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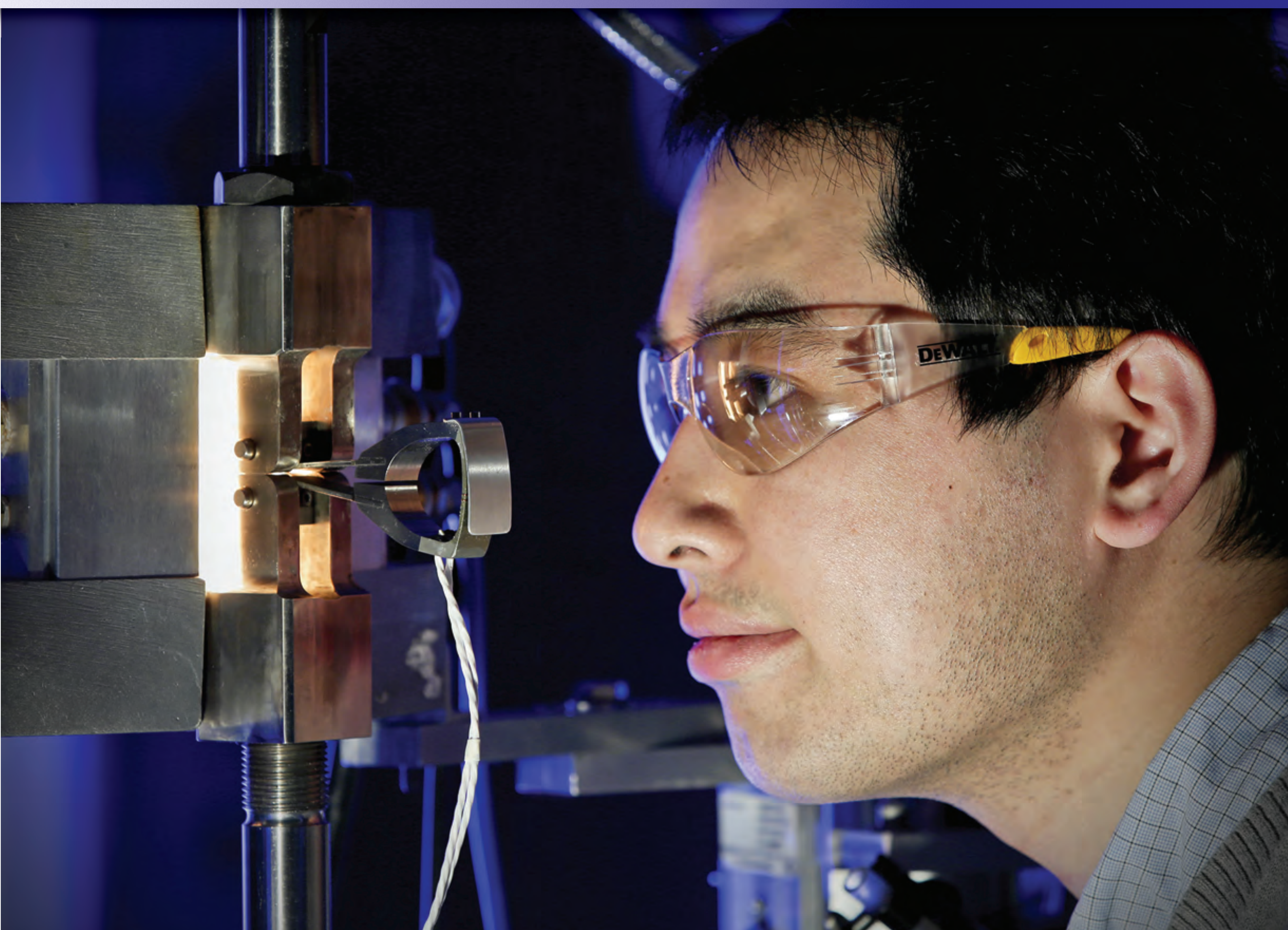

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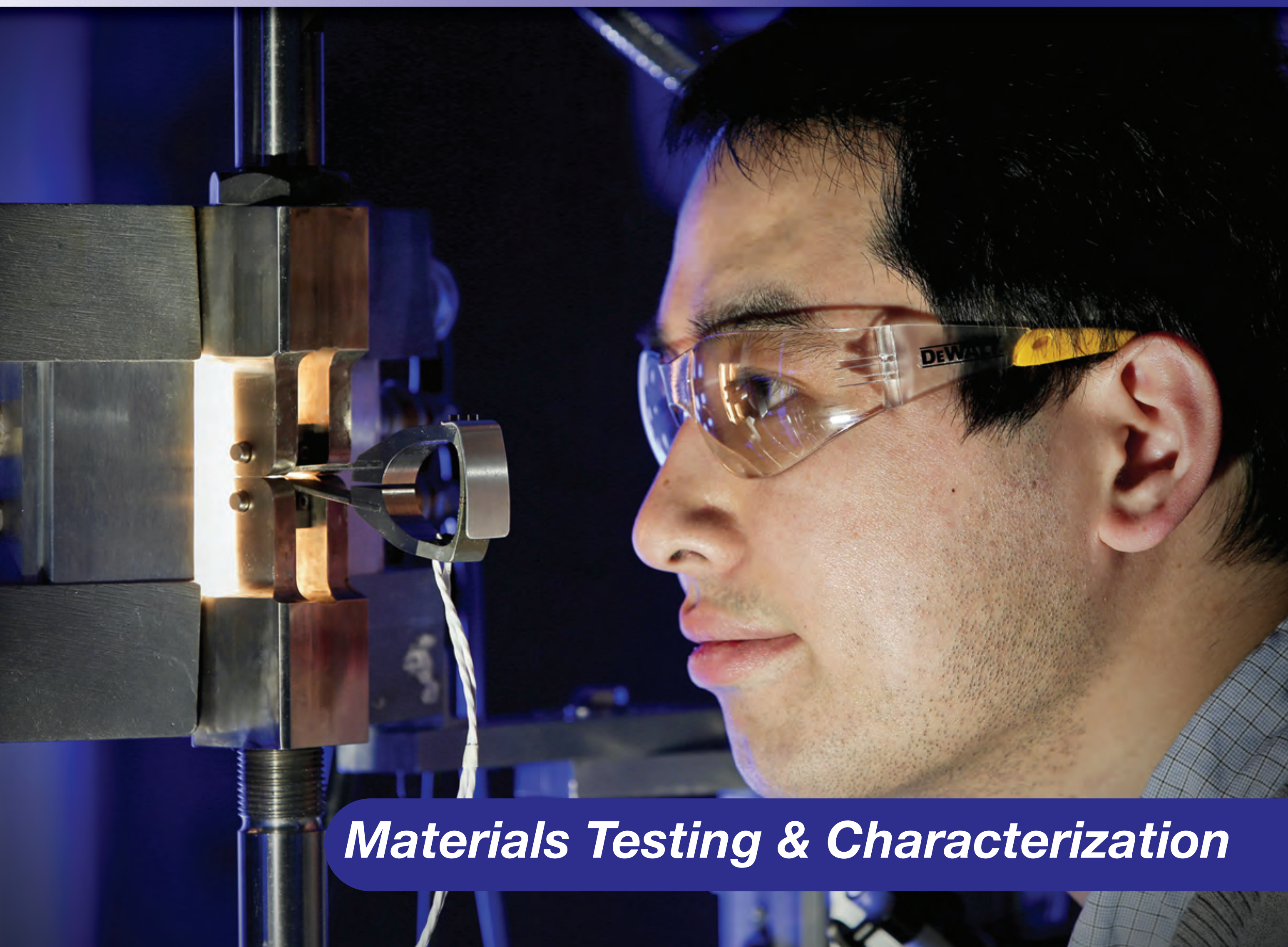

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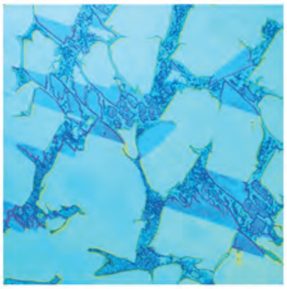

ON THE COVER:
Scientists in the Materials Science & Technology Division at Oak Ridge National Laboratory (ORNL) set up a novel testing apparatus to determine elevated temperature fracture toughness in metals. Courtesy of ORNL, Tenn. www.ornl.gov.

contents

DEPARTMENTS

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ASM International 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.

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materials witness

Prepare to be amazed

From the real-life "Lost" drama about the disappearance of Malaysia Airlines Flight 370 to Vladimir Putin staking his claim on Crimea to Watson being used to help cure brain cancer, there is no shortage of amazing news these days. Likewise, the world of materials science is also full of fantastic discoveries and mindboggling news. If you had to pick the most amazing materials-related story as of late, what would it be?

My vote goes to MIT's recent work on "living materials." In January, we reported on one of their projects involving genetically modified viruses being used to help produce nanowires to solve some problems facing lithium-ion batteries. The gist of the research is that the virus-built nanowires feature a rough and spiky surface that dramatically increases surface area, significantly improving the rate of charging and discharging within the battery.

Now, another group at MIT is using bacterial cells to produce biofilms that can incorporate nonliving materials, for example, quantum dots or gold nanoparticles. It's a best-of-both-worlds scenario: Researchers say that these living materials combine the advantages of living cells—which respond to the environment, produce biological molecules, and span multiple length scales—with the benefits of nonliving materials that can add functions such as conducting electricity or emitting light. The team believes that these hybrid materials are worth exploring for use in energy applications such as batteries and solar cells, in addition to diagnostic devices and scaffolds used in tissue engineering.

If ASM's recent survey about emerging technologies is any indication, these are just the sorts of materials that will have the most impact on society over the next few years. The ASM Emerging Technologies Awareness Committee conducted a survey of roughly 300 members (R&D leaders within their organizations) to gain feedback on materials-related technologies believed to be the most promising for the near future. The top five categories chosen by respondents include high-performance materials, energy materials, additive manufacturing, nanotechnology, and integrated computational materials engineering. Based on these results, ASM will consider developing new events, education courses, and publications around these topics. As discussed previously in this column, the idea of moving boldly into the future necessitates embracing these emerging technologies.

In other Society news, ASM is proud to be part of President Obama's newly announced American Lightweight Materials Manufacturing Innovation Institute (ALMMII), being led by EWI, University of Michigan, and The Ohio State University. ASM is part of the new consortium of 60 members, including leading manufacturers of aluminum, high strength steel, and titanium, along with universities and laboratories involved in research and development of lightweight metals. Next up this year is a new Advanced Composite Manufacturing Institute, slated for $70 million in DOE funding over five years. The institute will primarily target continuous or discontinuous carbon and glass fiber composites, materials based on thermoset or thermoplastic resins with superior strength and stiffness-to-weight ratios relative to other materials. Funding closes April 22 with full information available at www.energy.gov.

No matter what type of material you find yourself working on these days, we hope it's amazing. Feel free to send us progress reports along the way and we will include them in future issues.

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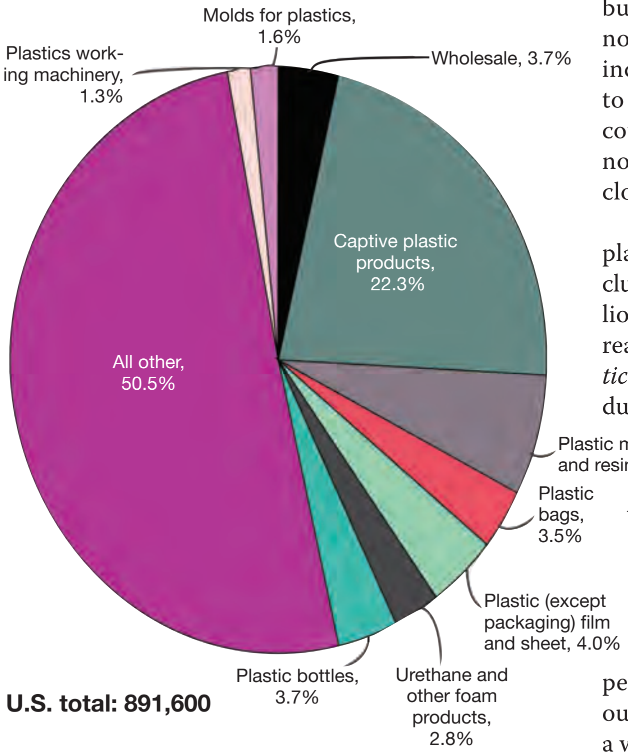
market spotlight

Just one word: Plastics

A new report from SPI, the plastics industry trade association, presents a detailed overview of the state of the U.S. plastics industry. *Size and Impact of the Plastics Industry on the U.S. Economy,* published November 2013, notes that this industry has been one of the economy's largest and fastest growing. Although hit hard by the 2008-2009 recession, it is now recovering. Most plastics are used in manufacturing and services are becoming increasingly important. Lower inflation, dollar value reduction, and lower natural gas prices have spurred U.S. exports, moderating the recession effects. Those same advantages should help the plastics industry in the future, according to analysts. Mirroring numerous other industries, a shrinking number of businesses indicate a continuing consolidation trend. Key findings of the newly released report include:

The U.S. plastics industry is large, accounting for 892,000 jobs and $373 billion in shipments during 2012. California has the largest plastics industry employment, but as a percentage of total non-farm employment, the industry is most important to Michigan, where it accounts for 15.8 of every 1000 non-farm jobs. Indiana is a close second.

Plastics Industry Employment by Sector, 2012



U.S. total: 891,600

Source: SPI, www.plasticsindustry.org.

When suppliers to the plastics industry are included, jobs grow to 1.41 million, and total shipments reach $456 billion. The *plastic products* portion of the industry was the eighth largest U.S. industry in 2011, while the *plastic materials and synthetics* sector (including rubber and fiber) was the twelfth largest.

Employment in plastics manufacturing grew 0.1% per year from 1980 to 2012, outpacing manufacturing as a whole, and shipments grew at a 2.3% annual rate from 1980 to 2012. The recent industry slowdown largely reflects the recession and slowing of the manufacturing sector as a whole.

The plastics industry has improved over the past two years.

Although manufacturing is still the main outlet for plastics, an increasing share of plastics is going into services including wholesale and retail trade; finance, insurance, and real estate; and healthcare. The U.S. plastics industry, as documented by government data, operated an estimated 15,949 manufacturing establishments in 2012 excluding businesses that produce captive plastic products or supply goods and services to the plastics industry. *For more information, visit www.plasticsindustry.org.*

feedback

More on Metallurgy Lane

Our American metals history is so interesting, especially when it includes descriptions of why things happened. I can see that Charles Simcoe, author of the new "Metallurgy Lane" series, spent a lot of time on his research including extensive travel. The most surprising thing I learned from the article is that anthracite coal was used directly for fuel in blast furnaces. I wonder if he came across the historical Greenwood Furnace* in Eastern Pennsylvania, and whether or not the Cornwall open pit mine* near Harrisburg is still operating?

Edward Dunn

[I was aware of the Greenwood Furnace, but didn't know it was an ASM Historical Landmark until I did some research after Dunn's email. The Cornwall mine closed after the underground part flooded during Hurricane Agnes in 1972 and the open pit was abandoned in 1973. It had been in operation for more than 230 years.—Charles R. Simcoe]

Pig iron production

I'd like to add a side note about pig iron production. The blast furnaces near St. James, Mo., (circa 1830) used "long leaf" pine charcoal at the rate of three tons of charcoal per ton of iron produced. The two furnaces produced about 16 tons of pig per day, hence used 24 tons of charcoal. Pine produces very little charcoal compared to hard woods, so vast stretches were denuded. No replanting was done and rain washed away what little soil was there to begin with. The railroads took the rest of the pines for ties (circa 1850-1870). Today the Ozarks have only scrub oak and cedar. The irony (pun intended) is that the major industry there today is still charcoal, now used in our country's barbeque pits!

Chuck Dohogne

Wonder of the world

Charles Simcoe wrote a good article on wrought iron (February issue), but he failed to mention one of the wonders of human civilization—the Ashoka Pillar (Delhi Iron Pillar*) in India. It was manufactured sometime around the 4th century and has stood on open ground since. It has neither weathered nor shows any signs of rust or pitting.

Ashok Bhambri

**ASM Historical Landmarks. See more at www.asminternational.org/membership/awards/historical-landmarks.*

We welcome all comments and suggestions. Send letters to frances.richards@asminternational.org.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* Courtesy of Dr. Artur Indzhykulian, Harvard Medical School

Recreating Roman funeral masks

During the Roman Empire, wealthy families created masks of males that were displayed in their houses after death and also used in funeral ceremonies. The masks, called *imagines maiorum,* were created out of beeswax, according to written sources. While none of these masks have survived, there are three modern-day wax masks that bear an uncanny resemblance to doctoral students in the Classics Department at Cornell University, Ithaca, N.Y. In a seminar on Greek and Roman portraiture taught by associate professor Annetta Alexandridis, the students wanted to create their own masks as part of a larger research project on wax as a material in ancient Rome.

From left, Annetta Alexandridis, Carrie Fulton, Jennifer Carrington, and Katie Jarriel display their wax masks. Courtesy of Lindsay France/University Photography.

"We found that beeswax tends to be more brittle, so we used foundry wax," says graduate student Katie Jarriel. They first made silicone molds of each person's face, with the help of a restoration expert. A plaster casting was applied on top to help the silicone hold its shape. Once the silicone dried, wax was poured in the mold. After the casts were completed, students considered how they would have been worn by the actors and observed how quickly they started to deteriorate. In Roman times, they would have been duplicated and repaired if they were damaged. "So if a nose fell off, they would have built a new one out of wax," explains Alexandridis. *For more information: Annetta Alexandridis, 607/254-7263, aa376@cornell.edu, www.cornell.edu.*

Fiber reinforced polymer (FRP) composite material products such as this trail bridge are suitable for structurally demanding applications and corrosive environments.

Fiber reinforced polymer bridges

Composite Advantage, Dayton, Ohio, under its FiberSPAN brand, launched a range of new fiber reinforced polymer (FRP) trail bridge and bridge deck products. The new line combines high performance with aesthetics and is maintenance-free, according to company sources. Engineered for superior strength, the bridge and deck products resist corrosion from water and chemicals, are light weight for easy installation, and provide a nonslip surface. The composite trail bridges and bridge decks are available in gray or beige but also can be fabricated in custom colors. They are designed to meet the industry standard of 90 lb/ft^2 pedestrian live load and can withstand a 15,000-lb vehicle load. Railing options include fiberglass, stainless steel, and steel. *www.compositeadvantage.com.*

Invisible coating protects Finnish coins

The Mint of Finland chose Beneq's patented nSILVER invisible protective coating to prevent tarnishing of its special numbered series of EUR 20 coins. The coins honor Tove Jansson, the Finnish creator of the Moomin books for children. The protective coating is based on Beneq's atomic layer deposition (ALD) technology and prevents silver from tarnishing by protecting it from airborne sulfur and other chemicals or liquids, which react with the surface.

The coating is completely transparent on silver, enhances surface reflectivity, and gives the coated article a brighter and glossier appearance. nSILVER coats the silver with a fully transparent, conformal, and pinhole-free thin film consisting of ceramic material. The thin film layers bond with the silver layer and provide a flawless protective barrier. nSILVER is applied using the ALD coating method, which enables thin films to grow on articles of any shape. The coating is extremely uniform with flawless quality, due to the way small ALD vapor molecules penetrate even the narrowest grooves. *www.beneq.com.*

Mint of Finland's commemorative Tove Jansson (EUR 20) coin is protected by Beneq nSILVER anti-tarnishing treatment. Courtesy of Mint of Finland.

briefs

IBC Advanced Alloys Corp., Vancouver, signed a nonbinding memorandum of understanding (MOU) with **Nu-Cast Inc.,** Londonderry, N.H., to collaborate on new beryllium-aluminum investment casting projects and opportunities, initially for the aerospace sector. The MOU outlines a framework for increasing manufacturing capacity and improving production efficiencies of IBC's proprietary near-net-shape beryllium-aluminum castings. The parties will also focus on joint business development initiatives aimed at increasing market share for IBC's castings, which offer significant cost savings and improved delivery times compared to existing production methods. www.ibcadvancedalloys.com, www.nu-cast.com.

