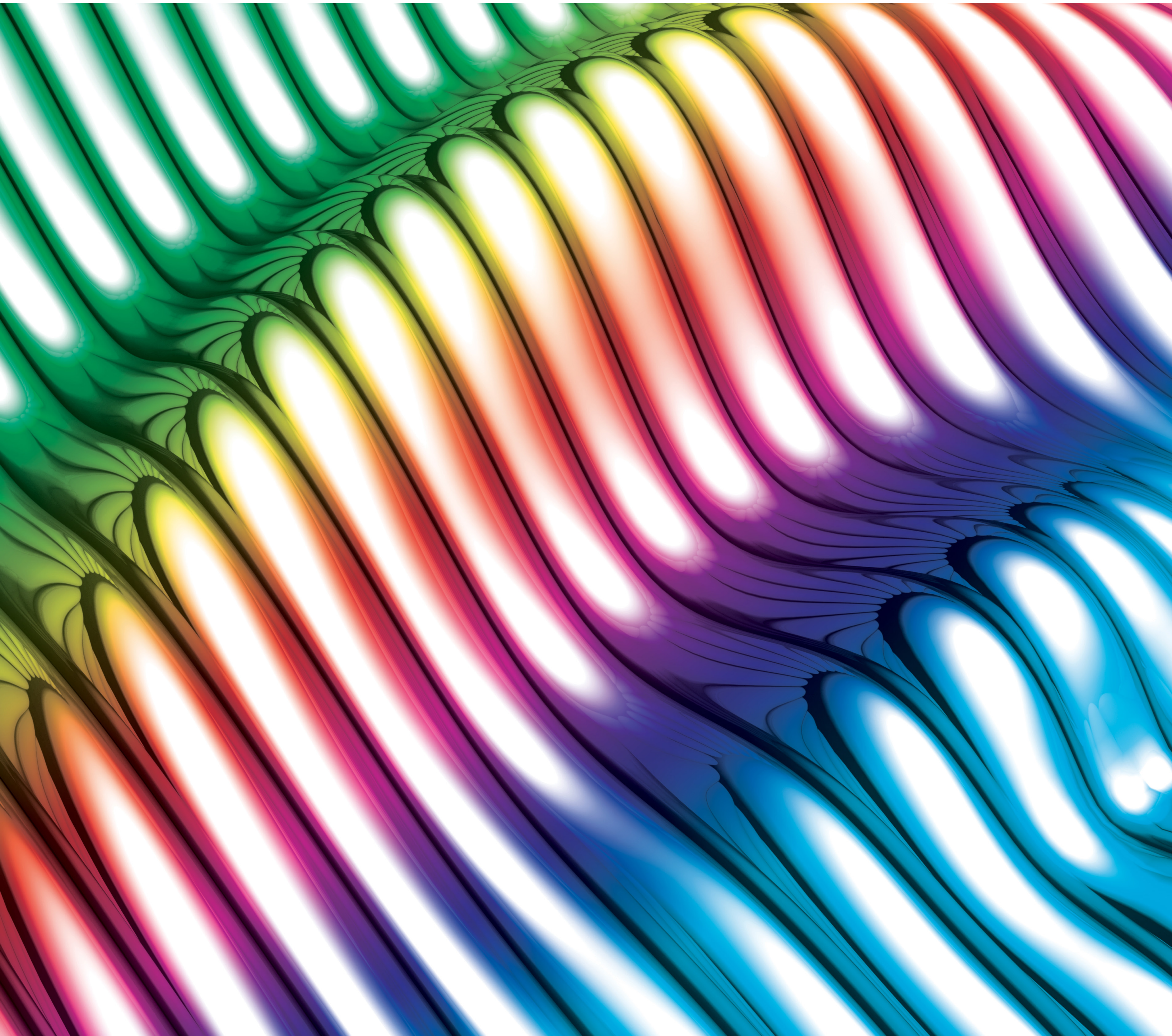
MPC
Making Matter, Matter®

Materials Day

New Frontiers in Metals Processing



Materials Resources:

Materials Processing Center provides an environment where students and professionals from industry, government and academia collaborate to identify and address pivotal multidisciplinary issues in materials processing and manufacturing at MIT.
http://mpc-www.mit.edu

