Shaping the Future of Ceramics Wrap Up Session

Moderator: David W. Johnson, Jr., Journal of the American Ceramic Society

Rapporteur Reports on Major Issues and Opportunities Identified in ICC4 Theme Areas

The American Ceramic Society
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ICC4 Theme Areas and Rapporteurs

Biology and Medicine	Vivek Pawar, Smith & Nephew, Inc.
Workforce Development	Martha Mecartney, University of California, Irvine
3rd Ceramic Leadership Summit Track	Marina Pascucci, CeraNova Corporation
Glass (Cross-Cutting)	Louis Mattos Jr., The Coca-Cola Company
Aerospace	Todd Steyer, The Boeing Company
Electro-, Optical-,Magnetic-Ceramics and Devices	Andrea Testino, Swiss Federal Institute of Technology Domain Paul Scherrer Institute
Environment, Energy, and Transportation	Yutai Katoh, Oak Ridge National Laboratory
	S.K. Sundaram, Alfred University
	Paolo Colombo, University of Padova
Infrastructure	Mohammad Pour Ghaz, North Carolina State University
Nanostructured Ceramics	Sylvia Johnson, NASA Ames Research Center
	Omer Van der Biest, Leuven University
Security and Strategic Materials	Peter Wray, The American Ceramic Society

Biology and Medicine

Vivek Pawar, Smith & Nephew Inc.

Major Issues Identified

1. *Regulatory pathway (time, burden of proof)*
2. *High fracture toughness bioglass ceramics*
3. *Attaching ceramics to existing long bone implants*

Biology and Medicine

Vivek Pawar, Smith & Nephew Inc.

Major Emerging Opportunities Identified

1. *Fundamental understanding of bioactive ions (Sr, Zn etc) used in Bioglass on cells*
2. *From CAD to implant*
3. *Multilevel (biology+ceramicist+industry+surgeon) collaboration for next generation of ceramics*

Workforce Development Track

Martha Mecartney, University of California, Irvine

Major Issues Identified

1. *Many students looking for alternative career paths, but most universities not offering good broad classes emphasizing entrepreneurship and business aspects.*

2. *Major challenges to international collaborations that were identified by women and young investigators include how to obtain funding and finding collaborators.*

3. *In the U.S., Engineering does not attract a diverse group of students (gender and ethnic diversity), limiting the pool of available talent.*

Workforce Development Track

Martha Mecartney, University of California, Irvine

Major Emerging Opportunities Identified

1. *Development of effective entrepreneurial classes for expanding career options for our students, excellent pool as entrepreneurial skill is linked to learning ability, ceramic engineers = smart students.*

2. *Strong support for international collaborations via Japan Society for the Promotion of Science and Shanghai Institute of Ceramics/Chinese Academy of Science - identify ways to most effectively share this information (similar programs for other countries?) and promote networking (example - WIRES).*

3. *ACerS and international Ceramics organizations can play a key role in supporting diversity by promoting best practices for professionalization and full integration of all participants..*

3rd Ceramic Leadership Summit Track

Marina Pascucci, CeraNova Corporation

Plenary – Executive Breakfast – Panel – Session

Major Issues Identified

1. Intellectual Property – determining who owns IP; what is worth protecting and how to protect; cost of protecting IP (patent, litigation); understanding and dealing with new "first to file" rules.

2. Assessing whether an idea has value – demand pull vs. technology push; product vs. market oriented; license technology, sell product directly, partner / joint venture.

3. Funding required at various stages – type of funding (private, government, VC); development, prototyping, testing, manufacturing / scale-up.

3rd Ceramic Leadership Summit Track

Marina Pascucci, CeraNova Corporation

Entrepreneurship: where risk meets innovation – with the goal of creating a product.