The new **Paläon Schöningen** research and experience center, Germany, has a reflecting facade that mirrors the surrounding countryside. **ThyssenKrupp Plastics** supplied roughly 4500 m^2 of ALUCOBOND panels with a special mirror finish for the building, which opened in June 2013. Panels were installed using a special adhesive and rivet technique to make the skin of the Paläon appear like an oversize mirror. ALUCOBOND is a strong yet flexible material consisting of two aluminum face sheets and a polymer core. It is extremely weatherproof, impact resistant, and vibration damping. www.thyssenkrupp.com.

The unusual design of the Paläon with ALUCOBOND panels won the 2013 German Facade Award for rainscreen cladding.

Using additives to decrease vehicle weight

Milliken, Ghent, Belgium, developed an innovative and high performance reinforcing agent, Hyperform HPR-803i and Hyperform HPN nucleating additives for polyolefins. Hyperform HPR-803i enables automotive designers to create parts that are up to 15% lighter without compromising performance. It is added at a lower rate than mineral fillers to polypropylene (PP) compounds, to lower their density. Hyperform HPR-803i compounds are suitable for injection molding operations originally designed for talc-filled compounds, simplifying testing requirements and reducing implementation costs. PP compounds reinforced with HPR-803i maintain their mechanical properties even after multiple recycling and compounding operations. Part surface appearance can also be improved, and HPR-803i lets processors reduce pigment usage while still meeting color requirements. Scratch appearance is improved, which allows for further optimization. *www.millikenchemical.com.*

Nickel implants pose no health threat

Nickel-titanium alloys are increasingly used for cardiovascular implants in minimally invasive surgery. Once implanted, these alloys can release small amounts of nickel due to corrosion. There is a concern that, over time, this could lead to nickel contamination in the patient's body, potentially causing health problems. However, scientists at Friedrich Schiller University Jena, Germany, found that the release of nickel from wires made of nickel-titanium alloys is very low and decreases over longer periods.

An occluder made of a nickel-titanium alloy used to correct a defective cardiac septum.

Fine wires from a superelastic nickel-titanium alloy applied in the form of occluders (medical implants used to correct a defective cardiac septum) were examined. Wire samples, which underwent different mechanical and thermal pretreatment, were exposed to highly purified water and the nickel release over predefined time intervals was examined. Depending on the material's pretreatment, considerable amounts of nickel may be released due to the mechanical strain of the implant during surgery for the first few days or weeks after. "In the long run, however, the nickel release decreases to amounts of a few nanograms per day and is hence far below the amount of nickel that we absorb anyway through our food on a daily basis," says Prof. Andreas Unidisz. *For more information: Andreas Undisz, 49 3641-947768, andreas.undisz@uni-jena.de, www.uni-jena.de.*

Electronics in extreme environments

Ionix Advanced Technologies Ltd., a spin-out company from the University of Leeds, UK, received funding from IP Group plc. to accelerate commercialization of devices based on high-temperature piezoelectric materials developed by the university. Piezoelectric technology, which converts environmental physical forces into electricity, is used in everything from sonar to industrial sensors to ultrasound scans in pregnancy. The new materials work in extreme conditions such as high tem-

Quanex Building Products Corp., Houston, signed a purchase agreement to sell its interest in **Nichols Aluminum LLC,** a wholly owned subsidiary, to **Aleris,** Beachwood, Ohio, for $110 million in a cash transaction subject to customary regulatory approvals. Nichols has a long history of producing flat-rolled aluminum sheet products for a number of key industries across North America. www.quanex.com.

peratures and pressures, opening up their use in new markets such as aerospace, oil and gas, and nuclear power. Prof. Andrew Bell spearheaded the research and notes the new materials are compatible with existing manufacturing methods for piezoelectric ceramics and therefore can be mass-produced at similar cost to current materials. The fundamental science is the same: Physical changes to the piezoelectric material's crystal lattice create an electrical change or, conversely, create physical changes when an electrical current is applied. However, the new ceramics include novel ingredients such as bismuth and iron and have a greatly increased tolerance. *For more information: Andrew Bell, 44 (0)113 3432370, a.j.bell@leeds.ac.uk, www.leeds.ac.uk.*

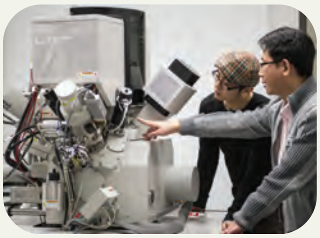
Aluminum smelter and rolling mill to close in Australia

Alcoa Inc., Pittsburgh, is permanently closing its Point Henry aluminum smelter and two rolling mills in Australia. The smelter will close in August and the rolling mills by the end of 2014. A comprehensive review found that the 50-year-old smelter has no prospect of becoming financially viable. The two rolling mills serve the domestic and Asian can sheet markets, which have been impacted by excess capacity. The closures will reduce the company's global smelting capacity by 190,000 metric tons (mT) and reduce their can sheet capacity by 200,000 mT. Including the closure of the Point Henry smelter, Alcoa announced closures or curtailments representing 551,000 mT of smelting capacity, exceeding the 460,000 mT placed under review in May 2013. Once the Point Henry closure is complete, the company's total smelting operating capacity will be approximately 3,760,000 mT, with approximately 655,000 mT, or 17%, of high cost capacity offline. *www.alcoa.com.*

Allegheny Technologies Inc., Pittsburgh, acquired **Dynamic Flowform Corp.,** Billerica, Mass. Dynamic Flowform uses a precision flowforming process to produce thin-walled components in net or near-net shapes across multiple alloy systems, including nickel-base alloys and superalloys, titanium and titanium alloys, zirconium alloys, and specialty and stainless alloys. "We have identified significant growth opportunities for Dynamic Flowform's products, especially in the aerospace and oil and gas markets. These opportunities are expected to benefit from ATI's existing global marketing and sales capabilities, and ATI's supply chain experience and relationships with OEMs," says ATI chairman, Rich Harshman. www.atimetals.com.

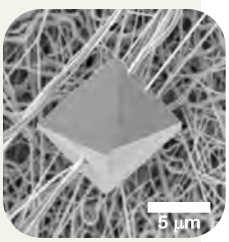
briefs

FEI Co., Hillsboro, Ore., installed a suite of high-end electron microscopes at **Simon Fraser University's (SFU) Centre for Soft Materials,** Vancouver, B.C. Systems include the Tecnai Osiris transmission electron microscope and Helios DualBeam scanning electron microscope/focused ion beam. The systems join several other FEI microscopes in the 4D LABS facility where the new multimillion dollar center is housed. www.fei.com, www.sfu.ca.



Scientists use the Helios NanoLab DualBeam at Simon Fraser University.

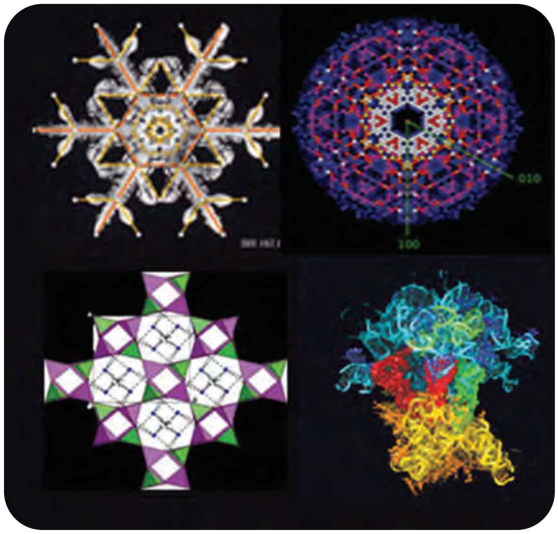
JEOL USA Inc., Peabody, Mass., launched an image contest to showcase some of the best work of its electron microscope users. A winning entry is being selected each month this year, judged by JEOL's SEM and TEM applications teams for both technical and artistic qualities. All submissions are part of an online gallery with a description of the sample and technique used. The first winner—Nano Bling—was submitted by Colin Davis of **Rocky Mountain Laboratories** in Golden, Colo. The image, taken with an older model field emission SEM installed in the 1990s, was chosen for its contrasting textures and amorphous threads leading to an ordered sharply angular crystal. www.jeolusa.com.



Nano Bling. Courtesy of Rocky Mountain Laboratories.

2014 is International Year of Crystallography

One hundred years ago, x-rays were used for the first time to determine the crystal structure of materials. The pioneering work of Max von Laue, for which he won the Nobel Prize in physics, was followed by a joint award in 1915 (also in physics) to father and son Sir William Henry Bragg and William Lawrence Bragg. Since then, more than 25 Nobel Prizes were awarded in areas related to x-ray diffraction, such as crystallography, electron microscopy, and topics related to the structure of matter and its properties.



From left, clockwise, crystal structures of a snowflake, free electron laser, zeolite, and ribosome. Courtesy of the International Union of Crystallography.

The United Nations proclaimed 2014 to be the International Year of Crystallography as a way to commemorate not only the achievements of von Laue and the Braggs, but also to mark the 400th anniversary of Johannes Kepler's observation of symmetry in ice crystals, which sparked wider study of the role of symmetry in matter.

The discovery of x-rays in the late 19th century transformed the field of crystallography, which previously relied on classifying crystals based on morphological appearance. The interaction of x-rays with crystals showed that x-rays are electromagnetic waves with a wavelength of about 10^{-10} m, and that the internal structure of crystals was spatially periodic over long distances. Since then, crystallography has become a basic discipline of many branches of physical and biological sciences, including materials science and metallurgy. Understanding the role of defects in crystal lattices and how they affect the deformation of metals has revolutionized the design of materials for the infrastructure of the industrialized world. *www.iycr2014.org, www.llnl.gov.*

WPI leads project to design lightweight metals for military vehicles

Worcester Polytechnic Institute (WPI), Mass., is the lead institution on a $7.4 million, multi-university award from the U.S. Army to support development of new metallurgical methods and lightweight alloys to help build more effective and durable military vehicles and systems. WPI will receive $2.1 million through the two-year award to develop databases and computer modeling techniques that make it possible to predict nanoscale properties of lightweight alloys (primarily aluminum, titanium, and magnesium), and to use these computational tools to design and test new alloys for specific military applications.

"The military wants new alloys that are strong enough to be used structurally, tough enough to function as armor, and light enough to improve the mobility and fuel economy of vehicles," says Richard Sisson, director of WPI's Materials Science and Engineering Program and principal investigator for the Army award.

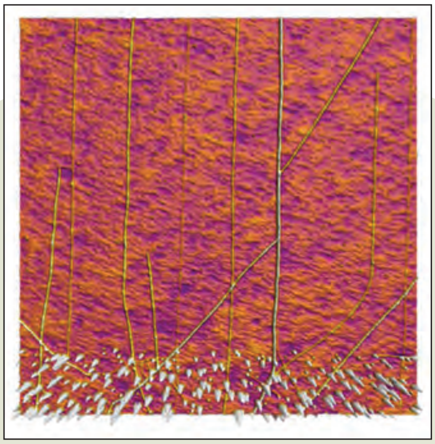
Sisson is working with co-principal investigators Diran Apelian, director of the Metal Processing Institute (MPI), and Makhlouf Makhlouf, director of the MPI's Aluminum Casting Research Center. They are using a variety of modeling techniques, including thermodynamic and kinetic models plus laboratory studies, to predict the microstructure and microchemistry of new alloys. A variety of metallurgical processes, including heat treating, are also being studied. From this work, modelling tools that can be used to improve existing alloys or design new alloys with the desired properties are being derived.

The award also includes a focus on high-strength magnesium alloys used by the military, particularly in aircraft components. Current alloys contain rare earth elements (REEs) that are expensive and difficult to obtain, as most come from China. WPI will develop new magnesium alloys that require fewer REEs or use more readily available elements. Methods for extracting REEs from ores outside of China and for recovering REEs from recycled metals are also being explored. *For more information: Richard Sisson, 508/831-5335, sisson@wpi.edu, www.wpi.edu.*

Science award spurs university research

Testing equipment manufacturer Zwick/Roell, Germany, is calling for papers to be submitted for the 2014 Zwick Science Award. University scientists with a Ph.D. or master's degree who have published a thesis within the last few years are invited to submit papers describing the innovative use of mechanical testing equipment. Submissions must be received by November 2014. Special consideration will be given to applications where some or all of the equipment was designed and produced as part of the thesis. Zwick is looking for interesting applications of materials testing. For example, among the leading submissions for the 2013 award is a paper from Oxford University titled, "Forced Reeling of Bombyx Mori Silk," which describes the process of pulling silk from a silk worm.

First prize includes the Paul Roell Medal and €5000, second prize is €2000, and third prize is €1000. Travel expenses and accommodations will be provided so recipients can attend the awards ceremony. *For more information: Robert Strehle, robert.strehle@zwick.de, www.zwick.com.*



Carbon nanotubes and bundles emerging from a line of catalyst particles. 5 μm scan courtesy of Scott MacLaren, senior research scientist, University of Illinois Urbana-Champaign.

Asylum Research, Santa Barbara, Calif., an **Oxford Instruments** company, invites all Cypher and MFP-3D AFM users to enter their best atomic force microscopy (AFM) data, including images, force curves, or videos, in the Asylum Research Image Contest. All scientists will receive a gift pack just for sending in their images and an Apple iPad will be awarded to one winning entry at the end of each quarter. www.asylumresearch.com/imagecontest.

industry news

Emerging Technology

briefs

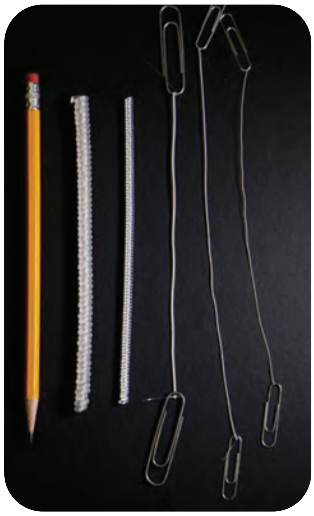
The **National Science Foundation (NSF)** announced a new **Center for Dielectrics and Piezoelectrics** to be collocated at **Penn State** and **North Carolina State University.** NSF will provide $830,000 over five years to support operations and infrastructure, and additional funding will come from member companies and organizations. Areas of research include high energy-density electrochemical capacitors for power electronics and the energy grid; dielectrics with low-temperature processing for flexible electronics; capacitors for extreme environments; polymer nanocomposite dielectrics to enhance storage density and improve insulation for power distribution; and piezotronic transistors. www.mse.ncsu.edu/cdp.

The **DOE's Oak Ridge National Laboratory,** Tenn., is partnering with machine tool manufacturer **Cincinnati Inc.,** Harrison, Ohio, to develop a large-scale polymer 3D printing system. The partnership aims to accelerate commercialization of a new additive manufacturing machine that can print large polymer parts faster and more economically than current technologies. By building a system 200-500 times faster, and capable of printing polymer components 10 times larger than today's additive machines, the project could introduce significant new capabilities to the U.S. tooling sector, according to ORNL scientists. www.ornl.gov, www.e-ci.com.

Scientists make muscles with fishing line

An international research team led by The University of Texas at Dallas, and including University of British Columbia electrical and computer engineering professor John Madden and Ph.D. candidate Seyed Mohammad Mirvakili, created inexpensive artificial muscles that generate far more force and power than human or animal muscles of the same size.

"In terms of the strength and power of the artificial muscle, we found that it can quickly lift weights 100 times heavier than a same-sized human muscle can, in a single contraction," says Madden.



University of Texas at Dallas researchers and international collaborators made artificial muscles in a variety of sizes from polymer fishing line. Courtesy of UT Dallas.

Artificial muscles constructed out of materials such as metal wires and carbon nanotubes are expensive to fabricate and difficult to control. Madden and his colleagues used high-strength polymer fibers made of polyethylene and nylon instead, which are twisted into tight coils to create artificial muscles able to contract and relax. The muscles are thermally powered by temperature changes, which can be produced electrically by the absorption of light or by the chemical reaction of fuels. Twisting the polymer fiber converts it to a torsional muscle that can spin a heavy rotor more than 10,000 rpm. Subsequent additional twisting, so that the polymer fiber coils like a heavily twisted rubber band, produces a muscle that dramatically contracts along its length when heated, and returns to its initial length when cooled. If coiling is in a different twist direction than the initial polymer fiber twist, the muscles instead expand when heated.

Compared to natural muscles, which contract by only about 20%, these synthetic versions can contract by about 50% of their length. Muscle strokes also are reversible for millions of cycles as muscles contract and expand under heavy mechanical loads. Twisting together a bundle of polyethylene fishing lines produces a coiled polymer muscle that can lift 16 lb. Operating in parallel, similar to how natural muscles are configured, 100 of these polymer muscles could lift roughly 0.8 tons.

The new muscles were used to manipulate surgical forceps and could find use in robots and low-cost devices to help people with impaired mobility, according to the researchers. *For more information: John Madden, 604/827-5306, jmadden@ece.ubc.ca, www.ece.ubc.ca.*

Nanofiber mesh enables wearable kidney dialysis

Mitsuhiro Ebara and colleagues at the International Center for Materials Nanoarchitectonics, National Institute for Materials Science in Ibaraki, Japan, developed a way of removing toxins and waste from blood using an inexpensive and easy-to-produce nanofiber mesh. The material could be incorporated into a blood purification product small enough to be worn on a patient's arm, reducing the need for expensive, time-consuming dialysis. The mesh is made using two components—a blood-compatible primary matrix polymer made from polyethylene-co-vinyl alchohol (EVOH) and several different forms of zeolites, naturally occurring aluminosilicates. Zeolites have microporous structures capable of adsorbing toxins such as creatinine from blood. The mesh was made via an electrospinning process, using an electrical charge to draw fibers from a liquid. The team found that the silicon-aluminum ratio within the zeolites is critical to creatinine adsorption. Beta type 940-HOA zeolite had the highest capacity for toxin adsorption, and shows potential for a final blood purification product. Researchers are confident that a product based on their nanofiber mesh will soon be a compact and affordable alternative to dialysis for kidney failure patients around the world. *www.nims.go.jp.*

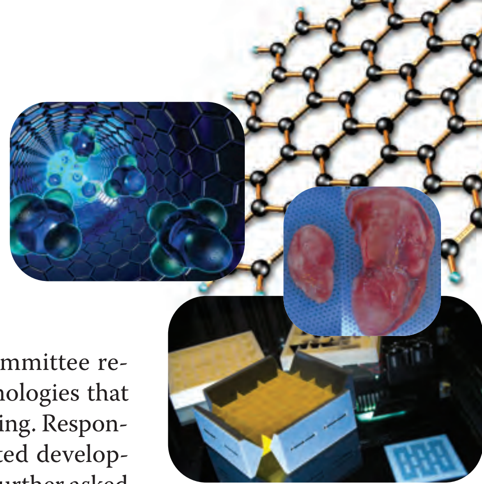
A newly-fabricated nanofiber mesh for removing toxins from blood, made by WPI-MANA researchers, may be incorporated into wearable blood purification systems for kidney failure patients.

ASM announces emerging technologies survey results

ASM International's (Materials Park, Ohio) Emerging Technologies Awareness Committee recently conducted a survey of several hundred ASM members to gain feedback on technologies that members believe will have the most impact on the future of materials science and engineering. Respondents were asked to name three materials-related technologies and three process-related developments expected to have a significant impact within the next few years. Respondents were further asked to clarify which of these technology developments they expect to have the single greatest impact.

"One of the goals of ASM's Emerging Technologies Awareness Committee is to identify the latest trends and areas of interest within materials engineering. Surveys such as this are very helpful, in that they gather feedback on leading-edge topics that ASM can then build content and courses around," says committee chair Roger Narayan, FASM, professor of biomedical engineering at North Carolina State University, Raleigh.

