EASTERN NEW YORK CHAPTER

HUDSON-MOHAWK CHAPTER

2005 ASM/TMS SPRING SYMPOSIUM

MATERIALS FOR EXTREME ENVIRONMENTS

PROGRAM AND ABSTRACTS

May 23rd & 24th, 2005

GE Global Research
Niskayuna, NY

MATERIALS FOR EXTREME ENVIRONMENTS

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OBJECTIVES

Co-sponsored by the Eastern New York Chapter of ASM and the Hudson-Mohawk Chapter of TMS, a Technical Symposium on a topic of materials science and engineering is held annually in the spring. The purposes of the technical symposium are to provide opportunities for technical information exchange between professionals, to provide continuing education for professionals, and to educate students in science and engineering fields in Eastern New York.

2005 Spring Symposium Organizing Committee

Tom Angeliu (KAPL)
Steve Attanasio (KAPL)
Bernard Bewlay (GEGR)
Erin Breithaupt (KAPL)
Laurent Cretegny (GEGR)
Evan Dolley (KAPL)
Kathy Dunn (SUNY, Albany)
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Sarah Lewis (RPI)
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Michelle Othon (GEGR)
Lou Peluso (GEGR)
Ed Ritchey (KAPL)
Linda Schadler (RPI)
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Tymm Schumaker (KAPL)
George Swinler (KAPL)
Seth Taylor (GEGR)

2005 ASM/TMS Spring Symposium
Materials for Extreme Environments
GE Global Research, Niskayuna, NY

Monday, May 23rd, 2005

7:30 - 8:30	Check-in/registration and coffee
8:30 - 8:45	Opening Remarks: Mike Wollman Manager, Space Power Program Lockheed Martin – KAPL, Inc.

Session I **Materials Characterization in 3-D**
Chairs: Steve Attanasio and Erin Breithaupt, Lockheed Martin – KAPL, Inc.

8:45 - 9:30	David Seidman (Northwestern University) –*Temporal Evolution of the Nanostructure of a Model Nickel-base Superalloy (Ni-Al-Cr) Utilizing Atom-probe Tomography, Electron Microscopy, and Lattice Kinetic Monte Carlo Simulation*
9:30 - 10:15	Matthew Weyland (Cornell University) – *Electron Tomography in the Physical Sciences*
10:15 - 10:30	Break
10:30 - 11:15	James Evertsen (University of Albany) – *Contrast Mechanism and Three Dimensional Imaging by Focused Ion Beam Analysis of Microelectronic Devices*
11:15 - 12:00	Peter Lee (University of Wisconsin) – *3D Imaging Used as a Tool for the Quantification of Microstructures and Surfaces of Low Temperature Superconductors*
12:00 - 1:00	*Lunch*

Session II **Structural Materials for High Temperature**
Chairs: Dan Lewis and Tim Hanlon, GE Global Research

1:15 - 2:00	Gerald Meier (University of Pittsburgh) – *Oxidation Problems in Solid Oxide Fuel Cells*
2:00 - 2:45	Sharvan Kumar (Brown University) – *Deformation Behavior of a Two-phase Mo-Si-B Alloy*
2:45 - 3:00	*Break*
3:00 - 3:45	Young-Won Kim (UES, Inc.) – *Linking Gamma TiAl Alloys and Conventional Titanium Alloys: Recent Development*
3:45 - 4:30	Dallis Hardwick (Air Force Research Laboratory) – *Continuing Challenges for Materials in Propulsion*
4:45 - 5:30	**Tour of GE Global Research**

2005 ASM/TMS Spring Symposium

Materials for Extreme Environments

GE Global Research, Niskayuna, NY

Monday evening, May 23rd, 2005

6:00 - 7:00	Hors d'oeuvres and Cash Bar Reception (Glen Sanders Mansion)	
7:00 - 8:00	Symposium Dinner	
8:00 - 9:00	Dinner Talk:	Matthew Nordan (Lux Research Inc.) *The Commercial Outlook for Nanomaterials*

Abstract and Biographical Sketch of Matthew Nordan can be found on page 14

Directions to Glen Sanders Mansion:

- Turn right out of the GE Global Research Center onto the traffic circle
- Take first right off traffic circle onto River Rd.
- Follow River Rd. through light at Balltown Rd (River Rd. becomes Rosa Rd. at this light)
- Follow Rosa Rd. to Nott St. (Ellis Hospital will be on your left), take a right onto Nott St.
- Follow Nott St. to Erie Blvd., take left onto Erie Blvd.
- Travel into downtown Schenectady (~0. 6 mile) and turn right at State St. (Rt. 5)
- Take State St. (~ 1 mile) over the Mohawk River on the Western Gateway Bridge
- Turn left at the first light just over the bridge onto Glen Ave.
- The Glen Sanders Mansion is the first building on the left.

2005 ASM/TMS Spring Symposium

Materials for Extreme Environments

GE Global Research, Niskayuna, NY

Tuesday, May 24th, 2005

7:30 - 8:30 *Check-in and coffee*

Session III **Materials for Space Applications**
Chairs: Tom Angeliu and Tymm Schumaker, Lockheed Martin - KAPL

8:30 - 9:10 Steve Zinkle (Oak Ridge National Laboratory) – *Materials for Space Reactor Applications*

9:10 - 9:50 Tim McGreevy (Oak Ridge National Laboratory) – *Mechanical Property Considerations for Materials in Space Reactor Applications*

9:50 - 10:00 Break

10:00 - 10:40 Herng-Jeng Jou (QuesTek) – *Application of Computational Materials Design to Assess and Develop Structural Materials for Space Nuclear Applications*

10:40 - 11:20 Sarah Watson (Lockheed Martin – KAPL, Inc.) – *Analysis of the Creep Performance of Selected Refractory Metals of Interest to Space Nuclear Power Systems*

11:20 - 12:00 Jerry Gould (Edison Welding Institute) – *Solid State and Resistance Joining Technologies for Fusion Energy Systems*

