–SiC composite nozzle showed almost no observable erosion even after five 20 s firings with an average ablation rate below 10-3 mm/s.

3:20 PM

(HTCMC-S4-039-2026) Chemophysical crack-healing mechanisms through N_2 annealing in SiC coatings on C/C composites

J. Baek[3]; Y. Zhang[3]; B. Lim[1]; H. Jung[2]; I. Sihn[1]; S. Lee*[3]

1. DaiYang, Republic of Korea
2. SPACEPRO, Republic of Korea
3. Purdue University, USA

We report an integrated experimental and first-principles study of crack mitigation in SiC coatings deposited on carbon–carbon (C/C) composites via post-deposition N_2-annealing. Although SiC is widely used for high-temperature protection of C/C composites, its practical deployment is limited by extensive cracking caused by microstructural defects and large thermal-expansion mismatch with the substrate. We show that N_2 annealing reduces crack density by more than 80%, representing a substantial improvement in coating integrity. Electron microscopy and X-ray diffraction reveal that N_2 annealing induces the formation of α-Si_3N_4 within the SiC matrix. Density-functional calculations and ab initio molecular-dynamics simulations identify two synergistic atomistic mechanisms responsible for this crack-healing behavior. First, the incorporation of N_2 leads to the formation of short, strong Si–N and C–N bonds, producing volumetric contraction that closes intergranular voids and increases mechanical properties. Second, dissociated nitrogen atoms promote atomic-scale reconstruction at crack interfaces, generating a high-cohesion Si_3N_4 interphase that bridges and stabilizes crack surfaces. These mechanisms provide a fundamental basis for N_2-mediated crack healing in SiC coatings and establish an effective route to enhancing the mechanical reliability of SiC for extreme-environment applications.

3:40 PM

(HTCMC-S4-040-2026) Ultrasonic Machining (Ultrasonic Impact Grinding) of SiC/SiC CMCs

E. Norton*[1]

1. Bullen Ultrasonics Inc, R&D, USA

Ceramic Matrix Composites (CMCs) made from silicon carbide (SiC) have become a viable choice in applications requiring high temperature strength, low thermal movement, low density and chemical strength while also offering higher toughness than traditional ceramics. However, machining CMCs can be challenging and especially for some feature configurations. Ultrasonic Machining (UM), sometimes referred to as Ultrasonic Impact Grinding (UIG), can be an option to consider for overcoming these challenges. This presentation will outline current ultrasonic machining capabilities and expected outcomes for feature geometry feasibility, manufacturing tolerances, wall taper, surface roughness, internal radii constraints and other design for manufacturing (DFM) topics. Ultrasonic machining technology incorporates a loose abrasive process that interacts with tool vibrations causing abrasive induced workpiece erosion. UM is well suited for typical design features such as slots, through features, holes and 3D surface contour. UM can achieve high depth to width ratios for slots, counterbores, holes and similar depth related features. Multiple geometries can be machined at one time, giving this technology a unique ability to scale economically. Advantages and disadvantages will be discussed for UM vs other machining technologies such as CNC grinding, laser ablation and electrical discharge machining.

HTCMC-12 Symposium 6- Carbon/Carbon – Carbon Fiber Reinforced Carbon Composites

HTCMCS6- Mechanical and thermal properties, Application and performance

Room: Pelican
Session Chair: Matthias Krodel, ECM - Engineered Ceramic Materials GmbH

1:30 PM

(HTCMC-S6-001-2026) Studying and prediction of microstructures and mechanical properties of C/C-materials (Invited)

N. Langhof*[1]; F. Wich[1]; M. Moos[3,1]; S. Schafföner[2,1]

1. University of Bayreuth, Ceramic Materials Engineering, Germany
2. University of Bayreuth, Chair of Ceramic Materials Engineering, Germany
3. Universitat Bayreuth, Germany

C/C are lightweight materials (< 2.0 g/cm^3), with high strength, temperature and wear resistance. Hence, C/C can be found in thermal protection systems, as aircraft brakes and in hypersonic vehicles. To increase its oxidation resistance (> 400 °C) it can be infiltrated with liquid silicon. The obtained C/C-SiC is applied as ceramic brakes of passenger cars. Despite of the usage of C/C since several decades, the prediction of cracks during fabrication, the resulting microstructures and mechanical properties are very challenging. Within this study the formation and the prediction of these crack patterns in different C/C materials was investigated. Therefore, CFRPs were manufactured via warm pressing of a novolak type resin and HT-C-fibers (fiber volume: 35 % - 55 %). Their interlaminar fracture toughness were studied between after pyrolysis temperatures between 550 °and 1000 °C. Finally, some C/C samples were infiltrated with liquid silicon at > 1420 °C and their strength measured. In parallel a phase filed simulation-based model was established, that can predict the formation and shape of the cracks during pyrolysis. Hence, different microstructures were simulated and gave some new insights and findings. The fracture toughness decreases with increasing pyrolysis temperature. For C/C-SiC strengths up to 162 MPa were measured and the strong decreasing trend with decreasing fiber volume discussed.

2:00 PM

(HTCMC-S6-002-2026) Dependence of graphitization kinetics on atomic mobility in hard and soft carbon via XRD

C. R. Dixon*[1]; J. Wiggins[2]

1. University of Southern Mississippi, Polymer Science and Engineering, USA
2. University of Southern Mississippi College of Arts and Science, Polymer Science and Engineering, USA

Graphitization of carbon precursors depends on the ultimate heat treatment temperature (HTT), which determines the final crystallite stack height (Lc) and interplanar spacing (d-spacing). Above a critical temperature, carbon atoms gain sufficient thermal energy to overcome kinetic barriers, heal defects, and reorganize into ordered graphitic stacks. However, the mechanism and influence of thermal path dependency on structural evolution remain unclear due to the predominance of ex-situ characterization techniques. This study applied in-situ XRD to examine structural changes during pyrolysis of both graphitizing and non-graphitizing carbon precursors. Pitch provided insight into the formation of graphitic order from an initially amorphous state, and polyether ketone ketone (PEKK) served as a benchmark non-graphitizing carbon. In pitch, XRD spectra revealed a d-spacing plateau near graphitization, followed by sudden expansion and an increase in Lc, with a continuous progression from an amorphous halo to a turbostratic peak. PEKK demonstrated no change in long range order through pyrolysis, with

reversible peak shift due to thermal expansion. These results provide new insight into diffusion mechanisms governing graphitization and highlight the importance of atomic mobility on carbon microstructure evolution.

