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Materials in Energy Applications

Advanced Elastomers for Oil & Gas •
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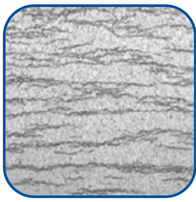
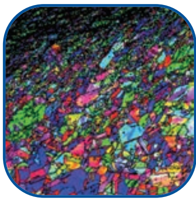
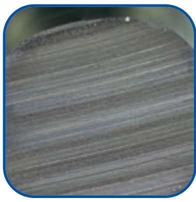
ON THE COVER:
An offshore platform used for deepwater exploration and production. Developing energy resources in ever more hostile environments requires materials that can withstand corrosion as well as temperature and pressure extremes. Courtesy of Element Materials Technology, St. Paul, Minn. www.element.com.

contents







DEPARTMENTS

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materials witness

Science, selfies, and a splendid new year

Looking back on 2013, it was certainly an interesting year. Depending on the authority one consults, the vaunted Word of the Year honor goes to either "science" or "selfie." The folks at Merriam-Webster chose *science,* based on a 176% increase in lookups of the word in 2013 versus 2012. Scientific topics regularly made the news, "from climate change to educational policy," according to editor Peter Sokolowski. Over at the Oxford University Press, *selfie* takes the top spot based on language research by the editors revealing a 17,000% increase in usage during 2013 over 2012.

Other 2013 science news worth noting includes some real gems. One particularly funny story concerned hackers who wanted to retaliate against the National Security Agency (NSA) for cyber-spying on Brazil. Only problem, they got the name wrong and hacked NASA's web page instead, leaving a nasty "Stop spying on us" message on the innocent space agency's site. Oops! Another story in the same "never mind" category was the full-page ad placed by the Seattle Metropolitan Chamber of Commerce in the *Seattle Times,* promoting the growth of aerospace in Washington and recognizing that the state is still a contender for Boeing 777X production. The ad title says "The Future of Washington," but instead of an image of a 777, *somebody* used a large photo of an Airbus A319. Chamber spokeswoman Terri Hiroshima admitted it was a "cringe-worthy error."

Very good news for materials scientists looking for work, courtesy of Boeing: The company will add 300-400 research jobs in North Charleston, S.C., as it spreads work across the country. The new Center for Manufacturing Technology in North Charleston will focus on assembly and automation, as well as composites fabrication and repair, electromagnetic effects, and nondestructive evaluation. Apply at www.boeing.com/boeing/careers.

Ending the year on a bit of a sour note was Johnson & Johnson, who will pay $2.5 billion to settle roughly 8,000 lawsuits having to do with faulty hip implants that caused injuries and required additional surgeries. The problems reported by patients were caused by tiny metal particles that make their way into the hip joint and damage the surrounding bone and tissue.

Keeping up with good news in 2013 was also easy to do. Most recently, the National Institute of Standards and Technology (NIST), Gaithersburg, Md., announced in late November that it selected a consortium led by Northwestern University to create a new NIST-sponsored center of excellence for advanced materials research. The Center for Hierarchical Materials Design (CHiMaD) will receive funding in part by a $25 million award from NIST over five years.

Even better, the consortium plans to work closely with ASM International, QuesTek Innovations (a spin-off of Northwestern), and Fayetteville State University, N.C. This announcement promises to hold much excitement for ASM in 2014 and beyond, as the new center focuses on developing the next generation of computational tools, databases, and experimental techniques to support the Materials Genome Initiative.

New departments in *AM&P* this year also promise to be interesting and exciting. In this issue, we debut both *Metallurgy Lane,* which explores developments in the metals and materials industries, and *Success Analysis,* our new back page featuring in-the-field reporting on advances in materials science and engineering. We wish you all a happy and healthy 2014!

F. Richards

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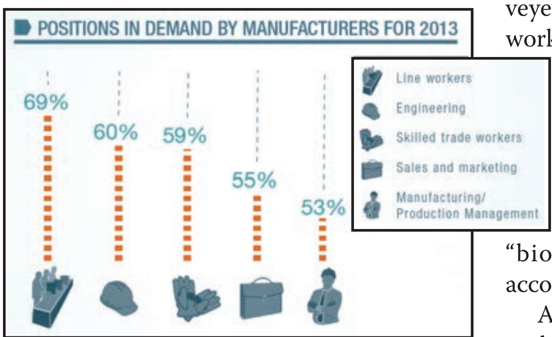
market
spotlight

Manufacturing survey reveals ticking biological clock

The recently released Industry Market Barometer (IMB) from ThomasNet.com highlights several interesting trends, some positive and others worrisome. Respondents include 1209 North American engineers and purchasing agents, business owners and managers, and sales and marketing executives from manufacturers, distributors, and service companies. The majority represent small companies (fewer than 100 employees and less than $10 million in revenue), mirroring the makeup of the industrial/manufacturing segment. Responses provide a unique opportunity to peer into the strategies of these smaller companies.

In 2012, manufacturing accounted for roughly $1.9 trillion, or almost 12%, of U.S. GDP. More than half (55%) of the manufacturers surveyed grew in 2012, and nearly two-thirds (63%) achieved growth in 2013. Even so, a crack is slowly coming to the surface, say analysts. Research reveals that a lack of fresh talent threatens the sector's future vitality. The companies surveyed represent today's manufacturing workforce, which is heavily populated by employees who are 45 and older. With Generation Y (18-32 years old) expected to make up 75% of the workforce by 2025, and older employees exiting in droves, manufacturing's "biological clock" is ticking away, according to report authors.



A closer look at the IMB findings reveals a jarring disconnect between the growth of manufacturers and their lack of urgency when it comes to filling their talent pipeline. For example, eight out of ten manufacturers report that younger employees represent a very small fraction of their workforce—and most don't see this changing soon. Findings point to a need for a collective "succession plan." As a starting point, manufacturers need to address the pervasive myths about what a career in American manufacturing really means. Three out of four IMB respondents (73%) say that negative perceptions about the profession are deterring new generations from joining. Yet, the same manufacturers are vocal about the many rewards their industry offers and many have developed creative partnerships with schools to engage their "best and brightest," pointing to educators as their ray of hope for the future. Yet the jury is out on whether these efforts alone will be enough, say analysts.

Of the survey respondents' open job postings, 60% are looking for engineers, 59% need skilled trade workers, 55% are hiring sales and marketing people, and 53% seek manufacturing/production management personnel. However, a lack of basic skills in young workers is a drawback to recruitment. More than 25% of companies say high schools should offer more technical training to encourage students to pursue manufacturing careers. Other suggestions include placing a stronger emphasis on STEM courses, greater partnerships between manufacturers and colleges and technical schools to inform students about opportunities, and parents encouraging their children to consider manufacturing careers. *For more information, visit www.thomasnet.com/imb.*

feedback

Put materials specification where it belongs

If we go back a few decades, cars were composite—mostly steel, some rubber (tires). There were miscellaneous other things too, such as glass, rubber, and wiring insulation. Mankind has developed a tendency to over-specify iron and steel. Iron is probably useful for engine blocks and steel may be useful for frames, but it needs a coating better than paint. Powder coating may be sufficient, though I think electroless nickel-plated, powder-coated steel would be better, as steel has little or no corrosion resistance. Having a coating that can stand up to most in-service abuse is useful, although that coating must be on top of a more resistant coating, which will continue to protect the steel until the first coating can be replaced after wearing off.

In terms of the cosmetic exterior (the body), steel has no business being there, unless designers want to consider stainless steel. (I thought not.) Aluminum is useful too, but it is not a durable substrate for paint.To use steel or aluminum for an auto body is to plan for a limited vehicle lifetime. Composites should work better for oil pans, valve covers, and the front cover of the camshaft drive mechanism because they provide corrosion resistance plus sound deadening. Composites also have increased thermal resistance, important to operating an engine in cold climates. But people need to get away from incorporating a release compound into the bulk of molding compounds used to make body parts. Release compounds are intended to separate the mold from the part: They have no business being a uniform component of the part.

I've seen many job postings where part of the position involves specifying materials. These jobs mostly call for mechanical engineers, and materials specification is almost always an "insignificant" job function. A senior mechanical engineer might have 1000 hours of materials experience, yet I have more than 35,000 hours. I am not going to design cars, but I sure as heck know more about materials than a senior mechanical engineer. Get materials specification where it belongs, not as a side task for an engineer who doesn't understand materials.

G.H., P.Eng.

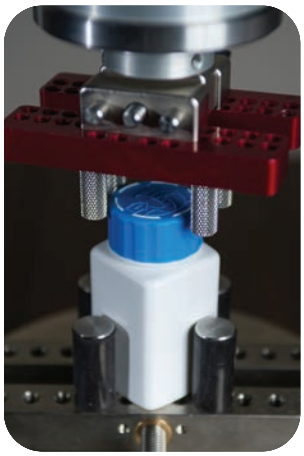
We welcome all comments and suggestions. Send letters to frances.richards@asminternational.org.

Sugarcane hard hat is sweet on safety

Safety products supplier MSA, Pittsburgh, developed what is said to be the world's first "green" protective hard hat manufactured from sugarcane. Unlike conventional hard hats manufactured from high-density polyethylene (HDPE) sourced from nonrenewable petrochemicals, the V-Gard GREEN helmet is manufactured using HDPE sourced entirely from sugarcane ethanol. Eric Beck, MSA's global director of strategic marketing, explained that through the natural process of photosynthesis, sugarcane cultivation captures CO_2 from the atmosphere, thereby reducing greenhouse gas emissions. Green high-density polyethylene is 100% recyclable in the same stream as conventional HDPE, making it suitable for reuse in nonsafety products and further enhancing the sustainability benefits of the new hat. The earth-friendly helmet will be marked with a recycling label to further remind users to recycle their hat at the end of its lifetime. *www.safetyworks.com.*

Easy-open medicine bottles aid arthritis patients

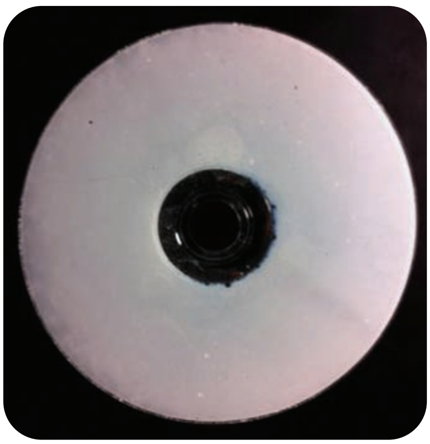
Pfizer Inc., New York, worked with researchers at the Georgia Tech Research Institute (GTRI), Atlanta, to develop an easy-to-open and child-resistant container and cap to dispense one of its rheumatoid arthritis medicines. When GTRI researchers began proposing bottle and cap possibilities to the company, the cap's material and the shape of the bottle were important design elements, according to Brad Fain, principle research scientist. The team suggested coating the cap with a rubberlike thermoplastic elastomer to increase friction, making the bottle easier to grasp and rotate. They also recommended selecting a noncylindrical container that would be easier to grasp. Medicine bottles and caps were fitted with force sensors that measured the top-down and rotational forces that people with arthritis could comfortably apply. From this data, the maximum allowable force required to push down on the cap as well as the maximum force required to rotate and remove the cap were determined. Data collected by GTRI was used as evidence of compliance with U.S. Arthritis Foundation requirements when Pfizer applied for the ease-of-use commendation. *For more information: Brad Fain, 404/407-7261, brad.fain@gtri.gatech.edu, www.gtri.gatech.edu.*



Equipment used by GTRI product design researchers measures the forces required to open prescription medicine containers. Courtesy of Georgia Tech/Rob Felt.

Spinning CDs clean sewage

Researchers in Taiwan came up with a practical application for old audio CDs: breaking down sewage. "Optical disks are inexpensive, readily available, and commonly used," says Din Ping Tsai, a physicist at National Taiwan University. Tsai and colleagues used the large surface area of optical disks as a platform to grow tiny, upright zinc oxide nanorods about a thousandth the width of a human hair. Zinc oxide is an inexpensive semiconductor that can function as a photocatalyst, breaking apart organic molecules like the pollutants in sewage when illuminated with UV light. Because the disks are durable and able to spin quickly, contaminated water that drips onto the device spreads out in a thin film that light can easily penetrate, speeding up the degradation process. The team's complete wastewater treatment device is approximately one cubic foot in volume. The device uses a UV light source and a system that recirculates water to further break down pollutants.



The reactor was tested with a solution of methyl orange dye, a model organic compound often used to evaluate the speed of photocatalytic reactions. After treating a half-liter solution of dye for 60 minutes, more than 95% of contaminants were broken down. The device can treat 150 ml of wastewater per minute, according to researchers, and could be used on a small scale to clean water contaminated with domestic sewage, urban runoff, industrial effluents, and farm waste. *For more information: Din Ping Tsai, dptsai@sinica.edu.tw, 02/2652-5186, www.ntu.edu.tw/english.*

briefs

Pershing Gold Corp., Lakewood, Colo., initiated the metallurgical studies needed for mine planning and permitting activities at Relief Canyon. The company selected **McClelland Labs Inc.,** Sparks, Nev., to conduct a series of metallurgical tests designed to determine the best crush size and agglomeration method, with the objective of increasing gold recovery and determining waste rock characterization. To support this study, Pershing recently drilled five large-diameter diamond core holes located in the north and south pits to provide representative samples for the tests. Approximately 1380 ft of core will be sent to the McClelland facility where it will be split, crushed, sampled, and subjected to metallurgical analysis. www.pershinggold.com, www.mettest.com.

The University of Washington's Applied Physics Laboratory, Seattle, teamed up with **OceanGate Inc.,** Everett, Wash., to build an innovative five-person submarine that would travel to almost 2 miles below the ocean's surface. The submarine, named Cyclops, has a carbon-fiber hull that can take passengers to 9842 ft. **The Boeing Co.** worked with OceanGate and UW on initial design analysis of the 7-in.-thick pressure vessel. The design uses a strategy where each strip of carbon fiber and resin is precisely placed to ensure that there will be no gaps or weak points. The battery will be a lithium-polymer design that will also make the sub lighter and able to dive longer and faster than traditional subs. www.apl.washington.edu, www.oceangate.com, www.boeing.com.

Planting plastic

Kenny McCabe, a horticulture research associate and graduate student at Iowa State University, Ames, and James Schrader, an assistant scientist in horticulture, are part of a five-year study of the production and performance of different kinds of bioplastic pots. The study is supported by a $1.94 million grant from the U.S. Department of Agriculture and led by William Graves, professor of horticulture and associate dean of the graduate college. The team operates within the Center for Crops Utilization Research and is hoping to build a Center for Bioplastics and Biocomposites (CB^2) with grant money from the National Science Foundation. The proposed center has three major goals: to improve the basic understanding of the processing and properties of bioplastics; to provide reliable data about bioplastics for industry; and to support large-scale manufacture and use of biorenewable plastics. The team's long-term goal is to increase the bioplastics market share by at least 20%. *For more information: Kenny McCabe, 515/294-2751, kgmccabe@iastate.edu, www.iastate.edu.*

Iowa State's Kenny McCabe studies plant performance in pots made from bioplastics.

Self-healing metal

Massachusetts Institute of Technology, Cambridge, researchers found that under certain conditions, putting a cracked piece of metal under tension has the reverse effect, causing the crack to close and its edges to fuse together. The reason lies in how grain boundaries interact with cracks in the crystalline microstructure of a metal—in this case nickel, which is the basis for superalloys used in extreme environments, such as in deep-sea oil wells. By creating a computer model of that microstructure and studying its response to various conditions, researchers found that there is a mechanism that can, at least in principle, close cracks under any applied stress.

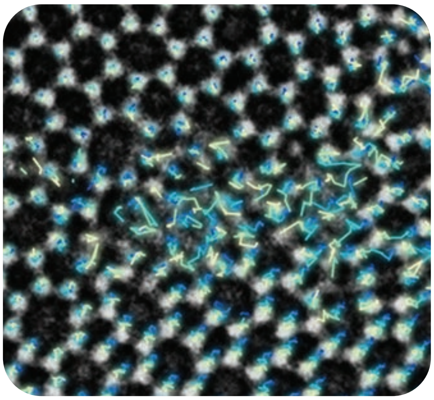
Self-healing occurs only across a certain kind of boundary—one that extends partway into a grain, but not all the way through it. This creates a type of defect known as a disclination. These defects have intense stress fields, which can be so strong that they actually reverse what an applied load would do. The work was funded by the BP-MIT Materials and Corrosion Center. *For more information: Michael Demkowicz, 617/324-6563, demkowicz@mit.edu, http://demkowicz.mit.edu.*

Novelis, Atlanta, completed a two-year, $400 million expansion program in Seoul, South Korea. The expansion of its Yeongju and Ulsan plants increases the company's production capacity in the region by more than 50% to approximately one million metric tons of aluminum sheet per year. The expansion includes a hot rolling finishing mill, cold rolling mill, pusher furnace, high-speed slitter and annealing furnaces, in addition to the previously commissioned fully-integrated recycling center at Yeongju. The demand for aluminum in the Asian automotive market is expected to exceed the 25% compound annual growth rate projected globally over the next five years, as more automobile manufacturers move to build lighter, more fuel-efficient vehicles. www.novelis.com/en-us.

Bent glass dance floor for atoms

A research team led by David Muller, professor of applied and engineering physics and co-director of the Kavli Institute at Cornell for Nanoscale Science, Ithaca, N.Y., and the University of Ulm, Germany, used an electron microscope to bend, deform, and melt a one-molecule-thick glass. These are all things that happen just before glass shatters, and for the first time, the researchers directly imaged such deformations and the resulting "dance" of rearranging atoms in silica glass.

"No one has ever been able to see how the atoms in a glass rearrange when you push on them," says Muller. Researchers imaged thin glass with a transmission electron microscope and shot a beam of high-energy electrons at the glass, causing visible structural deformation. Muller described the electrons as "tickling" the glass in order to deform it and simultaneously image what was happening. "Everyone thought it was impossible to see atoms moving in a glass, and suddenly we were able to do it with this new, ultrathin glass. You could say, we have identified some of the basic dance moves," Muller added. These insights may eventually lead to atom-by-atom designs for stronger glass panes or more robust transistors. *For more information: David Muller, 607/255-4065, dm24@cornell.edu, http://muller.research.engineering.cornell.edu.*



The trajectories of atoms in silica glass as it deforms, overlaid on a transmission electron microscopy image. Courtesy of Pinshane Huang.

Expansion ensures beryllium availability

Materion Brush Beryllium & Composites, Elmore, Ohio, completed a significant milestone of its capabilities and operations for proprietary investment cast AlBeCast aluminum beryllium products. Materion is reportedly the world's only mine-to-mill integrated beryllium producer. Aluminum beryllium castings provide favorable cost/benefit advantages for end users requiring a combination of ultra-light weight, stiffness, mechanical stability, and thermal properties. The investment follows a major expansion of the Elmore facility's primary beryllium production capacity undertaken during the past several years as part of an innovative private-public partnership between Materion and the U.S. Department of Defense. This capability supports the beryllium product lines required to meet both defense and critical civilian needs. *www.materion.com.*

Liquidmetal Technologies Inc., Rancho Santa Margarita, Calif., delivered missile canards for a future test of **Lockheed Martin's** Extended Area Protection and Survivability missile—an advanced performance, highly affordable hit-to-kill missile interceptor designed to defeat rocket, artillery, and mortar targets with reduced probabilities for collateral damage. The unique alloy and processing methods yield parts with dimensional consistency and precision at an affordable cost. www.liquidmetal.com, www.lockheedmartin.com.

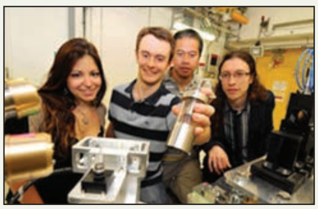
industry news

TESTING CHARACTERIZATION

briefs

The **state of Texas** recently awarded $1 million to the new **Oil & Gas Materials Technology Center,** part of **Element Houston.** The center, located on a 5.3-acre campus adjacent to the Houston energy corridor, will use the funds to research applications of high performance polymers for energy applications. The $5 million laboratory, Element's largest single site investment, also offers advanced fracture mechanics and corrosion testing. www.element.com.

The **University of Manchester,** UK, received a **Queen's Anniversary Prize** for its efforts to support strategic development in advanced materials and manufacturing. The award recognizes the university's expertise in developing new techniques for 3D imaging of material structures and defects, and interpreting the state of stress, microstructure, and damage in engineering materials and components. www.manchester.ac.uk.

