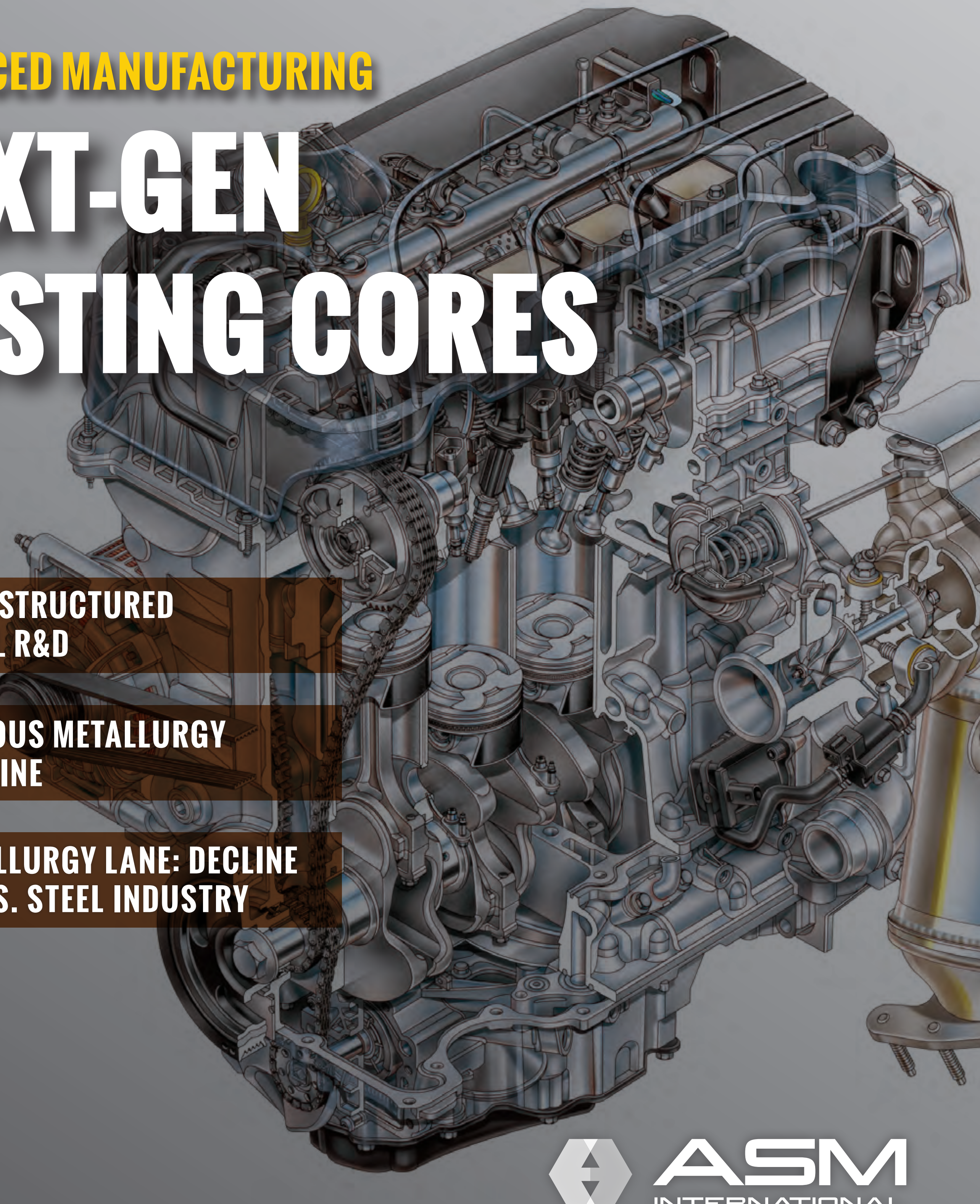
JANUARY 2017 | VOL 175 | NO 1

ADVANCED MATERIALS & PROCESSES

AN ASM INTERNATIONAL PUBLICATION



ADVANCED MANUFACTURING

NEXT-GEN CASTING CORES

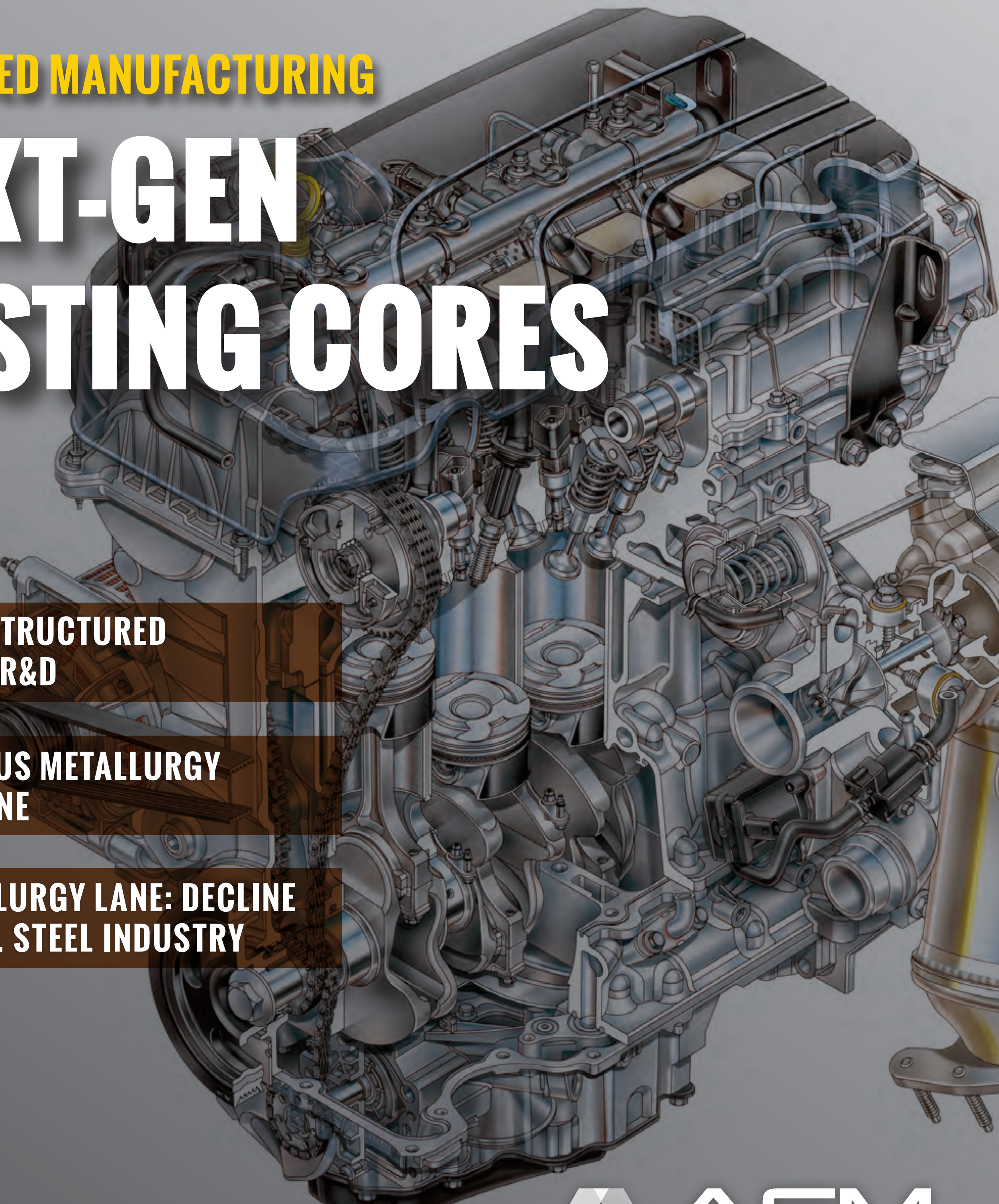
P.18

ASM INTERNATIONAL

JANUARY 2017 | VOL 175 | NO 1

ADVANCED MATERIALS & PROCESSES

AN ASM INTERNATIONAL PUBLICATION



ADVANCED MANUFACTURING

NEXT-GEN CASTING CORES

ASM INTERNATIONAL

MTS High-Temperature Solutions

MTS®

Establish materials testing capabilities up to 1500° C

» Superior Performance
» Versatile Platform
» Application-specific Thermal Subsystems

LCF solution meets the requirements of ASTM E606-04e1 or ISO 12106

MTS Thermomechanical Fatigue (TMF) testing solutions supports temperatures up to 1200 °C

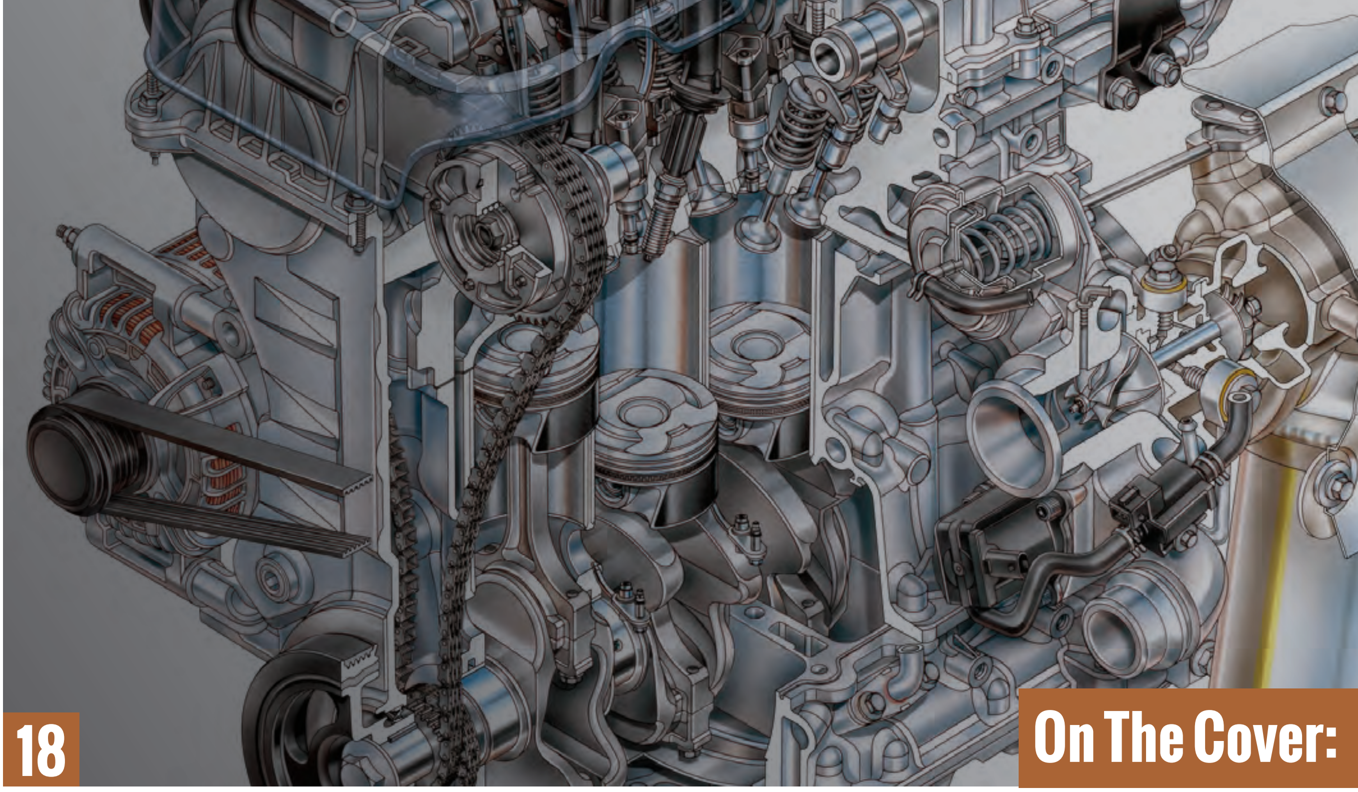
MTS high-temperature solution profiling a button head metallic specimen in 1200 °C

Contact MTS today and learn how high-temperature solutions can reduce data variability and provide repeatable, reliable results.

www.mts.com | 952.937.4000

MTS MATERIALS TEST SOLUTIONS

be certain.

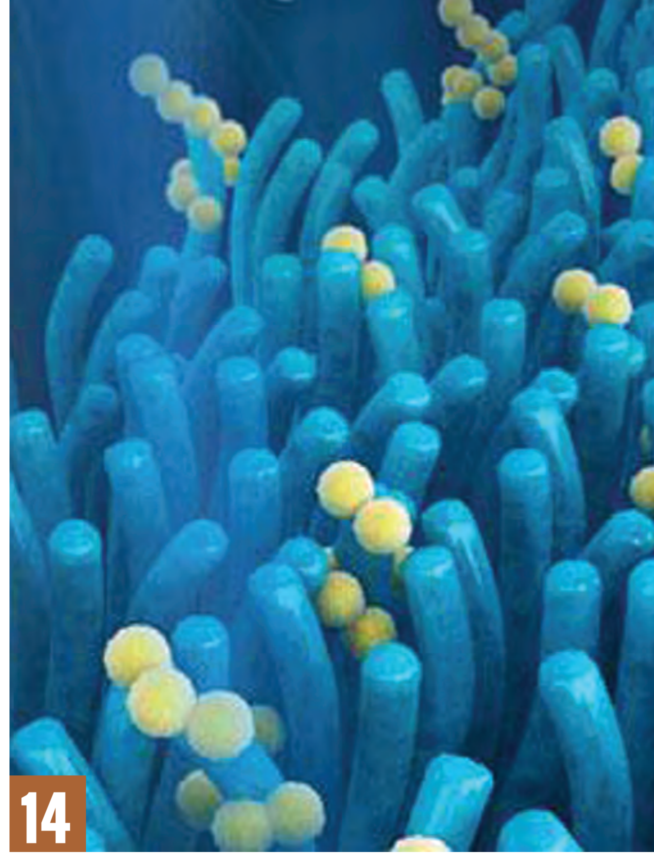


On The Cover:

Engine block produced using precision sand and high pressure die casting. Courtesy of GM Research and Development Center.

ADVANCED MATERIALS & PROCESSES

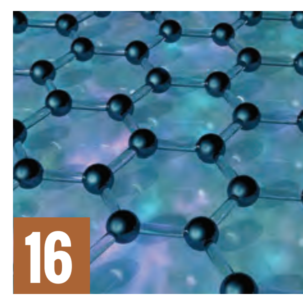
January 2017 | VOL 175 | NO 1



14

FEATURES

8



16

TRENDS

INDUSTRY NEWS

DEPARTMENTS

Advanced Materials & Processes (ISSN 0882-7958, USPS 762080) is published monthly, except bimonthly July/August and November/December, by ASM International, 9639 Kinsman Road, Materials Park, OH 44073-0002; tel: 440.338.5151; fax: 440.338.4634. Periodicals postage paid at Novelty, Ohio, and additional mailing offices. Vol. 175, No.1, JANUARY 2017. Distributed at no charge to ASM members in the United States, Canada, and Mexico. International members can pay a $30 per year surcharge to receive printed issues. Subscriptions: $475. Single copies: $51. POSTMASTER: Send 3579 forms to ASM International, Materials Park, OH 44073-0002.
Change of address: Request for change should include old address of the subscriber. Missing numbers due to "change of address" cannot be replaced. Claims for nondelivery must be made within 60 days of issue. Canada Post Publications Mail Agreement No. 40732105. Return undeliverable Canadian addresses to: 700 Dowd Ave., Elizabeth, NJ 07201. Printed by Publishers Press Inc., Shepherdsville, Ky.

Check out the Digital Edition online at asminternational.org/news/magazines/am-p

ADVANCED MATERIALS & PROCESSES

ASM International
9639 Kinsman Road, Materials Park, OH 44073
Tel: 440.338.5151 • Fax: 440.338.4634

Frances Richards, *Editor-in-Chief*
frances.richards@asminternational.org

Julie Lucko, *Editor*
julie.lucko@asminternational.org

Ed Kubel and Erika Steinberg, *Contributing Editors*

Jim Pallotta, *Creative Director*
jim.pallotta@asminternational.org

Susan Kandzer Design, *Layout and Design*

Kelly Sukol, *Production Manager*
kelly.sukol@asminternational.org

Press Release Editor
magazines@asminternational.org

2017 HOLDS PROMISE FOR RENEWAL

Happy New Year! We hope you all had a relaxing and refreshing holiday season and are ready to face the challenges of the year ahead. As a logophile, one of my favorite New Year's traditions is to find out what Merriam-Webster selects as its "Word of the Year." For 2016, the winning word is *surreal*. The dictionary editors report that surreal was looked up much more frequently in 2016 than in previous years and experienced three major interest spikes—after the March terror attacks in Brussels, the July coup attempt in Turkey and terror attacks in Nice, and following the recent U.S. presidential election. Merriam defines surreal as "marked by the intense irrational reality of a dream."

The word is actually fairly new, dating back to the 1930s and only defined by Merriam-Webster in 1967. It stems from surrealism, the early 1900s artistic movement that sought to portray the unconscious mind in dreamlike ways that were "beyond reality." The fact that materials science is the opposite of surreal is somehow very comforting. This field of science and engineering is rooted in matter and reality, and firmly entrenched in the physical world. Dark matter aside, materials science is anything but surreal.

Speaking of real and present matters, ASM is in the midst of what we are calling the "ASM Renewal," in which we are evaluating every aspect of our technical society and making concrete, actionable, and forward-looking plans for improvement and growth. As part of these renewal efforts, we have started to collect stories from our members about how ASM has helped them in their careers and lives.

Think about it. Have you attended one of our technical conferences, education classes, or a local chapter meeting where you learned something new or made a connection that helped you in your job? Perhaps one of our online databases, reference publications, or scientific journals gave you just the insight you needed to accomplish a specific task? Or maybe you made a networking connection that helped you land your dream job? We want to hear your stories! We plan to feature some of them on the ASM website, within the pages of this magazine, and in our communications to the broader technical community. Our goal is to grow ASM and make it the most useful and vibrant technical community it can be—for you, our highly valued members.

If you have a success story to share, feel free to contact me at the email below. In the meantime, we wish you all a happy and prosperous 2017!

F. Richards

frances.richards@asminternational.org

MARKET SPOTLIGHT

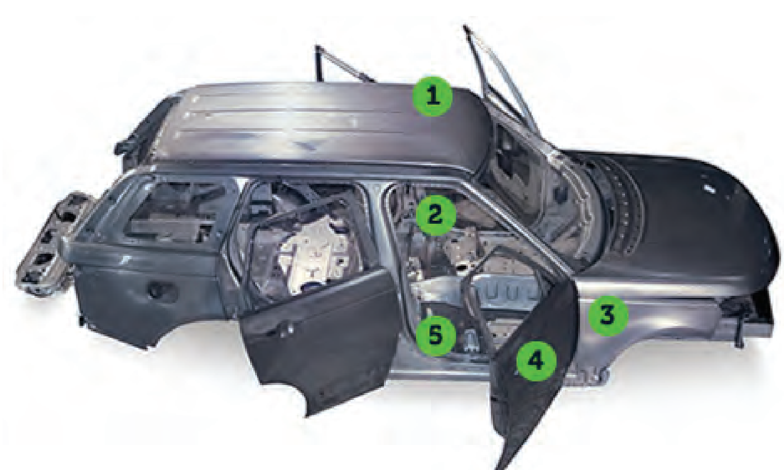
LIGHTWEIGHT AUTOMOTIVE BODY PANELS MARKET REVVING UP

Future Market Insights, Valley Cottage, N.Y., released a new report, *Lightweight Automotive Body Panels Market: Global Industry Analysis and Opportunity Assessment, 2016-2026.* Global sales were valued at $99.6 billion at the end of 2016, seeing 3.9% growth over 2015. Body panels such as bumpers, hoods, door panels, roofs, and trunk lids are manufactured using lightweight materials such as high-strength steel, aluminum, magnesium, and polymers and composites to provide desired strength with reduced weight. A 25% reduction in automobile weight saves approximately 3.5 to 5 tons of greenhouse gas emissions over the life of an average car.

According to analysts, steady recovery in global automotive production along with an increasing focus on lightweighting is driving market demand for lightweight body panels. Further, rising disposable income with growing economic conditions has also spurred global automotive production. With increased production, concerns about greenhouse gas emissions is rising globally. In order to tackle these emissions, governments across the globe are implementing stringent regulations to meet fuel emission standards. To comply with these regulations, manufacturers are expected to increase their focus on automotive lightweighting. However, high costs associated with lightweighting materials hinder widespread adoption and are likely to restrict market growth over the forecast period. The lightweight automotive body panels market is segmented on the basis of material type (metals, polymers and composites); component type (bumpers, hood, door panels, trunk lids, roof, others); and vehicle type (passenger car, light commercial vehicle, heavy commercial vehicle). Key findings of the new report include:

- The metals segment is valued at $92.7 billion at year-end 2016.
- Door panels comprise 32.9% market share at year-end 2016.
- The passenger car segment will expand at a CAGR of 5.5% over the forecast period.