Microphotonics Center @ MIT builds interdisciplinary teams, focused on collaborative research for the advancement of basic science and emerging technology pertaining to integrated photonic systems.
http://mphotonics.mit.edu

The Communications Technology Roadmap (CTR) is a project under the Microphotonics Industry Consortium, which in turn is part of the MIT Microphotonics Center. The purpose of this Roadmap is to understand the interaction between technology, industry, and policy dynamics and from there, formulate a vision for the future of the microphotonics industry.
http://mph-roadmap.mit.edu/

The Crystal Physics and Electroceramics Laboratory is devoted to the modeling, processing, characterization and optimization of energy related devices (sensors, batteries, fuel cells, solar/photolysis cells) and the integration of sensor, actuator and photonic materials into microelectromechanical (MEMS) systems.
http://electroceramics.scripts.mit.edu/

Center for Materials Science & Engineering is devoted to the design, creation, and fundamental understanding of materials that are capable of enhancing the human experience.
http://mit.edu/cmse

Department of Materials Science & Engineering is known as the world-wide leader in its field, pioneering advances in engineering sciences and technologies.
http://dmse.mit.edu

Dates for future Materials Day events:

Wednesday, October 14, 2015

Massachusetts Institute of Technology

MATERIALS PROCESSING CENTER

Materials Day at MIT

New Frontiers in Metals Processing

October 21, 2014

Metals continue to play critical roles in all aspects of technology, from micro- and nano-scale devices that enable our massively networked culture, to the buildings we live and work in. Despite this, research on metals processing has recently had a relatively low profile compared to research on other classes of materials, especially within universities. This is changing. In the past two decades we have seen an explosion in research on processing and properties of nanoscale materials and structures, tremendous advances in tools and methods for materials characterization at a range of length scales, and remarkable progress in computational design and modeling of the processing-structure-property relationships of materials. These new tools and methods are driving a renaissance in innovation, design and processing of metallic materials. This year's Materials Processing Center - Materials Day Symposium will focus on new activities and emerging opportunities for research on metals and metal processing. Speakers will include research leaders from General Motors, Lockheed-Martin, Schlumberger, and INFINIUM, as well as faculty from MIT.

Materials Processing Center
Massachusetts Institute of Technology
77 Massachusetts Avenue
Room 24-517
Cambridge, MA 02139
http://mpc-www.mit.edu
email: mpc@mit.edu

Materials Day Agenda

8:00 am **Registration** (Kresge Auditorium)

8:45 am **Welcome and Overview**
Professor Carl V. Thompson
Director, Materials Processing Center
Department of Materials Science & Engineering
MIT

Session I:

9:00 am **Integrated Computational Materials Engineering (ICME) of Generation Three Advanced High Strength Steels**
Louis G. Hector, Jr., Ph.D.
GM Technical Fellow
General Motors R & D Center

9:40 am **Nanocrystalline Metals Stabilized for Commercial Use**
Professor Christopher A. Schuh
Department Head
Danae and Vasilis Salapatas Professor of Metallurgy
Department of Materials Science & Engineering
MIT

10:20 am **Break**

Session II:

10:40 am **Advanced Materials and Manufacturing at Lockheed Martin**
Slade H. Gardner, Ph.D.
Lockheed Martin Fellow
Lockheed Martin Space Systems Company
Advanced Technology Center

11:20 am **Towards Sustainable Metal Production by Molten Oxide Electrolysis**
Professor Donald R. Sadoway
John F. Elliott Professor of Materials Chemistry
Department of Materials Science & Engineering
MIT

12:00 - 1:00 pm **Lunch**
Student Center, 3rd floor, Twenty Chimneys/Mezzanine Lounge
(Bldg. W20)

Session III:

1:10 pm **Metallurgy in the Oil & Gas Industry - A Wellbore Perspective**
J. David Rowatt, Ph.D., PE
Research Director
Schlumberger-Doll Research

Manuel Marya, Ph.D.
Materials Engineering Manager
Schlumberger Technologies Group

1:50 pm **Uncovering the Inner Workings of Metal Corrosion by Combining Surface Sensitive Experiments and Multi-scale Modeling**
Professor Bilge Yildiz
Associate Professor of Nuclear Science & Engineering
MIT

2:30 pm **Clean Metal Production for Clean Energy**
Adam C. Powell, Ph.D.
CTO, Co-Founder
INFINIUM, Inc.