12:00 - 1:00 *Lunch*

Session IV **Materials by Design**
(Chairpersons: Liang Jiang, GE Global Research, Linda Schadler, RPI)

1:15 - 1:55 Pulickel Ajayan (Rensselaer Polytechnic Institute) – *Tailoring Carbon Nanotube Architectures for Applications*

1:55 - 2:35 Greg Sawyer (University of Florida) – *Tribology of Polymeric Nanocomposites*

2:35 - 3:15 Mohan Manoharan (GE Global Research) – *Nanoceramics for Harsh Environments*

3:15 - 3:30 *Break*

3:30 - 4:10 Mark Opeka (Naval Surface Warfare Center) – *Materials Selection and New Directions for Ultra-High Temperature Hypersonic Materials*

4:10 - 4:50 Lance Snead (Oak Ridge National Laboratory) – *Ceramic Composites for Next Step Nuclear Power Systems*

4:50 - 5:00 *Concluding Remarks*

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PROGRAM AND ABSTRACTS

May 23rd & 24th, 2005

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Materials Characterization in 3-D

Session I

Chairs: Steve Attanasio & Erin Breithaupt, KAPL

Authors and Titles

David Seidman (Northwestern University)
Temporal Evolution of the Nanostructure of a Model Ni-base Superalloy (Ni-Al-Cr) Utilizing Atom Probe Tomography, Electron Microscopy and Lattice Kinetic Monte-Carlo Simulations

Matthew Weyland (Cornell University)
Electron Tomography in the Physical Sciences

James Evertsen (University of Albany)
Contrast Mechanism and Three Dimensional Imaging by Focused Ion Beam Analysis of Microelectronic Devices

Peter Lee (University of Wisconsin)
3D Imaging Used as a Tool for Quantification of Microstructure and Surfaces of Low Temperature Superconductors

Temporal Evolution of the Nanostructure of a Model Ni-base Superalloy (Ni-Al-Cr) Utilizing Atom-Probe Tomography, Electron Microscopy and Lattice Kinetic Monte-Carlo Simulations

David Seidman
Northwestern University

Abstract

We are studying the temporal evolution of the nanostructure of a model nickel-base superalloy, Ni-Al-Cr, utilizing atom-probe tomography (APT) and electron microscopies, and lattice kinetic Monte Carlo (LKMC) simulation. A single-phase alloy is aged in the γ (fcc) plus γ' ($L1_2$) phase field and the nucleation of γ'-precipitates is observed using both APT and LKMC simulation, from precipitates containing as few as 20 atoms via APT studies. We follow, at 873 K, the nucleation trajectories into the regimes where the γ'-precipitates are nucleating and growing, and then into the regime where they are growing and coarsening. APT permits us to follow the chemical changes occurring during all stages with sub-nanoscale resolution. Hence, we follow the temporal evolution of the chemical compositions of the γ (fcc) plus γ' ($L1_2$) phases and observe the transition from time-dependent regime to the quasi-steady-state regime. In parallel we are using LKMC simulations, whose results are compared with experimental observations. LKMC simulations play an important role in understanding the coarsening of γ' ($L1_2$) precipitates by a coagulation and coalescence mechanism, as opposed to the classical coarsening via the condensation-evaporation mechanism. Research supported by the National Science Foundation, Division of Materials Research.

Biographical Sketch

David Seidman is currently a Walter P. Murphy Professor of Materials Science and Engineering and the Director and Founder of the Northwestern University Center for Atom-Probe Tomography (NUCAPT). He has twice been awarded a John Simon Guggenheim Memorial Foundation Fellowship, awarded a Alexander Von Humboldt Stiftung Prize, awarded a Max Planck Research Prize of the Max-Planck-Gesellschaft, is a fellow of both the TMS (Minerals-Metals-Materials) and the American Physical Society, and a holder of a Robert Lansing Hardy Gold Medal of the TMS (Minerals-Metals-Materials).

Electron Tomography in the Physical Sciences

Matthew Weyland
Cornell University

Abstract

One of the principal challenges in modern materials science is the understanding and manipulation of increasingly complex structures on nanometre length scales. This inherent complexity leads to another challenge; that of accurate visualization on the nanoscale. Traditionally, transmission electron microscopy (TEM) and scanning TEM (STEM) have been two of the most powerful instruments for this visualization. However both these techniques are fundamentally projectional in nature, they average through the beam direction, and if the structure under study shows some variation along the beam direction it will remain largely unresolved. This is essentially the same problem that biological TEM faced in the 1960s, that of complex overlapping structures at the nanoscale. One solution found to this problem is electron tomography, which has developed in the biosciences into a mature, widely applied technique. In recent years several different research groups have demonstrated the use of electron tomography to tackle problems in materials science; for example by application to block co-polymers, nanostructured catalysts and semiconductor devices. In addition different imaging modes, which have not previously been used in biological tomography, have been pioneered for tomography of materials specimens. These techniques, which include high angle annular dark filed (HAADF) STEM and energy filtered TEM (EFTEM), can offer superior contrast and more information than traditional bright field (BF) tomography.

The speaker will review the fundamental principles of electron tomography followed by an exploration of how the technique has been modified and applied in materials science. The speaker will conclude with an examination of the state of the art, and a discussion of the ultimate limitations to tomographic resolution.

Biographical Sketch

A native of England, Matthew graduated from Brunel University, London in 1998 with a B.Sc in materials science and technology. For his postgraduate studies he moved to Girton College, University of Cambridge and studied for his Ph. D under Dr. P. A. Midgley in the Department of Materials Science and Metallurgy. He defended his Ph. D thesis, titled “Two and Three Dimensional Nanoscale Analysis: New Techniques and Applications” in 2001. This thesis pioneered the application of three dimensional electron microscopy, in particular STEM and EFTEM tomography, to nanoscale materials systems. In 2002 Matthew was awarded a prestigious two year "Royal Commission for the Exhibition of 1851" fellowship to continue his research in Cambridge. In 2004, he joined the Muller group at the School of Applied and Engineering Physics, Cornell University as Postdoctoral researcher. His current research interests include the investigation of the resolution limits to electron tomography, characterization of functional nano-materials and the investigation of new imaging modes in the electron microscope.