For more information, visit futuremarketinsights.com.



After decades of using aluminum for components such as doors and hoods, automakers are now introducing all-aluminum vehicles. Key applications for automotive aluminum include: 1) Body-in-white or complete vehicle body; 2) structural components; 3) body panels and side walls; 4) doors, hoods, and trunks; and 5) car trims and sealings. Courtesy of novelis.com.

FEEDBACK

READER QUESTIONS HYDRINO HYPOTHESIS

I generally find the "Industry News" department easy to read and technically informative. I presume someone verifies the story backgrounds so we can trust that we are reading legit information, but occasionally something slips through. In this case, it is "Clean, Green Electric Power on the Horizon" [October issue, "Energy Trends"]. These folks are promoting truly wishful technology, full of promise but not much physics. They've been pushing their "hydrino" theory for about 30 years now and have yet to make the leap to reality, but they continue to find suckers, er, investors. For more information, see "A Critical Analysis of the Hydrino Model," New Journal of Physics, Vol 7, 2005, by Andreas Rathke of the European Space Agency. Rathke finds "no theoretical support of the hydrino hypothesis." The company's press releases are new, but the fundamental "incompatibility of hydrino states with quantum mechanics" has not changed. You will recognize we are at "the horizon" when Brilliant Light Power Inc. sends a bag of hydrinos to Materials Park. Until then, keep this and all related nonsense on the "Stress Relief" page.

William Ellis

ERRATA

In the November/December issue, "Metallurgy Lane," the sentence describing a basic oxygen furnace (BOF) should have read: "Steel from the BOF was teemed into a machine that channeled the metal through a container where it solidified and was prepared for the rolling mills."

[Thank you to our careful readers for noticing this error. It will be corrected in the upcoming book version of this historical series.—Eds.]

CRAB SHELLS COULD HELP HEAL WOUNDS

Chitosan is a sugar typically derived from shrimp and crab shell waste, which is known for its biocompatible, biodegradable, antibacterial, antifungal, analgesic, and hemostatic properties. This makes it an excellent candidate for a number of biomedical applications, except that it has limited mechanical strength. Researchers are working on developing composites that combine chitosan with nanofillers, making the resulting material stronger.

Scientists at the University of Minho, Portugal, are finding success in combining bioactive glass nanoparticles with chitosan to develop synthetic bone grafts. Bioactive glass is a glass-ceramic biomaterial that binds well to physiological structures such as bone. Bone cells were found to grow relatively quickly and cover grafts made of bioactive glass and chitosan. Graphene oxide has been used in combination with chitosan to develop *nanocarriers* that can deliver drugs to target tissues, avoiding the negative side effects that conventional drugs can have on other bodily tissues. Silver nanoparticles are also being tested as nanofillers in combination with chitosan to develop wound dressings with antibacterial properties. While initial results are promising, further research is needed. *www.uminho.pt/en.*

Chitosan is a sugar typically derived from shrimp and crab shell waste. Courtesy of Alex Barabas.

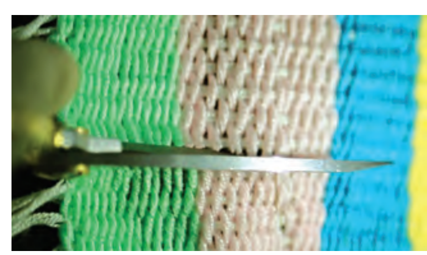
VELLO Bike+ is a self-charging, electric folding bike.

SELF-CHARGING ELECTRIC BIKE BOOSTS PEDAL POWER

VELLO Bike+ is said to be the first self-charging, electric folding bike on the market—the battery can be fully recharged while riding, meaning cyclists will never run out of power. The energy with this new system is harvested as before, by braking and pedaling downhill, but it now converts mechanical energy into electrical energy due to the integrated kinetic energy recovery system. In this way, additional energy is generated to recharge the lithium-ion battery and released to give an extra boost when riding uphill. The self-charging mode can be deactivated and set to the highest assistance level to provide constant pedal support for at least 35 km (20 miles) at a speed of max. 25 km/h (15 mph). When the battery is empty, it can be recharged by connecting it to the power socket. Through the free app, users can set the level of pedal assistance, track their route, and even lock their bike remotely. *http://vello.bike.*

SHIRT POWERS PHONES WITH SUN RAYS

Scientists report the first fibers suitable for weaving into tailorable textiles that can capture and release solar energy. To collect solar power, Wenjie Mai at Jinan University, Xing Fan of Chongqing University, and colleagues in China, created two different types of fibers. One contains titanium or a manganese-coated polymer along with zinc oxide, a dye, and an electrolyte. These fibers are interlaced with copper-coated polymer wires to create the solar cell section of the textile. To store power, researchers developed a second type of fiber made of titanium, titanium nitride, a thin carbon shell to prevent oxidation, and an electrolyte. These fibers are woven with cotton yarn. When combined, the new materials form a flexible textile that can be cut and tailored into a smart garment that is fully charged by sunlight. Researchers say the clothing could power small electronics including tablets and phones. *For more information: Wenjie Mai, wenjiemai@gmail.com, http://english.jnu.edu.cn.*



A new textile that captures and stores solar energy can be cut and sewn to make clothes that power small electronics. Courtesy of the American Chemical Society.

Are you working with or have you discovered a material or its properties that exhibit OMG - Outrageous Materials Goodness?
Send your submissions to Julie Lucko at julie.lucko@asminternational.org.

METALS | POLYMERS | CERAMICS

HYDROGEN STORAGE MATERIALS BOOST EFFICIENCY

A Florida State University, Tallahassee, researcher has designed new materials that could be used to store hydrogen fuel more efficiently in vehicles or other devices that use clean energy. Jose Mendoza-Cortes, assistant professor in the College of Engineering, is using complex mathematical equations and computer simulations to design porous materials made with transition metals—compounds involving cobalt, iron, or nickel—that cause hydrogen to bond with it.

This next-generation design could then be placed in the tank of a hydrogen fuel vehicle. The idea is that since hydrogen will bind to the actual device, more hydrogen could be packed in and condensed into a tank. Because the hydrogen easily sticks to the device, the tank would never actually reach empty. Additionally, it would take a smaller energy expenditure to fill the tank. "In other words, more hydrogen can be stored at lower pressures and room temperature, making some of these materials good for practical use," says Mendoza-Cortes. As of 2016, Toyota, Hyundai, and Honda have produced hydrogen fuel cars. *For more information: Jose Mendoza-Cortes, mendoza@eng.fsu.edu, www.fsu.edu.*

SynerMag alloy is the key structural material in Magmaris—said to be the first clinically proven, metallic cardiovascular scaffold, manufactured by Biotronik. Courtesy of Business Wire.

MAGNESIUM IMPLANT NATURALLY RESORBS

A new bioresorbable magnesium alloy from Magnesium Elektron, UK, won the 2016 Product of the Year award at the Bionow Life Science Industry Awards. The SynerMag alloy is used to make temporary patient implants and is the key structural material in Magmaris—reportedly the first clinically proven, bioresorbable metallic cardiovascular scaffold. Because it is made of magnesium, the scaffold has some unique advantages over polymer-based options in terms of deliverability and radial resistance following implantation. After repairing an artery over a several-month period, the SynerMag-based Magmaris scaffold resorbs naturally, allowing vessels to restore vasomotion as soon as six months later. *magnesium-elektron.com.*

GLASS GEARS HOLD PROMISE FOR SPACE ROBOTS

At NASA's Jet Propulsion Laboratory (JPL), Pasadena, Calif., technologist Douglas Hofmann and his team are building a better gear for precision robotics made from bulk metallic glass (BMG). "Our team of researchers and engineers in collaboration with groups at Caltech and UC San Diego, have put BMGs through the necessary testing to demonstrate their potential benefits for NASA spacecraft. These materials may

BRIEFS

Houghton International, Valley Forge, Pa., launched a redesigned website to deliver streamlined access to detailed information regarding the company and its solutions. The site provides information regarding global operations and advanced products and services in 14 languages across all platforms and devices. *houghton-intl.com*

Steel slag stockpile next to a steel factory. Courtesy of TU Eindhoven.

Researchers at **Eindhoven University of Technology,** the Netherlands, are working toward making cement from the hundred million tons of steel slag waste generated from steel production each year. Steel slag has a mineralogical composition that closely resembles cement and contains the same components, but in different ratios. If successful, the new cement will cut tens of millions of tons of CO_2 emissions each year. *www.tue.nl/en.*

be able to offer us solutions for mobility in harsh environments, like on Jupiter's moon Europa."

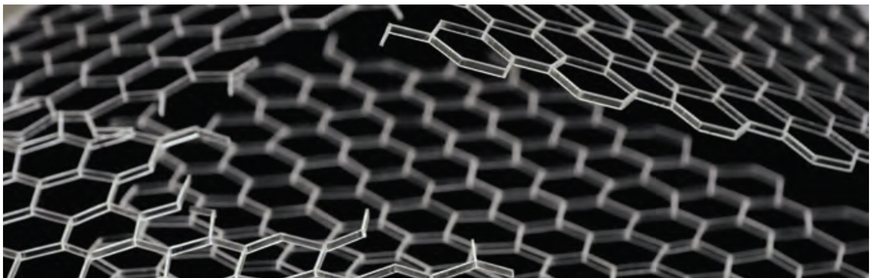
The mystery material can be explained as both a metal and a glass by looking at its atomic structure. Metals have an organized crystalline arrangement, but if they are heated to a liquid state, they melt and atoms become randomized. Upon rapid cooling—about 1832°F (1000°C) per second—their non-crystalline, liquid form can be trapped in place, producing a random arrangement of atoms with an amorphous microstructure. That structure gives these materials their common names—amorphous metals, or metallic glass.

By virtue of being cooled so rapidly, the material is technically a glass. It can flow easily and be blow-molded when heated, like windowpane glass. When this glassy material is produced in parts greater than about four tenths of an inch (1 mm), it is called bulk metallic glass, or BMG.

Among their attractive qualities, BMGs have low melting temperatures. That allows parts to be cast using injection-molding technology, similar to what is used in the plastics industry, but with much higher strength and wear-resistance. BMGs also do not get brittle in extreme cold, a factor that can lead to gear tooth fractures. This last quality makes the material particularly useful for the robotics being developed at JPL. Not only can BMGs allow gears to perform at low temperatures, they can also be manufactured at a fraction of the cost of their steel counterparts without sacrificing performance. This is potentially game changing for reducing the cost of robots that use strain wave gears, which are often their most expensive components. *For more information: Douglas Hofmann, dch@jpl.nasa.gov, www.jpl.nasa.gov.*

Bulk metallic glass does not become brittle in extreme cold, making it an ideal material for robotics operated in space. Courtesy of NASA/JPL-Caltech.

TESTING | CHARACTERIZATION



Plastic honeycomb lattice, pulled apart in an experiment studying how material rigidity affects the way things break. Courtesy of Sidney Nagel, et al.

RIGIDITY'S ROLE IN HOW MATERIALS CRACK UP

Researchers discovered a correlation between the rigidity of a material and its failure behavior, allowing scientists to tune the former to improve the latter. Through a series of experiments and computer simulations, the team from the University of Chicago, New York University, and Leiden University, the Netherlands, found that in a rigid system—for instance, window glass—bonds are tightly packed and break in clean, narrow, relatively straight cracks. In a system with low rigidity, however, there are fewer bonds and they tear at seemingly random points throughout the material, eventually connecting in an irregular pattern and resulting in failure. The team also found that as a material is made more flexible, its failure zone becomes wider, offering the equivalent of a close-up view of the break behavior. "Reducing the rigidity of a material is, in a sense, like holding a magnifying glass that allows you to zoom in on the width of a crack, which is generally microscopic but can become as big as the sample size," explains Leiden physicist Vincenzo Vitelli. The discoveries open the door to a systematic theory that could allow researchers to more accurately predict material failure and control cracking. *chicago.edu, nyu.edu, www.universiteitleiden.nl/en.*

RECORD-BREAKING MAGNET PULLS ELEMENTS INTO VIEW

A magnet 10 years in the making smashed the record to become the strongest in the world for nuclear magnetic resonance (NMR) spectroscopy. Developed at the National High Magnetic Field Laboratory based at Florida State University, Tallahassee, the 33-ton series connected hybrid (SCH) magnet reached its full field of 36 T, more than 40% stronger than the previous world record NMR and more than 50% more powerful than the highest field high-resolution NMR magnet. The SCH's field is not only high tesla, but high quality, remaining constant over both time and space.

Existing NMR magnets are only strong enough to locate a handful of elements, notably hydrogen, carbon, and nitrogen. With the SCH, zinc, copper, aluminum, nickel, and gadolinium—of interest for battery and other materials research—will now be observable, as will oxygen, a prize for biologists. The

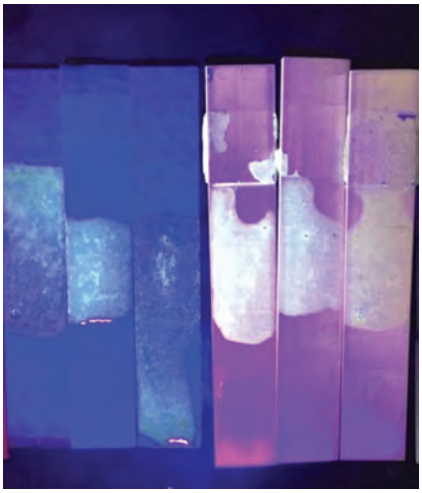
The National MagLab's 33-ton, 36-tesla SCH magnet. Courtesy of Florida State University.

BRIEFS

The **University at Buffalo,** N.Y., received a $2.9 million **National Science Foundation** grant to develop a database laboratory open to the scientific community that collects, interprets, and learns from massive amounts of information. The lab will conduct large-scale materials modeling and simulation using an untapped collection of visual data. *buffalo.edu.*

A new database laboratory will help researchers commercialize new materials such as graphene. Courtesy of University at Buffalo.

The **Airworthiness Assurance Center,** operated by **Sandia National Laboratories,** Albuquerque, N.M., for the **Federal Aviation Administration,** developed the first course to train inspectors in the airline and aircraft manufacturing industries in nondestructive inspection (NDI) techniques for solid-laminate composite materials. The Composite NDI Training Class provides an overview of composite materials, in-depth knowledge of NDI techniques, and hands-on training. *For more information: 505.284.2200 or email sneidig@sandia.gov.*



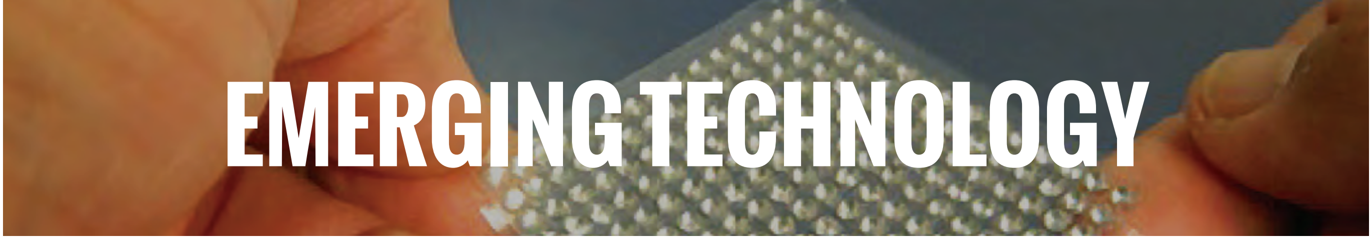
Fiberglass and aluminum test strips illuminated by UV light. White areas show polymer/quantum dot coating. Courtesy of LASIR Lab, Vanderbilt University.

new magnet will also allow researchers to vary the field strength and toggle between elements in a sample, increasing data volume and quality. *nationalmaglab.org.*

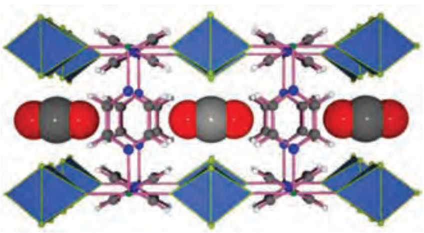
COLOR ME STRESSED

Researchers at the Laboratory for Systems Integrity and Reliability (LASIR) at Vanderbilt University, Nashville, Tenn., developed a new type of smart sensing material that changes color as it is subjected to different loads. This "mood ring material," which could be used to detect infrastructure damage before it becomes critical, consists of an optically clear polymer matrix embedded with 1-5 wt% white light quantum dots that emit broad spectrum light—unlike those used in other sensing materials, which emit only specific wavelengths. When fiberglass and aluminum strips coated with the new material are subjected to varying levels of external load under 1250 lb, the intensity of the material's emission spectrum decreases as the load increases. Under higher stresses, results are more complex. Compression tests on epoxy cylinders show the emission spectrum increasing with stress—possibly because deformation crowds nanoparticles into the testing area. When surface-coated fiberglass samples are loaded under tensile stress, the emission spectrum decreases until fibers begin to fail, at which point it begins to rise—possibly because previously hidden nanoparticles are exposed when the fibers split.

The new material could prove more effective and affordable for detecting damage than today's alternatives—a complex network of sensors or inspection by the human eye. *vanderbilt.edu.*



EMERGING TECHNOLOGY



Solid MOF for carbon dioxide capture. Courtesy of King Abdullah University.

NEW MOF OFFERS DIRECT CO_2 CAPTURE

Researchers at the King Abdullah University of Science and Technology (KAUST), Saudi Arabia, developed a new metal organic framework (MOF) that can trap carbon dioxide at concentrations as low as 400 ppm—potentially low enough to capture the gas as it is generated. The gas adsorbtion and storage capabilities of a specific MOF are determined by the chemical composition and geometry of its major components—metal ions or clusters held in place by organic molecules known as linkers. Square-shaped grid layers composed of Ni(II) metal centers and pyrazine linkers are bridged by pillars composed of niobium, oxygen, and fluorine atoms.

"The ability to control the distance between the fluorine atoms allows us to create the ideal square-shaped pockets for trapping carbon dioxide molecules effectively and efficiently," explains Professor Mohamed Eddaoudi. The MOF could be adapted to static industrial processes, such as those used at cement factories, but could also be used on board vehicles to capture CO_2 at the point of emission—a significantly more effective and efficient method than removing it after it has mixed with the atmosphere. *www.kaust.edu.sa*.

INTESTINE-INSPIRED MATERIAL BEATS BATTERY BREAKDOWN

Researchers at the University of Cambridge, UK, developed a prototype of a next-generation lithium-sulfur battery that could have five times the energy density of today's lithium-ion batteries. The design incorporates a chemically functional layer inspired by the lining of the human gut that drastically slows the degradation of active material, overcoming a key obstacle to the commercial development of this type of battery.

When a Li-S battery discharges, the lithium and sulfur interact to form chain-like polysulfides. Over several cycles, segments of these polysulfides can break off and enter the electrolyte, decreasing the available active material. The Cambridge team's functional layer lies on top of the cathode to trap the detached active material and fix it to a conductive framework so it can be reused. Modeled after villi—the fingerlike protrusions that line the small intestine, increasing its surface area and absorbing nutrients—the material consists of tiny, one-dimensional zinc oxide nanowires grown on a scaffold. It uses a lightweight carbon fiber mat for support, which reduces overall battery weight and, due to its flexibility, allows the layer to mimic how the small intestine works even further. Because of the layer's strong chemical bond with the polysulfides, the active material can be used for much longer, greatly increasing the battery's lifespan. "This is the first time a chemically functional layer with a well-organized nano-architecture has been proposed to trap and reuse the dissolved active materials during battery charging and discharging," explains Ph.D. student Teng Zhao. *www.cam.ac.uk.*

Computer visualization of villi-like battery material. Courtesy of Teng Zhao.

BRIEF

Thermo-Calc Software AB, Sweden, and **QuesTek International LLC,** Evanston, Ill., will establish a joint company, **QuesTek Europe AB,** Sweden, to offer integrated computational materials engineering modeling services and novel materials design and development in the European market. The new endeavor will combine the Materials by Design methodology developed in the U.S. by QuesTek with the software and databases in the Thermo-Calc platform. *thermocalc.com, questek.com.*

PROCESS TECHNOLOGY

TITANIUM PRODUCTION FORGES AHEAD

In collaboration with industry partners, engineers at the University of Sheffield, UK, are developing a new production process for aerospace grade titanium alloys. Dubbed FAST-forge, the process involves the transformation of rutile sand to novel titanium alloy aerospace components in three steps—production of titanium powder from rutile sand, field assisted sintering technology, and a one-step forging process. FAST-forge promises increased design flexibility and, potentially, improved buy-to-fly ratios—a boon in an industry where the manufacture of some components sees 90% of forged titanium alloy machined away to waste.