Major Emerging Opportunities Identified

1. *Successful entrepreneurs are resourceful – many are "affiliated" with academic or research institutions – utilize facilities, expertise, staff.*
2. *Opportunities for small companies to work with large companies.*
3. *Opportunities to access and license technology developed at National Laboratories, and opportunities for funding esp. for manufacturing initiatives.*
4. *Opportunities for making valuable, marketable products from "waste" materials.*
5. *Licensing to several entities for different markets (example from China).*

Glass

Louis Mattos, Jr; The Coca-Cola Company

Major Issues Identified

1. *Glass Strength*
2. *Surface Science of Glass*
3. *Decrease in research funding and graduate students in glass science*

Glass

Louis Mattos, Jr.; The Coca-Cola Company

Major Emerging Opportunities Identified

1. *Consumer Electronics: Flexible/rollable displays; data transfer (> 100TB/s)*

2. *Energy: Thin film semiconductors on glass substrates, laminated glass for weight reduction*

3. *Functional Glass: Mesoporous silica nanoparticles for drug delivery; antimicrobial glasses*

Aerospace Track

Todd Steyer, The Boeing Company

Major Issues Identified

1. *Microstructures of even the more mature material systems still may not unlock the full potential of the material for applications.*
2. *We need to nurture all along the path of getting a material developed, produced, certified, and into service.*
3. *High cost remains a significant consideration*

Aerospace Track

Todd Steyer, The Boeing Company

Major Emerging Opportunities Identified

1. *Ceramic Matrix Composites are making their way to applications in propulsion systems and structures.*
2. *Materials to enable hypersonic flight, e.g. ultra-high temperature ceramics, show promise*
3. *Fundamental and applied research areas for consideration: understanding damage accumulation mechanisms, life prediction/modeling, and developing nondestructive inspection and repair methods*

Electro-, Optical-,Magnetic-Ceramics and Devices

Andrea Testino, Paul Scherrer Institut, Switzerland

Major Issues:

1. Ceramic electronic components market is growing mainly because of portable electronics. Devices miniaturization is driven by this trend, towards extremely tiny components. The effort of academic and industrial scientists are focusing not only on new materials and advanced characterization tools but on advanced ceramic processing techniques too in order to push down the miniaturization technical limit.

2. Advanced analytical tools and deeper understanding of the solid state chemistry have revealed the importance of grain boundaries characteristics and sub-micron scale structures. Nanoscale engineering has become crucial in many fields. The production sub-micron powders prepared by conventional methods has reach the level where new ideas (i.e. bottom-up synthesis methods) are necessary.

3. Many ceramic components are based on metals with an environmental impact (e.g. Pb, Cd, Te) or limited resources (e.g. REE). A growing scientific activity is devoted to greener formulations, less rare raw materials, and the entire life-cycle of ceramic components.

Electro-, Optical-,Magnetic-Ceramics and Devices

Andrea Testino, Paul Scherrer Institut, Switzerland

Emerging Opportunities:

1. "Healthcare" and "Energy" are appealing markets. Bio-integrated electronics based on flexible silicon integrated circuit open opportunity for social benefit (i.e. business success) beyond imagination. Energy market is in need of materials which can operate at higher temperature and higher energy density with improved reliability . Ceramic materials open new opportunities.

2. The fact that established technologies are coming to technical limitations, requires the re-evaluation of technologies which have not yet been used on industrial level. Solutions may come from disciplines outside of the traditional ceramic manufacturing world as well.

3. Academic and industrial scientists are living in two different worlds. Industries show amazing achievements and successful products without talking about what they are not able to do, where academics could help. On the other hand, often academics pay limited attention on reproducibility or carrying out applied research too far from the real world. New forms of open collaboration are needed in order to establish long term industry-academic win-win situation and a faster benefit for the entire society – the real common target.

Environment, Energy and Transportation

Yutai Katoh, Oak Ridge National Laboratory

Major Issues Identified: Generic

1. *Improved efficiency are needed in all energy systems: gas turbines, solar, wind, transformers, transmission lines, batteries, e-car, power electronics, buildings.*

2. *Limited ability of net-shaping for complex geometries is still limiting use of ceramic materials for certain applications.*

3. *Predictive capabilities for performance and reliability of ceramic components in today's complex energy systems are largely missing.*

Environment, Energy and Transportation

Yutai Katoh, Oak Ridge National Laboratory

Major Issues Identified: Specific

1. *Fuel efficiency is the main issue for combustion systems.*
2. *Cost and durability issues for materials for commercial SOFC.*
3. *Efficiency and performance of chemical processes have been hampered by lack of high performance materials for gas separation and purification.*
4. *Complex and expensive systems for emission control.*
5. *Limited performance for today's capacitors for e-vehicles.*