Of the 300 total responses, most could be placed into 11 major categories including: Additive manufacturing/3D printing; biomedical or bio-based materials; energy materials such as fuel cells and batteries; environmentally friendly/recycled or substitute materials; high-performance materials for light weight, high strength, high temperature applications; integrated computational materials engineering (ICME) and computational modeling; welding and joining; metals processing technologies; nanomaterials and nanomanufacturing; smart or multifunctional materials; and surface coatings/engineering. Of these categories, the top five included high-performance materials (66 responses), energy materials (50 responses), additive manufacturing (39 responses), nanotechnology (35 responses), and ICME (26 responses). The survey was not intended to provide statistically significant data, but rather to gain a deeper understanding of what members perceive to be the most promising next-generation technologies related to materials engineering. *For more information: Frances Richards, 440/338-5151 ext. 5563, frances.richards@asminternational.org, www.asminternational.org.*



Emerging technologies such as bio-based materials, 3D printing, and nanotechnology scored highly on ASM's recent membership survey about next-generation materials and processes likely to have the greatest impact on society over the next few years. Images courtesy of the Smithsonian, Purdue University, Lawrence Berkeley National Lab, and University of Pennsylvania.

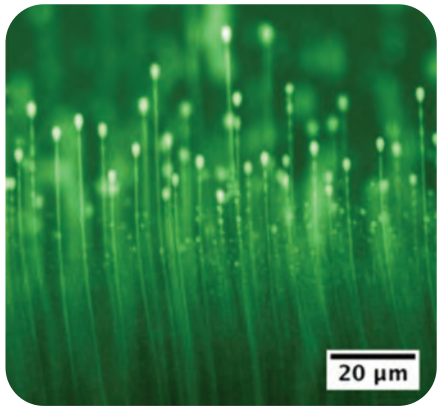
industry news

Energy Trends

Growing hairy materials at the microscale

Scientists at the DOE's Argonne National Laboratory, Ill., attacked a tangled problem by developing a new technique to grow tiny "hairy" materials that assemble themselves at the microscale. Epoxy is the key ingredient and it is added to a mixture of hardener and solvent inside an electric cell. An alternating current is run through the cell while long, twisting fibers spring up—similar to the way Chia Pets grow.

"The process is very simple, the materials are inexpensive and available, and they can grow on almost every surface we've tried," explains physicist Igor Aronson. By tweaking the process, many different shapes can be grown—short forests of dense straight hairs, long branching strands, or "mushrooms" with tiny pearls at the tips. Although the structures can be permanent, the process is also instantly reversible. *www.anl.gov.*



These tiny "mushrooms" could be useful in new energy technologies. The scale bar shows 20 µm, about the size of a single bacterium. Courtesy of Alexey Snezhko and Igor Aronson/Argonne National Laboratory.

Gummy material prevents fires in lithium batteries

Researchers from Washington State University, Pullman, developed a chewing gum-like battery material that could dramatically improve the safety of lithium ion batteries. The biggest risk comes from the battery's electrolyte, which is made from either a liquid or gel. These acidic liquid solutions can leak, potentially causing fires or chemical burns.

Professor Katie Zhong's research group developed a gum-like lithium battery electrolyte, which conducts electricity as well as liquid versions, but does not create a fire hazard. The material—a liquid-solid hybrid—contains liquid electrolyte material that hangs on solid particles of wax or a similar material. Current can easily travel through the liquid parts of the electrolyte while solid particles provide protection. If the material gets too hot, the solid melts and stops conduction, preventing fire hazards. The electrolyte material is flexible and lightweight, and can be stretched, smashed, and twisted. *For more information: Katie Zhong, 509/335-7658, katie_zhong@wsu.edu, www.wsu.edu.*

Flat-pack lens boosts solar power

Researchers at the State Key Laboratory of Precision Measuring Technology & Instruments, Tianjin University, China, are able to craft the surface structures on a Fresnel lens with an array of microscopic cones (rather than concentric ridges), bringing incident light to a point at a more precise depth on the photoactive layer in solar panels.

Initial tests with their precision-machined Fresnel solar collector showed a peak power four times higher than standard panels at low resistance. The difference in power falls off quickly as the device's resistance rises, which it does as it gets hotter under sunlight and as a byproduct of generating electricity. Nevertheless, the differential would be enough to boost its electrical output, substantially offsetting the additional cost of the Fresnel collector so that the overall cost of solar panels might be reduced. This simple addition to older, less efficient solar panels might also make them viable for places and applications where modern devices of higher intrinsic efficiency are not commercially tenable. *www.tju.edu.cn/english/Research/Facilities.*

Researchers at the **Helmholtz Center Berlin** (HZB), Germany, demonstrated that tiny voids within the silicon network are partly responsible for reducing solar cell efficiency by roughly 10 to 15% as soon as use begins. Defects in amorphous silicon come in two types: Those that are uniformly distributed and those that are concentrated in clusters on internal surfaces of small voids—known as microvoids—which form within the material during solar cell manufacturing. www.helmholtz-berlin.de/index_en.html.

briefs

The **DOE** recently announced that the U.S. solar industry is more than 60% of the way to achieving cost-competitive, utility-scale solar photovoltaic (PV) electricity—only three years into the Department's decade-long SunShot Initiative. To facilitate further progress, $25 million in funding will help strengthen U.S. solar manufacturing for PV and concentrating solar power technologies and maintain a strong domestic solar industry—supporting the broader Clean Energy Manufacturing Initiative. www.energy.gov.

Plastic shopping bags, an abundant source of litter on land and at sea, can be converted into diesel, natural gas, and other useful petroleum products, according to researchers at the **Illinois Sustainable Technology Center at the University of Illinois,** Champaign. The conversion produces significantly more energy than it requires and results in transportation fuels—diesel, for example—that can be blended with existing ultra-low-sulfur diesels and biodiesels. Other products, such as natural gas, naphtha (a solvent), gasoline, waxes, and lubricating oils such as engine oil and hydraulic oil also can be obtained from shopping bags. www.istc.illinois.edu.

Used plastic shopping bags can be converted into petroleum products that serve a multitude of purposes. Courtesy of Julie McMahon.

Self-cleaning solar coating improves energy collection

Under the sponsorship of the DOE's Efficiency and Renewable Energy SunShot Concentrating Solar Power Program, Oak Ridge National Laboratory, Tenn., is developing a low-cost, transparent, anti-soiling (self-cleaning) coating for solar reflectors to optimize energy efficiency while lowering costs and avoiding negative environmental impacts. The surface layer is based on a superhydrophobic coating technology shown to effectively repel water, viscous liquids, and most solid particles. Coatings are deposited by conventional painting and spraying methods using a mixture of organics and particles. In addition to being economical, these methods can be easily deployed in the field during repairs and retrofitting.

Solar power reflectors collect dust and sand, reducing their energy efficiency—a challenge ORNL researchers are tackling by developing a low-cost, anti-soiling coating.

The anti-soiling coating loses less than 0.3% of transparency over the entire solar radiation wavelength range. When exposed to several hundred hours of accelerated UV radiation and 100 hours of salt fog exposure, the coating exhibited no degradation in superhydrophobic or optical transmission properties. When glass slides with the anti-soiling coating were exposed to sand and dust in a custom-made wind tunnel, the particles did not adhere to the coated surface of the slides. *www.ornl.gov.*

Metal implants could ease chemotherapy side effects

Cancer patients could one day experience fewer side effects from chemotherapy following a discovery that opens the door for more targeted treatments. Researchers at the Edinburgh Cancer Research UK Centre at the MRC Institute of Genetics and Molecular Medicine, the University of Edinburgh, identified a possible way of treating tumors that would see doctors place harmless metal implants at the cancer site. Scientists found that they could alter the chemical composition of commonly used chemotherapy drugs so that they only become active when they come into contact with palladium. They hope that by implanting small devices coated with palladium into patients' tumors, the drugs would become activated only where they are needed, causing minimal damage to healthy tissue.

"It will be several years before we're able to start treating patients, but we're hopeful that this approach will lead to better tolerated cancer therapies in the future," explains project leader Asier Unciti-Broceta. *www.research.ed.ac.uk.*

Comprehensive surface finishing guide debuts

The National Association for Surface Finishing (NASF), Washington, announced the release of a much-anticipated resource for the surface coatings industry: *Advanced Surface Technology,* a comprehensive reference for a wide range of coating and finishing applications. The publication is both a practical guide for any professional or operator in the coatings industry, as well as a core text for teaching engineers and scientists at all levels in the field of surface technology. The two-volume hardcover set is authored by Per Moller and Lars Pleth Nielsen and contains the most current information in a reader-friendly format. In addition, it is filled with numerous easy-to-understand illustrations, charts, and descriptive graphics and should serve as an inclusive and handy tool for finishers, suppliers, and the OEM community, according to NASF sources. *www.NASF.org.*

briefs

Bayer MaterialScience LLC, Pittsburgh, participated in the SSPC conference in Lake Buena Vista, Fla., discussing the safe use of polyurethane coatings, which include isocyanates as a raw material and are applied on commercial and industrial infrastructure. Safe handling recommendations, training, and on-site monitoring are components of the company's product stewardship program. These activities should help contractors prepare for inspections as well as address concerns that may arise from OSHA's recently announced National Emphasis Program (NEP) for isocyanates. www.bmsnafta.com, www.osha.gov.

Boyd Coatings Research Co. Inc., Hudson, Mass., developed the CRC 6000-line hydrophobic coating, primarily for use on radomes, satellite dishes, and other communication installations to prevent water film from building up and hindering signals. CRC 6000 is a solid dispersion of fluorocarbon polymer and an aliphatic, moisture-cure, two-part polyurethane that creates a hard film with superior UV-resistance and long-term water repellency. The coating was designed to create a high contact angle (140°+) for water droplets, allowing them to roll off and leave a perfectly dry surface. www.boydcoatings.com.

The Material Works Ltd. (TMW), Red Bud, Ill., announced that after reviewing the results of a battery of paint performance and welding tests, **General Motors** and **Chrysler** approved its strip steel processed by eco pickled surface (EPS) technology as a replacement for acid pickled steel. The process removes the layer of oxide (mill scale) from the surface of hot rolled steel, imparting a clean and uniform surface. The process uses no hazardous substances to accomplish its pickling and leaves the steel inherently rust-resistant, so it does not require the oil film that is applied to acid pickled steel to prevent rusting. www.epsprocess.com.

briefs

ROFIN-SINAR Technologies Inc. (ROFIN), Plymouth, Mich., acquired **FiLaser USA LLC** (FiLaser), Portland, Ore. ROFIN manufactures lasers and laser-based systems for industrial material processing applications. Products range from single laser beam sources to complex systems, covering technologies such as CO_2, fiber, solid state, and diode lasers, and the entire power spectrum from single-digit watts up to multi-kilowatts. FiLaser develops advanced laser process technology for precision cutting and drilling brittle materials including glass, sapphire, and semiconductor substrates with applications in the touch panel, LCD, cell phone display, LED, and semiconductor markets. www.rofin.com, www.filaser.com.

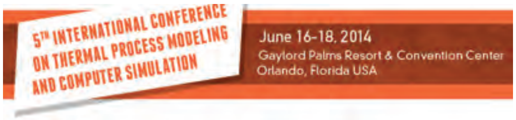
The **ThyssenKrupp Steel USA** rolling and coating plant in Calvert, Ala., was sold to a consortium of **ArcelorMittal** and **Nippon Steel & Sumitomo Metal Corp.** Upon closing, ThyssenKrupp received a purchase price of $1.55 billion from the consortium. www.thyssenkrupp.com, www.nssmc.com.

AM/NS CALVERT

A faculty team at the **South Dakota School of Mines & Technology,** Rapid City, received nearly $1 million in funding from the **U.S. Dept. of Defense – Army Research Lab** through a sub-award from the **University of Alabama.** Focusing on novel extraction technologies for rare earth ores, the research will use a multidisciplinary approach to develop new leaching and concentration techniques and strategies for recovery of rare earth metals. www.sdsmt.edu.

Conference highlights thermal process modeling

ASM International's Heat Treating Society, Materials Park, Ohio, will cosponsor the 5th International Conference on Thermal Process Modeling and Computer Simulation (ICTPCS), taking place June 16-18 in Orlando, Fla. The other conference cosponsor is the International Federation for Heat Treating and Surface Engineering (IFHTSE). Additional industrial sponsors include Bodycote and the Computational Materials Data Network. The event will collocate with the 2014 AeroMat Conference and ICTPCS attendees will have access to all AeroMat technical sessions and the exposition area. The conference has evolved from a predominately theoretical meeting involving specialists in computational materials science, solid mechanics, and fluid mechanics to one comprised of both theoretical and practical implementation of modeling and simulation.



Sixty-four technical presentations will explore the broad field of thermal process modeling, while several papers deal strictly with computational issues of efficiency, accuracy, and solver methods. Some processes covered include surface treatments such as carburizing, nitriding, thermal spraying, and cladding; immersion quenching in liquids that boil; gas quenching processes; phase transformations during heating and cooling; induction hardening and spray quenching; controlled cooling of castings and forgings; and welding.

Keynote presentations will be given by Dr. Sabine Denis of Université de Lorraine, Prof. Christoph Beckermann of the University of Iowa, and Dr. Howard Kuhn of the University of Pittsburgh. Their respective subjects include immersion quenching with transient boiling; distortion, stresses, and defects in solidifying castings; and modeling of additive manufacturing processes. *For more information, visit www2.asminternational.org/content/Events/modeling/index.jsp.*

Nanostructured alloy for copper-beryllium replacement

Integran Technologies Inc., Toronto, received the 2013 Strategic Environmental Research and Defense Program (SERDP) Project-of-the-Year Award for Weapons Systems and Platforms for developing a nanostructured alloy that can replace copper-beryllium. Beryllium is particularly useful because it is both lightweight and strong. However, it is a toxic material that can be harmful to workers who must handle it during assembly and repair.

With support from the U.S. Dept. of Defense SERDP program and Industry Canada's Strategic Aerospace and Defense Initiative (SADI) program, Integran developed and validated an electroforming process that produces a nanostructured alloy to match the desirable properties of copper-beryllium, particularly for use as high-load bushings. The pulsed electroplating process creates near-net-shape components that require little to no machining to achieve final dimensions, producing little material waste. This innovative process can be used successfully for large metal sheets and high conductivity wires, both of which are used in multiple military applications.

"The validation testing performed in this project demonstrates that these nanostructured alloys could result in substantial cost savings for the U.S. DoD and Canadian military through the decreased use of toxic substances," says Brandon Bouwhuis, Integran's aerospace and defense R&D unit manager. *www.integran.com.*

Canadian Plastics Industry Association joins recycling effort

The recycling committee of SPI: The Plastics Industry Trade Association announced that the Canadian Plastics Industry Association (CPIA) joined SPI's effort to pursue zero waste by participating in RecyclePlastics365.org, a recycling marketplace that connects buyers and sellers of scrap plastic materials and recycling services. Launched in June 2013, the recycling website is accessible to both association members and nonmembers. Buyers, and those seeking recycling services, can search for suppliers via keyword search or by clicking on a category to find suppliers. *www.recycleplastics365.org.*

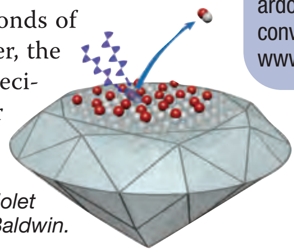
Manipulating surfaces with single-atom precision

Scientists at Macquarie University, Australia, discovered a natural phenomenon that shows how light could be used to pick apart a substance atom by atom, enabling new possibilities for nanoscale diamond devices.

"Lasers are known to be very precise at cutting and drilling materials on a small scale—less than the width of a human hair, in fact—but on the atomic scale they have notoriously poor resolution," explains lead researcher Richard Mildren. "If we can harness lasers at higher resolutions, opportunities at the atomic level are tremendous, especially for future nanoscale devices in data storage, quantum computers, nanosensors, and high-power on-chip lasers."

Traditional lasers that separate materials by super heating the surface at the laser beam's focal point have severe limitations especially with regard to fabrication challenges in nanodevices. Mildren and his colleagues discovered that it is possible to remove atoms from a surface, using ultraviolet lasers, and confine the interaction to the atomic scale. The phenomenon avoids the heat generation problem that previously restricted making very small and precise cuts.

"So far, we have used the technique to demonstrate structures in diamonds of roughly 20 nanometers, the size of large molecules," says Mildren. "However, the technique looks highly promising to manipulate surfaces with single-atom precision, more than 10,000 times smaller than what is possible with standard laser machining techniques." *www.mq.edu.au.*



Researchers at Macquarie University removed atoms from a surface using ultraviolet lasers and confined the interaction to the atomic scale. Courtesy of Chris Baldwin.

Lockheed Martin, Bethesda, Md., received three 2014 Manufacturing Leadership Awards for achievements in advanced manufacturing, environmentally friendly practices, and customer relationships from the Manufacturing Leadership Council of **Frost & Sullivan,** San Antonio. Continuous improvement initiatives resulted in robotic spray and mold-in-place automated equipment and techniques that apply precise amounts of low-observable material on aircraft parts. Another award-winning production technique involves machining titanium. Lockheed Martin was a major developer of cryogenic machining, which uses liquid nitrogen as a coolant to allow tools to work faster and longer. The new process also eliminates hazardous waste associated with conventional coolants. www.lockheedmartin.com.

industry news

Nanotechnology

briefs

Researchers at **Seoul National University,** Korea, found that nanoscale 3D objects such as freestanding nanowalls can be constructed using additive manufacturing. Even without the motion of the substrate, nanojets are spontaneously laid down and piled to yield nanowalls. A thin metal line on an insulating plate focuses the electrical field, suppressing the instability of the electrical nanojets. To stack fibers in a controlled fashion, the fiber deposit is manipulated to attract rather than repel the incoming nanojets by quickly draining the electrical charge. A nanowall that lines the ground is formed, which implies that various freestanding structures can be created in a desired shape. www.useoul.edu.

Stephen Goodnick, professor at **Arizona State University,** Phoenix, gave a talk on nanoelectronics advances that could increase performance of solar energy systems at the 2014 annual meeting of the **American Association for the Advancement of Science (AAAS),** Chicago, in February. Innovations driven by nanoelectronics research enable photovoltaic technology to significantly improve the ability to convert sunlight and heat into electric power. New types of nanostructure-based devices can facilitate production of photovoltaic solar cells that achieve better energy-conversion efficiency. *Stephen Goodnick, 480/965-9572, stephen.goodnick@asu.edu, www.asu.edu/aine/index.htm.*

Protecting troops with nanoceramics

The U.S. Army Research Laboratory dedicated a 5-year program to advanced metals and ceramics for armor and anti-armor applications. To provide greater protection against blunt trauma and higher velocity ammunition than can be provided by a standalone soft ballistic vest, hard body armor was developed. It includes a rigid facing comprising ceramic inserts, steel or titanium panels, and a ballistic fabric backing.

In hard armor with ceramic inserts, the projectile's kinetic energy is absorbed and dissipated in localized shattering of the ceramic tile and blunting of the bullet material during impact. Armor ceramics are critical for weight reduction in current and future military and civilian applications. Realizing the full potential of armor ceramics requires an understanding of how the structure of armor-ceramic materials, at several length scales, affects the inherent ballistic performance and its variability among identical components.

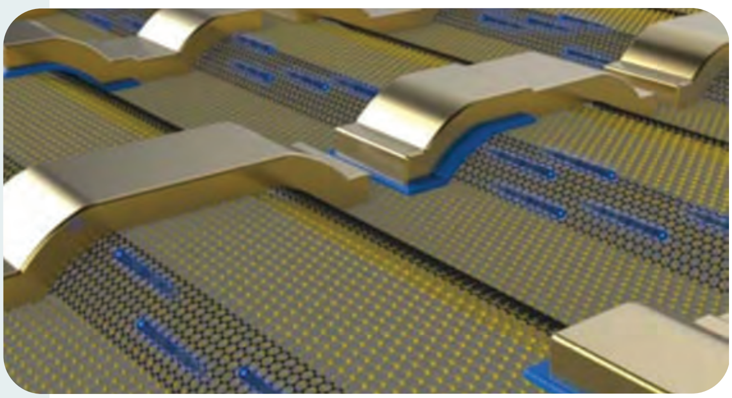
Researchers at **Karlsruhe Institute of Technology,** Germany, and **Carnegie Mellon University,** Pittsburgh, developed the first adhesive tape that not only adheres to a surface as reliably as the toes of a gecko, but also has similar self-cleaning properties. Elastic microhairs of variable size were used and, instead of dirt particles, micrometer-sized glass spheres were distributed on a smooth plate. An artificial adhesive tape covered by microhairs was pressed onto the plate, shifted, and lifted off. When the diameter of the spheres exceeded that of the microhairs, the adhesive force disappeared after the first contact. After eight to 10 test cycles, however, the gecko-inspired adhesive tape reached 80 to 100% of its original power again. www.kit.edu/english, www.cmu.edu.

