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JUNE 2014 • VOL 172, NO 6

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Composites Testing/Characterization

INCLUDED IN THIS ISSUE

- Dynamic Testing of Composites
- Using Composites to Fight Corrosion
- Composites Testing for Automotive Lightweighting

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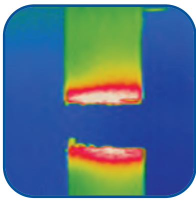
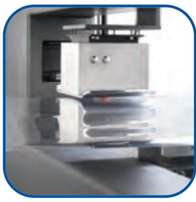
ON THE COVER:
Final assembly of the BMW i3 electric vehicle at the Leipzig, Germany, plant. The i3 features a passenger cell comprised entirely of carbon fiber-based composites. The drive module is aluminum and must be joined to the passenger cell using specialized adhesives. Courtesy of BMW AG and Zwick/Roell, Ulm, Germany. zwick.com.

contents





DEPARTMENTS

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materials witness

A celebration of science and life

Richard Fields (at NIST from 1977-2004) with Frances Richards and NIST's ASM Historical Landmark designation.

As I write this column, I'm sitting in the airport one day after NIST's 100th anniversary celebration of its metallurgy division and 50th year of its polymers program. Longtime NISTers Bob Shull and Chad Snyder spent several months pulling together amazing speakers and entertainment to commemorate a century of materials science advances at the National Bureau of Standards (NBS), which became the National Institute of Science and Technology (NIST) in 1988. The festivities were full of interesting and funny stories, tales of technology advances, and an optimistic look toward the future of materials science and engineering (MS&E).

Looking back with a nod to the past, associate director for laboratory programs Willie May—with 43 years under his belt at NIST—kicked off the celebration with a warm welcome and a bit of history from 1901, when NBS was first established. Eric Lin, MS&E division chief, then thanked the sponsors (including a shout-out to ASM) and talked about NIST's dedication to public service, technical excellence, and an open and dynamic working environment.

Lin turned things over to Isaac Sanchez, a fixture in the polymers division during the 1970s and 80s, who shared a few good stories plus some tidbits of advice that helped shape his life. One gem he kept in mind throughout his career involved Ed DiMarzio, his original NIST advisor. DiMarzio said you don't need hundreds of great ideas to build a career, only two or three good ones per year. Sanchez admitted that, in reality, he's only had about one good idea each year, but this has sustained him throughout a long and interesting career.

In the next lecture, Richard Fields spoke about several disaster investigations NIST has been involved with from the early days to recent times. He shared how tragedies drove the creation of the metallurgy division: From 1902 to 1912, 41,578 train derailments occurred, with roughly 13,000 deaths each year. The division was established in 1913 to improve train safety, which translated to improvements in steelmaking. This knowledge was then transferred to shipbuilding, with technologies such as welded construction vs. rivets. Fields also spoke about bridge collapses, airline accidents, and the Twin Towers investigation, and how such tragedies can lead to new standards and technologies.

Next up, several other interesting speakers rounded out the day, followed by a lively reception catered by Dogfish Head Alehouse. The best part besides tasty craft beer and pork sliders? NIST director Pat Gallagher presented a gift to renowned materials scientist John Cahn. You could have heard a pin drop when Cahn spoke. He recalled that before he came to NIST, he was a "tired 49-year-old professor" with no time for his own research, as he spent all his hours helping students write grant proposals. His wife accepted a job with the Carter Administration and was headed to D.C. At that point, Cahn was faced with either a commuter marriage or looking for a new position, so he called some NIST contacts and landed a position there. It gave him a new lease on life, and he expressed his gratitude for a hugely rewarding second career. The takeaway? You never know what's just around the corner.

F. Richards

frances.richards@asminternational.org

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

Frances Richards, *Senior Editor*
frances.richards@asminternational.org

Julie Kalista, *Editor*
julie.kalista@asminternational.org

Barbara L. Brody, *Art Director*

Joanne Miller, *Production Manager; Editor, ASM News*
joanne.miller@asminternational.org

Press Release Editor
magazines@asminternational.org


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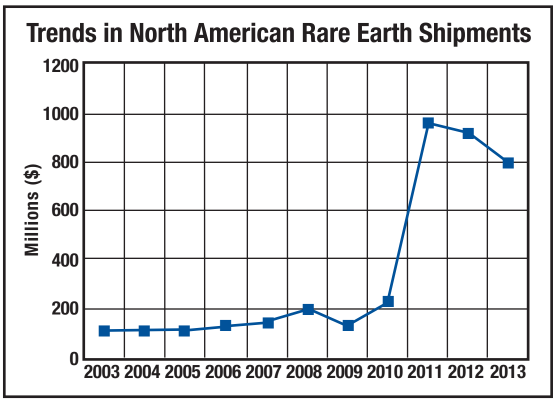
Free report explores economic impact of rare earth industry

Rare earth products are essential ingredients in magnets and magnetic powders, catalysts, metallurgical additives, polishing powders, phosphors, glass additives, ceramics and other engineered rare earth materials, as well as batteries, motors and generators, lasers, drives, sensors, and other components and systems used in a variety of industries. In turn, these products are used in health care, clean energy, automotive, lighting, communications, audio equipment, defense, electronics, advanced optics, oil refining, and many other sectors.

In a first-of-its-kind analysis, the Rare Earth Technology Alliance and the American Chemistry Council recently released a free report that takes an in-depth look at the economic impact of rare earths. *The Economic Benefits of the North American Rare Earths Industry* analyzes the economic footprint of the rare earth industry in terms of its direct, indirect, and induced effects as measured by output, payrolls, jobs, and tax revenue. Some highlights include:

- The rare earth industry directly contributes to the North American economy with $795 million in shipments, employing nearly 1050 workers with a payroll of $116 million.
- Adding other upstream impacts to its direct impact, the industry generates a total of $1.9 billion in economic output in North America.

The industry supports $329.6 billion in economic output in downstream end-market products and technologies that employ 618,800 workers (with a combined payroll of $37.6 billion) in the U.S. and Canada.



Based on data from the Census Bureau, U.S. Geological Survey, and Statistics Canada, North American shipments of rare earth materials were $795 million in 2013. This includes both mining and manufacturing of basic rare earth materials. Source: Rare Earth Technology Alliance.

