The National Academies of
SCIENCES • ENGINEERING • MEDICINE

Defense Materials Manufacturing and its Infrastructure (DMMI)

Workshop on:
High Temperature Materials Systems:
Emerging applications, materials and science gaps

NAS building, 2101 Constitution Avenue, N.W., in Washington, D.C, Room 210
May 10-11, 2022

Abstract

The performance of future DOD platforms is highly reliant upon the emergence of materials able to survive repeated operation at very high temperatures (>1500 ºC) while subjected to high stresses from aerothermal and maneuver loads, severe thermal gradients, extreme thermal shock, and particle impacts while enduring exposure to high speed, sometimes ionized, reacting gas flows. Examples include components for the hot sections of future gas turbines, scram jet propulsion systems and rocket nozzles, hypersonic leading edges (especially those with the lowest drag), the thermal protection systems of re-entry vehicles and the aerothermal structures of high-speed interceptors. Many applications are DOD specific and require new materials and supply chains, (including the redevelopment of supply chains for obsolescent material systems). Most materials used in ultrahigh temperature environments within the lower atmosphere can only survive if appropriately protected from reaction with the environment. However, the co-development of a material plus reliable coatings system has been rarely and adds complexity and cost to material system development. This workshop will explore the design of materials and their environmental protection/coating systems, to address unmet combinations of material properties needed for future ultrahigh temperature applications (Session I). It will investigate candidate systems including those based upon coated refractory metal alloys, ultrahigh high temperature ceramics, as well as ultrahigh temperature ceramics and composites, and investigate the current tools for accelerated discovery and optimization of these material/coating systems. Session II will explore the status of manufacturing including new approaches to near net shape, scalable, sustainable manufacture and the requisite supply chain. Special attention will be paid to approaches and facilities needed for testing in extreme environments (Session III). Finally, it will explore the science gaps needed to be bridged to accelerate the development of these material systems (Session IV).

May 10, 2022

OPEN SESSION

7:30 Working Breakfast

8:00 Welcome, Introductions –**Haydn Wadley** (U. Virginia, DMMI CHAIR)

8:15 Workshop scope and objectives – **Carlos Levi** (UCSB, Workshop Chair)

8:30 **Keynote Speaker: Kevin Bowcutt**
Chief Scientist Hypersonics, Boeing, NAE
Topic: *Future needs and applications for high temperature materials*

9:15 Discussion

Topic 1: Design Challenges in High temperature Materials Systems
Introductions by: **David Marshall (NAE)** (Remote) Q&A Lead by: **Diane Chong (NAE)**

9:30 **Speaker: Tresa Pollock**
Alcoa Distinguished Prof. of Materials, UCSB, **NAE**
Extending alloy temperature capabilities above 1500°C

10:00 Break

10:20 **Speaker: William Fahrenholtz**
Curator's Professor of Ceramic Engineering, MUS&T
Opportunities and Challenges in the design of ultra-high temperature ceramic systems

10:50 **Speaker: Matthew Begley**
Professor of Mechanical Engineering and Materials, UCSB
The challenge of System Design: Thermomechanical and thermochemical issues

11:25 Lunch

12:25 **Panel Discussion on *Design Issues***
Introductions by: **Diane Chong (NAE)** Q&A Lead by: **David Marshall (NAE)** (Remote)

Panelist: **Dave Van Wie**
JHU – Applied Physics Lab, **NAE**
Materials challenges in the hypersonic environment

Panelist: **Jeffrey Williams**
Consulting Engineer, GE Aviation
Integration of materials development and processing into mechanical design

Panelist: **Michael Maloney**
Pratt and Whitney, retired, **NAE**
Alloy and coating design challenges in advanced energy systems

Panelist: **Olivier Sudre**
Senior Fellow, CMCs, Pratt & Whitney
Ceramic Matrix Composite Design Challenges for use in Extreme Environments

Topic 2: Manufacturing Challenges in HT Material Systems
Introductions by: **Carlos Levi** Q&A lead by **Lourdes Salamanca-Riba**

13:45 **Speaker Noah Philips**
Senior Principal Metallurgist, ATI
Challenges in Processing Advanced Refractory Alloys

14:15 **Speaker: Frédéric Monteverde**
National Research Council, Italy **(**Remote)
Topic: *UHTC composite manufacture* and shaping

14:45 Break

15:00 **Speaker: Don M. Lipkin**
Senior Principal Scientist, GE Research
Critical Materials Through a GE Lens

15:30 **Panel Discussion on *Technology Gaps and Supply Chain Challenges,***
(including scalable manufacturing issues)
Introductions by: **Lourdes Salamanca-Riba,** Q&A lead by **Carlos Levi**

Panelist: **Vasisht Venkatesh**
Pratt and Whitney
ICME-based advanced manufacturing

Panelist: **David Smathers**
H.C. Starck
Consolidation issues for MPEA materials solid or powder.