Carbon nanotubes (CNTs) are being considered as a reinforcing material to enhance the mechanical properties of ceramics, particularly fracture toughness, which is likely to improve their resistance against multiple bullets. Recent studies show that CNTs in ceramics like alumina and silicon carbide can have a strong influence on microstructure, fracture mode, and mechanical properties. An improvement of up to 94% in fracture toughness was observed when 4 vol.% of CNTs are added to alumina. *www.arl.army.mil.*

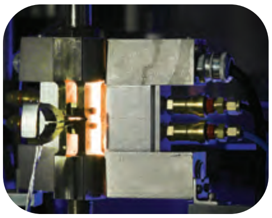
Graphene ribbons highly conductive at room temperature

An international team including researchers from the French National Centre for Scientific Research (CNRS), Université de Lorraine, the SOLEIL synchrotron facility, all in France, Georgia Institute of Technology, Atlanta, Oak Ridge National Laboratory, Tenn., and Université de Leibniz, Germany, produced graphene ribbons in which electrons move freely. The team devised a novel way of synthesizing such ribbons, and demonstrated their exceptional electrical conductivity at room temperature. The nanoribbons hold great promise for next-generation electronics, say researchers.

The team synthesized 1D graphene from silicon carbide and was able to obtain graphene ribbons of very high structural quality, made of an extremely narrow sheet of carbon only 40 nm wide. In order to obtain ribbons with regular edges, nanometer-deep steps were etched into the silicon carbide, producing graphene ribbons directly on the sidewalls of the steps. *www.gatech.edu.*



Conceptual drawing of an electronic circuit comprised of interconnected graphene nanoribbons (black atoms) that are epitaxially grown on steps etched in silicon carbide (yellow atoms). Electrons (blue) travel ballistically along the ribbon and then from one ribbon to the next via the metal contacts. Electron flow is modulated by electrostatic gates. Courtesy of John Hankinson/Georgia Institute of Technology.



Determining Ductile Fracture Toughness in Metals

Xiang (Frank) Chen
Randy K. Nanstad, FASM*
Mikhail A. Sokolov
Eric T. Manneschmidt
Materials Science and Technology Division, Oak Ridge National Laboratory, Tenn.

Ductile fracture toughness testing is useful for evaluating a material's structural integrity. Three different techniques are explored here.

Ductile fracture toughness determination, such as the *J-integral* vs. crack growth resistance (J-R) curve, is a useful tool for evaluating a material's structural integrity in the presence of preexisting defects. The J-R curve can calculate the work (energy) per unit of fracture surface area needed to drive crack growth. A typical J-R curve is shown in Fig. 1. From it, the material fracture toughness near the initiation of stable crack growth (Jq) can be derived. In addition, tearing modulus (T_R), representing the material's resistance to stable crack growth, can be calculated based on the slope of the J-R curve between two exclusion lines (dashed red lines in Fig. 1). Since the introduction of the J-R curve, there have been extensive efforts devoted to developing simple and reliable methods to determine this aspect of various materials. This article briefly reviews three widely used J-R curve test methods in metals: Elastic unloading compliance (EUC), normalization, and direct current potential drop (DCPD). The main differences between these methods involve crack size determination. More details about performing the J-R curve test can be found in ASTM standard E1820-11[1].

Specimen configuration and test apparatus

Different types of specimens can be used for the J-R curve test. Figure 2 illustrates three commonly used configurations: A standard compact C(T) specimen, single edge bend SE(B) specimen, and standard disk-shaped compact DC(T) specimen. After machining, the sample undergoes fatigue precracking to create the initial sharp crack. Initial crack size is usually controlled to be ~a/W=0.5 where *a* is the crack size and *W* is the specimen width. Afterwards, side-grooving on both sides of the specimen (e.g., C(T) and SE(B) specimens in Fig. 2) is usually performed to ensure a straight crack front. Total thickness reduction of 20% (10% on each side) due to side-grooving functions well for many materials.

Both servo-hydraulic and electromechanical load frames can be used for the J-R curve test. Figures 3 and 4 show the experimental apparatus for performing this test on a C(T) and SE(B) specimen, respectively. The experimental setup of a DC(T) specimen is similar to that of a C(T) specimen. As shown in Fig. 3, the J-R curve test apparatus for a C(T) specimen consists of a pair of clevises with pins for loading the specimen and a displacement gage for measuring the specimen's crack mouth opening displacement (CMOD). In contrast, the test fixture for a SE(B) specimen (Fig. 4) employs a central pin to press the specimen, plus two roller pins to support it. The load line

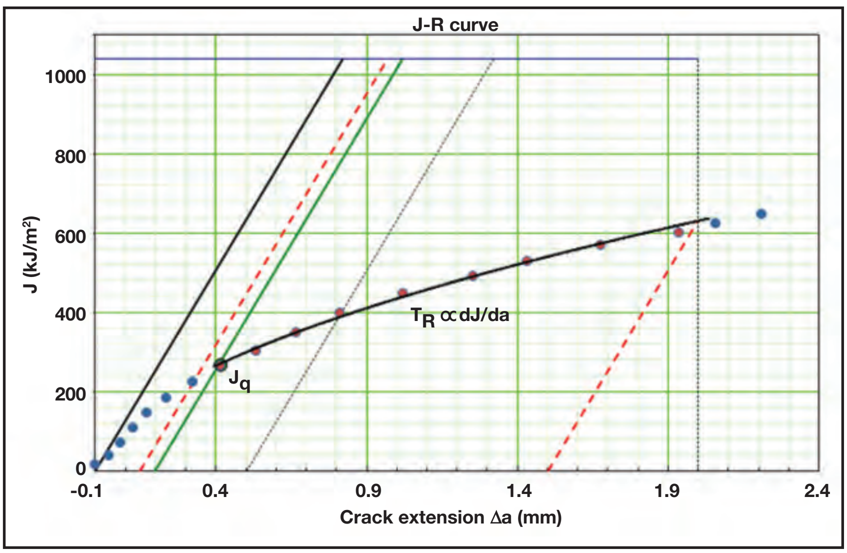


Fig. 1 — *A typical J-R curve shows the fracture toughness near the initiation of stable crack growth (Jq) and tearing modulus (T_R).*

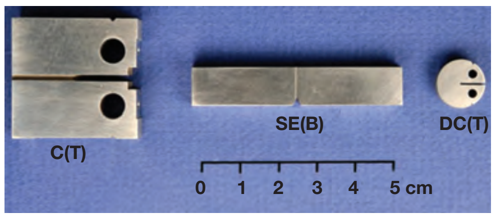


Fig. 2 — *Three commonly used specimen configurations for the J-R curve test. Left to right: Standard compact C(T) specimen, single edge bend SE(B) specimen, and standard disk-shaped compact DC(T) specimen.*

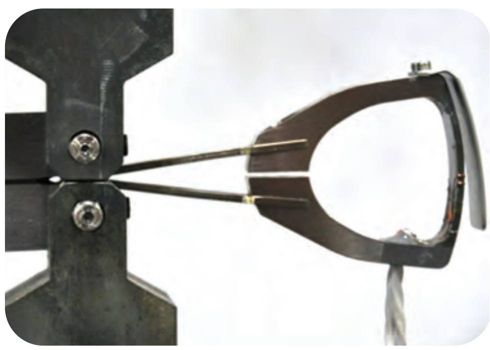


Fig. 3 — *Apparatus for the J-R curve test of a compact specimen.*

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displacement of the SE(B) specimen is measured from the displacement of the specimen notch root by a LVDT sensor. Alternatively, the CMOD of the SE(B) specimen is measured by a displacement gage. For both C(T) and SE(B) specimens, a load cell (not shown in Figs. 3 and 4) measures specimen load.

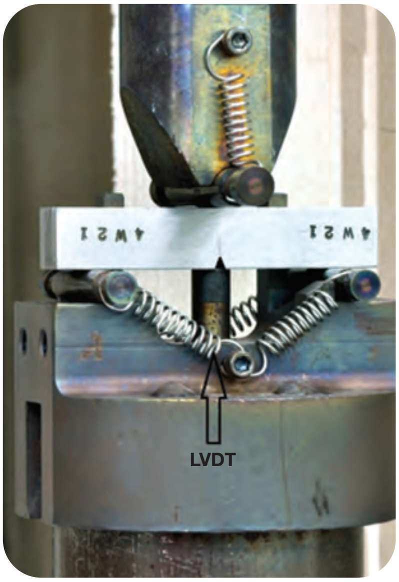

Fig. 4 — *Apparatus for the J-R curve test of a single edge bend specimen.*

Elastic unloading compliance (EUC)

Because a J-R curve consists of two parts, *J-Integral* and crack growth, determining this curve naturally involves calculating both aspects. In *elastic unloading compliance* (EUC), the *J-Integral* is calculated as:

$$J_{(i)} = J_{el(i)} + J_{pl(i)} \qquad (1)$$

where $J_{el(i)}$ and $J_{pl(i)}$ are the elastic and plastic components of *J-Integral*, respectively. For $J_{el(i)}$:

$$J_{el(i)} = \frac{K_{(i)}^2 (1-\nu^2)}{E} \qquad (2)$$

where ν is Poisson's ratio, E is Young's modulus, and $K_{(i)}$ is the stress intensity factor. $K_{(i)}$ depends on specimen configuration, load level, crack size, and other factors. The equation for calculating $J_{pl(i)}$ follows:

$$J_{pl(i)} = \left[J_{pl(i-1)} + \frac{\eta_{pl(i-1)}}{b_{(i-1)}} \times \frac{A_{pl(i)} - A_{pl(i-1)}}{B_N}\right] \times \left[1 - \gamma_{pl(i-1)} \frac{a_{(i)} - a_{(i-1)}}{b_{(i-1)}}\right] \qquad (3)$$

where $a_{(i)}$ is the current crack size, $b_{(i)}$ is the unbroken ligament size, B_N is the specimen net thickness, $A_{pl(i)}$ is the plastic area under the load versus load-line displacement record for the specimen, $\eta_{pl(i-1)}$ equals 1.9 for a SE(B) specimen and $(2+0.522b_{(i-1)}/W)$ for a C(T) or DC(T) specimen, and γ equals 0.9 for a SE(B) specimen and $(1+0.76b_{(i-1)}/W)$ for a C(T) or DC(T) specimen. In order to obtain the real-time crack growth value, EUC measures the material compliance (the ratio of displacement increment to force increment) by periodic unloading and reloading of the specimen. For instance, a typical load-displacement record for a J-R curve test using EUC is shown in Fig. 5(a). Each short straight line in Fig. 5(a) represents an unloading-reloading sequence. The rest of the curve resembles a load-displacement curve in a tensile test, i.e., initial elastic deformation followed by plastic deformation and load drop after passing the maximum load level. Once the material compliance value is obtained, equations in ASTM standard E1820-11[1] can be applied to convert the compliance result to the estimated real-time crack size. Eventually, combining the *J-Integral* and crack growth results yields the J-R data as shown in Fig. 5(b).

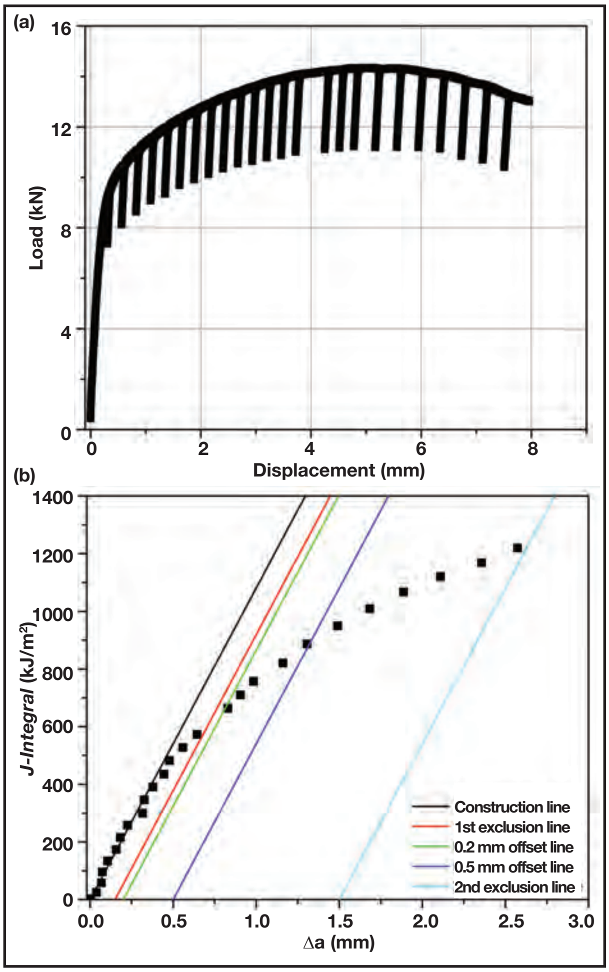

Fig. 5 — *(a) Load-displacement record for a J-R curve test with elastic unloading compliance (EUC); (b) J-R data determined by EUC.*

Since its introduction, the EUC method has gained wide popularity for the J-R curve test. However, EUC still faces considerable challenges for testing in extreme environments. For example, in elevated temperature testing (above 500°C), the compliance measurement in EUC is affected by the material relaxation behavior and increased friction between loading clevises and pins, which results in unreliable crack size measurement. In addition, EUC is relatively time-consuming due to the periodic unloading-reloading requirement. In order to solve these issues, alternative J-R curve test methods, such as normalization and DCPD, could be used.

Normalization

The *normalization* technique was initially developed by Herrera and Landes et al.[2, 3] and later studied by Joyce and Lee[4, 5]. In some cases, this method can be applied to determine a J-R curve directly from a load-displacement record taken together with initial and final crack size measurements from the specimen fracture surface. Because the compliance measurement is eliminated, the load-displacement curve in the normalization method does not require the unloading-reloading portion as in EUC—see Fig. 6(a)—greatly simplifying the test and reducing test time.

The *J-Integral* calculation for the normalization method is the same as that in EUC, described previously. In addition to initial and final crack size measurements, intermediate crack sizes are required to derive the full J-R curve. In the normalization method, detailed procedures for deriving intermediate crack sizes are lengthy and complicated[1]. In principle, the normalized load (P_{Ni}) and plastic displacement (v_{pli}')—both of which are functions of the current crack size a_i—are calculated first using only measured initial and final crack size data. After calculation, the normalized load and plastic displacement are fitted with the following normalization function:

$$P_{Ni} = \frac{a + bv_{pli}' + cv_{pli}'^2}{d + v_{pli}'} \quad (4)$$

where *a, b, c,* and *d* are fitting constants. Afterwards, the normalized load is recalculated with an assumed crack size and compared with the normalized load from Eq. (4). Then the assumed crack size used for calculating the normalized load is adjusted until the deviation between the calculated normalized load and the normalized load from Eq. (4) is within the ±0.1% range. After repeating this procedure, all intermediate crack sizes are derived and the J-R curve is determined in the normalization method, which reveals an excellent agreement with the J-R curve from EUC. See Fig. 6(b).

The normalization technique is more favorable for tests with high loading rates or in extreme environments. Despite these advantages, this method has a very strict requirement for crack growth—the final physical crack extension must be within the lesser of 4 mm or 15% of the initial uncracked ligament[1]. Unlike EUC, real-time crack growth estimates are not available in the normalization method. Therefore, strict crack growth control may be difficult to realize during the test for the normalization method.

Direct current potential drop (DCPD)

As an alternative J-R curve test method[6-10], *direct current potential drop* (DCPD) combines the advantages of both the EUC and normalization methods. It does not require the unloading compliance measurement, so the load-displacement test record is simplified and the same as the normalization method in Fig. 6(a). In addition, DCPD provides experimental real-time crack size measurements as in EUC. DCPD relies on passing a constant direct current through the specimen, then measuring the voltage generated across an area in the specimen. See Fig. 7(a). As the crack propagates in the specimen, less area is available for the passage of the constant current, resulting in an increase of the effective electrical resistance and potential measurement, i.e., the potential drop in Fig. 7(b). Thus, a correlation can be made between crack length and potential drop in DCPD. In order to convert the potential drop measurement to the crack size, Johnson's equation is usually applied[11-12]:

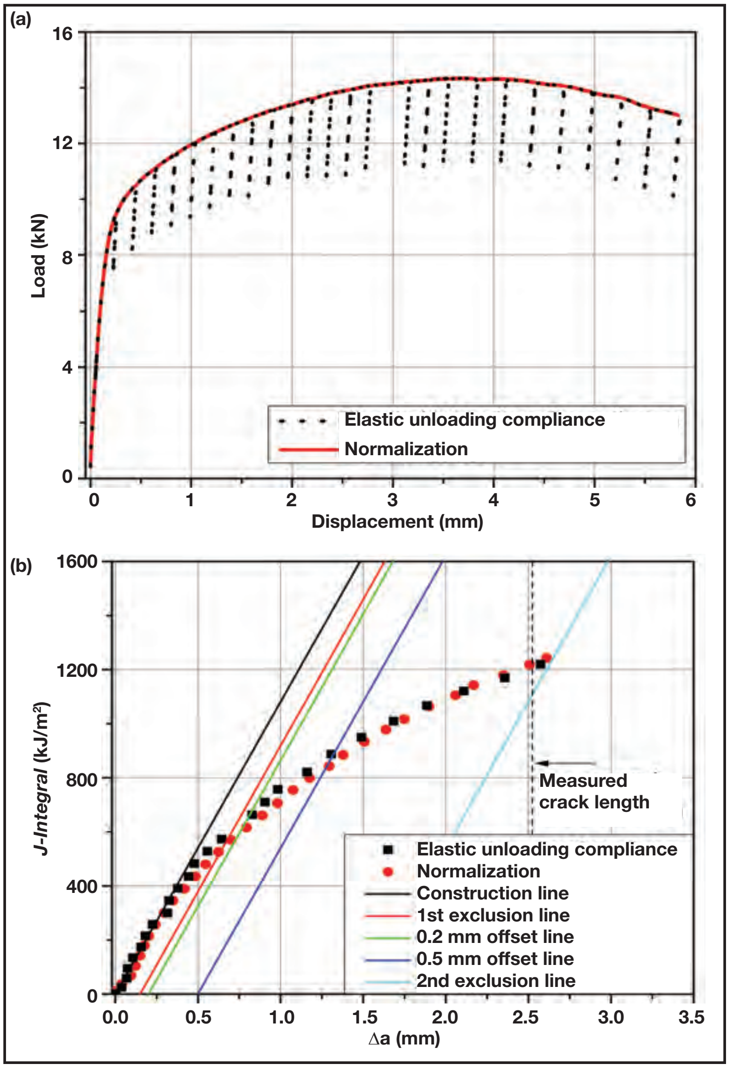

Fig. 6 — *(a) EUC vs. normalization load-displacement record for the J-R curve test; (b) comparison of J-R curves derived by EUC and normalization.*

$$a = \frac{2W}{\pi} \cos^{-1} \frac{\cosh(\pi y/2W)}{\cosh\{(U/U_0)\cosh^{-1}[\cosh(\pi y/2W)/\cos(\pi a_0/2W)]\}} \quad (5)$$

where a is the crack length corresponding to potential drop U, W is specimen width, y is one-half of the potential gage span, and a_0 and U_0 are initial crack length and potential drop, respectively. During the J-R curve test

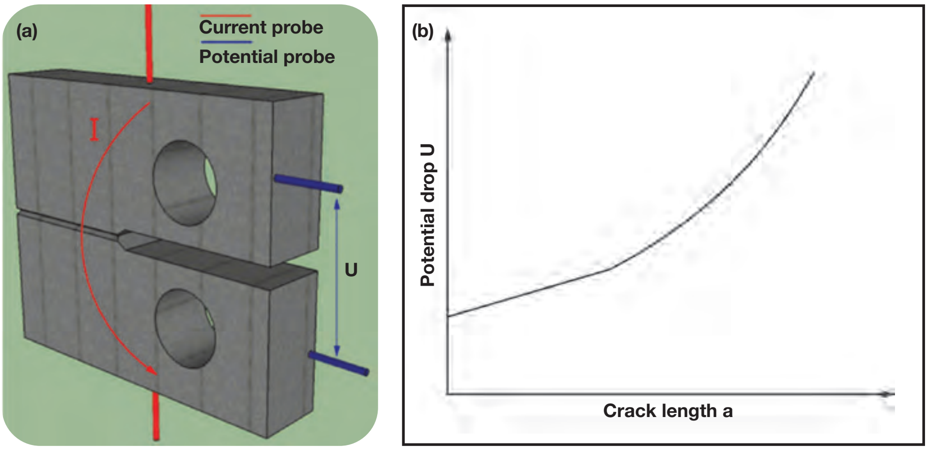

Fig. 7 — *Schematic for (a) direct current potential drop measurement and (b) crack-growth-induced increase in potential drop.*

with DCPD, potential drop is measured continuously or periodically from the specimen, so a real-time crack size measurement is available. The *J-Integral* calculation is performed in the same manner as EUC or normalization to yield the J-R curve.