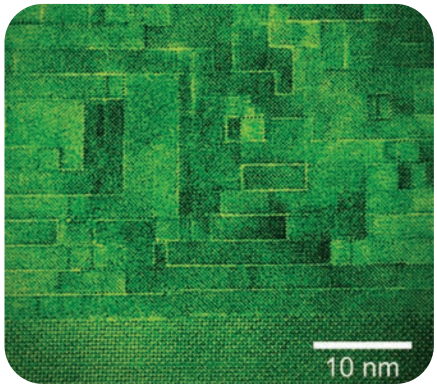


Researchers at the University of Manchester recently received a Queen's Anniversary Prize.

What is known to be the biggest and most advanced wind energy testing facility in the U.S. is now open in North Charleston, S.C., supported by a $47 million **Department of Energy** grant and $60 million in outside funding. Led by **Clemson University's Restoration Institute,** the facility will test and validate new turbines. Machinery that converts both onshore and offshore wind to electricity will also be tested. Engineers will be able to simulate 20 years' worth of wear and tear on drivetrains in just a few months. www.clemsonenergy.com.

Self-correcting crystal holds promise for advanced electronics

Researchers from the National Institute of Standards and Technology (NIST), Gaithersburg, Md., joined with an international team to engineer and measure a promising new class of nanostructured materials for microwave and advanced communication devices. Based on NIST's measurements, the novel materials—a family of multilayered crystalline sandwiches—could enable an innovative class of compact, high performance, high efficiency components for devices such as mobile phones.



Electron microscope image of a cross section of the newly characterized tunable microwave dielectric shows thick layers of strontium titanate "bricks" separated by thin "mortar lines" of strontium oxide that help promote largely defect-free brick growth. Courtesy of David Mueller.

"These materials are an excellent example of what the Materials Genome Initiative refers to as materials-by-design," explains NIST physicist James Booth. "Materials science keeps getting better at engineering complex structures at an atomic scale to create materials with previously unheard-of properties."

According to NIST materials scientist Nathan Orloff, "People have created tunable microwave dielectrics for decades, but they use up way too much power." The new materials work well up to 100 GHz, setting the stage for the next generation of advanced communications devices.

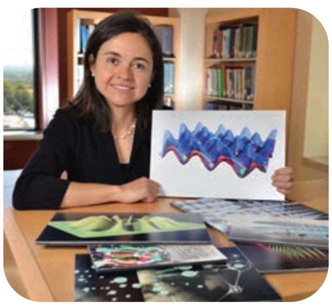
Modern cellphone dielectrics use materials that suffer from defects within their crystal structure, which interferes with the dielectric properties and leads to power loss. One major feature of the new materials, says Orloff, is that they self-correct, reducing the effect of defects in the part of the crystal where it counts.

The new material has layers of strontium oxide, believed to be responsible for the self-correcting feature, separating a variable number of layers of strontium titanate. Layers are grown as a thin crystalline film on top of a substrate material with a mismatched crystal spacing that produces strain within the strontium titanate structure that makes it a less stable dielectric, but one that can be tuned.

The new sandwich material performs so well as a tunable dielectric, over such a broad range of frequencies that the NIST team had to develop a new measurement technique to measure its electronic characteristics. "We were able to characterize the performance of these materials as a function of frequency running from 10 hertz all the way up to 125 gigahertz," says Orloff. "This material has a much lower loss and a much higher tunability for a given applied field than any material we have seen." *www.nist.gov.*

Research aims to model behavior of ultra-cold atoms

Ana Maria Rey, a National Science Foundation (NSF)-funded scientist and research assistant professor at the University of Colorado Boulder's Department of Physics is a recent recipient of one of the prestigious MacArthur fellowships, a $625,000 award popularly known as a "genius" grant.



Ana Maria Rey of the University of Colorado Boulder received a MacArthur Fellowship in 2013 to study the behavior of ultra-cold atoms. Courtesy of Casey Cass.

Since 2008, Rey also received about $500,000 in NSF funding for work that includes modeling the behavior of ultra-cold atoms and polar molecules. She and her colleagues create artificial materials by trapping atoms with light. This research could lead to new materials for more effective superconductors, as well as new magnetic behavior that could speed up computer development. One of the eventual goals, for example, is to develop new materials that superconduct at room temperature, rather than only in extreme cold.

"This will help everything, because nowadays you have to cool the materials down, which is very expensive," she says. "If we don't have to cool them down, everything that uses superconductivity can be made much less expensively."

Rey is also developing a comprehensive theoretical framework for an optical-lattice quantum computer based on alkaline earth metals, and she has proposed solutions for problems associated with storing, addressing, and transporting qubits, the quantum equivalent of traditional computing bits. Among other things, she hopes to resolve long-standing obstacles to large-scale entanglement between atoms, which quantum computers require for both communication and calculations. Such research could produce smaller and faster computers with capabilities that classical computers do not now have. *For more information: Ana Maria Rey, 303/492-7801, arey@jilau1.colorado.edu, www.colorado.edu.*

Brits use blimp to study clouds

A team of British scientists recently traveled across the U.S. in the world's largest blimp—Skyship 600—as part of a BBC expedition team to study clouds as well as biological activity in the air. Microscopes from Carl Zeiss Microscopy LLC, Germany, were used in the research activities. Researchers traveled from Florida to California, stopping at 13 different air fields along their route. Carl Zeiss Microscopy loaned an inverted, compound microscope (Axio Vert.A1) and a stereo microscope (Stemi 2000) to the temporary labs set up at the air fields. The main goal was to explain changes in weather and its effects. Also, data was correlated to current weather, migratory, and wildlife patterns. The Cloud Lab will be seen on BBC Two television later this year. *www.zeiss.com, www.airshipsonline.com/airships/ss600.*

EWI, Columbus, Ohio, developed a new tool called EWI SpotSight to reduce the need for destructive testing of spot welds in manufacturing. The tool employs matrix-phased array-based ultrasonic imaging technology to accurately evaluate the effectiveness of component joints by visualizing weld images with real-time feedback. Originally developed for the automotive industry, SpotSight can be used in many applications for structural inspection of metal, plastic, braze, and composite joints. www.ewi.org.

industry news

briefs

The **Department of Energy's Office of Science** recently announced 59 projects that will share nearly 6 billion core hours on two of America's fastest supercomputers to advance knowledge in critical areas from sustainable energy technologies to materials research. Allocations come from the Innovative and Novel Computational Impact on Theory and Experiment (INCITE) program. Through it, advanced computational research projects from academia, government, and industry gain access to powerful computing facilities at **Oak Ridge** and **Argonne** national labs. For example, Argonne's Larry Curtiss and a team from **IBM** received 100 million core hours to address the chemical and physical mechanisms that could lead to breakthroughs for lithium-air batteries, while Poul Jørgensen from **Aarhus University**, Denmark, received 24 million core hours to study supramolecular wires made of a new class of organic gel. www.doeleadershipcomputing.org/incite-program.

Penn State, State College, and its **Materials Research Institute** launched a center to discover what new properties can be created when atom-thick 2D layers of elemental materials and chemical compounds are formed or when those layers are built into new 3D structures. Mauricio Terrones, the center's director and a professor of physics, chemistry, and materials science and engineering, announced the concept of the **Center for Two-Dimensional and Layered Materials** earlier this year. Its mission is to conduct international, multidisciplinary research on 2D layered materials, with the goal of discovering new phenomena and applications that could be transformed into high impact products. www.mri.psu.edu/centers/2dlm.

EMERGING TECHNOLOGY

Purdue joins effort to solve rare earth metals shortage

Carol Handwerker, the Reinhardt Schuhmann Jr. Professor of Materials Engineering, discusses materials sustainability issues in electronics with students. Courtesy of Purdue University/Vincent Walter.

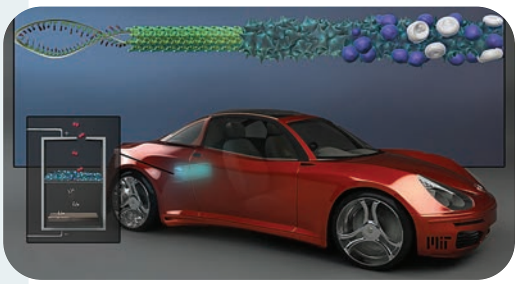
Researchers at Purdue University, West Lafayette, Ind., are part of a consortium of national labs, industry, and other universities forming the Critical Materials Institute (CMI)—a new national research hub focused on developing solutions to the shortages of rare earth metals and other materials vital for U.S. energy security. A five-year, $120 million grant from the Department of Energy launched the CMI in September as the newest DOE Energy Innovation Hub. Led by Ames Laboratory in Iowa, the hub is one of five such sites established since 2010.

Purdue's John Sutherland, head of environmental and ecological engineering, will lead an effort to develop closed-loop material cycles for rare earth elements (REEs) used in making magnets for lighter and more efficient generators that power wind turbines, materials also used in hybrid vehicles and hard disks. Materials engineering professor Carol Handwerker and her team will develop a technology roadmap in collaboration with the overall CMI enterprise for applying a systems view of the risks to pursue new materials and energy technologies instead of relying on rare earth materials.

CMI will initially focus on developing solutions to shortages for five REEs as well as lithium and tellurium, and the technologies that use these critical materials, including electric vehicle motors and batteries, wind turbines, energy-efficient lighting, and thin-film solar cells. *For more information: Carol Handwerker, 765/494-0147, handwerker@purdue.edu, www.purdue.edu.*

Virus biology holds promise for better batteries

Researchers at Massachusetts Institute of Technology, Cambridge, found that adding genetically modified viruses to the production of nanowires could help solve some problems facing lithium-air batteries. Increasing the wire's surface area is key, as it increases the area where electrochemical activity takes place during battery charging or discharging. An array of nanowires, each about 80 nm across, was produced using the genetically modified M13 virus, which can capture molecules of metals from water and bind them into structural shapes. In this case, wires of manganese oxide—a favorite material for a lithium-air battery's cathode according to professor Angela Belcher—were actually made by the viruses. But unlike wires grown through conventional chemical methods, these virus-built nanowires have a rough, spiky surface, dramatically boosting their surface area.



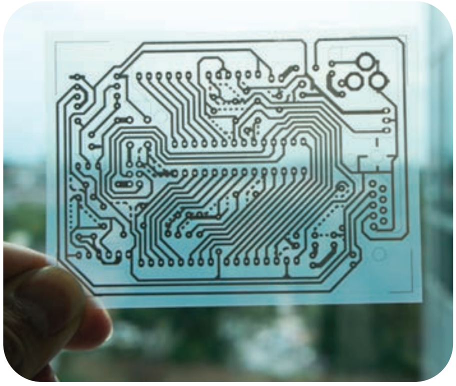
Virus-built nanowires have a rough, spiky surface, dramatically increasing their surface area. Courtesy of MIT.

Belcher, the W.M. Keck Professor of Energy and a member of MIT's Koch Institute for Integrative Cancer Research, explains that this process of biosynthesis is similar to how an abalone grows its shell, in that case, by collecting calcium from seawater and depositing it into a solid, linked structure. The increase in surface area produced by this method can provide a big advantage in lithium-air batteries' rate of charging and discharging. But the process also has other potential advantages, says Belcher. Unlike conventional fabrication methods, which involve energy-intensive high temperatures and hazardous chemicals, this method can be carried out at room temperature using a water-based process. *For more information: Angela Belcher, 617/252-1163, belcher@mit.edu, www.mit.edu.*

industry news

Novel method cranks out inkjet-based circuits

Researchers from Georgia Tech, the University of Tokyo, and Microsoft Research developed a new method to rapidly and inexpensively make electrical circuits by printing them with commodity inkjet printers and off-the-shelf materials. For roughly $300 in equipment costs, anyone can produce working electrical circuits in the 60 seconds it takes to print them. The technique, called "instant inkjet circuits," allows the printing of arbitrary-shaped conductors onto rigid or flexible materials and could advance the prototyping skills of non-technical enthusiasts.



A single-sided wiring pattern for an Arduino microcontroller is printed on a sheet of coated PET film. Courtesy of Georgia Tech.

"We believe there is an opportunity to introduce a new approach to rapidly prototyping fully custom-printed circuits," says Gregory Abowd, Regents Professor in the School of Interactive Computing at Georgia Tech and an investigator in the study. "Unlike existing methods for printing conductive patterns, conductivity in our technique emerges within a few seconds and without the need for special equipment."

Recent advances in chemically bonding metal particles allows researchers to use silver nanoparticle ink to print the circuits and avoid thermal bonding, or sintering, a time-consuming and potentially damaging technique. Printing circuits on resin-coated paper, PET film, and glossy photo paper works best. The team also made a list of materials to avoid, such as canvas cloths and magnet sheets. To make the technique possible, researchers optimized commercially available tools and materials including printers, adhesive tape, and the silver ink. Designing the circuit itself was accomplished with desktop drawing software, and even a photocopy of a drawing can produce a working circuit. Once printed, the circuits can be attached to electronic components using conductive double-sided tape or silver epoxy adhesive, allowing full-scale prototyping in hours. *For more information: Gregory Abowd, gregory.abowd@cc.gatech.edu, www.cc.gatech.edu.*

Single-step auto parts manufacturing via thixoforming

Following years of research, the technology involving thixoforming—the shaping of metals in a semi-solid state—is beginning to yield results. CIC marGUNE, the Cooperative Research Centre for High-performance Manufacturing, Spain, is exploring the possibility of modifying the current process for manufacturing automotive parts, using thixoforming technology instead. Research is being conducted in collaboration with nearby CIE-Legazpi and Mondragon University to simplify the current process of manufacturing auto parts, which typically consists of three or four steps.

"The aim is to produce the final part in a single step, which would bypass the whole process in between," says Mikel Intxausti of CIE-Legazpi.

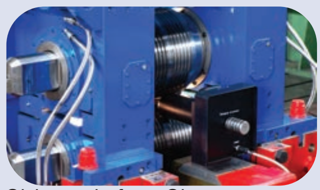
As yet, there are no manufacturers using this process, which is why Mondragon University engineer Jokin Lozares is working with a clear goal in mind—taking thixoforming technology from the lab to industry. On a laboratory scale, researchers have already managed to reduce to a single step what in industry now requires three or four different procedures. During thixoforming, material is kept between a liquid and solid state and is shaped in that semi-solid state, which offers certain advantages in comparison to conventional forging.

"To produce the same part, thixoforming technology uses about 20% less material than forging, because no surplus material is obtained in the new process, and the final part with the desired geometry is directly achieved," explains Lozares. "A process that now requires three or four steps is cut to a single step, allowing infinitely more complex geometries to be achieved." *www.margune.org.*

briefs

Lincoln Electric Holdings Inc., Cleveland, acquired an ownership interest in **Burlington Automation Corp.,** a manufacturer of 3D robotic plasma cutting systems. Based in Hamilton, Ontario, the company serves the structural steel, construction, oil and gas, and general fabrication markets in North America, with its main products sold under the PythonX brand. Lincoln Electric also will acquire **Robolution GmbH,** a European provider of robotic arc welding systems. Based outside of Frankfurt, Germany, the company serves leading automotive OEMs and Tier 1 suppliers. www.lincolnelectric.com.

Siemens Metals Technologies, Austria, won an order to supply Chinese steel manufacturer **Qingdao Special Iron & Steel Co. Ltd.** with a flat bar rolling mill. The new mill has a production capacity of 600,000 metric tons a year and manufactures flat bars with widths of between 60-160 mm and thicknesses from 6-60 mm for applications in the automotive and construction industries. Commissioning is scheduled for early 2015. www.siemens.com/metals.



Sizing train from Siemens.

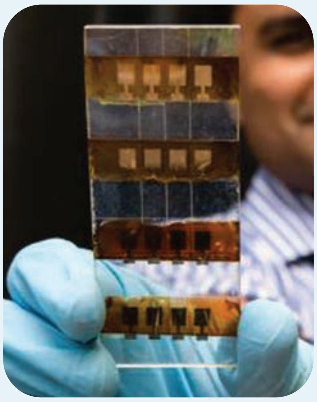
Novelis Inc., Atlanta, commissioned a $200 million expansion of its rolling operations in Oswego, N.Y., increasing the company's North American capacity for producing automotive aluminum sheet by 240,000 tons, five times their existing capacity in the region. The Oswego facility is an integrated recycling, hot rolling, and cold rolling complex producing aluminum sheet for the beverage can, automotive, and building and construction industries. www.novelis.com.

industry news

ENERGY TRENDS

briefs

Scientists at **Nanyang Technological University (NTU),** Singapore, developed next generation solar cells made of organic-inorganic hybrid perovskite materials. They are about five times less expensive than current thin-film solar cells, due to a simpler solution-based manufacturing process. Perovskite is known to be a remarkable solar cell material as it can convert up to 15% of sunlight to electricity, close to the efficiency of current solar cells, but scientists did not know why or how, until now. www.ntu.edu.sg.



Close-up of the new perovskite solar cells made in NTU's Energy Research Institute. Courtesy of Nanyang Technological University.

Building on President Obama's broad-based plan to cut carbon pollution and support clean energy innovation across the country, Energy Secretary Moniz recently announced about $60 million to support innovative solar energy research and development. As part of the department's **SunShot Initiative,** these awards will help lower the cost of solar electricity, advance seamless grid integration, and support a growing U.S. solar workforce. www1.eere.energy.gov/solar/sunshot.

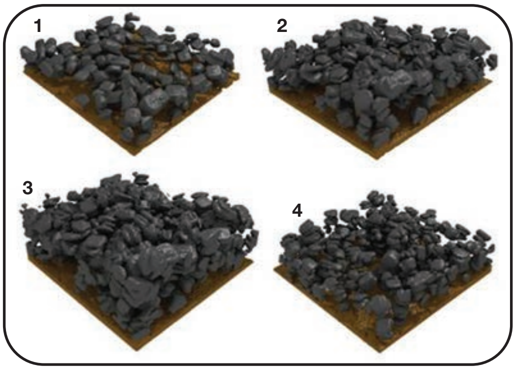
Green magnets attract research

Researchers at Case Western Reserve University, Cleveland, received a second $1 million federal grant to create an eco-friendly material for better power-converting magnets in wind turbines and electric cars. The group believes it can make magnetic powder out of inexpensive and plentiful iron and nitrogen, which can be compacted to form magnets with the desired properties. Engineers are combining early materials science with recent methods they developed to increase the carbon concentration in stainless steel way beyond the usual equilibrium solubility limit.

The Ames National Laboratory, Iowa, is providing a starting powder of specially engineered spherical alloy particles. Engineers will design and build a fluidized-bed reactor at Case to optimize the processing parameters. *For more information: David Matthiesen, 216/368-1366, david.matthiesen@case.edu, www.case.edu.*

Why lithium-ion batteries fail

In the search for higher energy density batteries, scientists have experimented for more than 20 years with materials capable of repetitively alloying and de-alloying with lithium. Laboratory-scale experiments show that batteries with such materials have energy densities multiple times that of intercalation materials; however, these alloying materials are not yet exploited in industry due to limited lifetimes. Martin Ebner, PhD student at the Laboratory for Nanoelectronics in the Department of Information Technology and Electrical Engineering (D-ITET), Zurich, explains, "Their capacity typically fades after a couple of charging and discharging cycles." This is attributed to a massive—up to threefold—expansion of the electrode material during charging. During discharge, the materials contract again, but do not reach their original state. Electrode particles break apart, the electrode structure disintegrates, and the fragments lose contact with the rest of the cell. *www.lne.ethz.ch.*



Particles of a tin oxide electrode experiencing structural changes during charging (1-3) and discharging (3-4). Courtesy of Martin Ebner, Laboratory for Nanoelectronics, ETH Zurich.

Tree hugging battery made of wood

An episode of the American Chemical Society's (ACS') Global Challenges/Chemistry Solutions podcast series describes the development of a battery made from a sliver of wood coated with tin. It shows promise for becoming a tiny, long lasting, efficient, and environmentally friendly energy source. The device is 1000 times thinner than a sheet of paper, according to researchers. It is well known that wood fibers from trees are supple and naturally designed to hold mineral-rich water, similar to the electrolyte used in batteries. Researchers decided to explore using wood as the base of an experimental sodium-ion battery. Using sodium rather than lithium would make the device environmentally friendly. Lab experiments show the device performed successfully though 400 charge-discharge cycles, putting it among the longest-lasting of all sodium-ion nanobatteries. *www.acs.org/globalchallenges.*

Colorado State University, Fort Collins, researchers are nearing the prototype phase for a lithium ion battery that could be safer, less expensive, faster charging, and more environmentally friendly than conventional batteries. The team developed one component at a time—starting with a copper foam structure purchased to serve as the current collector on the anode side of the battery. Foam is relatively easy to manufacture and has a 3D structure that increases the surface area of the electrodes and brings them closer together, thereby increasing power density. The intricate 3D structures use the electrode material more efficiently than a flat surface. www.colostate.edu.