In the report, *rare earth* is used as a generic term for the 15 lanthanides of the periodic table as well as scandium and yttrium. Rare earths were discovered in 1787 by Karl Axel Arrhenius, an officer in the Swedish army, when he gathered the black mineral ytterbite (later renamed gadolinite) from a feldspar and quartz mine adjacent to the hamlet of Ytterby, Sweden. Due to similarity in the elements and the fact that they occur in nature as a group, or subgroup, without separation by natural forces, rare earth elements are not easily isolated. The first commercial applications for rare earths arose during the 1880s with the introduction of the Welsbach incandescent lamp, which initially required the oxides of zirconium, lanthanum, and yttrium. By 1900, rare earths found other applications in lighting. Over the past 110 years or so, the use of rare earths has grown from a few hundred metric tons to more than 80,000 tons consumed annually. *For more information, visit rareearthtechalliance.com.*

feedback

Holley needs help

I have been enjoying your articles on "The Age of Steel." Thank you for putting these together. A number of years ago, I visited the Holley monument in Washington Square Park. At the time, his name was clearly visible but the inscription had weathered away. I contacted ASM with a suggestion that the Historical Committee make it a project to install a plaque with the details of who he was. I heard no reply, so I assume nothing was done. Is it time to try again?

J.W. Matousek, ASM Life Member

The bust of Alexander Lyman Holley stands in Manhattan's Washington Square Park, but could use an informative plaque.

Historical files, book available

I enjoyed the recent "Age of Steel: Part II" article immensely (April issue). Charles Simcoe is to be commended for writing this article series. I have taken an interest because I read a book on the Homestead steel strike about 60 years ago. I worked at U.S. Steel Homestead Works in the metallurgy department from 1951 to 1954. Later, I was the primary nickel specialist for an INCO nickel distributor. During this time, I called on U.S. Steel's Johnstown Works where they had the original Kelly converter in their reception room.

After closing my company two years ago, I've been disposing of my library. I have files on the conversion of a blast furnace from making iron to making ferromanganese by Pittsburgh Coke and Chemical Co. at their plant on Neville Island, Pa. I also have a small book called *Acid Electric Steelmaking* printed by ASM in 1947. I would like these things to go to whomever would be interested, free of charge.

J. Gray Bossard, ASM Life Member

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

Frisbees sport recycled beach plastic

Beach Clean Frisbee made from recycled plastic collected at UK beaches.

Axion Polymers, UK, processed a total of 88 kg of assorted plastics collected from six area beaches in last year's *Big Beach Clean-Up* organized by the Marine Conservation Society and Marks & Spencer (M&S). M&S used that plastic to create their Beach Clean Frisbee. Extensive testing at Axion's Salford facility proves that rigid plastic debris, such as small toys and bottle tops, can be recycled into new products.

"We applaud M&S for their efforts. Using plastic from litter to create new products is clearly an interesting approach, yet it's only the tip of the iceberg in terms of the opportunity that exists to use recycled plastics from all sources in new consumer goods," says Axion director Keith Freegard. *axionpolymers.com.*

Building spaceships with artificial bone

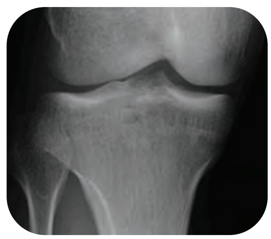
Mars Express spacecraft after release of the Beagle 2 lander. Courtesy of ESA.

Using a high-tech 3D printer, scientists at the Karlsruhe Institute of Technology, Germany, created a lightweight but very strong material inspired by the intricate microscopic architecture of bones. The research could pave the way for future super-light materials that could be used in microfluidics devices or to make lighter, less expensive spacecraft.

Even though experts have managed to make artificial cellular materials like aluminum foam, which is full of air pockets and much lighter than solid metal, there's a trade-off—the porous metal is much weaker than its solid counterpart. Engineering strong materials less dense than water (about 1000 kg/m^3) is not easy to do.

Researchers used a 3D laser lithography machine to build very tiny microstructures out of a ceramic-polymer composite. They made several different designs, from cubic grids with diagonal supports to hexagonal honeycomb-like structures. These light building materials were remarkably tough, exceeding the strength-to-weight ratio of all engineering materials with a density less than that of water, say researchers. *kit.edu/English.*

Shock-absorbing bone goo offers osteoporosis insight



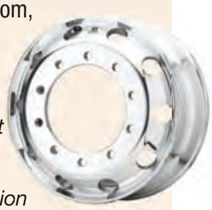
Knee with patella x-ray. Courtesy of Eric Schmuttenmaer.

A team from Cambridge's Department of Chemistry and Advanced Imaging Centre, UK, used a combination of NMR spectroscopy, x-ray diffraction, imaging, and computational modeling with the Department of Physics and Astronomy at University College London to reveal citrate layers in bone. Citrate, a by-product of natural cell metabolism, mixes with water to create a viscous fluid that is trapped between the nanoscale crystals that form bones. The fluid allows enough movement, or slip, between these crystals so that bones are flexible and do not shatter under pressure. If citrate leaks out, the crystals—made of calcium phosphate—fuse together into bigger and bigger clumps that become inflexible, increasingly brittle, and more likely to shatter. This could be the root cause of osteoporosis.

"Bone mineral was thought to be closely related to this substance called hydroxyapatite. But what we've shown is that a large part of bone mineral—possibly as much as half of it—is made up of this goo, where citrate is binding like a gel between mineral crystals," says Melinda Duer, who led the study. "This nanoscopic layering of citrate fluid and mineral crystals in bone means that the crystals stay in flat, plate-like shapes that have the facility to slide with respect to each other. Without citrate, all crystals in bone mineral would collapse together, become one big crystal, and shatter." *For more information: Melinda Duer, 012.233.36483, mjd13@cam.ac.uk, ch.cam.ac.uk.*

briefs

Alcoa Inc., Pittsburgh, invested $13 million to expand its wheel manufacturing plant in Europe, to meet growing demand for its lightweight aluminum truck wheels. The expansion of the Székesfehérvár, Hungary, facility enables production of twice as many Dura-Bright EVO surface-treated wheels in Europe by early 2015, compared to current production levels. The Dura-Bright EVO surface-treated wheel is 10 times more resistant to corrosion primarily caused by road salts and weather. The wheel is also up to three times more resistant to chemicals, including hydrofluoric acid, found in some truck wash cleaning agents. This enables use of a wider variety of cleaning solutions to simplify maintenance, while preserving wheel integrity and brightness. alcoa.com, alcoawheels.com.



Alcoa is doubling production of its lightweight Dura-Bright EVO surface-treated truck wheels through a production line expansion in Hungary. Courtesy of Business Wire.

Titanium alloy golf clubs can cause dangerous wildfires, according to **University of California Irvine** scientists. When a club coated with the lightweight metal is swung and strikes a rock, it creates sparks that can heat to more than 3000°F for long enough to ignite dry foliage. Orange County fire investigators asked the university to determine whether such clubs could have caused blazes at local golf courses a few years ago. Course conditions were recreated in the lab to match conditions on the days the fires occurred. Using high-speed video cameras and powerful scanning electron microscope analysis, they found that when titanium clubs were abraded by striking or grazing hard surfaces, intensely hot sparks flew out of them. In contrast, when standard stainless steel clubs were used, there was no reaction. uci.edu.