Once the original J-R curve from DCPD is obtained, adjustments are needed to differentiate potential drop due to stable crack growth from material deformation[7, 13]. Although difficulties still exist in adjusting DCPD data to yield valid J-R curve results, new methodology[14] shows improved results over previous DCPD adjustment methods[15] with promising J-R curve results. As shown in Fig. 8, after incorporating the new adjustment procedure, ductile fracture toughness near the initiation of stable crack growth (Jq) from DCPD is in excellent agreement with results from EUC and normalization, whereas only small deviations are observed in tearing modulus (T_R) results.

Summary

This article presents the experimental setup and three different techniques—EUC, normalization, and DCPD—for evaluating ductile fracture toughness in metals using the J-R curve. The *J-Integral* calculation is the same in all three methods, with differences primarily involving crack size measurements. EUC relies on material compliance to derive the real-time crack size, while for the normalization method, initial and final crack lengths are measured and intermediate crack sizes are determined based on the normalization function. For DCPD, the correlation between potential drop and crack size is exploited to assess crack size. All three methods are applicable for testing in the normal temperature range. However, for elevated temperature tests, the material relaxation behavior and increased friction between the loading clevises and pins degrade the accuracy of the elastic compliance measurements for the EUC method, so normalization or DCPD should be used. In addition, the original J-R curve based on DCPD requires adjustment to account for the deformation-induced potential drop.❍

Acknowledgment

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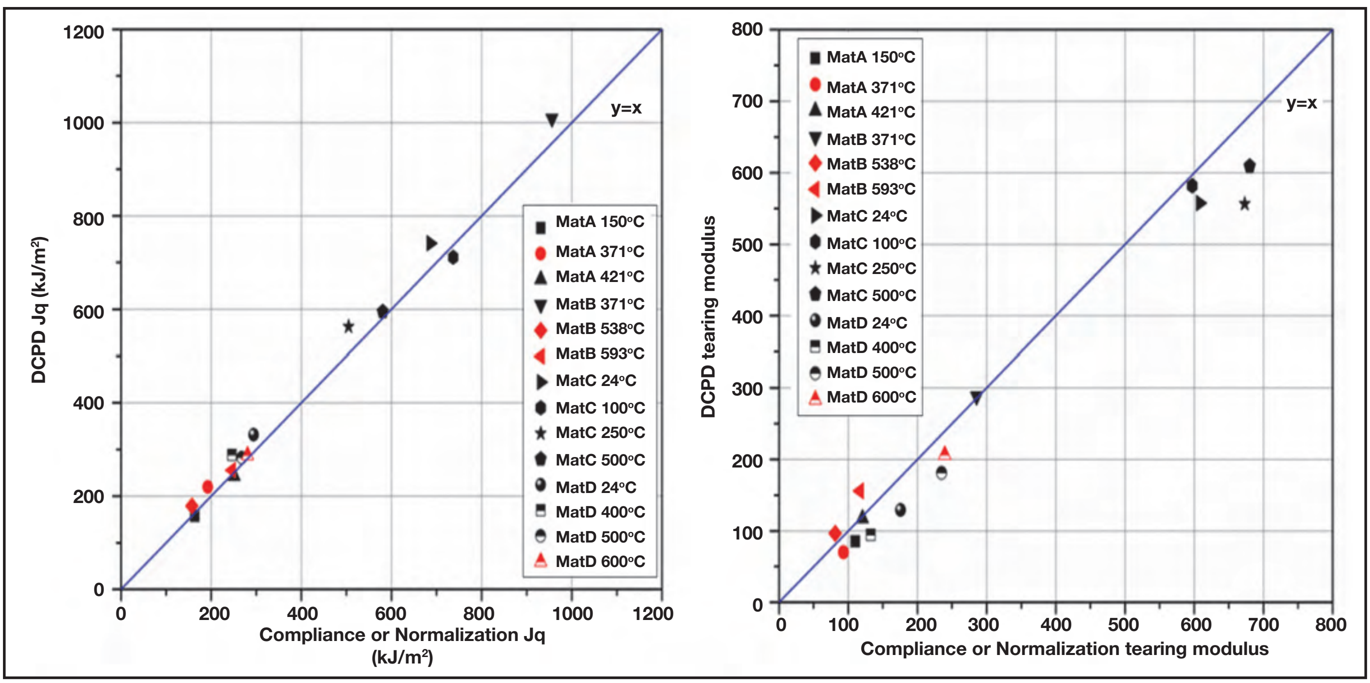

Fig. 8 — *Comparison of post-adjustment DCPD J-R curve results with EUC (black symbols) or normalization (red symbols)[14].*

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Analyzing Metals with Handheld Laser-Induced Breakdown Spectroscopy (LIBS)

Metal producers, inspectors, and recyclers are under constant pressure to increase both the volume and quality of tested materials. Because testing in non-laboratory settings has become common—close to the production line, in situ, or at chemical facilities or handling yards—testing is regularly performed with portable instrumentation.

Technicians and operators who must use this equipment are seeking faster and more comprehensive analysis from tools that minimize damage to tested goods. One such method—laser-induced breakdown spectroscopy (LIBS)—is an established technology that provides nearly instantaneous and virtually nondestructive analysis with minimal or no sample preparation and without an ionizing radiation source. LIBS is now taking its first leap into the field of metal analysis via handheld equipment.

Laser-induced breakdown spectroscopy

Accurate metal analysis in the field has been traditionally performed using handheld x-ray fluorescence (XRF) and mobile optical emission spectroscopy (OES) instruments. LIBS has long been available in a benchtop form, which until recently was limited to laboratories for metal analysis. Today, LIBS can be found as a standalone handheld analyzer and it is becoming a viable and economical option for high-volume metal alloy analysis.

LIBS is an atomic emission spectroscopy technique capable of analyzing any element in any physical state. It is limited only by the instrument's laser power, sensitivity, and spectrometer wavelength range. The technology combines the speed and ease of XRF—without a radiation source—and the expanded elemental range of OES while minimizing sample preparation and damage. Drawing on the strengths of established portable XRF and OES technologies, the handheld LIBS instrument quickly and accurately analyzes metals using a laser-based spectrometer, which is virtually nondestructive.

How it works

LIBS is an atomic emission technique whereby the instrument's laser—commonly a neodymium-doped yttrium aluminum garnet (ND:YAG) laser—fires a series of nanosecond-long pulses through a small focusing lens onto the sample. The focused beam ablates a tiny amount of the sample's surface and subsequently ionizes the removed material to create a plasma. The plasma expands as it is bombarded by the laser and excites electrons in the plasma's constituent atoms. As electrons relax and atoms return to a stable state, they emit photons that are characteristic of the element and electron transitions. The spectrometer uses a scanning monochromator (e.g., Czerny-Turner), a prism, or grating to disperse light. A photomultiplier or charge-coupled device (CCD) detector array collects emitted radiation over a defined wavelength range, typically between 170-1100 nm.

Making LIBS portable

Laboratory LIBS instruments have been available since the early 1960s.

Fig. 1 — *mPulse is a handheld portable scrap metal analyzer that enables one-second analysis results used in the field to sort scrap metal.*

Fig. 2 — *The portable mPulse LIBS analyzer allows faster sorting and metal grading.*

Nanotechnology advances over the past decade have enabled these laboratory systems to be turned into powerful and compact portable instruments. The first truly self-contained handheld LIBS instrument was introduced in 2013. The miniaturization of electronic components as well as two key advances made this possible: First, a laser source of a practical size became powerful and stable enough for use in the smaller design footprint; and second, a mobile power source in the form of a nonexplosive lithium iron phosphate (LiFeP) battery was developed to provide enough power to operate the laser and electronics for up to 1000 analyses.

LIBS vs. XRF and OES

The primary objective of LIBS, OES, and XRF instruments is to either qualitatively or quantitatively analyze a material. Portable versions of these instruments simplify the operation of complex spectrometers into point-and-shoot tools that can be used with minimal training or understanding of the instrument's inner workings.

OES and LIBS share similarities on the detection side as both are atomic emission techniques. Where LIBS uses a laser to create the plasma in which the elements are excited, OES uses an arc or spark between an electrode and the sample. Because of this, OES requires a conductive sample and is constrained to metal analysis only. LIBS is considered a virtually nondestructive technique because only one nanogram of material is consumed during a typical measurement. OES is considered destructive because it removes far more material (approximately one microgram). Nevertheless, within industrial sectors and for many applications, the burn mark is recognized as a quality seal and serves as confirmation of sample analysis.

XRF uses a radiation source, either an x-ray tube or radioactive isotope, to excite atoms and a detector to interpret the spectrum, typically at wavelengths >1 nm. Because no material is consumed during analysis, XRF is also considered nondestructive. Unlike the relatively complex LIBS or OES spectrum, which may contain dozens of characteristic lines for each element present in the sample, an XRF spectrum is relatively simple, containing two to five characteristic lines per element.

In all three techniques, a portion of the electromagnetic spectrum is monitored and the number of incidents at each discrete wavelength is counted over a period of time to determine the amount of each element in the analyzed sample. Where LIBS and OES require a means to disperse the emitted light to separate it into different wavelength bands, XRF, more specifically energy-dispersive XRF, does not require any additional hardware between the sample and detector.

The LIBS laser is very powerful, but is focused to a microscopic point on the sample and causes virtually no sample heating around the test area. Outside of the focal point, the laser is virtually harmless, provided the beam is not aimed directly into the retina from a short distance. The laser will not penetrate the human body and is non-ionizing. Further, laser light is considered noncarcinogenic.

Metal analysis

Thousands of portable metal analyzers are sold annually for a variety of purposes including quality control at production facilities, inspection of petrochemical process equipment, and rapid sorting at scrap recycling facilities. These analyzers are typically based on either XRF or OES. XRF is more common for alloy sorting and materials identification purposes because it is self-contained, accurately measures a wide range of elements, and is easy to transport and operate. XRF is safe, but because it uses a radiation generating device—either an x-ray tube or radioactive isotope source—some regions require licensing and certification to use it.

OES instruments can measure elements critical to the metal industry that

XRF cannot, namely carbon, which enables distinguishing low and high grades of stainless steel, and very low concentrations of sulfur and phosphorus in steel. OES determines the nitrogen content and thereby identifies duplex steels. However, this technique is less portable, requires more calibration maintenance, typically uses an argon gas purge, and sometimes requires additional sample preparation.

Handheld LIBS features the benefits of both techniques—it can measure lighter elements than XRF (e.g., beryllium in copper alloys), minimal sample preparation is required, and operation is rapid and does not require a radiation source or gas purge. Depending on the application, XRF and OES can make it difficult to measure small or awkwardly shaped samples such as turnings and granules. LIBS systems are capable of measuring large or small samples because the laser is focused to a smaller area (on the order of 1 mm). For the handheld LIBS instruments, the laser is focused at the leading edge of the analyzer such that the sample should be in contact with the instrument. The only limitation to the sample size is the user's ability to conveniently hold and position the analyzer to the sample. Operators only need to touch the instrument outlet to the desired sample area and squeeze the trigger. Typical analysis lasts approximately one second and measurement results are shown on the screen.

Conclusions

Mobile OES and handheld XRF analyzers have been around for decades, and the core components have vastly improved in performance and accuracy, putting them on par with laboratory versions of the same technology. These instruments can be used in new applications due to user interface improvements and minimal maintenance requirements.

LIBS is just now entering a new handheld format, which presents both obstacles and opportunities for continued development. As LIBS continues to mature, manufacturers will go through similar learning curves to XRF and OES technologies. They will continue to offer the ability to measure a wider range of elements and materials, analyze many different sample types such as powders and liquids, measure materials at longer distances from the sample, and implement new accessories that facilitate operation and analysis. As LIBS components continue to get smaller and become more capable, there is hope that handheld LIBS units will approach the performance of their laboratory counterparts. ❍

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In-House vs. Outsourced Materials Testing: **How to Decide**

Many companies are revisiting their decision to bring materials testing in-house. Some own aging testing equipment and must decide whether or not to invest in upgrades, while others currently outsource testing, and debate if an estimated 200% return-on-investment (ROI) for universal testing equipment is enough to bring testing activities back on site. When making this choice, quality and time are as important as ROI in the final analysis. By reviewing the impact on quality control and timeliness, issues can be better understood and a blueprint for gaining bottom-line cost efficiencies can be developed.

Quality results

Materials testing represents a key quality threshold in the manufacturing process—specific, clear, and relevant data from which material qualities and overall product quality can be accurately assessed is needed. What is being tested, how quality is defined for specific products, and overall business strategies must be considered when deciding whether to insource or outsource testing functions.

When reviewing day-to-day operations, including manufacturing processes, the business and operational impact of testing must be determined. Testing data that lacks credibility, is difficult to use, or negatively impacts inventory can destroy performance. Is testing a major part of new product development or continuous improvement of existing products? Is it connected to brand management? For example, companies that tout their products as being the most flexible or strongest in the market rely on testing and documentation to back up those claims. When these results are central to branding claims, being confident in the testing process is critical.

Another consideration is the role of testing in workflow iteration adjustments. The more significant these ongoing testing results are to workflow, the greater the need for real-time or near real-time adjustments to testing schedules. External testing firms may or may not be able to accommodate testing timetables that can keep pace as quickly as an internal process. How does testing align with overall business strategies? For some companies, expanding or updating testing capabilities can help set the stage for business growth.

Other quality factors include regulatory requirements such as ASTM or ISO standards. If meeting these benchmarks is vital to new business, companies must be confident in their tester's ability to deliver accurate results.

Testing complexity also plays a role in decision-making—some materials require highly complex tests; other materials are straightforward. A mix of testing needs can result in a variety of testing sources, including both outsourced and in-house options, rather than making an either-or decision. Once the impact of testing quality is determined, testing quality measurements can then be determined. This is particularly important when considering a move from in-house to outsourced testing, or vice versa. Measuring ROI is challenging when quality specifications vary.

Quantity must also be considered: How many tests and

Universal Testing Machine

OUTSOURCE SCENARIO		%	#	$	Totals $
1	Outsource Cost Per Test			250	
2	# of Tests per year		250		
3	Therefore Outsource Cost				62500
4	Holding Cost of Materials				
5	Estimated Stock Value at Outsourced Location			200,000	
6	Time required by outsourcer to produce data in weeks		1		
7	Annual borrowing cost of capital in %	8%			
8	Therefore Holding Cost of Materials				76923
9	Penalties/Returned by Customer - Cost Per Year			10000	10000
10	Cost of Operator			-65000	-65000
11	**Total Dollar Cost Saving/Benefit**				84423
12	Total proposed investment				35000
13	**Indicative first year return**				241%

Fig. 1 — *ROI calculation for in-house vs. outsourced testing. Tests conducted by the new equipment in this scenario include tension, compression, peel, and bend. When considering all factors—quality, time, and cost—it is clear that in-house testing is the better option for many companies.*

how many different types of tests must be performed? For example, a large number of the same test typically requires one tester, whereas a large number of different tests may require multiple testers or a universal tester. Capabilities can be extended by retrofitting in-house testers with additional controllers and/or fixtures.

The importance of quality and broader business strategies must also be considered. For example, when control over the materials testing process is critical to a business process, it is easier to justify the costs of rehabbing existing machines or purchasing new equipment for in-house testing. For situations that require a large number of routine mechanical tests, such as friction or force, and a few highly complex tests, such as those with multiple parameters, a mix of insourcing and outsourcing may be best. A business known for timely product upgrades would more likely turn to in-house testing to better accommodate frequent adjustments. The key is to arrive at the insourcing vs. outsourcing decision after giving appropriate weight to the broader issues that impact product quality and business performance.

Time factors

Time is also an important factor as it involves not only understanding the limits before product and service quality decline, but also the turnaround providing the greatest efficiencies in quality and cost. Turnaround speed for receiving test results is the most important criteria. For example, it is essential to know how quickly test results are needed for product development and/or new iterations, if delays in testing create production bottlenecks, or if testing speed impacts the ability to fill orders in a timely manner.

Sometimes too much stock is tied up in external testing facilities, which can easily outweigh the expense of investing in an in-house tester. It is critical to know if all products must be tested prior to shipment, or just a representative sample. Missed deadlines or penalties due to testing problems should also be considered.

Issues on this "checklist" often clarify the value of in-house testing or, if these are not concerns, show that outsourced testing is the better option. Because of their immediacy and high visibility, time factors can actually outweigh cost considerations when it comes to testing. When combined with quality issues, time considerations should steer the materials testing debate.

Cost considerations

Cost scenarios are another important factor in revisiting the decision-making around in-house vs. outsourced testing. The "cost checklist" starts with a deceptively simple question: How important is it to save money in meeting testing needs?

To answer this question accurately, criteria must be viewed through the lens of quality and time considerations, as well as the advances in functionality, relative to cost, of new testing equipment in the past 10 years. ROI is an effective cost-measurement method. Capital investment in a new universal tester vs. dollars spent on external testing must be measured using the following factors:

- Cost per test
- Number of tests performed each year
- Tied up stock value (at outsourcer)
- Borrowing cost (if necessary) to invest in testing equipment
- Outsourcer's turnaround time on tests
- Penalties incurred (if any) due to missed deadlines
- Cost of operator to run testing equipment
- Potential investment in a new system

By bringing these components together (illustrated in Fig. 1), it is possible to determine a complete ROI picture of insourcing vs. outsourcing.

Conclusions

Manufacturers must test materials. The challenge lies in identifying not only the cost, but also the quality and time factors that will determine if testing should be conducted in-house, outsourced, or both. Thorough analysis that includes all business concerns enables a better understanding of how and where bottom-line testing efficiencies exist. This process provides a blueprint for optimal testing quality that meets and even anticipates broader strategic goals. ❍

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ITSC 2014

Not Fiction: Thermal Spray the Key Technology in Modern Life!

May 21-23, 2014 • Barcelona, Spain

The International Thermal Spray Conference and Exhibition (ITSC) features a three-day exposition, conference, poster session, education courses, young professional competition, social events, and much more. At ITSC, attendees will find information about thermal spray equipment, research and specialist institutes, applied research, and the latest innovations conveniently located in one big forum. The exposition will be held in the Palau de Congressos de Catalunya in northwest Barcelona.

The three-day exposition is an integral part of ITSC 2014. Exhibitors are experts who offer visitors a wealth of problem-solving information and cost-saving opportunities. Dates and times of the exposition include:

- May 21, 12:30 p.m. – 5:00 p.m.
- May 22, 9:00 a.m. – 5:00 p.m.
- May 23, 9:00 a.m. – 5:00 p.m.