3:10 pm **Wrap-up and Discussion**

Materials Research Review Poster Session

3:30 pm **Poster Session and Social**
La Sala De Puerto Rico
2nd Floor Stratton Student Center
(Bldg. W20)

5:30 pm **Poster Awards**

5:45 pm **Adjourn**

Professor Carl V. Thompson

Director
Materials Processing Center
Stavros Salapatas Professor of Materials Science and Engineering
Massachusetts Institute of Technology

Biography

Prof. Thompson received his S.B. in Materials Science and Engineering from MIT, and his S.M. and Ph.D. in Applied Physics from Harvard University, the latter in 1981. He was an IBM postdoctoral Fellow in the Research Laboratory of Electronics at MIT in 1982, and joined the faculty of MIT in 1983. Prof. Thompson spent the 1990-91 academic year in the Department of Metallurgy and Materials Science at Cambridge University and the 1997-98 academic year at the Max Planck Institut fur Metallforschung in Stuttgart Germany, and 2012 at the Karlsruhe Institute of Technology. He served as the President of the Materials Research Society in 1996, served on the MRS council from 1991 to 1997. He is currently the Director of MIT's Materials Processing Center, Co-Chair of the Program for Advanced Materials for Micro- and Nano-Materials of the Singapore-MIT Alliance and Co-Director of the Skoltech Center for Electrochemical Energy. Prof. Thompson has been a consultant with over thirty companies, including Intel, IBM, DEC, and a number of start-ups involved in development of microelectromechanical devices and systems. He has also collaborated in research with Intel, IBM, DEC, AMD, Motorola, TI, Chartered Semiconductor, and other companies.

Prof. Thompson's research interests include structure evolution during formation and processing of thin films and nanostructures, the mechanical and electrical properties of nanostructures, and the incorporation of thin films and nanostructures in electronic, electromechanical, and electrochemical devices and systems.

Louis G. Hector, Jr., Ph.D.

GM Technical Fellow
General Motors R & D Center

Integrated Computational Materials Engineering (ICME) of Generation Three Advanced High Strength Steels

Abstract

While traditional material development methods often involve laborious trial-and-error testing, Integrated Computational Materials Engineering (ICME), which falls under the umbrella of the Materials Genome Initiative, is offering a means for materials development under a more compressed time scale. Advanced high strength steels (AHSS), which contain multiple phases (e.g. ferrite, bainite, pearlite, austenite, martensite), and may exhibit phase transformation with strain, are fertile ground for ICME. However, prediction of macro-scale constitutive behavior based upon the multi-scale physical, chemical, and mechanical phenomena in these complex microstructures is a formidable challenge for ICME. Unprecedented collaboration between universities, industry, and government labs will be required to address AHSS development, curating of data, and the implementation of these materials into products that benefit the American consumer. This presentation will begin with a brief overview of a new, DOE/USAMP-funded ICME program aimed at the development of an ICME model of Generation Three (Gen 3) AHSS. The lack of commercial Gen 3 steels that meet DOE targets is offering significant challenges to this new ICME program. We will emphasize how the program is meeting these challenges following three thrusts: (1) making Gen 3 steels to DOE targets; (2) passing experimental measurements of key properties to an ICME model that produces microstructure-based constitutive models; (3) material evaluation in forming and vehicle performance simulations. Although the Gen 3 AHSS ICME program is "mission oriented," we will emphasize the important role of universities for providing the necessary foundation in fundamental materials science and engineering.

This presentation is based upon work supported by the Department of Energy under Cooperative Agreement Number DE-EE0005976 with United States Automotive Materials Partnership LLC (USAMP).

