
General

CREATING A VISION FOR THE FUTURE OF ADVANCED CERAMICS

Frank Kuchinski
Triton Systems, Inc.
200 Turnpike Road
Chelmsford, MA, 01824

Karen Hall
United States Advanced Ceramics Association
1800 M Street NW, Suite 300
Washington, DC, 20036-5802

ABSTRACT

The United States Advanced Ceramics Association (USACA) has supported programs to insert advanced ceramics in government and targeted end-user applications since 1989. These have included a variety of programs with DOE, DOD, NIST, and NASA, as well as investigating the application of advanced ceramics in energy-intensive industries.

In 1999, USACA and the U.S. Department of Energy co-sponsored a workshop to bring together a broad range of ceramic manufacturers and end-user companies. The 1999 workshop produced an Advanced Ceramics Technology Roadmap that set forth the research, development and demonstrations needed for improving advanced structural ceramics. In April 2004, USACA conducted a workshop to revisit the Advanced Ceramics Roadmap to assess progress and ongoing needs, as well as to focus on the manufacturing and fabrication requirements to insert advanced ceramics into the marketplace.

These activities led to the creation of three new USACA-led initiatives: The Ceramic Materials for Energy Independence Initiative; The Technology Transition Initiative; and The Ultra High Temperature Ceramics Initiative.

BACKGROUND

The United States Advanced Ceramics Association

USACA is the premier association that champions the common business interests of the advanced ceramic producer and end-user industries. USACA was formed in 1985 to facilitate the commercialization of the United States' advanced ceramics industry and quickly became the leading voice of the advanced ceramics industry before the U.S. Congress and federal agencies.

USACA recognizes that the key to the industry's survival is the identification of new commercial market opportunities for advanced ceramics. USACA has a long-standing commitment to promoting the use of advanced ceramics as the foundation for a new generation of high-efficiency and high-performance products for surface transportation, aerospace, defense, energy, and industrial applications.

The objectives of USACA are to develop and maintain close working relationships between its membership and the industries they serve; provide liaison between its members and Congress, government agencies, and allied interest industrial organizations and associations; advocate continued and increased funding of research and development on advanced ceramics with congressional leaders and their staffs; provide a mechanism for dissemination of advanced

To the extent authorized under the laws of the United States of America, all copyright interests in this publication are the property of The American Ceramic Society. Any duplication, reproduction, or republication of this publication or any part thereof, without the express written consent of The American Ceramic Society or fee paid to the Copyright Clearance Center, is prohibited.

ceramics information; and to promote the benefits of advanced ceramics to Congress, government agencies, and targeted industrial end-users. USACA accomplishes these objectives through a committee structure that guides and supports the staff.

USACA continues to support the needs of the advanced ceramics community through workshops, support of the Annual Conference on Composites, Materials, and Structures (Cocoa Beach, FL), and a quarterly electronic newsletter. In addition, USACA has formed close relationships with similarly aligned organizations, such as the American Ceramic Society, with whom USACA has a Memorandum of Understanding to facilitate information exchange.

Advanced Ceramics Technology Roadmap

In 1999, USACA and the U.S. DOE co-sponsored a workshop to bring together a broad range of ceramic manufacturers and end-user companies. This roadmap, which summarizes the insights of those 40 workshop participants, set forth the research, development and demonstrations needed for improving advanced structural ceramics. Achievement of the RD&D will significantly improve energy efficiency and productivity in many industries and help them reach their performance targets for 2020.

USACA conducted a workshop in April 2004 sponsored by DOE to revisit the Advanced Ceramics Technology Roadmap. It was important to assess progress and ongoing needs, as well as to focus on the manufacturing and fabrication requirements to insert advanced ceramics into the marketplace.

Advanced ceramic materials being incorporated into hot-sections of distributed energy technologies are allowing them to meet strict emission standards while increasing energy efficiency by operating at higher temperatures. Future efficiency and emissions improvements will significantly benefit from the continued research and development of advanced ceramics.

Key challenges for advanced ceramics include improvements in silicon nitride durability (impact resistance), engine integration technology (attachments), design and analysis tools for life prediction, coatings to reduce environmental degradation and leakage of gas flows, and cost reduction. Additional challenges include utilizing new materials, operational maintainability (repair), and scale-up (manufacturing).

The supply of advanced ceramics for application to gas turbines and engines has become of increasing concern because of industry restructuring. It has resulted in fewer suppliers and many of the remaining suppliers being captive to gas turbine manufacturers, which may lead to higher costs or limited product availability.