Preserving food in a whole new way

For the past 100 years, the way refrigerators preserve food has been rooted in technology dating back to the mid-1800s, but that is about to change. GE Appliances, Louisville, Ky., researchers are developing the next leap in home refrigeration technology—magnetic refrigeration (more specifically, magnetocaloric refrigeration). The technology uses no refrigerants or compressors and is 20% percent more efficient than refrigeration technology currently in use. In addition, the new approach can be applied to other heat pump applications such as HVAC and has the potential to impact nearly 60% of the average U.S. household's energy consumption.

The system uses a water-based fluid rather than a chemical refrigerant such as Freon to transfer heat from inside the refrigerator and achieve the cooling process. Instead of a compressor, magnets create a field that agitates particles in the fluid, causing it to cool. The magnetic field strength determines how cold the fluid becomes, and in turn, how quickly it cools the refrigerator. Research is progressing rapidly and is on track to move from the lab to residential homes within the next five years. *ge.com/appliances.*

Polymer used to make hybrid electric engine covers

More producers of automotive engine covers are switching to DSM's Akulon Ultraflow glass and mineral reinforced polyamide 6. Compared to other grades of polyamide 6, this one offers up to 80% improved flow and enables cycle time reductions of 15% to 40%. Such substantial reductions are achieved through a combination of shorter injection—and holding pressure times, faster crystallization speed, and the option to use processing temperatures 30° to 40°C lower than competing polyamides—which allows for a shorter cooling time. Wall thicknesses can be cut by as much as 20%. The excellent flow properties of Akulon Ultraflow have minimal effect on its mechanical properties, which remain in line with those of more conventional reinforced polyamides. In addition, the high dimensional stability of the material eliminates the need for large flat parts like engine covers to be put into special cooling fixtures after molding to prevent distortion. *dsm.com/automotive, akulon.com.*

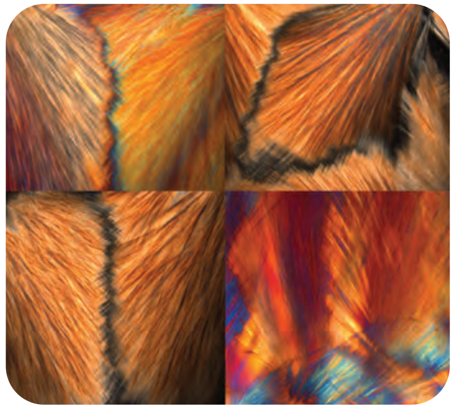
Akulon Ultraflow polyamide 6 used by Miniature Precision Components for hybrid electric engine covers. Courtesy of DSM Engineering Plastics.

Glass production reject finds new use

A form of crystal that was long considered an unwanted and unloved "stone" in glass making could find practical use as an inexpensive and efficient optical diffuser, which scatters and softens light in a variety of industrial and household applications. Devitrite is a form of crystal produced when commercial soda-lime-silica glass is heat treated for extended periods. As it degrades the performance of glass by making it opaque, it was considered a troublemaker in early 20th century glass manufacture. Improvements in commercial glass manufacturing removed it from the final product altogether.

However, researchers from the University of Cambridge, UK, discovered that devitrite actually possesses many useful characteristics. In fact, the very optical characteristics that help to make devitrite unwanted in commercial glass can make it extremely useful as an inexpensive and efficient optical diffuser. Devitrite grown in glass consists of needlelike crystals, and forms into fanlike shapes. The tiny spacing between the needles is similar to that of the visible light wavelength, so when light passes through devitrite, it scatters at angles up to 120°.

Devitrite-based diffusers scatter light more broadly than sandblasted devices, while giving some control over the shape of the beam, and at lower cost than engineered holographic devices. Devitrite can be produced on a large scale, simply by treating ordinary window glass with heat. The crystals grow into the glass itself, making the diffusers robust and resistant to damage. In addition, the high melting point of the glass means the diffusers can withstand temperatures in excess of 500°C. *www.cam.ac.uk.*



Fans of devitrite crystals. Courtesy of Haider Butt.

Graphene keeps copper wires cool

As computer chip components shrink, the copper wiring that connects them must also shrink. However, as these wires get thinner, they heat up tremendously. A potential solution to this interconnect fever has been found in the form of graphene. Alexander Balandin of the University of California Riverside, and Kostya Novoselov, a physicist at University of Manchester, UK, left graphene on the copper to see how it affected the metal's thermal properties. They found that a sandwich made of graphene on both sides of a sheet of copper improves its ability to dissipate heat by 25%. Balandin notes that the graphene itself does not seem to conduct the heat away. Rather, it alters the structure of the copper, improving the metal's conductive properties. Heat moving through copper is usually slowed by the crystalline structure of the metal. Graphene changes this structure, causing those walls to move farther apart, and allowing heat to flow more readily, says Balandin. *For more information: Alexander Balandin, 951.827.2351, balandin@ee.ucr.edu, engr.ucr.edu.*

Karlsruhe Institute of Technology, Germany, researchers developed microstructured lightweight construction materials of the highest stability. Although their density is below that of water, stability relative to weight exceeds that of massive materials, such as high-performance steel or aluminum. The new materials are inspired by the framework structure of bones and the shell structure of bees' honeycombs. To produce them, 3D laser lithography was applied. Laser beams harden the desired microstructure in a photoresist. This structure is then coated with a ceramic material by gas deposition. Finished structures were subjected to compression via a die to test stability. kit.edu/English.

Highly stable ceramic-polymer composite framework with individual elements only a few hundred nm thick. Courtesy of J. Bauer/KIT.

briefs

Element Materials Technology, St. Paul, Minn., opened a new state-of-the-art laboratory in Plymouth, Mich. The company's 42nd location worldwide, the facility will serve the automotive industry, providing materials and component testing, and product qualification testing to the transportation and industrial markets, including automotive manufacturers and their suppliers. Services include environmental, vibration, and interior testing, including component durability and airbag deployment. element.com.

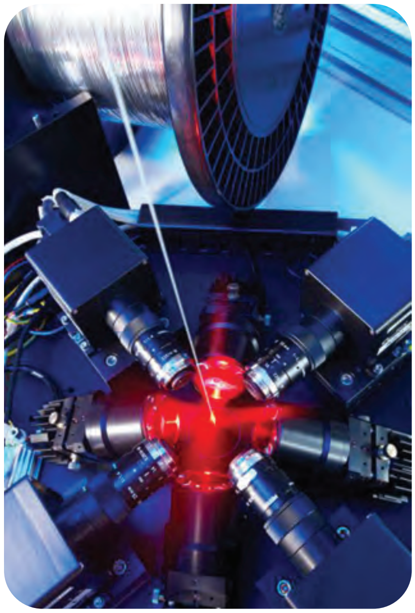
MTI Instruments Inc., Albany, N.Y., received ISO 9001:2008 quality management certification, authorized by **TÜV Rheinland,** a global provider of independent testing and certification services. MTI manufactures noncontact measurement systems and sensors including computerized general gauging instruments for position, displacement, thickness, and vibration applications using laser, fiber optic, and capacitive sensor measurement technologies. mtiinstruments.com.