Environment, Energy and Transportation

Yutai Katoh, Oak Ridge National Laboratory

Major Emerging Opportunities Identified: Generic

<< Generic Opportunities>>

1. *Tremendous opportunities for ceramic materials in all spectrum of technologies for improved energy efficiency.*
2. *Innovative net-shaping technology such as ceramic additive manufacturing has potential to expand market of structural ceramics.*
3. *Multi-scale modeling is the key to enable predictive capability for performance and reliability of ceramic components.*

Environment, Energy and Transportation

Yutai Katoh, Oak Ridge National Laboratory

Major Emerging Opportunities Identified: Specific

1. *Ceramic components in combustion systems improve fuel efficiency of transportation and generator systems through reduced weight and improved efficiency.*
2. *Low cost manufacturing of SOFC components seems possible in various ways.*
3. *Ceramic membranes for high performance and high temperature gas separation.*
4. *Catalytic ceramic hot gas filter can offer efficient/simple emission control.*
5. *Ceramic dielectric materials (and design) for revolutionary e-car capacitors.*
6. *THz electromagnetic regime shows great promise for science and technology. Ceramic materials science and THz technology can contribute to each other.*

Environment, Energy and Transportation 3rd

S. K. Sundaram, The New York State College of Ceramics, Alfred University

Major Issues Identified

1. *Fundamental understanding of cellular (porous) ceramics to exploit their multifunctionality*
2. *Nanoscale control of grain boundary phases in non-oxide ceramics (SiC, Si_3N_4, SiAlON) for range of applications*
3. *Angstrom-Nanoscale control of redox control for energy conversion*

Environment, Energy and Transportation

S. K. Sundaram, The New York State College of Ceramics, Alfred University

Major Emerging Opportunities Identified

1. *Cellular ceramics for energy applications (gas storage, ultracapacitors)*
2. *Cost barrier coming down in the case of non-oxide ceramics for high-end applications*
3. *High temperature solar-thermal conversion using known ceramic systems*

Environment, Energy and Transportation

Paolo Colombo, University of Padova, Italy

Major Issues Identified

1. *Issue 1. Reliability and Performance, Safety, Cost (BATTERIES)*

2. *Issue 2. Long term stability and thermal stability of components. Need for improved glass-ceramic sealants (HT SOFC)*

3. *Issue 3. Improve filtration efficiency and decrease pressure drop while maintaining strength at acceptable levels. Creation of multifunctional units: combine trapping and oxidation catalyst in a single component (DPF)*

Environment, Energy and Transportation

Paolo Colombo, University of Padova, Italy

Major Emerging Opportunities Identified

1. *Emerging Opportunity 1. Improved energy storage systems → improvement in the quality of renewable energies. $LiMn_2O_4$ nanorods and NWs (benefits going into the nanoscale)*
2. *Emerging Opportunity 2.* Large power stations, electrolysis cells for water and carbon dioxide, automotive and portable applications. Metal-supported SOFCs.
3. *Emerging Opportunity 3. Extend the use of ceramic filters/highly porous components to other applications*

Materials design, Innovative fabrication processes, Microstructure optimization, Advanced characterization tools, Modeling

Nanostructured Ceramics: EHS Track

Sylvia Johnson, NASA Ames Research Center

"Many of the "big bangs" in technology enabled by materials are "stitched together" by nanomaterials, ".. Gary Calabrese, Corning, ICC4 Plenary

What are effects on people of nanomaterials?

- *Environmental health and safety*
- *Use of nanomaterials to fight disease*

Major Issues Identified

1. *What are we measuring and therefore testing/evaluating? Issues with definitions, characterization techniques, sampling, metrology, comparability of data.*
2. *Multidisciplinary research (materials, biology, medicine, EHS) leads to communication / cultural issues that can slow/confuse/distort results. Large increase in data/publications and turnover/entry of new researchers can lead to repetition of work and mistakes*
3. *Confusion: Many agencies throughout world writing specifications etc. Difficult to sort through it all. Issues with setting occupational exposure levels which can invoke very strict protection measures (isolation). Need for industrial hygienists to be trained specifically in nanomaterials. Issues with safety at lab level where early research is done, often by students/inexperienced researchers.*

