Creating a Vision for the Future of Advanced Ceramics

January 2005

Frank Kuchinski
Director, USACA
Triton Systems

Co-author: Karen Hall,
Technical Director
USACA Overview

• Formed in 1985 to facilitate the commercialization of the United States’ advanced ceramics industry
• Located in Washington, DC
• Broad swing in membership over the past decade but now stable and growing

Regular members
• COI Ceramics
• Corning
• Deere & Company
• GE Power Systems Composites
• Goodrich Corporation
• UT Battelle/Oak Ridge National Laboratory
• Saint-Gobain High Performance Materials
• Siemens Westinghouse Power

Emerging members
• Refractron Technologies Corp
• Surmet Corporation
• Synterials, Inc
• Triton Systems
USACA Purpose & Objectives

• Provide liaison between USACA 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.
  – Promote the benefits of advanced ceramics to Congress, government agencies, and targeted industrial end-users.
• Develop and maintain close working relationships between USACA’s membership and the industries they serve.
• Provide a mechanism for dissemination of advanced ceramics information.
USACA Past Achievements

- Actively supported DOE CFCC, DOE HTML, DOE CSGT, DOE AIM, DARPA CIP, DARPA AIM, DARPA SFF, NIST ATP, DOD IHPTET, NASA HSCT, NASA UEET, etc.
- Prepared a DOE sponsored study on the application of advanced ceramics in energy intensive industries
- Prepared a DOE sponsored Roadmap on advanced ceramics
- Later revisited the Roadmap to review progress, determine priorities
Advanced Ceramics Technology Roadmap

- September 1999 Workshop
- 40 participants
- First step in reaching consensus on priority needs advanced ceramics industries
- Addressed:
  - Ceramic matrix Composites
  - Monolithic Ceramics
  - Ceramic Coating Systems
Roadmap Update Workshop

- April 2004 Workshop
- 34 participants
- Update existing roadmap to focus on manufacturing and fabrication requirements
  - Top manufacturing technical challenges
  - Top RD&D manufacturing needs
Advanced Structural Ceramics
– Solving Critical Problems

Power Generation and Transportation
- Extend equipment life
- Decrease emissions
- Decrease fuel consumption
- Reduce weight
- Reduce costs

Industrial Processing and Manufacturing
- Increase energy efficiency
- Increase recycling, including process chemicals and water
- Decrease maintenance
- Extend equipment life
- Decrease emissions
## Major Areas of Cross-Cutting RD&D Need

<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Materials Database</td>
<td>Data to use in material selection and support analytical design and life prediction</td>
</tr>
<tr>
<td>Design and Life Prediction</td>
<td>Analysis tools to enable component design (replace “build and break”)</td>
</tr>
<tr>
<td>Non-Destructive Evaluation</td>
<td>Methods and equipment for low cost inspection and quality assurance</td>
</tr>
<tr>
<td>Fabrication Optimization</td>
<td>Materials reliability to improve manufacturing scale-up capabilities and reduce costs</td>
</tr>
<tr>
<td>Demonstrations</td>
<td>Verify component viability through field testing</td>
</tr>
</tbody>
</table>
Technology Challenges: Monolithic Ceramics

- Reduce costs for dense machining with ability to remove large volumes of stock without damage
- Maintain long-lived environmental barrier coatings or develop materials with adequate environmental stability
- Establish test methods for characterization of produced components to meet specifications provided by end-users
- Improve/maintain “as-processed” surface strength and dimensional control in complex gas turbine and other product components
RD&D Needs: Monolithic Ceramics

- Develop coatings that resist oxygen and water diffusion
- Increase strength and toughness of monolithics to compete with high cost composites
- Develop non-line-of-sight coating processes such as low cost slurry coating development
- Demonstrate a near term product “success story”
Technology Challenges: Ceramic Matrix Composites

- Need for manufacturing process material condition monitoring for better process control
- Improve consistency in material properties particularly with CMC manufacturing in small quantities
- Improve durability and longevity of CMC
- Improve performance to satisfy application requirements
- Need for robust composite design models to support design concerns
- Reduce costs and increase reliability of non-destructive techniques
RD&D Needs: Ceramic Matrix Composites

- Improve joining technologies
- Increase oxidation protection coating durability
- Invest early in scale-up issues and identify key issues
- Require comprehensive testing at the sub-element, rig, field, and flight stages
- Consistent level of funding and focused effort on advanced ceramics
Major Workshop Findings

• Future efficiency and emissions improvements will significantly benefit from the continued research and development of advanced ceramics

• Significant manufacturing challenges remain

• There is concern about the capabilities of manufacturers to supply a potential growing demand for advanced ceramics for application to gas turbines and engines

• Declining government R&D funding for advanced ceramic materials is a problem for new companies

• Strengthening public-private partnerships in advanced ceramics is paramount
USACA Ongoing Activities

- Promote the benefits of advanced ceramics to Congress, Government Agencies, and targeted industrial end-users
- Hold workshops on topics of interest to the advanced ceramics industry
- Support the Cocoa Beach meeting as the primary forums for information dissemination
- Publish online Newsletter
- Work closely with aligned organizations (MOU with ACerS)
Recent Activities

• Fall 2003
  – Status Aerospace Hot Structures and Gas Turbine Materials progress and needs

• Spring 2004
  – Status progress being made in meeting mission needs of the Federal Agencies
  – Update Roadmap

• Fall 2004
Market Forces Driving Changes in USACA

• Investment in advanced materials de-centralized by the Federal Government
  – Absence Of Designated USG Material Line Items.
  – Included in systems budgets but minimal due to priorities

• Gas Turbines Viewed as “Mature Technology”
  – Requires different forms of partnership with the Federal government
What does it all mean for Materials?