Biography

Lou Hector, Jr. is a GM Technical Fellow in the Chemical and Materials Systems Lab at the General Motors R&D Labs in Warren, Michigan. He conducts fundamental and applied research in computational and experimental materials science. Lou earned his B.S. (Honors) degree in Physics from Loyola University Chicago in 1981, and then completed his Ph.D. in Mechanical Engineering from Northwestern University in 1986. He joined GM R&D in January 2001 after nearly 14 years at Alcoa Technical Center where he researched problems in casting, rolling, forging, conversion coatings, tribology, and focused energy beam machining. His current research at GM R&D addresses automotive materials such as advanced high strength steels, non-ferrous alloys, Li-ion batteries, shape memory alloys, biomimetic materials, complex fabrics, catalytic materials, plastics, composites, and hydrogen storage materials. He also uses stereo digital image correlation to measure shape, deformation and fracture that spans strain rates ranging 10–5/s to 5×102/s. Lou is currently a PI on a DOE award for Integrated Computational Materials Engineering (ICME) of Gen 3 advanced high strength steels. Since graduating from Northwestern, Lou has co-authored over 195 publications, participated as Co-PI in 7 NSF GOALI grants, and holds 9 U.S. patents. His published research has received more than 3760 citations on GOOGLE Scholar. Lou received the 2014 Brimacombe Medal from The Minerals, Metals & Materials Society (TMS). He also received 3-John M. Campbell Innovation Awards for contributions to fundamental materials science and engineering, and the Charles L. McCuen Innovation Award for advancements in Mg forming.

Professor Christopher A. Schuh

Department Head
Danae and Vasilis Salapatas Professor of Metallurgy
Department of Materials Science & Engineering
Massachusetts Institute of Technology

Nanocrystalline Metals Stabilized for Commercial Use

Abstract

When the grain size of a metal is refined to a scale on the order of just a few nanometers, its strength, hardness, wear resistance, and other properties improve in dramatic ways. There is therefore significant interest in designing and deploying such nanocrystalline alloys for structural applications. However, refining the grain structure is a struggle against equilibrium, and nanocrystalline materials are often quite unstable; the grains grow given time even at room temperature, and the associated property benefits decline over time in service. In this talk, our efforts to design stable nanocrystalline alloys will be described. We rely on selective alloying as a method to lower the energy of grain boundaries, which can bring a nanocrystalline structure closer to equilibrium. This talk will highlight the path from theory, to proof-of-concept laboratory demonstration, to scale-up and commercialization of such alloys. Beginning from early successes with nanocrystalline alloy coatings, the talk will also outline future opportunities in sheet and bulk net-shape products. The prospects of stable nanocrystalline metals in a wide variety of applications will be described, including as substitute materials to reduce cost and cost volatility, as greener alternatives to legacy technologies, and as next-generation structural materials with large performance increments over incumbent metals.

Biography

Christopher A. Schuh is the Department Head and the Danae and Vasilis Salapatas Professor of Metallurgy in the Department of Materials Science and Engineering at MIT. He joined MIT in 2002, having received a B.S. degree at the University of Illinois at Urbana-Champaign, and a Ph.D. at Northwestern University, both in the field of Materials Science and Engineering. Prof. Schuh also held the Ernest O. Lawrence postdoctoral fellowship at Lawrence Livermore National Laboratory. Prof. Schuh's research is focused on structural metallurgy, and seeks to control disorder in metallic microstructures for the purpose of optimizing mechanical properties. Prof. Schuh has published more than 140 papers in scientific journals, and his research has received international attention through several awards, including the Robert Lansing Hardy Medal of the Metals, Minerals, and Materials Society. Prof. Schuh co-founded Xtalic Corporation, a technology spin-out company that has commercialized a new process for dynamically controlling the nanostructure in electrodeposited metals, with applications ranging from automotive and machine components to electronics. In 2011, Prof. Schuh was named a MacVicar Fellow of MIT, recognizing his contributions to engineering education.

Slade H. Gardner, Ph.D.

Lockheed Martin Fellow
Lockheed Martin Space Systems Company
Advanced Technology Center

Advanced Materials and Manufacturing at Lockheed Martin

Abstract

Advanced materials and manufacturing processes have been a hallmark feature in the legacy of Lockheed Martin products. There are many well established engineering heuristics for reducing the cost in manufacturing structures and there are operational philosophies that increase the capability or complexity of a manufactured article. A relatively new combination of heuristics and philosophies allows additive manufacturing methods that are, by name material additive in nature, rather than subtractive, and provide opportunities to extend beyond conventionally accepted part geometry and design. Additive deposition of material is automated for reduction in touch labor which directly reduces part cost and features precise repeatability. Dr. Gardner's team has developed and demonstrated unique additive manufacturing equipment and capabilities to include point wise composition control and scale-up of filled polymer deposition with articulated robotic equipment. Another material system of interest is titanium and where additive manufactured titanium propellant tank domes promise to replace equivalent domes made from forgings while eliminating half the cost and reducing the production lead time from 12 months to 1 month. Every spacecraft requires propellant tanks and each tank has two domes. Therefore this study represents a significant business case for the Space Systems Company. Lockheed Martin has ongoing developments in metallic and polymer/composite additive manufacturing with the goal of increasing capability and complexity of parts. The development and utility of these manufacturing processes will be presented.