New engine coatings promise longer life

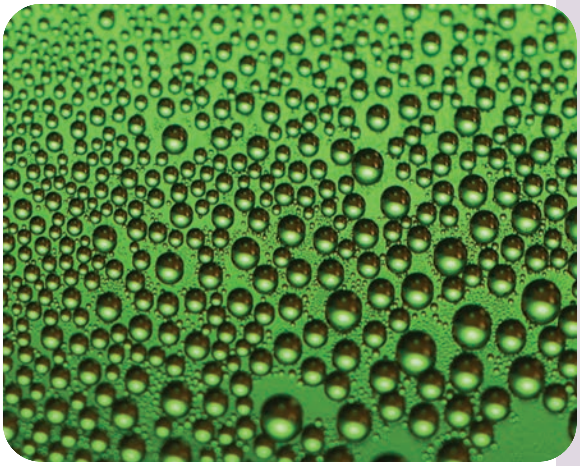
Self-healing thermal barrier coatings (TBCs) designed to improve gas turbine engine efficiency were developed by researchers at Delft University of Technology, the Netherlands. The TBCs were tested in aero-engines, but can potentially be used in ships, submarines, and even for generating electrical power.

Researchers working on the self-healing thermal barrier coatings (SAMBA) project wanted to develop a system of applying new ceramic TBCs to the most critical parts of engines. This would enable operators to push the engines beyond the melting point of the structural components. By allowing higher operational temperatures, the ceramic coatings can save companies fuel and reduce CO_2 emissions. The ceramic TBCs' ability to repair small cracks therefore has the potential to prolong the lifetime of coatings by 20-25%, and thus significantly reduce maintenance costs. *www.sambaproject.eu.*

Improved hydrophobic materials boost power plant efficiency

Researchers at Massachusetts Institute of Technology, Cambridge, say they found a way to improve the efficiency of steam condensation—the key to worldwide production of electricity and clean water. It has been known for years that making steam-condenser surfaces hydrophobic could improve the efficiency of condensation by causing the water to quickly form droplets. But most hydrophobic materials have limited durability, especially in steamy industrial settings. The new approach to coating condenser surfaces should overcome that problem, according to researchers.

The covalent-bonding process the team developed is significantly more stable than previous coatings, even under harsh conditions. Tests of metal surfaces coated using the team's process show "a stark difference," says Kripa Varanasi, professor of mechanical engineering. The material stood up well even when exposed to steam at 100°C in an accelerated endurance test. The coating can easily be applied to conventional condenser materials—typically titanium, steel, copper, or aluminum—in existing facilities, using a process called initiated chemical vapor deposition. *For more information: Kripa Varanasi, 617/324-5608, varanasi@mit.edu, http://varanasi.mit.edu.*



On typical hydrophobic coatings, droplets forming from high-temperature steam soon spread out to coat the surface, quickly degrading their performance. The coating seen here maintains its ability to foster droplet formation over long periods.

Coatings protect against rust

Rice University, Houston, researchers discovered that atomically thin sheets of hexagonal boron nitride (h-BN) protect what is underneath them from oxidizing even at very high temperatures. Researchers made small sheets of h-BN via chemical vapor deposition (CVD), a process they said should be scalable for industrial production. The thin material was grown on nickel foil and was found to withstand high temperatures in an oxygen-rich environment. Researchers also grew h-BN on graphene and found sheets of h-BN could be transferred to copper and steel with similar results. "What's amazing is that these layers are ultrathin and they stand up to such ultrahigh temperatures," says materials scientist Pulickel Ajayan. "At a few nanometers wide, they're a totally noninvasive coating. They take almost no space at all." *For more information: Pulickel Ajayan, 713/348-5904, ajayan@rice.edu, www.rice.edu.*

briefs

Advenira Enterprises Inc., Sunnyvale, Calif., was issued U.S. Patent No. 8,507,035. It covers the company's Hybrid 3D coater that allows nanocomposite material to be applied to virtually any substrate shape or material including polycarbonate, ceramic, quartz, aluminum, and others. This is an alternative to the commonly used vacuum and non-vacuum deposition techniques. Key advantages of solution derived nanocomposite (SDN) technology reportedly include excellent uniformity and performance at lower cost with high throughput and material use. The coating can substantially improve production processes, which in turn enables smaller chip size and longer battery life for portable devices. www.advenira.com.

Titan Spine, Mequon, Wis., conducted a study that shows that its implant surface technology promotes superior production of angiogenic growth factors as compared with PEEK (poly-ether-ether-ketone) and smooth titanium alloy materials. The study compared the production of osteogenic (bone formation) and angiogenic (blood vessel formation) growth factors by human osteoblast cells cultured on PEEK, smooth titanium alloy, and Titan Spine's roughened titanium alloy surface. This osteogenic environment may enhance bone formation, implant stability, and fusion. www.titanspine.com.

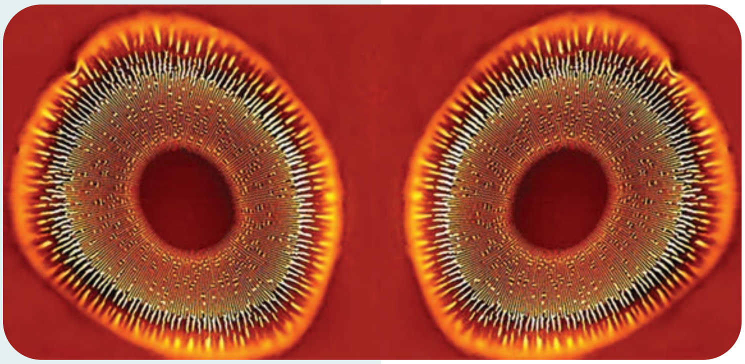
The **University of Central Florida,** Orlando, signed its first license agreement with student-led spinout company **Mesdi Systems Inc.** Mesdi specializes in the production and implementation of advanced spray equipment used to manufacture nanomaterials and ultra-thin coatings. The agreement gives Mesdi the tools it needs to scale-up its proprietary equipment that is currently being implemented to manufacture next-generation lithium-ion batteries. www.ucf.edu.

industry news

NANOTECHNOLOGY

briefs

Scientists from the **National Physical Laboratory (NPL),** UK, contributed nanoscale images of bleached hair, gold nanoparticles, and the impact of cluster guns to the Guardian's nanotechnology blog, Small World. One image shows nanostructures created by blasting carbon-containing molecules with bismuth atoms. The blog, in association with a European Commission-funded project called Nanopinion, aims to discuss advances in nanotechnology. It features a monthly gallery called "Postcards from the nanoworld," which brings together the most picturesque and interesting images at the nanoscale. www.theguardian.com/science/gallery/2013/sep/06/nanotechnology-world-pictures.



One of the NPL images shows nanostructures created by blasting carbon-containing molecules with bismuth atoms.

Researchers at **Eindhoven University of Technology (TU/e), Delft University of Technology,** and **Philips,** all in the Netherlands, show that energy losses in a nanowire solar cell can be significantly reduced by "cleaning" the surface with a special etching method. The solar cell has an efficiency of 11.1%, putting it just below the current world record, but it was reached with much less use of material. This is the latest step forward in the rapid development of this type of solar cell in recent years. www.tue.nl/en.

How gold nanoparticles deliver drugs without damage

Researchers at Massachusetts Institute of Technology, Cambridge, and the Swiss Federal Institute of Technology, Lausanne, Switzerland, figured out how nanoparticles of pure gold, coated with a thin layer of a special polymer, deliver drugs, nutrients, or biosensors without damaging or destroying cells. They also discovered the size limits of particles that can be used through a combination of lab experiments and computer simulations.

First, coated gold nanoparticles are fused with lipids that form the cell wall. Scientists also demonstrate an upper limit on the size of such particles that can penetrate the cell wall—a limit that depends on the composition of the particle's coating. The coating applied to the gold particles is a mix of hydrophobic and hydrophilic components that form a monolayer on the particle's surface. Several different compounds can be used, say researchers.

Evidence shows that the gold particles have therapeutic properties, which could be a side benefit. Gold particles are also very good at capturing x-rays—so if they could be made to penetrate cancer cells, and were heated by a beam of x-rays, they could destroy those cells from within. "So the fact that nanoparticles are made of gold may be useful," says Darrell Irvine, professor of materials science and engineering and biological engineering. Irvine is also interested in harnessing this cell-penetrating mechanism as a way of delivering drugs to the cell's interior, by binding them to the surface coating material. *For more information: Darrell Irvine, 617/452-4174, djirvine@mit.edu, http://web.mit.edu/biomaterials.*

Researchers from the **Institute for Color Science and Technology,** Iran, produced a new type of coating with desirable anticorrosion properties by using zinc oxide nanoparticles, for applications in the automotive industry. The nanoparticles are used in a formulation for vehicle electrocoating, and adsorb ultraviolet light to stop it from reaching the inner layer. As a result, coating damage is prevented. www.irancolorinstitute.com.

Kavli Foundation endows new nanosciences facility

The Kavli Foundation endowed a new institute at the University of California, Berkeley, and the Lawrence Berkeley National Laboratory to explore the basic science of how to capture and channel energy on the nanoscale. The Kavli Energy NanoSciences Institute (Kavli ENSI) will be supported by a $20 million endowment, with The Kavli Foundation providing $10 million and UC Berkeley raising matching funds. The institute will explore fundamental issues in energy science, using tools developed to study and manipulate nanomaterials to understand how solar, heat, and vibrational energy are captured and converted into useful work by plants and animals or novel materials.

"The field of nanoscience is poised to change the very foundations of how we should think about future energy conversion systems," says Kavli ENSI Director Paul Alivisatos. "We don't fully understand some foundational issues about how energy is converted to work on really short length scales."

Alivisatos explains that much of today's energy research focuses on improving well-known technologies, such as batteries and solar cells. On the nanoscale, however, energy is captured, channeled, and stored in totally different ways dictated by the quantum mechanical nature of small-scale interactions.

Kavli ENSI scientists plan to investigate how heat flows in nanomaterials and whether the vibrational energy, or phonons, can be channeled to make thermal rectifiers or transistors analogous to today's electronic switches. They also aim to develop novel materials with unusual nanoscale properties, and design materials that could sort, count, and channel molecules along prescribed paths to carry out complex chemical conversions. *www.berkeley.edu.*

Tinius Olsen Inc.

Time tested

The first universal testing machine was the inspiration of Tinius Olsen, an inventor passionate about finding new ways to test the limits of materials. By 1880, he had proven and patented enough of his revolutionary ideas and designs to create an entire line of testing machines and launch his own company.

Today, Tinius Olsen is managed by the fifth generation of the Olsen family and has long since emerged as a global leader in the manufacture of materials testing equipment. With the emergence and growth of new materials, from engineering plastics to advanced composites, the company's product line has expanded exponentially. Likewise, its third-party accredited technical team supports an ever-growing worldwide customer base. Tinius Olsen is an essential resource for anyone with materials to test.

Tinius Olsen products

The company designs and manufactures one of the world's most comprehensive families of machines for determining the mechanical properties of materials. Its major product line include hydraulic and electro-mechanical floor model universal testing machines and bench-top units, all of which can be provided with a wide variety of tooling, control, and software options.

Metal components testing

Advanced Super "L" hydraulic universal testing machines, available with closed-loop servo control, today offer frame capacities from 150 kN to 2.7 MN (30,000 to 600,000 lbf).

The Super "L" console has been totally redesigned to provide simple operational controls from a handheld terminal and an extremely quiet hydraulic power package, all contained in a single enclosure with a significantly smaller footprint. Additionally, this console can be adapted to provide a simple, cost-effective scheme converting pumping units from manual to servo control capabilities.

Six entirely new models of the cost efficient "T" series of bench-top testing machines have been added as well.

Tinius Olsen Inc.
1065 Easton Road, Horsham, PA 19044
tel: 215/675-7100; fax: 215/441-0899
e-mail: sales@tiniusolsen.com
Web: www.tiniusolsen.com

NSL Analytical

Setting the Standard for Materials Testing

NSL Analytical Services, Inc. is an Independent Commercial Materials Testing Laboratory that offers a broad spectrum of analytical and metallurgical testing for quality control, failure analysis, product performance, material selection and characterization.

Since 1945, NSL Analytical has helped customers reach the highest standards of product quality from design to product launch. If you require material characterization, process evaluation, failure analysis, quality control or specialized testing, you can trust the Chemists, Metallurgists, and Technicians at NSL Analytical to provide accurate, reliable and repeatable testing results.

Our testing capabilities include:

- Inorganic Trace Element Analysis
- Metallurgical Evaluations
- Mechanical Testing
- Microscopy Evaluations
- Lead and Phthalates Testing
- Consumer Product Safety Testing
- Organic and Polymer Lab Services
- Composite and Advanced Materials Testing
- Thermal Analysis
- Ophthalmic Lens and Frame Testing
- Bulk Chemistries for Alloys, Ceramics and Other Materials
- Hazardous Substance Testing for RoHS and WEEE Initiatives

For a complete list of our advanced testing services, visit our website at www.NSLanalytical.com.

NSL maintains major industry accreditations and approvals to provide specialized services such as:

- ISO/IEC 17025
- Nadcap
- 10 CFR Part 21 reporting program, with compliance to applicable requirements from 10 CFR 50 Appendix B
- Certified test reports, in accordance with ASME section III NCA-3800 (where applicable)
- Audited by NIAC and NUPIC member customers
- CPSC/CPSIA
- GE-S-400
- Boeing
- SNECMA
- P&W

Polymer Testing
NSL's experience with polymeric materials includes analysis and testing of catalysts, thermal stabilizers, fillers, and pigments in polymers and composite materials. Our polymer testing lab offers customers the expertise required to help solve a wide variety of polymer and composite materials problems. Testing services include:

- Elemental and Chemical Analysis
- Thermal Analysis
- Physical Properties
- Compositional Analysis

To ensure accuracy and reliability, our polymer testing methods adhere to ASTM standards.

Metallurgical Testing
Last year, NSL Analytical invested over $1.6 million on a new Metallurgical Testing facility. The lab houses machining, mechanical testing and microscopy equipment. Our Materials Analysts, Metallurgists and Metallurgical Engineers are experienced in microscopy evaluations, failure analysis, and mechanical testing of ferrous and non-ferrous metals to perform Material Verification, Material Certification, and Failure Analysis.

Trace Analysis Testing Services
As a material testing lab for aerospace, nuclear, refractory, and metalworking industries, NSL's chemistry testing services include major element analysis of sample materials with concentrations from parts per billion levels to 99.99%. Our chemistry analysis services are used to provide independent verification of materials, certification of raw materials, and failure analysis.

NSL Analyical has capabilities to perform analysis of rare earth elements, C, S, O & N analysis, halogens, high temperature alloys, refractory elements, and precious metals with the latest analytical techniques.

We are dedicated to high quality and quick turnaround to meet deadlines – and meet them consistently. Customers can trust us with their most critical materials testing needs.

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Understanding How Materials Corrode in Nuclear Reactors

Kumar Sridharan, FASM*
University of Wisconsin-Madison

The corrosion of structural materials and control of coolant chemistry are key factors that impact the lifetime of nuclear reactors and the development of future reactors.

Corrosion of structural materials is an important consideration for both today's nuclear reactors and the development of future advanced reactor concepts. Corrosion can decrease the effective wall thickness of components and can generate activated oxide or corrosion product debris particulates in reactor systems. In conjunction with improper microstructure and tensile stress in the material it can also lead to stress corrosion cracking (SCC). Radiation-induced segregation (RIS) of elements to grain boundaries can also promote SCC.

While light water reactors (LWR) use pressurized high-temperature water as a coolant, other coolants such as molten metal, helium, and molten salt are being considered for higher temperature advanced reactor technologies with enhanced capabilities and improved efficiencies. Materials development and selection for corrosion resistance is critical in all reactor designs. In addition, control of coolant chemistry is a viable option for mitigating corrosion. In this article, corrosion issues in four reactor concepts that use vastly different coolant types are reviewed.

Light water reactors

Most power reactors worldwide are LWR, using water as the coolant and operating in the 250-350°C temperature range. Boiling water reactors (BWR) operate at pressures of ~7MPa, while pressurized water reactors (PWR) operate at higher pressures (~15MPa) and temperatures than BWR. Zirconium alloys are used in LWR for fuel cladding due to their high neutron transparency. These alloys are predominantly zirconium (~98%) with small amounts of other constituents such as tin, niobium, iron, chromium, and nickel[1]. Historically, Zircaloy-2 and Zircaloy-4 have been used as cladding materials. More recently, zirconium alloys such as ZIRLO and M5 were developed for superior corrosion resistance. In LWR environments, Zr alloys react with high-temperature water to form Zr-oxide and hydrogen or directly with dissolved oxygen in water to form Zr-oxide:

$$Zr + H_2O = ZrO_2 + H_2$$
$$Zr + O_2 = ZrO_2$$

Oxidation of Zr cladding is a limiting factor in achieving higher fuel burn-ups to reduce costs. Radiation can potentially enhance oxidation rate, an effect attributed to the creation of diffusion-enhancing point defects in the oxide layer and the radiolysis of water, which can release free oxygen[2]. In most cases, Zr alloys exhibit uniform corrosion. Early stages are marked by the formation of a dense oxide film with tetragonal crystal structure, which follows a cubic growth law and is therefore very protective. Next, a regime of columnar oxide growth is accompanied by transformation of the oxide to a monoclinic crystal structure.

Oxide thickness measurements of Zr alloys from autoclave tests demonstrate a series of cyclic patterns, each following cubic oxide growth law during initial exposure with an eventual transition to linear growth law behavior. Micro-cracking of the oxide due to compressive stresses or stresses from crystallographic transformation is attributed to this peculiar growth behavior. It is evident that water coolant chemistry plays an important role in corrosion[3].

In PWR, boron (in the form of boric acid) is added to water to reduce core reactivity, while LiOH is added to counteract the boric acid's acidic effect. Infusing lithium into oxide mechanically destabilizes the oxide layer and adversely affects its protective qualities. Another form of Zr alloy corrosion in BWR is nodular corrosion, which manifests as circular nodules in the early stages of oxidation. Thicker oxide layers are observed on Zr alloys in the vicinity of stainless steel and Inconel components. This is known as shadow corrosion and is thought to occur due to galvanic effects.

Hydrogen diffusion produced from corro-

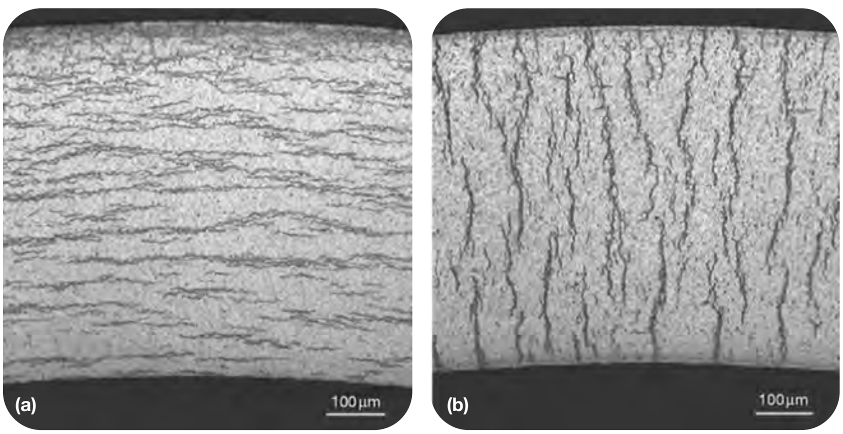

Fig. 1 — *(a) Circumferential and (b) radial hydrides formed in Zr alloy claddings as a result of corrosion[3].*

**Member of ASM International and ASM Thermal Spray Society* sion reactions in the Zr alloy is an important cladding degradation mechanism[2]. The hydrogen can form a zirconium-hydride phase in a plate-like morphology with associated embrittling effects in the cladding. The orientation of these hydride phases (circumferential or radial, Fig. 1) continues to be the subject of ongoing studies. Delayed hydride cracking (DHC) is a particular concern when hydrides dissolve and reprecipitate in an orientation more favorable to crack initiation.