2:20 PM

(HTCMC-S6-003-2026) Altering crystallite dimensions in benzoxazine derived carbon through iron catalyzed graphitization

T. Schneider[1]; C. R. Dixon*[1]; J. Wiggins[2]

1. University of Southern Mississippi, Polymer Science and Engineering, USA
2. University of Southern Mississippi College of Arts and Science, Polymer Science and Engineering, USA

Thermoset polymers are widely used as carbon precursors to generate carbon-rich solids upon pyrolysis at temperatures above 800 °C. However, carbon derived from traditional thermosets such as phenolics exhibit low thermomechanical performance compared to graphitizable precursors such as pitch. This limitation arises from the dense crosslinked networks inherent to thermosets which constrain molecular rearrangement during carbonization leading to a reduction in crystallite thickness (Lc) and lateral size (La). Recent studies in our labs have shown that the presence of iron catalysts significantly influence crystallite development in benzoxazine polymers. This presentation reviews our investigation of pyrolyzing high-char benzoxazine polymers (>60% at 1000 °C in N_2) with the incorporation of metallic particles leading to >4X increase in crystallite carbon size and significant improvement in carbon microstructure at 1000 °C. We will also review TGA-MS data showing changes in the degradation pathways associated with incorporation of iron catalysts and high-temperature X-ray diffraction (XRD) used to track the evolution of crystallite thickness (Lc) as a function of metal content and pyrolysis temperature.

2:40 PM

(HTCMC-S6-004-2026) Test and progressive failure analysis of a 2.5D carbon-carbon brake disk

G. J. Janszen*[1]; A. Airoldi[1]; E. Novembre[1]; M. Gallo[1]; R. Passoni[2]; A. Tasca[2]

1. Politecnico di Milano, Department of Aerospace Science and Technology, Italy
2. Brembo NV, Italy

Automotive brake disks for motorsport are among the most structurally demanding applications for carbon-carbon composites. The presence of notches and holes, and the combined torsional and bending loads during braking induce complex stress states that represent a challenge for the analysis of structural integrity. Moving from the characterization of a fabric reinforced 2.5D C/C laminate with tensile tests, the work presents the development and the calibration of an inelastic material model with damage variables associated with a multi-modal failure criterion, to be used within a Progressive Failure Analysis (PFA) approach. The response of a whole disk is experimentally assessed until failure by using a test bench, specifically designed to apply a quasi-static mechanical load system, equivalent to the one exerted during braking. A complete FE model of the test bench and of the C/C disk is developed and analyzed by applying the calibrated PFA approach. The results show an appreciable correlation with the experimental data, considering the torque at failure, the local strains measured by strain gauges applied on the disk faces, and the morphology of the final fracture at the end of the test. The numerical approach described can be considered a valuable tool to analyze the macroscopic response of C/C laminates and to provide reliable design indications.

HTCMCS6- Material, process development

Room: Pelican
Session Chair: Matthias Krodel, ECM - Engineered Ceramic Materials GmbH

3:20 PM

(HTCMC-S6-005-2026) Pathways to high-interlaminar shear strength carbon-carbon (Invited)

B. Goodman*[1]

1. Goodman Technologies, LLC, USA

This study aims to develop innovative pathways for enhancing interlaminar shear strength in carbon-carbon (C/C) composites, addressing delamination challenges through AI-empowered additive and robotic manufacturing integrated with aligned nanoforest technologies. Methods encompassed collaborative scaling of AI-driven 3D printing for continuous fiber ceramic nanocomposites via automated robotic manufacturing systems, incorporating roll-to-roll prepreg production and fiber patch placement with Hi-Nicalon SiC reinforcements or Carbon fiber. Aligned carbon nanotube nanoforests were embedded using a nano-Velcro mechanism into prepregs, including the first nanoforesting of non-crimp 3D fabrics for Z-directional reinforcement. Melt-infiltrated ceramic matrix composites were advanced through partnerships. Arc-jet testing validated spacecraft thermal protection system designs. Results showed up to118% gains in interlaminar shear strength and 120% improvements in Mode I fracture toughness. An 18-inch manufacturing coupon was demonstrated. These various super nanocomposites enabled reusable hot structures penetrating smoke and extreme environments. In conclusion, these pathways establish the world's first super nanocomposites for C/C, revolutionizing spacecraft thermal protection, hypersonic applications, and defense systems by reducing weight, costs, and sustainment demands.

3:50 PM

(HTCMC-S6-006-2026) Near-net shape Noobed 3D fabric pre-forms - Key to accelerate wider adoption of CMCs (Invited)

P. Khokar*[1]; N. Khokar[1]

1. Fureho AB, Sweden

Accelerating wider adoption of CMCs requires processing flexibility to efficiently convert brittle and expensive fibres like SiC, AlOx, quartz, and carbon pitch, which are available in relatively small volumes, into a variety of high-performing pre-forms. Traditional laminate pre-forms are prone to delamination. Weaving and braiding often damage these brittle fibres and cannot create complex near-net shapes required, e.g., for aircraft engine parts. Fureho's proprietary Noobing Technology uniquely overcomes these limitations by directly producing individual, near-net shape 3D fabric pre-forms, including double-curvature types. This process incorporates fibres in X-Y-Z directions without crimp. The Z-direction fibres provide high delamination resistance, significantly improving toughness and reliability. Unlike weaving or braiding, Noobing works on a unique 3D fabric-forming principle that significantly reduces setup and production times, and raw material requirements. This enables rapid prototyping and reduces wastage of expensive fibres, lowering both costs and environmental impact. The individual 3D fabric pre-forms are easy to handle for direct placement in mould/chamber, further streamlining CMC conversion. The consistent fibre arrangement across batches, results in a predictable performance and reduced frequency of quality testing, making CMCs economically and technically more attractive.