Biography

Dr. Slade Gardner is a technology and strategy leader for implementation of Advanced Manufacturing and Materials at Lockheed Martin Space Systems Company (SSC) leading the maturation and acceptance of Additive Manufacturing. His Additive Manufacturing portfolio includes large metal demonstrations, custom alloy formulations, large polymer and composite demonstrations, novel polymer composite materials and equipment development for additive clusters. Dr. Gardner is the inventor of large scale Point Wise Composition Control. He is currently focusing technical leadership and strategic planning for Lockheed Martin SSC's Advanced Manufacturing 'Factory of the Future'. In addition to additive manufacturing his molded thermoplastics portfolio is best known as the "APEX" family of nanocomposite thermoplastics for which he created the development strategy, staffed and lead the team for material formulation and implementations. Prior to working at Lockheed Martin SSC, Slade worked for more than a decade at Lockheed Martin Aeronautics in the Skunk Works division. Slade's additional experience includes composite manufacturing, tooling development, processing science and fabrication methods. His published research includes structure-process-property relationships of tailored interphase composites for performance and durability improvements. He has a BS in Chemical Engineering from Lafayette College, Easton, PA and a Ph.D. in Chemical Engineering from Virginia Tech, Blacksburg, VA where he worked under a fellowship from the National Science Foundation Science and Technology Center for High Performance Polymers and Composites. Personal interests include traveling with his wife, all seasons of mountain sports and he is an avid motorcycle enthusiast.

Professor Donald R. Sadoway

John F. Elliott Professor of Materials Chemistry
Department of Materials Science & Engineering
Massachusetts Institute of Technology

Towards Sustainable Metal Production by Molten Oxide Electrolysis

Abstract

Molten oxide electrolysis (MOE) produces liquid metal and oxygen gas by the electrolytic decomposition of molten metal oxide. Since no carbon is used either as reductant or heat source, there are no CO2 emissions from the smelter, and specific energy consumption is 1/3 lower than current technology. For example, MOE produces pure iron, i.e., carbon-free and nitrogen-free. Since the source of sulfur in steel is the coke used in the blast furnace, MOE iron is sulfur-free. MOE is economically viable at about 1/10 the scale of today's technology. Obviously, the source of electricity for an MOE smelter must be carbon-free as is the practice with aluminum, e.g., hydroelectric or nuclear. Notably, even when electricity is generated by burning natural gas, the carbon footprint of MOE is lighter than that of current technology. The relevant electrochemistry of the process will be presented along with the materials science behind the oxygen evolving inert anode.

Donald R. Sadoway is the John F. Elliott Professor of Materials Chemistry in the Department of Materials Science and Engineering at the Massachusetts Institute of Technology. He obtained the B.A.Sc. in Engineering Science, the M.A.Sc. in Chemical Metallurgy, and the Ph.D. in Chemical Metallurgy, all from the University of Toronto. After a year of postdoctoral study at MIT as a NATO Fellow, Dr. Sadoway joined the faculty in 1978. The author of over 150 scientific papers and holder of 19 U.S. patents, his research is directed towards the development of rechargeable batteries for grid-level storage and environmentally sound technologies for the extraction of metals. The fundamental tenet that drives his choice of problems is how to reduce cost at the discovery stage. To push these ideas from lab bench to marketplace, he is the founder of two companies, Ambri and Boston Electrometallurgical. With recordings of his chemistry lectures broadcast throughout the world on MIT OpenCourseWare, his impact on engineering education extends far beyond the lecture hall at MIT. Viewed over 1,500,000 times, his TED talk from February 29, 2012 is a narrative about inventing inventors as much as it about inventing technology. In 2012 he was named by Time magazine as one of the 100 Most Influential People in the World.