A decline in government funding for advanced ceramic materials R&D has occurred due to shifts in priorities and rising interest in alternative energy sources. Hydrogen energy systems and fuel cells are receiving funding because they are less mature and viewed by many as being in greater need of federal R&D investment. The workshop provided a set of ideas that could be used to strengthen research planning and raise awareness about the need for and benefits from the development of advanced ceramics for energy conversion equipment such as engines and turbines.

Strengthening existing public-private partnerships in advanced ceramics is one of the keys, including stronger industry, university, and national laboratory teams to accelerate technology development and enhance the chances for market acceptance.

Forming Industry-led Initiatives

USACA's three most recent workshops looked in various ways at the advanced ceramics needs in aerospace and federal agencies. The result of these workshops was the formation of three initiatives in December 2004 to focus on high-payoff applications and stimulate champions. The first workshop, held in the Fall of 2003, reviewed the status of aerospace hot structures and gas turbine materials progress and needs. In the spring of 2004, USACA explored the status of progress being made in meeting mission needs of the federal agencies. In the fall of 2004 USACA held a workshop to investigate initiatives in energy, technology transition, and ultra-high temperature materials.

Key thoughts that came out of these workshops were as follows:

- The advanced ceramics community should think & strategize in capability terms.
- Performance parameters need to be translated into capability parameters.
- Capability based on new (or novel applications of) materials & structures needs to be demonstrated.
- The advanced ceramics community should rethink and perhaps redefine the boundary between material & structure.
- Future discussions and planning should include a viable industrial base and a solid technology base.

It was clear that there was a real opportunity for USACA to lead initiatives to facilitate insertion of advanced ceramics in key areas. Advanced ceramics are wear-resistant, corrosion-resistant, lightweight, and more stable than other materials in high-temperature environments. Because of this combination of properties, advanced ceramics have an especially high potential to resolve a wide number of today's material challenges in process industries, power generation, aerospace, transportation, and military applications. Such applications are vital to maintaining global competitiveness, decreasing energy consumption, and minimizing pollution. These initiatives could provide the framework for a stronger partnership between an alliance of the advanced ceramics industry and the U.S. federal government with the goal of establishing a viable and sustainable advanced ceramics industrial base.

The DOE and DOD could encourage these initiatives by strengthening collaborative efforts in advanced ceramics research. By combining their expertise in materials, components, and manufacturing processes these agencies can help to accelerate the timetable for developing light, strong, corrosion-resistant ceramics capable of performing effectively under an array of environmental conditions.

The advanced ceramics industry needs to expand its scope of thinking and planning horizons to develop leap-frog ideas for distributed energy applications including opportunities for waste heat recovery, heat transfer, and thermal storage. These applications could potentially highlight advanced ceramics in a nationally recognized research and design agenda.

THREE NEW INITIATIVES

Ceramic Materials for Energy Independence

This initiative is focused on specific needs of the US DOE. It is chaired by Jay Morrison, Siemens Westinghouse. USACA created this initiative to accelerate development of advanced ceramic materials that are wear-resistant, corrosion-resistant, lightweight, and more stable than

other materials in high-temperature environment in critical energy-related applications. The formation of this initiative is based upon the following:

- There is a strong desire on the part of industry to develop advanced materials for power generation end users of conventional technologies, advanced central and advanced distributed resources.
- An important element of a secure energy future is the use of distributed power production resources to provide more options for serving critical loads in times of power disturbances and terrorism. The DOE has identified the need for advanced materials to better perform these critical functions and goals for fuel flexibility, and efficient and durable central and distributed energy generation.
- Industry needs to see a potential market for it to invest in continued development of advanced ceramics.

USACA's goal for this initiative is to achieve advanced ceramic material insertion into the energy marketplace. To accomplish this goal, the USACA Board of Directors set the following objectives: Create an energy security vision for advanced material requirements that can provide durable, efficient affordable, fuel-flexible generation in central and small distributed resource packages to complement the existing base of power generation assets; Develop programmatic metrics that can lead to the vision; and Develop strategies to address barriers to market insertion and propose plans/initiatives of action.

The Committee will include USACA members, DOE stakeholders, national laboratories and other interested parties that can contribute to the Initiative. An invitation to participate will be extended to relevant industry associations, such as the American Ceramics Society, the Gas Turbine Association, US Fuel Cell Council, and Engine Manufacturers Association.