Renishaw plc, UK, received a **Queen's Award for Enterprise 2014** in the "Innovations" category for its inVia Raman microscope. The award was granted for continuous development of the inVia with ultra-fast Raman imaging, which enables rapid generation of high-definition 2D and 3D chemical images for material analysis. The microscopes use Raman scattering to analyze the chemical structure and composition of materials. renishaw.com.

Optical inspection system enables rapid in-line inspection

Researchers at Fraunhofer Institute for Physical Measurement Techniques IPM, Freiburg, Germany, achieved in-line inspection at extremely high production speeds. Their optical inspection system, WIRE-AOI, can detect defects in strip products such as pipes, rails, wires, and boards in real-time. The inspection system detects micro-defects that zoom past at 10 m/s and are no thicker than a human hair. Workers see the processed defects depicted on a monitor and can remove corresponding pieces.

The defect location is marked and the associated camera image is stored in a database, enabling strip product manufacturers to identify, classify, and document defects during production. If a workpiece exceeds predefined parameters, a visible and audible alarm is activated. Four high-speed cameras deliver images of defects, with each camera capable of shooting 10,000 images per second and processing them in real-time.



With the WIRE-AOI wire inspection system, four cameras collectively deliver 40,000 analyzed images per second. Courtesy of Fraunhofer IPM.

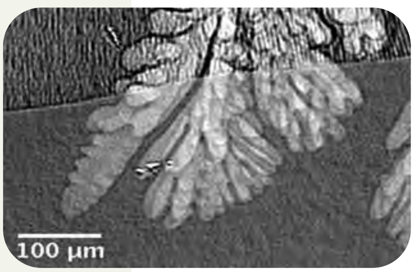
"Only a handful of models for industrial camera inspection are able to record this number of images in the first place, much less analyze them in real-time," says Daniel Carl, group manager for Inline Measurement Techniques at IPM. Prerequisite for this peak performance are cellular neuronal networks. "That means each pixel is itself a computer in its own right. In order to program these, you need specialized knowledge about parallel architectures that the team at IPM has at its disposal."

Corresponding software must first enable the system to analyze the images shot by the camera. An LED light developed by the team makes the images super-sharp. Its light shines at 5 millionths of a second, as bright as 100 suns, and flashes 10,000 times per second. Another feature is sturdy housing, as the process can get rough when making strip products. For example, in wire production, blanks are either rolled or drawn through dies, which can get messy or experience extreme vibration. The inspection system—with its sensitive electronic and optical components—is in the middle of the production line and workpieces travel directly through it. *For more information: Daniel Carl, 49.761.885.7549, daniel.carl@ipm.fraunhofer.de, www.ipm.fraunhofer.de.*

Nondestructive imaging sheds light on metal solidification

Los Alamos researchers and collaborators are using nondestructive imaging techniques to study solidification of metal alloy samples. The team used complementary methods of proton radiography at the Los Alamos Neutron Science Center (LANSCE), N.M., and synchrotron x-ray radiography at Argonne National Laboratory (ANL), Lemont, Ill., to make the measurements. This is the first time high-energy protons were used to nondestructively image a large metal sample during melting and solidification. Such real-time imaging could provide the insight needed to control metal microstructure and lead to advanced manufacturing processes to produce materials with desired properties.

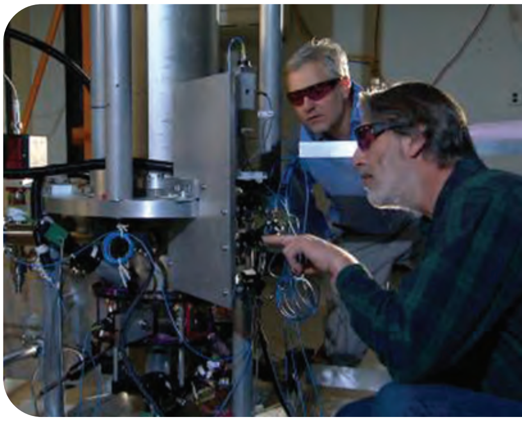
X-ray image of a 200-micron thick Al-14 at.% Cu alloy during directional solidification, highlighting growth of an aluminum-rich branched structure (dendrite) and advancing solid-liquid (planar) interface.



Scientists can peer into a metal during processing without destroying it using high energy proton radiography (pRad) and synchrotron x-ray radiography. Amy Clarke of Metallurgy (MST-6) led a team that demonstrated the ability to use pRad imaging to examine large volumes (greater than 10,000 mm^3) of metallic alloys during solidification. The studies were complemented with local, higher resolution observations via synchrotron x-ray radiography, a technique that favors examination of small volumes (less than 1 mm^3) and low-density metals. Proton radiography enables direct observations of structural outcomes as a function of processing. It also enables studies of 3D processes, such as fluid flow encountered during solidification for which thick sections, rather than thin (constrained) sections, better represent processes that occur in actual castings. This information bridges the micro- and macro- length scale regimes and provides insight into solidification processes. *lanl.gov.*

NIST launches new U.S. time standard

The National Institute of Standards and Technology (NIST), Gaithersburg, Md., officially launched a new atomic clock, called NIST-F2, to serve as the new U.S. civilian time and frequency standard, along with the current NIST-F1 standard. NIST-F2 would neither gain nor lose one second in about 300 million years, making it roughly three times as accurate as NIST-F1, which has served as the standard since 1999. Both clocks use a "fountain" of cesium atoms to determine the exact length of a second. NIST scientists recently reported the first official performance data for NIST-F2, which has been under development for a decade, to the International Bureau of Weights and Measures (BIPM), located near Paris. That agency collates data from atomic clocks around the world to produce Coordinated Universal Time, the international time standard. According to BIPM data, NIST-F2 is now the world's most accurate time standard. *nist.gov.*



Physicists Steve Jefferts (foreground) and Tom Heavner with the NIST-F2 "cesium fountain" atomic clock, a new civilian time standard for the U.S. Courtesy of NIST.

industry news

Emerging Technology

briefs

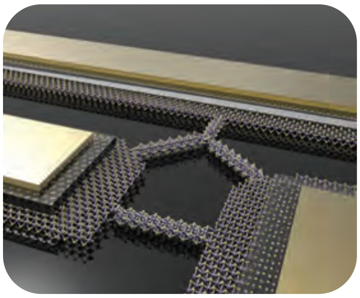
To research further into different areas of advanced materials, including the possibility of invisibility cloaks, £2.5 million is being invested by the UK's **Engineering and Physical Sciences Research Council.** Concepts in fields such as acoustic metamaterials and thermal cloaking will be applied in order to engineer designer metamaterials with specific properties. Leading UK scientists based at **Imperial College London,** the **University of Liverpool,** and **Liverpool John Moores University** will work on the five-year study. www.epsrc.ac.uk.