Because titanium is compatible with carbon, it is used for fasteners and high-strength forgings in many civilian aircraft, which are increasingly manufactured from carbon composite fuselage and wing structures. Orders for these aircraft are forecast to rise over the next decade due to increased air travel, but with titanium's current world mill production capacity at approximately 130,000 tons, supply may not be able to meet increasing demand unless additional sources are made available. "Titanium is a lightweight and inherently corrosion resistant material, giving it performance, environmental, and cost advantages over high grade steels," says Martin Jackson, director of aerospace engineering and co-director of the Sheffield Titanium Alloy Research Group. "But it is three times the cost of steel, with limited supply. The FAST-forge process shows how the benefits of titanium over steel can be achieved more efficiently and at lower cost." *www.sheffield.ac.uk.*

Transforming rutile sand to titanium aerospace components involves three steps: Ti powder production from sand, field assisted sintering, and forging. Courtesy of University of Sheffield.

BOOSTING EFFICIENCY IN MMC MANUFACTURE

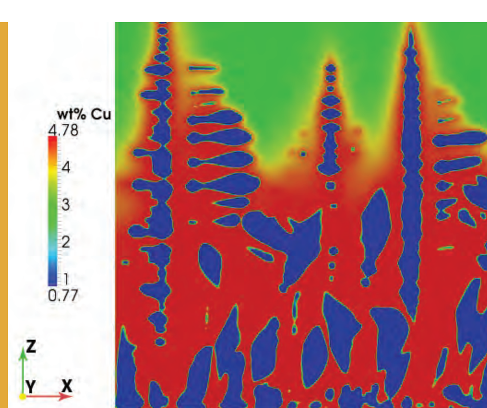
The Detroit-based public-private consortium, Lightweight Innovations for Tomorrow (LIFT), and Materion Corp., Mayfield Heights, Ohio, are joining forces to identify new efficiencies in the manufacture of lightweight aluminum metal matrix composites (MMCs) for transportation components. Their two-year collaboration with industry experts and university researchers will examine the consolidation and metalworking methods necessary to fabricate mechanically alloyed MMCs derived from powder metal for use in large-scale automotive and aerospace platforms. The team will explore alternatives to hot isostatic pressing (HIP), which they believe will reduce production time and costs while maintaining high standards for specific modulus and strength-to-weight ratio. Among other goals, the initiative will investigate several product forms, including extrusions, 3D near-net-shape HIP, press and sinter parts, and thin sheet.

LIFT is a public-private partnership that aims to develop and deploy advanced lightweight materials manufacturing technologies.

The project team also includes Boeing, Lockheed Martin, GKN, Case Western Reserve University, Pennsylvania State University, University of Tennessee, Massachusetts Institute of Technology, and Oak Ridge National Laboratory. The group aims to render MMCs with greater commercially viability than current versions, for application in automotive, industrial, and aerospace products in the short term and additional transportation platforms in the future. *www.lift.technology, materion.com.*

BRIEF

NASA, Washington, awarded **California State University,** Los Angeles two grants totaling $840,000 to conduct materials science experiments with the International Space Station. The project will use simulation to examine how materials solidify under different circumstances—in space, in the absence of gravity, and on earth where gravity is present. *nasa.gov, calstatela.edu.*



Copper distribution around dendritic microstructures during solidification of an Al-Cu alloy. Courtesy of Mohsen Eshraghi.

SURFACE ENGINEERING

NEW COATINGS PROTECT PIPE INTERIORS

Axalta Coating Systems, Houston, recently developed two new high temperature, corrosion-resistant internal pipe coatings. Nap-Gard 7-0017HT and 7-0017VHT Black Beauty FBE products are thermosetting epoxy powders designed to provide excellent chemical resistance when operating in temperatures to 200°C (392°F).

Corrosion caused by carbon dioxide and hydrogen sulphide, often found in sour crude oil, is a major challenge for the oil and gas industry. These high glass transition temperature, internal pipe coatings are designed to combat this problem. When properly applied with Nap-Gard 7-1808 primer, the new coatings exhibit extreme corrosion protection against high levels of H_2S, CO_2, and methane, even at elevated temperatures and pressures. *axaltacs.com.*

CHEMICAL VAPOR DEPOSITION PRODUCES BIODEGRADABLE POLYMERS

Researchers from the University of Michigan, Ann Arbor, Northwestern Polytechnical University, China, and the Karlsruhe Institute of Technology, Germany, introduced the first chemical vapor deposition (CVD) method to produce degradable polymers. Biomolecules or drugs can be attached using special side groups, which allows coating of biodegradable implants.

The achievement was made using two special types of monomers—the paracyclophanes usually used for this process were combined with cyclic ketene acetals. While classic polymers based on paracyclophanes are connected exclusively through carbon-carbon bonds, the ketene acetal converts during polymerization so that ester bonds are formed within the polymer backbone. Such bonds can be broken in aqueous environments.

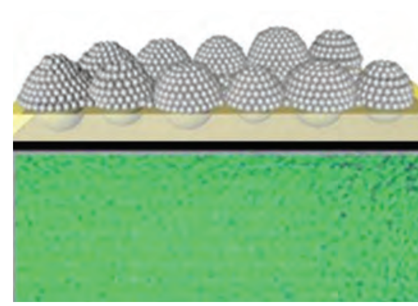
New high temperature, internal pipe coatings protect against corrosion. Courtesy of Axalta.

"The speed of degradation depends on the ratio of the two types of monomers as well as their side chains," explains lead researcher Jörg Lahann. "Polar side chains make the polymer film less hydrophobic and accelerate degradation because water can penetrate more easily. The speed of degradation can thus be tailored to the intended use." Tests show that neither the polymer nor its degradation products are toxic. *For more information: Jörg Lahann, lahann@umich.edu, www.umich.edu.*

BUG EYES INSPIRE REFLECTIVE MATERIALS

Retroreflective materials, including some tapes and road paints, work by bouncing light back toward the original source, such as a car's headlights, making them bright and easy to see. Existing retroreflectors are typically made with glass microbeads and microprisms. Dyes, pigments, or plastic layers are often added for color. However, they tend to reduce light reflection and colors can fade over time. Researchers at the National Chung Hsing University, China, and colleagues turned to the compound eyes of insects for a new way to address these limitations.

An array of glass microspheres was evenly coated with smaller balls of silica, resulting in a brilliantly colored, retroreflective material. Color can be adjusted by changing the size of the silica crystals and brightness can be boosted by adding layers. At 250 nm and 40 layers deep, crystals appear bright green and reflect more light than commercial coatings with no color. In addition to boosting the brightness of objects for safety reasons, researchers say that by reflecting rather than absorbing light, the material could be applied to buildings to reduce the urban heat-island effect. *www.nchu.edu.tw/en-index.php.*



The structure of bug eyes (top) is inspiring colorful reflective materials (bottom). Courtesy of the American Chemical Society.

BRIEF

MetaSOL nanotechnology coatings from **MetaShield LLC**, N.Y., provide a 1.2% (absolute) efficiency boost for triple junction solar cells, according to an independent research study. The material is a nanoparticle embedded, glass-based coating that increases efficiency using advanced light trapping technology. The formula is sprayed directly onto a solar cell's existing antireflective coating and hardens at room temperature, forming a transparent ~200 nm glass film. *metashield.com.*

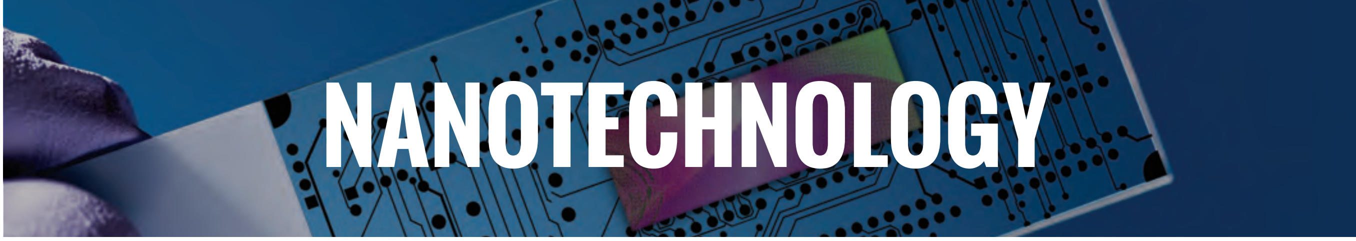
LECO

SIMPLIFY YOUR ADDITIVE MANUFACTURING WITH LECO

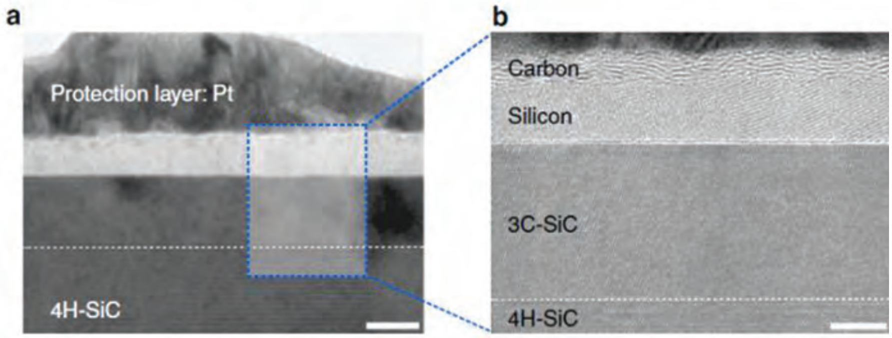
Additive manufacturing has quickly taken hold as an efficient means of creating complex parts without significant waste or numerous labor intensive steps. LECO Corporation has the solutions you need to control your entire additive manufacturing process from start to finish. Elementally, LECO's 836 series is ideal for the wide-range measurement of oxygen, nitrogen, and hydrogen, and the 844 series is the benchmark for simultaneous carbon and sulfur measurement. The 836 series loading mechanism ensures your sample is consistently dropped without any loss of material, and that the powder sample is analyzed with minimal atmospheric blank. The 844 series can combust the most refractory of materials with a detection range covering ppm to percent. The 836 and 844 can easily handle both raw powders and finished product, with limited method changes. Once your elemental determinations are complete, you can continue your analysis with LECO's complete line of metallographic products for sectioning, mounting, grinding, and polishing. Finally, the AMH55 automatic hardness testing system can easily measure impressions on varying surface conditions over a wide number of applications, providing precise and productive hardness measurements. Optional color contour mapping of your test area is also available.

LECO European Application and Technology Center

Our instrument capabilities are designed with our customers in mind—increasing productivity and giving you the results you need to ensure excellence in your materials. Visit www.leco.com to learn more.



NANOTECHNOLOGY



After just one 30-ns laser pulse, an SiC substrate is melted and separates into a carbon and a silicon layer. Courtesy of IBS.

LASER ANNEALING ENABLES ULTRATHIN NANOMATERIALS

Researchers at the Institute for Basic Science, together with a team at KAIST, both in South Korea, discovered a graphene synthesis mechanism using laser-induced solid state phase separation of single-crystal silicon carbide (SiC). Their research clarifies how this laser technology can separate a complex compound (SiC) into its ultrathin elements. Using high resolution microscope images and molecular dynamic simulations, scientists found that a single-pulse irradiation of xenon chloride excimer laser of 30 ns melts SiC, separating a liquid SiC layer, a disordered carbon layer with graphitic domains (about 2.5 nm thick) on the top surface, and a polycrystalline silicon layer (about 5 nm) below the carbon layer. Additional pulses cause the sublimation of the separated silicon, while the disordered carbon layer is transformed into multilayer graphene. *www.ibs.re.kr/eng.do, kaist.edu.*

WATCH NEW CERAMIC NANOTECHNOLOGY IN ACTION

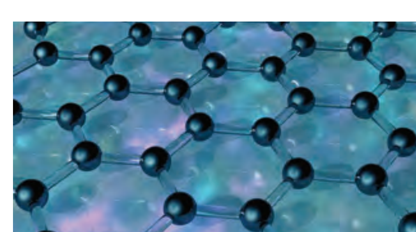
A new watch from Bausele Australia uses an innovative material called Bauselite developed in partnership with Flinders University's Centre of NanoScale Science and Technology, Australia. The advanced ceramic nanotechnology is featured in the company's Terra Australis watch. Apart from the face, the case is the most prominent feature on a watch head—so it needs to be visually appealing but also lightweight and strong, says company founder Sydneysider Christophe Hoppe. Using a new technique, the team created a ceramic-like material that can be produced in small batches via a non-casting process, which helps eliminate defects found in conventional ceramics. "Bauselite is strong, very light and, because of the way it is made, avoids many traps common in conventional ceramics," explains Hoppe. The new material also allows holes to be drilled more precisely. "It means we can make bolder, more adventurous designs," he adds. *bausele.com.*

Each timepiece features red earth from the Outback, beach sand, or opal—allowing wearers to take a piece of Australia with them wherever they go.

2D MATERIALS ENHANCE ELECTRONIC DEVICES

A new study by an international team of researchers led by the University of Minnesota, St. Paul, highlights how manipulating 2D materials could make modern day devices faster, smaller, and more efficient. Researchers examined the optical properties of dozens of 2D materials to unify understanding of light-matter interactions and explore possibilities for future research. They found that polaritons—a class of quasiparticles formed through the coupling of photons with electric charge dipoles in solid—allow the marriage of photon light particle speed with the small size of electrons. "With our devices, we want speed, efficiency, and we want small. Polaritons could offer the answer," says Tony Low, assistant professor of electrical and computer engineering. By exciting the polaritons in 2D materials, electromagnetic energy can be focused down to a volume a million times smaller compared to when it is propagating in free space.

"Layered 2D materials have emerged as a fantastic toolbox for nanophotonics and nanooptoelectronics, providing tailored design and tunability for properties that are not possible to realize with conventional materials," explains Low. *For more information: Tony Low, tlow@umn.edu, twin-cities.umn.edu.*



2D materials allow strong light-matter interactions through polaritons.

Regardless of the industry you are in or the processes you run, *The Ipsen, Harold* blog is devoted to providing expert-curated best practices, maintenance tips and details about the latest industry news and innovations.

Want to know what everyone else is reading?

Here are our top blog posts of 2016 ...

5 Quick Tips on How to Become a Brazing Superhero
When it comes to vacuum aluminum brazing there are a lot of advantages, but you also need to know the details on how to properly braze your parts.

Finding Leaks in Your Vacuum Furnace – Part I
This video walks you through the step-by-step process for performing a leak check, from calibrating the helium mass spectrometer to determining which part of the furnace is the source of the leak.

A Daily Checklist for Preventative Maintenance
An effective method for extending the life of your vacuum furnace is following a carefully scheduled preventative maintenance plan. This post covers the tasks that should be performed on a daily basis.

A Look Inside the Furnace: Choosing the Best Hot Zone for Your Needs
When choosing between all-metal or graphite hot zones, it's important to consider your processes, materials, temperatures, ramp rates and uniformity ranges.

The Importance of Validating Your Furnace:
Temperature Uniformity Surveys and Other Useful Tips
Nothing is more important than validating your furnace equipment. One of the most important tests you can perform is a Temperature Uniformity Survey.

Read the posts at www.IpsenHarold.com or scan the code to the right.

Scan the QR code to read the blog

Download *Quick Scan* or *QR Droid* app to scan code

Special Courses!

Expanded Vacuum and Atmosphere Trainings for 2017

Whether you've been in the industry for five months or 25 years, staying up-to-date on new methods and industry innovations is a key contributor to success. Ipsen will begin 2017 by hosting a series of three-day Ipsen U classes, as well as teaching local one-day seminars throughout the United States. These trainings focus on advancing your knowledge of atmosphere and vacuum heat-treating equipment, processes and maintenance through applied learning.

Learn more and register at www.IpsenUSA.com/Training

Ipsen

DEVELOPING STRONG CORE TECHNOLOGY FOR HIGH PRESSURE DIE CASTING

A new technology is needed in order to manufacture certain lightweight automotive components, in particular those with hollow structures of complex geometry.

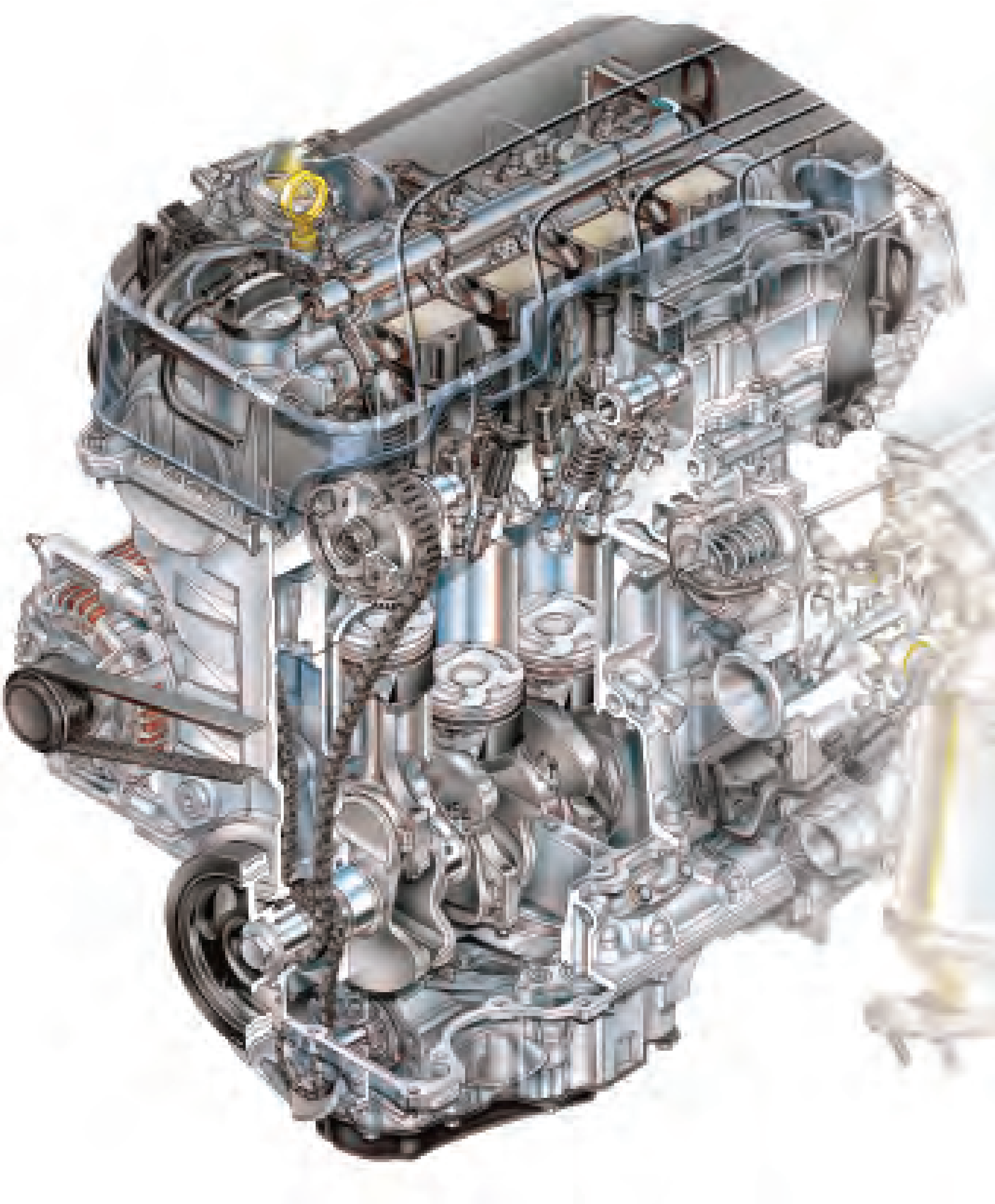
Frank Czerwinski, Gabriel Birsan, Frank Benkel, and Wojciech Kasprzak
CanmetMATERIALS, Natural Resources Canada

Mike J. Walker
General Motors, Warren, Mich.

Jock Smith
General Motors of Canada Ltd.

Douglas Trinowski
HA International, Westmont, Ill.

Ignacio Musalem
Cana-Datum Moulds Ltd., Canada



Automotive components such as engine blocks require internal cavities or passages, either to avoid costly machining or for weight reduction. For example, engine camshafts and crankshafts feature an incorporated hollow structure for the latter purpose. In order to manufacture a component with internal cavities during casting processes, cores must be installed before the metal is poured. A core is a replica—an inverse one—of the internal features of the part to be cast (Fig. 1).