• We need to think & strategize in capability terms.
• Industry collaboration/cooperation is paramount and cannot afford to define everything “competitive”
• Performance parameters need to be translated into capability parameters.
• We need to focus on some high payoff applications & stimulate champions.
• Capability based on new (or novel applications of) materials & structures needs to be demonstrated.
• We need to rethink and perhaps redefine the boundary between material & structure.
• In all discussions and planning we need to remember that a viable industrial base and technology base must eventually be obtained.

Reference: Sloter
The Opportunity

Advanced Structural Ceramics Have the Potential to Solve Energy Security and National Security Challenges

– Distributed Power Generation
– Aerospace
– Transportation
– Military
USACA Response

- Identify pre-competitive initiatives to insure international competitiveness and help sustain the US advanced ceramics industrial base.
- Re-invigorate the working relationship with government sponsors of advanced ceramics R&D
- Form strategic alliances with organizations having related interests
  - ACerS, GTA, AIA
- Expand membership
- Continue to:
  - Support sponsors in maintaining/strengthening current initiatives
  - Support Cocoa Beach meeting
  - Hold workshops of interest to industry
Rationale

• Greater levels of DOE and DOD coordination could be a source of leveraging limited federal R&D resources for advanced ceramics
• Greater creativity is needed among developers of advanced ceramic materials to devise new product applications and attract more industries and potential funding sources
• New advanced ceramics materials and manufacturing initiatives could accelerate development and supporting the manufacturing base, which is still in its infancy
Ceramic Materials for Energy Independence

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 Department of Energy 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.
Ceramic Materials for Energy Independence Initiative
U.S. Department of Energy
Committee Chair: Jay Morrison, Siemens Westinghouse

• 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 of action.
Examples of Energy Opportunities

• Solar Turbines Mercury 50
  – Engine design includes advanced materials
• ATS Program
  – corrosion & erosion resistance
• Gas turbine combustor liners
• Advanced materials for microturbines, recuperators, graphite foam heat sinks
• More durable/reliable NG spark plugs or ignition systems
• Valves, valve seats, manifolds, & turbocharger housings
• High temperature superconducting materials
DOD Advanced Ceramics
Technology Transition Initiative

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:
  – 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.
Ceramic Technology Transition Initiative
U.S. Department of Defense
Committee Chair: Bob Licht, Saint-Gobain

• 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.
• Establish a sustainable advanced ceramics industrial base through the use of the Defense Production Act.
Examples of DOD Opportunities in Energy & Power Technologies

- Hybrid/Electric Combat Vehicle
- Electric Warship
- More Electric Aircraft
- Solid oxide fuel cells (AC materials)
- Armor weight reduction
- Increased power and efficiency
- Expand capabilities of weapons and detection systems
- Decrease vulnerability
- Increase reliability
- Reduce cost of equipment, systems and deployment
- Examples: Ceramic gun barrel, CMCs for Navy Air Vehicle Applications, opaque and transparent armor, hot section components
UHT Ceramics Initiative

• 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 Department of Defense 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.
Ultra High Temperature Ceramics Initiative
U.S. Department of Defense
Committee Chair: Frank Kuchinski, Triton Systems

Prepare Materials Development, Product Demonstration and Insertion Plan for Ultra High Temperature Ceramic Materials. This should include:

• 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 ceramics materials
• Create ceramic technologies and a manufacturing infrastructure to support important requirements for ultra high temperature materials.
Examples of UHT Opportunities

• IHPTET/JTAGG III – Helicopter Engine
  – High temperature rise CMC Combustor

• Tiled airfoil technology
  – Need low cost methods to fabricate high-precision monolithic structures

• Flameholder ceramic insertion for durability

• Ceramic Impeller for V-22 shaft driven compressor
Committee Meetings

The committees formed by the 3 new initiatives will be meeting during the conference:

• DoD Advanced Ceramic Technology Transition Initiative: Monday, Jan. 24th.
  – Committee only meets at 12 pm.
  – Open meeting is scheduled for 6-7 pm.

• UHT Ceramics Initiative: Tuesday, January 25th.
  – Committee only meets at 12 noon.
  – Invitational meeting is scheduled for 6-7 pm.
  – Invitations went out to stakeholders based on 2004 Cocoa Beach Registration list.

• Ceramic Materials for Energy Independence: Wednesday, Jan. 26th.
  – Committee only meets at 7 am.
  – Invitational meeting is scheduled for 5-6 pm.
  – Invitations went out to stakeholders based on 2004 Cocoa Beach Registration list.
Participation

• The Committee includes USACA members, Federal Agency stakeholders, national laboratories and other interested parties that can contribute to the Initiatives.

• An invitation to participate will be extended to relevant industry associations, e.g. ACerS, GTA, USFCC, Engine Manufacturers Association.

• Other interested parties have an opportunity to provide input during open or invitational meetings.

• Open meeting(s) will be signposted.
Summary

- Advanced Ceramics play a key role in multiple USG 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’s 3 new initiatives hope to create a vision and strategy to ensure product insertion in critical US applications.
For Further Information

For more details on any of the material presented here, please visit the USACA website at:

www.AdvancedCeramics.org

or see any of the USACA members here for information on USACA membership.
USACA Representatives

The following USACA members and staff are here to speak with you:

Executive Director: Jeffrey Serfass
Coordinator: Brian Schorr
Executive Committee Members:
Ken Etkin, myself, Arvid Pasto
Committee Chairmen: Bob Licht, Jay Morrison, myself