Nanostructured Ceramics: EHS Track

Sylvia Johnson, NASA Ames Research Center

Major Emerging Opportunities Identified

1. *Use/design of nano materials to carry drugs to specific sites in body: combination of biology/pharmacology/medicine/materials; opportunities for new educational programs?*
2. *Linking understanding of medicine and nano occupational issues to better understand causes (and thus prevention/treatment) of disease (cardiovascular disease essentially cause by human-produced nano particles (LDL) resulting from exposure to a high dose of "toxin" ("fatty food")*
3. *Growing need to develop, specify and validate measurement and testing techniques and standards. International collaboration in place but needs to grow.*

Nanoceramics

Omer Van der Biest, Leuven University

Nanostructured ceramics is a very broad field encompassing many forms of ceramics ranging from nanostructured particles, fibers, rods, tubes, sheets, surfaces and bulk materials developed for a wide range of sectors/applications. Major Issues Identified

1. *Upscaling of size of nanostructures; interfacing with the micro-, meso- and macroworld; integration into practical devices.*
2. *Upscaling of nanomanufacturing process to increase production rate, improve yield and reliability, manage costs. This may require invention of new ways of producing nanostructures.*
3. *Development of hybrid materials including ceramics, metals, and organic materials.*

Nanoceramics

Omer Van der Biest, Leuven University

Major Emerging Opportunities Identified

1. *Bulk nanostructured oxide ceramics (Ref: J. Binner, Loughborough U., Poster). In particular nanostructured YTZP resistant to hydrothermal ageing produced by industrial pressing and sintering as well as slip casting.*
2. *New nanoscale devices with new combinations of functional properties (Ref: work by the group of Prof Zhong Lin Wang at Georgia Tech) nanogenerators for energy harvesting, the piezotronic transistor.*
3. *Extending property limits e.g. nanostructured thermoelectrics (ref. EMPA).*

INFRASTRUCTURE

Mohammad Pour-Ghaz, North Carolina State University

Major Issues Identified

The quest for sustainability requires us to reduce the environmental loadings of construction materials. New construction materials are being developed.

1. *New materials require extensive experimental efforts to characterize them*
2. *The byproducts that are being used in construction materials are changing*
3. *Nano-particles used in construction materials may be considered hazardous materials*
4. *New material processing techniques are needed to implement new materials*
5. *Acceptance issues associated with the new materials and material processing techniques*

INFRASTRUCTURE

Mohammad Pour-Ghaz, North Carolina State University

Major Emerging Opportunities Identified

1. *New innovations in using traditional concrete; use of LCA (Lemay, NMRCA)*
2. *New approaches in design of new cements (Barcelo, Lafarge), new material processing techniques (Tselebidis, BASF), use of CO_2 to produce new construction material (Lemay, NMRCA), bio-inspired materials (Rushing, US Army; Raimondo, CNR ISTEC), cellulose nano-materials (Moon, Purdue), Innovative use of polymers (Siam, Thailand)*
3. *Multi-scale modeling to predict properties of materials and understand the nonlinearities in coupled properties (Jennings, MIT)*
4. *New service life prediction models*

Security and Strategic Materials

Peter Wray, The American Ceramic Society

Major Issues Identified

1. *Awareness of threats and strategies regarding strategic materials and rare earths being discussed on many levels within Administration and Congress, but activities and planning still dispersed.*
2. *Old war-oriented concepts of "national stockpile" (piles of rocks approach) have been slow to change, efforts to redefine federal responsibilities underway.*
3. *Greater payoff in getting bulk defensive structural materials to retain their properties rather than finding new "super" materials.*

Security and Strategic Materials

Peter Wray, The American Ceramic Society

Major Emerging Opportunities Identified

1. *Administration and Congress need greater input from materials organizations regarding long-term effect of not having coherent national strategy and risk-management systems to implement strategy.*
2. *New efforts to find distributed sources for key minerals and rare earths will take time, but need to be supported. Meanwhile efforts to improve efficient, nonwasteful use of materials in existing supply chains needs to be a focus.*
3. *Structured composite materials systems ("Struct'd Mats"), bio-inspired combinations and structures, and transparent armor are among frontier opportunities.*

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