4:20 PM

(HTCMC-S6-007-2026) A novel high-char-yield thermoplastic precursor route for potential net-shape carbon–carbon composites fabrication (Invited)

R. Downes*[1]

1. FSU, Industrial and Manufacturing Engineering, USA

Carbon–carbon (C/C) composites enable operation in extreme thermal environments, yet conventional pitch and phenolic precursors limit processing efficiency and microstructural control. This work presents a thermoplastic-derived precursor as a new pathway for high-performance C/C fabrication. The thermoplastic system exhibits exceptionally high char yield and delayed thermal decomposition above 500 °C, enabling improved mass retention, thermal stability, and shape fidelity relative to traditional precursors. Thermogravimetric analysis, controlled carbonization, and three-dimensional X-ray computed tomography were used to assess thermal behavior, morphology evolution, and porosity development during initial heat treatment. Results show the formation of continuous, load-bearing carbon networks with interconnected porosity after first carbonization without re-infiltration. Quantitative CT reveals low overall porosity with predominantly open pore structures, indicating efficient polymer-to-carbon conversion while retaining microstructural features favorable for densification. These results establish thermoplastic-derived C/C composites as a distinct precursor class offering improved processing control, reduced mass loss, net-shape fabrication, and enhanced performance consistency for aerospace and other extreme-environment applications.

4:50 PM

(HTCMC-S6-008-2026) Low-density carbon nanotube yarn graphitized Laminates (Invited)

C. Evers*[1]

1. Florida State University, USA

Carbon/carbon (C/C) laminates are manufactured with carbon nanotube (CNT) yarns and graphitized. An interwoven CNT yarn and CNT aerogel manufacturing process is developed, and yarn type, resin type, and resin impregnation are compared. A densification treatment was performed on the laminates to achieve ultra-high CNT volume fraction, which eliminate micro-scale porosity typically observed with μCT in the matrix of C/C composites. Moreover, TEM revealed unique nanostructures of alternating graphitic layers and multi-wall carbon nanotubes, which is shown to be consistent throughout the laminate with WAXS. The CNTs and low resin content resulted in a density ~25% lower than typical C/C composites. However, nano-scale porosity remained, which was evaluated with FIB 3D tomography. This microstructure resulted in specific in-plane thermal conductivity superior to aluminum and high electrical conductivity which led to good EMI shielding properties. The manufacturing process of graphitized laminates with CNT and graphitic nanostructures led to an innovative combination of high properties and low density which opens the possibility of multifunctional C/C composites that can also act as lightweight structural components.

HTCMC-12 Symposium 9- Joining and Integration Technologies for Ceramic Matrix Composites

HTCMCS9- Joining of CMCs to CMCs or ceramics

Room: Silver Pearl 2/3
Session Chairs: Carla Malinverni, Politecnico di Torino; Monika Tatarkova, Ustav anorganickej chemie Slovenska akademia vied

1:30 PM

(HTCMC-S9-001-2026) Joining of SiC and SiC_f/SiC: Focused on Si-C reaction bonding (Invited)

S. Park[1]; S. Joo[1]; J. Jung[1]; D. Yoon*[1]

1. Yeungnam University, School of Materials Science and Engineering, Republic of Korea

Because of the difficulty in fabricating a complex-shaped SiC by sintering due to its strong covalent bonding and low self-diffusivity, the development of reliable joining technique is essential to expand the practical application of SiC-based materials in aerospace and nuclear reactor. In this talk, after delivering the overview of various SiC joining techniques developed so far, special attention is paid to the Si-C reaction bonding because it demands relatively lower joining temperature (≦1550°C) and short time (≦1 h), revealing a relatively high joint strength (≧150 MPa). This presentation also discusses long-lasting key questions associated with the Si-C reaction bonding, including the optimal filler composition for minimizing free Si, the effect of surface roughness on the joint strength, the ideal filler thickness for achieving the maximum joint strength, and the typical defects observed at the joint. To examine these questions, SiC is joined using a filler tape composed of SiC and C with varying thicknesses of 10–100 μm, followed by molten Si infiltration at 1430°C under vacuum. Additionally, the surface roughness of the SiC base is adjusted to four levels to evaluate its effect on the joint strength, while common defects are identified too. The results indicate that a finely polished SiC base joined with SiC/C = 70/30 wt.% tape of ≦ 50 μm thickness results in a high joint strength of ≧250 MPa.

2:00 PM

(HTCMC-S9-002-2026) Investigation of joining and repair techniques for oxide-oxide ceramic matrix composites

J. Alexander*[1]; J. Binner[2]

1. University of Birmingham, United Kingdom
2. University of Birmingham, Ceramic Science & Engineering, United Kingdom

The fabrication of large / complex ceramic parts is challenging. The ability to easily bond multiple smaller parts will enable a cost-effective way to create these. As well as this, being able to join dissimilar materials enables the production of components with tailorable properties across them. Joining of ceramics is also a stepping stone in the repair process. This is of high interest since the fabrication of advanced ceramic materials is costly both financially and energetically and therefore would enable the repair of parts that fall out of specification during manufacture, and the extension of service life of damaged components. However, challenges exist when trying to produce joints which yield mechanical properties sufficient for use in challenging environments. The current work explores some joining methods and assesses their physical and mechanical properties.