Beyond the above objectives, desired outcomes include increased communications between the U.S. DOE and the advanced ceramics industry; and a sustainable advanced materials infrastructure that satisfies energy security requirements.

Advanced Ceramics Technology Transition Initiative

This initiative will mainly support critical needs of the U.S. DOD. It is chaired by Bob Licht, Saint-Gobain High Performance Materials.

USACA created this initiative to develop pathways to affordable advanced ceramic materials that are wear-resistant, corrosion-resistant, lightweight, and more stable than other materials in high-temperature environment in critical military applications. The emphasis in this initiative is in the application of available ceramics through efforts to reduce manufacturing costs. The formation of this initiative is based upon the following:

- There is a strong desire on the part of industry to develop advanced materials for military end users.
- The Department of Defense requires advanced materials to better perform critical missions. Applications include:
 - Mirrors
 - Space transportation vehicles
 - Ceramic body, aircraft and vehicle armor
 - Improved transparent armor
 - Small military engines

- Gas turbine
- Propulsion systems
- Erosion/corrosion resistant components
- There is national interest in assuring a domestic supply base for military-critical technologies.
- Industry needs to see a potential market to warrant continued development of advanced ceramics.

USACA's goal for this initiative is to achieve advanced ceramic material insertion into the military marketplace. To accomplish this goal, the USACA Board of Directors set the following objectives: Increase the technology readiness level and affordability of advanced ceramics through advances in manufacturing technology; Demonstrate enhanced war fighter capability by the application of advanced ceramics; and Establish a sustainable advanced ceramics industrial base through the use of the Defense Production Act.

The Committee will include USACA members, DOD stakeholders, laboratories and other interested parties that can contribute to the Initiative.

Beyond the objectives above, desired outcomes include: Development of industry partnerships where necessary, with government, to accelerate the application of high performing ceramics; Better communications between government agencies and the advanced ceramics industry; and Increased availability of advanced materials for the DOD.

Ultra High Temperature Ceramics Initiative

This initiative will mainly support key needs of the U.S. DOD and National Aeronautics & Space Administration. It is chaired by Frank Kuchinski, Triton Systems.

USACA created this initiative to accelerate development of advanced ceramic materials that are wear-resistant, corrosion-resistant, lightweight, and more stable than other materials in high-temperature environment in critical defense and space applications. The formation of this initiative is based upon the following:

- There is a strong desire on the part of industry to develop advanced materials for military end and aerospace users.
- The DOD requires advanced materials to better perform critical missions and to serve evolving applications including:
 - High velocity flight
 - Digital solid propulsion for kill vehicles
 - Mirrors
 - Aerospace nozzles
 - Scram jet missiles
 - Hypersonic propulsion
 - Space-based vehicle hot structures
 - Electromagnetic transparency materials
- There is national interest in assuring a domestic manufacturing base for military and space-critical technologies.
- Industry needs to see a potential market to warrant continued development of advanced ceramics.

USACA's goal for this initiative is to achieve advanced ceramic material insertion into the military and aerospace marketplace. To accomplish this goal, the USACA Board of Directors

set the following objectives: Perform an analysis of the impact on cost and mission capability by not having access to high temperature materials necessary to perform future critical functions; Create awareness of the needs among users of advanced ceramic materials; and Create ceramic technologies and a manufacturing infrastructure to support important requirements for ultra high temperature materials.

The Committee will include USACA members, Department of Defense and NASA stakeholders, laboratories and other interested parties that can contribute to the Initiative. The concept of developing a users consortium will be explored to help prepare the prime contractors and other users for specifying these new materials.

Beyond the above objectives, desired outcomes include: Better communications among government agencies, systems developers, and the advanced ceramics industry; Increased availability of advanced materials for the Department of Defense and NASA; and Generate the funding to implement resulting initiatives.

CONCLUSIONS

- Advanced Ceramics play a key role in multiple US Government applications
- Needs in advanced materials are similar across DOE, DOD, and NASA
- Joint and/or collaborative R&D programs will promote faster product transition and leverage available limited resources.
- USACA hopes to create a vision and strategy to ensure product insertion in critical US applications through its 3 new initiatives.

REFERENCES

¹USACA, US Department of Energy, Energetics, Richerson & Associates, "Advanced Ceramics Technology Roadmap: Charting Our Course," *Joint USACA/DOE Publication*, (2000).