Contrast Mechanism and Three Dimensional Imaging by Focused Beam Analysis of Microelectronic Devices

James Evertsen
University of Albany

Abstract

Accurate knowledge of the three-dimensional internal microstructure of a material system is highly desirable and can be achieved through the use of Scanning Electron Microscope (SEM) images of planes created by repeated Focused Ion Beam (FIB) milling through a structure of interest using a CrossBeam FIB. These images can then be combined to render a three-dimensional object similar to the tomographic imaging used in medical CAT scans. This talk will focus on the method used to collect images and optimum parameters for data collection. Also we will discuss using other signals that can be used to generate three-dimensional images in the CrossBeam FIB including Position Tagged Spectrum EDS maps and Electron Backscattered Diffraction maps.

Biographical Sketch

James Evertsen is currently a Ph. D. student at the College of Nanoscale Science and Engineering SUNY at Albany and he received his B.S. in Physics from SUNY at Albany in 2003. Prior to that he was an Electronics Technician in the U.S. Navy (1992 – 2000). He has received funding from grants through General Electric Research Corporation and the SRC/MARCO Interconnect Focus Center. His current research activities involve scanning electron microscopy and focused ion beams with a focus on ion solid interactions. James is a coauthor on a paper titled “Three Dimensional Imaging of Microelectronic Devices Using a CrossBeam FIB” which was just awarded Outstanding Paper at International Symposium for testing and Failure Analysis (ISTFA) 2004.

3D Imaging Used as a Tool for the Qualification of Microstructures and Surfaces of Low Temperature Superconductors

Peter Lee
University of Wisconsin

Abstract

This presentation will concentrate on simple low-cost imaging techniques that can be applied to a wide variety of applications in materials science. Techniques will be illustrated by 3D anaglyphs, projections and animations. The examples that will be shown were created in order to reveal topology and aid the quantitative analysis of superconductors developed to create high magnetic fields in high energy physics and fusion applications as well as superconducting RF cavities. In particular this talk will look at fractography and surface topology and the use of tilt pairs and the creation of image stacks and their interpolation. Internet links and demonstrations will be provided for freeware software that can be used by the audience after the meeting as an introduction to these techniques.

Biographical Sketch

Peter J. Lee is a Senior Scientist at the University of Wisconsin-Madison Applied Superconductivity Center, where the primary focus of his research has been the quantitative microchemical and microstructural analysis of superconductors. His approach has been to combine micro-chemical analyses by TEM/STEM, FESEM, Scanning Auger and electron microprobes with quantitative image analysis techniques and correlating the data with physical property measurements performed at the Center. He has published over and 70 refereed papers on Low Temperature Superconductors and has published 5 reviews on the field and recently edited the book “Engineering Superconductivity”. He was elected to the Board of the Applied Superconductivity Conference in 2002 and to the Board of the International Cryogenic Materials Commission in 2004.

Structural Materials for High Temperature

Session II

Chairs: Dan Lewis & Tim Hanlon, GE Global Research

Authors and Titles

Gerald Meier (University of Pittsburgh)
Oxidation Problems in Solid Oxide Fuel Cells

Sharvan Kumar (Brown University)
Deformation Behavior of a Two-phase Mo-Si-B Alloy

Young-Won Kim (UES, Inc.)
Linking Gamma TiAl Alloys and Conventional Titanium Alloys: Recent Development

Dallis Hardwick (Air Force Research Laboratory)
Continuing Challenges for Materials in Propulsion

Oxidation Problems in Solid Oxide Fuel Cells

Gerald Meier
University of Pittsburgh

Abstract

The principles of operation of fuel cells have been understood for over a century and they have been used to generate electricity for selected applications. However, fuel cells have never achieved wide scale commercialization because of numerous economic and technical issues. There is currently renewed interest in fuel cells as devices which can provide electric power with high efficiency and reduced pollution.

This presentation will include a description of the operating principles of fuel cells and the general classes of cells. The talk will then be focused on a particularly versatile type of cell, the Solid Oxide Fuel Cell (SOFC), and the materials of construction. Finally, results from the speaker's laboratory on the properties of metallic interconnects for SOFCs will be described. Particular emphasis will be placed on the oxidation behavior of the interconnects, which must simultaneously withstand degradation from air on one side (cathode) and the fuel gas on the other (anode). At the same time, the interconnects must not form oxide surface films with high electrical resistivity (thus eliminating alumina- or silica-forming alloys). A variety of chromia-forming ferritic alloys have been oxidized under conditions typical of the anode and cathode sides of SOFCs i.e. in air, air+H_2O, and H_2/H_2O at temperatures between 700 and 900˚C. The oxidation kinetics, oxidation morphologies, and electrical conductivities of the oxide scales will be described. Factors relating to metallurgical stability of the alloys and evaporation of chromium oxide scales will also be discussed.

Biographical Sketch

Professor Meier received a B.S. in Metallurgical Engineering from Carnegie Institute of Technology in l964 and a Ph. D. in Metallurgical Engineering from The Ohio State University in l968. He spent one year as a Postdoctoral Research Fellow at Universitat Münster in Germany. He has been on the faculty at the University of Pittsburgh since 1969. His research has focused on the high temperature oxidation and corrosion of alloys and the use of coatings for protection. He has authored or co-authored one book and over100 articles on these subjects. He has worked as a research collaborator or consultant with many of the companies in the gas turbine and aerospace industries. The following are selected recent publications:

1. M. J. Stiger, N. M. Yanar, M. G. Topping, F. S. Pettit, and G. H. Meier, "Thermal Barrier Coatings for the 21st Century", Z. für Metallkunde, 90, 1069 (1999).
2. E. Schumann, C. Sarioglu, J. R. Blachere, F. S. Pettit, and G. H. Meier, "High-Temperature Stress Measurements During the Oxidation of NiAl", Oxid. Metals, 53, 259 (2000).
3. C. Sarioglu, E. Schumann, J. R. Blachere, F. S. Pettit, and G. H. Meier, "X-ray Determination of Stresses in Alumina Scales on High Temperature Alloys", Materials at High Temperatures, 17, 109 (2000).