The University of Chicago's Institute for Molecular Engineering will build a major new facility for nanoscale fabrication within the **William Eckhardt Research Center,** supported by a $15 million gift from the **Pritzker Foundation.** In recognition of the gift, the 12,000-sq-ft building will be named the **Pritzker Nanofabrication Facility.** With advanced tools and enough room for a wide range of projects, the space will support work on new applications in computing, health care, communications, smart materials, and more. uchicago.edu.

Illustration of high-speed optical networks that could enable quantum information processing and communication. Courtesy of Peter Allen.

Electron beam builds teeny tiny nanowires

Junhao Lin, a Vanderbilt University Ph.D. student and visiting scientist at Oak Ridge National Laboratory (ORNL), Tenn., discovered how to use a finely focused beam of electrons to create some of the tiniest wires ever made. The flexible metallic wires are only three atoms wide—one-thousandth the width of microscopic wires used to connect the transistors in today's integrated circuits. According to collaborators, the technique is an exciting way to manipulate matter at the nanoscale and should boost efforts to create electronic circuits out of atomic monolayers, the thinnest possible form factor for solid objects.



Molecular model of nanowires made of TMDCs.

The tiny wires are made of a special family of semiconducting materials that naturally form monolayers, called transition-metal dichalcogenides (TMDCs). TMDCs are made by combining molybdenum or tungsten with either sulfur or selenium. Atomic monolayers have exceptional strength, flexibility, transparency, and high electron mobility. Interest in them was sparked in 2004 by the discovery of an easy way to create graphene. Yet despite graphene's promising properties, converting it into useful devices is problematic, which is why scientists have turned to other monolayer materials like the TMDCs. Other research groups have already created functioning transistors and flash memory gates made of TMDC materials. Now, the discovery of how to make wires provides the means for interconnecting these basic elements. *vanderbilt.edu.*

Strain engineering enables new areas of materials research

In the ongoing search for new materials for fuel cells, batteries, photovoltaics, separation membranes, and electronic devices, one newer approach involves applying and managing stresses within known materials to give them dramatically different properties. Known as *elastic strain engineering,* the discipline was long envisioned by theorists, but only arose formally about 20 years ago. It initially focused on pure silicon, whose tensile stress improves the speed of charges in integrated circuits, and on metal catalysts, where tensile stress improves surface reactivity.

"Traditionally, materials are made by changing compositions and structures, but we now recognize that strain is an additional parameter that can be changed, instead of looking for new compositions," says Bilge Yildiz, associate professor of nuclear science and engineering at Massachusetts Institute of Technology (Cambridge), one of the pioneers of this approach. "Even though we are dealing with small amounts of strain—displacing atoms within a structure by only a few percent—the effects can be exponential."

Putting these theoretical improvements into practice in a device, however, is a major challenge. Yildiz focuses on improving diffusion and reaction rates in metal oxides, which could affect how fast an energy storage or conversion device, such as a battery, works. Oxides are more complex than pure silicon or metal catalysts, says Yildiz, but offer a much larger array of potential material properties. For example, oxides including cobaltites and manganites, used as fuel-cell electrodes, show performance gains through stretching and straining. *For more information: Bilge Yildiz, 617.324.4009, byildiz@mit.edu, mit.edu.*

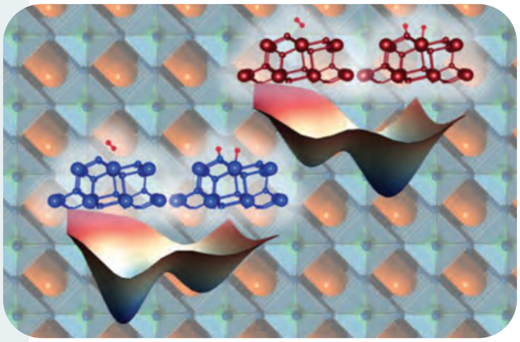
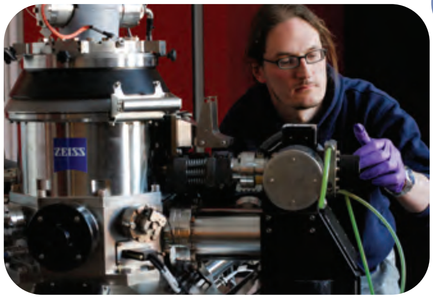


Illustration background shows a perovskite oxide structure. By straining this material, the energy barrier to surface reactions is reduced. Energy barriers are shown by 3D graphs in foreground images. Courtesy of Mostafa Youssef, Lixin Sun, and Bilge Yildiz.

New method makes ample amounts of high quality graphene

Researchers at AMBER (Advanced Materials and BioEngineering Research), the materials science center headquartered at Trinity College Dublin, developed a new method of producing industrial quantities of high-quality graphene, which was previously impossible.

The subject of ongoing international research, the AMBER discovery is said to be the first to perfect large-scale production of pristine graphene materials. Jonathan Coleman, professor of chemical physics at Trinity College and AMBER, and his team used a simple method to transform flakes of graphite into defect-free graphene using commercially available tools, such as high-shear mixers. They demonstrated that not only could graphene-containing liquids be produced in standard lab-scale quantities of a few hundred ml, but also that the process could be scaled up to produce hundreds of liters and more. *www.ambercentre.ie.*

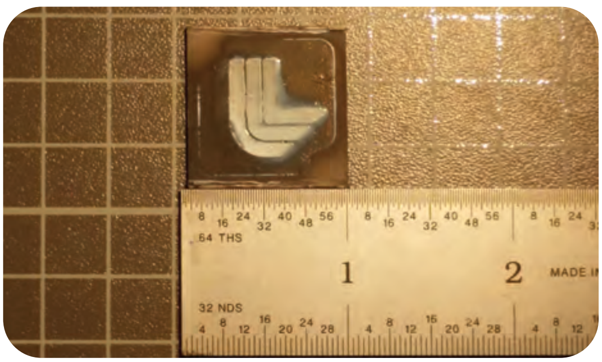


A team led by Jonathan Coleman discovered a new method to produce large volumes of high-quality graphene.

Additive manufacturing approach uses light to form composites

For almost 100 years, electrophoretic deposition (EPD) has been used as a method to coat materials by depositing particles of various substances onto the surfaces of manufactured items. EPD is most commonly used to apply primer to new car bodies on assembly lines. The car's body is positively charged while the liquid primer in the dunk tank is negatively charged, forcing the primer to attract to the metal surface. In its traditional use, EPD can only deposit material across the entire surface and not in specific, predetermined locations, until now.

Researchers at Lawrence Livermore National Laboratory (LLNL), Calif., created a technique called light-directed electrophoretic deposition, which uses photoconductive electrodes and dc electrical fields to dynamically pattern the surface material. This allows the material to build up in targeted areas where the light contacts the photoconductor's surface, enabling arbitrarily patterned, 3D multimaterial composites to be created over large areas with fine resolution.