Depending on the casting technique, cores may either be completely integrated into the casting die/mold or loosely inserted there. After the metal solidifies and the component is released, the core must be broken, removed from the product, and disposed, although some applications exist for reusable cores. Depending on the particular method, when shifting from gravity casting to low pressure and high pressure die casting, core strength requirements vary as melt pressure increases[1]. This article addresses the deficiency of existing technologies for manufacturing certain lightweight automotive components, in particular those with hollow structures of complex geometry.

COMMERCIAL APPLICATIONS

Research on core casting encompasses a variety of core types and casting techniques. According to recent developments, a sand core technique produces automotive body frame nodes by ablation casting[2]. The combination of high properties and hollow shapes make ablation cast nodes ideal for a lightweight frame structure. Sand cores create complex hollow internal sections, further reducing weight. Cores enable production of large, thin wall, hollow shapes that are lightweight and feature superior properties due to high cooling rates. However, the most challenging application using strong/breakable cores in high pressure die casting has not been actively investigated.

Vehicle lightweighting with aluminum or magnesium alloys improves fuel economy and reduces emissions. This represents a complementary approach for hybrid and fuel cell vehicles to increase vehicle performance, particularly range. The strategic vision to reduce vehicle weight by up to 20% has not been achieved, in part due to barriers in manufacturing technologies. Development of a high-volume, low-cost casting process that uses new generation casting cores will advance manufacturing and enable production of high-integrity components with full heat treatment capabilities. Such a technology would reduce component cost and increase vehicle competitiveness.

TECHNICAL CHALLENGES

The design and manufacture of casting cores remains a constant global challenge for foundries. This is due in part to the growing complexity of core shapes, greater strength requirements, and core removal techniques that require new materials for the core base and for binder and coating development. There is also pressure to develop better cores, which magnifies the increasingly stringent environmental, health, and safety regulations. A significant technology gap exists in the application of cores for high pressure die casting—the technique of choice for large-scale manufacturing of structural automotive components.

As a result, parts manufactured using current die casting methods typically do not contain complex internal passages or cavities that require the core to be broken before removal. Salt cores, which have appropriate strength and may be dissolved after casting, can be applied but have only achieved limited success[3]. Therefore, cores made of granular media such as sand or similar materials represent a more promising research focus.

The key challenge is to develop cores that are strong enough to withstand injection pressure (especially in gating areas) and pressure intensification during holding periods, thus allowing generation of high integrity, hollow structural castings. In addition, cores must also break up easily after casting for removal purposes.

Currently, suitable base core materials, binder materials, and surface coating solutions are not available to create an optimum core structure. However, inorganic binders are receiving renewed attention from the automotive industry. Further, knowledge of the interaction between new core materials and molten alloys is critically important. This interface is highly linked to casting defect formation, which prevents the successful manufacture of high integrity structural components. In such a defined project scope, closing the knowledge gap through core development is a priority.

CORE VERIFICATION

To prove the strong core concept, two-step verification should be performed that covers design and manufacturing of casting cores and implementation of cores to high pressure die casting. A test component consisting of a two-cavity test die featuring a simplified geometry with two cylinders of approximately 70 mm diameter, 200 mm length, with wall thickness of 2 and 4 mm was selected. The test die with a configuration of runners and overflows

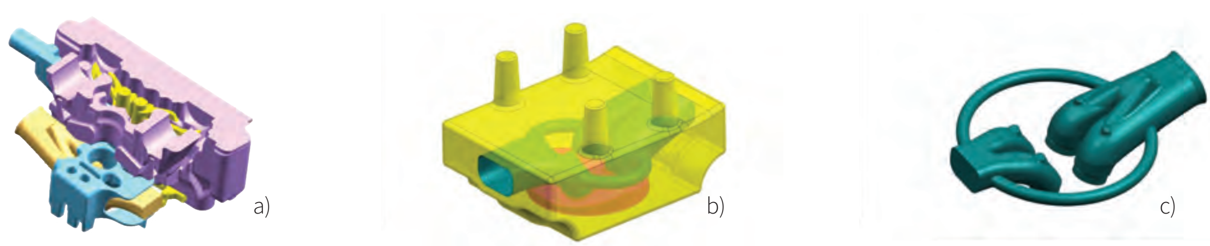


Fig. 1 — 3D model shows core concept in casting: (a) part of complex geometry; (b) simplified test component with view of the part with marked core inside; (c) essential core structure with a ring for assembly purposes. Due to the complex shape, the core cannot be removed from the part without breaking.

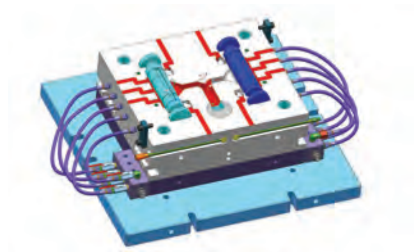


Fig. 2 — CAD drawing of two-cavity die built for high pressure die casting trials.

shown in Fig. 2 was built to suit the high pressure die casting system. Molten metal is delivered by a central runner and fed to each cylinder through a single gate located in the cylinder center. The core shape, also shown in Fig. 2, consists of two flanges beyond the cylinder ends, which are designed for core installation inside the die cavity.

A metal flow simulation verified die design and cavity filling conditions. The value of metal injection velocity at the gate, as it flows into the core, represents the essential parameter for core design. For a plunger speed of 1 m/s, the approximate melt velocity at the gate will reach 15 m/s (Fig. 3).

MANUFACTURING TECHNIQUE

Cores are made of silica sand and the binding system is a water soluble material that can withstand casting temperatures and be easily removed by dissolution after casting. The binder is mixed with the granular media at 1-5 wt%, binder to media. The mixed material is then blown into the corebox and dried using heated tooling and hot air. The level of binder to granular media is such that there remains interconnected porosity in the manufactured core. This porosity allows the water based

Fig. 4 — Clamp area of high pressure die casting machine with cores installed directly before die closing and injection of liquid alloy.

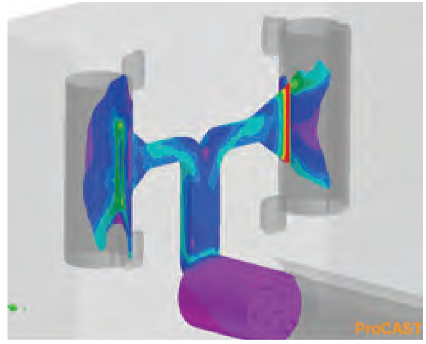


Fig. 3 — Modeling of die filling during injection shows melt velocity at different locations within the runners and cast part. For a plunger velocity of 1 m/s, the corresponding melt velocity at the gate is 6 m/s.

solution to penetrate the core in order to dissolve it after casting.

A shield, made of metal, ceramic, or glass fiber, or a combination, may be placed near the casting in-gates to protect the core from the high velocity impingement of metal coming from the gates during filling. The shield may be a bit larger than the gate area, but could be any desirable or practical size. Generally, the shield may either be placed in the corebox during core making or affixed to the core after production.

TEST RESULTS

Performance of experimental cores was tested using a 1200-ton Bühler high pressure die casting machine and commercial grade aluminum alloy A356 (Fig. 4). The 800 kg load of molten metal was held in a Stotek furnace at 710°C. A variety of core solutions were tested with sand, surface coatings, and shields inserted in gate areas. A variety of casting process parameters, such as injection speed or injection pressure, were also tested. Casting trials show that correctly designed cores do not collapse during injection and allow manufacturing of sound parts. Figure 5 shows that the essential part of the cores remains inside components.

Once optimal core design and structure are determined, implementation in a commercial part with a more complex shape and varying wall thickness will occur. Another series of tests will take place at a commercial die casting facility.

Fig. 5 — Aluminum test components manufactured using strong core technology and high pressure die casting.

SUMMARY

CanmetMATERIALS, in collaboration with General Motors and other industrial partners, worked to develop core technology for high pressure die casting in order to enable high volume and low-cost manufacturing of lightweight automotive components with complex hollow structural shapes. Although experimental verification of the concept using a part with simplified geometry looks promising, the technique requires further testing using commercial components with internal cavities of complex geometry. **~AM&P**

For more information: Frank Czerwinski is senior research scientist and innovative casting group leader, CanmetMATERIALS, 183 Longwood Rd. South, Hamilton, Ontario, L8P 0A5, 905.645.0887, frank.czerwinski@canada.ca, www.canmetmaterials.nrcan.gc.ca.

Acknowledgments

The authors acknowledge the financial support of the ecoEnergy Innovation Initiative program of Natural Resources Canada and General Motors, and thank members of the Innovative Casting Group at CanmetMATERIALS for assistance during casting trials.

References

1. F. Czerwinski, M. Mir, and W. Kasprzak, Application of Cores and Binders in Metalcasting, *Int. J. Cast Met. Res.*, Vol 28, p 129-139, 2015.

2. A. Prescenzi, Cast Body Nodes for 2016 Acura NSX, *SAE Int. J. Mater. and Manuf.*, Vol 8, p 722-730, 2015.

3. T. Flessner and C. Marr, Die Casting Using Casting Cores, U.S. Patent 5,303,761, 1994.

DEVELOPING NANOSTRUCTURED METAL AT THE ATOMIC AND NANO SCALES

Affordable bulk production of a newly developed nanostructured bainitic steel is possible without using severe deformation or complex heat treatments.

Rosalia Rementeria, Francisca G. Caballero , Lucia Morales-Rivas, and Carlos Garcia-Mateo

A nanostructured bainite has been developed by heat treating high-carbon, high-silicon steels. The new material is being produced in bulk and affordably without using severe deformation or complex heat treatments. The bainitic structures consist of nanoscale ferrite crystals 20-60 nm thick interwoven by austenite. Nanostructured bainite has one of the highest known densities of ferrite/austenite interfaces. The material has the highest strength/toughness combination ever recorded in bainitic steels (~2.2 GPa/40 MPa·m$^{1/2}$)[1] and has extraordinary rolling-sliding wear performance[2]. This article discusses the characteristics and significance of nanostructured bainite in terms of the transformation mechanism.

HEAT TREATMENT AND TRANSFORMATION KINETICS

Generally, low transformation temperatures lead to fine-grained microstructures that have both strength and toughness. First-generation nanostructured bainitic steels were designed using models based on the atomic mechanism of displacive transformation theory[3]. The bainite start temperature (B_s)—the highest temperature at which bainite can be formed—was lowered mainly due to high carbon concentrations. In addition, the alloys contained enough silicon to suppress cementite precipitation from austenite. Cementite is a splitting and void-initiating phase, best eliminated from strong steels. The tradeoff to achieve the nanoscale in these bainitic steels is extremely long transformation times. For instance, the bainite reaction in first-generation nanocrystalline bainitic steels took up to 90 days at a transformation temperature of 125°C[3]. However, rapid heat treatment may be required on a commercial basis.

Alloy composition can be tailored to increase the magnitude of free energy change that accompanies austenite decomposition ($\Delta G_{\gamma\alpha} = G_\alpha - G_\gamma$), where G_α is the Gibbs free energy of ferrite and G_γ is the Gibbs free energy of austenite; thus accelerating both nucleation and growth rates. Theoretical design in second-generation nanostructured bainite led to processing times of hours as opposed to days by reducing carbon, manganese, chromium, and molybdenum contents and by refining the prior austenite grain size with the help of niobium additions[2]. However, the effect of the prior austenite grain size on bainite kinetics appears to accelerate the reaction through coarse prior austenite grains[4]. Coarse austenite grains increase growth rate and decrease nucleation sites of bainitic transformation. Growth rate is more important than nucleation, so the overall outcome was acceleration of the bainite reaction.

The latest research into accelerating the bainite reaction suggests partial martensite transformation with subsequent transformation upon up-heating[5]. Though the quenching and bainite transformation process occurs more quickly than in direct isothermal transformation, industrial production lines are not yet prepared for this kind of heat treatment.

TENSILE PROPERTIES

Low-temperature transformation bainite is harder than previously achieved, with values in excess of 700 HV. Selected alloy compositions along with transformation conditions and microstructural parameters of second-generation nanostructured bainitic steels are shown in Table 1. After transformation at 220° and 250°C, hardness values are always over 600 HV30 with a bainitic ferrite plate thickness of 30-40 nm. Corresponding strength and ductility data of the selected microstructures, in terms of yield strength (YS), ultimate tensile strength (UTS), uniform elongation (UE), and total elongation (TE) are illustrated in Fig. 1.

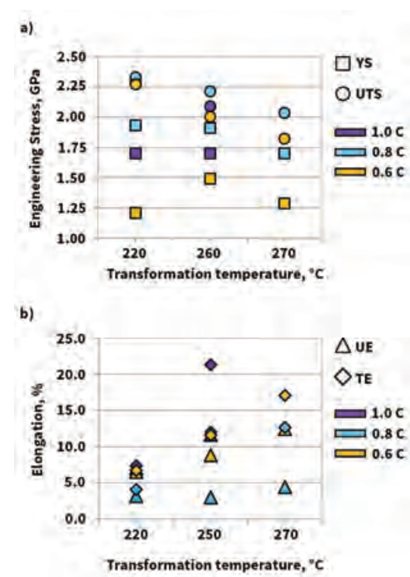


Fig. 1 — Tensile properties on select grades and transformation conditions.

TABLE 1 – SECOND GENERATION BAINITIC STEEL NANOSTRUCTURE PROPERTIES

ID	Chemical composition, wt%	T ,°C	Time, h	V_γ, %	*t*, nm	V_α/t, nm^{-1}	Hardness, HV30
1.0 C	1.00 C, 2.90 Si, 0.75 Mn, 0.50 Cr	220	22	36	28	2.29	650
		250	16	34	39	1.69	625
0.8 C	0.88 C, 1.54 Si, 0.69 Mn, 0.50 Cr	220	22	22	32	2.44	710
		250	16	18	38	2.16	659
		270	7	24	36	2.11	615
0.6 C	0.65 C, 1.60 Si, –1.25 Mn, 1.60 Si, 1.75 Cr, 0.15 Mo, 0.12 V	220	22	24	38	2.00	643
		250	15	22	37	2.11	600
		270	7	32	48	1.44	554

KEY
T: transformation temperature; Time: transformation time; V_γ volume fraction of austenite; *t*: bainitic ferrite plate thickness; V_α/t, ratio between the volume fraction of bainitic ferrite and the plate thickness.

The strength and hardness of the structure are mainly due to the volume fraction of the ferritic phase (V_α), while plate thickness is responsible for further strengthening. Accordingly, hardness and yield strength values correlate well with the ratio V_α/t as shown in Table 1. Strength residue—after accounting for bainitic-ferrite plate thickness—comes from dislocation forests, the intrinsic strength of the iron lattice, and solution strengthening[1]. Therefore, at the same transformation temperature, higher carbon grades (1.0 C and 0.8 C) exhibit superior tensile properties, with UTS values greater than 2 GPa.

Microstructural parameters in terms of phase volume and scale fail to predict elongation values. For instance, ductility at the lowest transformation temperature is relatively low for all compositions. However, sensitive and unsystematic improvement occurs when transforming at 250°C despite the fact that microstructural parameters do not significantly change. Retained austenite mechanical stability might be the key to the ductility in those microstructures[6].

NANOSCALE FERRITE

Transmission electron microscopy (TEM) micrographs of 0.6 C steel transformed at 220°C for 22 hours are shown in Fig. 2. Some bainitic ferrite plates are exceptionally long and thin (~50 nm), with a structure consisting of an intimate mixture of ferrite and austenite (Fig. 2).

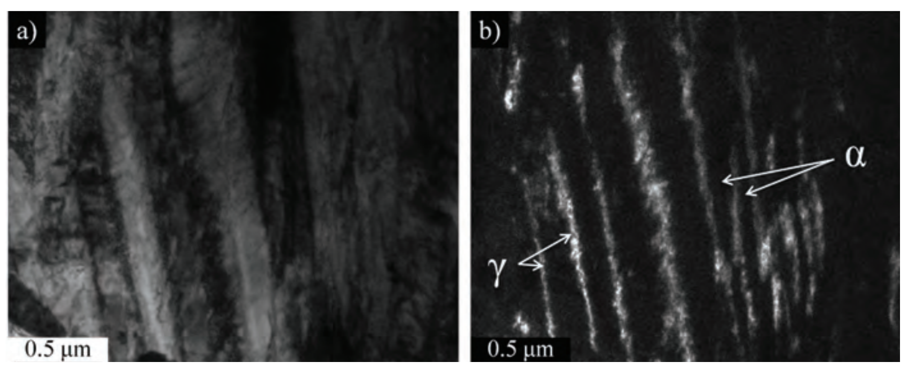


Fig. 2 — TEM of microstructures obtained at 220°C for 22 h in 0.6 C steel. a) Bright-field image. b) Corresponding dark-field image of retained austenite films where bainitic ferrite plates lie between.

Nearly all ferrite laths in a bainite sheave have the same crystallographic orientation. In displacive transformations, it is generally assumed that the close-packed {111} plane of austenite (face-centered cubic, or fcc) is parallel to a {110} plane of the bainitic ferrite (body-centered cubic, or bcc). In nanobainitic steels, most bainitic plates and parent austenite interfaces have an orientation relationship (OR) close to the Nishiyama–Wassermann (N-W), $\{111\}\gamma||\{110\}\alpha$ with $<110>\gamma||<001>\alpha$[7]. From a single austenite crystal, 12 crystallographic variants can be formed with an N–W orientation relationship due to the symmetry of cubic systems. A crystallographic packet is a group of crystallographic variants with a common {111} austenite plane. Each bainitic packet can be divided into bainitic blocks of the three variants of the N–W relationship satisfying the same parallel plane relationship. This causes the obtained microstructure to be highly misoriented, with a wide variety of microstructural barriers.

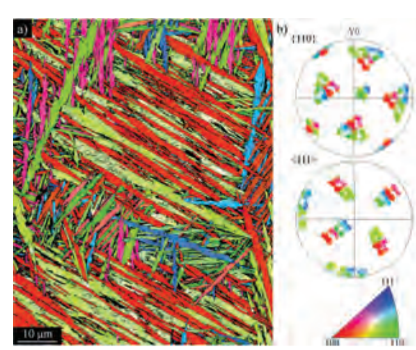


Fig. 3 — a) Inverse pole including a single prior austenite grain of 0.6 C steel transformed to bainite at 270°C for 7 h. The black thin lines represent either misorientation angles greater than 10° or austenite films. b) {011} and <111> pole figures representing all orientations of bainite laths corresponding to (a), showing the typical N-W pattern.

The inverse pole figure color map image in Fig. 3 shows the bainitic structure formed from a prior austenite grain at 270°C for 7 h in 0.6 C steel. Colors correspond to the crystallographic orientation normal to the observed plane, representing different crystallographic variants. Black boundaries were drawn where the misorientation angle is greater than 10° or austenite is present. A prior austenite grain was divided by bainitic packets consisting of three bainitic blocks where each block contains a single variant of the bainitic lath.

RETAINED AUSTENITE

The nanoscale structure is not exclusive to bainitic ferrite, as retained austenite trapped between the plates of ferrite also has a size <100 nm (Fig. 2b)—so-called *nanofilms*. In low-temperature bainitic structures, the term *microblock* is used to denote blocks of retained austenite >1000 nm, while *submicron block* refers to those between 100 and 1000 nm. Figure 4 shows the multiscale character of the austenite in 0.6 C steel transformed at 250°C for 15 h.

Morphology and the chemical composition are key factors controlling the mechanical stability of austenite. Carbon has the strongest influence on enhancing mechanical stability[6], while at an atomic level, there is a strong correlation between austenite feature size and the amount of carbon retained in solid solution (the smaller the size, the higher the carbon level)[8].

Transformation-induced plasticity (TRIP) of austenite is thought to enhance ductility if the austenite is moderately stable against straining; for example, when associated strain hardening effectively increases resistance to necking and fracture. To this end, a wide distribution of sizes of retained austenite in the microstructure (Fig. 4) leads to effective variations of austenite stability, spreads the transformation effect along straining, and postpones localization[9].

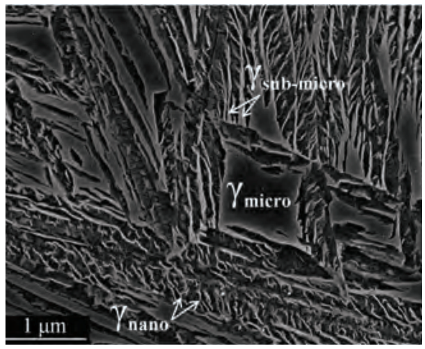


Fig. 4 — SEM of microstructures in 0.6 C steel obtained by isothermal transformation at 250°C for 15 h.