ITSC is a golden opportunity for the global thermal spray community to meet, network, exchange key information and ideas, and conduct business. The conference officially opens with an awards ceremony and plenary lectures on Wednesday, May 21. The ITSC awards banquet occurs Thursday, May 22. The conference program offers more than 200 presentations from distinguished speakers covering several topics ranging from fundamental science to industrial applications.

Plenary sessions:

- "Plasma sprayed solutions: From the coating of the top to their integrated functionality on aeroengine components," by K. Ostolaza, ITP Technical Fellow Material and Processes.
- "The history of thermal spraying: From Max Ulrich Schoop to the present time," by S. Hartmann, obz innovation gmbh.

Education courses:

Thermal Spray Technology, Processing, and Evaluation
May 18-20, 8:00 a.m. – 5:00 p.m.
Instructors: Christopher C. Berndt, FASM, TS-HoF and Douglas G. Puerta

Thermal spray technology and coatings solve critical problems in demanding environments. They provide solutions to problems involving repair, wear, high temperature and aqueous corrosion, and thermal protection. Thermal spray can also be used to manufacture net-shapes, advanced sensors, and materials for the biomedical and energy/environmental sectors. These and other emerging applications take advantage of the rapid and cost-effective capabilities of thermal spray technology in the OEM and repair industries.

Thermal Spray for Gas and Oil Industries
May 20, 8:00 a.m. – 5:00 p.m.
Instructor: André G. McDonald

Given the special needs of the oil and gas sector for wear and corrosion resistant coatings with high longevity, the certification process and validation of the coatings produced by those examining them needs to be different. Therefore, this course includes training and testing information that applies specifically to the oil and gas sector.

Introduction to Advanced Diagnostic Techniques Applied to Thermal/ Cold Spray Processes
May 20, 8:00 a.m. – 5:00 p.m.
Instructors: Luc Pouliot and Christian Moreau

This course provides a historical perspective of diagnostic techniques development as well as a detailed description of basic principles of operation for sensors and an extensive series of examples of the practical use of sensors in research and production environments.

Palau de Congressos de Catalunya.

Special events:

Opening of ITSC 2014 with Awards Ceremony and Plenary Lectures
Wednesday, May 21
9:00 a.m.

Opening of the ITSC 2014 Exposition and Poster Session
Wednesday, May 21
12:30 p.m.

Exhibitor Reception and Poster Session
Wednesday, May 21
5:40 p.m.

ITSC 2014 Awards Banquet
Thursday, May 22
8:00 p.m.

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DVS GERMAN WELDING SOCIETY

ICME Helps Develop
Friction Stir Welding Process for Steels

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Developing a process model to improve understanding of thermal, mechanical, and microstructural effects—plus optimizing process parameters—during the friction stir welding of steels is essential in order to implement Integrated Computational Materials Engineering.

**Member of ASM International*

Integrated Computational Materials Engineering (ICME) is a relatively new discipline that shows great promise for reducing the cost and time required to design and deploy new materials, manufacturing technologies, and products. It has been successfully used in some product development programs to date.

Although considerable effort has been put into model development over the past three decades, and while many of these computational models are now in use, significant challenges to comprehensive development and implementation of these models in ICME remain. This article introduces an ICME implementation framework for product development using a welding process and discusses requirements for a welding process modeling tool for ICME. Development of the friction stir welding (FSW) process modeling tool is discussed in detail.

Implementation framework

A proposal for implementing ICME to develop products using manufacturing processes such as welding is shown in Fig. 1. The framework includes three major blocks: Product requirements, manufacturing process modeling tools, and the final product. Product requirements include property requirements, design, and materials. Manufacturing process modeling tools include process parameters, a thermal model, microstructure model, and property model, as well as performance prediction tools. The final product must be validated and verified with regard to materials and design.

The process tool is the engine of ICME, as shown in Fig. 1. The thermal model is optional because some manufacturing processes such as cold forming do not experience a temperature change. For thermally-related processes such as welding and heat treatment, the thermal model predicts temperature by conducting heat transfer analysis.

To develop a welding process modeling tool, model development, validation, and application are necessary. This article explores how ICME is used to develop a friction stir welding (FSW) modeling tool, which can also be used in a FSW process to develop products.

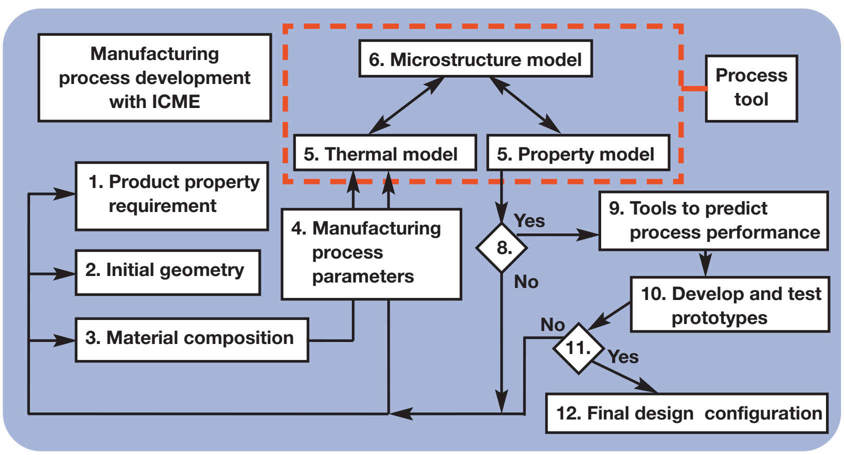

Fig. 1 — *ICME implementation framework.*

Numerical models for FSW

FSW was originally intended for aluminum alloys but now includes a variety of materials such as magnesium, copper, titanium, and steel. The process is extremely successful with aluminum alloys but has not progressed as smoothly with steels due to their complicated physical properties, such as thermal, mechanical, and microstructural effects. It is essential to develop a process model to improve understanding of these physical phenomena and optimize process parameters during FSW of steels in order to use ICME.

A thermal model for FSW was developed based on the finite element method. In the model, surface heat flux is applied on the shoulder surface and body flux is applied in the pin volume. A microstructure model developed by M.F. Ashby and colleagues was implemented in the FSW process model to predict the distribution of individual phases such as ferrite, bainite, and martensite, and the hardness map around the weld area.

Model validations

Analyses simulated the welding experiment performed by D.M. Failla and J. Lippold[1, 2] to validate the FSW model. The specimen was made of HSLA-65, and was 12 mm thick, 150 mm wide, and 300 mm long. Thermal boundary conditions including air convection and strong cooling on the clamping and support surface are specified in the thermal analysis. Mechanical constraint from welding fixtures was simulated in the thermo-mechanical analyses. Contact between the FSW tool and weldment was modeled by a contact pair.

Thermal analysis

The thermal model conducted transient thermal analysis by inputting welding parameters: Rotation speed 850 rpm, travel speed 3.39 mm/s, and load 15.569 kN. Abaqus software was used as a solver in the thermal analysis. Temperature-dependent material properties, density, thermal conductivity, and specific heat for HSLA-65 were also input to the thermal model. Thermal analysis results were compared with results collected by Failla and Lippold[1, 2] to verify the thermal model.

Figure 2 shows the predicted temperature distribution at 75 seconds. The tool predicts high temperature, but after the tool moves away, temperature in the weldment cools down. Figure 3 shows the predicted temperature historic comparison between the model and experimental measurement[1, 2]. Both model predictions and measurements indicate that the temperature in the FSW stir zone of steel can be higher than 1200°C. The comparison shows the model can predict the same temperature distribution observed during the experiment, thus validating the thermal model.

Microstructure analysis

The predicted temperature evolution was input to the microstructure model to predict microstructure and hardness. Figure 4 shows a comparison of hardness between model prediction (Fig. 4a) and experiment[1, 2] (Fig. 4b) at a weld cross-section. The model predicted hardness in the tool stir zone close to the hardness measurement. But the size and shape of the hardness map exhibit some differences between the prediction and experiment. This may have occurred due to the difference between FSW tool dimensions in the model versus the experiment. Tool dimensions in the model are found by scaling the FSW tool photo in Ref. 1.

Conclusion

An ICME framework for developing a product using manufacturing processes includes product requirements, manufacturing process modeling tools, and the final product. Using FSW as an example, model tool development was introduced, which includes a thermal model, microstructure model, and mechanical model. The thermal and microstructure models were validated with experimental data. Models are able to reasonably predict temperature and hardness distributions as seen in the experiment. ❍

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References:

1. D.M. Failla, Friction Stir Welding and Microstructure Simulation of HSLA 65 and Austenitic Stainless Steels, MS Thesis, The Ohio State University, 2009.
2. D.M. Failla and J. Lippold, Ferrous Alloy Friction Stir Welding and Microstructure Simulation, FABTECH International & AWS Welding Show, 2009.

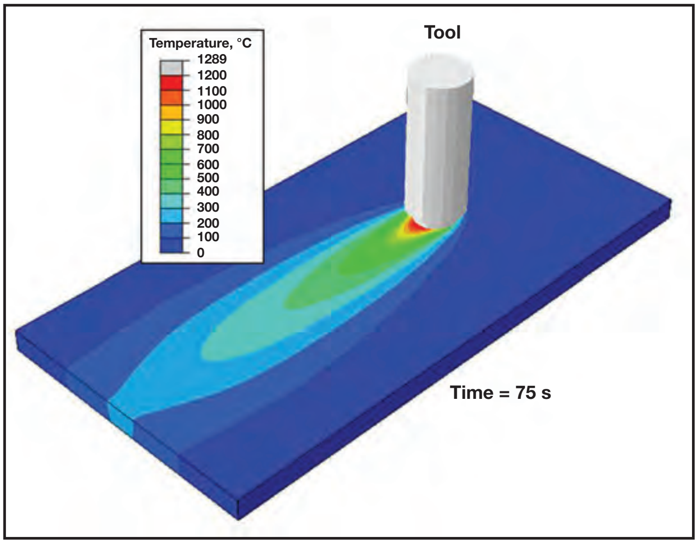


Fig. 2 — *Predicted temperature evolution during FSW.*

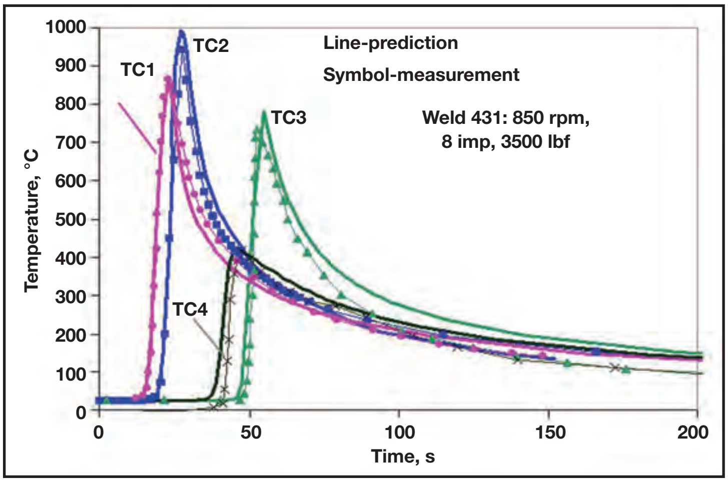


Fig. 3 — *Temperature history comparison of prediction and experiment[1, 2].*

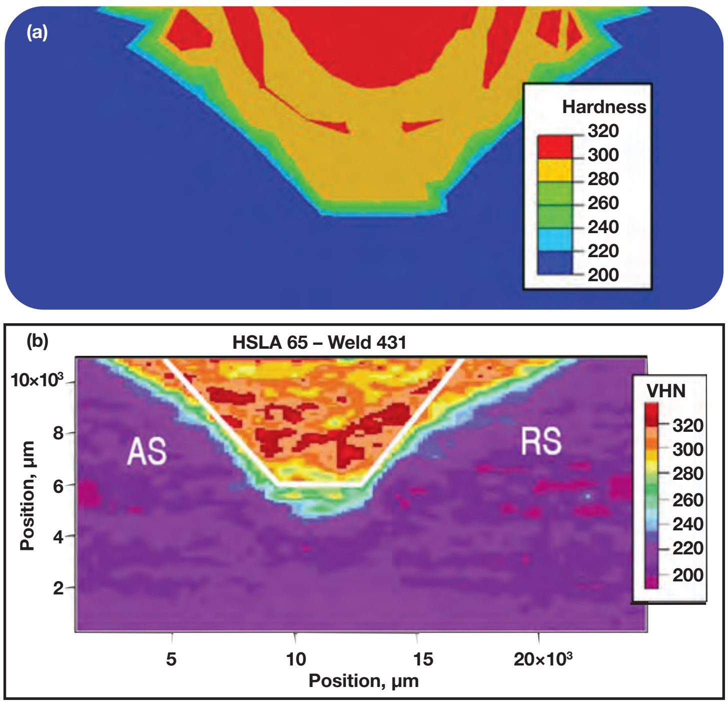


Fig. 4 — *Hardness comparison at weld cross-section between prediction and measurement. (a) Predicted hardness distribution, (b) Measured hardness map by Failla and Lippold[1, 2].*

Metallurgy Lane

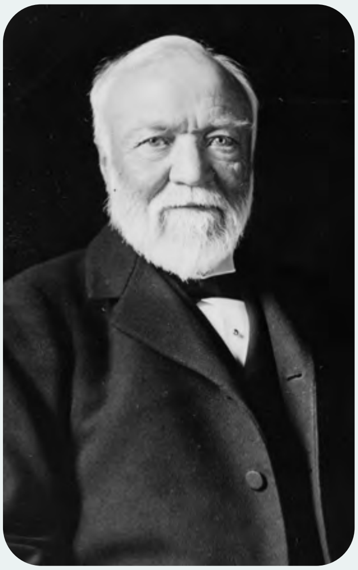
The Age of Steel: Part II

By 1875, the Bessemer steel industry had spread across the country from eastern Pennsylvania to St. Louis, with the epicenter in Pittsburgh.

Metallurgy Lane, authored by ASM life member **Charles R. Simcoe**, is a yearlong series dedicated to the early history of the U.S. metals and materials industries along with key milestones and developments.

Pittsburgh was home to a number of plants with multiple converters and the required blast furnaces and rolling mills to serve the growing demand for steel rails and beams. A major factor in the city's prominence was the availability of coal for coke. Connellsville, south of Pittsburgh, had coal fields that produced the finest metallurgical coke in the world. Andrew Carnegie pulled all these factors together to build his steel empire.

Carnegie made his first major investment in ironmaking simply to supply material for his bridge company. In 1872, he joined the ranks of the select few U.S. steelmakers by building a Bessemer steel plant. Carnegie named his new steel mill after J. Edgar Thomson—arguably the most influential railroad executive in America at the time—because he needed the railroads as customers for his new plant.



Andrew Carnegie, American businessman and philanthropist, circa 1913. Courtesy of Library of Congress/U.S. public domain.

The Edgar Thomson Steel Works was constructed in 1873-75 and Alexander Holley was the engineer in charge. Andrew Carnegie was twice blessed in hiring Holley because he got two great steel men in the bargain. Holley had been a consultant on the new Bessemer shop at Cambria Iron Company in Johnstown, Pa., where he worked with Captain William (Billy) Jones, who resigned when he was not promoted to superintendent. Jones contacted Holley, who immediately hired him as his assistant on the Thomson Works. After construction, Carnegie hired Jones as general superintendent. Jones became another star in the long line of top-quality men that Carnegie enlisted in forging his great steel empire.

Captain Billy Jones

Jones was a truly unique manager who came from the same mold as John Fritz. He worked various jobs and eventually joined the Cambria Iron Company. He also joined the Union Army shortly after the Civil War got underway. His experience and maturity won him a commission and he was mustered out as a captain at the end of the war, returning to Cambria where he became an assistant to the general superintendent. Jones was known as a mechanical genius and true friend of his workers and his patents were a major factor in the great advances of the steel output of Carnegie's empire and of the industry in general during the 1880s.

Captain William (Billy) Jones, inventor of the hot car transfer ladle. Courtesy of www.thehopkinthomasproject.com.

One invention alone—the "hot car transfer ladle" that moved molten metal from blast furnaces to Bessemer converters—eliminated the need to remelt pig iron to make steel. Royalties from his many patents earned Jones $15,000 annually during the late 1880s when his salary was $35,000. He became world renowned and was the first American invited to visit the great Krupp Works in Germany. His greatest legacy, however, was as a leader of men. Captain Billy Jones was killed in 1889 at the age of 50 when a furnace exploded. His death was not only a loss and shock to his fellow workers, but to the entire steel industry and especially the city of Pittsburgh. Steelmaking is said to have ceased while the city mourned at his wake and funeral. Captain Billy lived for his work and his men. Now that both are long gone, his name has been forgotten by many. He deserves better.

Carnegie's empire expands

As Carnegie's steel empire grew, he became a major client of the coke industry. The chief player in this game was a young Pennsylvanian named Henry Clay Frick. Like so many successful entrepreneurs, Frick was very lucky. Just as he was expanding the manufacture of coke, Carnegie became one of his most important customers. Frick reorganized in 1881 to raise capital and Carnegie bought a small interest in the company. However, Andrew was never one to remain a small shareholder if the business was successful. Within several years, he bought out some of the other shareholders, and the next time Frick needed capital for more expansion he sold even more stock to Carnegie. With that, the controlling

State militia troops sent to break the 1892 strike at Carnegie's Homestead Works. Courtesy of www.libcom.org.

Henry Clay Frick, early coke entrepreneur and general manager of the Carnegie Corp. Courtesy of Library of Congress/ U.S. public domain.

interest in the Frick Coke Company passed to the Carnegie Bros. Company.

After Tom Carnegie's death, Andrew enticed Frick into the steel company to become the general manager. Thus began the team of Carnegie and Frick that would complete the steel empire that had been slowly growing during the past 15 years. Carnegie's empire now included the Edgar Thomson Steel Works, Homestead and Duquesne Steel Works, the Frick Coke Company, the Keystone Bridge Company, and a variety of small mills, mines, and coke works. It was the largest steel operation in the country. Within a few years (by 1892), the output of the newly organized Carnegie Steel Company would exceed half that of the entire steel industry of Great Britain, and Andrew Carnegie owned more than 50% of it.

Great strike of 1892

However, the year 1892 would go down in history for the great strike of the Amalgamated Association of Iron and Steel Workers at the Homestead Works. Frick was determined to break the union. To ensure control of the situation should force be needed, he arranged for 300 armed guards from the Pinkerton Agency to stand by ready to help. Frick then rejected the first proposals submitted by the union and offered terms he knew would be unacceptable. The workers walked out. When the local authorities were intimidated by the laborers who were joined by the whole town of Homestead, Frick sent for his Pinkerton force. The 300 guards came down the Monongahela River in two steel barges and attempted to land at the Homestead plant. Workers lined the riverbank and the guards were met by a hail of gunfire. The battle raged all day, but suffered few casualties.

Late in the afternoon, the guards surrendered and the union leaders promised them safe passage out of town. However, when they came ashore they were attacked by the entire town. The men, women, and even children unleashed a fury that killed three of the guards and injured the rest. Several days later, 8000 troops from the state militia arrived to take over the plant and return it to management. Labor relations and worker morale never recovered at Homestead. Frick's reputation, as well as that of Carnegie, would never again ride as high within the industrial and political scene.

Skyscrapers and steel move upward and onward

By the 1890s, steel was being used in many new applications where it permitted breakthroughs in engineering and construction. One of these was the emerging world of skyscrapers. The 1890s witnessed such buildings going up in Chicago—the birthplace of these structures—as well as Saint Louis, Buffalo, New York City, and other rapidly growing population centers. The cost of steel had been driven down by Carnegie and his competitors to the lowest the world would ever see. What they all needed was rapid growth in their markets. This is what they got, because they were standing on the threshold of the American Technological Revolution.

Architect and "father of skyscrapers" Louis Sullivan's Prudential Building, Buffalo, N.Y. Courtesy of Library of Congress/U.S. public domain.