Panelist: **Rod Eggert**
Coulter Foundation Professor, Colorado School of Mines
Supply chain issues – economics of critical materials

Panelist: **Carolina Tallon Galdeano**
Assistant Professor, Virginia Tech (Remote)
Processing challenges in ultra-high temperature ceramics

16:50 Wrap up and final comments – **Carlos Levi** (Remote) and **Haydn Wadley**

5:00 Adjourn meeting day 1

May 11, 2022

OPEN SESSION

7:30 Working Breakfast

8:00 Welcome, plans for today – **Haydn Wadley and Carlos Levi** (Remote)

8:15 **Keynote Speaker, Douglas Fletcher,** (Professor, University of Vermont)
Plasma Testing of High-Temperature Materials

9:00 Discussion

Topic 3: Testing for Extreme Environments

Introductions by: **Katherine Faber** (Remote**)** Q&A Lead by **Brent Carey**

9:15 **Speaker: Mark Opeka**
Materials Engineering Fellow, Southern Research
Testing for Extreme Environments

9:45 Break

10:05 **Speaker: Frank Zok**
Distinguished Professor, UCSB
Probing Composite Microstructure and Thermomechanical Behavior at High Temperature

10:35 **Speaker: David Marshall**
Research Professor, Univ. of Colorado, **NAE** (Remote)
Topic: *Assessing Mechanical behavior at very high temperatures*

11:10 Lunch

12:10 **Panel Discussion on *Testing HT Materials Systems***

Introductions by: **Brent Carey** Q&A Lead by **Katherine Faber** (Remote)

Panelist: **Andrew Detor**
Sr. Principal Scientist, GE Research
Navigating the multiphysics challenge in extreme environment testing

Panelist: **Craig Robinson**
Chief, Environmental Effects & Coatings Branch, NASA Glenn Research Center
NASA Glenn Research Center High Heat Flux Laser Facility

Panelist: **Rodney Bowersox**
Texas A&M
Texas A&M High Enthalpy Testing

Panelist: **David Poerschke**
Assistant Professor, University of Minnesota
Environmental interactions, thermodynamic foundation

Topic 4: Critical research needs to enable progress in HT systems

Introductions by: **Edwin Thomas (NAE)** Q&A Lead by **Subhash Singhal (NAE)**

13:30 **Speaker: Nathan Jacobson**
consultant to NASA Glenn
Topic: *Vapor Pressures: Vapor Pressures: Measurement, Calculation, and Importance in High Temperature Materials Performance*

14:00 **Speaker: Alexandra Navrotsky**
Professor, ASU, **NAS**
Topic: *Challenges in measuring thermodynamic properties at very high temperature*

14:30 Break

14:50 **Speaker: Mark Asta**
Oppenheimer Professor, UC Berkeley **(**Remote)
Topic: *Computational approaches to high temperature systems*

15:25 **Panel Discussion on *Science gaps for implementation of HT Materials Systems***

Introductions by: **Subhash Singhal (NAE)** Q&A Lead by **Edwin Thomas (NAE)**

Panelist: **David Clarke**
Harvard, **NAE**
Radiation heat transfer issues in very high temperature materials

Panelist: **Anton van der Ven**
UCSB (Remote)
Modeling phase stability in refractory metal systems and oxides

Panelist: **Scott McCormack**
Assistant Professor, UC Davis
In-situ phase equilibria and crystallography up to 3000˚C and beyond

Panelist: **Daniel E Marren**
TRMC/JHTO, Scientific research Corporation
The hypersonics workforce pipeline challenge

16:35 **Wrap up discussion** for the full workshop

Moderated by **Carlos Levi** and **Haydn Wadley**

16:55 **Adjourn meeting**