Other components of LWR such as steam generator tubing, pipes, control rod drive mechanisms, core support structures, and shroud bolts are made with materials such as AISI 304 and 316 stainless steels, and Ni-based alloys such as Alloys 600, 690, 718, and 800H. SCC is a concern in these components, particularly at welds. For 304 and 316 stainless steels, sensitization dramatically promotes SCC. Very low carbon nuclear grade (NG) stainless steels and stainless steels with niobium additions (grade 347) with superior resistance to SCC have been developed. Hydrogen is often injected into the water in BWR to negate the effect of dissolved oxygen and reduce SCC. Alloy 600 was employed for steam generator piping, but intergranular cracks were observed after multiple years of service. Alloy 690 with higher resistance to SCC is being considered.

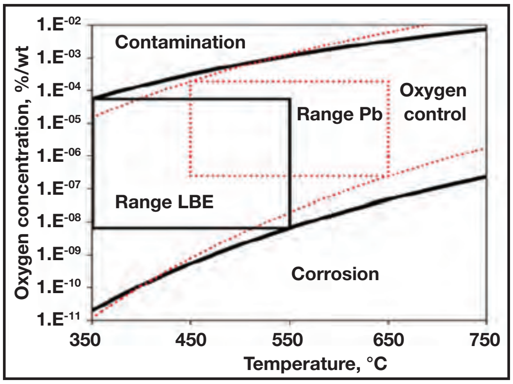

Fig. 2 — *Parameter space defined by oxygen concentration and liquid lead and LBE coolant temperature for corrosion control[4].*

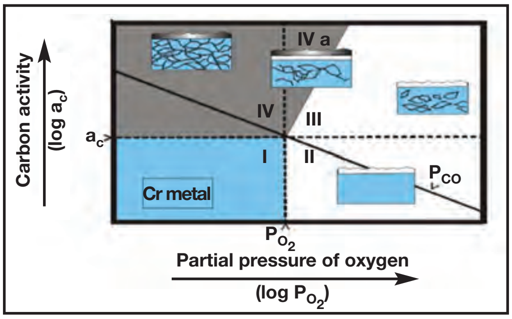

Fig. 3 — *Map of carbon activity and oxygen partial pressure showing regimes of surface corrosion degradation mechanisms for IN 617 in high temperature impure helium[7, 8].*

Lead fast reactors

Lead fast reactors (LFR) provide notable benefits such as burning long-lived actinides to shorter-lived ones, and alleviate the challenge of long-term nuclear waste storage. LFRs typically use a liquid Pb-Bi eutectic (LBE) alloy as coolant. LBE has a low neutron cross section, low melting point (~123.5°C), and excellent thermal properties. Operating temperatures are in the 350-550°C range. Corrosion resistance of structural materials in contact with high temperature liquid LBE is an important requirement in this type of reactor. Primary corrosion mechanisms are long-term dissolution of the alloy in liquid LBE and oxidation of the alloy surface from reaction with oxygen in the LBE melt. Ni, Fe, and Cr have solubility in LBE, but Ni has particularly high solubility. For this reason, Ni-based alloys may not be suitable for this application.

Ferritic steels are being actively considered for LBE environments. It is desirable to have a small amount of dissolved oxygen in the LBE melt to enable a thin "self-healing" protective oxide layer to form on the surface as a barrier between LBE and the underlying steel. Free energy considerations favor the formation of Fe-, Cr-oxides relative to PbO and BiO. Higher oxygen concentrations, however, can lead to thicker and mechanically unstable oxides making active oxygen control in the LBE melt crucial. A typical oxygen concentration window is deemed to be in the range of 1×10^{-6} to 1×10^{-8} wt% depending on the steel and temperature[4]. Figure 2 shows the oxygen concentration and coolant temperature regime

TABLE 1 — ALLOY COMPOSITION

	Concentration, wt%[4]									
Material	**Fe**	**C**	**Mn**	**Si**	**Cr**	**Ni**	**Mo**	**Al**	**V**	**W**
HT-9	Bal.	0.18	0.4	0.2	12.26	0.49	1	—	0.3	0.46
T91	Bal.	0.105	—	0.43	8.26	0.13	0.95	—	0.2	—
EP823	Bal.	0.16	0.55	1.09	11.7	0.66	0.74	—	0.3	0.6
MA756	Bal.	0.04	—	—	20	—	—	4.5	—	—
PM2000	Bal.	0.01	—	—	20	—	—	5.5	—	—
316L	Bal.	0.002	1.8	0.46	17.5	12.3	2.3	—	—	—
Alloy 600	6.0-10	<0.15	<1.00	<0.50	14-17	Bal.**	—	—	—	—
Alloy 690	7.0-11	<0.05	<0.50	<0.50	27-31	Bal.	—	—	—	—
IN718	Bal.	<0.08	<0.35	<0.35	17-21	50-55**	2.8-3.3	0.2-0.8	—	—
304 SS	Bal.	<0.08	<2.0	<1.0	17.5-20	8.0-11	—	—	—	—
347 SS	Bal.	<0.08	<2.0	<1.00	18.0	11.00	—	—	—	—
IN 800H	Bal.	0.05-0.1	—	—	19-23	30-35	—	0.15-0.6	—	—
Hastelloy-N	4.0-6.0	0.04-0.08	—	—	6.0-8.0	Bal.	15-17	—	—	—

** Niobium (+ tantalum)*
*** Nickel (+ cobalt)*

for corrosion control in liquid lead and LBE environments

Ferritic-martensitic (FM) steels such as HT9, which have an extensive database of radiation damage, and T91, which allows for higher operating temperatures, are being considered for LFR cladding applications[5]. Typical oxide layer structures developed on these steels in LBE comprise an outer Fe_3O_4 (magnetite) layer and inner spinel compound ($[Fe, Cr]_3O_4$) layer. A notable advancement in FM steels for LBE applications is EP-823, developed by Russian programs. This steel contains Si (1-1.3%) resulting in an SiO_2 surface layer that provides improved protection in LBE environments. Ferritic oxide dispersion strengthened (ODS) steels such as MA956 and PM2000 containing aluminum also perform well in LBE environments due to the formation of a protective alumina film on the surface. Refractory metals such as W, Mo, and Ta were tested with promising results. Flow-assisted erosion and corrosion is an important concern in LBE and can become quite dominant at flow rates above roughly 2 m/s, depending on the steel and the temperature[4-6].

High temperature gas-cooled reactors

High temperature gas-cooled reactors (HTGR) are being considered for electricity production and as a source of by-product process heat for powering chemical plants. Helium was chosen as the coolant gas due to its excellent heat transfer characteristics. The reactor gas outlet temperatures have not been fully established, but temperatures of 850°C or higher are being targeted. While helium is inert, long-term corrosion due to its impurities such as methane, carbon monoxide, hydrogen, carbon dioxide, and water is an important consideration. The most critical metallic component in HTGR is the heat exchanger.

Two alloys being considered for this application are Alloy 617 and Haynes 230. The environmental degradation of these alloys in a helium environment was investigated in Japan and Germany in the 1980s and more recently at CEA in France and Idaho National Laboratory in the U.S.[7-9] Studies show that depending on the partial pressure of these impurities and temperature, a variety of surface reactions can occur including oxidation, carburization, and decarburization. Ideally, a protective oxide is desirable, but this layer should not be destroyed by carburization or decarburization[8]. Examples of potential surface reactions with alloys' metallic constituents (M, reactions listed below) include oxidation of metal by water or carbon monoxide, decarburization of surface by water, and reduction of protective surface oxide by methane[9].

$$xH_2O + M = MO_x + x/2H_2$$

$$xCO + M = MO_{2x} + C$$

$$H_2O + C = CO_2 + H_2$$

$$xCH_4 + MO_x = xCO_2 + 2xH_2 + M$$

Based on thermodynamic equilibrium considerations, regimes of environmental interaction mechanisms were mapped as a function of carbon activity and oxygen partial pressure. The map (Fig. 3 for Alloy 617) provides a basis for coolant chemistry control for mitigating corrosion[7, 8]. The regimes include: I: strongly reducing, II: highly oxidizing, III: stable outer oxide and stable internal carbides, IV: strongly carburizing internally and externally, IVa: strong external carburization with stable oxide layer. Regime III represents the highest environmental stability where a stable surface oxide protects the alloy surface and the mechanical integrity is maintained by stable carbides. Figure 4a and b show cross-sectional images of corrosion layers in IN 617 after exposure at 1000°C under oxidizing and carburizing conditions, respectively[8].

Fluoride salt-cooled high temperature reactor

The high volumetric heat capacity of molten salts in general has garnered considerable interest for their use as a coolant, heat transfer, and thermal storage media in many energy-related applications. The fluoride salt-cooled high temperature reactors (FHR) use molten fluoride salts as coolant. These salts have a high boiling point (alleviating concerns about loss-of-coolant accidents) and a high solubility for

Nb	Ti	Y_2O_3	Co
—	—	—	—
0.075	—	—	—
—	—	—	—
—	—	0.5	—
—	—	0.5	—
—	—	—	—
—	—	—	—
—	—	—	—
4.75-5.5	0.65-1.15	—	<1.0
—	—	—	—
0.8*	—	—	—
—	0.15-0.6	—	—
—	—	—	—

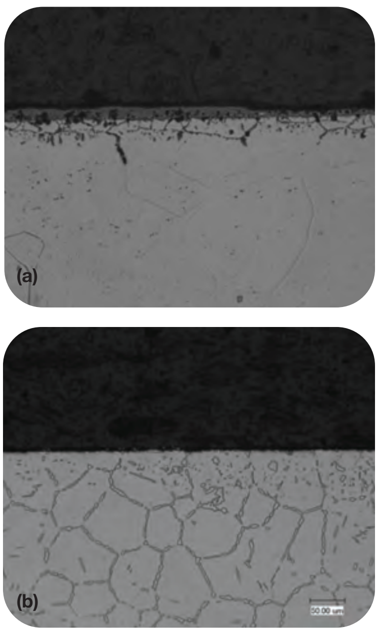

Fig. 4 — *Cross-sectional images showing corrosion layers in IN 617 after exposure at 1000°C for 500 hours (a) under oxidizing conditions showing an oxide layer and slight surface decarburization, and (b) under carburizing conditions showing carbide phase formation at grains and grain boundaries[8].*

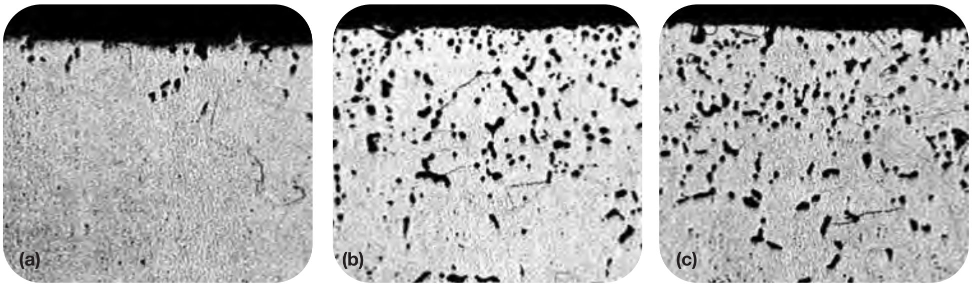

Fig. 5 — *Cross-sectional images of Alloy 600 after corrosion tests in fuel-containing molten fluoride salt performed in MSRE program at Oak Ridge National Laboratory showing the effect of Ni, Fe, HF impurities in the salt on corrosion. (a) low Fe and Ni, (b) high Fe and Ni, and (c) high HF[13].*

many fission products. FHR is intended for operation at 700°C or higher[10]. This concept originates back to research performed at Oak Ridge National Laboratory during 1950-70[11]. Under the program known as molten salt reactor experiment (MSRE), a 7.5 MW molten salt reactor with uranium fuel dissolved in a molten fluoride salt was built and operated at 650°C. The present FHR concept uses solid TRISO fuel particles immersed in the molten salt medium, but many of the corrosion challenges will be similar to those experienced in MSRE. Fluoride salt FLiBe (2LiF-BeF_2) is being considered as a primary coolant for FHR.

Corrosion of structural materials in molten fluoride salt is an important issue in FHR[12]. In most high temperature environments, corrosion resistance is achieved by promoting the formation of a protective oxide film on the alloy surface. However, in molten fluoride salt systems, any such protective oxide films dissolve by the fluxing action of the salt and cannot be used for corrosion protection. Once the passive oxide film is removed, corrosion proceeds by the attack of the least noble constituent of the freshly exposed alloy surface. Thermodynamically, the salt fluorides are more stable than metal fluorides, indicating that most structural alloys should be stable in molten fluoride salts.

Ni is relatively immune to corrosion in molten fluoride salts. Studies show that impurities such as moisture can dramatically accelerate corrosion due to the formation of hydrogen fluoride[13]. Examples of impurity reactions are listed below. In the case of FLiBe, for example, water could react with Be- and Li- fluorides in the salt and produce HF gas, which in turn could leach the Cr in the alloy into the salt as fluorides. Impurities such as Ni or Fe in the salt can also promote dissolution of Cr into the salt. Figure 5 illustrates the effect of impurities in the molten fluoride salt on corrosion from MSRE research.

$$BeF_2 + H_2O = BeO + 2HF$$

$$2LiF + H_2O = Li_2O + 2HF$$

$$2HF + Cr = CrF_2 + H_2$$

$$NiF_2 + Cr = CrF_2 + Ni$$

Other types of corrosion in molten salts include dissimilar material corrosion where deterioration is driven by elemental activity differences between various materials in the molten salt. For example, corrosion of stainless steel tested in a molten fluoride salt in graphite crucibles is significantly greater than in stainless steel crucibles[12]. Thermal gradients can also drive corrosion due to the strong dependence of solubility on temperature. Corrosion products that dissolve at the higher temperature sections of the system can partially plate-out in the relatively cooler sections of the system. Corrosion control in molten salts begins with using high purity salts with extensive purification treatments. For FLiBe and other fluoride salts, sparging with H_2/HF is effective for purification. Controlling the salt's redox potential by adding elements such as beryllium is also effective in mitigating corrosion[11].

Hastelloy N—a relatively low Cr content alloy with Mo—was developed by the MSRE program exclusively for molten fluoride salt applications[11, 13]. This alloy must be code-certified for use at the higher temperatures required for FHR. Currently, 316L stainless steel with active redox control is being considered for FHR applications. FHR will also involve other materials such as graphite and SiC/SiC composites. Corrosion testing and evaluation of all these materials in molten FLiBe salt at the intended high temperatures of FHR is required and being conducted as a part of the FHR development program in the U.S. and China.❍

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Development of Hardfacing Alloys for Power Generation Applications

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Development of wear-resistant hardfacing materials using powder metallurgy/hot isostatic pressing technology offers an alternative to today's cobalt-based materials and those that suffer delamination damage.

Many issues exist concerning the specification, manufacturing, and use of high-performance valves in the fossil and nuclear power generation industries. Increased unit flexibility (cyclic operation), higher-temperature operation (for higher efficiency), and radiation exposure (nuclear power) are key drivers for new opportunities in the development of materials and manufacturing processes for valve components. A recent article in *AM&P* discussed the promise of powder metallurgy and hot isostatic pressing (PM/HIP) technology for ferritic and stainless steel components production. This technology addresses a wide range of issues regarding cast valve components, including inspection, performance, and supply chain pinch points such as procurement, machining, and rework or refurbishment, including weld repair[1].

Ongoing research and development at the Electric Power Research Institute (EPRI), detailed in this article, examines the application of wear-resistant hardfacing materials using the PM/HIP process. The hope is to eliminate weldability and residual stress challenges associated with some of the hardfacing alloys, as well as provide a wider range of potential alloy solutions for two key concerns, detailed here. Table 1 provides chemical compositions of the materials discussed in this article.

A drive to eliminate cobalt from hardfaced components such as valve seats, discs, and stems remains in the nuclear power industry. Hardfaced component wear during operation may result in transporting Co to the reactor where it is transformed into highly radioactive Co^{60}. This isotope has a half-life of more than five years and is a major culprit in occupational radiation exposure to plant personnel working on valve components or near potential crud trap sites during outages.

Delamination (also referred to as liberation or disbonding) of hardfacing material from ferritic valve seat and disc substrates results in collateral damage to the steam turbine and valve operational function(s) (i.e., failure). An example of delamination hardfacing in a Grade 22 valve disc is shown in Fig. 1. This problem has

TABLE 1 — MATERIAL CHEMICAL COMPOSITION

	Hardfacing		*Potential Butter Layers*			*Substrate Materials*		
Element	**Alloy 6**		**Alloy 21**	**FM625**	**ER309**	**316L**	**Grade 22**	**Grade 91**
Industry	Nuclear and Fossil	Nuclear Candidate	Fossil	Fossil	Fossil	Nuclear	Fossil	Fossil
C	0.9-1.4	2.5	0.20-0.35	0.10 max	0.04-0.12	0.030 max	0.05-0.15	0.07-0.14
Ni	—	—	2.0-3.0	58.0 min	12-14	10-14	—	0.40 max
Cr	27-32	25	26-29	20-23	23-24	16-18	1.9-2.6	8.0-9.5
Fe	—	Bal.	—	1.0 max	Bal.	Bal.	Bal.	Bal.
Mo	—	3.2	4.5-6.0	8.0-10.0	0.3 max	2-3	0.87-1.13	0.85-1.05
Mn	—	≤1.0	—	0.50 max	1.0-2.5	2 max	0.30-0.60	0.30-0.60
Si	—	≤0.5	—	0.50 max	0.30-0.65	1 max	0.5 max	0.20-0.50
P	—	—	—	0.02 max	0.030 max	0.045 max	0.025 max	0.020 max
S	—	—	—	0.015 max	0.020 max	0.030 max	0.025 max	0.010 max
Co	Bal.	—	Bal.	Bal.*	—	—	—	—
Others	W: 4.0-6.0	V: 0.5	—	Nb: 3.15-4.15 Al: 0.40 max Ti: 0.40 max	—	N: 0.10 max	—	Nb: 0.06-0.10 V: 0.18-0.25 Al: 0.020 max Ti: 0.010 max

*Ni+Co

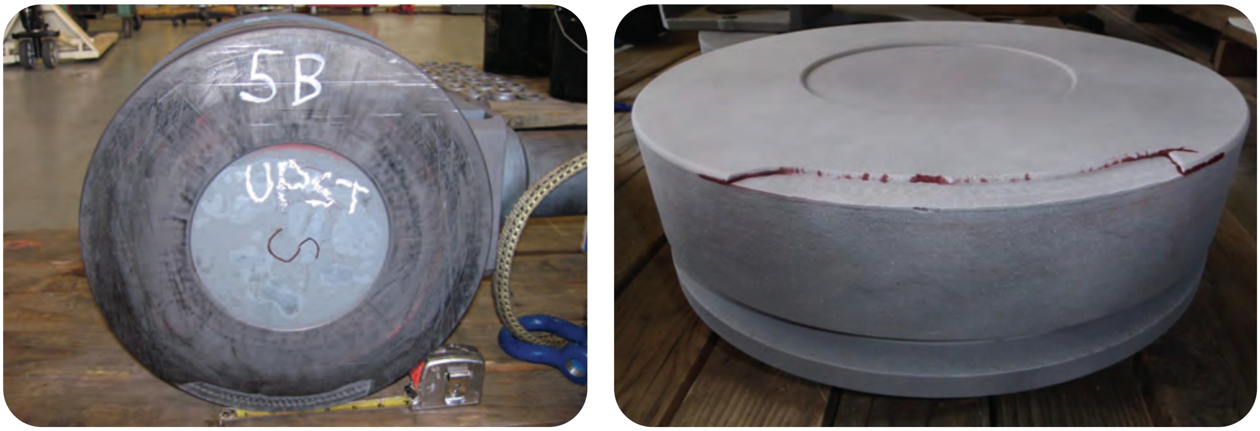

Fig. 1 — *Delamination of hardfacing material from a ferritic valve disc operating in a cycling, gas-fired power plant at 1050°F after roughly 35,000 hours.*

been identified in several gas-fired, cycling units over the last decade and has resulted in confusion and misinformation regarding the best inspection, repair, and fabrication techniques to prevent it.

EPRI's research efforts, in collaboration with The Ohio State University and Carpenter Technology Corp., are targeting these two key issues in the power generation industry through a wide range of practical and fundamental disciplines to find viable, long-term solutions.