4. C. Sarioglu, M. J. Stiger, J. R. Blachere, R. Janakiraman, E. Schumann, A. Ashary, F. S. Pettit, and G. H. Meier, "The Adhesion of Alumina Films to Metallic Alloys and Coatings", Materials and Corrosion, 51, 1 (2000).
5. A. G. Evans, D. R. Mumm, J. W. Hutchinson, G. H. Meier, and F. S. Pettit, "Mechanisms Controlling the Durability of Thermal Barrier Coatings", Progr. Materials Sci., 46, 505 (2001).
6. R. A. Handoko, J. L. Beuth, G. H. Meier, F. S. Pettit, and M. J. Stiger, "Mechanisms of Interfacial Toughness Loss in Thermal Barrier Coating Systems", Key Engineering Materials, 197, 165 (2001).
7. G. M. Kim, N. M. Yanar, E. N. Hewitt, F. S. Pettit, and G. H. Meier, "The Effect of the Type of Thermal Exposure on the Durability of Thermal Barrier Coatings" Scripta Mater., 46, 489 (2002).
8. J. R. Blachere, E. Schumann, G. H. Meier, and F. S. Pettit, "Textures of Alumina Scales on FeCrAl Alloys" Scripta Mater., 49, 909 (2003).
9. M. C. Maris-Sida, G. H. Meier, and F. S. Pettit, "Some Water Vapor Effects during the Oxidation of Alloys that are α-Al_2O_3 Formers", Metallurgical and Materials Trans. A, 34A, 2609 (2003).
10. K. Onal, M. C. Maris-Sida, G. H. Meier, and F. S. Pettit, "Water Vapor Effects on the Cyclic Oxidation Resistance of Alumina-Forming Alloys", Materials at High Temperatures, 20, 327 (2003).

Deformation Behavior of a Two-Phase Mo-Si-B Alloy

Sharvan Kumar
Brown University

Abstract

Mo-Si-B alloys are being considered as possible candidates for high-temperature applications beyond the realm of Ni-based superalloys. In this presentation, the high-temperature compression response as well as the monotonic and cyclic crack growth behavior (as a function of temperature) of a two-phase Mo-Si-B alloy will be discussed and compared to an off-the-shelf TZM alloy. A limited amount of compression results from a three-phase Mo-Si-B alloy will also be included. Deformed microstructures were characterized using optical, scanning and transmission electron microscopy techniques as appropriate. The microstructural observations will be used to rationalize mechanical properties that were measured; results from finite element analysis of representative microstructures will also be used to rationalize microstructural damage. The role of creep in influencing high-temperature fatigue response will be explored.

Biographical Sketch

Sharvan Kumar is a Professor in the Division of Engineering at Brown University in Providence, RI. He joined Brown in January 1995. His current research interests are in understanding Defects, Deformation and Fracture of Structural Materials, particularly multiphase metallic materials and intermetallic compounds. Prior to joining Brown, Prof. Kumar worked at Martin Marietta Laboratories in Baltimore, MD as a senior scientist for almost 10 years with research focus on intermetallics and their composites, and Al alloys for aerospace applications. He was a co-inventor of a family of Al-Cu-Li alloys that are currently used in constructing the external fuel tank of the Space Shuttle. Prof. Kumar obtained his PhD in Materials Engineering from Drexel University in 1984 with a thesis on the physical metallurgy of powder-processed high speed tool steels. He has over 125 research publications in refereed journals, gives numerous invited talks at national and international forums, was recognized by the Maryland Science Center in 1994 as Maryland's Distinguished Young Scientist, is a Fellow of ASM International, and twice the recipient of the Best Technical Paper Award at the International Symposium on Structural Intermetallics.

Linking Gamma TiAl Alloys and Conventional Titanium Alloys: Recent Development

Young-Won Kim
UES, Inc.

Abstract

Conventional Ti alloys are used below 1000°F, due to their limitations in oxidation resistance, burn resistance and also creep resistance. There are various turbine engine components that are exposed or experience higher temperatures, which, for example, include back-stage compressor blades, stators and disks, engine cases in hot sections, nozzle flaps and TPS. Presently, these components are exclusively made of wrought superalloys, such as Inconel 625 and IN 718, which are heavier than Ti alloys by 85% or more. For the last two decades, tremendous resources and efforts have been spent on the development of lightweight gamma alloys (based on γ-TiAl and α2-Ti3Al) as the replacements of the heavy superalloys. In spite of remarkable improvements achieved in oxidation and creep resistance over the years, gamma alloys have not been implemented in aerospace vehicles yet primarily due to their brittleness, unconventional processing requirements, and unfriendly machinability. While gamma TiAl alloys will eventually find their use for high temperature (1300°-1600°F) applications, there has been growing, immediate need of light-weight metallic materials that are ductile, tough, oxidation- and creep-resistant up to 1400°F, and processible and machinable by conventional means. This talk will briefly review the advances made in the development of gamma TiAl alloys, and discuss our recent effort in the development of new Ti-based alloy systems that may link conventional titanium alloys and gamma TiAl alloys. The implications with the potential advent of such exciting new structural alloys will be discussed.

Biographical Sketch

Education and Experience: PhD in Metallurgy and Materials Science, University of Connecticut (1976)**;** 1991-Now: Sr. Scientist, UES, Inc., Ohio: R&D of TiAl-based alloys in processing/ microstructure/property relationships, alloy design, process development, and scaling-up (both ingot and powder metallurgy)**;** 1981-90: Group Leader, Metcut Research Associates, Inc, Ohio: R&D of the physical metallurgy and processing-microstructure-property relationships of high strength & temperature aluminum alloys and light-weight Intermetallics; 1986-96:Adjunct Professor, University of Dayton, Ohio; 1976-1980: Scientist, Air Force Materials Laboratory, Ohio: Physical metallurgy and microstructure/property relationships in aluminum alloys; Research Associate, Univ. of Connecticut and Carnegie Mellon Univ. : Work on amorphous alloys; and surface hardening of steels.