Professor Bilge Yildiz

Associate Professor of Nuclear Science & Engineering
Massachusetts Institute of Technology

Uncovering the Inner Workings of Metal Corrosion by Combining Surface Sensitive Experiments and Multi-scale Modeling

Abstract

Formation of stable native films that passivate corrosion (i.e. reduce the metal corrosion rate) is essential for the usability of the metal in a given environment. The passive films also serve as a barrier to hydrogen penetration into the metal that causes embrittlement and fracture. Corrosion is a very costly problem, more than 4% of GNP in the US and ~$12 billion to US utilities; impacting many energy systems and broadly the infrastructure. It can be seen as an “old” problem; but an emerging confluence of novel computational and experimental methods presents an exceptional opportunity to uncover and control the microscopic mechanisms governing material corrosion. In this talk, I will present our work combining synchrotron x-ray and scanning probe experiments combined with atomistic and mesoscale modeling, which uncover corrosion and hydrogen related degradation of materials, and which provide guidance on the design of more robust surfaces against corrosion and hydrogen ingress. First, I will present that, by performing atomistic calculations, we were able to quantify the dependence of hydrogen ingress into the metal on the electronic structure of the surface passive films on zirconium alloys, and give design guidelines for alloy compositions that minimize hydrogen ingress through the passive film in general. Second, I will show that by performing synchrotron x-ray photoelectron spectroscopy and atomistic calculations, we were able to quantify the chemical and electronic properties of sulfide films on steels, and develop more accurate and predictive corrosion models by using this information.

Biography

Bilge Yildiz is an associate professor in the Nuclear Science and Engineering Department at Massachusetts Institute of Technology (MIT), where she leads the Laboratory for Electrochemical Interfaces. She received her PhD degree at MIT in 2003 and her BSc degree from Hacettepe University in Turkey in 1999. After working at Argonne National Laboratory as research staff, she returned to MIT as an assistant professor in 2007. Her research centers on molecular-level studies of oxygen exchange kinetics on surfaces at elevated temperatures, under stress and in reactive gases, by combining in situ surface sensitive experiments with first-principles calculations and novel atomistic simulations. The scientific insights derived from her research impact the design of novel surface chemistries for efficient and durable solid oxide fuel/electrolysis cells, and for corrosion resistant films in a wide range of extreme environments as in nuclear energy generation and oil exploration. She was the recipient of the Charles Tobias Young Investigator Award of the Electrochemical Society in 2012, the Somiya Award of the International Union of Materials Research Societies for international collaboration in 2012, and an NSF CAREER award in 2011.

J. David Rowatt, Ph.D., PE

Research Director
Schlumberger-Doll Research

Metallurgy in the Oil & Gas Industry - A Wellbore Perspective

Abstract

Metals are the most widely used type of engineering material in the oil and gas (O&G) industry. Within upstream exploration and production (E&P) activities, metals are subject to a variety of technical challenges including processing and fabrication requirements, high design loads, and extreme environmental conditions. In addition, they are highly subject to supply chain issues including raw material cost and supply. As efforts to enhance recovery from existing fields and find and develop new fields continue to grow to meet world energy demand, so do the technical and supply chain challenges for metals associated with these efforts. Nowhere is this more evident than with downhole tools where the environmental and loading conditions are the most extreme and where "exotic" metals are most commonly used. Metallurgy – including advanced and novel processing methods – is therefore critical to the development of technologies for downhole tools and the E&P industry in general.

This presentation will provide an overview of the E&P activities associated with a typical O&G well with a focus on downhole tools and environments where metals and metallurgy play an important role. Selected examples of current technology as well as future R&D needs will be presented. Finally, the evolving environment for technology development including the roles and relationships of academia, government, and industry will be discussed.

Biography

Since joining Schlumberger in 1997, David's career has encompassed a variety of domestic and international assignments in technical and managerial roles related to R&D and manufacturing of oilfield equipment. He has led the development of innovative technologies for some of the oil and gas industry's most challenging problems including slimhole rotary steerable drilling tools, electric submersible pumps for extreme environments, and advanced materials for zonal isolation and stimulation. David currently serves as the Research Director for Mechanical and Materials Sciences in the Cambridge, Massachusetts where his group conducts basic and applied research supporting Schlumberger's engineering and field operations.