2:20 PM

(HTCMC-S9-003-2026) Novel joining of high-entropy ceramics (HfTaZrNbTi)C and Cf/SiC composites with high-entropy alloy interlayers

N. Hosseini[1]; S. Gambaro[2]; F. Valenza[2]; S. sahin.ates@tubitak.gov.tr[5]; Z. Chlup[4]; A. Kovalcíkova[3]; M. Tatarkova[1]; I. Dlouhy[4]; P. Tatarko*[1]

1. Ustav anorganickej chemie Slovenska akademia vied, Ceramics, Slovakia
2. Istituto di Chimica della Materia Condensata e di Tecnologie per l'Energia Consiglio Nazionale delle Ricerche Sede di Genova, Italy
3. Ustav materialoveho vyskumu Slovenskej akademie vied, Slovakia
4. Ustav fyziky materialu Akademie ved Ceske republiky, Czechia
5. Tubitak Marmara Arastirma Merkezi, Turkey

High-entropy carbide (HEC) ceramics based on (HfTaZrNbTi)C were joined using a HfTaZrNbTi high-entropy alloy (HEA) interlayer to develop robust ceramic–metal interfaces. The HECs were consolidated by the field-assisted sintering technique (FAST), while the HEA interlayers were produced through arc melting, cold rolling, and subsequent heat treatment at 1200 °C. Joining was carried out in a FAST furnace at four temperatures (1500, 1600, 1700, and 1800 °C). Microstructural and interfacial analyses revealed dense, continuous, and crack-free joints with well-bonded interfaces across all processing conditions. Mechanical performance was assessed via four-point bending, with the highest room-temperature strength of 330 MPa achieved for joints processed at 1800 °C. High-temperature bending tests showed that these joints maintained their structural integrity up to 1000 °C without notable degradation. Finally, the feasibility of joining (HfTaZrNbTi)C HEC to a Cf/SiC composite using the same HEA interlayer was also examined. The results of shear tests showed that the sample delaminated across the Cf/SiC matrix, indicating a very strong interface was formed. This work was supported by the Slovak Research and Development Agency under the Contract no. APVV-21-0402. The support of project SAS-TUBITAK/JRP/2023/807/HiTemCom (No. 720464) is also acknowledged.

2:40 PM

(HTCMC-S9-004-2026) Development and integration of high-temperature ceramic matrix composites using refractory transition metals-based alloys

M. Tatarkova*[5]; H. Ünsal[5]; S. sahin.ates@tubitak.gov.tr[2]; F. Valenza[1]; X. Zhou[4]; V. Casalegno[3]; P. Tatarko[5]

1. Istituto di Chimica della Materia Condensata e di Tecnologie per l'Energia Consiglio Nazionale delle Ricerche Sede di Genova, Italy
2. Marmara Universitesi, Turkey
3. Politecnico di Torino, DISAT, Italy
4. Chinese Academy of Sciences Ningbo Institute of Materials Technology and Engineering, China
5. Institute of Inorganic Chemistry, Slovak Academy of Sciences, Department of Ceramics, Slovakia

Ultra-High-Temperature Ceramic Matrix Composites are promising materials for extreme environments due to their superior thermal and mechanical stability. In this work, CVD β-SiC and C_f/SiC ceramics were successfully joined with $ZrSi_2$-based alloys using SPS. The wetting and phase interaction of molten transition metal disilicide ($ZrSi_2$) on the surface of CVD β-SiC and C_f/SiC was first investigated in different atmospheres (vacuum and Argon). The $ZrSi_2$ powder was then used as an interlayer for joining of both CVD β-SiC and C_f/SiC using SPS at different temperatures (1400 – 1650°C). A non-homologous interlayer was formed, consisting of both ZrC and remaining $ZrSi_2$. In addition, a significant reaction with SiC and C_f/SiC substrates led to the dissolution of SiC and infiltration of the filler into the base materials. Therefore, the $ZrSi_2$-C (10 wt.%) powders mixture was used to form a uniform SiC-ZrC composite interlayer by in-situ reactions between $ZrSi_2$, C, and SiC-based ceramics. The strength of the joints significantly improved with the increasing joining temperature, and reached the initial strength of the un-joined materials. This work was supported by the Slovak Research and Development Agency under the Contract no. APVV-SK-CN-23-0015 and the project SAS-TUBITAK/JRP/2023/807/HiTemCom (No. 720464). The support of CNR-SAS-2024–03 is also acknowledged.

HTCMCS9- Design and Modeling

Room: Silver Pearl 2/3

Session Chair: Dang-Hyok Yoon, Yeungnam University

3:22 PM

(HTCMC-S9-005-2026) Evaluating CMC assemblies using a discrete model for composite (DM4C) approach (Invited)

M. Flores*[1]; A. Deleo[1]; S. Phenisee[1]; D. Pelessone[1]

1. ES3, USA

Multiscale performance prediction remains constrained by single-material focus and limited integration across length scales. This effort introduces a Discrete Model for Composite (DM4C) approach—explicitly modeling two or more scales—to simulate the bearing response of a ceramic matrix composite (CMC) assembly. Both the fastener and plate are modeled as through-thickness interlock 3D woven composites, with the fastener evaluated at the fiber/matrix level (microscale) and the plate at the tow level (mesoscale). This framework captures the influence of microstructural architecture on structural performance under mechanical loading. By linking processing, microstructure, and bearing response, the approach supports traditional design methods while enabling the integration of advanced CMC systems. The result is a predictive modeling capability that enhances reliability and performance assessment of CMC assemblies in extreme environments.

3:52 PM

(HTCMC-S9-006-2026) Multiscale characterization of fusion-welded SiC-based UHTCs using an experimental–ICME approach

A. Emdadi*[1]; J. Watts[1]; A. Ayon[1]

1. Missouri University of Science & Technology, Materials Science and Engineering, USA

Fusion welding of SiC-based UHTCs is a promising route to robust joints for hypersonic and nuclear systems, but reliability is limited by gaps in our understanding of weld-pool solidification, defect formation, and process–structure relationships. In this AFOSR-supported project, we are developing an integrated experimental and ICME framework to study plasma arc welding (PAW) of SiC-based ceramics. We fabricate SiC–ZrB_2 coupons across hypo/near/hyper-eutectic compositions, perform PAW, and characterize the resulting microstructures and mechanical response. We then couple macroscale thermo-mechanical models, thermo-fluid simulations of weld-pool flow and porosity with quantified property uncertainty, and thermodynamic-based multi-phase-field models of fusion-zone solidification. We adapt binary-alloy PFM to ceramics by incorporating ceramic-specific thermophysical properties and interface dynamics, validating the framework in a Ni–Nb alloy before applying it to a SiC–ZrB_2 eutectic. While experiments show needle-shaped SiC morphologies that govern joint properties, the current ceramic PF model predicts mainly planar growth, exposing gaps in how interfacial energetics, anisotropy, and kinetics are treated. Ongoing work applies uncertainty quantification and ICME upscaling to reduce these gaps and enable microstructure-informed process design for reliable fusion-welded SiC joints.