Publications and Patents: Over 140 technical papers; Six U.S. Patents

Technical Activities and Recognition: (1) Organized various international symposia and workshops and edited/co-edited six proceedings books; (2) Conducted over 40 invited lectures and seminars; (3) Member of technical societies and committees including TMS/ASM; (4) Selected as an outstanding alumnus of the year, Univ. of Connecticut, 2003; (5) Served as a Council Member, TMS Structural Materials Division, 2001-04; (6) Fellow of ASM International, 1998; (7) Refereed a national TiAl program, Germany (1999 & 2003) and a European Community TiAl consortium program (1998).

Continuing Challenges for Materials in Propulsion

Dallis Hardwick
Air Force Research Laboratory

Abstract

The challenge for materials development for propulsion has always been developing lighter weight materials that can be used at higher temperatures. More recently, the community has been attempting to address the issues related to durability and lifing. An additional challenge is that of low production volume which can result from low demand/high cost or from a desire for purpose-built systems. The materials development and materials community is being asked to tackle all of these problems and this talk will outline the issues and provide some examples from both gas turbine and liquid rocket propulsion.

Biographical Sketch

Dr. Hardwick received her BSc and PhD from the University of New South Wales in Sydney, Australia. This was followed by post-doctoral work at Mc Gill University and Carnegie Mellon University. She has had a varied career including time at Martin Marietta Research Labs, Los Alamos National Labs, Rockwell Science Center and Boeing Commercial Aircraft. She is currently at the Air Force Research Lab where she is manager of the contract programs related to materials for air-breathing propulsion.

Keynote Talk

Monday Evening, May 24th, 2004
Glen Sanders Mansion

Cocktails 6:00 p.m. | Dinner 7:00 p.m. | Keynote Talk 8:00 p.m.

The Commercial Outlook for Nanomaterials

Matthew Nordan
Vice President of Research
Lux Research, Inc.

Nanomaterials such as carbon nanotubes, quantum dots, and metal nanoparticles enable valuable applications from materials to electronics to healthcare. But the commercial outlook for most categories of nanomaterials looks brutal as entangled patents, commodity economics, and foreign competition conspire to reduce suppliers' pricing power. Larger economic rents are likely to be sustained by companies that tap nanomaterials to build novel intermediate and final products. This presentation will predict the commercial outlook for nanomaterials based on proprietary data and frameworks from nanotech analysts Lux Research Inc.

Biography

Matthew Nordan heads Lux's research organization. He leads a team of analysts who advise corporations, startups, financial institutions, and governments on the impact of nanotechnology and related emerging technologies. Matthew joins Lux with seven years of experience in analyzing emerging technology at Forrester Research, where he held a variety of senior management positions. Most recently, Matthew headed Forrester's North American project consulting line of business. Earlier, Matthew spent four years based in the Netherlands growing Forrester's operations in Europe, where he launched and led research practices in retail, mobile commerce, and telecommunications. Matthew also built Forrester's European consulting line of business and partnered with trade publishers in three countries to measure corporate technology spending on the continent.

Matthew has been invited by news outlets including CNN and CNBC to comment on emerging technology markets and has been widely cited in publications such as The Wall Street Journal and the Financial Times. He has delivered advice to clients and presented at conferences in North America, Europe, Southeast Asia, Japan, Australia, and South Africa. Beyond the corporate sphere, Matthew has participated in developing public-sector technology strategy for organizations including the World Economic Forum, the European IT Observatory, and the Dutch transportation ministry. Matthew is a summa cum laude graduate of Yale University, where he conducted cognitive neuroscience research on the neural pathways mediating emotion and memory.

Materials for Space Applications

Session III

Chairs: Tom Angeliu & Tymm Schumaker, KAPL

Authors and Titles

Steve Zinkle (Oak Ridge National Laboratory)
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Sarah Watson (Lockheed Martin – KAPL, Inc.)
Analysis of the Creep Performance of Selected Refractory Metals of Interest to Space Nuclear Power Systems

Jerry Gould (Edison Welding Institute)
Solid State and Resistance Joining Technologies for Fusion Energy Systems

Materials for Space Reactor Applications

Steve Zinkle
Oak Ridge National Laboratory

Abstract

NASA is currently investigating the feasibility of a variety of challenging scientific mission that would require unprecedented levels of spacecraft power and propulsion to achieve the mission objectives. These new missions would require power levels well in excess of 1kWe, which is the approximate maximum sustained power level currently achievable from chemical, solar, or radioisotope source for spacecraft missions. The current status of the materials technologies required for the successful development of near-term space nuclear power and propulsion systems will be reviewed, with particular emphasis on potential cladding and structural materials (stainless steel, superalloys, refractory alloys). A brief overview of issues for potential neutron reflector and radiation shield materials may also be presented. Mechanisms that limit the performance (chemical compatibility, fuel burnup, mechanical stress, radiation levels) for the various structural materials proposed for space nuclear reactors will be summarized. In particular the important roles of thermal creep and radiation hardening and embrittlement in establishing the operating temperature limits of prospective structural materials will be outlined.

Biographical Sketch

Following graduation in 1985 from the University of Wisconsin (Ph. D. Nuclear Engineering, MS Materials Science), Steve joined Oak Ridge National Laboratory as a Eugene P. Wigner fellow, and is presently a Corporate Fellow and leader of the Nuclear Materials Science & Technology Group within the Metals and Ceramics Division. His research is focused on the physical metallurgy of structural materials and the investigation of radiation effects in ceramics and metallic alloys for fusion and fission (terrestrial and space reactor) systems. He is the author or coauthor of more than 200 peer-reviewed publications, and is an associate editor of the Journal of ASTM International. He is a fellow of the American Ceramic Society and ASM International, and is also active in TMS (The Minerals, Metals and Materials Society), the American Nuclear Society and the Materials Research Society.