Need for Co-free hardfacing materials

The development of Co-free hardfacing materials is highly challenging in several aspects. In general, there is a lack of uniform, consistent wear performance data for hardfacing materials candidates. Such information may exist in proprietary databases with material manufacturers or OEMs, however, little is publicly available. This is evident given the difficulties in assessing wear-resistant materials across a wide range of potential wear mechanisms (abrasion, erosion, and galling), and across the range of operational temperatures. To address some of these challenges, nuclear OEM research facilities may use one-off tests to assess potential materials. These tests simulate, on a small scale, actual valve operating conditions. Aside from several decades of acceptable service experience in both power generation industries, relatively little comparison data exists between mainstay hardfacing materials such as Alloy 6 and other material options.

The evaluation of candidate hardfacing materials also presents issues in producing quantitative results to existing wear standards as well as extrapolating lab results to real-world material and operational behavior. Two ASTM standards recognize and validate this point: ASTM G98 "Standard Test Method for Galling Resistance of Materials" and ASTM G133 "Standard Test Method for Linearly Reciprocating Ball-on-Flat Sliding Wear" aim to provide qualitative comparisons[2, 3]. However, regarding ASTM G133, the reported volume loss of the flat specimen (conducted in accordance with the standard) deviates from measurements taken by a laser microscope by as much as 150%[4].

Advanced characterization methods such as laser microscopy demonstrate the ability to improve test method accuracy, and also provide a quantitative means to evaluate candidate materials. The confocal laser microscope used by EPRI features a resolution as low as 5 nm in the laser axis, yielding extremely precise results[5]. An example of a wear scar on a flat and ball specimen, analyzed using laser microscopy, is shown in Fig. 2.

Understanding wear mechanisms

A detailed, predictive understanding of all potential wear mechanisms incorporating fundamental materials properties as well as mechanical behavior, microstructure, and part geometries does not exist—especially for the highly varied structures found in some alloy/composite systems. The initial lattice structure and transformation behavior of a given material under wear conditions may play a critical role in assessing performance, but few experimental studies are available, and conducting such an assessment is challenging. Through the combination of synchrotron diffraction, neutron diffraction, scanning electron microscopy (SEM), electron backscatter diffraction (EBSD), transmission electron microscopy (TEM), and an exhaustive physical examination of a large variety of alloy specimens tested to ASTM standards, a coherent description of the physical mechanisms of a variety of

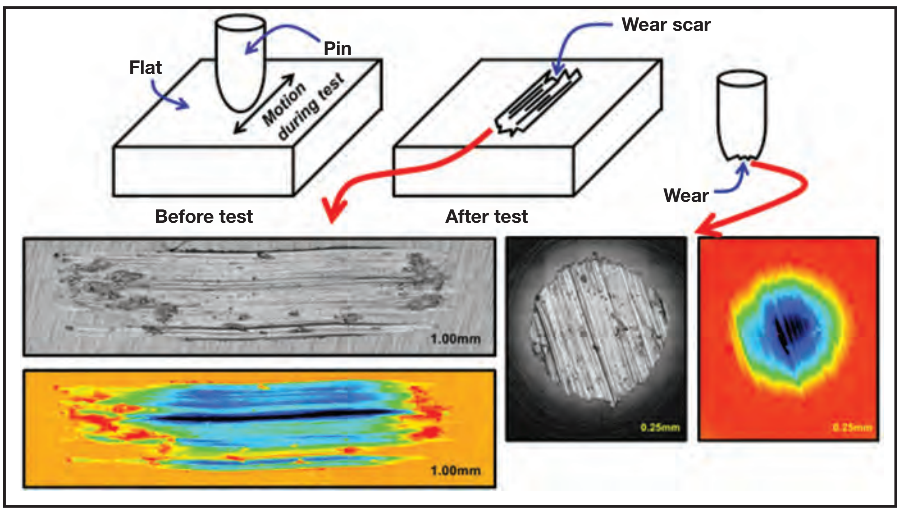

Fig. 2 — *Representative laser image and color height map for the flat and pin specimens tested to ASTM G133.*

materials are being developed for materials subjected to sliding and galling wear conditions[6].

Advanced methods of materials characterization are needed, in part, because examined materials may exhibit either a combination—or all—of the following phases: Ferrite, austenite, martensite, carbides, and nitrides. Additionally, and under the immense local deformation process that occurs during galling or sliding wear, examined materials may exhibit a combination of phase transformations (either by stress or rapid temperature rise at the surface), preferential deformation of phases, strain localization, and/or oxidation. All of these factors may contribute to overall material performance. Furthermore, resistance to wear is temperature dependent, making it imperative that materials be examined across the entire range of potential valve operating conditions.

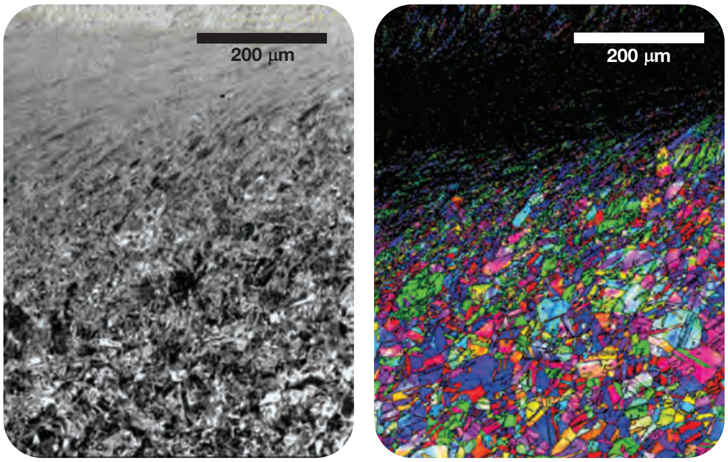

Fig. 3 — *Scanning electron microscope image (left) and electron back scatter diffraction (EBSD) image (right) of a cross-section from an ASTM G98 button specimen. The massive deformation near the specimen surface is indicated by a large black region in the EBSD image. Image analysis was conducted through a collaborative effort between The Ohio State University and the BAM Institute.*

Hardfacing alloy performance is determined in part by the transition of the wear mechanism during increasing load. Metal alloys in unlubricated sliding contact typically undergo adhesive wear with micron-sized particle formation at low to intermediate loads. Above a critical load, however, many metals exhibit a transition to galling, with large surface deformations and bonding, accompanied by significant wear debris, high friction, and eventual seizure. In austenitic hardfacing materials, such as Alloy 6, resistance to galling and sliding wear is a result of a strain-induced martensite phase transformation, which is a consequence of high work hardening at the contact surfaces. In martensitic hardfacing materials, such as Everit 50, the transition to galling can be eliminated as a result of a deformable tribofilm formation due to phase transformations to austenite (i.e., a micron-dimension sacrificial layer). An example of results provided using SEM-EBSD for a button tested to ASTM G98 is shown in Fig. 3. Understanding these fundamental wear mechanisms is vital to the design and optimization of hardfacing materials candidates.

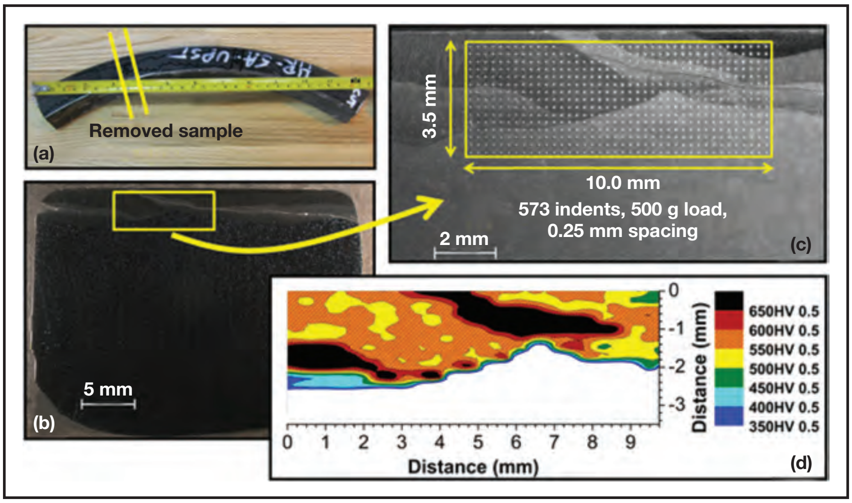

Fig. 4 — *Results of a hardness map (c and d) conducted on a cross-section (b) taken from an out-of-service hot reheat valve seat (a). The hardness values exceed 650 HV 0.5, a significant level as Alloy 6 normally exhibits an as-deposited hardness value of roughly 450 HV 0.5.*

Solutions depend on collaboration

Serious deficiencies exist regarding compatibility of given substrate materials, the butter layer (also known as buffer layer), and the selected hardfacing material for use in cycling fossil applications. Performance inconsistencies, including failure time and crack location, can be partially attributed to the many material combinations already identified, such as: Grade 22 and 91 substrates; 309 stainless steel, Alloy 625 and Alloy 21 butter layers, and Alloy 6 or 21 hardfacing layers. Recent investigations into the failure mode reveal at least two contributing components to the rash of documented failures—a brittle, hard metallurgical phase with little inherent ductility and accumulation of welding residual stresses, which may assist or drive crack initiation and/or propagation in service. Cracking in service follows the hard region highlighted in black (>650 HV 0.5) shown in Fig. 4. Work is currently underway to take advantage of inherent advantages in the PM/HIP process—such as low dilution and no issues regarding weldability—to address and solve issues associated with delamination of hardfacing materials.

To solve some of the industry's most challenging concerns, collaboration among end users, manufacturers, and research organizations must occur. By integrating the efforts of various industry players in mutual research and development, a wide range of research tools, fundamental disciplines, and engineering expertise can help achieve faster and better technology advances. This approach typically results in sound engineering solutions that are more likely to be implemented in the long-term. This is because research results are critically reviewed and, in many cases, an eventual consensus may be reached regarding the best path forward. With this in mind, several key items have been achieved in this project so far, including:

- Identification of wear mechanisms in candidate austenitic materials and martensitic materials for nuclear valve applications.

- Standard methods for examination of tested specimens to ASTM G98 and ASTM G133 to provide quantifiable results. A database of roughly 20 different materials including both commercially available and developmental hardfacing alloys has been assembled.
- Identification of multiple failure modes in cycling, fossil-fired valve applications due to different material combinations.
- Potential solutions to the selection of appropriate butter layer(s) for use in cycling fossil applications were identified using thermodynamic simulations.

Ongoing research provides intriguing results, which may lead to identification of material(s) that will solve issues across the nuclear and fossil industries. The promise of PM/HIP has sparked intrigue in solving material incompatibility issues using a function graded composition controlled (FGCC) methodology to layer or grade between two materials. Further, the ability to deposit materials using this manufacturing process allows optimization of wear behavior as opposed to weldability, for example.

PM/HIP also provides an attractive alternative in the nuclear industry, where difficulties in welding previously developed replacement hardfacing materials (such as NOREM) often result in continued use of the Co-based Alloy 6. In response to the power industry's critical need for improved component life, EPRI research projects—from the fundamental science of wear and galling to practical issues of investigating failed service components—are being conducted to provide both near- and long-term solutions. ❍

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fig. 1

fig. 2

fig. 3

Advanced Elastomers for Deepwater Oil Exploration

Through rigorous testing and qualification, advanced materials enable major oil companies to operate in ever more extreme environments.

The oil and gas industry is focusing on deepwater exploration for developing reserves of natural oil and gas, as "easy" reserves are becoming scarcer. The trend towards deeper, colder, and more extreme environments within recent years is demonstrated by discoveries of mega-fields such as that off the shores of Brazil. According to a report by Douglas-Westwood in 2013, more than \$232 billion will be spent on deepwater projects between now and 2020. Such a substantial investment hints at the anticipated challenges that companies involved in exploration and production expect when accessing oil at depths of anywhere up to 2 miles below sea level.

While the projection highlights the most obvious challenges as financial in nature—such enterprises are more costly than onshore or fixed offshore operations—few alternatives exist. With rapidly emerging economies such as China and India, global energy demand shows no sign of stopping, with oil as the dominant source of power for the near future. The single greatest challenge oil producers face when extracting deepwater oil is not an economic one, but rather a technical hurdle.

The environment of fields found at depths of 1.25 miles and deeper make deploying standard equipment unfeasible. For example, these fields have unusually high levels of CO_2 that can occur in the production stream, which comes out of the reservoir in a super-critical state, at a temperature exceeding 88°F (31°C) and pressure of 74 bar. In this state, the CO_2 exists as a dense phase fluid, displaying characteristics of both liquid and a gas, and poses difficulties for equipment used to transport oil from the well to the surface. Valves and blowout preventers are attacked by super-critical CO_2, but also damagingly high levels of corrosive H_2S found in deepwater environments.

This CO_2 can be useful if injected back into the reservoir to reduce oil viscosity and assist its flow back to the well. Using such full-field subsea separation and boosting and injection systems, the Statoil Hydro-operated Tordis field in the North Sea increased recovery by an extra 35 MMbo (millions of barrels of oil) and extended the life of the field by 15 to 17 years in 2007. At higher temperatures and pressures in deeper water, longstanding issues of corrosion, pressure, and temperature all pose greater problems for compressors and other components.

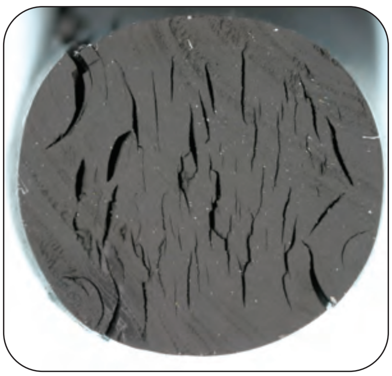

Fig. 1 — *Typical decompression failure of FKM material.*

Fig. 2 — *Super-compressed CO_2 at pressure and temperature surrounding the elastomer during decompression.*

Elastomer selection and qualification

Element Material Technology, St. Paul, Minn., is currently involved in the research, development, and qualification of next-generation materials designed to offset problems posed by deepwater extraction. Elastomers are being considered due to their flexible and pliant nature, which makes them well suited as sealing components. The team was recently approached by a client seeking to operate in a field discovered off the coast of Brazil at a depth of 1.25 miles in order to characterize a range of advanced elastomers.

At this depth, elastomers are more susceptible to chemicals and can become structurally altered. The valves and components are in contact with oil and gas at temperatures of 248°F (120°C) and must contend with high pressures and rapid gas decompression events, so qualification and selection of the best materials for this environment is critical.

Seven well characterized primary products were selected for qualification to deliver optimum performance and to represent the full range of three core varieties of elastomers—hydrogenated nitrile butadiene rubber (HNBR), fluoroelastomer (FKM), and perfluoroelastomer (FFKM). Each elastomer type has particular strengths—FFKM is particularly suited to high temperatures and chemically aggressive environments, while HNBR performs well at lower temperatures. FKM has good resistance to thermal and chemical environments and gas decompression events.

Rapid gas decompression and pressure resistance are primary concerns when selecting a particular elastomer for these components. However advanced the material may be, under pressure and over time, damaging chemical elements such as super-critical CO_2 and H_2S will diffuse into the polymer and permeate through it. If rapidly decompressed, the change in pressure means gases are forced out of the material, potentially causing blistering or cracks as they escape, as seen in Fig. 1. Under constant pressure, fluid diffused into the material can cause swelling and weakening, potentially causing leakage.

To overcome this issue, elastomers are

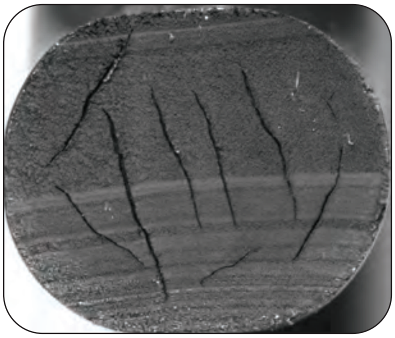

Fig. 3 — *Typical decompression damage to traditional HNBR material.*

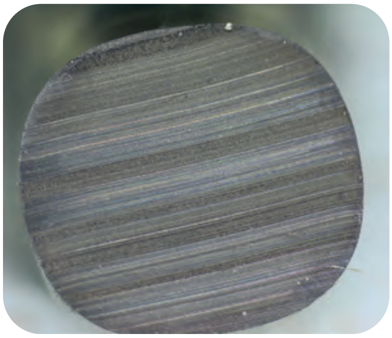

Fig. 4 — *Best modern HNBR after decompression test at identical conditions.*

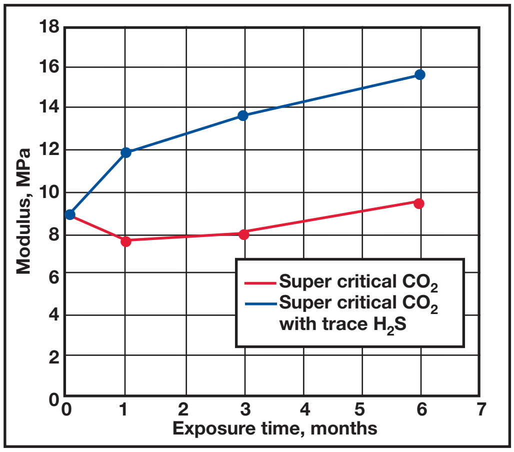

Fig. 5 — *HBNR performance in a gas environment at 167°F (75°C) in 90% CO_2 at 600 bar pressure.*

being produced in grades that are molecularly more robust and reliable. The selected elastomers are relatively new, as the most recent was developed 18 months ago. One particular FFKM was specifically engineered to resist gas decompression, historically a major weakness of this elastomer. The limits of HBNR also have been expanded, with one variety exhibiting unprecedented resistance to high pressure in tests.

Pressure testing elastomers

To qualify and provide accurate, statistical data on these seven elastomers, each was subjected to a variety of tests at specific temperature ranges, pressures, and fluid ratios to simulate existing environmental conditions at the well and to meet the component's required lifetime. Tests covered three areas of interest: Long-term aging, mechanical performance, and rapid gas decompression performance.

An extensive test matrix was conducted during a one-year span. Much effort was dedicated to performance testing, to ensure that each material was capable of withstanding long-term exposure to various fluid chemical elements. Seven high-pressure exposure tests up to 626 bar and 212°F (100°C) were conducted, with multiple combinations of oil, water, CO_2, H_2S, and methane. To perform these high-pressure exposures, bespoke stainless steel pressure vessels designed in-house were used. These have a capacity of approximately 3 liters at 5 cm wall thickness, and enabled testing of each elastomer at the required pressures of nearly 10,000 lb/in^2. Exposure tests monitored swelling, changes in hardness, change in compression set, and tensile properties after 1-, 3-, and 6-month durations.

To qualify the effects of decompression and material performance, each elastomer was also subjected to three, separate rapid decompression test scenarios at 626 bar and 212°F (100°C), which simulates operational deepwater environments. To complement these tests, an innovative pressure system with a custom sapphire-based viewing window was designed. To create a pressurized environment, the ends of a standard pressure vessel are sealed with sapphire windows. The environments can be observed and recorded; various fluids can be pumped into the vessel where a material sample is mounted, to view the seal performance under a wide range of simulated conditions to the point of failure or physical damage. Different swell rates under gas decompression for elastomers being exposed to super-critical CO_2 were recorded (Fig. 2). In addition, the exact point at which material changes occur was charted, delivering previously unobtainable data.

Results and conclusions

The overall outcome was a definitive list that ranked the seven elastomers and identified those best suited for the specific simulated deepwater environment. Two show significantly superior performance results across the testing range and were thus recommended for operational deployment. One HBNR displayed particularly impressive resistance to damage under rapid decompression. When taken as a benchmark, a comparable product tested several years prior suffered noticeable cracks in a cross section of the testing sample (Fig. 3). Under identical conditions and viewed in situ through the sapphire-based window, the best performing modern HBNR is characterized by uniform resistance (Fig. 4).

The operational integrity of this HBNR also remained unaffected by super-critical CO_2. After benchmark performance levels under conditions with heavy levels of both super-critical CO_2 and H_2S, tests were repeated without hydrogen sulphide to determine if the CO_2 produced a negative reaction. While H_2S with super-critical CO_2 has a highly damaging effect over six months as expected, super-critical CO_2 alone caused negligible performance fluctuations (Fig. 5).

Advanced materials, such as these elastomers, give component designers an option over metal-to-metal seals, which do not perform as well and present various challenges. The elastomer performance exhibited during testing positions it as a versatile material, while its inherent flexibility makes it well suited for other offshore technologies, such as bonded hoses that transport oil from ship to ship. Capable of operating at a wide range of temperatures and pressures, the more robust varieties can be formed into larger diameter products that are less likely to fracture when deployed in heavily rolling seas.