CARBON SUPERSATURATION IN FERRITE

Atom probe tomography shows a high level of carbon in bainitic ferrite without linear or surface defects, which was over 10 times above what was expected[10]. As transformation temperature decreases, the carbon amount remains high after transformation.

There are two possible explanations of the abnormally high carbon content in bainitic ferrite. The first points toward a change in symmetry from the conventional cubic unit cell (bcc) into a tetragonal lattice (bct). The second points to a high density of point defects, particularly vacancies[11].

Synchrotron radiation and x-ray diffraction experiments show a tetragonal or slightly orthorhombic unit cell of bainitic ferrite capable of holding the excess carbon[12]. Likewise, first-principles calculations prove that when tetragonal ferrite is in para-equilibrium with austenite, it has a much greater solubility for carbon than is the case for cubic ferrite under the same conditions[13]. In this scenario, the retrograde shape of the α/α+γ equilibrium phase boundary in the Fe–C phase diagram is displaced toward higher carbon solubility in ferrite providing that tetragonality (*c/a* ratio) increases as seen in Fig. 5.

On the other hand, specific interstitial lattice sites near defects in bainitic ferrite provide lower-energy sites for carbon than the regular interstitial lattice positions, which would result in an increased solubility of carbon in the ferrite. Computational calculations support this increased solubility of carbon in cubic iron caused the formation of vacancy-carbon complexes[14]. However, further experimental evidence of this unusually high density of vacancies in bainitic ferrite is required.

SUMMARY

Nanostructured bainitic steels have been theoretically designed and manufactured using conventional industrial practices, achieving mechanical properties never recorded before in bainite structures. Bainitic steel microstructures consist of extremely fine plates of carbon-supersaturated ferrite and retained austenite. The increased solubility of carbon in ferrite might form

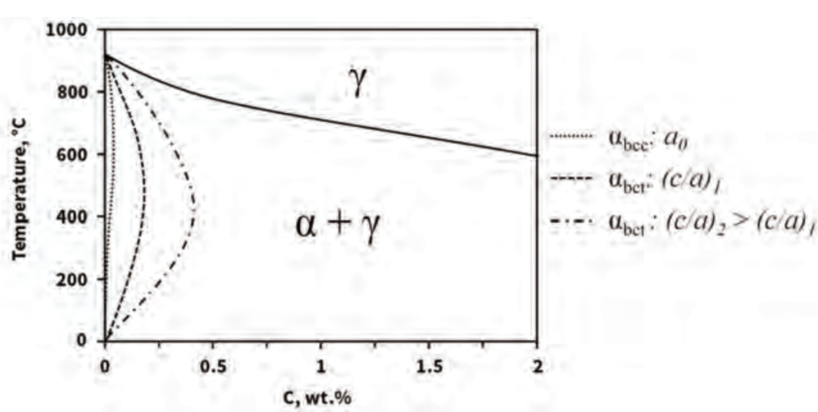


Fig. 5 — Fe–C binary phase diagram considering only ferrite and austenite show the effect of tetragonal ferrite (α_{bct}) with different c/a ratios on the α/α+γ equilibrium phase boundary compared to cubic ferrite (α_{bcc}).

a better basis for phase transformations theory on alloy design. Potential applications have yet to be fully explored. **~AM&P**

For more information: Rosalia Rementeria is research associate, Spanish National Center for Metallurgical Research (CENIM-CSIC), Avda. Gregorio del Amo 8, E-28040 Madrid, Spain, rosalia.rementeria@cenim.csic.es, www.cenim.csic.es.

References

1. C. Garcia-Mateo and F. Caballero, Ultra-high-strength Bainitic Steels, *ISIJ Int.*, Vol 45, p 1736-1740, 2005.

2. T. Sourmail, et al., Evaluation of Potential of High Si High C Steel Nanostructured Bainite for Wear and Fatigue Applications, *Mater. Sci. Technol.*, Vol 29, p 1166-1173, 2013.

3. F. Caballero and H. Bhadeshia, Very Strong Bainite, *Curr. Opin. Solid State Mat. Sci.*, Vol 8, p 251-257, 2004.

4. F. Hu, P. Hodgson, and K. Wu, Acceleration of the Super Bainite Transformation Through a Coarse Austenite Grain Size, *Mater. Lett.*, Vol 122 p 240-243, 2014.

5. W. Gong, et al., Effect of Prior Martensite on Bainite Transformation in Nanobainite Steel, *Acta Mater.*, Vol 85, p 243-249, 2015.

6. C. Garcia-Mateo, et al., Tensile Behaviour of a Nanocrystalline Bainitic Steel Containing 3 wt% Silicon, *Mater. Sci. Eng. A*, Vol 549, p 185-192, 2012.

7. H. Beladi, et al., Crystallographic Analysis of Nanobainitic Steels, *Scr. Mater.*, Vol 60, p 455-458, 2009.

8. F.G. Caballero, et al., Examination of Carbon Partitioning into Austenite During Tempering of Bainite, *Scr. Mater.*, Vol 63, p 442-445, 2010.

9. K. Hase, C. Garcia-Mateo, and H. Bhadeshia, Bimodal Size-Distribution of Bainite Plates, *Mater. Sci. Eng. A*, Vol 438, p 145-148, 2006.

10. F. Caballero, M. Miller, and C. Garcia-Mateo, Carbon Supersaturation of Ferrite in a Nanocrystalline Bainitic Steel, *Acta Mater.*, Vol 58, p 2338-2343, 2010.

11. S. van der Zwaag and J. Wang, A Discussion on the Atomic Mechanism of the Bainitic Reaction in TRIP Steels, *Scr. Mater.*, Vol 47, p 169-173, 2002.

12. C. Garcia-Mateo, et al., Low Temperature Bainitic Ferrite: Evidence of Carbon Super-Saturation and Tetragonality, *Acta Mater.*, Vol 91, p 162-173, 2015.

13. J. Jang, H. Bhadeshia, and D. Suh, Solubility of Carbon in Tetragonal Ferrite in Equilibrium with Austenite, *Scr. Mater.*, Vol 68, p 195-198, 2013.

14. Q. Jiansheng, et al., Computer Simulation on the Interaction Between Vacancy and Carbon Impurity in α-Fe, *Nucl. Instrum. Methods Phys. Res., Sect. B*, Vol 267, p 3179-3181, 2009.

FERROUS METALLURGY: PAST, PRESENT, AND FUTURE DEVELOPMENTS

Significant advancements in metallurgy were highlighted at a special symposium presented at the Materials Science & Technology 2016 conference recently held in Salt Lake City.

Kester D. Clarke, Colorado School of Mines, Golden

The historical and technological developments that have driven metallurgy as a science provide a fundamental understanding of metals processing. This enables manufacturers to produce advanced materials and components that allow designers to push technical and scientific innovation across industries. Knowledge of the past ensures that both current and future metallurgists understand the significance of technologies developed to reach the capabilities we have today, and reveals the areas of need for fundamental understanding and technology development moving into the future. Armed with this knowledge, the next generation of metallurgists and materials scientists can once again revolutionize metals manufacturing and improve the quality of life for people around the world.

Bessemer converter, Kelham Island Museum, Sheffield, England.

To highlight some perspectives from significant advancements in metallurgy, an invitation-only symposium was organized at the Materials Science & Technology 2016 conference in Salt Lake City on October 24. Entitled "Ferrous Metallurgy: Past to Present," it was the second time this symposium has been organized, with the first taking place at MS&T14 in Pittsburgh. The goal of each symposium is to showcase important developments in metallurgy and the effects they have had on manufacturing and society.

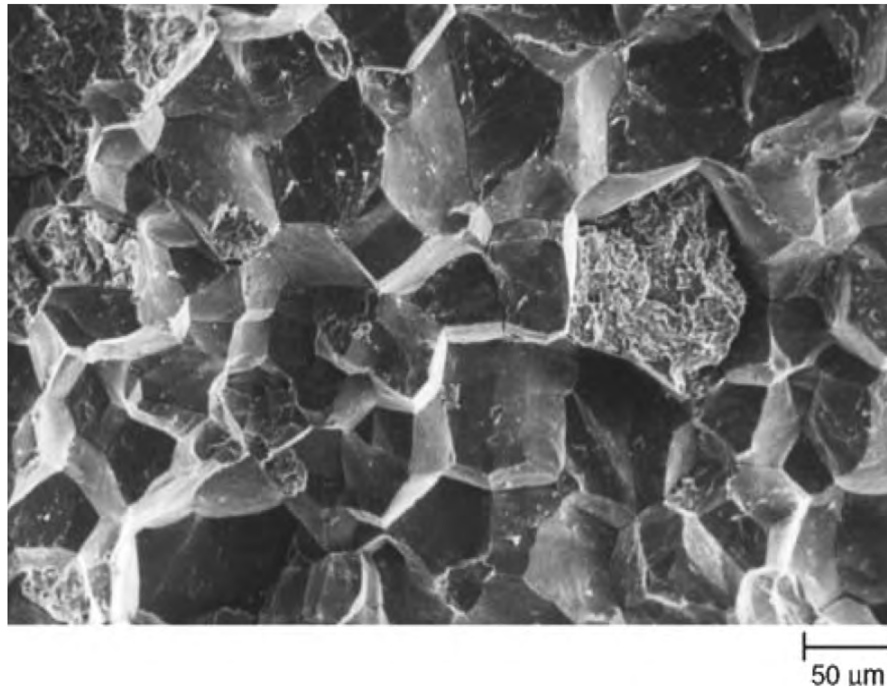
The first symposium brought together discussions on noteworthy historical aspects of ferrous metallurgy to remind us of the excellent work that has been done in the past and highlight the technological challenges to be overcome. Presentations focused on metallurgical eras ranging from cast iron smelting in the 8th century BC to the present day, and topics ranging from better understanding of microstructure-property relationships as characterization techniques improve to the development of science-based understanding of materials. In addition, significant industrial challenges such as understanding embrittlement in large ingot production, manufacture of plate armor at the end of the 19th century, and North American industrial development were addressed. Each speaker provided a valuable perspective on where we are today, how we got here, and where we need to go in the future.

Here, we highlight the subjects and topics presented in this symposium's second edition at MS&T16, which again covered a broad range of related topics to provide perspective on the drivers behind historical metallurgy development. Six invited speakers presented on topics ranging from the Bessemer process development to the history of very large forging presses, the latest developments in high temperature microscopy to the implementation of fine-grain practice in steel manufacturing, and from the fundamental understanding of near-equilibrium phase transformations to the mechanisms behind embrittlement in quenched and tempered steels. Recommended reading on each topic is listed in the references section.

SYMPOSIUM HIGHLIGHTS

In "The Age of Bessemer Steel," *AM&P* editor-in-chief Frances Richards presented the story behind the development of the revolutionary processing pathway that simultaneously reduced the cost and increased the quality of steel, fueling the Industrial Revolution and enabling reliable rail transport across continents. Based on the articles, "Metallurgy Lane: The Age of Steel" (Parts I and II) published by ASM life member Charles Simcoe in this magazine, the talk highlighted that both Henry Bessemer (of Sheffield, England) and William Kelly (of Kentucky) simultaneously and separately (around 1850) discovered that bubbling air through molten blast furnace cast iron removes carbon, thus enabling efficient steel production.

Along with Robert Mushet's discovery that the addition of manganese reduces "hot-shortness" by manganese sulfide formation, these developments allowed William Kelly to open a small plant using his process in Wyandotte, Mich., in 1863. At the same time, Alexander Lyman Holley was able to navigate the patent space in the U.S. and build the first Bessemer steel plant in Troy, N.Y., in 1865. By the end of the century, Andrew Carnegie became the leading producer of steel and the industrial and technological revolution was at full steam.



Brittle intergranular fracture along prior austenite grain boundaries in carbon steels quenched and tempered to martensite, known as quench embrittlement.

Jon Tirpak, FASM, immediate past president of ASM, then spoke about the technology development that enabled the move from hammer forging of steels in the years prior to World War II to hydraulic press use to control strain rates. This development allowed light metal forging and enabled the burgeoning aerospace industry. After the war, technologies originally developed in Germany were transferred to the U.S. and U.S.S.R., and a race to produce the largest presses to enable the production of large aluminum, magnesium, titanium, and steel components ensued. ASM International recognized the historical significance of six of these heavy hydraulic presses worldwide in 2013 by naming them ASM Historical Landmarks.

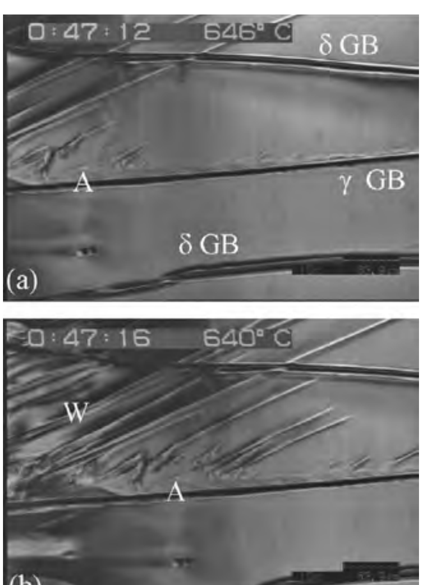
Alcoa's 50,000 ton press, Cleveland, refurbished in 2012.

Press size correlates directly to the size of components that can be produced, which determines the largest aircraft size possible. In a world where new technologies for manufacturing components are being developed, including additive manufacturing, this talk highlighted the critical need to teach and develop expertise in processes such as forging. Unlike many other techniques, materials produced by forging feature refined grain structures and substantial mechanical work, and allow designers flexibility and opportunities to reduce weight in large structural components where properties and repeatability are critical to performance.

The third speaker, Prof. Rian Dippenaar from the University of Wollongong, discussed development of high-quality lenses that enabled optical metallography use, which in turn allowed for identification of phases and constituents in microstructures, transforming metallurgy. Initial observations using optical metallography were open to interpretation and each successive improvement in lens quality increased available magnifications, which further clarified microstructural details.

Dippenaar related these developments to current work using laser-scanning confocal microscopy to observe high-temperature microstructure development in-situ. Using this technique, important changes in microstructure such as solidification, and diffusional and displacive solid-solid phase transformations in real time, may be observed. Laser-scanning confocal microscope development now allows unprecedented observation of these phenomena as they happen, and interpretation of these results requires many years of study moving forward. The ability to characterize materials at higher resolutions and in real processing environments is a critical area where technological developments promise to unveil previously misunderstood fundamentals of metallurgy.

An area where improved characterization will continue to enhance understanding and result in vastly improved performance is steel processing. Prof. Emeritus George Krauss, FASM, Colorado School of Mines, gave an example by discussing the phenomena of



Observation of formation of Widmanstätten ferrite (W), from ferrite allotriomorphs (A) during cooling from austenite (γ) in an Fe-C alloy.

Cross-section of meteorite shows 3D microstructure formed over millions of years.

steel embrittlement. Several conditions exist where low ductility is observed in steels, including quench cracking, temper embrittlement, tempered martensite embrittlement, hydrogen embrittlement, and quench embrittlement. There was a focus on quench embrittlement, which results in intergranular fracture on prior austenite grain boundaries.

Krauss summarized the efforts over the past 40 years to understand low toughness that occurs in quenched and tempered steels with carbon levels of approximately 0.5 wt% and above. Through high quality characterization by various methods, it has been shown that cementite formation on prior austenite grain boundaries is associated with this reduction in ductility, and that alloying elements such as phosphorous further aggravate the problem. Over time, a map of tempering temperature vs. carbon content has been developed, showing that quench embrittlement occurs only in high carbon steels tempered at low temperatures. Understanding the mechanisms behind phenomena such as quench embrittlement allow the use of high strength steels with microstructures designed to avoid conditions where brittle failure would occur.

The fifth speaker, Robert Glodowski of RJG Metallurgical LLC, highlighted the importance of understanding microstructural development as a function of processing in his presentation, "The Evolution of Ferrous Grain Size Control: Standards and Practice." In the late 1950s, it was often necessary to specify use of alloying for austenite grain size control to ensure that hot rolled steels were heat treatable, and that the quality of the resulting products was satisfactory. However, as steelmaking and rolling processes steadily improved, the need for grain size control via alloying and prescribed processing procedures for as-rolled steels disappeared.

Improved processing technologies enabled controlled thermal and mechanical rolling techniques, which eliminated the need to separately roll for shape and heat-treat for properties. Because the fine-grained austenite quality requirement is often still cited in standards, the perception that they are still needed remains, even though they do not benefit modern as-rolled steels. Grain-refining alloy additions and associated testing increases the steelmaking process cost, and may in fact cause other quality problems and an unwarranted sense of security to the user. This is another example where a fundamental understanding of microstructural development as a function of processing is imperative to enable manufacturing with the highest possible quality at the lowest possible cost.

Finally, Prof. John Jonas from McGill University discussed how the study of meteorite microstructures could be used to better understand microstructure formation fundamentals. Because meteorites cool extremely slowly (around 1°-100° C per million years), the microstructures that form do so in near-equilibrium conditions, allowing observation of phase transformations that occur over time periods not practical in laboratory tests. This understanding can then be compared and contrasted to phase transformations that occur during manufacturing processes such as rolling.

In meteorites, phase growth occurs slowly and in the absence of stress; in rolling, transformations are rapid and occur under stress. The use of electron backscatter diffraction (EBSD) shows that the applied stress during rolling allows rapid ferrite formation at temperatures above those for equilibrium conditions, and also produces preferential crystal orientation selection with respect to rolling directions. In addition, ferrite formation during rolling results in softening and load drops as well as physical volume increases. This understanding allows metallurgists to better understand the phase transformations that occur during processing, design tailored processes to manipulate microstructure development, and improve the materials produced by rolling processes.

SUMMARY

All six speakers in this special symposium shared examples of the importance of understanding how the specific manufacturing process affects microstructure development in metals. The fundamental understanding of microstructure allows metallurgists to select manufacturing processes and schedules to tailor the microstructure, and therefore mechanical properties and performance, for a particular component.

Moving toward the future, continued improvements in the control of manufacturing processes and the ability to test and characterize materials will enable substantial further improvements in manufacturing capabilities. Metallurgists who understand this relationship will be better able to exploit technological advances and provide great benefits to manufacturing and society. It is critically important for industry to promote the education and training of metallurgists to ensure advanced understanding and capabilities.

Further reading related to each topic is referenced below. These symposia were organized through the AIST Metallurgy: Processing Products and Applications Technology Committee (MPPATC) and will be organized for a third time at MS&T18. Contact Kester Clarke (kclarke@mines.edu) if you would like to participate in the future or have topic ideas of interest. **~AM&P**

For more information: Kester Clarke is assistant professor, Colorado School of Mines, 1500 Illinois St., Golden, CO 80401, 303.384.2301, kclarke@mines.edu, www.mines.edu.

References

1. "The Age of Bessemer Steel," presented by Frances Richards. C.R. Simcoe, "Metallurgy Lane: The Age of Steel, Parts I and II," *Adv. Mater. Processes*, March and April 2014.

2. "Historic Heavy Hydraulic Presses: Transitioning from Ferrous to Nonferrous Forgings," Jon Tirpak. *Forge Magazine*, North American Forging is Advanced Manufacturing Series: Parts 1-7. Part 1 available at www.forgemag.com/artcles/84311-north-american-forging-is-advanced-manufacturing.

3. "Advances in High-Temperature Microscopy," presented by Rian Dippenaar. Dominic Phelan, Nicole Stanford, Rian Dippenaar, In Situ Observations of Widmanstätten Ferrite Formation in a Low-Carbon Steel, Mat. Sci. and Eng.: A, Vol 407, Issues 1-2, p 127-134, October 2005, ISSN 0921-5093, http://dx.doi.org/10.1016/j.msea.2005.07.015.

4. "Quench Embrittlement: History and Importance in High Carbon Steels," presented by George Krauss. G. Krauss, Steels: Processing, Structure, And Performance, Second Edition, ASM International, 2015.

5. "Widmanstätten Ferrite: From Meteorites to Rolling Mills," presented by John Jonas. Y. He, et al., "Crystallographic Relations between Face- and Body-Centred Cubic Crystals Formed Under Near-Equilibrium Conditions: Observations from the Gibeon Meteorite," *Acta Mater.*, Vol 54, p 1323-1334, 2006; C. Ghosh, C. Aranas Jr., and J.J. Jonas, "Dynamic Transformation of Deformed Austenite at Temperatures above the Ae3," *Prog. Mater. Sci.*, Vol 82, p 151-233, 2016.