Mechanical Property Considerations for Materials in Space Reactor Applications

Tim McGreevy
Oak Ridge National Laboratory

Abstract

Mechanical property consideration for materials in space reactor applications will vary significantly for static versus dynamic reactor systems. Static systems will require consideration of short term poperties usch as yield & ultimate strength, uniform elongation, and irradiation embrittlement; long term considerations will include thermal stability and thermal creep resistance. Dynamic reactor designs may need to consider additional properties such as fatigue, creep-fatigue, and crack growth. Static system mechanical property considerations will be discussed, primarily tensile properties & thermal creep resistance. Several classes of alloys for space reactor applications will be discussed including stainless steels, Ni-based superalloys, ferritic and martensitic stainless steels and refractory alloys. The extent of databases, current infrastructure for production and fabrication, scatter, and extrapolation of data will be discussed.

Biographical Sketch

Tim McGeevy currently works for the Metals & Ceramics Division of Oak Ridge National Laboratory (ORNL). He received his B.S. & M.S. from Bradley University in Peoria, IL and his Ph. D. at the University of Illinois in Urbana-Champaign, all in mechanical engineering. His background is primarily in materials behavior – fatigue, creep, and fracture. Tim conducted research for Caterpillar Inc. of Peoria, IL for 7 years in the area of fatigue, fracture, and high temperature materials. Through a partnership with ORNL, an inexpensive cast stainless steel (CF8C-Plus) was developed for gas turbine and diesel engine applications that raises the upper use temperature of CF-8C from 600-650 C to 850 C. Caterpillar and ORNL received an R&D100 award for development of CF-8C-Plus in 2003. He is a member of ASM and ASME, and serves as Secretary for ASME Section III, subsection NH “Elevated Temperature and Design Subgroup”. Currently, Tim works on programs related to high temperature materials use and design methodology, including Generation IV and Next Generation Nuclear Plant, space reactor materials, and isotope heat sources at ORNL in Oak Ridge, TN.

Application of Computational Materials Design to Assess and Develop Structural Materials for Space Nuclear Applications

Herng-Jeng Jou
QuesTek

Abstract

Abstract not available at time of printing

Biographical Sketch

Dr. Jou obtained a Ph. D. in solid mechanics from University of Minnesota in 1995. In 1998, he joined QuesTek Innovations and was instrumental in the development and implementation of the Company's Materials by Design* technology. Dr. Jou was named QuesTek's Director of Technology in 2002, and is responsible for managing the Company's research and computational materials design teams. Dr. Jou's work has focused on mechanistic materials modeling of hierarchical microstructure and the development of QuesTek's proprietary Computational Materials Dynamics* (CMD) software platform. Utilizing CALPHAD multicomponent Thermo-Calc/DICTRA tools, he has developed sophisticated mechanistic process-structure and structure-property models, such as diffusional and diffusionless phase transformation, strengthening, and general-purpose precipitation models and software. QuesTek's CMD platform has been successfully used for computer-aided systems design and optimization of QuesTek's high performance alloys, and has provided the foundation of accelerated materials insertion and qualification for both government and commercial market applications.

Analysis of the Creep Performance of Selected Refractory Metals of Interest to Space Nuclear Power Systems

Sarah Watson
Lockheed Martin
Knolls Atomic Power Laboratory

Abstract

This investigation re-analyzed previously published creep data for selected refractory metals (Nb-1Zr and Ta-8W-1Re-1Hf-0.025C, i.e. ASTAR 811C) exposed to molten lithium. Reanalysis of these data sheds insight into factors that can confound comparison of creep data and into the rate controlling processes that control creep deformation. Specifically, analysis of the Nb-1Zr and ASTAR 811C shows that the Larson-Miller parameter, commonly used to compare refractory metal creep data, does not apply to these data and can lead to large errors in the predicted creep performance. The assumption of a Larson-Miller "constant", often taken as C=15 for refractory metals, is unsupported by the present analyses. Instead, the diffusion based Dorn parameter well describes the Nb-1Zr data while the Manson-Haferd parameter describes the ASTAR 811C data. The applicability of the Dorn analysis to the Nb-1Zr data indicates that stress independent diffusion controls the creep rate. The apparent activation energy for creep deformation in Nb-1Zr is approximately 100 kJ/mol, which suggests that interstitial element loss to the environment could be the rate controlling process. Analysis of the ASTAR 811C data shows a much larger apparent temperature dependence {~298 kJ/mol for 40 ksi (276 MPa) applied stress} with a clear applied stress-activation energy interaction. Comparison of the Nb-1Zr and ASTAR 811C creep master curves show that for a nominal goal of 1% creep in 100,000 hrs under 100 MPa, Nb-1Zr is likely limited to temperatures below 950 K and the ASTAR 811C is likely limited to temperatures below 1350 K.

Biographical Sketch

Sarah graduated from The University of Tulsa in 2003 (BS Mechanical Engineering). She then joined Knolls Atomic Power Laboratory (KAPL) as part of the Engineering Leadership Development Program. Sarah has worked in the areas of advanced nuclear reactor design, waste disposal, and reactor materials. She is currently pursuing a Masters degree in Structural Engineering at The Graduate College of Union University.