At these largely unexplored depths, even a single valve is a critical component that needs to be fully functioning and maintain its integrity for up to 30 years. Advanced materials are enabling the major oil companies to operate at deepwater levels and it is only through rigorous testing and qualification that confidence can be gained in their use. ❒

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Metallurgy Lane

Iron in America: 1645 to 1850

The steel industry of the U.S. rose out of the iron plants of our colonial past. Here we take a brief historical look at the early days of ironmaking.

Metallurgy Lane is a new series authored by ASM life member **Charles R. Simcoe,** developed to share the early history of the U.S. metals and materials industries along with key milestones and developments. Simcoe, a World War II veteran, holds a degree in metallurgical engineering from Purdue University and spent his career in physical metallurgy R&D at Westinghouse Atomic Power Division, Battelle Memorial Institute, Armour Research Foundation, and Simonds Steel Co.

Ironmaking commenced in the British Colonies as early as 1645 at the Saugus Iron Works in Massachusetts, although the effort was never financially successful and closed in 1676. The site is now completely restored in tribute to America's industrial heritage. A more successful metals operation was the Raynham Forge Plant near Taunton, Mass., which opened in 1656 and operated until 1880.

Other early furnaces were built at Braintree, Mass., in 1648 and at New Haven, Conn., in 1658. In 1716, Thomas Rutter built a bloomery forge to make wrought iron in Berks County, Pa., and in 1720, constructed the Colebrookdale Blast Furnace. Anthony Morris later built the famous Durham Furnace and Ironworks near Easton, Pa., on the Delaware River.

Early pioneers make headway

Another early iron pioneer was Peter Grubb, who discovered the iron ore deposit where he located the famous Cornwall Iron Mine in 1736. This open-pit mine became the largest source of iron ore in America until the debut of the great ore deposits of Michigan and Minnesota more than a century later. Grubb built the Cornwall Iron Furnace and the town of Cornwall itself for housing his Welsh workers in 1742, naming the town in honor of his father's English birthplace. Between these very early iron plants and the time of the Revolutionary War, ironmaking spread to many of the New England Colonies.

Wherever bog iron ore or other iron-bearing minerals were found in conjunction with plentiful supplies of wood for charcoal, iron could be made, provided either a local population or water transportation to a ready market was also available. Ironmaking spread to New Jersey by 1710, with later operations at Oxford Furnace (1741-1882) and at the Pine Barrens in southern New Jersey where the 20,000-acre Martha Furnace operated as one of the biggest facilities ever constructed. Prior to the war, Peter Hasenclever's Long Pond Ironworks was one of the largest such investments at approximately $250,000.

The Principio plant in Maryland was another substantial operation. At the time of its 1751 debut, it boasted four blast furnaces and two forges, with timber covering 30,000 acres. Principio was destroyed by the British Army in 1777, rebuilt for the war of 1812, and then destroyed by the British a second time. In 1836, the Whitaker brothers acquired it and restored it once again. The Principio Co. was absorbed into Wheeling Steel Co. in 1920.

Ironmaking expands into Pennsylvania and beyond

Pennsylvania had become the major iron-producing region by the time of the Revolutionary War. The availability of ore, wood for charcoal, limestone for flux, and the major waterways of the Susquehanna, Schuylkill, and the Lehigh-Delaware Rivers and their tributaries kept this region productive until—as happened earlier in England—wood for charcoal became scarce. These iron plantations produced from a few hundred tons to as much as 1000 tons, resulting in the ironmakers of colonial America turning out approximately 30,000 tons of iron in 1775 alone.

The furnace at Saugus Iron Works, Mass., circa 1645. Courtesy of John Phelan.

Early cooking implements from colonial New Hampshire. Courtesy of www.cowhampshireblog.com.

A cast iron stove plate made at Colebrookdale Furnace, Pa., circa 1765. Courtesy of the State Museum of Pennsylvania.

Peter Hasenclever's Long Pond Ironworks, N.J., a furnace from the Civil War era. Courtesy of KForce at en.wikipedia.

Iron production in the new United States increased from these 30,000 tons at the beginning of the American Revolution to 54,000 tons from 153 furnaces by the 1810 census. The slow growth was largely due to a general lack of industrialization in America: Per capita iron consumption hardly changed in this 35-year span. Another factor keeping growth in check was the relatively inexpensive iron imported from England. It was cheaper to make iron from coke in Britain and ship it to major East Coast port cities than to continue using charcoal in the inland U.S. plantations and then transporting finished iron to growing population centers.

Philadelphia and the canal systems

The beginnings of a solution to the English import problem came about because the city of Philadelphia was desperately seeking a way to prevent the influx of farm products and manufactured goods from areas north and west of the city using the Susquehanna River to ship from Baltimore. Philadelphia was the largest port in the new U.S. and its politicians were battling to maintain this position against New York City and nearby Baltimore. Top priority was to capture the local trade leaking out to Baltimore and to transport energy resources from the new anthracite coal mines from the region in Pennsylvania's northeastern corner to metropolitan areas along the coast. The only solution to bulk transportation at this point was by water. While there were many natural streams in this corner of Pennsylvania, they contained numerous obstacles to navigation. This meant building canals.

Canals were not new to America, as they had been dug in New England with some effectiveness. With the successful attempt to build one across upstate New York all the way to Lake Erie, a project just coming to completion in the mid-1820s, many attempts were undertaken to build them throughout the country. One of the most profitable was the Delaware and Hudson Canal, built with private capital.

This canal system was masterminded by three brothers by the name of Wurts, who had tied their future to that of the anthracite coalfields behind Moosic Mountain in the Scranton, Pa., area. Yet two major problems existed—finding a way to get the coal out of the wilderness of Northeast Pa. and down to the cities on the coast, especially New York, and convincing people that anthracite coal (known as stone coal) was an acceptable fuel. The Wurts brothers believed if they could get the coal to New York at a reasonable cost, its value would soon sell itself, a belief shared by their ally Philip Hone, then mayor of New York City.

Technical expertise for the project came from Benjamin Wright, chief engineer of the Erie Canal. The logical route for the new canal was across the Delaware River into New York, northeast up the valleys west of the Shawangunk Mountains, down Rondout Creek to Kingston, New York, and then through the Hudson River. It was a natural waterway, even though it meant the canal went northeast when New York City was southeast.

Other canals were built on the Susquehanna, Schuylkill, Lehigh, and Delaware Rivers. The Union Canal system linked the Susquehanna and the Schuylkill with the coal fields above Reading, Pa. With the sudden availability of anthracite coal in Southeastern Pa., the ironmasters soon learned to adapt it to their blast furnaces. The hard coal did not have to be processed to coke and was usable directly from the mine. Just as coke had revived the British iron industry a century earlier, anthracite coal accomplished the same result for the iron industry in Southeastern Pa. The industry had been in a long period of decline because it was running out of wood. This strategy of improved water transportation with the fortuitous application of anthracite coal in ironmaking worked sufficiently well to allow this region to become the first major iron producer in America.

The passage of a half-century and a Civil War would occur before Pittsburgh would replace Philadelphia as the leader in ironmaking. During this time, Philadelphia would begin manufacturing the mill machinery and building the factories for products made of iron, thereby serving as a major incubator for the American Industrial Revolution.

When the Erie Canal was funded in 1817, Benjamin Wright became the chief engineer who directed the successful completion of the greatest artificial waterway in the world. Courtesy of Francis Delafield Wright III; www.marblecemetery.org.

For more information: Charles R. Simcoe can be reached at crsimcoe@yahoo.com. For more metallurgical history, visit www.metals-history.blogspot.com.

The Materials Information Society

ASM's Progress Report to the Membership

ASM's Leadership meets annually to review and discuss our organization's strategic direction. In our strategic planning sessions held this past summer, the leadership validated our mission, vision and core values as well as our value proposition, which states:

ASM serves materials professionals, nontechnical personnel and managers worldwide by providing high-quality materials information, education and training, networking opportunities, and professional development resources in cost-effective and user-friendly formats. ASM is where materials users, producers, and manufacturers converge to do business.

Despite the challenges of a rapidly changing marketplace, economic and political uncertainty, ASM's Leadership affirmed that the organization today stands as a one-of-a-kind world class Materials Information Society dedicated to the professional advancement of its members and the materials community. We also believe that there is more to do to enhance our offerings.

New Initiatives That Engage

Although our core focus will not change... We have designated additional priorities for 2014. Among them is more deeply engaging with our members and steering our organization around their aspirations. We will talk to our members about the kind of ASM they would like, and what more we can do to help them advance in their careers. We believe this will be particularly valuable to our younger members who hold the future to our organization. That's why we are excited to report ASM will be placing added emphasis on serving and activating students.

We are currently looking at new ways to better link high school and college students with our local chapters, create more student-focused communications, leverage our members who are interested in mentoring younger people and better connect industry to student talent. Serving the unique needs and expectations of this next generation of ASM members is vital to our continued relevance and value to the materials science community in the years ahead.

In addition to ASM's critical issues of Life-Long Learning and Education, Content Is Everything Material, Emerging Technologies and Volunteerism, we are pleased to announce that we have added Branding as a fifth critical issue. We are currently in the process of a re-branding initiative, which will be instrumental in better informing members and the public of ASM, including opportunities for: professional development, access to information and problem solving via networking, and the value we provide for employers. In the coming year we will be happy to share developments around our updated brand with you.

Community is our most important strategy.

In this amazing age of escalating technology, it's all the more critical that ASM place great emphasis on its human side - we are a community. Nothing beats the person-to-person relationships that we foster - between teachers and students, between volunteers and beneficiaries, between suppliers and customers. What greater purpose can we embrace than to connect people who have so much to give with those hungry to experience more? Igniting and building relationships is what ASM is all about.

In the years ahead, we ask all members to do their part to nurture this special community of ours. Help ensure that a growing diversity of ASM constituents can be brought together to reach for the most aspirational of goals. Achieving ASM's own strategic goals depends on it! Join us in reaching out, connecting, collaborating and, in turn, elevating the global value of our materials science community. Together, we all stand to benefit.

Prof. C. Ravi Ravindran, FASM
President 2013-2014

Thomas S. Passek
Managing Director

ASM's Five Critical Issues:

Life-Long Learning and Education

Life-Long Learning and Education help materials professionals remain technically current so that they may advance their careers at any point in the professional life cycle and contribute to the continued growth and sustainability of the materials community.

Content is Everything Material

ASM International has a strong history as a resource for high-quality materials science and engineering content. Most of this content is created through a framework that enables members and volunteers to capture and share their knowledge and expertise. ASM also has strategic partnerships with other organizations to increase its content assets, which are available to the greater materials community.

With advances in web infrastructure and online networks, and based on ASM's work to create a strong technology environment, ASM has the opportunity to further expand its position to provide content assets that are "Everything Material."

Emerging Technologies

To keep up with the changing needs of our members and other professionals, we have identified materials-related areas where rapid changes and developments are taking place, and we are working to disseminate authoritative and useful knowledge related to these technologies.

Volunteerism

Volunteers provide the energy that propels ASM at the chapter level as well as the national level. Not only are volunteers the leaders of our society, they are the foundation for developing new content, products and services that our members and customers need and value. As with all volunteer-driven organizations, we face challenges in bringing new volunteers to our society and our chapters — challenges that involve not only attracting new volunteers, but also helping them stay motivated and connected, and feeling appreciated for their contributions.

The achievement of our long-term goals can only be realized through teamwork that includes ongoing member participation through ASM Chapters, Committees, and Affiliate Societies, partnering with ASM staff to develop programs, products, and services that add value to the materials community.

Branding

ASM has a broad and diverse membership, affiliated groups, and product mix. This has led to a lack of clarity and understanding of the society's value and relevance.

We are working to identify our key differentiating factors and improve how we deliver and communicate their value to the materials community. We will align our communities and build a brand platform that defines our organization's attributes, values and behaviors.

2013-2014 ASM Board of Trustees

2013-2014 President of ASM International

C. (Ravi) Ravindran

Dr. Jack G. Simon, FASM
President, Technology Access Inc.
Aiken, S.C.

It is with great pleasure that I introduce ASM International's 2013-2014 president, Professor Comondore (Ravi) Ravindran. I have known Ravi for 32 years, so I have a lot to tell you about our new leader.

Personal

My last visit to Ryerson University, Toronto, was in September 2013. Once again I was struck by the love and devotion everyone at Ryerson has for Ravi. It begins with the person who sells him a cup of coffee and continues with his students, dean, and university president. This is what ASM International can expect from its next leader. Ravi is not a showy person, but will listen effectively, help create a vision, and then develop a plan to execute it. He is both a consensus builder and a strong motivator.

I also know that Ravi would tell you that the honor he is most proud of is being husband to his wife Shanti and father to his three children, Nikila, Vikram, and Shobita. Nikila is a gastroenterologist, Vikram a pulmonologist, and Shobita a lawyer. I have watched Ravi and Shanti raise their children and it is no surprise that he has motivated them to excel and be successful.

Ravi Ravindran, ASM International's 2013-2014 president.

"If you want a job done, engage Ravi and it will be done right and with a lot of enthusiasm."

Education and training

Born in India, Ravi received his early training in materials science at the University of Madras and the Indian Institute of Science and earned his master's and doctorate from the University of Manitoba. Ravi has not forgotten his early roots and has done much to help advance ASM International in India, Canada, America, Europe, and Asia.

In 1973, Ravi began his career as a product and process development metallurgist with Manitoba Steel Rolling Mills. Early on, he became chief engineer and in 1982 was promoted to chief metallurgist. In 1985, he became group vice president of Galtaco Automotive Castings and Stampings Corp. with major foundries in Ontario and a large stamping plant in Michigan. In 1989, he joined the faculty of Ryerson University. Ravi brings 16 years of industry experience and 25 years of academic experience to his role as ASM president.

Service to ASM and the materials community

Ravi and I first met at the ASM International Materials Week technical conferences held at numerous venues in the U.S. and Canada. We found we had much in common as I had just taken over the job of divisional metallurgist of the Buick Motor Division of General Motors after serving for several years as chief metallurgist for Chevrolet's metal casting plants. Ravi invited me to Ryerson to discuss his vision to form a Center for Near-Net Shape Processing of Materials.

One can look back today and congratulate Ravi on the success of this center in advancing research on lightweight metals processing. The center first began research in lost foam metal casting of nodular iron, then in casting of thin wall aluminum, and is now investigating magnesium alloys. What many people may not know is that Ryerson had little research going on when Ravi was hired. Today, the university thrives due to the external research it conducts. Ravi had the vision and used his unique abilities as a consensus builder to get approval for his center. In addition, he has developed many international partnerships and has been able to attract distinguished visitors and support several foreign students earning advanced degrees.

Pictured left to right, Shobita Ravindran, Dr. Nikila Ravindran, Ravi, Mrs. Shanti Ravindran, and Dr. Vikram Comondore.

Excellence

Ryerson University awarded Ravi the 2012 Chancellor's Award of Distinction for sustained teaching and educational leadership, the university's top award. Previously, he was awarded the University Distinguished Scholar Award for research excellence in 1995. Ravi also served as president of the Canadian Academy of Engineering during 2007-2008 and was co-general chair of the International Council of Academies of Engineering and Technological Sciences in 2009. He has won numerous awards, including the 2013 CIM-MetSoc Research Excellence Award, and his research center received the AFS Outstanding Organization Award for Excellence in Magnesium Research in 2009.

As a Fellow of many societies including ASM, CAE, CIM, INAE, AAAS, and Engineers Canada, Ravi has shared his research by presenting technical papers at major international conferences. When I visit ASM Canadian chapters, they refer to him as "Mr. ASM of Canada." ASM has also honored Ravi with the Allan Ray Putnam Award in 2006, the M. Brian Ives ASM Canada Council Lectureship in 2004, and the MacDonald Young Award in 1995.

I have visited Ravi several times and have observed him closely for more than 30 years. My first impression was that of a humble, sincere man who got things done. He has extraordinary personal skills and is always positive, supportive, considerate, and upbeat, and is a good listener as well. He does not hesitate to encourage people to look in different dimensions for the overall benefit of the community. If you want a job done, engage Ravi and it will be done right and with a lot of enthusiasm.

As an example, Al Romig and I were forming ASM Materials Camps throughout the U.S. and asked for Ravi's help to establish one in Canada. Ravi jumped right in and formed the first Canadian Materials Camp and served as its chairman. With his leadership, our camp programs have now grown throughout Canada and India as well. I had the same experience while reviving the Alpha Sigma Mu International Honor Society for Materials Science and Engineering. We were international in name only, had declined as an organization, and were on the verge of disbanding. I called on Ravi and he formed an Alpha Sigma Mu Chapter at Ryerson and I was privileged to be present when we inducted the first student members. Alpha Sigma Mu is now thriving under Dr. Fred Schmidt's leadership, but it took Ravi to get Canada involved.

Ravi's passion is in teaching materials science and engineering. He engages his students every day and builds complex ideas from fundamentals step-by-step, explaining concepts and relationships and also sharing his industrial experience. This passion and "real world" industry knowledge will help Ravi lead ASM International in the coming year and his enthusiasm will be contagious.

Vision

Ravi brings a unique combination of senior management experience in industry and leadership in research and teaching in academia. He is committed to using e-technology for quality and delivery of services to our members and customers. He believes that ASM must ensure currency and relevancy in content, strategic updating of information and delivery systems, and sound financial management. He is committed to exceptional member service and values volunteers as pillars of our society. He feels that almost everything we offer is due to our volunteers, with the trustees, management, and staff as enablers.

With a dramatic decline in membership reflecting the trend in professional societies in general, Ravi is committed to exceeding the aspirations of members. He proposes to establish two types of memberships—a traditional membership and an electronic membership for those who prefer electronic networking, free webinars, and web-based downloads onto computers or devices. He thinks of our chapters as individual marketplaces, each with its own technical focus and distinct from one region to another.

Ravi feels that ASM needs to establish and fortify a strong position as the gateway, keystone, and clearinghouse for materials information. Indeed, he is committed to making our products readily accessible according to the latest speed-of-life standards. He is also dedicated to the idea of creating a key portal system to enable online links and access to government standards and sister societies and to expanding ASM's materials information resources and online databases to include new advances and technologies.

For Ravi, one priority dear to his heart is developing students as future members and leaders of ASM. For the past 25 years, engineering students have been his extended family. He has nurtured student participation on the Board and encouraged them to actively participate in ASM Materials Camps. He proposes the creation of a Materials Camp Alumni Portal, allowing alums to remain connected with peer groups as they emerge as ASM members. Ravi believes that chapters can also take this up at the grassroots level through science fairs and a "Materials Day" where volunteers promote the importance of materials to society. He also proposes more active roles for the Foundation, chapters, and the Alpha Sigma Mu Honor Society in enabling internships, co-op placements, and jobs with direct mutual access for employees and students in a materials opportunities e-platform.

Ravi is delighted that the 2013 MS&T mega-conference in Montreal reinforced ASM's leadership in joint programming with sister and affiliate societies in delivering new and advanced developments to larger audiences. He proposes that besides large conferences, ASM consider periodic programming with related societies such as ASME and ASCE to deliver programs that transgress boundaries and espouse commonalities of knowledge in materials science and engineering.

We are fortunate to have Ravi at the helm of ASM International during revolutionary changes in information technology and continued global economic upheavals. He will represent all ASM members worldwide with the same effectiveness he has demonstrated as a father, husband, teacher, researcher, and leader. Let us congratulate Ravi and join him as he moves forward in his vision for ASM. ❍

Ravi and Detroit Chapter chair Susan Hartfield-Wunsch celebrate ASM's 100th anniversary.

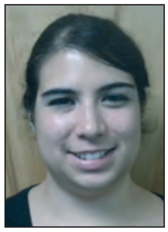
Maxwell Kellogg of Cal Poly San Luis Obispo receives a $2500 scholarship check from (left to right) Chuck Daugherty and Dick Berryman, of the Los Angeles Chapter, and Ravi.

"Ravi is dedicated to the idea of a key portal system to enable online links and access to government standards and sister societies, and to expanding ASM's materials information resources and online databases."

President Ravindran Appoints Committee Council Chairs

ASM International President C. Ravi Ravindran, FASM, appointed a chair to each of the society's general committees and councils. All appointments were unanimously approved by the Board of Trustees. Terms began September 1, 2013. Congratulations to all of our ASM International leaders!