It was at this critical juncture in American history that Andrew Carnegie decided that he had taken his steel empire about as far as he was going to go. He was 65 years old and his lifelong philosophy had been to turn away from moneymaking for its own sake in order to do something more useful with his life and fortune. At Frick's suggestion, he agreed to entertain offers for his interest in the steel empire that had taken more than 25 year to assemble. He sold to J.P. Morgan who folded his Carnegie Steel Company into a new corporation named United States Steel.

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

ASMnews®

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White House Announces ASM as **Member of Lightweight Metals Institute**

President Obama hosted an event at the White House on February 25 to announce new steps in a partnership with the private sector to boost advanced manufacturing and strengthen U.S. defense capabilities. ASM International's (Materials Park, Ohio) managing director Thom Passek attended to represent the technical society at the ceremony.

The President announced two new manufacturing innovation institutes led by the Department of Defense and supported by a $140 million Federal commitment combined with more than $140 million in non-federal resources: (1) Detroit-area headquartered consortium of businesses and universities, with a focus on lightweight and modern metals manufacturing; (2) Chicago headquartered consortium of businesses and universities that will concentrate on digital manufacturing and design technologies.

ASM will be part of the consortium focusing on lightweight modern metals manufacturing technologies. The American Lightweight Materials Manufacturing Innovation Institute (ALMMII) is led by a collaboration between EWI, University of Michigan, and The Ohio State University. The new consortium will involve 60 members, including leading manufacturers of aluminum, high strength steel, and titanium, along with universities and laboratories involved in research and development of lightweight metals. The institute will seek to accomplish advanced research through partnerships among key players in industries such as automotive, aerospace, defense, and energy. ASM's specific role within the consortium will be defined over the coming months.

ALMMII
Partnership for Manufacturing Innovation

ALMMII's mission is to serve U.S. manufacturing by supporting innovative manufacturing technologies, and enable cost-effective lightweighting of components across a wide range of industries.

Two days after the Washington announcement, ASM Managing Director Thom Passek, ASM Vice President Sunniva Collins, and ASM President Ravi Ravindran (left to right) met at Materials Park to discuss the new institute and their vision for ASM.

ASM members from these and many other companies will play key roles in the new institute: Materion, Honda, MesoCoat, Boeing, QuestTek, WPI, GE, and Thermo-Calc.

...in this issue

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From the Foundation:
Update from the Chair

Dr. Stephen Copley
Chair 2012-2014
ASM Materials Education
Foundation Board of Trustees

The ASM Materials Education Foundation had a fantastic year in 2013 and 2014 promises to be even better. Twenty undergraduate scholarships were awarded including the 100th G.A. Roberts Scholarship on the 100th year anniversary of ASM International. Also, 20 K-12 Teacher Grants were awarded (increased from 10 last year) as well as six student chapter grants, two awards in the undergraduate design competition and an award to a distinguished teacher. The Foundation continued to support a National Merit Scholarship, the City of Materials, Materials Radio, and Science Fairs.

Our premier program, ASM Materials Camp, continued to grow. In 2013, the Foundation conducted 27 student camps and 44 teacher camps. The Pick-Up-the-Pace (PUP) goal of 50 camps by 2015 is in sight. Since 2000, 9965 students and 5607 teachers have participated in ASM Materials Camps at a total of 479 different locations. Because teachers typically reach 100 students per year, our camps could potentially reach more than 560,000 students during the 2013-2014 academic year! In 2013, we welcomed our new Director of Development and Operations, Nichol Campana, whom you met via this column in the February issue of *AM&P*.

Looking ahead to 2014, the Foundation plans to offer 49 teacher camps. Through several committees, we are exploring promising new approaches to excite young people in materials, science, and engineering careers. These include: (1) a program focused on 6th to 8th grade students, which will be piloted at the Roper Mountain Science Museum, Greenville, S.C., during the summer; (2) materials, science, and engineering education via the Internet, and (3) an advanced teacher camp on additive manufacturing in collaboration with Carnegie Mellon University, Penn State University, and America Makes, the National Additive Manufacturing Innovation Institute (NAMII). These and other new approaches will be advanced by our vice chair, David Spencer, when he becomes Foundation chair at the MS&T'14 Board Meeting.

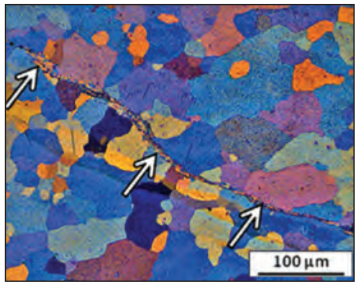
It is a great privilege serving as chair of the ASM Materials Foundation. I would like to thank the Foundation Board of Directors, staff, ASM International, and all of our individual and corporate supporters and volunteers and to appeal for your continued assistance in making the Foundation's programs a success.

2014 IMC – Revised Rules –
Fewer Classes and Larger Prize Money

The International Metallographic Contest (IMC) and Exhibit, cosponsored since 1972 by the International Metallographic Society (IMS) and ASM, is being held in conjunction with the 47th IMS Annual Meeting in Hartford, Conn., August 3-7. The contest features the best work of metallographers and microstructure analysts from around the world. A recent revision of the contest rules has resulted in fewer classes and larger prize money. The changes also are intended to encourage participation and to simplify the submission process.

The five classes include:

- Light Microscopy—All Materials
- Electron Microscopy—All Materials
- Undergraduate Student Entries—All Materials
- Artistic Microscopy—Color
- Artistic Microscopy—Black and White



The weld interface in an extrusion-welded magnesium alloy. From the 2013 IMC Jacquet-Lucas award winning entry.

Best-in-Show receives the most prestigious award available in the field of metallography, the Jacquet-Lucas Award, which includes a cash prize of $3000. The award has been endowed by Buehler since 1976. First place winners in Classes 1, 2, 4, and 5 receive $500 and first place winners in Class 3 (student entries) receive $1000 and the George L. Kehl Award. The DuBose-Crouse Award is presented for innovation in metallography in Classes 1, 2, and 3. Second and third place winners in all Classes receive $200 and $100, respectively.

All entries are displayed at the IMS Annual Meeting and again in the fall during MS&T.

For contest rules and entry information, visit IMS at www.metallography.net and click on Awards, or email sarina.pastoric@asminternational.org. Submission deadline is July 19.

Historical Landmark Celebration—Cleveland, May 9

Alcoa Cleveland was honored for having Historic Heavy Hydraulic Closed Die Forging Presses of the World and named as an ASM Historical Landmark Winner in 2013. These giant presses enabled quantum changes in the approach of modern aircraft design by producing large, forged monolithic structures. In turn, this capability provided designers with greater flexibility in the application of new alloys; lighter, stronger, and affordable aerostructures; and more powerful and fuel efficient gas and turbine engines. Alcoa Cleveland will hold a dedication ceremony at their location in Ohio on Friday, May 9.
For more information, contact Cary Dell at cary.dell@alcoa.com.

With Gratitude: **A Letter to ASM Volunteers**

By Gay Eyerman
Contributing Editor

Over the past three years, I've enjoyed meeting 32 ASM volunteers at my dining room table. That's where I interview members over the phone for the Volunteer Profile feature in *ASM News*. It's been my privilege to hear your stories, learn about your careers, and ask why you volunteer with ASM.

I've interviewed engineers, consultants, managers, students, retirees, professors, metallurgists, researchers, and technologists...along with a rocket engineer, special effects designer, and one recent grad working as an insurance agent while looking for her first job in materials engineering. It's truly a diverse group of members—approximately one-third of them women.

Here are some of the common qualities I see in ASM volunteers and some of my favorite quotes:

You want to give back.

"We pass the torch to the next generation." It often begins with gratitude for a mentor, job referral, or technical resource. Giving back brings great fulfillment in helping new members, students, chapters, committees, Material Advantage, Teacher Camps, Materials Camps, and science fairs.

You push yourselves.

"When I stop learning, it's time to hang up my career." Volunteers often say that ASM helps them recharge professionally, advance their careers, and build leadership skills.

You value relationships.

"ASM is my extended family." Personal friendships, job contacts, and mentors are key relationships that open doors and create lasting bonds, even when jobs change.

I've enjoyed the humility of so many volunteers—many attributing their success to help from others. I love hearing about high school demos or college moments that inspired a new direction. ASM volunteers have a passion for STEM education and appreciate that "you make the biggest decisions in life when you're the least prepared—around age 18."

Volunteers often reflect on dramatic changes in the steel and auto industries and other evolving technologies. All are concerned about engaging the next generation and are committed to making ASM relevant and responsive. There is general agreement that "these things don't happen in a vacuum—volunteers are critical."

Volunteers are greatly valued and appreciated by staff. You are the heart of ASM. You truly make it all happen, from writing books, speaking at symposiums, and organizing camps to running local chapters and serving on national committees. This is our time to say thank you—for pouring yourself into this "labor of love," selflessly giving your time and talent to serve ASM and the entire materials science community.

For all you do...thank you!

You are the heart of ASM. You truly make it all happen, from writing books, speaking at symposiums, and organizing camps to running local chapters and serving on national committees.

Dorfman Inducted into Thermal Spray Hall of Fame

Mitchell R. Dorfman, FASM, has been approved for membership into the Thermal Spray Hall of Fame. His induction will take place at ITSC 2014 in Barcelona, Spain, May 21-23. Dorfman's nomination was based on his extensive thermal spray research and development and his worldwide service to the thermal spray community both through his employment and his many ASM Thermal Spray Society (TSS) activities over the years.

Dorfman is a Sulzer Metco Fellow and Director of Ceramics, Materials Development at Sulzer Metco (U.S.) Inc. in Westbury, N.Y. During his 30-year career there, he has led development of numerous materials for the turbine and industrial markets. He is currently on the TSS Board, serving as ASM Board liaison. He is a past TSS president, has chaired numerous ITSC sessions and TSS conferences, and has served as a reviewer of technical papers for the *Journal of Thermal Spray Technology.* The author of more than 50 papers and holder of 14 patents, Dorfman received his B.E. in mechanical engineering and M.S. in materials science both from SUNY Stony Brook. Dorfman most recently served as division editor on the revision and expansion of *ASM Handbook,* Volume 5A, *Thermal Spray Technology*. The TSS is pleased to honor Dorfman with Hall of Fame membership for his exemplary service, leadership, and guidance.

Chapter News

Toronto MA Execs Meet with President Ravindran

University of Toronto Material Advantage Chapter executives met with ASM president Ravi Ravindran on March 6 to discuss the chapter program, ASM Scholarships and Awards, and careers in materials science and engineering. From left to right: Anthony Lombardi, ASM 100th fundraising coordinator, Ph.D. candidate; Abdallah Elsayed, ASM 100th fundraising coordinator, Ph.D. candidate; Ayman El-zoka, chair, 4th year undergraduate; President Ravindran, FASM; Hans Zhang, vice chair, 4th year undergraduate; Jeff Otto, vice chair, M. Eng. Candidate.

Houston's Spouse and Past Chair Night

ASM Houston Chapter's Spouse and Past Chair night was held March 4 at Fung's Kitchen. Guests enjoyed a fabulous Chinese banquet and journeyed with speaker, D. Scott MacKenzie Ph.D., FASM, through the historical capitals of China.

Seated (left to right) at the Houston meeting are Marco Deuterio, David Fitzgerald, FASM, Diane Nielsen, and Edgar Zapata. Standing (left to right) are Bob Badrak, Bob Koester, FASM, Joel Russo, Eric Drake, FASM, and Bill Bailey.

Stan Galanski (left) receives a plaque from Willie Howie, Houston chair, in recognition of 50+ years of service to the Houston Chapter of ASM.

Hartford March Meeting

Past chair of the ASM Hartford Chapter, Arnie Grot (second from right), presents a Speaker Mug to Maurice "Gus" Gustin, director of sales, TIMET Powder Metals of Exton, Pa., (second from left) at ASM Hartford Chapter's March 6 meeting. Gus gave a presentation on "Titanium in the Automotive Industry." Amber Black (left), chair of the ASM International Volunteerism Committee, gave a *Coffee Talk* on the benefits of volunteering, based on her personal experience at the local and international levels of the Society. Rainer Hebert, ASM Hartford vice chair, was the program's technical chair.

L.A.'s February Meeting

Members of the ASM Los Angeles Chapter meet for happy hour at the Pour Haus wine bar downtown, before a tour of the nearby Los Angeles Times Olympic Printing Plant.

No more Line-O-Type! The tour guide shows one of the thin aluminum sheets which are etched and used in high speed transfer printing of the Los Angeles Times and several other newspapers. (The light color in the room is to avoid exposing photosensitive materials).

For a list of upcoming ASM Training Courses, see our ad on page 43 of this issue.

Members in the News

Misra Receives Hind Ratan Award and More

Devesh Misra, FASM, Distinguished Professor and Director, Center for Structural and Functional Materials, University of Louisiana at Lafayette, received the Hind Rattan Award (translated "Jewel of India") of 2014. The NRI Welfare Society of India award recognizes Misra's exceptional services to the society, achievements, and contributions to the field, and for the significant efforts that he has made in building relations between India and North America, The award was given in New Delhi on January 26, the Republic Day of India. More recently, Dr. Devesh Misra was awarded Distinguished Alumnus Award from his alma mater, Department of Metallurgical Engineering, Indian Institute of Technology, Banaras Hindu University, on November 14, 2013.

Scully Honored with Sword

In September 2013, **Prof. John R. Scully, FASM,** was presented with the Institute of Corrosion's (ICorr) U.R. Evans Award. He is the Charles Henderson Chaired Professor of Materials Science and Engineering and Co-Director of the Center for Electrochemical Science and Engineering at the University of Virginia. In addition to being granted an Honorary Life Fellowship in the Institute, Scully was presented with an engraved sword. The lifetime achievement award recognizes outstanding international achievements in pure or applied corrosion science. The presentation was part of a joint meeting with the Royal Society of Chemistry's Electrochem2013 and ICorr at the University of Southampton. His acceptance included a keynote lecture, "Some Advances and Challenges in Understanding the Influence of Microstructural Heterogeneity on Corrosion."

Schadler Appointed *JMR* Associate Editor

On March 12, *Journal of Materials Research (JMR)* editor-in-chief Gary Messing announced the appointment of **Prof. Linda S. Schadler, FASM,** as associate editor for polymers and organic materials. The journal is published by the Materials Research Society. Schadler is the Russell Sage Professor in Materials Science and Engineering and the Associate Dean of Academic Affairs in the School of Engineering at Rensselaer Polytechnic Institute. She is an experimentalist and her research has focused on the behavior of two-phase systems, primarily polymer composites. Schadler was named as one of the Top 100 Materials Scientists worldwide in the last decade by Times Higher Education, 2011. She is a current member of ASM International's Board of Trustees.

AIST Honors Asfahani

Riad I. Asfahani, FASM, was selected as the recipient of the Association of Iron & Steel Technology's (AIST) 2014 Richard J. Fruehan Award for his paper entitled "Control of Ca-Containing Inclusions in Al-killed Steel Grades." Established in 2005 to honor Dr. Richard J. Fruehan, a devoted teacher and outstanding scientist dedicated to the steel industry, the award is given to the author of a process metallurgy technical paper judged to be the best of class by the AIST Metallurgy Technology Division. The award will be presented during the AIST Metallurgy, Processing, Products & Applications Technology Committee meeting, colocated with MS&T14 in Pittsburgh on October 14.

Distinguished Alumnus and HTCMC Awards for Singh

Dr. Mrityunjay Singh, FASM, chief scientist, Ohio Aerospace Institute, Cleveland, was awarded the Distinguished Alumnus Award by the Indian Institute of Technology-BHU, Varanasi, in India. He previously received Distinguished Alumnus Award from the Metallurgy Department of IIT-BHU in 2004. In addition, he also received the HTCMC International Achievement Award for his contributions in the field of high temperature ceramic matrix composites. Singh was recognized for his pioneering and seminal contributions and global leadership in the field of science, engineering, and applications of advanced ceramic and composite materials and technologies.

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Members in the News

Weertman Elected MRS Fellow

The new class of 22 Fellows of the Materials Research Society (MRS) will be recognized at the 2014 MRS Spring Meeting, April 21-25, in San Francisco. **Prof. Julia R. Weertman, FASM,** of Northwestern University, is among them. Fellows are selected for their distinguished accomplishments and their outstanding contributions to the advancement of international materials research. Weertman is being honored "for pioneering contributions in materials research and seminal and groundbreaking work on dislocations, fatigue, small-angle x-ray diffraction, and nanostructured materials."

Gschneidner Wins Acta Materialia and Science Award

Karl A. Gschneidner Jr., FASM, senior metallurgist at the DOE's Ames Laboratory, received the 2014 Acta Materialia Materials and Society Award on February 18. The award honors scientists who have made a major impact on society through materials science. Gschneidner, known as "Mr. Rare Earth," is considered the world's foremost authority on the science of rare earth elements. Through his long scientific career and expert testimony before Congress in 2010 and 2011, Gschneidner has been instrumental in bringing attention to the importance of rare earths for the nation's energy and security future. Gschneidner, is also an Anson Marston Distinguished Professor of materials science and engineering at Iowa State University.

Hecker Receives AAAS Award for Science Diplomacy

Siegfried Hecker, FASM, director emeritus of Los Alamos National Laboratory and an internationally recognized expert in plutonium science, global threat reduction, and nuclear security, was chosen by the American Association for the Advancement of Science (AAAS) to receive the 2013 Award for Science Diplomacy. Hecker was honored for his "lifetime commitment to using the tools of science to address the challenges of nuclear proliferation and nuclear terrorism and his dedication to building bridges through science during the period following the end of the Cold War." He led cooperative programs in Russia, Kazakhstan, and North Korea. Hecker, a metallurgist, received his doctoral degree from Case Western Reserve University in Cleveland.

NAE Elects New Members

The National Academy of Engineering (NAE) elected 67 new members in February, bringing their total U.S. membership to 2,250. Election to NAE is among the highest professional distinctions accorded to engineers. Three ASM members are among the newly elected.

Alan W. Cramb, FASM, provost, senior vice president for academic affairs, and Charles and Lee Finkl Professor of Metallurgical and Materials Engineering, Illinois Institute of Technology, Chicago, was acknowledged for contributions to the development of high-integrity continuously cast steels.

George M. Pharr, IV, FASM, Chancellor's Professor and McKamey Professor of Engineering, department of materials science and engineering, University of Tennessee, Knoxville, was honored for the development of methods for determining mechanical properties of materials by nanoindentation.

David Bruce Spencer, founder, chairman, and chief technology officer, wTe Corp., Bedford, Mass., was recognized for invention and entrepreneurship in materials manufacturing and recycling.

VOLUNTEERISM COMMITTEE

Profile of a Volunteer

Kathy Hayrynen, FASM
Director of Research & Development
Applied Process Inc.

Mentors make a difference. Kathy Hayrynen feels fortunate she had strong mentors at every stage of her career—most of them ASM fellows. She met her first mentor, Don Mikkola, in her senior year of high school during a research internship at Michigan Tech. "Later, he gave me a membership application to ASM and said 'you need to pursue this organization, it will be important in your career!'"

With her interest in metallurgy, Hayrynen earned a Ph.D. at Michigan Tech and joined Applied Process Inc., specializing in heat treatment of metals, specifically austempering of cast iron and steel. She is responsible for day-to-day operations of the R&D department and is liaison to multiple technical organizations. Kathy chaired the Detroit ASM chapter, served on the Awards Policy committee at the national level, and was named a 2006 ASM Fellow. Asked why she is a loyal volunteer, Kathy explains, "ASM helps me stay current and gives me the opportunity to give back to the next generation."

Most of her volunteer time is spent organizing the summer camp for high school and middle school teachers at the University of Michigan in Ann Arbor. "What I like best is the look on a teacher's face when they learn something hands-on to take back and engage their students," says Kathy. "We do more good this way than working one-on-one with a student. When you do something for a teacher, they influence hundreds."

Kathy engages next-generation engineers by getting them involved with students closer to their own age, in activities such as judging science fairs. "People need a voice and guidance. They are waiting for mentors and there's nothing greater than seeing them get that." ASM has served that role in Kathy's life, allowing her to give back as her own mentors did for her. "My career path—and my success—would never have happened without my involvement in ASM."