Solid State and Resistance Joining Technologies for Fusion Energy Systems

Jerry Gould
Edison Welding Institute

Abstract

Advanced nanostructured ferritic alloys (NFA's) are currently under development. These materials provide excellent resistance to high temperature thermal aging, neutron irradiation damage and high-temperature creep. These materials are of prime consideration for fusion reactor structural applications. NFA's are dispersion strengthened with a high density of stable nano-size atomic clusters (NC). Application of these materials requires advanced joining technologies that retain properties that are similar to those of base materials. Conventional joining technologies disrupt these nanoclusters by either coarsening or dissolution, reducing thermal stability of the assembled component. This study has investigated the application of some non-conventional joining technologies to a representative of this material class. The joining technologies selected included friction stir welding (FSW) and electro-spark deposition (ESD) processes. The material under consideration was MA957, a dispersion strengthened alloy with a high number density of Y-Ti-O NC.Results from this study show that the MA957 alloy could successfully be joined using both ESD and FSW processes. The microstructural implications of the FSW and ESD processes were assessed using optical transmission electron microscopy, as well as small angle neutron scattering (SANS). The FSW microstructure was a uniform fine grain structure, characteristic of the process. Resulting joints also showed excellent joint efficiency in transverse tensile testing with a uniform hardness across the weld region and base metal. The ESD microstructure was a uniform matrix of extremely small-scale weld deposits and intermittent porosity and voids. ESD welds also showed relatively good joint efficiency in transverse tensile testing. The SANS results suggested some damage to the nanoclusters in the FSW welds, with more extensive degradation in ESD welds. This project was sponsored by the Department of Energy under contract DE-FG02-04ER86181.

Biographical Sketch

Dr. Gould obtained a Ph. D. in Metallurgical Engineering & Materials Science from Carnegie-Mellon University. Since 1985, Jerry has been on the senior technical staff at EWI concentrating on forge welding activities. Prior to this, he was senior research engineer at the Inland Steel Company Research Laboratory. His major area of expertise is resistance spot welding of sheet steels. Activities in this area have included thermal modeling, weld solidification, electrode deterioration, weldability of various materials and process kinetics. Jerry has published over 90 technical papers and articles on various aspects of resistance welding and welding metallurgy. He has authored or co-authored ten EWI Cooperative Research Reports and was the recipient of the AWS James A. Lincoln gold metal award in 1995.

Materials by Design

Session IV

Chairs: Liang Jiang, GE Global Research & Linda Schadler, RPI

Authors and Titles

Pulickel Ajayan (Rensselaer Polytechnic Institute)
Tailoring Carbon Nanotube Architectures for Applications

Greg Sawyer (University of Florida)
Tribology of Polymeric Nanocomposites

Mohan Manoharan (GE Global Research)
Nanoceramics for Harsh Environments

Mark Opeka (Naval Surface Warfare Center)
Materials Selection and New Directions for Ultra-High-Temperature Hypersonic Materials

Lance Snead (Oak Ridge National Laboratory)
Ceramic Composites for Next Step Nuclear Power Systems

Tailoring Carbon Nanotube

Pulickel Ajayan
Rensselaer Polytechnic Institute

Abstract

The talk will focus on the recent developments in our laboratory on the fabrication of carbon nanotube based architectures tailored for various applications. Various organized architectures of multiwalled and singlewalled carbon nanotubes can be fabricated using relatively simple vapor deposition processes and the work in attaining control on the directed assembly of nanotubes will be highlighted. We have pursued several electrodes novel applications for these structures, for example, as nanostructured electrodes for gas breakdown sensors, horizontal and vertical electrical interconnects, unique filters for separation technologies, thermal management systems, multifunctional brushes, and polymer infiltrated thin film composites. Some of these promising applications of carbon nanotubes and composites will be reviewed from the perspective of what has been accomplished in recent years. Our efforts on the strategies of growth and manipulation of nanotube-based structures and our recent success in controllably fabricating hierarchically branched nanotube structures will be discussed.

Biographical Sketch

Professor Ajayan earned his B. Tech in metallurgical engineering from Banaras Hindu University in 1985 and Ph. D. in materials science and engineering from Northwestern University in 1989. After three years of post-doctoral experience at NEC Corporation in Japan, he spent two years as a research scientist at the Laboratoire de Physique des Solides, Orsay in France and nearly a year and a half as an Alexander von Humboldt fellow at the Max-Planck-Institut fur Metallforschung, Stuttgart in Germany. In 1997, he joined the materials science and engineering faculty at Rensselaer as an Assistant Professor. Presently he is full Professor and holds the Henry Burlage Endowed Chair in Engineering at RPI. Professor Ajayan's research interests include synthesis and structure-property relations of nanostructures and nanocomposites, applications of nanomaterials, phase stability in nanoscale systems and electron microscopy. He is one of the pioneers in the field of carbon nanotubes and was involved in the early work on the topic along with the NEC group. He has published one book and 175 journal papers with more than 6500 citations. He has given 160 invited talks including keynote and plenary lectures in more than 20 countries in North America, Europe and Asia. He is on the advisory editorial board of several journals including Advanced Materials, Small, and the Journal of Nanoscience and Nanotechnology. He is also a consultant for several companies in the US and Europe.

Tribology of Polymeric Nanocomposites

Greg Sawyer
University of Florida

Abstract

Over the past 5 years our research group has been engineering wear resistant solid lubricant nanocomposites. The composites are comprised of Polytetrafluoroethylene and a wide variety of nanoparticles. The overarching goal of this research is to engineer materials that can operate for extended periods of time in extreme environments. In particular, applications in the high and low temperature vacuum environment of space will be discussed. These composites have shown extraordinary performance in the laboratory, providing the lowest dry sliding wear rate for polymeric materials ever. The blending and processing techniques for these nanocomposites will be detailed as well as tribological measurements and measurement techniques.

Biographical Sketch

Dr. Sawyer is an Assistant Professor in the Department of Mechanical and Aerospace Engineering at the University of Florida. He received his Ph. D. in 1999 from Rensselaer Polytechnic Institute specializing in Tribology. He is an author on 30 journal publications and 4 patents. Dr. Sawyer is an Associate Editor for the journal "Tribology Transactions". He was the inaugural recipient of the ASME Marshall B. Peterson Award, and was also a recipient of the ASME Burt L. Newkirk Award.