Asphahani

Bartolo

Black

Boardman

Boyette

Brochu

Bush

Camponeschi

Chawla

Cherolis

Colins

Epler

Freed

Fulton

Grice

Committee/Council chairs include:

Dr. Aziz I. Asphahani, FASM, chief executive officer, QuesTek, was appointed chair of the Investment & ASM Materials Education Foundation Investment Committee.

Prof. Laura Bartolo, professor, Kent State University, continues as chair of the Materials Property Database Committee.

Ms. Amber Black, applications engineer, PTR-Precision Technologies Inc., was appointed chair of the Volunteerism Committee.

Mr. Bruce Boardman, FASM, manager, materials engineering, John Deere (retired), continues as the chair of the New Products and Services Committee.

Mr. Brian Boyette, senior materials engineer, NAVAIR FRC East, was appointed chair of the Aeromat Organizing Committee.

Dr. Mathieu Brochu, professor, McGill University, continues as the chair of the Canada Council.

Ms. Margaret Bush, senior materials engineer, Medtronic, was appointed chair of the Technical Books Committee.

Dr. Erin L. Camponeschi, materials quality engineer, Cabot Microelectronics Corp., continues as co-chair of the Emerging Professionals Committee.

Prof. Krishan K. Chawla, FASM, professor, University of Alabama at Birmingham, continues as chair of the *International Materials Review* Committee.

Mr. Nicholas E. Cherolis, technical leader of failure analysis, Rolls Royce Corp., was appointed chair of the Failure Analysis Committee.

Dr. Sunniva R. Collins, FASM, visiting associate professor, Case Western Reserve University, continues as chair of the Awards Policy Committee.

Dr. Mario E. Epler, manager, Alloy and Process Modeling, Carpenter Technology Corp. was appointed chair of the *AM&P* Editorial Committee.

Continued on next page

...in this issue

ASM International
The Materials Information Society

Submit news of ASM and its members, chapters, and affiliate societies to
Joanne Miller, editor, *ASM News* • ASM International, 9639 Kinsman Road, Materials Park, OH 44073
tel: 440/338-5151, ext. 5662 **fax:** 440/338-4634 **e-mail:** joanne.miller@asminternational.org
Contact ASM International at 9639 Kinsman Road, Materials Park, OH 44073 **tel:** 440/338-5151, ext. 0, or 800/336-5152, ext. 0 *(toll free in U.S. and Canada)* **fax:** 440/338-4634 **e-mail:** MemberServiceCenter@asminternational.org **website:** www.asminternational.org

Dr. Robert L. Freed, senior consultant, DuPont Co., continues as chair of the Education Committee.

Mr. Robert J. Fulton, FASM, president, Hoeganaes Corp. (retired), continues as treasurer and chair of the Finance Committee.

Mr. Daniel R. Grice, manager, metallurgical services, IMR Test Labs, was appointed chair of the Emerging Professionals Committee.


Jamuar


Knight


Maldonado


Mansuetti


Narayan


Newkirk


Petrova


Raj


Taylor


Turchi


Winnicka


Wong

Mr. Jayant Jamuar, technical director, Kadyani Forge Ltd., was appointed chair of the India Council.

Dr. Richard Knight, FASM, professor of materials engineering, Drexel University, continues as chair of the College & University Committee.

Dr. Julio G. Maldonado, advising materials engineer, Chevron Energy Technology, Ltd., continues as chair of the Action in Education Committee.

Ms. Sarah L. Mansuetti, director of quality assurance, Rex Heat Treat, was appointed chair of the Web Committee.

Prof. Roger J. Narayan, FASM, UNC-NCSU-Dept. of Biomed Eng., was appointed chair of the Emerging Technologies Committee.

Dr. Joseph W. Newkirk, associate professor, Missouri University of Science and Technology, continues as chair of the Handbook Committee.

Dr. Roumiana Petrova, senior university lecturer, New Jersey Institute of Technology, was appointed chair of the ASM & MS&T Programming Committee.

Dr. S.V. Raj, FASM, materials research engineer, NASA Glenn Research Center, continues as chair of the *Journal of Materials Engineering & Performance* Committee.

Dr. Douglas J. Taylor, senior scientist, TPL Inc., was appointed chair of the Membership Committee.

Dr. Patrice Turchi, group leader, Lawrence Livermore National Laboratory, continues as chair of the Alloy Phase Diagram Committee.

Dr. Maria B. Winnicka, engineer, H.C. Starck Inc., was appointed chair of the Chapter Council.

Mr. Terry Wong, principal engineer, Rocketdyne, was appointed chair of the Content Committee.

ASM International 100th ANNIVERSARY 1913-2013

Award Deadline – February 1, 2014

ASM International has recognized the achievements of individuals and organizations that contribute to materials science and engineering for more than 90 years. Continue this great tradition by nominating candidates for ASM Awards. We especially look forward to nominations for Honorary Membership, J. Willard Gibbs, Historical Landmark, William Hunt Eisenman, and Medal for the Advancement of Research awards. Theses distinguished awards will be presented during MS&T'14 inPittsburgh in October 2014.

Deadline: February 1
Edward DeMille Campbell Memorial Lecturer
★Distinguished Life Membership
★ William Hunt Eisenman Award
Gold Medal
★Historical Landmarks
★Honorary Membership
★Medal For The Advancement Of Research
Allan Ray Putnam Service Award
Albert Sauveur Achievement Award
Albert Easton White Distinguished Teachers Award
★J. Willard Gibbs Phase Equilibria Award
Silver Medal Award

Deadline: March 1
Bradley Stoughton Award For Young Teachers

Deadline: March 15
Engineering Materials Achievement Award – EMAA

Deadline: April 1
International Student Paper Contest

Nomination Forms, Rules and Past Recipient Lists can be found at: www.asminternational.org
For more information contact Christine Hoover, Awards Administrator at christine.hoover@asminternational.org or 440/338-5151, ext. 5509.

ASM Board of Trustee Nominations

There has never been a more exciting time to become a nominee for vice president or trustee of ASM International! The society's 2015 vice president and trustee elects will be a voice for the membership and shape ASM's future through leadership and implementation of the ASM Strategic Plan. Those nominated and elected will become an integral part of the Board of Trustees, which includes three student members.

Qualifications: Requires an understanding of ASM's activities and objectives on a local, society, and international level, as well as issues and opportunities that the society will face in the next few years; general knowledge of international trends in the engineered materials industry and profession is also necessary.

Duties: Board members undertake various assignments (as individuals or on subcommittees) during intervals between regular meetings. Trustees also make chapter visits and serve as board liaisons to ASM's various committees and councils to provide guidance in accordance with the Strategic Plan. Responsibilities require initiative, judgment, and knowledge of current activities in the engineered materials field.

Guidelines: Nominees for vice president must have previously served on the ASM Board, and those selected as trustees should be capable of assuming the ASM presidency. Finally, members selected to serve on the board will represent all of ASM, not solely their respective chapters, affiliate societies, or geographic areas, and must use prudent judgment when considering issues affecting society activities.

Deadline for nominations is **March 15, 2014**. For more information, visit www.asminternational.org, or contact Leslie Taylor at 440/338-5151 ext. 5500 or leslie.taylor@asminternational.org.

Nominations Now Being Accepted for **ASM Thermal Spray Society Board**

The terms of two current members of the ASM Thermal Spray Society Board will expire in October 2014. The ASM TSS Nominating Committee is currently seeking nominations to fill these positions.

In accordance with the TSS Rules for Governance, the Nominating Committee is particularly seeking nominees for vice president and one director from all segments of the thermal spray community.

Nominees must be a member of the ASM Thermal Spray Society and must be endorsed by five TSS members. Board members whose terms are expiring may be eligible for nomination and possible reelection on an equal basis with any other nominee. Nominations must be received no later than **March 1, 2014.**

A nomination form can be obtained via the ASM TSS website at http://tss.asminternational.org. If you have questions, contact Charles M. Kay, ASM TSS Nominating Committee Chair, at cmkay@asbindustries.com.

HTS Seeks Young Professional for Board Position

The ASM Heat Treating Society Board is seeking a qualified individual to fill the Young Professional Board Member position. HTS values the input and participation of young people at all levels of activity and wants to hear more of what the next generation has to say and contribute.

Young professionals must be within 10 years of graduation, have an interest in the field of heat treating, and be a member of ASM or ASM-HTS. This nonrenewable, one-year term as a voting member of the HTS Board begins in September 2014. The Young Professional Board member must attend two regularly scheduled HTS Board meetings (to be financially supported by their company) and participate in four regularly scheduled teleconferences. **Application deadline is Feb. 1, 2014**.

For more information and details on how to apply, visit http://hts.asminternational.org and click on Membership and Networking, and then Board Nominations.

2014 Bradley Stoughton Award for Young Teachers

Winner receives $3000 • Deadline March 1, 2014

This award recognizes excellence in young teachers in the field of materials science, materials engineering, design, and processing.

Do you know a colleague who:

- Is a teacher of materials science, materials engineering, design, and processing
- Has the ability to impart knowledge and enthusiasm to students
- Is 35 years of age or younger by **May 15** of the year in which the award is made
- Is an ASM Member

Visit the ASM website at www.asminternational.org for complete rules and nomination forms.

Heat Treating Society Seeks Board Nominations

The ASM HTS Awards and Nominations Committee is seeking nominations for three directors.

Candidates must be an HTS member in good standing. Nominations may be submitted by a chapter, council, committee, HTS member, or affiliate society. The HTS Nominating Committee may consider any HTS member, even those who have previously served on the HTS Board. **Nominations are due March 1, 2014.**

For more information and to access the nomination form, visit http://hts.asminternational.org and click on Membership and Networking and then Board Nominations; or contact Sarina Pastoric at 440/338-5151 ext. 5513 or sarina.pastoric@asminternational.org.

President Ravindran Dedicates **100th Anniversary Plaque**

ASM president Ravi Ravindran, FASM, visited the ASM headquarters on December 5, 2013, to share a festive holiday meal with the ASM staff, unveil a new plaque to commemorate ASM's 100th Anniversary, and raise a toast to this significant milestone. ASM vice president **Sunniva Collins, FASM,** attended the celebration, as well.

In an address to the staff, President Ravindran reflected on ASM's influence and expanse over the past 100 years, citing the growth of chapters, our involvement with more materials, and ever changing technologies. He stated that "our assets are people" including our membership, volunteers, board, and staff. Ravindran dedicated the new plaque to our founding fathers, William Park Woodside and William Hunt Eisenman, and the ASMers of the next century.

ASM president Ravi Ravindran, FASM unveiled a new plaque that reads: *1913-2013 Commemorating 100 Years of ASM….Informing, Educating and Connecting the Materials Community to solve problems and stimulate innovation around the world. From the four corners of the earth, our members show that when you strive to be better, everything around you becomes better too. Look around you…Materials are everywhere.*

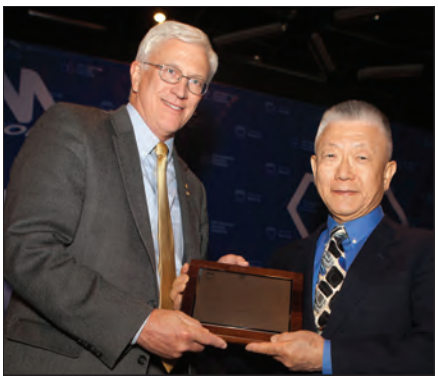
Muzyka Earns **Roberts Award**

The ASM Materials Education Foundation honored **Donald R. Muzyka, FASM,** a native of Northampton, Mass., with the 2013 George A. Roberts award for "making a significant impact to reach students and teachers, in efforts to increase awareness of materials and applied science careers." The award was presented in Montréal during MS&T'13.

Muzyka has a Ph.D. in materials science from Dartmouth College and is the retired President and CEO of Special Metals Inc. He spent his 42-year career developing and producing high performance metals and alloys for numerous applications. An active member of ASM, he joined in 1963 and served as ASM president in 2003. Don joined the Board of the ASM Materials Education Foundation in 2000 and has served as a trustee and treasurer.

During the past 14 years, nearly 10,000 high school students and 5,600 teachers have attended the Materials Camps sponsored by the ASM Foundation.

For more information on the camps, contact jeane.deatherage@asminternational.org or visit www.asminternational.org, and select ASM Foundation.



JFAP **Best Paper Award** presented at MS&T'13

Michael Stevenson, editor of the *Journal of Failure Analysis and Prevention* (*JFAP*), announced that the *JFAP* Volume 12 Best Paper is "Replaying the Fracture Process of a Failed Space Shuttle Orbiter Thruster" by **Takao Kobayashi, Donald Shockey,** and **Jeremy Jacobs.** The winning article was published in the December 2012 issue. The award includes a plaque and $1000 worth of ASM products and services.

Gern Maurer, ASM outgoing president (left), presented the Volume 12 JFAP Best Paper Award to Takao Kobayashi (right) on October 28 during MS&T'13 in Montréal.

Prof. Zi-Kui Liu, FASM, Receives **2014 J. Willard Gibbs Phase Equilibria Award**

ASM is pleased to announce that **Prof. Zi-Kui Liu, FASM and ASM trustee,** professor of Materials Science and Engineering, The Pennsylvania State University, University Park, Pa., is the 2014 J. Williard Gibbs Phase Equilibria Award recipient. He is cited "for his contributions in computational thermodynamics through integrated first-principles calculations and the CALPHAD method and for the advancement of phase-equilibria theory, database development, materials design, and promotion of thermodynamics."

The Gibbs Award was established in 2007 to recognize outstanding contributions to the field of phase equilibria. The award honors J. Willard Gibbs, one of America's greatest theoretical scientists.

In addition to many other contributions, Gibbs laid the thermodynamics foundations of phase equilibria with his brilliant essay, "On the Equilibrium of Heterogeneous Substances," published in 1876 and in 1878 in the *Transactions of the Connecticut Academy*.

Prof. Liu will receive his award at MS&T'14 in October 2014 in Pittsburgh.

IMS Joins ASM, HTS and TSS In Seeking **Student Board Member Applications**

We're looking for Material Advantage student members to provide insights and ideas to the ASM, HTS, TSS and IMS Boards!

We are pleased to announce the continuation and expansion of our successful Student Board Member Programs. In addition to ASM, HTS and TSS, IMS is also seeking Student Board Members. Each Society values the input and participation of students and is looking for their insights and ideas.

An Opportunity like No Other!

- All expenses to attend meetings paid for by the respective Society
- Take an active role in shaping the future of your professional Society
- Actively participate in your professional Society's Board meetings
- Gain leadership skills to enhance your career
- Add a unique experience to your resume
- Represent Material Advantage and speak on behalf of students
- Work with leading professionals in the field

Opportunities Specific to each Society:

ASM International
- Attend three (3) Board meetings (June 16-18, 2014, October 12-15, 2014, and February/March 2015)
- Term begins June 2014

ASM Heat Treating Society
- Attend two (2) Board meetings (October 2014 and Spring 2015)
- Participate in four (4) teleconferences
- Term begins September 2014

ASM Thermal Spray Society
- Attend one (1) Board meeting in October 2014
- Participate in two (2) teleconferences
- Receive a one-year complimentary membership in Material Advantage
- Term begins October 2014

International Metallographic Society
- Participate in monthly teleconferences
- Attend one (1) Board Meeting (August 2-6, 2015)
- Term begins August 2014

Technical Books: **Call for Proposals**

ASM is a leading publisher of technical references and has a worldwide reputation for quality and excellence in its publications, with 100 years of experience in publishing materials information.

We are seeking proposals from authors for books on topics related to the selection, processing, evaluation, and application of engineering and scientific materials. We are especially interested in manuscripts that are practical in nature and offer readers hands-on guidance.

ASM has extensive marketing access and promotes its publications to approximately 1.8 million materials professionals, as well as to libraries and other institutions in North America and worldwide. Books are also available in eBook format.

Share your knowledge and expertise, serve your profession, create an information resource, and enhance your professional reputation by publishing with ASM!

Please contact: Karen Marken, senior managing editor, Reference Content, at 440/338-5151 ext. 5545 or email karen.marken@asminternational.org.

ASM 100th Anniversary Photos on Facebook

See photos from the annual ASM Award Dinner that recognized and honored many ASM dignitaries and an album from ASM's 100th Anniversary Gala now on ASM's facebook page. Visit www.facebook.com/asminternational.

For information on upcoming ASM Courses, contact Liz Halderman, ASM Lifelong Learning Representative at liz.halderman@asminternational.org.

ASM International — The Materials Information Society — **Emerging Professionals**

Are you an Emerging Professional and a dedicated volunteer within ASM International?

Do you know an Emerging Professional deserving of recognition?

Apply for the Emerging Professional Achievement Award

The Emerging Professional Achievement Award was introduced to honor individuals in our society who make an impact on ASM International shortly after graduation from school. The Emerging Professionals Committee would like to invite you to nominate an outstanding member of your chapter who has completed their degree (either baccalaureate or post-baccalaureate) within the last 0-5 years. The link to the rules and nomination form is listed below.

Nominations are due by February 1.

View the award rules and nomination form – www.asminternational.org

Members in the News

Olson Elected to Royal Swedish Academy

Greg Olson and daughter Elise are received by the Royal Family in Sweden.

Gregory P. Olson, FASM, QuesTek Innovation LLC's chief science officer and company co-founder, was elected to the Royal Swedish Academy of Engineering Services as a foreign associate. He was honored at their Annual Meeting on October 25, 2013, which culminated with a banquet in Stockholm City Hall, where Dr. Olson and his daughter were received by the Royal Family. The individuals who comprise the Academy serve as advisors to the EU commission, while also partaking in projects and studies that convey the potential of technology in solving societal and economic problems. Olson served on an advisory board for the KTH Royal Institute of Technology, Stockholm, regarding the future of their materials research platform, and expects to continue providing his expertise on similar IVA advisory committees for materials-related solutions. He is a Walter P. Murphy Professor of Materials Science and Engineering at Northwestern University.

Chou Receives Nadai Medal

On November 20, **Tsu-Wei Chou, FASM,** received the Nadai Medal from the American Society of Mechanical Engineers (ASME) for his work on composite materials. The award was presented at the 2013 ASME Mechanical Engineering Congress and Exposition in San Diego. Chou, Pierre S. du Pont Chair of Engineering at the University of Delaware, shared his perspectives on composites science and technology during the Nadai Medal Lecture at the event. He was previously named one of the top 100 materials scientists of the decade.

IN MEMORIAM

ASMer Forever

Sherman E. Elliott Jr., 84, of Rockford, Ill., passed away May 25, 2012. He was a University of Illinois, College of Engineering graduate and served in the U.S. Army and Army Reserve. Elliott was hired as chief metallurgist for the W.F. and John Barnes Rockford Ordinance Plant during the Korean War. He later worked at Barber Coleman and Rockford Products, and then retired from Rockford Power Train. He had 63 years of ASM membership and was a past president of the Rockford Chapter. Per Elliott's wishes, a vintage ASM logo was engraved on his tombstone.

Word has been received at ASM Headquarters of the death of Life Members **Curt B. Beck,** of Pampa, Tex. (North Texas Chapter), **Peter F. King** of Union City, Ind. (Detroit Chapter), and **John J. Kozelski** of Levittown, Pa. (Philadelphia Chapter).

Srolovitz Awarded Materials Theory Award

The Materials Research Society (MRS) named **Prof. David J. Srolovitz, FASM,** University of Pennsylvania, to receive its 2013 Materials Theory Award for exceptional advances in theoretical materials science. Srolovitz received his award at the 2013 MRS Fall Meeting on December 4 in Boston, where he presented his talk, "Polycrystalline Microstructure At-Scale." Among Srolovitz's seminal contributions is his work on the topology and kinetics of grain growth in polycrystals.

RPI Appoints Ramanath with Endowed Professorship

In November, **Ganpati Ramanath** was named the John Tod Horton '52 Professor of Materials Engineering at Rensselaer Polytechnic Institute (RPI). Ramanath is a professor in the Department of Materials Science and Engineering and a member of the Rensselaer Nanotechnology Center. His research focuses on nanomaterials and interfaces for applications in electronics and energy. Ramanath's work has been featured internationally by many news organizations, including Thompson Reuters, Scientific American, MSNBC, and others.

Metallurgist Sanders Creates Brass University Seals

Paul Sanders, assistant professor of materials science and engineering, at Michigan Technological University in Houghton, was asked by the Undergraduate Student Government to cast the University seal and put it in the Memorial Union kiosk. Sanders took on the challenge using the university's foundry and soliciting help from students. He also found alumni to donate 300 lb of red brass, an alloy of copper, tin, and zinc, to cast the seals. Sanders is shown decanting the melted brass into a student-made sand mold. The deep bronze colored seals will be polished and mounted in the kiosk for the university community to enjoy.