Proof-of-concept logo 3D printed using a new additive manufacturing process, light-directed electrophoretic deposition (EPD). Courtesy of LLNL.

Light-directed EPD was used to produce an alumina ceramic-tungsten nanoparticle composite. Initially, the tungsten nanoparticles were deposited across the photoconductive surface then illuminated through a laser-cut aluminum mask. A differently shaped mask was substituted along with the new material to deposit the ceramic material. In the future, aluminum masks will be replaced by digitally projected ones for a completely automated deposition system.

Light-directed electrophoretic deposition has the potential to elevate traditional EPD from a single layer, single material coating process to a true additive manufacturing technique that allows unique composites to be formed. For example, void areas can be precisely created in a part to control polymer material behaviors for energy absorption or within cellular material to create veins or blood vessels for manufactured organs. *llnl.gov.*

briefs

Proto Labs Inc., Maple Plain, Minn., acquired **FineLine Prototyping Inc.,** Raleigh, N.C. Proto Labs uses CNC machining and injection molding to manufacture custom parts. FineLine provides high-quality stereolithography, selective laser sintering, and direct metal laser sintering services to a variety of industries, such as medical, aerospace, computer/electronics, consumer products, and industrial machinery. protolabs.com.

SQuAD Forging installed a 10,000-ton-capacity aerospace hydraulic forging press at its manufacturing facility in Aequs SEZ (special economic zone), Belgaum, India. The closed die, hydraulically operated hot forging press is reportedly the largest of its kind in India and will be used to forge large airplane components and parts such as landing gears and various actuation and structural parts. The new press, expected to begin production by September, can forge aluminum, steel, and titanium parts up to 400 kg. squadforge.com.

Power generation and distribution firm **ABB Ltd.,** Zurich, recently installed the largest single-shot short-circuit ring brazing system developed by **EFD Induction Inc.,** Madison Heights, Mich. The system, installed at the Italian ABB plant outside Milan can braze rings with diameters to 1500 mm. The system is comprised of customized coils, an EFD Induction Sinac 250/320 power source, and mounting table. The first project involved brazing a 1500-mm-diameter short-circuit ring for a wind tunnel motor. efd-induction.com.

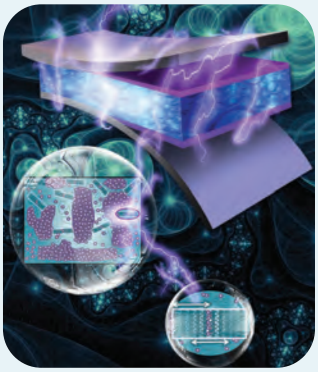

An ABB technician uses the new EFD system to heat a short-circuit ring.

industry news

Energy Trends

briefs

Research from **North Carolina State University,** Raleigh, reveals that solar cell efficiency is based on a delicate balance between the size and purity of the interior layers, or domains. Polymer-based solar cells are intended to have two domains, consisting of an electron acceptor and an electron donor material. However, these domains are not separate and pure, and many more than two can exist. Current processing methods create a complex, multi-domain structure, which impacts all of the factors involved in the solar cell's efficiency. ncsu.edu.

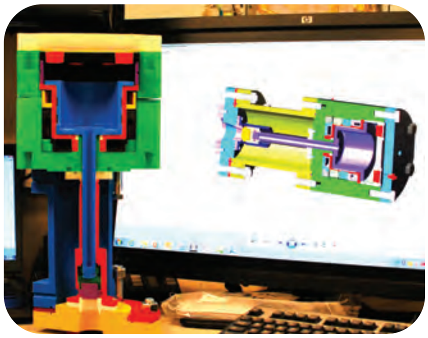


Interior of a solar cell.

A breakthrough by researchers at **Oregon State University,** Corvallis, could reduce the cost of solar energy, speed production processes, use environmentally benign materials, and make the sun almost a "one-stop shop" that produces both the materials for solar devices and the energy to power them. The work is based on use of a "continuous flow" microreactor to produce nanoparticle inks that make solar cells by printing. Simulated sunlight is focused on the solar microreactor to rapidly heat it, and allows precise temperature control to aid the quality of finished products. The light used in experiments was artificial, but the process could use direct sunlight—at a fraction of the cost of current approaches. oregonstate.edu.

3D printing enhances fusion research

ITER, the international fusion research facility, is now under construction in St. Paul-lez-Durance, France. US ITER staff at DOE's Oak Ridge National Laboratory, Tenn., are using desktop 3D printing to help colleagues design and configure components more efficiently and affordably. Although full-scale models cast or machined from metal and other materials continue to have value and will still be a part of the US ITER development process (as will 3D computer modeling), the affordability and accessibility of desktop 3D printing offers a number of advantages. "It's a lot more time consuming and expensive when you find a mistake in a metal prototype than in a 3D printed component. 3D printing is very low cost. With metal, you may have to start over if you can't re-machine it, " says Mark Lyttle, an engineer working on the pellet injection and plasma disruption mitigation systems. *ornl.gov.*



A 3D-printed version of a fast gas valve for the disruption mitigation system.

World-record current in a superconductor

In the framework of the High-Luminosity LHC project, experts from the CERN (European Organization for Nuclear Research) superconductors team recently obtained a world-record current of 20 kA at 24K in an electrical transmission line consisting of two 20-m-long cables made of magnesium diboride (MgB_2) superconductor. This result makes the technology a viable solution for long-distance power transmission. The result was achieved at a temperature of 24K (-249˚C) and is kept homogeneous over the 20 m length of the line by a forced flow of helium gas. Following development, the full 2 × 20 m MgB_2 superconducting line was successfully powered to the world-record current of 20 kA, showing that this technology has great potential for the transmission of electrical power. *http://home.web.cern.ch.*

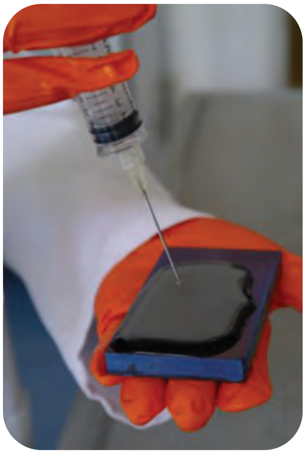
Nanocrystalline copper turns CO into fuel