HTCMCS9- Testing and NDE

Room: Silver Pearl 2/3
Session Chair: Mark Flores, The University of Texas El Paso College of Liberal Arts

4:12 PM

(HTCMC-S9-007-2026) Evaluation of YAS glass-ceramic-joined SiC/SiC CMCs under direct flame exposure for steelmaking applications (Invited)

C. Malinverni*[1]; V. Casalegno[1]; P. Bertrand[2]; J. Maier[3]; C. Prentice[4]; M. Salvo[1]

1. Politecnico di Torino, DISAT, Italy
2. Univ. de Technologie de Belfort-Montbéliard, France
3. Fraunhofer-Zentrum fur Hochtemperatur-Leichtbau HTL, Germany
4. ATL, Archer Technicoat Ltd, United Kingdom

Driven by the need for higher energy efficiency and lower environmental impact, the steelmaking industry is adopting advanced high-temperature materials and low-emission production technologies. Ceramic matrix composites (CMCs), valued for their thermo-mechanical stability in extreme environments, are strong candidates for next-generation furnace components. This study used a yttrium aluminosilicate (YAS) glass-ceramic as a joining material for SiC/SiC CMCs to create durable joints for radiant tube systems. A tailored joining process was developed to ensure structural integrity at high temperatures, and joint performance was evaluated under direct flame exposure. The joints were tested at temperatures up to 1200 °C to simulate in-service combustion and assess thermal stability and potential degradation, such as interfacial reactions, microcracking, and oxidation. Post-exposure analysis showed that the joints preserved structural cohesion with no interfacial reactions or failure. SEM characterization confirmed interface stability after flame testing. Mechanical behavior was assessed through shear tests at room temperature before and after flame exposure, and in all cases, the failure occurred within the composite layers rather than at the joint, demonstrating the strength of the YAS–SiC/SiC joints for high-temperature applications.

4:42 PM

(HTCMC-S9-008-2026) Improving XCT fidelity for SiC/SiC end-plug joints using super-resolution reconstruction methods

J. D. Arregui-Mena*[1]; A. K. Ziabari[2]; O. Rahman[2]; T. Koyanagi[3]

1. Oak Ridge National Lab, Nuclear Materials Science & Technology Group, USA
2. Oak Ridge National Laboratory, Electrification and Energy Infrastructure Division, USA
3. Oak Ridge National Laboratory, USA

Continuous SiC fiber–reinforced SiC matrix (SiC/SiC) composites are leading candidates for accident-tolerant fuel cladding and advanced reactor applications, but their deployment depends on the development of reliable, irradiation-resistant joint materials. In this work, miniature prototype end-plug joint materials were characterized using X-ray computed tomography (XCT) and analyzed with super-resolution (SR) algorithms to enhance the fidelity of conventional scans. Three joint concepts were examined: transient eutectic phase (TEP) sintering, calcia–alumina (CA) glass-ceramic joining, and hybrid SiC (HSiC) formed by combining preceramic polymer. High-resolution XCT volumes, acquired on selected regions of each joint type, were used as reference data to train and validate the SR framework, enabling improved recovery of fine features such as small pores, and thin glass or polymer-derived SiC layers that are only partially resolved in lower-resolution scans. The SR-enhanced XCT datasets were subsequently segmented using artificial-intelligence-based workflows to quantify and compare the characteristic microstructural features. This combined XCT–SR–AI segmentation approach provides a pathway to more accurate, large-volume characterization of SiC joint microstructures, supporting future efforts to improve this type of technologies.

Friday, June 5, 2026

GFMAT-3 Symposium 5- Porous Ceramics for Advanced Applications Through Innovative Processing

GFMATS5- Porous Ceramics for Advanced Applications Through Innovative Processing

Room: Shorebreak 1
Session Chairs: Jianfeng Yang, Xi'an Jiaotong University; Adriana Joyce, Adva Cera

8:30 AM

(GFMAT-S5-001-2026) Fabrication of porous silicon nitride ceramics with macro-sized pores by organic ball template via gel-casting or die-pressing method (Invited)

J. Yang*[1]; F. Li[1]; J. Li[1]; B. Wang[1]

1. Xi'an Jiaotong University, State Key Laboratory for Mechanical Behavior of Materials, China

In the pursuit of advanced biomaterials suitable for orthopedic applications, macro-porous silicon nitride has emerged as a highly promising candidate due to its exceptional biocompatibility, mechanical strength, and potential to stimulate tissue regeneration. Fabrication of macro porous silicon nitride ceramic materials was performed using two strategies. First, expanded polystyrene (EPS) particles as pore-forming agents and gel-casting molding for preform preparation. Second, die pressing with PMMA particles covered by ceramic powder with phenolic resin as the binder. Porous Si_3N_4 ceramics with controllable porosity and pore size were prepared by the above processes. Pore size, porosity and compressive strength of as obtained samples have been varied according to template size and the solid content of Si_3N_4 in starting powder mixtures. Ultimately, successful preparation of porous/dense composite Si_3N_4 ceramic materials was achieved. These developed approaches offer a customizable strategy for advanced orthopedic biomaterials, addressing the need for reliable solutions in musculoskeletal regenerative medicine.

9:00 AM

(GFMAT-S5-002-2026) Novel processing method and material properties for nuclear-grade silicon carbide foam

O. Trieu*[1]; J. Zhang[1]; O. Godinez[1]; T. Abrams[2]; G. Jacobsen[1]

1. General Atomics Electromagnetic Systems Group, USA
2. General Atomics, USA

Silicon carbide (SiC) foam combines the insulating properties of foams with the high temperature capability and stability of SiC ceramic. In particular for nuclear applications, SiC is highly resistant to irradiation to damage levels exceeding 75 displacements per atom, and retains its strength at temperatures approaching 2200°C. General Atomics Electromagnetic Systems (GA-EMS) is developing a scalable, cost-effective method to convert carbon foam into nuclear-grade SiC foam, intended for use as flow channel inserts in fusion reactors. The project has reached key milestones, including the fabrication of large planar samples up to 6 inches and achieving a maximum compressive strength of 5.86 MPa at 85% porosity by mass. With adjustable porosity and complete beta-phase SiC (B-SiC) conversion confirmed by X-ray diffraction (XRD), these foams have the potential to drive advancements in industries reliant on extreme environment materials.