David's technical background is in machine and system design with an emphasis on solid mechanics and advanced materials. David graduated from the University of Illinois in 1991 with a B.S. in Aerospace Engineering and received his M.S. and Ph.D. degrees in Mechanical Engineering and Materials Science from Rice University in 1993 and 1995 respectively. David is a licensed Professional Engineer and a member of the American Society of Mechanical Engineers (ASME), the Society of Petroleum Engineers (SPE), and the Industrial Research Institute (IRI).

David has authored or co-authored several technical papers for professional journals, industry publications and conference proceedings and has been awarded numerous domestic and international patents for his inventions. He has developed technical courses on machine design for downhole oilfield equipment and has been an invited speaker on the topics of oilfield technology and manufacturing for many professional society and industry events.

Manuel Marya, Ph.D.

Materials Engineering Manager
Schlumberger Enabling Technologies Group
Co-presenter

Metallurgy in the Oil & Gas Industry - A Wellbore Perspective

Biography

Dr. Marya is Materials Engineering manager and principal engineer in Schlumberger Enabling Technology Group, based in Rosharon & Sugarland, TX. After completing his education in France, Canada, and the US where he received M.S and Ph.D. (Colorado School of Mines), he spent a combined 5 years with General Motors R&D (MI) and NanoCoolers (TX) before joining Schlumberger in 2005. Dr Marya has over 80 journal and conference proceeding publications, 30 US patents, and is a book chapter author in the Springer Handbook of Mechanical Engineering (2007). His publications cover subjects such as laser processes, welding and joining, electromagnetic processing, alloy design and new alloys, surface engineering, corrosion, digital-image correlation techniques. Dr. Marya is a past recipient of the AWS Graduate Fellowship Award (2000), the IIW Henry Granjon Prize (2002), the AWS William Spraragen Memorial Award (2006), the O&G Harts Meritorious Award for Engineering Innovation (2014). Dr. Marya periodically reviews articles for several journals and is a regular speaker at companies, universities, national labs in US, Japan, Singapore, and France and a frequent technical committee member of the Thermec symposiums.

Adam C. Powell, Ph.D.

CTO & Co-Founder
INFINIUM, Inc.

Clean Metal Production for Clean Energy

Abstract

The past five years have seen enormous growth in renewable energy and energy efficiency technologies. Between 2008 and 2013, wind energy grew from 1.3% to 4.2% of the nation's electricity production, solar energy grew from 0.2% to 0.8%, and US electric and plug-in hybrid vehicle sales grew from 2800 to over 97,000.