IMS Members in Montréal

The International Metallographic Society was well represented in Montréal last October at MS&T'13 and at the festivities for ASM's 100th Anniversary. At the Gala were (from left) Randall Barnes (IMS executive director), Dave Fitzgerald (IMS past president), Rick Blackwell (current IMS president), Frauke Hogue (IMS past president), Brian Joyce (IMS director), Dan Dennies (IMS director), and Ryan Deacon (*MMA* editor).

Uhlenburg Recognized with Award of Industry Merit

At its recent Fall Meeting, the Metal Treating Institute (MTI) recognized **Jeff Uhlenburg,** from Donovan Heat Treating in Philadelphia with the Award of Industry Merit. He is a fifth generation heat treater. This award is given in recognition of an MTI member's commitment to the betterment of the commercial heat treating industry. Jeff has testified to Congress on many occasions through the National Association of Manufacturers on healthcare, labor, and energy. Jeff served for 10 years on the MTI board of trustees and served as 2009-2010 MTI president.

Chapter News

Boston Explores Composites and Camps

Peter Jepsen shows the growth of attendance at ASM Materials Camps.

In his talk, "Transitioning Technology from Fundamental Research to Commercialization: A Brief History of Metal Matrix Composites," James Cornie of Metal Matrix Cast Composites described the benefits of careful alloy choice in preventing phase segregation and poor as-cast microstructure. He also discussed major applications of metal matrix composites, such as thermal management of electronics.

Peter Jepsen opened the night with a review of the ASM Materials Education Foundation and its programs. He described the ASM Materials Camp, the one-day Materials Experience, and the ASM Teachers' Camp held in Boston last July, which received overwhelmingly positive feedback from attendees.

Warren Sees the Future at NAMII

The ASM Warren Chapter visited American Makes, the National Additive Manufacturing Innovation Institute (NAMII), in Youngstown, Ohio, on October 17. Attendees were shown various processes that use 3D printing technology to build objects from plastic or metal materials. This futuristic manufacturing method has many applications for custom products without hard tooling and with short lead times. Opened in September 2012, NAMII's mission is to accelerate and integrate additive manufacturing technologies to the U.S. manufacturing sector in order to increase domestic competitiveness. Corporate partners gain access to the Institute's technology and expertise.

Alamo's 'Steely' Tour

The ASM Alamo chapter and CMC Commercial Metals hosted a tour of the continuous production of steel used for rebar and other applications. The CMC Plant tour was attended by students from The University of Texas at San Antonio, The University of Texas at Pan Am, and St. Mary's.

VOLUNTEERISM COMMITTEE

Profile of a Volunteer

John Halchak, FASM
Senior Fellow, Aerojet Rocketdyne

Q: Where can you meet a rocket engineer who worked on the Apollo 11 moon landing rocket and the Space Shuttle?
A: At an ASM chapter meeting.

John Halchak, FASM, is a senior fellow with Aerojet Rocketdyne in Los Angeles and a long-standing member of ASM, joining during his junior year in metallurgical engineering at Pennsylvania State University in 1961. He spent his entire career with one company (though it changed hands four times), working primarily on defense contracts and projects for NASA. As a fellow, he has become a respected technical resource and mentor for the company. John is also a regular presenter at UCLA and numerous other universities. As a volunteer with the ASM San Fernando chapter, he is happy to share his experience and wisdom with younger engineers.

"ASM has been a great place to meet peers in the local area, to get contacts and information, and of course the ASM reference books are of tremendous value," says Halchak. He finds volunteering to be very rewarding, having inspired people to join the company or explore careers in engineering or science. His latest project is helping Los Angeles middle school students take part in the Team America Rocketry Challenge. "A middle school talk is harder than a university student talk!" he chuckles. "How do you hold their interest and not talk over them or down to them?"

He hasn't shied away from the challenge. Halchak continues to volunteer and inspire students, including his oldest daughter who became a materials engineer and works for SpaceX, a commercial company revolutionizing the design of advanced rockets and spacecraft.

Halchak hopes the new generation of engineers and metallurgists will see the value in joining a technical society—something that all young engineers did in years past.

SEE WHAT'S NEW WITH ASM EDUCATION - 2014

"I've learned a lot that I can take back with me to my job to better my work performance."

NEW!

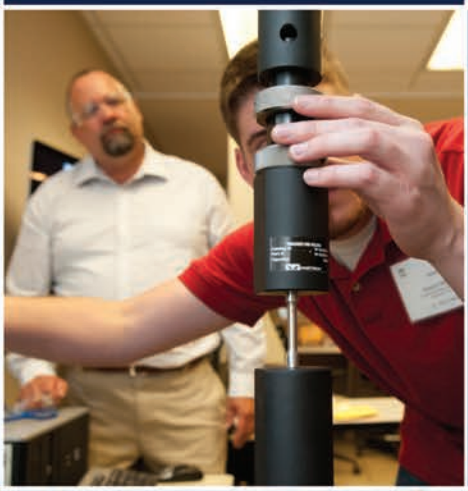
BLENDED LEARNING

Start your classes online with required pre-work before attending the live sessions with instructor led collaborative group work. Blended learning gives you the opportunity to work at your own pace, reduce your travel costs and time off the job, while adding to your individualized learning experience.

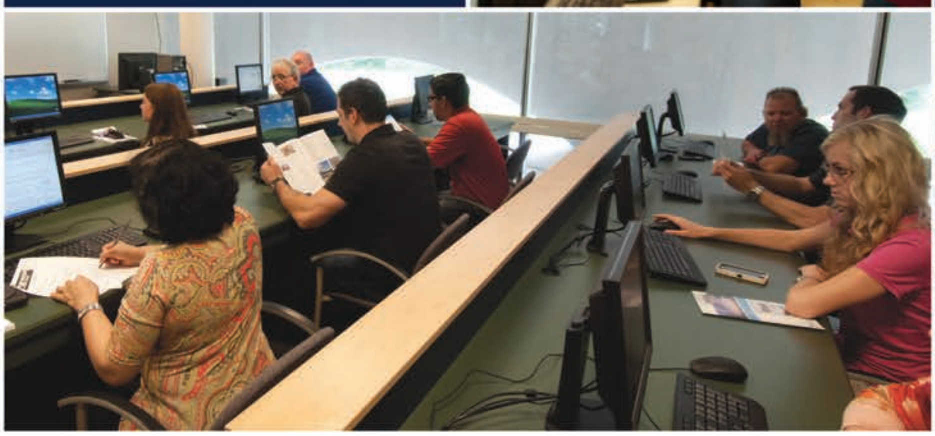
AVAILABLE 24/7

ONLINE INTERACTIVE COURSES

Start an ASM Online Course when you're ready and learn at your own pace. Everything is delivered online, and our training professionals are with you every step of the way for your individualized learning. Reduce your travel costs and time from your job. Earn CEUs to keep your professional certification current or work towards an ASM Certificate Program.



"It was very nice to see equipment from several manufacturers which allowed me to use products other than the lab I work in."



COURSE	DATE	LOCATION
Metallurgy for the Non-Metallurgist	1/13-16	ASM World Headquarters
Introduction to Thermal Spray	2/3-4	ASM World Headquarters
How to Organize and Run a Failure Investigation	2/3-4	Hilton Garden Inn Irvine East / Lake Forest Foothill Ranch, CA, USA
Thermal Spray Safety Management	2/5	ASM World Headquarters
Principles of Failure Analysis (3-day)	2/5-7	Hilton Garden Inn Irvine East / Lake Forest Foothill Ranch, CA, USA
Heat Treating for the Non-Heat Treater	2/10-12	Hilton Garden Inn North Charleston, SC, USA
Materials for Nuclear Power Plants	2/24-26	Hilton Garden Inn North Charleston, SC, USA
Introduction to Metallurgical Lab Practices	2/25-27	ASM World Headquarters
Practical Heat Treating	3/3-6	ASM World Headquarters
Metallographic Techniques	3/3-6	Allied High Tech Rancho Dominguez, CA, USA
Titanium and Its Alloys	3/10-13	ASM World Headquarters
Elements of Metallurgy	3/10-13	ASM World Headquarters
Refractory Technology	3/17-19	ASM World Headquarters
Heat Treat, Microstructure & Performance of Carbon & Steel Alloys	3/24-26	ASM World Headquarters
Reverse Engineering: A Material Perspective	3/31-4/2	ASM World Headquarters
Metallurgy for the Non-Metallurgist	4/7-10	ASM World Headquarters
Superalloys	4/8-10	Hilton Garden Inn North Charleston, SC, USA
Vacuum Heat Treating	4/9-10	ASM World Headquarters
Corrosion	4/14-17	ASM World Headquarters
Principles of Failure Analysis	4/14-17	ASM World Headquarters
Advanced Metallographic Techniques	4/14-17	Struers Westlake, OH, USA
Aluminum and Its Alloys	4/22-24	ASM World Headquarters
Mechanical Testing of Metals	4/28-5/1	ASM World Headquarters

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products & literature

JEOL Ltd., Japan, introduced a new **scanning electron microscope** with expanded pressure range, large specimen chamber, and high resolution for imaging and characterizing a wide variety of sample types and sizes. The JSM-IT300LV extends vacuum pressure range to 10-650 pA, which enhances SEM imaging versatility for samples that are wet, oily, outgas excessively, or are nonconductive without pretreatment. It features multiple ports for analytical attachments such as energy dispersive x-ray spectrometer, electron backscatter diffraction, cathodoluminescence detectors, wavelength dispersive x-ray spectrometer, chamberscopes, and heating/cooling substages. www.jeol.co.jp/en.

LECO Corp., St. Joseph, Mich., introduced the 736 Series **oxygen/nitrogen analyzer** developed for accurate measurement of oxygen and nitrogen content of inorganic materials, ferrous and nonferrous alloys, and refractory materials using the inert gas fusion technique. The series features an improved detector design with thermostatic construction and increased protection for ambient temperature fluctuations, while a long-life emitter drive and drift-free detection circuitry improve long-term stability. Additional options include batch or process autoloaders for automated sample loading and an integrated liquid-to-air radiator with dual dc cooling fans. www.leco.com.

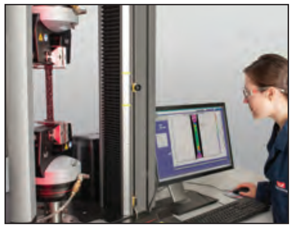
Carl Zeiss X-ray Microscopy, Pleasanton, Calif., introduced the Crossbeam series **microscope system** for high-speed materials analysis and processing. The newly developed FIB column enables fast and precise materials processing that can be observed with the field emission SEM in real-time. The 3D analytics, ability to image magnetic and non-conductive specimens with maximum resolution, and unique materials contrasts are beneficial. www.zeiss.com.

FEI, Hillsboro, Ore., released the Tecnai Femto **ultrafast electron microscope** (UEM), enabling scientists to explore ultrafast events and processes that occur at the atomic and molecular spatial scale over time spans measured in femtoseconds. These include fundamental processes such as light energy absorption and transformation into heat or mechanical changes (photoactuation) and the crystallization or recrystallization of materials, including large biological molecules for structural analysis. www.fei.com/tecnai-femto.

Physik Instrumente (PI), Auburn, Mass., introduces N-603 **linear positioning stages,** which replace a conventional piezo actuator with a high-resolution, NEXACT series piezo stepping drive to offer a theoretically unlimited travel range. Frictionless, titanium flexure joints guide the drive motion with a crosstalk of just a few µm. Strain gauge sensors with approx. 0.25% linearity are used as position sensors, guaranteeing a positioning accuracy of roughly 5 µm on the entire travel range. The result is a position-controlled linear actuator with µm precision, at a height of just 7.4 mm and travel range of 2 mm. www.physikinstrumente.com.

Materion Brush Performance Alloys, Mayfield Heights, Ohio, introduces three new products for its BrushForm 158 product line (BF TM12, BF TM04, and BF TM06) specifically for next-generation electronics devices. These new **copper-nickel-tin alloys** are designed to provide optimal strength in very thin gauges. The alloys offer higher strength than other copper alloys, but do not contain beryllium. The materials are RoHS compliant and infinitely recyclable. www.materion.com.

Instron, Norwood, Mass., released new Digital Image Correlation (DIC) **software.** This novel combination of hardware and software optically detects strain and displacement within a defined area on the surface of specimens or components exposed to loads. It then visualizes these in real-time on a computer screen, so they can be traced over the entire duration of the test. Associated DIC software provides visualization and saves data at an adjustable rate of up to 50 Hz in the form of individual images for subsequent analysis in post-processing mode. www.instron.com.



Formulated with silver-coated nickel filler, EP79FL from Master Bond, Hackensack, N.J., is a two part, **electrically conductive epoxy** for bonding, sealing, and coating applications. It has volume resistivity of less than 0.005 ohm-cm and is flexible upon curing, making it suitable for applications involving thermal cycling as well as thermal and mechanical shocks. It adheres well to metals, composites, glass, ceramics, vulcanized rubbers, and many plastics while offering a T-peel strength that exceeds 25 pli. EP79FL is serviceable over the 4K to 275°F temperature range, allowing it to be used in cryogenic environments. www.masterbond.com.

Outokumpu, Espoo, Finland, released two new **high-chromium stainless steel grades,** ferritic grade EN 1.4622 and austenitic grade EN 1.4420. The ferritic 4622 grade is suitable for demanding applications including facades, elevators, and automotive use. It has similar corrosion resistance but better deep-drawability than the standard 304 grade. The austenitic 4420 grade is acid-resistant and is suited for use in heavy industries, such as construction, pulp and paper, or structures, piping, and water treatment applications. Compared to the 316L, it has improved corrosion resistance and higher strength. www.outokumpu.com.

Olympus Corp., Tokyo, launched its "Microscope Components for Integration" **website** with easy access **to expert microscope component solutions** for streamlined system development and construction. Visitors can explore a wide range of solutions including individual components, objective lenses, optical microscope frames, modular microscope assemblies, and optical microscope modules. www.olympus-ims.com/en/component.

ad index

editorial preview

FEBRUARY 2014

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stress RELIEF

Michigan Tech rolls back into Guinness Book with giant snowball

Michigan Tech's (Houghton) ASME student chapter gathered 30 strong on the softball field and began to roll snow in hopes of getting back into the *Guinness Book of World Records.* It took 2.5 hours to create the massive snowball with a circumference of 32.94 ft. Estimates were that it weighed in the neighborhood of 3-4 tons, said Parshwa Patwa, who led the effort. Licensed surveyors Steven Hein and Casey Storm verified the snowball's size, and Patwa, a third-year mechanical engineering major, captured the entire event on a two-hour video. Guinness verified the record, and Patwa received the official certificate in September 2013. *www.mtu.edu.*

Martian penny viewed on Earth in ultra-hi-res

An instrument aboard NASA's Curiosity rover on Mars sent an ultra-high-resolution image of a penny back to scientists on Earth. The coin was photographed by the Mars Hand Lens Imager (MAHLI) aboard Curiosity in northern Gale Crater on Mars. The penny, a 1909 VDB edition minted in Philadelphia during the first year that Lincoln cents became available, is part of the MAHLI calibration target. At 14 µm per pixel, this is the highest resolution image that the MAHLI can acquire, said R. Aileen Yingst, senior scientist. The image was obtained as part of a test; it was the first time that the rover's robotic arm placed the MAHLI close enough to a target to obtain MAHLI's highest-possible resolution. The previous highest-resolution MAHLI images, which were pictures of Martian rocks, were at 16-17 µm per pixel. *www.msss.com/all_projects/msl-mahli.php*

Image of a U.S. penny acquired by MAHLI aboard NASA's Curiosity rover on Mars. During the penny's 14 months on Mars, it has accumulated Martian dust and clumps of dust, despite its vertical mounting position. Courtesy of NASA/JPL-Caltech/MSSS/Planetary Science Institute.

Rats may require Oreo rehab

Students from Connecticut College, New London, along with neuroscience professor Joseph Schroeder found that "America's favorite cookie" is as addictive as cocaine—at least for lab rats. And just like most humans, rats go for the middle first. In a study designed to shed light on the potential addictiveness of high-fat/high-sugar foods, Schroeder and his students found that rats formed an equally strong association between the pleasurable effects of eating Oreos and a specific environment as they did between cocaine or morphine and a specific environment. They also found that eating cookies activated more neurons in the brain's "pleasure center" than exposure to addictive drugs.

"Our research supports the theory that high-fat/high-sugar foods stimulate the brain in the same way that drugs do," says Schroeder. "It may explain why some people can't resist these foods despite the fact that they know they are bad for them."

While it may not be scientifically relevant, neuroscience major Jamie Honohan said it was surprising to watch the rats eat the famous cookie. "They would break it open and eat the middle first," she said.

Research shows the rats conditioned with Oreos spent as much time on the "drug" side of the maze as the rats conditioned with cocaine or morphine. *www.connecticutcollege.edu.*

SUCCESS ANALYSIS

Welcome to *Success Analysis*, a new department featuring in-the-field reporting on significant advances in materials science. In each issue, we will highlight a state-of-the-art facility, product, research project, or organization making a noteworthy impact on the world of materials engineering.

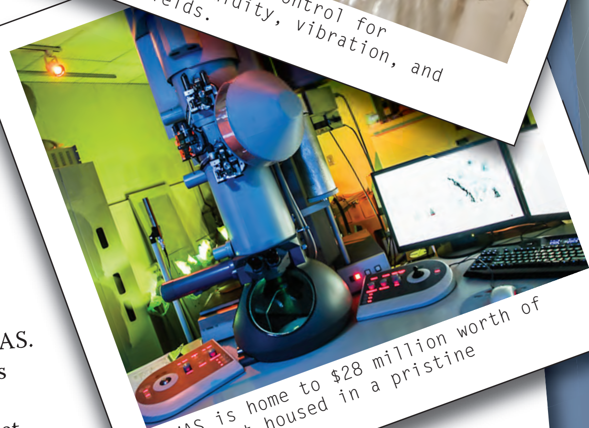
Specimen Name: Center for Electron Microscopy and Analysis (CEMAS)

Vital Statistics:

- New materials characterization epicenter at The Ohio State University features $28 million worth of equipment, including 10 FEI electron microscopes.
- The 20,000-sq-ft center includes two electron microscopes from FEI's Titan line, optimized to perform atomic scale analysis. Three additional transmission electron microscopes, two dual-beam focused ion beam instruments, and three scanning electron microscopes are also available. In addition, the center hosts two x-ray diffractometer systems, facilities for nanoindentation, and an extensive array of sample preparation facilities.
- Microscopes live in a pristine environment in this purpose-built facility, free from the effects of vibration, fluctuations in temperature and humidity, and magnetic fields.

Ohio State's elite electron microscopy facility celebrated its grand opening on September 18, 2013.


Specialized systems control for temperature, humidity, vibration, and magnetic fields.


CEMAS is home to $28 million worth of equipment housed in a pristine environment.

Success Factors:

- Instrumentation and expertise at CEMAS enables analysis of materials beyond metals and ceramics. Researchers from both industry and academia can investigate cellular structures of polymers, tissues, organic membranes, nanoparticles, and gels.
- Due to CEMAS' direct connection to OARnet's 100 gigabits-per-second network, any organization connected to OARnet's network can purchase time and directly operate the instruments from a remote location with no perceptible delay.
- The center aims to revolutionize how scanning electron microscopy is taught to students. "Since CEMAS' microscope collection can be controlled from outside the room, we no longer need to teach three students at a time," says director David McComb. "We can teach 25 or 30 students at once and we can give them control of the microscope so everyone can see what's going on."

About the Innovators:


David McComb

An expert in the development and application of electron energy-loss spectroscopy, David McComb was recruited to Ohio State to design and lead CEMAS. Working closely with McComb as academic advisors are Professors Hamish Fraser and Michael Mills.

Designing the center to help each microscope meet its exact specification took as long as the physical construction of converting an old mattress factory into a world-class research facility. Required modifications include controlling for temperature to plus or minus 0.1°C without creating air currents, avoiding vibrations, and removing magnetic fields wherever possible.

What's Next:

The facility is now open for use by interested parties from academia and industry alike, with remote microscope operation possible. Book equipment time by contacting CEMAS.

Contact Details:

Center for Electron Microscopy and Analysis (CEMAS)
1305 Kinnear Rd., Columbus, OH 43212
614/643-3110, cemas@osu.edu, www.go.osu.edu/electron