9:20 AM

(GFMAT-S5-003-2026) Control of hierarchical porosity in alumina through additive process design

A. Joyce*[1]

1. Adva Cera, USA

Recent advances in additive manufacturing technology have enabled the creation of technical ceramics with complex, hierarchical porosities. The design freedom and print resolution offered by digital light processing (DLP) 3D printing present an opportunity to improve upon the performance of porous ceramics used in filtration, membrane separation, and lightweight structural support applications that also require an element of thermal resistance. By coupling engineered latticing with different firing profiles during additive processing, ceramic components with distinct microporosities within a macroporous structure can be achieved. In this study, alumina samples were produced using DLP 3D printing, in which a slurry composed of ceramic particles suspended in photopolymerizable resin is cured layer-by layer into a 3D structure and thermally processed to achieve the final component. Different combinations of high- and low-density lattice designs and firing profiles were used to produce samples with 15-40% interconnected microporosity. Samples were characterized using nitrogen pycnometry to measure density, four-point bend to determine modulus of rupture, and SEM to evaluate pore size. Optimization of these additive process design parameters then becomes a viable method for fine-tuning hierarchical porosity and associated material properties in alumina components according to given applications.

HTCMC-12 Symposium 1- Computational Modeling and Design of New Materials and Processes

HTCMCS1- Simulation of materials degradation

Room: Osprey
Session Chair: Guillaume Couegnat

8:30 AM

(HTCMC-S1-010-2026) Microscale Modeling and Simulation of Machining SiC/SiC Composites Produced by Chemical Vapor Infiltration (Invited)

S. Unseld*[1]; R. Goller[1]; D. Koch[2]

1. Technische Hochschule Augsburg, Mechanical Engineering, Germany
2. Institute of Materials Resource Management, Germany

This work presents a microscale modeling framework for analyzing the machining behavior of SiC/SiC composites. A statistical geometry model is introduced to reconstruct realistic microstructures from polished cross-section images, enabling statistically representative simulations of fiber, matrix, and porosity distributions. The representative volume at microscale is analyzed and identified. Non-linear friction behavior at the tool–workpiece interface is modeled using a viscous friction model. The influence of fiber orientation on machinability—reflected in surface topography, cutting forces, and characteristic fracture phenomena—is investigated through parametric simulations. Model predictions are validated using orthogonal cutting experiments supported by high-speed imaging, force measurements, chip-formation analysis, and comparisons of resulting surface topographies. The presented approach provides a physics-based foundation for understanding microstructural effects on machining outcomes and for improving process reliability in SiC/SiC composite manufacturing.

HTCMCS1- Data mining and first-principles computations

Room: Osprey
Session Chair: Gerard Vignoles, University Bordeaux

9:00 AM

(HTCMC-S1-011-2026) Illuminating early stage oxidation of ZrC from an ab-initio density-functional theory perspective

P. Wurzner[3]; S. Feld[1]; M. Möller[1]; B. Chen[3]; Q. Hong[2]; Y. Tang*[3]

1. Technische Universiteit Delft Faculteit Elektrotechniek Wiskunde en Informatica, Netherlands
2. Arizona State University, USA
3. Technische Universiteit Delft Faculteit Luchtvaart- en Ruimtevaarttechniek, Netherlands

Zirconium carbide (ZrC), an ultra-high temperature ceramic (UHTC), holds significant potential for applications in extreme environments, such as thermal protection systems (TPS) for reusable launch vehicles and components for next-generation nuclear reactors. Despite many attractive properties, its oxidation resistance remains a major concern. The early stage oxidation mechanism of ZrC is highly complex and remains elusive. Through a novel computational methodology that simulates large-scale complex phenomena by partitioning the system into many small simulation cells and applying statistical analysis to the ensemble results, we developed an algorithm that dynamically maintains partial pressures of reactants and products: oxygen atoms are introduced to the simulation cell as they are consumed by reaction, while gaseous carbon products (carbon monoxide and carbon dioxide) are removed as they form. This methodology enables dynamic simulation of oxidation over significantly longer effective timescales than conventional AIMD while maintaining full DFT-level accuracy. Simulations are performed across the 873–1273 K temperature range, capturing mechanisms including oxygen incorporation into the ZrC lattice, displaced carbon chain formation, and volatile product formation, which could lead to potential design guidelines for enhanced oxidation resistance.

9:20 AM

(HTCMC-S1-012-2026) Data-driven composition screening and experimental validation of single-phase high-entropy UHTCs

E. F. Bermudez[1]; L. F. Morales[1]; A. G. Castellanos*[1]

1. The University of Texas at El Paso, Aerospace and Mechanical Engr. Dept., USA

This work presents a data-driven approach for identifying single-phase high-entropy ultra-high temperature ceramics (HE-UHTCs) through machine learning–based composition screening. A materials informatics framework employing support vector machines, artificial neural networks, and random forest models was used to evaluate compositionally complex carbide- and boride-based UHTC systems based on thermodynamic, physical, and chemical descriptors, targeting compositions with a high likelihood of phase stability. Selected compositions were then synthesized and characterized to assess the accuracy of the model predictions. Phase formation and microstructural uniformity were examined using X-ray diffraction, scanning electron microscopy, and energy-dispersive spectroscopy. The results show that several compositions identified through the screening process form single-phase bulk ceramics with chemically homogeneous microstructures. Overall, this study demonstrates that data mining and machine learning can serve as effective surrogate tools for guiding composition selection and accelerating the experimental discovery of high-entropy UHTCs.