Nanoceramics for Harsh Environments

Mohan Manoharan
GE Global Research

Abstract

As part of the Nanotechnology program we are developing a new generation of ceramics with structures engineered at multiple length scales from nano to macro. These nanoceramics have several potential applications in energy, transportation and healthcare. This talk will outline some opportunities where nanoceramics exhibit superior performance in harsh environments. Two specific applications that will be addressed are bio-inspired ceramics for the hot gas path of turbines and harsh environment sensors.

Biographical Sketch

Education
PhD, 1988, Metallurgical Engineering, Ohio State University, Columbus, OH
MS, 1987, Metallurgical Engineering, Ohio State University, Columbus, OH
BS, 1985, Metallurgical Engineering, Indian Institute of Technology, Madras, India

Experience
Dr. Manoharan works at GE Global Research in the Nanotechnology program leading a group developing a new generation of nanoceramics for a variety of structural and functional applications. Dr. Manoharan has worked in both industry and academia. He spent four years at Unilever Research where his research focused on structure property relationships and processing techniques for soft solid composites. He spent five years as a faculty member at the Nanyang Technological University in Singapore where he was an Associate Professor until 1999. He was also a faculty member of the Singapore-MIT alliance, which is widely regarded as a new model for global education and is a collaborative research and teaching alliance between MIT, Nanyang Tech University and the National University of Singapore. He has 50 publications in refereed journals, 10 granted and 20 filed patents and over 50 conference presentations.

Materials Selection and New Directions for Ultra-High Temperature Hypersonic Materials

Mark Opeka
Naval Surface Warfare Center

Abstract

The status of the research and development of ultra-high temperature (UHT), non-oxide ceramic and metallic materials is summarized. Thermodynamics-based calculations show the temperature limits in oxidizing environments for state-of-the-art, high temperature SiO_2-forming materials such as SiC, Si_3N_4, and $MoSi_2$. In addition, such calculations reveal that the applications of many materials are limited by the formation of high vapor pressures at the interface between the base material and the oxide scale which forms in oxidizing environments. Materials based on ZrB_2 and HfB_2 are good candidates for UHT environments due to their ability to attenuate such high vapor pressure-induced limitations. Metals, such as iridium, exhibit a qualitatively different vaporization behavior which is contrasted with the boride ceramics. Arc heater test results show the oxidation and ablation of the boride materials in UHT environments, and also show the superior performance of these boride ceramics compared to the UHT carbides and nitrides of Zr and Hf. New boride compositions and development directions for improved oxidation resistance are also discussed.

Biographical Sketch

Dr. Mark M. Opeka is a Research Materials Engineer for the Naval Surface Warfare Center, Carderock Division in West Bethesda, MD. He earned his BS and MS in Mechanical Engineering, and his PhD in Materials Science, all from the Univ. of Maryland. His PhD included significant studies in metallurgical thermodynamics and oxidation kinetics. He has worked for the Navy for 28 years on the development of high temperature materials for weapons systems, including work with refractory metals, cermets, and carbon-carbon, carbon-phenolic, and ceramic composites. He currently manages development and characterization programs associated with rhenium and C-SiC composites for the Navy and MDA, and provides consultation for Air Force rocket nozzle material developments of tungsten and TaC. He is also conference chairman for the annual restricted Cocoa Beach Conference on Composites, Materials, and Structures.

Ceramic Composites for Next Step Nuclear Power Systems

Lance Snead
Oak Ridge National Laboratory

Abstract

It is a fact that C/C's have found only specialized use as structural materials, and SiC/SiC composites have never been used as a high-stress structural component. The limited application of these materials is due primarily to their relative immaturity, lack of design codes governing application, and a conservative approach to structural design. However, one key to improving thermal efficiency of power reactors is increasing operating temperatures above the softening point of both standard alloys and superalloys. At these temperatures (>900°C,) the only materials that can be considered are refractory alloys and ceramic composites.

A primary benefit to the use of composites is the inherent "engineerability" of the systems. For structural applications, the architecture for both SiC/SiC and C/C will be three dimensional to avoid the very low inter-laminar shear stresses inherent in 2-D architecture. However, the actual 3-D architecture can vary widely depending on the applications optimizing for strength, stiffness, or thermal conductivity in the most critical orientation. For example, control rod sleeves would likely use a spiral-weave as compared to a balanced or orthogonal weave in shroud or core-block application. It is important to note that due to the limited understanding of the mechanical performance, irradiation behavior, and design rules, each materials and architectural variant will be treated on a proof basis. In other words, each material will undergo a complete series of irradiation and performance tests to prove itself, rather than relying on limited testing in support of standard modeling.

Up to the maximum off-normal temperature assumed for the Next Generation Nuclear Plant (NGNP) (~1500°C) neither SiC or graphite fiber composites exhibit degradation in mechanical properties (excluding oxygen effects). Both materials have similar decreases in thermal conductivity with temperature, though graphite composites have significantly higher absolute thermal conductivity. The main differences between the systems are the relative maturity of manufacture of the C/C system, allowing more design flexibility and lower cost, and the relative insensitivity to irradiation of the SiC/SiC system. Because SiC composite manufacture is less mature than C/C, the determining factor in selecting the system is essentially economic, related to the up-front cost on deploying SiC/SiC balanced with the potential benefit of a longer-lived or lifetime component. This presentation will review the application of these composite systems to the next generation gas reactors including manufacturing, performance and irradiation effects.

Biographical Sketch

Dr. Snead is a distinguished staff member in the metals and ceramics division at Oak Ridge National Laboratory. He received his B.S., M.S., and Ph. D. from Rensselaer Polytechnic Institute in Nuclear Engineering. He is an author on over 100 journal publications and has given lectures all over the world. Dr. Snead recently won the American Nuclear Society Technical Achievement Award in 2004 and was the inaugural recipient Miya-Abdou Nuclear Technology Award in 2002. Among his other awards are the Fusion Power Associates David J. Rose Excellence in Fusion Engineering Award and the UT-Battelle (ORNL) Technical Achievement Award. Dr. Snead has been a guest editor for the Materials Research Society, The Journal of Nuclear Materials, Philosophical Magazine, and Fusion Technology.