Canada Council Award Nominations due April 30

ASM's Canada Council is seeking nominations for its 2014 awards program. These prestigious awards include:

- **The G. MacDonald Young Award** – the ASM Canada Council established this award in 1988 to recognize distinguished and significant contributions by an ASM member in Canada. This award consists of a plaque in addition to a piece of Canadian native soapstone sculpture.
- **M. Brian Ives Lectureship** – This award was established in 1971 by the Canada Council of ASM to identify a distinguished lecturer who will present a technical talk at a regular monthly meeting of each of those Canada ASM Chapters who elect to participate. The winner receives a $1,000 honorarium and travels to each ASM Canada Chapter throughout the year to give their presentation at the expense of the ASM Canada Council.
- **John Convey Innovation Awards** – In 1977, the Canada Council created a new award to recognize sustaining members companies' contributions for further development of the materials engineering industry in Canada. The award considers a new product and/or service directed at the Canadian or international marketplace. Two awards are presented each year—one to a company with more than $5 million in sales.

Nomination forms and award rules can be found at www.asminternational.org/membership/awards.

For more information contact Christine Hoover at christine.hoover@asminternational.org or 440/338-5151 ext. 5509.

ASM/TMS Release **New Energy Materials Journal**

ASM International and The Minerals, Metals & Materials Society (TMS) announce the highly anticipated first issue of *Metallurgical and Materials Transactions E: Materials for Energy Systems,* a new journal of peer-reviewed, original research, and review articles focused on the science and technology of energy materials. A major goal of the publication is to help advance materials solutions for energy and environmental challenges.

The journal, published in partnership with Springer Science+Business Media, joins the established *Metallurgical and Materials Transactions A: Physical Metallurgy and Materials Science* and *Metallurgical and Materials Transactions B: Process Metallurgy and Materials Processing Science* publications. The journal will be published quarterly.

The articles from the first two volume years of *Metallurgical and Materials Transactions E* will be available online for free at the SpringerLink website: http://link.springer.com/journal/40553.

Metallurgical and Materials Transactions E is under the editorial leadership of David Laughlin, FASM, principal editor, and editors Victorino Franco, Steven J. Zinkle, FASM, and Sridhar Seetharaman (not pictured) who is an editor on *Metallurgical and Materials Transactions A, B,* and *E.* Laughlin is Alcoa Professor of Physical Metallurgy at Carnegie Mellon University. Franco is a professor in the condensed matter physics department at Sevilla University in Spain. Zinkle is Governor's Chair, Department of Nuclear Engineering, University of Tennessee, Knoxville. Seetharaman is TATA Steel and Royal Academy of Engineering Joint Chair for Research into Low Carbon Materials Technology in the Warwick Manufacturing Group (WMG) at the University of Warwick.

Editors of MetTrans E include, left to right: Victorino Franco, David Laughlin, FASM, and Steven J. Zinkle, FASM.

IN MEMORIAM

Gareth Thomas, FASM, of Irvine, Calif., founder of UC Berkeley Lab's National Center for Electron Microscopy (NCEM) and one of the world's foremost experts on electron microscopy, passed away on February 7. He was 81. A native of Wales, Thomas earned his Ph.D. in metallurgy from Cambridge University, and joined the Berkeley faculty in 1960, becoming a professor of metallurgy and a faculty scientist at Berkeley Lab in 1966. Thomas served as director of NCEM from 1983 to 1991. In 2006, he was named UC Berkeley's Emeritus Professor of Materials Science and Engineering. Thomas once said that the experience of using electron microscopy to image atoms was like "gaining sight after being blind." He dedicated his professional life to sharing and enhancing that experience for a generation of scientists.

Thomas served on the Acta Materialia Inc. Board of Governors and was editor-in-chief from 1995-98 of both *Acta Materialia* and *Scripta Materialia.* He received their Gold Medal in 2003.Thomas also won the following ASM awards: the ASM Gold Medal (2001), Albert Sauveur Achievement Award (1991), IMS Henry Clifton Sorby Award (1987), ASM Fellow (1976), Grossman Publication Award (1966), and 1965 Bradley Stoughton Teaching Award (1965).

products & literature

Instron, Norwood, Mass., announces the MPX Series of **motorized pendulum impact testers** for metals impact testing to Charpy and Izod standards. The series offers a range of testing capabilities from 300-900 J and comes standard with Fracta software, which allows for reliable data acquisition and reporting of absorbed energy. Upgrading to Impulse data acquisition software and instrumentation allows direct measurement of impact force and striker velocity. MPX is designed with an automatic test start as soon as the door closes, allowing for rapid testing. Interchangeable hammer weights allow easy adjustment of impact energy, eliminating the need to change hammer shafts. An integrated guard and safety control system is also included. www.instron.com.

Arkema, France, launched its first range of **liquid thermoplastic resins** under the brand Elium. The resins are transformed using the same processes as composite thermosets with results that are lightweight, cost-effective, and recyclable. They polymerize quickly and can be used to design structural parts and aesthetic elements. Composite parts made of Elium are 30-50% lighter than the same parts made of steel and have the same resistance. Because of their thermoplastic properties, the resins can be used to design composite parts that are easily thermoformed and recyclable with comparable mechanical performance to epoxy parts. www.arkemagroup.com.

Carl Zeiss Microscopy LLC, Thornwood, N.Y., announces a special promotion on the ZEISS ELYRA P.1, a highly sophisticated **3D superresolution light microscope.** Using PALM or dSTORM techniques, ELYRA P.1 can localize fluorescently-labeled structures in 3D, yielding achievable resolutions down to 20 nm laterally and 50 nm axially. Detection with an effective resolution down to 20 nm reveals substructure and patterns where conventional light microscopy simply shows co-localization. Users can correlate superresolution data with electron microscopy images for in-depth analyses. Special pricing is available for orders received by Sept. 30. www.zeiss.com/superrespromo.

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Advance your skills, learn from our respected international experts, and earn CEUs. ASM's accredited courses offer a variety of learning options that fit your career goals, schedule, and budget. Stay current in your career or stand out with an ASM certificate program. Also, make sure to join us for Additive Manufacturing Week in May! See below for more information.

Course	Date	Location
ADDITIVE MANUFACTURING Fundamentals of Additive Manufacturing Materials & Processes	5/12-13	National Additive Manufacturing Innovation Institute, Youngstown, OH, USA
ADDITIVE MANUFACTURING Symposium on Additive Manufacturing	5/14	Ohio Aerospace Institute Brook Park, OH, USA
Mechanical Testing of Metals	4/28-5/1	ASM World Headquarters
Introduction to Thermal Spray	5/5-6	ASM World Headquarters
Metallurgy of Steel for the Non-Metallurgist	5/5-7	ASM World Headquarters
Practical Fracture Mechanics	5/12-13	IMR Test Labs, Lansing, NY, USA
Medical Device Design Validation and Failure Analysis	5/12-13	ASM World Headquarters
Metallurgy of Welding and Joining	5/12-15	ASM World Headquarters
Fastener Metallography – 3-day	5/13-15	ASM World Headquarters
Practical Fractography	5/14-15	IMR Test Labs Lansing, NY, USA
Thermal Spray Technology, Processing, and Evaluation	5/18-20	Barcelona, Spain
Practical Induction Heat Treating	5/19-21	ASM World Headquarters
Metallographic Interpretation	5/19-22	ASM World Headquarters
Thermal Spray for Gas and Oil Industries	5/20	Barcelona, Spain
Introduction to Advanced Diagnostic Techniques Applied to Thermal/Cold Spray Processes	5/20	Barcelona, Spain
Stainless Steels	6/2-5	ASM World Headquarters
Practical Interpretation of Microstructures	6/2-5	Buehler, Limited Lake Bluff, IL, USA
Advanced High-Strength Steels	6/9-10	ASM World Headquarters
Introduction to Materials Science	6/9-11	ASM World Headquarters

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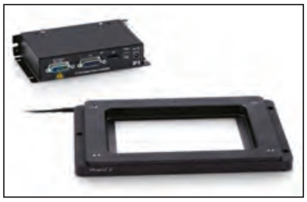
products & literature

Lake Shore Cryotronics, Westerville, Ohio, released a comprehensive **catalog for its temperature measurement and control products.** The downloadable catalog contains detailed specifications and guidance for choosing the best product for various research and industrial applications. It also provides guidance on choosing sensors and instruments for cryogenic refrigeration systems, including cryogen and cryogen-free cryostats, dilution refrigerators, and superconducting magnet systems. www.lakeshore.com/Pages/Downloads.aspx.

Princeton Instruments, Acton, Mass., released the IsoPlane 160 **imaging spectrograph,** said to be the world's first compact spectrometer to provide outstanding imaging, high spectral resolution, and excellent light-gathering power from the vacuum-UV (VUV) to the mid-IR range without performance tradeoffs. Key benefits of the 160 mm focal length spectrograph include high spectral and spatial resolution across the entire 27 × 14 mm focal plane, as well as complete flexibility in resolution and wavelength range. www.princetoninstruments.com.

Physik Instrumente LP, Auburn, Mass., introduces a new piezo-Z **nanopositioning system** for imaging and fast focusing applications, comprised of a large-aperture piezo stage and digital controller. P-736.ZR large-aperture, flexure-guided piezo nanopositioning stages are optimized for high resolution and very fast step and settle, required for real-time imaging applications. Travel ranges to 220 μm with sub-nanometer closed-loop resolution are well suited for surface metrology, microscopy, and imaging applications. Digital nanopositioning controllers can be quickly switched between focus tracking and closed-loop positioning and also accommodate fast focus and freeze applications. www.physikinstrumente.com.



MCI-2012 IntegraPel from Cortec Corp., St. Paul, Minn., is an integral **waterproofing and corrosion inhibiting admixture** designed to prevent or retard corrosion of steel reinforcement in new concrete structures. It uses a two-pronged approach to protect embedded steel and reduce the intrusion of corrosive species into concrete, and also provides a self-replenishing protective layer on embedded reinforcement with a migratory corrosion inhibitor. The admixture directly protects reinforcing steel and is suited as a corrosion preventative for concrete construction exposed to corrosive environments (carbonation, chlorides, and atmospheric attack). www.cortecvci.com.

Rigaku Raman Technologies Inc., Burlington, Mass., announces its next-generation **handheld analyzer,** the Rigaku Progeny, featuring an advanced miniature VPG-based optical engine with bench-top quality analytical performance in an ergonomic, IP-68 sealed enclosure. The analyzer's customizable workflow software is 21 CFR Part 11 compliant and has a smartphone-inspired user interface. A 1064-nm, high-power excitation laser optimizes speed and sensitivity of analysis and minimizes fluorescence interferences, broadening the range of materials that can be measured. A 512-pixel InGaAs detector delivers improved resolution, analytics, and signal to noise, handling the most challenging mixture analyses. www.rigakuraman.com.

ad index

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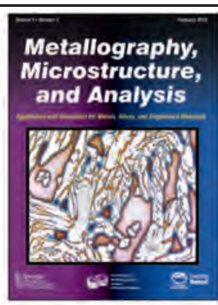

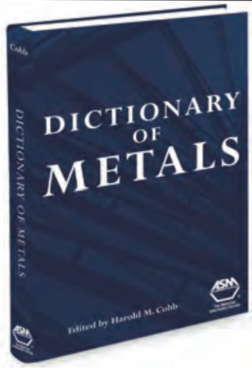

editorial preview

MAY 2014

Aerospace Materials & Applications

Highlighting:
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- Overcoming Barriers of Magnesium Flammability
- AeroMat Show Preview

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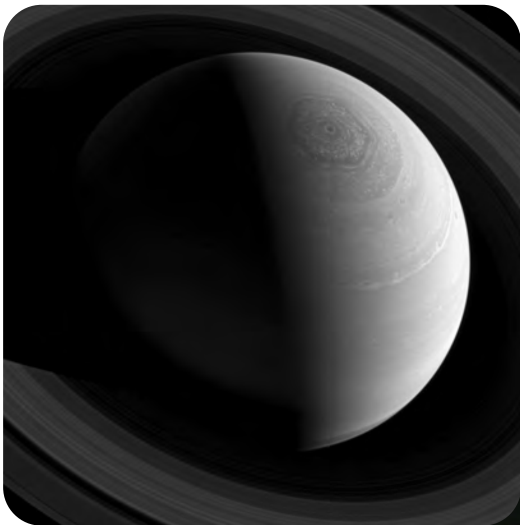
Stress Relief

Hexagon on Saturn

This view of Saturn looks toward the sunlit side of the rings from roughly 43° above the ringplane. It was taken with the Cassini spacecraft wide-angle camera in November using a spectral filter that preferentially admits wavelengths of near-infrared light centered at 752 nm. The picture was captured from approximately 1.6 million miles away and the scale is 93 miles per pixel. The Cassini-Huygens mission is a cooperative project of NASA, the European Space Agency, and the Italian Space Agency. The Jet Propulsion Laboratory (JPL), a division of the California Institute of Technology, Pasadena, manages the mission for NASA's Science Mission Directorate, Washington. The Cassini orbiter and its two onboard cameras were designed, developed, and assembled at JPL. The imaging operations center is based at the Space Science Institute in Boulder, Colo. *http://saturn.jpl.nasa.gov, www.nasa.gov/cassini.*



Just as Saturn's famous hexagonal-shaped jet stream encircles the planet's North Pole, the rings encircle the planet, as seen from Cassini's position above. Courtesy of NASA/JPL-Caltech/Space Science Institute.

3D printing pen

The 3Doodler is a 3D printing pen developed by Peter Dilworth and Maxwell Bogue of WobbleWorks LLC, Boston. 3Doodler began fundraising in February 2013 on the crowdfunding platform Kickstarter. Plastic thread made of either acrylonitrile butadiene styrene (ABS) or polylactic acid (PLA) is melted and then cooled while moving through the pen, which can be used to make 3D objects by hand. The pen has been described as a glue gun for 3D printing because of how the plastic is extruded from the tip, with 1 ft. of the plastic thread equaling "about 11 ft. of moldable material," according to company sources. *www.the3doodler.com.*

3Doodler is a handheld 3D printing pen that can draw in the air.

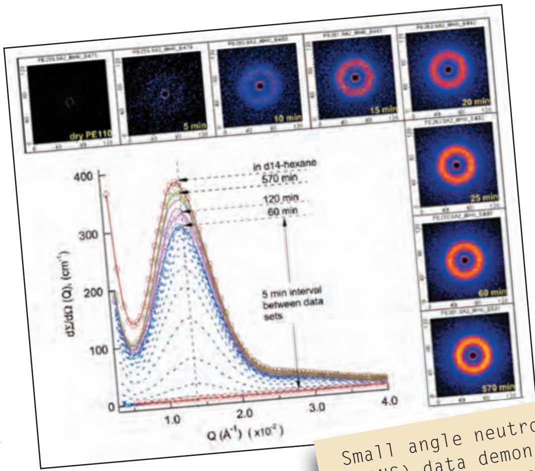
Scopey's Nano Adventures is an app created to teach future scientists about opportunities at the nanoscale. It features animated tutorials that strive to make learning creative and fun.

Young scientists explore nanotechnology

Ingenuity Lab, Edmonton, Alberta, is using an innovative method to teach elementary school children about the wonder of nanotechnology: Scopey's Nano Adventures. The app was designed to teach future scientists about myriad opportunities at the nanoscale. Designed for kids ages 5-10, the interactive application features animated tutorials that make learning creative and fun, according to developers. The application is now available on both iOS and Android devices and is free for Canadian users. Narrated by a cartoon microscope named Scopey, the app was tested in classrooms and science centers earlier this year and was well received by educators, children, and industry professionals. *www.ingenuitylab.ca/nextgen/scopey.*

SUCCESS ANALYSIS

Specimen Name: NIST nSoft Consortium



Small angle neutron scattering (SANS) data demonstrate increasing contrast of the long period of a linear polyethylene with increasing exposure time to d-cyclohexane vapor (from Kim and Glinka, 2009).

Vital Statistics:

"Soft materials" are the basis of plastics and composites—critical for producing everything from consumer goods to automobiles, but the light elements in these materials are difficult to observe and study with traditional tools. Neutrons, however, interact strongly with these light elements and are ideal for studying soft materials. The NIST Center for Neutron Research (NCNR) operates facilities designed for users from both industry and academia to study neutron interactions with matter.

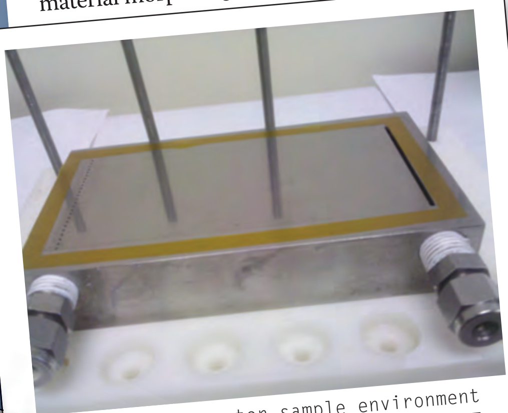
The goal of NIST's nSoft Consortium is to bring together companies and enable them to use neutron measurements to improve products made from soft matter. NIST scientists share their experience with member companies and together they work to identify and develop new measurement tools for understanding soft materials. Members participate in experiments, training programs, and meetings that enable them to adopt neutron-based tools into their research plans and conduct their own proprietary research using NIST facilities.

Success Factors:

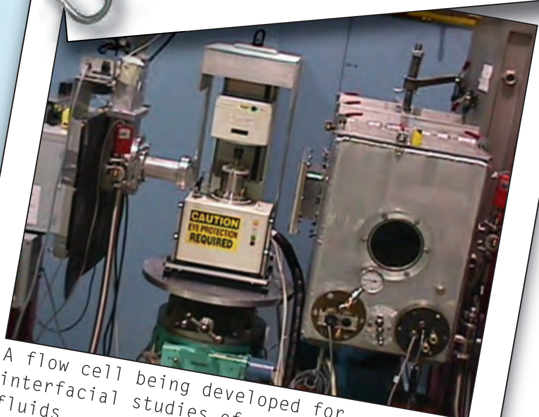
Formal operations at nSoft started with a kickoff meeting on August 14, 2012, and included a dozen companies from industries such as petroleum-based energy products, basic chemicals, consumer goods, and pharmaceuticals. The consortium's main technical objectives are to explore material morphology and topology, materials characterization under flow and strain, and shear and structure of soft material interfaces.

Molecular topology is a critical parameter of manufacturing soft materials. nSoft is developing neutron scattering and imaging methods to measure the spatial position and shape of long-chain branched polyolefins, used to control the flow rate and mechanical properties of the commodity plastics industry.

Incorporating a Couette rheometer on a SANS instrument ("rheo-SANS") demonstrates the capacity of neutrons to probe soft materials under dynamic conditions. nSoft will build on this effort at the NCNR to develop in situ measurements using a Sentmanat extensional rheometer, large amplitude oscillatory shear technology, and hyperbolic inlets to measure materials under high shear rates (approaching 1 million s-1).



The Couette rheometer sample environment for the 30-m SANS instrument at the NIST Center for Neutron Research.



A flow cell being developed for interfacial studies of soft materials and fluids.

About the Innovators:

The consortium is led by nSoft director Ronald Jones and NIST researchers Eric Lin, Dan Neumann, and Robert Dimeo. Members include Dow Chemical, DuPont, Genentech, Kimberly-Clark, MedImmune, Solvay, Chevron Phillips, ExxonMobil, and several others.

What's Next:

Soft materials are defined by their interfaces, including surfactants at an oil/water interface, polymer adsorbtion at a filler interface in composites, and the interphase between amorphous and crystalline regions in polyolefins. Depth penetration and sensitivity to contrast variations at internal interfaces allow neutrons to probe soft material interfaces, even during application of shear. Methods such as the overflowing cylinder, dynamic Langmuir trough, and time-resolved SANS are in development to probe this key component of material design for manufacturing.

Contact Details:

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Earth
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