Matthew Kanan and colleagues at Stanford University and Lawrence Berkeley National Laboratory, both in Calif., developed a new type of nanocrystalline copper electrode that catalyzes the electrochemical conversion of carbon monoxide to alcohols. Results from a standard copper foil electrode were compared with those using nanocrystalline copper electrodes. Both commercial nanoparticle electrodes were produced by rapidly vaporizing bulk copper before cooling to form isolated nanoparticles, while researchers produced electrodes by oxidizing the copper foil and reducing oxide. Like the standard foil electrode, only 5% of the hydrogen produced by the commercial nanoparticle electrodes reduced carbon monoxide. The oxide-derived electrodes were very effective at reducing carbon monoxide, with about 50% of the product a mixture of ethanol, acetate, ethylene, and propanol. Researchers suspect the explanation lies in the grain boundaries between nanoparticles in their electrode. "The grain boundary terminates at the surface, and at that surface termination you can have a different structure that wouldn't be stable on the normal surface of a particle," explains Kanan. *For more information: Matthew Kanan, 650.725.3451, mkanan@stanford.edu, stanford.edu.*

Engineers at **University of California San Diego** created ceramic materials that store hydrogen safely and efficiently. The compounds are made from mixtures of calcium hexaboride, strontium, and barium hexaboride and manufactured using combustion synthesis. The ceramics are essentially crystalline structures in a cage of boron. To store hydrogen, calcium, strontium, and boron are swapped with hydrogen atoms within the cage. Boron is mixed with metal nitrates and organic fuels, such as urea, in a box furnace at temperatures below 400°C (~750°F). The nitrates and organic fuels ignite, generating heat and driving the reaction without an external power source. ucsd.edu.

Implant coating promotes bone growth

Researchers at Uppsala University, Sweden, developed a responsive coating for implants to improve their integration into bone and to prevent rejection. Neutron scattering experiments at the Institut Laue-Langevin (ILL), France, show how a protein that promotes bone growth binds to this surface and can be released in a controlled way. Gels made by modifying hyaluronan, a biological molecule, can coat implants. Research shows the coated titanium surfaces can bind protein molecules that promote bone formation. These can be released slowly once the surface comes in contact with a solution of calcium ions. This process stimulates bone growth on implants. The gel layers, a few millionths of a millimeter thick, were characterized using neutron reflection at ILL, providing a detailed surface image. BMP-2, the protein that encourages bone growth, was bound to the gel. The protein layer was stable in water, but could be released slowly by adding solutions containing calcium, a process that was observed in real time using neutron reflection to track the amount of protein at the surface. *www.uu.se/en.*



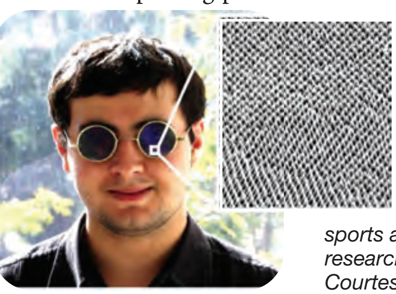
A gel-coated titanium surface binds proteins that promote bone formation. Courtesy of Ida Berts.

Coating offers grease-free lubrication and corrosion protection

Researchers at the INM – Leibniz Institute for New Materials, Germany, developed a functional coating that lubricates without grease and protects against corrosion at the same time. It is suitable as a coating for metals and metal alloys such as steel, aluminum, or magnesium. "We incorporated platelet-like solid lubricants and platelet-like particles in a binder. When this mixture is applied to a surface, it produces a well-ordered structure in which these various particles are arranged in a roof tile pattern," says Carsten Becker-Willinger, head of the Nanomers Program Division. This forms a so-called transfer film between the low-friction coating and the object through which surfaces can slide with minimal friction. "The particular mixture ratio means that our composite has a very low coefficient of friction. If we only used a solid lubricant, the coefficient of friction would be considerably higher," says Becker-Willinger. *www.inm-gmbh.de/en.*

Moth eyeballs inspire low-glare coating

Work by University of California Irvine scientists could reduce glare from solar panels and electronic displays, as well as dangerous glints on military weapons. "We found a very simple process and a tiny bit of gold can turn a transparent film black," says chemistry professor Robert Corn. The team was initially worried when they noticed what appeared to be soot on a flexible film designed to coat various products. Via painstaking tests, however, they realized they accidentally discovered a way to fabricate a surface capable of eliminating glare. The material can also keep grime in raindrops and other moisture from sticking. A repeating pattern of cones modeled on moth eyeballs at the nanoscale was etched on Teflon and other nonstick surfaces. A thin layer of gold was then applied over the cones and the shine from the gold and any light reflecting onto it was all but obliterated. The material is also highly hydrophobic. *For more information: Robert Corn, 949.824.1746, rcorn@uci.edu, uci.edu.*



UC Irvine undergraduate chemistry student George Auwaijan sports a pair of sunglasses coated with a new material invented by researchers that mimics the pattern of moth eyeballs to reduce glare. Courtesy of Gabriel Loget/UC Irvine.

briefs

Rice University, Houston, scientists mixed very low concentrations of diamond particles (roughly 6 nm in diameter) with mineral oil to test the nanofluid's thermal conductivity and how temperature affects its viscosity. They found it to be much better than nanofluids that contain higher amounts of oxide, nitride or carbide ceramics, metals, semiconductors, carbon nanotubes, and other composite materials. In tests, researchers dispersed nanodiamonds in mineral oil and found that a very small concentration—one-tenth of a percent by weight—raised the thermal conductivity of the oil by 70% at 373°K (211°F). rice.edu.

NEI Corp., Somerset, N.J., introduced NANOMYTE SuperCN Plus, a functionally graded coating that imparts superhydrophobic properties to the underlying substrate while providing greater abrasion resistance compared to existing superhydrophobic coatings. The coating consists of a hard and abrasion-resistant outer layer that transitions to a softer material closer to the substrate. Due to its graded structure, the coating maintains its superhydrophobicity and high contact angle even after moderate damage. Additionally, it exhibits good adhesion to the substrate. neicorporation.com.

Researchers at the **University of Arkansas** report achieving the highest efficiency ever in a 9 mm^2 solar cell made of gallium arsenide. After coating cufflink-sized cells with a thin layer of zinc oxide, the team reached a conversion efficiency of 14%. A small array of these cells—as few as nine to 12—generates enough energy for small LEDs and other devices. Better yet, surface modification can be scaled up and cells can be packaged in large arrays of panels to power large devices such as homes, satellites, or even spacecraft. uark.edu.

industry news

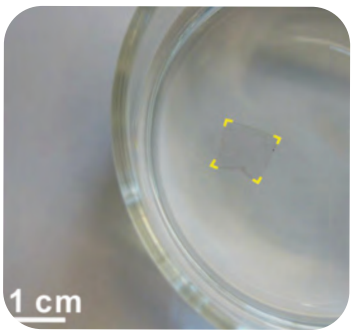
NANOTECHNOLOGY

Book explores bio-inspired nanomaterials

In a new book, *An Experimental Study on Adhesive or Anti-Adhesive, Bio-Inspired Experimental Nanomaterials,* published by De Gruyter, Italian scientists Emiliano Lepore and Nicola Pugno explore the potential of three categories of bio-inspired materials: Adhesives, anti-adhesives, and materials. In each area, the technologies are described in relation to how they were inspired by nature in an attempt to optimize their physical characteristics and performance in operation, with an aim to design and develop innovative products. The authors investigate a wide range of natural systems and use original experimental procedures to take a rigorous look at biomaterials. Special attention is given to bonding dissimilar materials, which due to their physical properties prohibit the application of more conventional joining techniques. In this field, inspiration comes from investigating the adhesive abilities of insects, spiders, and reptiles. *degruyter.com.*