TECHNICAL SPOTLIGHT

BOOSTING PERC SOLAR CELL OUTPUT

By limiting recombination, passivated emitter and rear cell (PERC) solar cells can provide an absolute efficiency boost of 1%, making their relative efficiency about 7% greater than that of other screen printing methods.

In solid state physics, an electron that acquires sufficient energy may move from the valence band to the conduction band of an atom. When it does, it generates two separate entities—an electron and an electron hole. Both are carriers of electric charges. When the two entities later move from the conduction band to the valence band, they recombine and lose their ability to carry a charge. This recombination greatly limits performance in common screen-printed solar cells, but is minimized by PERC (passivated emitter and rear cell) solar cells.

In common screen printed solar cells, recombination can occur wherever monocrystalline silicon contacts with metal. On the cell's top surface, opportunities for recombination are limited. The area covered by metal is typically less than 3% of the total, and much of the metal is separated from the silicon by insulation. Conversely, the cell's bottom surface is bonded to aluminum. This silicon-to-aluminum interface—the back surface field, or BSF—is where significant power is lost as the electron-hole pairs recombine in common solar cells.

However, in PERC cells, the BSF aluminum is separated from the die's silicon by an insulation layer. The insulation is patterned and interrupted at intervals by trenches that contain an aluminum paste. It is only in these trenches that there is contact between aluminum and silicon, so the complete cell experiences less power loss through recombination.

PERC CELL EFFICIENCY

PERC cells are forecast to grow from the current level (roughly 4%) to a much larger percentage of the solar cell market. Overall, a solar cell's power output depends on how much light the cell reflects and on the energy level produced at a desired wavelength. By limiting recombination, PERC cells can provide an absolute efficiency boost of 1%, making their relative efficiency about 7% greater than the efficiency of other widely used screen printing methods.

The highest PERC cell efficiency is achieved when the trenches are completely filled with aluminum paste and contain no air pockets. Sonoscan Inc., the maker of C-SAM* (C-mode scanning acoustic microscope) tools, and the Photovoltaic Manufacturing Consortium are working together to determine the impact of incompletely filled trenches on power output. This article covers the early stages of this work—the nondestructive and destructive imaging performed to characterize the trenches. Electroluminescence images, acoustic images, and scanning electron micrographs were used in this research.

IMAGING RESULTS

The electroluminescence image of one corner of a PERC cell featuring channels for aluminum paste cut into the silicon is shown in Fig. 1. To produce this image, an electric current was applied to the cell and variations in light output across the cell were recorded. Dark regions indicate poor electrical output. Metal structures such as the horizontal structure have poor electrical output. The trenches themselves are not visible but numerous, smaller vertically oriented structures may be seen. These structures might indicate local variations in the condition of the aluminum paste that fills the trenches.

To learn more about these structures, the cell was imaged acoustically with a Sonoscan C-SAM tool. This tool takes advantage of the fact that the interface between two materials will reflect some portion of a VHF or UHF ultrasound pulse that strikes the interface. The tool's transducer scans just above the sample surface. Because the ultrasonic frequencies used by the transducer do not travel through air, a small jet maintains a column of water between the moving transducer and the sample surface at all times.

As it moves at speeds that may exceed 1 m/s, the transducer sends an ultrasound pulse into the cell. When it is moving through a homogeneous material, the pulse is absorbed to some degree, but the material sends back no echoes. However, when the pulse

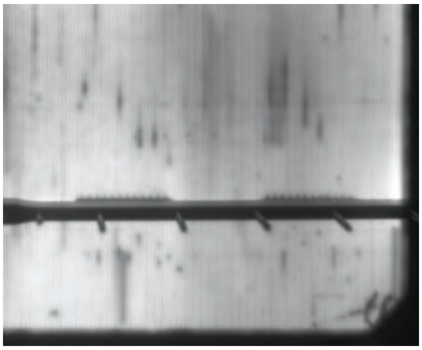


Fig. 1 — Electroluminescence imaging shows dark vertical lines that might be unfilled trenches.

encounters the interface between two materials, a portion is reflected back to the transducer as an echo signal, while another portion is transmitted across the interface and travels deeper into the sample, where it may encounter another interface and send back another echo signal. Any interface between a solid and air or another gas is an exception as at these interfaces, nearly all of the ultrasound is reflected as an echo signal. None is transmitted across the interface. The echo signal from a solid-to-air interface has the highest possible amplitude and therefore appears bright white in monochrome acoustic images. The color of solid-to-solid interfaces depends on the physical characteristics of the two materials at the interface, and ranges from light gray (high amplitude) to dark gray (low amplitude).

One region of the cell was acoustically imaged (Fig. 2). Four equally spaced trenches, all of which should be filled with aluminum paste, are marked by colored bars. Linear features parallel to the trenches are at a different depth and are not trenches.

The left trench marked by red bars is bright white, meaning that it is voided for the entire length shown here. During screen printing, the trench depth is not completely filled with aluminum paste.

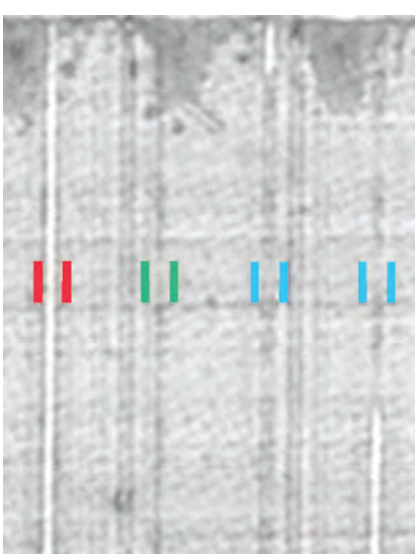


Fig. 2 — C-SAM imaging illustrates the difference between filled (dark) trenches and trenches that are partly or entirely unfilled (white).

The void that lies between the die and paste prevents electrical contact. The trench marked by green bars is dark—meaning it is completely filled. This is the desired condition that allows electrical contact between the silicon and aluminum paste. The two trenches marked by blue bars are partially filled and partially voided.

Throughout the cell, comparing the dark vertical features in the electroluminescence image in Fig. 1 to the trenches acoustically imaged in Fig. 2 reveals that only some of the acoustically visible voids also appear in the electroluminescence image. The cell was next sectioned through some of the trenches, and the trench cross-sections were viewed by a scanning electron microscope (SEM). Typical results are seen in Fig. 3.

In Fig. 3a, the rounded trench profile in the SEM image shows that the trench is completely filled by aluminum paste. Dark regions in the trenches in Fig. 2 would appear much like this in cross-section. In this figure, the aluminum layer bonded to the backside surface lies just above the trench. Electrical contact in this portion of this trench is acceptable.

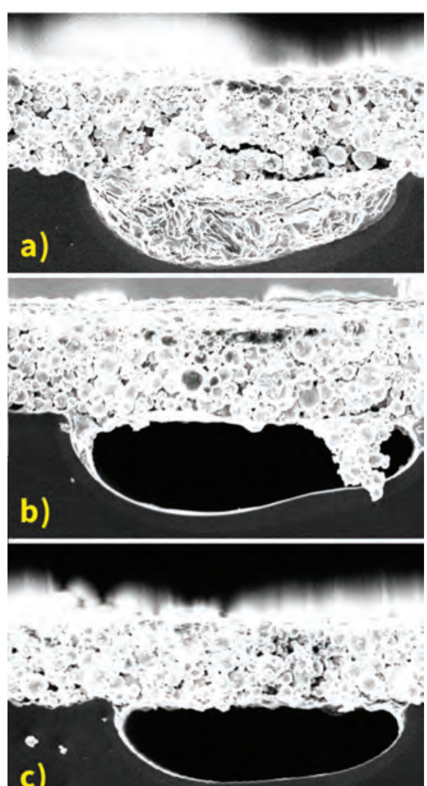


Fig. 3 — SEM images of cross sections through filled, partly filled, and unfilled trenches.

In Fig. 3b, the only area of the trench that has been filled is at the right. The efficiency of such a small fill is unknown, but it is likely to be limited. In Fig. 3c, the entire trench is voided and there is likely no electrical contact. In an acoustic image, this trench (along with that in 3b) would appear bright white.

CONCLUSION

Next steps in this research will include precise characterization of the relationship between the acoustic appearance of a trench and the degree of electrical contact between the aluminum paste and the solder. This information will permit better control over PERC production, maximize cell efficiency, and make it possible for PERC crystalline silicon solar cells to fulfill a prediction by the International Technology Roadmap for Photovoltaic that they will capture 45% of worldwide market share by 2024. **~AM&P**

For more information: Steve Martell is manager, advanced applications support, Sonoscan Inc., 2149 E. Pratt Blvd., Elk Grove Village, IL 60007, 847.437.6400, info@sonoscan.com, www.sonoscan.com.

*C-SAM is a registered trademark of Sonoscan Inc.

2016-2017 PRESIDENT OF ASM INTERNATIONAL

WILLIAM E. FRAZIER

Dale L. Moore, Director for Strategy and Innovation, Deputy Assistant Secretary of Defense for Research, Development, Test, and Evaluation, Washington

It is my honor and privilege to introduce ASM International's new president, Dr. William E. Frazier, FASM. Bill and I have known each other for over 25 years through our involvement in naval aviation research, development, acquisition, and support where he works as the Navy senior scientist for materials engineering as well as chief scientist of the air vehicle engineering department at the Naval Air Systems Command. Bill demonstrates a unique set of gifts and talents that have helped make the U.S. Navy and naval aviation what it is today—poised at the leading edge of technology and operating continuously in one of the harshest environments known to man.

Bill is driven by the pursuit of excellence and a sense of mission and purpose. He understands how to mentor and lead others to achieve new possibilities and greater heights of success. I like to think of Bill as a polymath who understands how complex systems and organizations work together, and how to make them the best they can be. He facilitates the creation of new knowledge and is a continuous learner who asks insightful questions that make people think—and rethink—the incredible possibilities before them. Bill has always been a great supporter of ASM and often takes the initiative to explore new possibilities and channels for creating value. His ability to both adeptly lead and manage to achieve real and meaningful results has always been his hallmark, but it is his care for people and wise council that make him who he is today.

BACKGROUND AND CAREER

Bill grew up poor in Philadelphia with his mother and brother, as his parents were separated. He learned the value of hard work at an early age, working long hours after high school. With the intent of studying pre-med, he earned a full scholarship to Temple University. After some soul searching, Bill

Janet and Bill Frazier on their wedding day.

BELIEFS AND VISION

Bill has outlined four beliefs that will guide his actions as president of ASM International. First, he believes that ASM is a society of professionals who do great things together that cannot be done individually. Second, ASM can provide maximum value to society and our profession by working at the intersection of design and engineering, manufacturing, and materials. Third, Bill believes that ASM's shared values of transparency, integrity, technical excellence, diversity, and constancy of purpose are the great enablers. And fourth, that ASM's future is bright and that we have numerous opportunities to contribute to our nation and our global society in meaningful and impactful ways that can literally change the world.

Bill understands that ASM is at a pivotal point in its trajectory. With the global expansion of knowledge now occurring at an unprecedented pace, we have a world full of new possibilities from the technical aspects of materials science and engineering to new and unique processes and applications, to the way that we synergize our efforts and collaborate for the greater good, to how we share and create new knowledge and innovation, and to the way that we apply that knowledge to ever-expanding applications. Both materials and manufacturing are entering a renaissance that will empower ASM to explore new domains of materials and manufacturing that were not on the radar just a few years ago. In our 103-year history, there has never been a more exciting time and a greater opportunity for leadership at ASM.

From left, Janet and Bill Frazier with their children, Laura King and Bill and Daniel Frazier.

married his high school sweetheart and the love of his life, Janet, and started working a variety of jobs that sparked his interest in materials—their properties, characteristics, and how to manufacture them. It was then that he decided to pursue an engineering degree at Philadelphia Community College and later transferred to Drexel University as a materials engineering major. Bill's life took on a new purpose as he had found his profession, his passion, and his community—which included ASM International.

Upon graduation in 1981, Bill went to work for the Naval Air Development Center (NADC) in Warminster, Pa. NADC is responsible for all the research and development activities that support naval aviation aircraft and systems. While there, he established a rapid solidification laboratory, powder processing facility, and transmission electron microscopy/x-ray diffraction capability. As he worked during the day to develop advanced materials for naval aviation, he continued his studies at Drexel to earn his M.S. and Ph.D. degrees in materials engineering in 1984 and 1987. He was then selected for the prestigious NAVAIR Senior Executive Leadership Development Program (SEMDP), which included a four-month residential advanced program management curriculum at the Defense Systems Management College. This move helped transform his adept technical and management skills into formidable, executive-level leadership skills.

Bill was then selected to be NAVAIR's first national competency leader for metals, ceramics, and nondestructive inspection. In this role, he was responsible for the end-to-end success of materials research, engineering, and support including over 60 scientists, engineers, and technicians located across six national sites. He also transitioned and established new advanced laboratory capabilities in the Becker Materials Laboratory at Patuxent River, Md., as part of the 1995 base realignment and closure transition of NADC to Southern Md. In this role, Bill led the aerospace materials division's quest to obtain dual certification in ISO 9001 and ISO/IEC Guide 25—a first in the federal government, setting a new bar of excellence for naval aviation and the Department of Defense.

In his capacity as national competency leader, Bill adeptly balanced and synergized a wide range of activities across the lifecycle and was responsible and accountable for safety and certification in these domains for all legacy, current, and future naval aviation platforms and systems. Bill led a number of "first time" efforts including AerMet 100 steel, which transformed naval aviation with high strength, corrosion-resistant landing gear and arrestment systems.

Bill was promoted in 2005 into the Navy's executive band as the Navy senior scientist for materials engineering where he serves as the chief scientist for NAVAIR's air vehicle engineering department. Based on his long record of achievements, accomplishments, and respect across the technical community, he was subsequently selected to be a NAVAIR Esteemed Fellow—an honor limited to 0.3% of NAVAIR's scientists and engineers. Bill has become a key strategic thought leader with significant influence on future naval aviation plans, and he has been the technical architect and driving force behind a number of critical strategic thrusts including: additive manufacturing; nanomaterials and metamaterials technology; durable aircraft materials and structures; corrosion-resistant alloy development; erosion-resistant rotor blade materials; and integrated structural health management.

Bill received the NAVAIR Esteemed Fellow Award from Vice Adm. David Dunaway in 2013.

Bill has authored over 90 publications, edited six books, and holds two U.S. patents. He was inducted as an ASM Fellow in 1996, and served as an ASM trustee from 2003-2007. He has also served on numerous committees including the AeroMat Committee and the Emerging Technologies Awareness Committee. Today, he continues to serve as associate editor for the *Journal of Materials Engineering and Performance* and is a key reader for *Metallurgical and Materials Transactions A.*

HIS PROMISE

Bill promises to do everything in his power to help lead ASM in pursuing these possibilities, reaching new heights of excellence, and achieving what has never been achieved to address both our most formidable challenges as well as our most enabling opportunities. His vision and promise include two major goals: ASM will be the number one provider of materials information in the form and manner that customers can most effectively and efficiently use no matter what field they work in or where they work; ASM will grow in membership, technical excellence, education, and strategic collaboration and partnerships.

Bill is passionate about leading ASM and is determined to see it thrive and contribute to our society in meaningful and profound ways. He thanks ASM for this humbling opportunity and will do all he can to make our 104th year the most productive and effective it can possibly be . **~AM&P**

THE DECLINE OF THE INTEGRATED STEEL INDUSTRY–PART II

THE U.S. STEEL INDUSTRY BEGAN ITS STEADY DECLINE IN THE LATE 1950s, A DEVASTATION OF EPIC PROPORTIONS THAT CONTINUED THROUGHOUT THE 1980s AND BEYOND.

During the recession of 1982, total steel production fell from 120 million tons to just 75 million in the span of one year, and imports accounted for 25% of the market for the first time. United States Steel Corp. (USS) operated at 36% of capacity and Bethlehem Steel lost $1.5 billion, with $900 million of that stemming from the cost of closing most of Lackawanna. Bethlehem finally closed the open hearth shop at Sparrows Point, Md., which they had built in 1958 as their hope for the future, a shop that had been obsolete for 20 years.

Between 1982 and 1987, Bethlehem lost another billion and cut its workforce in half, yet invested $2 billion in capital expenditures. In 1986, the company reduced staff at the research laboratory and sold five of its eight lab buildings to Lehigh University. A few years later, Bethlehem sold the remaining buildings to Lehigh, ending the grand attempt to restore the company through basic research results. Over time, the company also reduced staff at Martin Tower until the building was vacant by 2007. Today it is empty and contaminated with asbestos. By the end of the 1980s, Bethlehem found that it was hard to break the old culture with a board comprised of inside executives who continued to authorize projects that did not help restore profitability. By spreading new investments over many plants—most too inefficient to make a difference—instead of concentrating on the more modern Burns Harbor and Sparrows Point facilities, most of these efforts were wasted.

Demolition of three blast furnaces at the Ohio Works in Youngstown in 1984. Courtesy of urbanohio.com.

DEVASTATION IN PITTSBURGH

The 1980s hit the Monongahela River Valley near Pittsburgh especially hard. USS closed steelmaking at its Clairton Works in 1984, leaving only the coke making operations functional. That same year, USS also closed Duquesne Works. In 1986, it closed Homestead Works and sold Christy Park Works. In 1983, the company's Monroe Research Center had 3500 workers, but by 1991 head count was reduced to 500 and the facility later closed. The only remaining USS plants in Pittsburgh were the Edgar Thompson Works, the finishing plant at Irvin, and coke making at Clairton. In addition, plants owned by J&L were closed in 1985. Thus, Pittsburgh—the heart of the integrated steel industry for 100 years—was now a minor player in domestic steelmaking.

To offset the decline in steelmaking, USS bought Marathon Oil Co. in 1982. The company added to its oil holdings a few years later, purchasing Texas Oil and Gas Corp. In 1986, it renamed the parent company USX with USS as a subsidiary. These moves garnered a lot of criticism within the union and broader business world for using funds that could have gone into steel investments. However, Marathon Oil and Texas Oil and Gas earned profits over the next 20 years that supported the steel operations and provided funds to upgrade and purchase more efficient plants from bankrupt companies. USX divested its oil holdings in 2001 and changed its name back to USS.

OTHER WIDESPREAD CLOSURES

Republic Steel, the next casualty of the steel decline, was sold to LTV in 1984. LTV now owned three of the top "little steel" companies in the country whose history went back to 1900. With this heavy investment in companies in distress and no knowledge of the steel industry, LTV went bankrupt in 1986. After recovering from this bankruptcy, it went bankrupt several more times, finally closing all facilities in early 2000. Remaining assets were bought by Wilbur Ross, a fund manager who specialized in buying companies at bargain prices and attempting to revive them for resale. The devastation was especially damaging to Youngstown, Ohio. Quoting from UrbanOhio.com, "But it

"BUT IT WAS THE WILL OF MEN WHO CREATED YOU, YOUNGSTOWN, AND IT WAS THE WILL OF MEN WHO DESTROYED YOU. IN YOUNGSTOWN, WE MADE STEEL. AND YOU DIED TOO SOON."

Wilbur Ross, a turnaround specialist for bankrupt companies, and President-elect Donald Trump's choice for commerce secretary. Courtesy of Wikimedia Commons.

was the will of men who created you, Youngstown, and it was the will of men who destroyed you. In Youngstown, we made steel. And you died too soon."

USS closed its Fairless Works in 1991. That same year it also closed the Baytown, Texas, plant that was only 20 years old. From 1980 to 1998, production decreased from 17 million tons to 11 million and employees went from 150,000 to 20,000. By 1995, the remaining major operations of USS included the Edgar Thompson Works, Clairton coke plant, the Irvin finishing mill in Pittsburgh, the Gary Works, and its operation in Fairfield, Ala.

By 1982, Bethlehem had closed four of its plants—Bethlehem, Steelton, Johnstown, and Lackawanna—and lost over $1 billion, most of it in closing Lackawanna. Bethlehem had just 15,000 employees by 1999. However, imported steel was not the only factor in the decline of the integrated steel industry in the 1990s. Another was the inroads being made by the new minimill industry.

MINIMILLS AND MITTAL

The minimill industry that started making lower grade bars, angles, and reinforcing rods for concrete in 1970 had advanced to producing quality sheet and structural beams by the 1990s. This new industry was a major factor in Bethlehem's decline. The company's production decreased to nine million tons while Nucor, the minimill company, produced 10 million tons. After nearly 80 years, Bethlehem was no longer the second largest steel producer in the country.

National Steel Corp., one of the small steel companies that had been successful from its formation in 1929 until the 1980s, began to lose momentum as a result of poor management. The company filed for bankruptcy in 2002 and was bought by USS for $1 billion.