9:40 AM

(HTCMC-S1-013-2026) Tuning the composition of $(TiCeZrMoMn)O_2$ to enhance the structural, mechanical and thermal stability: First principles studies

M. Yadav*[1]; Y. Sudha Sistla[1]

1. Shiv Nadar Institution of Eminence, Chemical Engineering, India

First principles studies were used to design MO_2 (M= Ti, Zr, Ce, Mo, Mn) type optimum HEOs with superior properties by evaluating the structural, mechanical, and thermal properties by varying atomic fractions of metal cations. Results highlight that, non-equiatomic compositions could exhibit superior properties than equiatomic. For instance, density and hardness of equiatomic HEO were 5.43g/cm^3 and 6.48GPa while for non-equiatomic HEOs, values were in the order of 5.84g/cm^3 and 9.50GPa respectively. Further, bulk modulus (146.2–204.5 GPa) of HEOs suggest improved deformation resistance to volume changes under stress. The HEOs exhibited low shear modulus (62.10GPa-91.2GPa) indicating that these oxides are flexible and easily deformable. The Young's modulus and fracture toughness of HEOs were in the range of 163.40–238.2GPa and 1.38–1.90 MPa m$^{1/2}$ respectively. Minimum thermal conductivity (1.38–1.69 W/m K) suggests the suitability of HEOs for thermal barrier coatings. Among HEOs studied, $Ti_2Ce_2Zr_6Mo_5Mn_5O_{40}$ displayed highest hardness and fracture toughness and low minimum thermal conductivity suggesting its' application in high temperature applications. The Ti, Ce, Zr, Mo and Mn based HEOs displayed better elastic moduli, sound velocity, Debye temperature, thermal capacity and minimum thermal conductivity as compared to the HEOs reported in literature.

HTCMCS1- Modeling of materials processing

Room: Osprey
Session Chair: Simon Unseld, Technische Hochschule Augsburg

10:20 AM

(HTCMC-S1-014-2026) Modeling thermal-gradient chemical vapor infiltration: The case of SiC deposition using micro-wave heating (Invited)

G. L. Vignoles*[1]; R. Bechara[2]; G. Mangeon[1]; N. Bessouet[2]; S. Jacques[3]; R. D'Ambrosio[4]; G. Annino[5]; Z. Li[6]; J. Binner[7]

1. University Bordeaux, LCTS - Lab for ThermStructural Composites, France
2. Laboratoire des Composites Thermostructuraux, France
3. CNRS, LCTS, France
4. Istituto per i Processi Chimico-Fisici Consiglio Nazionale delle Ricerche, Italy
5. Istituto per i Processi Chimico-Fisici Consiglio Nazionale delle Ricerche Sede Secondaria di Pisa, Dipartimento di Scienze Chimiche e Tecnologie dei Materiali, Italy
6. University of Birmingham, United Kingdom
7. University of Birmingham, Ceramic Science & Engineering, United Kingdom

Chemical Vapor Infiltration is known as an excellent processing technique in terms of deposit quality and fiber preservation; however, its tendency to premature pore plugging or « crusting » is one of its worst drawbacks. Imposing a suitable thermal gradient (hotter inside, colder outside) during infiltration is a potentially excellent idea to fight this inconvenient. However, the precise control of this gradient is experimentally tough to obtain; this is where modeling plays a role. This presentation will address the modeling of the Thermal-Gradient Chemical Vapor Infiltration, applied to the case of SiC infiltration by Micro-Wave heating CVI (MW-CVI). The modeling approach includes : (i) image-based computations to produce effective thermal, geometrical and gas transfer properties of a fibrous preform and their evolution with temperature and degree of pore filling, (ii) computations of the whole multiphysics problem by finite elements on a resolution domain characteristic of the composite part and (iii) analytical or semi-analytical equations producing criteria for an optimal infiltration. Two distinct setups were modeled. Results of the models and experiments are compared and discussed. Guidelines for improving the process are given.

10:50 AM

(HTCMC-S1-015-2026) Molecular dynamics simulation for quantitative analysis of melt infiltration

K. Oba*[1]; M. Tsuganezawa[1]; K. Nishiguchi[2]; H. Shima[2]; Y. Nakanishi[2]; R. Inoue[1]; Y. Kogo[1]; Y. Arai[1]

1. Tokyo Rika Daigaku, Japan
2. Kabushiki Kaisha Mitsubishi Chemical Holdings, Japan

Ultra-high temperature ceramic matrix composites (UHTCMCs) are attracting attention as thermal protection materials used in re-entry vehicles and hypersonic passenger aircraft. UHTCMCs are fabricated using the melt infiltration method (MI), in which molten metal is infiltrated into porous carbon fiber-based substrate. MI enables the production of dense materials in a short time. However, the formation of matrix involves complex reactions between metal and carbon, making it challenging to predict infiltration behavior. Thus, the infiltration behavior of the molten metal must be quantitatively elucidated. Predictions of MI behavior require analyses that account for wetting at the solid-liquid interface, interfacial reaction, and atomic diffusion through the reaction layer. It is difficult to clarify these phenomena in high-temperature environments experimentally. Thus, the objective of this study is to propose an analytical method using simulations based on molecular dynamics (MD). MD simulations enable the tracking of atomic-scale behavior as a function of time evolution, allowing for the elucidation of carbide layer formation and the diffusion of carbon through these layers. In this study, MD simulation was employed to evaluate the interaction at the metal/carbon interface. In this presentation, we will discuss the relationship between carbon diffusion and infiltration behavior.

11:10 AM

(HTCMC-S1-016-2026) Preparation of CMC matrices by in-situ nitridation: Modeling combustion synthesis involving gases

G. L. Vignoles*[1]; E. Demenois[1]; T. Nguyen-Bui[1,3]; C. Descamps[1,2]

1. University Bordeaux, LCTS - Lab for ThermStructural Composites, France
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3. CEA/DAM, France

A promising route for the preparation of nitride- or oxynitride-matrix CMCs is the in-situ nitridation route. It has been put forward because of its ability to obtain an almost dense material out of a porous powder compact. A successful practical case has been developed by Taillet et al. several years ago, with the preparation of Si_2N_2O matrices by silicon/silica mixed slurry cast followed by in-situ heating under 30 bar N_2 gas pressure. The reaction being clearly exothermal, this process has been described as a case of Self-propagating High-temperature Synthesis (SHS, or "combustion synthesis"); however, a clear dependence of the reaction characteristics to the imposed initial nitrogen pressure indicates that the gas reactant also has an important influence. A numerical model of heat and mass transfer coupled to the chemical reaction and porous medium evolution has been set up in a home-made finite-volume solver. Results from the model obtained in different cases will be shown and discussed, highlighting the role of gas transfer during the combustion.