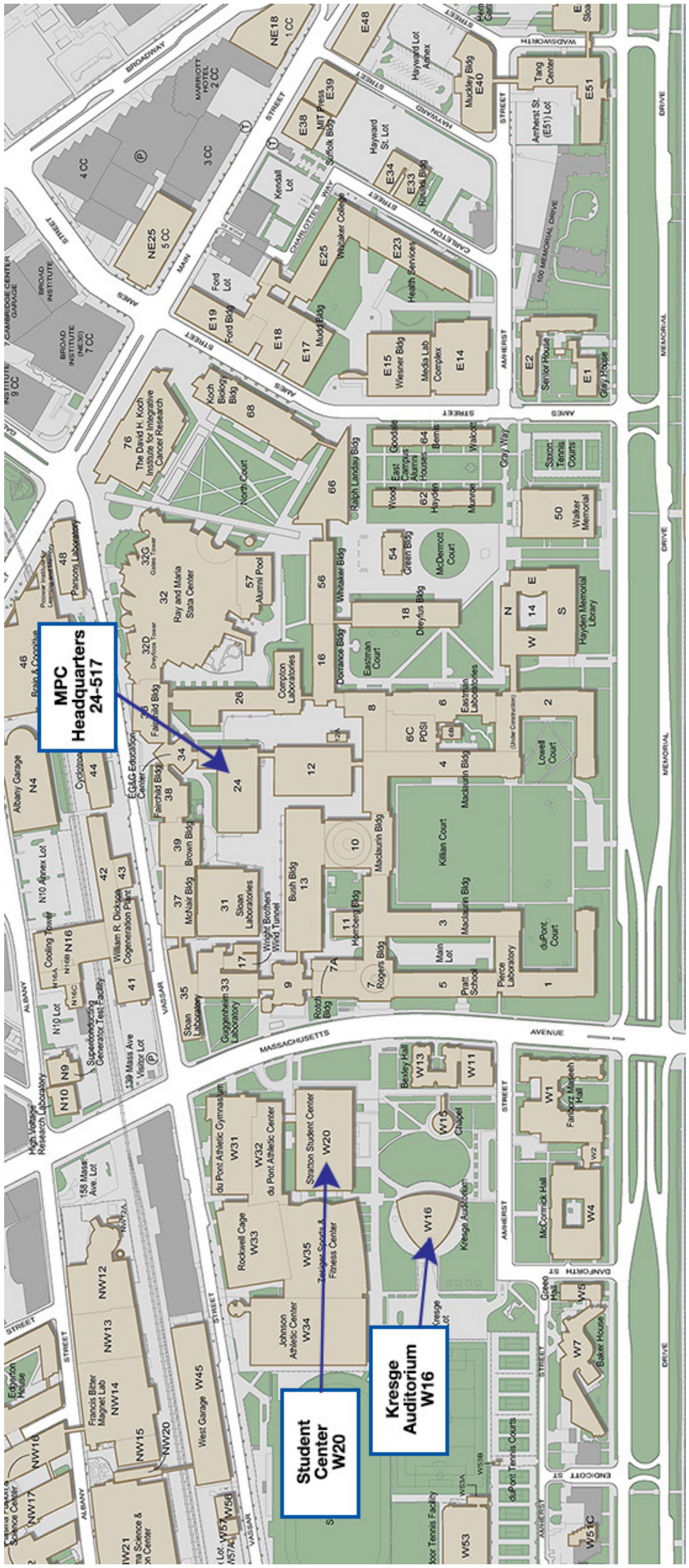
Unfortunately, these clean technologies rely on metals whose production is neither clean nor safe. The best generators and motors for windmills and hybrid/electric vehicles use rare earth permanent magnets, whose rare earth metals are almost entirely made in China with enormous air and water emissions. The shift from steel to aluminum and magnesium for more efficient motor vehicles requires 5-10 times more energy and GHG emissions in metal production. In the value chain from mines to final products, the most energy- and pollution-intensive step for these reactive metals is reduction of the metal from its oxide.

INFINIUM is developing a new molten salt electrolysis process to bring about clean metal production for clean energy and energy efficiency. Instead of carbon anodes, this process uses Pure Oxygen Anodes™ which employ a stabilized zirconia solid electrolyte between the molten salt and anode. This eliminates contamination of the product by carbon and its impurities. For rare earths, this enables 10-100 times larger batch size than current practice, and lower labor cost. It eliminates emissions of perfluorocarbons which are greenhouse gases with 6000-10,000 times the global warming potential of CO_2. It also creates a reducing environment enabling use of low-cost sealed steel vessels. It either produces a high-purity oxygen by-product, or can use natural gas to reduce the necessary electrical energy with no HF production. INFINIUM is starting commercially production of dysprosium-iron alloy now, and will add neodymium in 2015.

Biography

Adam Powell, CTO & Co-Founder of INFINIUM (formerly MOxST), has over 17 years experience designing, modeling, and improving processes for materials production and improvement. His expertise includes broad materials coverage: metal extraction/refining and products, thin films, ceramic coatings, polymer membranes, batteries, and electromagnetic propulsion. He has pioneered innovations in phase field modeling for solidification, fluid-structure interactions, electrochemistry, and immersion precipitation for polymer membranes.

Along with co-founder and CEO Steve Derezinski, Powell has grown INFINIUM to a team of 25 employees. He has led the company's innovations which have turned core solid electrolyte metal extraction patents from MIT and Boston University into a viable industrial process for clean efficient reduction of reactive metal oxides using Pure Oxygen Anodes™. He is the primary author of INFINIUM's rapidly growing patent portfolio currently with seven patents, and is the Principal Investigator on over $14M in competitive government grants & contracts. INFINIUM is rapidly scaling up its Pure Oxygen Anodes technology for dysprosium production from its oxide, with first commercial shipments going out next month, making the company the only North American producer of rare earth metals. The technology also scales very well for magnesium, where it can reduce the primary production cost by 40% and energy use by 50-80%. It is also in development for aluminum, where in can reduce cost by 10-20% and energy usage by 25-40% vs. today's Hall-Héroult cells. The team has also successfully demonstrated production of tantalum, titanium, and high-purity silicon using this technology.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