In 2001, Bethlehem suddenly demoted its chairman after only one and a half years in office and hired a turnaround specialist to run the company. He placed Bethlehem into bankruptcy and the company lost $1.9 billion that year. Out of the destruction, the remaining assets were purchased in bankruptcy court by Wilbur Ross and added to his holdings in International Steel Group (ISG). Bethlehem Steel—an icon of American industry that made everything from wire to armor plate to large forgings, built battle ships, aircraft carriers, cruisers, destroyers, landing ships, and freighters, as well as constructed the Empire State Building and Golden Gate Bridge—ceased to exist on May 2, 2002.

In the wake of this decline, Ross's holdings grew to include the LTV plants (the former J&L, YS&T, and Republic Steel) and the Burns Harbor and Sparrows Point Works of Bethlehem Steel. He improved operations by canceling the union contracts in bankruptcy and terminating thousands of employees. By reducing the labor force and revoking the benefits the union had won during the previous 50 years, these plants became profitable once again. Several years later, Ross sold ISG to Mittal Steel, a company whose largest shareholder was Lakshmi Mittal.

Lakshmi Mittal, chairman and CEO of ArcelorMittal. Courtesy of Wikimedia Commons.

ArcelorMittal headquarters in Luxembourg. Courtesy of Wikimedia Commons.

Mittal is an Indian company with worldwide holdings in steel production, headquartered in Luxembourg. It would later acquire Arcelor Steel, the largest steel company in Europe, and change the name to ArcelorMittal. With owership of the integrated mills from ISG, ArcelorMittal became the largest steel producer in the U.S. at 22 million tons capacity. It is also the largest steel producer in the world, with 100 million tons global capacity. After 100 years, the biggest integrated steel producer in the U.S. now has overseas ownership.

THE FATE OF THE WORKFORCE

The fate of Bethlehem along with Youngstown Sheet and Tube, J&L, Republic Steel, and many smaller integrated steel companies destroyed most of the remaining integrated steel companies in the U.S. These companies left tens of thousands of employees with no jobs, no health insurance, pension funds that had to be taken over by the federal government, abandoned plants, and cities such as Sparrows Point, Bethlehem, Johnstown, Pittsburgh, Lackawanna, Youngstown, Gary, and South Chicago losing up to half of their populations. The devastation was epic and the effects continue to ripple far into the future.

For more information: Charles R. Simcoe can be reached at crsimcoe1@gmail.com.

Discover what's possible through ASM Education.

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.

Course	Date	Location
Nitinol for Medical Devices	1/25-27	Santa Clara, CA
Heat Treating Furnaces and Equipment	2/9-10	ASM World Headquarters
Introduction to Metallurgical Lab Practices	2/13-15	ASM World Headquarters
Heat Treating for the Non-Heat Treater	2/21-23	North Charleston, SC
Science and Technology of Materials	2/21-23	ASM World Headquarters
How to Organize and Run a Failure Investigation	2/27-28	Foot Hill Ranch, CA

FOR MORE UPCOMING COURSES OR TO REGISTER, VISIT: www.asminternational.org/learning

QUESTIONS? CONTACT OUR EDUCATION SALES MANAGER AT: ravi.dodeja@asminternational.org

ASM INTERNATIONAL

AUTHORIZED IACET PROVIDER

ASMNEWS

PRESIDENT FRAZIER APPOINTS COMMITTEE COUNCIL CHAIRS


Apelian

Armstrong

Aurora

Bartolo

Battaile

Black

Bray

Chawla

Chong

Clauser

Druschitz

Durden

Forrest

Freed

Kodali

Lin

Mason

Morris

Prasad

Smith

Spangler

Taylor

Ulvan

Yue

ASM International President William E. Frazier, FASM, appointed a chair to each of the Society's general committees and councils. All appointments were unanimously approved by the Board of Trustees. Terms began September 1, 2016. Congratulations to all of our ASM International leaders!

Committee/Council chairs include:

Prof. Diran Apelian, FASM, Alcoa-Howmet Professor of Mechanical Engineering, Worcester Polytechnic Institute, was appointed chair of the Awards Policy Committee.

Ms. Beth Armstrong, staff scientist, Oak Ridge National Laboratory, was appointed chair of the Volunteerism Committee.

Mr. Premkumar Aurora, partner, Aurora Engineering Co., continues as chair of the India Council.

Prof. Laura Bartolo, CHiMaD data coordinator, Northwestern University, continues as chair of the Content Committee.

Dr. Corbett Battaile, principal member of technical staff, Sandia National Laboratories, continues as chair of the Materials Property Database Committee.

Dr. Amber Black, applications engineer, Precision Technologies Inc., continues as chair of the Emerging Technologies Awareness Committee.

Dr. Gary H. Bray, senior technical specialist, Alcoa, was appointed chair of the Aeromat Organizing Committee.

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

Dr. Dianne Chong, FASM, vice president, materials and process technology (retired), Boeing, was appointed chair of the Women in Materials Engineering Committee.

Mr. Craig Clauser, president, Craig Clauser Engineering, continues as treasurer and chair of the Finance Committee.

Dr. Alan P. Druschitz, associate professor, Virginia Tech, was appointed chair of the Handbook Committee.

Ms. Jessica Durden, materials application engineer, Rolls-Royce Corp., was appointed co-chair of the Emerging Professionals Committee.

Dr. David R. Forrest, FASM, technology manager, Department of Energy, was appointed chair of the ASM MS&T Programming Committee.

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

In This Issue

Submit news of ASM and its members, chapters, and affiliate societies to Frances Richards, editor, ASM News | ASM International
9639 Kinsman Road | Materials Park, OH 44073 | P 440.338.5151 ext. 5563 | F 440.338.4634 | E frances.richards@asminternational.org
Contact ASM International at 9639 Kinsman Road, Materials Park, OH 44073 | P 440.338.5151 ext. 0 or 800.336.5152 ext. 0 (toll free in U.S. and Canada) | F 440.338.4634 | E MemberServiceCenter@asminternational.org | W asminternational.org

Dr. Padma Kodali, engineering team leader, Caterpillar Inc., continues as chair of the Action in Education Committee.

Dr. Hua-Tay Lin, FASM, distinguished professor, Guangdong University of Technology, continues as chair of the Journal of Materials Engineering and Performance Committee.

Mr. Paul Mason, president, Thermo-Calc Software, continues as chair of the Alloy Phase Diagram Committee.

Mr. John D. Morris, polymer & composites engineer, Boeing, was appointed chair of the Chapter Council.

Dr. Somuri V. Prasad, FASM, principal member of technical staff, Sandia National Laboratories, was appointed chair of the AM&P Editorial Committee.

Dr. Mark F. Smith, FASM, deputy director, Materials Science and Engineering Center, Sandia National Laboratories, was appointed chair of the Investment Committee and the ASM Materials Education Foundation Investment Committee.

Ms. Madison Spangler, process safety management specialist, DCP Midstream, continues as co-chair of the Emerging Professionals Committee.

Dr. Douglas J. Taylor, R&D manager, Sandia National Laboratories, continues as chair of the Membership Committee.

Dr. Erhan Ulvan, technical manager, Acuren Group, continues as chair of the Canada Council.

Dr. Steve Yue, FASM, professor and chairman, McGill University, was appointed Chair of the Technical Books Committee.

ASM Seeks Vice President and Board of Trustees Nominations

ASM is seeking nominations for the position of vice president as well as three trustees. The Society's 2018 vice president and trustee elects will serve as a voice for the membership and will shape ASM's future through implementation of the ASM Strategic Plan.

Qualifications: Members must have a well-rounded understanding of the broad activities and objectives of ASM on a local, Society, and international level, and the issues and opportunities that ASM will face over the next few years. Further, they must also have a general appreciation for international trends in the engineered materials industry.

Duties: The duties of board members include various assignments between regular meetings. Trustees also assume the responsibility of making Chapter visits and serving as a board liaison to ASM's various committees and councils.

Guidelines: Nominees for vice president must have previously served on the ASM Board and those selected to serve as trustees should be capable of someday assuming the ASM presidency.

Deadline for nominations is **March 15.** For more information, visit asminternational.org/vp-board-nominations or contact Leslie Taylor, leslie.taylor@asminternational.org or 440.338.5151 ext. 5500.

Annual ASM Award Nominations due February 1

The deadline for the majority of ASM's awards is **February 1.** We are actively seeking nominations for all of these awards, a sampling of which is listed below:

- Edward DeMille Campbell Memorial Lectureship
- Distinguished Life Membership
- William Hunt Eisenman Award
- Gold Medal
- Silver Medal
- Bronze Medal
- Historical Landmarks
- Honorary Membership
- Medal for Advancement of Research
- Allan Ray Putnam Service Award
- Albert Sauveur Achievement Award
- Albert Easton White Distinguished Teacher Award
- J. Willard Gibbs Phase Equilibria Award

View forms, rules, and past recipients at asminternational.org/membership/awards/nominate. To nominate someone for any of these awards, contact christine.hoover@asminternational.org for a unique nomination link.

2017 Bradley Stoughton Award for Young Teachers

Winner receives $3000. Deadline is March 1. This award recognizes excellence in young teachers in the field of materials science, materials engineering, design, and processing.

Do you know a colleague who:

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

View forms, rules, and past recipients at asminternational.org/membership/awards/nominate. To nominate someone, contact christine.hoover@asminternational.org for a unique nomination link.

Gunnar Nils Eriksson Receives 2017 J. Willard Gibbs Phase Equilibria Award

ASM is pleased to announce that Dr. Gunnar Nils Eriksson, scientist, GTT Technologies, Germany, is the 2017 J. Willard Gibbs Phase Equilibria Award recipient. He is cited "for development of software for calculation of multicomponent, multiphase chemical equilibria and phase diagrams of various types, which promoted the application of computational thermodynamics in materials science and engineering."

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

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

Eriksson will receive his award at MS&T17, to be held in October in Pittsburgh.

DomesDay 2016—A Smashing Success

Ten teams from seven different schools came to MS&T16 to compete in the 3rd annual ASM Geodesic Dome Design Competition, DomesDay. Virginia Tech's VT 3D Print Team won first place with $1000. Coming in second was Virginia Tech's VT Metals team, winning $750. Third place, with $500, went to Aedificator from Arizona State University (ASU). Teams were judged based on an elevator speech, aesthetics, and mechanical strength, the last of which saw the dome being compression tested in front of a live audience on the convention floor. DomesDay was established in 2014 by the ASM Student Board Members. It is intended to familiarize Material Advantage students with a piece of ASM culture, the Dome, by involving them in a design and materials selection competition. For a full list of teams, photo gallery, and video, visit asminternational.org/students/domesday-competition. Special thanks to our sponsors, NSL Analytical and MTS.

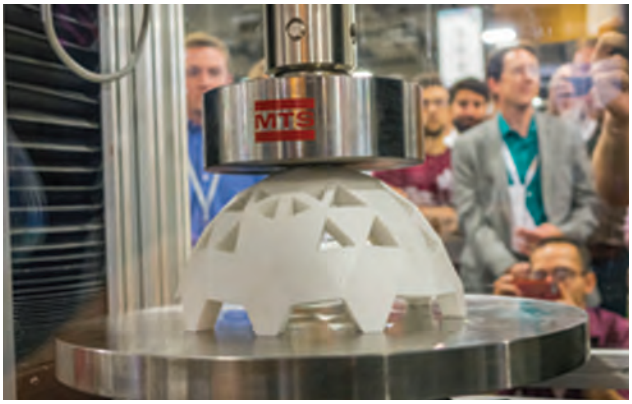
ASM Membership Fee Notice

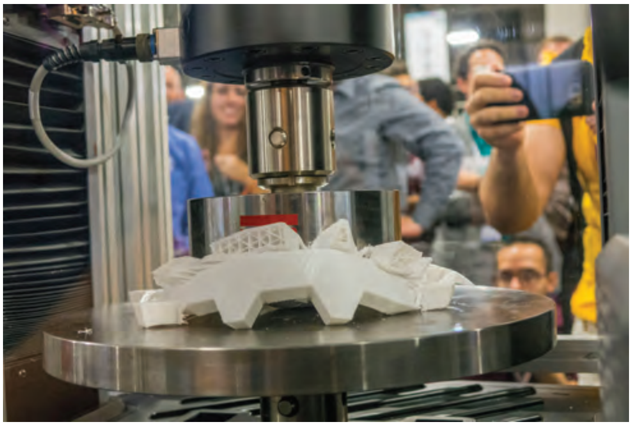
ASM International announces a slight increase in membership fees beginning January 1. First-year memberships will go from $117 to $122, subsequent years from $107 to $112, and multiple year renewals from $92 to $97 annually. When a member joins an affiliate organization as well, the affiliate will receive a rebate of $1 from the ASM membership fee. Members whose renewal notices were mailed prior to January 1 should pay the amount printed on their invoice.

ASM, FAS, HTS, IMS and TSS Seek Student Board Members

We're looking for Material Advantage student members to provide insights and ideas to the ASM, FAS, HTS, IMS, and TSS Boards. We are pleased to announce the continuation of our successful Student Board Member programs. Each Society values the input and participation of students and is looking for their insights and ideas.

- An opportunity like no other!
- All expenses to attend meetings paid for by the respective Society
- Take an active role in shaping the future of your professional Society
- Actively participate in your professional Society's board meetings
- Gain leadership skills to enhance your career
- Add a unique experience to your resume
- Represent Material Advantage and speak on behalf of students
- Work with leading professionals in the field





ASU's DomesDay entry before and after compression testing.

Opportunities specific to each Society:

ASM International

- Attend four board meetings (June 26-28, October 8-11 during MS&T17, March and June 2018)
- Term begins June 1

ASM Failure Analysis Society

- Attend two board meetings (fall 2017 and spring 2018)
- Participate in two teleconferences
- Term begins in September

ASM Heat Treating Society

- Attend two board meetings (October 23 during HTS Conference & Exposition and spring 2018)
- Participate in three teleconferences
- Term begins in September

ASM International Metallographic Society

- Attend one board meeting (October 2018)
- Participate in monthly teleconferences
- Term begins in August

ASM Thermal Spray Society

- Attend one board meeting in the second half of 2017
- Participate in two teleconferences
- Receive a one-year complimentary membership in Material Advantage
- Term begins in October

Application deadline is **April 1.** Visit asminternational.org/students/student-board-member-programs for complete form and rules.

ASM Thermal Spray Society Board Seeks Nominations

The terms of three ASM Thermal Spray Society (TSS) board members will expire in October, so the ASM TSS Nominating Committee is seeking nominations to fill these positions. In accordance with the TSS Rules for Governance, the Nominating Committee is seeking nominees for three directors from all segments of the thermal spray community. Nominees must be a member of the ASM Thermal Spray Society and must be endorsed by five TSS members. Board members whose terms are expiring may be eligible for nomination and possible reelection on an equal basis with any other nominee. Nominations must be received no later than **March 1.** A nomination form may be obtained via the ASM TSS website at tss.asminternational.org. For more information: Christian Moreau, ASM TSS Nominating Committee Chair, christian.moreau@concordia.ca.

Heat Treating Society Seeks Board Nominations

The HTS Awards and Nominations Committee is seeking nominations for three directors, a vice president, and a young professional board member. Candidates must be HTS members in good standing. Nominations should be made on the formal nomination form and can be submitted by a chapter, council, committee, HTS member, or an affiliate society. The HTS Nominating Committee may consider any HTS member, even those who have served on the HTS Board previously. **Nominations are due February 1.** For more information and the nomination form, visit the HTS website at hts.asminternational.org and click on Membership and Networking and then Board Nominations; or contact Joanne Miller at 440.338.5151 ext. 5513, joanne.miller@asminternational.org.

Failure Analysis Society Board Calls for Nominations

FAS is soliciting nominations for candidates for the FAS Board of Directors. Nominations are for one secretary (one-year term), one treasurer (one-year term), two board positions (three-year term), and one emerging professional (one-year term), beginning September 1. Any member of FAS in good standing is encouraged to nominate themselves or another member for one of these positions. Nomination packages are due **March 1.** Candidates are asked to provide a three-page nomination package to include the candidate's:

- Academic/business biography
- Failure analysis background
- FAS and ASM involvement
- Vision for the future of FAS
- Photograph and contact information
- Confirmation of employer's support

Nomination packages should be sent to Sarina Pastoric at sarina.pastoric@asminternational.org. For more information, call 440.338.5151 ext. 5541.

Emerging professionals are asked to submit an application. For application details, visit asminternational.org/web/fas and click on Membership and Networking and then Board Nominations.

Service on the FAS Board of Directors involves planning and driving the future strategy of your Society. The Board of Directors meets in person twice a year and conducts two teleconferences. Board members also provide liaison support to the several FAS Committees, which may involve additional conference calls. Candidates are encouraged to ensure they have their employer's support for this activity.

HTS AWARD DEADLINES

Nominations Sought for George H. Bodeen Heat Treating Achievement Award

ASM's Heat Treating Society (HTS) is currently seeking nominations for the George H. Bodeen Heat Treating Achievement Award, which recognizes distinguished and significant contributions to the field of heat treating through leadership, management, or engineering development of substantial commercial impact. Deadline for nominations is **February 1.**

ASM HTS/Bodycote 'Best Paper in Heat Treating' Contest

The ASM Heat Treating Society established the Best Paper in Heat Treating Award in 1997 to recognize a paper that represents advancement in heat treating technology, promotes heat treating in a substantial way, or represents a clear advantage in managing the business of heat treating. The award, endowed by **Bodycote Thermal Process-North America,** is open to all full-time or part-time students enrolled at universities (or their equivalent) or colleges. The winner will receive a plaque and a check for $2500. Deadline is **March 1.**

ASM HTS/Surface Combustion Emerging Leader Award

The ASM HTS/Surface Combustion Emerging Leader Award was established in 2013 to recognize an outstanding early-to-midcareer heat treating professional whose accomplishments exhibit exceptional achievements in the heat treating industry. The award, endowed by **Surface Combustion,** includes a check for $4000. The winning young professional will best exemplify the ethics, education, ingenuity and future leadership of our industry. Deadline for nominations is **April 1.**

For nomination rules and forms for all three awards, visit the Heat Treating Society website at hts.asminternational.org and click on Membership and Networking and then Society Awards. For more information or to submit a nomination, contact Joanne Miller at 440.338.5151 ext. 5513, joanne.miller@asminternational.org.

SEEKING NOMINATIONS FOR NEW EDFAS AWARDS

The Electronic Device Failure Analysis Society (EDFAS) is pleased to announce two new awards to recognize the accomplishments of its members. The awards will be given annually, with the inaugural EDFAS Lifetime Achievement Award and the EDFAS President's Award to be presented at ISTFA 2017. Nominate a worthy colleague today!

EDFAS Lifetime Achievement Award

The EDFAS Lifetime Achievement Award was established by the EDFAS Board of Directors in 2015 to recognize leaders in the EDFAS community who have devoted their time, knowledge, and abilities toward the advancement of the electronic device failure analysis industry.

EDFAS President's Award

The EDFAS President's Award recognizes exceptional service to EDFAS and the electronic device failure analysis community. Examples of such service include committee service, service on the Board of Directors, organization of conferences or symposia, development of education courses, and student and general public outreach. While any member of EDFAS is expected to further the Society's goals through service, this award recognizes those who provide an exceptional amount of effort in their service to the Society.

For complete rules and nomination forms for both awards, visit the EDFAS website at edfas.org, click on Membership and Networking and then Society Awards; or contact Joanne Miller at 440.338.5151 ext. 5513, joanne.miller@asminternational.org. Nomination deadline is **March 1.**

HIGHLIGHTS FROM THE FOUNDATION

FROM THE FOUNDATION


Apelian

Another year brings a new opportunity for us to share our excitement for materials science. In my role as chairman of the board of the ASM Materials Education Foundation, I know we must reach and promote the next crop of materials science engineers—they are the pipeline of students who will advance our industry's future. Luckily we are the best people to fulfill our mission and vision. Our upcoming initiatives emphasize the hands-on, discovery-based learning that will inspire the next generation to become a workforce skilled in science, technology, engineering, and math.

Starting with a materials-based, hands-on lesson plan for the youngest students in grades K through 6 and advancing through in-classroom and after-school middle school programs, our initiative builds on current curricula and expands as students dig deeper into how things work. Enhancing our online presence, we plan YouTube-based programs that offer "fun science demos" for younger students and include a channel for older students and teachers that connects new materials science trends with current curriculum.