HTCMC-12 Symposium 6- Carbon/Carbon – Carbon Fiber Reinforced Carbon Composites

HTCMCS6- Processing and applications

Room: Pelican
Session Chair: Bill Goodman, Goodman Technologies, LLC

8:30 AM

(HTCMC-S6-009-2026) Rough laminar pyrocarbon synthesized by CVD in a cold-wall reactor (Invited)

A. Bident[2]; G. Chollon[1]; S. Jacques*[1]

1. CNRS, LCTS, France
2. University of Bordeaux, LCTS, France

Laminar columnar pyrocarbon or rough laminar pyrocarbon (RL PyC) is a type of carbon obtained as a matrix at the core of carbon-carbon composites. These composites are typically manufactured industrially by chemical vapor infiltration (CVI) from hydrocarbons, in cycles lasting several weeks. RL PyC exhibits high structural anisotropy, comparable to regenerated laminar PyC (ReL PyC), which is typically synthesized via chemical vapor deposition (CVD) on dense substrates in hot-wall reactors. However, ReL PyC has fewer in-plane defects in the graphene layers than RL PyC, resulting in lower Raman D-band width values ($FWHM_D$). Laboratory tests show that PyC coatings several microns thick with identical structural and textural properties to those of PyC LR ($FWHM_D \approx 90\ cm^{-1}$, high anisotropy) can be deposited in just a few hours using CVD in a cold-wall reactor from propane on dense substrates. Characterization of mechanical properties using nanoindentation also shows properties similar to PyC LR. The common mechanisms in CVI and CVD that could explain the growth of RL PyC by both methods will be discussed.

9:00 AM

(HTCMC-S6-010-2026) Reducing energy consumption in high-temperature processing of carbon composites (Invited)

J. Schmidt*[1]

1. Schunk Kohlenstofftechnik GmbH, Germany

Fibre-reinforced carbon composites are increasingly utilized in heat treatment applications due to their exceptional thermal stability, low weight, and high strength at elevated temperatures. The production of these materials, however, requires processing at extremely high temperatures, often exceeding 2000 °C, which leads to significant energy consumption and associated costs. This challenge has driven research toward optimizing graphitisation processes to reduce energy demand without compromising material performance. Variations in graphitisation temperature strongly influence the microstructure and properties of carbon composites, including thermal conductivity, mechanical strength, and dimensional stability. This work explores the relationship between processing temperature and material characteristics, aiming to identify strategies for lowering energy usage while maintaining functional properties. The findings contribute to sustainable manufacturing approaches for advanced composites in high-temperature industrial environments.

HTCMC-12 Symposium 9- Joining and Integration Technologies for Ceramic Matrix Composites

HTCMCS9- Brazing

Room: Silver Pearl 2/3
Session Chairs: Michael Halbig, NASA Glenn Research Center; Jose Arregui-Mena, Oak Ridge National Lab

9:00 AM

(HTCMC-S9-009-2026) Joining and integration of ceramic matrix composites to metals for high temperature applications using brazing processes (Invited)

V. J. Prabhu*[1]; N. Ludford[1]; K. Amin[1]; J. Redman[1]

1. TWI Ltd, United Kingdom

The demand for advanced aerospace, defence, and nuclear systems continues to drive the development of structural materials capable of withstanding extreme thermal and mechanical loads. Ceramic matrix composites (CMCs), particularly Ox-Ox CMC and SiC-SiC CMC, offer high strength, thermal stability, and environmental resistance, but their integration with metals in large or complex assemblies remains challenging. This study investigates vacuum brazing as a scalable joining method for bonding CMCs to refractory metals such as tungsten (W) and niobium (Nb) using active braze alloys (ABAs), including Ag-Cu-Ti alloys, and copper-based ABAs. SEM/EDX analyses were conducted to examine ABA–CMC interfacial interactions, while additional assessments focused on the influence of ABA foil thickness on surface morphology and joint performance of SiC-SiC to W joints. Mechanical evaluation using block-shear testing at room temperature revealed that SiC-SiC CMC joined to tungsten with 100 μm 63Ag-35.25Cu-1.75Ti ABA achieved the highest shear strength of 26.7 MPa. These results highlight key parameters and possible hybrid joining technologies in the future for designing high-temperature assemblies in demanding environments.

9:30 AM

(HTCMC-S9-010-2026) Design, fabrication, and integration challenges for silicon carbide-based heat exchangers for thermal management applications (Invited)

M. C. Halbig*[3]; M. Singh[1]; M. Ranaiefar[3]; Y. Zheng[2]

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2. Northeastern University, Mechanical and Industrial Engineering, USA
3. NASA Glenn Research Center, USA

Next generation heat exchanger (HEX) systems which offer advancements in complex geometries, light weight, multiple materials, and high temperature capability are enabling for future aerospace applications. Of particular interest are HEX systems based on ceramic materials. Silicon carbide (SiC) is one of the most appealing materials due to its high thermal stability (decomposition temperature~2500°C), good thermal shock resistance, and retained flexural strength at elevated temperatures. Moreover, it is chemically inert and possesses high thermal conductivity (about 4x that of steel). The SiC-based materials utilized include monolithic SiC and SiC fiber/SiC matrix (SiC/SiC) ceramic matrix composites (CMCs). However, a key challenge in ceramic heat exchanger development is the fabrication of complex internal cooling channels. Fabrication of heat exchanges can be conducted either through the joining of sub-elements and panels to build up the HEX or through additive manufacturing to 3D print the net-shape of the HEX. Brazing of ceramic to metal is conducted for cooling channel and manifold integration to the HEX. This presentation will focus on the design, fabrication, and integration challenges for HEXs with examples of recent activities.

Author Index

*** Denotes Presenter**

*Denotes Presenter