Lastly, our innovative Student and Teacher Materials Camps (graduating approximately 13,000 students and 9000 teachers so far) brings it all together. As a professor at Worcester Polytechnic Institute, I see how hands-on learning inspires students every day. When students are engaged, the possibilities are truly thrilling. Students and teachers leave the camps with greater curiosity and a passion to discover more. Learning occurs best when it's joyous—the materials science camps allow us to share our own excitement and are an opportunity to give back. By offering your time, energy, and expertise, you advance our mission and make a real impact on society. I am inspired by the quote, "We make a living by what we get, but we make a life by what we give." Spend a few hours or a day with our campers at one of the two dozen nationwide camps. You'll be impressed anew by the potential materials science engineering holds. For more information, visit asminternational.org/foundation.

Diran Apelian

Chairman, ASM Materials Education Foundation

WOMEN IN ENGINEERING

*This new profile series introduces leading materials scientists from around the world who happen to be females. Here we speak with **Sarah Straub,** materials contact engineer for ExxonMobil Chemical.*


Straub

What does your typical workday look like?

As a materials engineer at one of the largest manufacturing complexes in the world, every day is busy. I provide materials support for refining and chemicals processing, which includes failure analysis, materials selection, and risk assessments. I also have the opportunity to participate in site and global initiatives to improve safety and reliability.

What part of your job do you like most?

Every day I am fulfilled in my work by knowing that I have a direct influence on the safety and reliability of my site. Having the opportunity to work with passionate and smart people who are working toward the same goals is inspiring.

What is your engineering background?

I have a Bachelor of Science in materials engineering and a minor in management from Rensselaer Polytechnic Institute. My concentration was in electrochemistry and corrosion, which applies directly to my current job.

What attracted you to engineering?

Although I had always been a problem solver, I thought engineering was boring when I was young. It wasn't until I was in high school that I even considered pursuing a STEM education. My father, who is a civil engineer, offered to bring me to an engineering outreach program for female high school students. Following a day of presentations, design challenges, and career discussions, I knew engineering would be a good fit. Fortunately, there were some metallurgists that attended this event so I was aware of the discipline early on. Attending my first materials class was like "love at first sight."

If a young person approached you for career advice about pursuing engineering, what would you tell them?

Engineers are problem solvers, communicators, and collaborators. Anyone with these characteristics has the potential to be a great engineer.

Hobbies?

Traveling, playing tennis, and watching hockey.

Last book read?

"The Fire Starter Sessions" by Danielle LaPorte.

Would you like to be featured in an upcoming Women in Engineering profile? Contact Vicki Burt at vicki.burt@asminternational.org.

SALT LAKE CITY HOSTS MS&T16: PHOTO GALLERY OF CONFERENCE HIGHLIGHTS

2016-2017 ASM Materials Education Foundation Board of Trustees.

Julie Christodoulou, FASM, presents the ASM/TMS Joint Distinguished Lecture in Materials and Society during the plenary session.

Attendees enjoyed the opening plenary session, which included a talk on the fatigue performance of steel presented by David Matlock, FASM, from Colorado School of Mines.

Diran Apelian, FASM, right, and 2016 Undergraduate Design Competition winners from California State Polytechnic University, Pomona.

Participants network at the ASM Women in Materials Engineering breakfast.

HIGHLIGHTS MS&T16

The ASM Edward DeMille Campbell Memorial Lecture was presented by A. Lindsay Greer of the University of Cambridge.

On left, Medal for the Advancement of Research winner Bhakta B. Rath, FASM.

2016-2017 ASM Board of Trustees.

Albert Sauveur Achievement Award winner Raj N. Singh, FASM, left, and family.

Virginia Tech's VT 3D Print Team won first place in the third annual ASM Geodesic Dome Design Competition.

MS&T16 HIGHLIGHTS

QuesTek leaders Aziz Asphahani, left, and Greg Olson, right, congratulate Ursula Kattner on winning the J. Willard Gibbs Phase Equilibria Award, endowed by QuesTek Innovations LLC.

Jennifer Carter receives the Bradley Stoughton Award for Young Teachers from Jon Tirpak, ASM immediate past president.

2016 Class of ASM Fellows.

Representatives from Oak Ridge National Laboratory accept the Engineering Materials Achievement Award.

Margaret Flury receives the Bronze Medal Award from Jon Tirpak, ASM immediate past president.

CHAPTERS IN THE NEWS

India Chapters Going Strong

ASM's India Chapters are poised to support a national initiative known as "Make In India!" In Mumbai this past October, commitment by the Indian government and industry was galvanized at an international conference with the theme of "emerging materials and processes for defense and infrastructure." This three-day event featured Shri Manohar Parrikar, Minister of Defense; Shri Narendra Singh Tomar, Minister of Steel and Mines; Dr. K. Sivan, director, Vikram Sarabhai Space Center; and Jon Tirpak, ASM immediate past president. The event was supported by ASM members including Pradeep Goyal, Premkumar Aurora, Suhas Sabnis, and Ashok Tiwari.

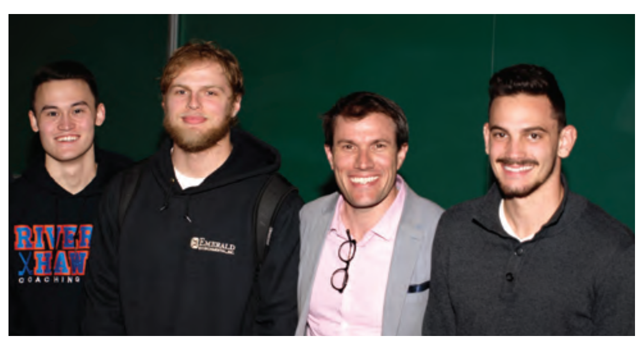
Chapters in Mumbai, Pune, Chennai, Bangalore, and Gujarat are actively pursuing programs and supporting members, enabling India to reach its objective of designing and building world class systems for cars, trains, ships, military systems, space systems, and more. With a strong turnout of representatives at the India Council meeting held in Mumbai, Tirpak unveiled a new ASM form of recognition—The President's Award. The first to receive this recognition was Premkumar Aurora for his years of unwavering service to ASM. The second plaque was presented to Nirav Jamnapara of the Gujarat Chapter. At Pune, Chennai, and Bangalore, plaques were presented to Prabhakar G. Renavikar, N. Sampathkumar, and R. Raghavendra Bhat, respectively.

The India Council meeting was well attended, including participation by three ASM past presidents Ravi Ravindran, Jon Tirpak, and Christopher Berndt.

ASM's Chennai Chapter hosts Jon Tirpak, immediate past president.

Northwestern PA Celebrates Student Night

Christopher Bettinger, associate professor at Carnegie Mellon University (CMU), spoke about *Edible Electronics: Materials & Structures for Ingestible Medical Devices* at the Northwestern PA Chapter's student night at Gannon University. Bettinger directs CMU's laboratory for biomaterials-based microsystems and electronics. The event was well attended by many students from the university.



From left, Brandon Lee, Adam Archacki, Dr. Christopher Bettinger, and James Mardula. The students are all studying biomedical engineering at Gannon University.

MEMBERS IN THE NEWS

Smith Celebrates 100th Birthday

Raymond L. Smith, FASM, celebrates his 100 year mark this month and ASM wishes him a happy and healthy year ahead. Born in 1917, Smith is ASM's oldest member and oldest past president, serving as our Society's leader in 1980. He became a Fellow in 1972 and received Honorary Membership in 1984. Smith retired as president of Michigan Technological University in 1979, after serving in this role for 16 years. He received his B.S. and M.S. degrees in mining engineering from the University of Alaska and earned his Ph.D in metallurgical engineering from the University of Pennsylvania. Smith has written extensively on the history of gold and was the invited keynote speaker at the 100th anniversary of the Klondike gold discovery in Alaska in 1897. Among his post-retirement activities, he has been involved in finding and recording the location of abandoned mines in and for the state of Arizona. Happy birthday, Ray!

Rao Receives Platinum Medal Award

K. Bhanu Sankara Rao, FASM, Ministry of Steel chair professor (Government of India) at Mahatma Gandhi Institute of Technology, Hyderabad, received the Platinum Medal Award from the Indian Institute of Metals for his outstanding contributions to the metallurgical profession, research and academia, and the Indian Institute of Metals. The award ceremony took place at the National Metallurgists Day celebrations held at the Indian Institute of Technology, Kanpur, on November 14, 2016.

Liu Selected for 2018 William Hume-Rothery Award

Zi-Kui Liu, FASM, was chosen by The Minerals, Metals & Materials Society to receive the 2018 William Hume-Rothery Award, established in 1972 to honor a great pioneer in alloy phases. The award presenation will take place at the TMS-AIMI annual meeting, to be held in Phoenix in March 2018.

Johnson Named Fellow of National Academy of Inventors

William L. Johnson, FASM, a professor at Caltech, was named a fellow of the National Academy of Inventors (NAI), which honors "academic inventors who have demonstrated a prolific spirit of innovation in creating or facilitating outstanding inventions that have made a tangible impact on quality of life, economic development, and the welfare of society." Johnson's research includes pioneering work with metallic materials such as bulk metallic glasses, noncrystalline metals with an amorphous atomic structure, and unusual engineering properties.

Rosei Elected to World Academy of Art and Science

Federico Rosei, FASM, director of the INRS Énergie Matériaux Télécommunications Research Center, has been elected a member of the World Academy of Art and Science for outstanding contributions to scientific research and technological innovation in the synthesis and characterization of multifunctional materials and their integration in devices. He is the first INRS professor to join this prestigious academy, which includes numerous Nobel laureates.

IN MEMORIAM

Edward L. Langer, Jr., FASM, 80, passed away on November 11, 2016. He was born in East Cleveland and earned his B.S. and M.A. degrees from John Carroll University and Kent State University, respectively. He was a teacher, coach, and administrator at St. Joseph's High School, Euclid High School, John Carroll University, and Kent State University, before beginning a 30-year career at ASM International, the last 12 as ASM's third managing director. Langer joined ASM in 1967 as coordinator of career development. He was then named director of chapter and member relations in 1969, director of service development and marketing in 1971, and planning director in 1974. He became assistant managing director in 1975, deputy managing director in 1980, and managing director in 1984. Langer also provided volunteer leadership to numerous civic and professional organizations including the Greater Cleveland Convention & Visitors Bureau, American Society of Association Executives, and The Council of Engineering & Scientific Society Executives.

Ralph Charles Daehn, Jr., FASM, died on November 9, 2016, at age 83. Born in 1933 in Oak Park, Ill., he served in the U.S. Army in Pine Bluff, Ark. He earned a bachelor's degree in mechanical and metallurgical engineering from the Illinois Institute of Technology and a master's in materials science and engineering from Northwestern University. His career included engineering positions at Danly Press Co., Continental Can Co., and Packer Engineering. At age 55, he started his own engineering consulting company, Materials Engineering Inc., Virgil, Ill., which remains successful today. In semi-retirement, he was active in consulting and worked for DS Containers in Batavia, Ill. Daehn was very active in ASM's Chicago Chapter, and received the Allan Ray Putnam Service Award in 2010.

ADVANCED MATERIALS & PROCESSES EDITORIAL PREVIEW

FEBRUARY 2017

Microscopy & Metallography

Highlighting:

- Grain Size Distributions
- Jacquet-Lucas Award Winner
- Advanced Imaging Techniques

Special Supplement:

International Thermal Spray and Surface Engineering newsletter covering coatings in the aerospace and defense industries.

Bonus Distribution:

M&M 2016 + IMS Annual Meeting
August 6-10, St. Louis, Mo.

Advertising closes January 5

March 2017

Aerospace Materials & Applications

Highlighting:

- Specialty Metals and Composites
- Additive Manufacturing Standards
- AeroMat Show Preview

Special Supplement:

HTPro newsletter covering thermal processing in the aerospace industry.

Bonus Distribution:

AeroMat 2017
April 10-13, Charleston, S.C.

Advertising closes February 6

Subscriptions/Customer Service:
800.336.5152 ext. 0
MemberServiceCenter@asminternational.org

Sales Staff:
***AM&P/iTSSe*/ASM Web Media**
Erik Klingerman, *National Sales Manager*
440.338.5151 ext. 5574
erik.klingerman@asminternational.org

Affiliate Sponsorships
Kelly Thomas, CEM.CMP, *National Account Manager*
440.338.1733
kelly.thomas@asminternational.org

AD INDEX

Advertiser	Page
Ipsen	5, 17
LECO Corp.	15
Master Bond Inc.	28
MTS Systems Corp.	IFC
NSL Analytical Services Inc.	IBC
Shimadzu Scientific Instruments Inc., Subs. Shimadzu Corp.	11, 24
Thermo-Calc Software AB	BC
Westmoreland Mechanical Testing & Research Inc.	49

The ad index is published as a service. Every care is taken to make it accurate, but *Advanced Materials & Processes* assumes no responsibility for errors or omissions.

STRESS RELIEF

This eye-catching bike path is not only effective, but also improves safety after dark. Courtesy of Strabag.

SOLAR BIKE PATH LIGHTS THE WAY

Urban planners in the Polish town of Lidzbark Warminski are testing a novel concept—a solar-charged bike lane. The luminescent path reflects the accumulated sunlight from the day and glows in the dark for more than 10 hours come sundown. At a cost of roughly $31,000, the new lane is about 6 ft wide and 330 ft long. The path is the brainchild of TPA Instytut Badan Technicznych and installed by Strabag, both European firms that specialize in creating and integrating innovative technology. Glowing blue phosphors were chosen as construction materials to be consistent with the local landscape. *tpaqi.com, strabag.com.*

STONE BALLS MAKE HANDY TOOLS

Scientists once thought spherical stones found in South Africa were used as tools, but new evidence indicates they were also weapons for defense and hunting. The research combines knowledge about how modern humans perceive an object's throwing affordance with mathematical analysis and evaluation of these stones as projectiles.

"Our study suggests that the throwing of stones played a key role in the evolution of hunting," says Geoffrey Bingham, professor in the psychological and brain sciences department at the Indiana University Bloomington. "We don't think that throwing is the sole, or even primary, function of these spheroids, but these results show that this function is an option that warrants reconsidering as a potential use for this long-lived, multipurpose tool."

The use of these stones, which date from between 1.8 million and 70,000 years ago, has puzzled archaeologists since they were unearthed at the Cave of Hearths in South Africa's Makapan Valley nearly 30 years ago. Researchers used computational models to analyze 55 ball-shaped stone objects from the South African site, finding that 81% are the optimal size, weight, and shape for hitting a target at a 25-m (82-ft) distance. The team also simulated the projectile motions the spheroids would undergo if thrown by an expert, as well as estimated the probability of these projectiles causing damage to a medium-size prey such as an impala. *For more information: Geoffrey Bingham, gbingham@indiana.edu, www.indiana.edu.*

Ball-shaped stone object from South Africa. Courtesy of Judy Maguire.

Yui Matusmoto, 4, plays with Edwin the Duck at his home in Tokyo. Courtesy of Yuri Kageyama.

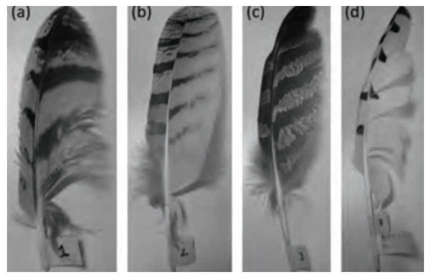
RUBBER DUCKY ENTERS DIGITAL ERA

Billed as the world's first smart duck, Edwin the Duck from Pi-Lab is yellow, cute, and waterproof, just like the traditional rubber ducky floating in many bathtubs. The difference is Edwin also reads and plays music. And he quacks rather than squeaks due to internal electronics. In addition, motion sensors turn Edwin into a game controller and he can even tell a story or play a song through the use of a free iPhone or Android app. Further, as a child moves Edwin up and down, an animated Edwin on the app swims or flies, or selects a response in a game or quiz. Tap on Edwin's wing and a light in his head turns him into a nightlight—but one that can also tell a bedtime story or play a lullaby. *edwintheduck.com.*

3D PRINTSHOP

THE SOUND OF SILENCE

Inspired by feathers that suppress flight sound, researchers developed a 3D-printed plastic attachment that can be retrofitted to an existing airfoil design to reduce wind turbine noise. The scientists—from Lehigh University, Virginia Tech, Florida Atlantic University, and the University of Cambridge—modeled their device on down from owl wings. The down consists of hairs that rise almost perpendicular to the feather surface, then bend in the flow direction to form a canopy at the top like a microscopic forest. The canopy pushes off the noisy air flow, suppressing frequencies over 1.6 kHz—including the range of greatest sensitivity in human hearing. To mimic this structure, the device consists of small "finlets," which can reduce turbine noise by 10 dB without affecting aerodynamics. This kind of noise reduction has implications beyond wind turbines and aircraft, and could be applied to other aerodynamic situations such as wind noise in automobiles. *lehigh.edu, vt.edu, fau.edu, www.cam.ac.uk.*



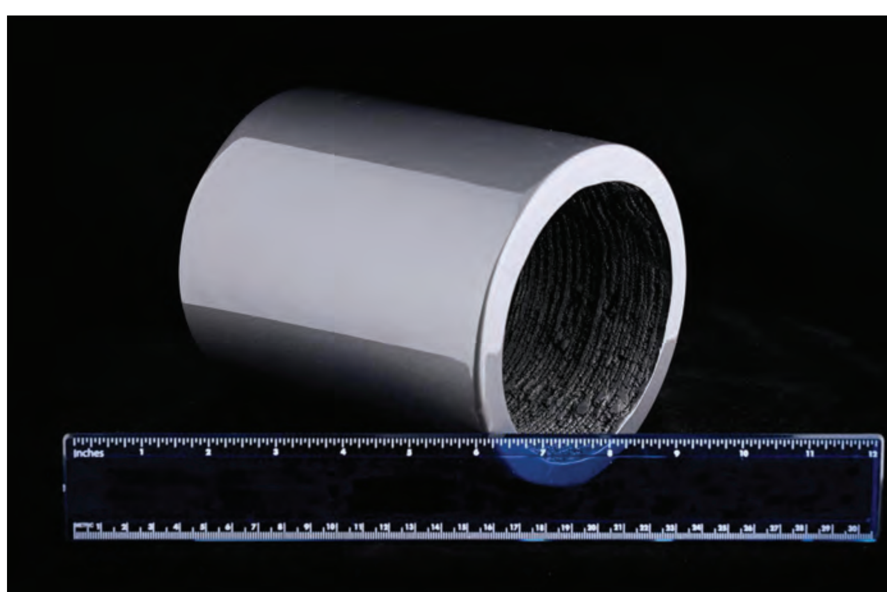
Feathers from (a, b) Eurasian eagle owl, (c) great gray owl, and (d) snowy owl. Courtesy of Ian A. Clark, et al.

GE INITIATIVE ADDS ON

GE, Fairfield, Conn., will purchase controlling shares of Arcam AB, Sweden, inventor of electron beam melting machines for metal-based additive manufacturing and a producer of metal powders for the aerospace and orthopedic industries. Arcam also operates AP&C, Canada, a metal powders operation, and DiSanto Technology, Shelton, Conn., a medical additive manufacturing (AM) firm, in addition to sales and application sites worldwide. The purchase comes on the heels of GE's $599 million acquisition of a 75% stake in Concept Laser GmbH, Germany, which designs and manufactures powder bed-base laser AM machines for the aerospace, medical, and automotive industries, among others. Concept Laser processes powder materials including titanium, nickel-base, and cobalt-chromium alloys, as well as hot-work and high-grade steels and aluminum. The recent acquisitions dovetail with GE's ongoing AM efforts, which include a $1.5 billion investment in manufacturing and additive technologies at their Global Research Center and the development of a worldwide network of centers for advancing AM science. *geadditive.com.*

PRINTING PREVAILS IN MAGNET MANUFACTURE

Scientists at the DOE's Oak Ridge National Laboratory (ORNL), Tenn., demonstrated that additive manufacturing (AM) can produce permanent magnets with mechanical, microstructural, and magnetic properties superior to those of bonded magnets made using traditional methods—all while conserving critical materials. To fabricate the isotropic, near-net-shape, neodymium-iron-boron bonded magnets, the Oak Ridge team began with composite pellets made of 65 vol% isotropic NdFeB powder and 35% polyamide (Nylon-12), then melted, compounded, and extruded them using the Big Area Additive Manufacturing machine. While conventional sintered magnet manufacturing can result in material waste of 30-50%, AM reuses that material, producing nearly zero waste, an especially important factor when manufacturing magnets with neodymium and dysprosium—rare earth elements mined and separated outside the U.S. AM is also more efficient than traditional injection methods. "Manufacturing is changing rapidly, and a customer may need 50 different designs for the magnets they want to use," explains researcher Ling Li. AM allows each magnet to be crafted quickly using computer-assisted design instead of requiring individual mold making and tooling. *ornl.gov.*



This isotropic, NdFeB bonded permanent magnet was 3D-printed at ORNL.