Nanotube-graphene material aims to simplify manufacturing

Carbon nanotubes (CNTs) are reinforcing bars that make 2D graphene much easier to handle in a new hybrid material grown by researchers at Rice University, Houston. In James Tour's chemistry lab, nanotubes are set into graphene in a way that not only mimics how steel rebar is used in concrete, but also preserves and even improves the electrical and mechanical qualities of both. To create the rebar graphene, researchers spin-coat and then heat and cool functionalized single- or multi-walled CNTs on copper foils, using the nanotubes as the carbon source. When heated, functional carbon groups decompose and form graphene, while nanotubes partially split and form covalent junctions with the new graphene layer. The interconnected, embedded nanotubes strengthen the graphene. "We can see in our images how well the nanotubes bear the load. When we stretch the material, the tubes get thinner," says Tour. *For more information: James Tour, tour@rice.edu, jmtour.com.*



A square-cm sheet of rebar graphene floats in water. Rebar allows the sheet to be transferred from one surface to another without using polymers in an intermediate step. Courtesy of Tour Group/Rice University.

Nanowire phenomenon seen for the first time

Scientists at IBM Research – Zurich and the Norwegian University of Science and Technology demonstrated that both efficient light emission and detection functionalities can be achieved in the same nanowire material by applying mechanical strain. Using this new physical phenomenon, scientists might be able to integrate light emitter and detector functions in the same material. This would drastically reduce the complexity of future silicon nanophotonic chips, say researchers. IBM scientist Giorgio Signorello explains, "When you pull the nanowire along its length, it is in a state that we call 'direct bandgap' and it can emit light very efficiently. When you compress the length of the wire instead, its electronic properties change and the material stops emitting light. We call this state pseudo-direct—the III-V material behaves similarly to silicon or germanium and becomes a good light detector." *zurich.ibm.com, www.ntnu.no.*

briefs

Researchers from the **Near Field NanoPhotonics Research Team at the RIKEN Center for Advanced Photonics,** Japan, developed a high-resolution microscopy technique that can resolve individual carbon nanotubes under ambient conditions. The technique involves replacing the atomic force microscope (AFM) tip on tip-enhanced Raman spectroscopy (TERS) with a scanning tunneling microscope (STM). A resolution of 1.7 nm was achieved using the new system, allowing carbon nanotubes to be visualized at the dimensions of their diameters. This makes it possible to extract the local property of the nanotubes optically without averaging. www.riken.jp/en.

Researchers at **Pacific Northwest National Laboratory,** Richland, Wash., added a powdered metal organic framework (MOF) to an electric battery's cathode to capture problematic polysulfides that cause lithium-sulfur batteries to fail after a few charges. During lab tests, the new battery maintained 89% of its initial power capacity after 100 charge-discharge cycles. Researchers plan to improve the cathode's materials mixture so it can hold more energy and also must develop a larger prototype and test it for longer periods of time to evaluate performance in real-world applications. pnl.gov.

Researchers at **University of the Basque Country,** Spain, and the **French National Centre for Scientific Research (CNRS)** studied contacts of carbon nanostructures with atoms of different chemical natures. A prototype carbon-based molecule made from 60 carbon atoms arranged in a sphere (a graphene sheet rolled into a tiny ball) was attached to the apex of an extremely tiny metal needle of a scanning tunneling microscope. This needle was then attached to individual metallic atoms to form a robust connection. By simultaneously measuring the electrical current passing through these connections, researchers deduced which individual metallic atom injected charges into the carbon-made molecule with the greatest efficiency. www.cnrs.fr, www.ehu.es.

Dynamic Testing Market for Composites
Sees Growth and Innovation

Peter Bailey
Instron
Buckinghamshire, UK

Some exciting trends are developing in the world of composites testing.

While today's composites encompass a broad and well-established family of materials, the commercial market for high-performance, structural composites has actually existed for well over 30 years. European automotive manufacturers have made considerable use of lower performance glass fiber reinforced polyester (GFRP) bodywork since the 1950s. In addition, adoption in the aerospace industry has resulted in a wide range of static test methods offering reliable results. However, there is still only limited consensus, so test houses and machine manufacturers must maintain an extensive catalogue of fixtures in order to meet diverse international and industry standards. It might seem that not much is happening with regard to composites testing innovation, but some exciting trends are now developing.

Fatigue testing

The wind energy industry is leading the way when it comes to composites testing development. In the past six to eight years, major manufacturers quickly adopted fatigue testing as a key part of composite materials evaluation. The nature of this industry has greater freedom than others in terms of qualification and adoption of new materials. In addition, significant levels of elastic strain are acceptable in turbine blades, and correctly balancing design life and cost can achieve a significant competitive edge. The most common implementation for fatigue testing of composites is in tension-tension mode. This is generally due to its simplicity in terms of specimen preparation, gripping, and setup. Research establishments are emphasizing the importance of compression-compression, or fully reversed fatigue tests on composites, because these are more representative and aggressive tests. However, they present a greater challenge in terms of equipment and specimen preparation, to avoid buckling or mixed mode loading.

For all fatigue load cases, there is major concern because composites exhibit an unpleasant combination of temperature sensitive behavior and heat generation during loading and failure (Fig.1). As a result, the testing process can severely affect measured properties. In static tests, these problems can be mitigated by a carefully controlled environment combined with very low load rates. In cyclic tests, this is impractical because they often test to failure or run-out at above one million cycles. At the 1 mm/min. rate of displacement preferred in static tests, this would take roughly two years for a single specimen.

General practice is, therefore, based around practical methodologies derived from metals fatigue, using a sinusoidally varying applied stress at 3-5 Hz frequency, typically described as peak stress and stress ratio. Compared with metals fatigue these are very low frequencies, yet tend to increase the surface temperature by 20°-40°C during testing, while less loaded specimens run <2°C above ambient temperature. The outcome is a lengthy test schedule of four to eight weeks of machine time to produce an SN curve for a single composite material, in one particular layup, with a poorly controlled specimen temperature and high degree of scatter.

Frequency optimization (automatic or manual selection of frequency for different stress levels) is sometimes used to reduce total test time. Slightly decreasing the test frequency for highly stressed specimens avoids overheating, while a small increase for lower stress levels saves considerable time. Researchers at the National Composites Certification and Evaluation Facility, University of Manchester, UK, found that it took 55 days of continuous running at 4 Hz to prepare an SN curve for woven carbon fiber composites and the average specimen temperatures ranged

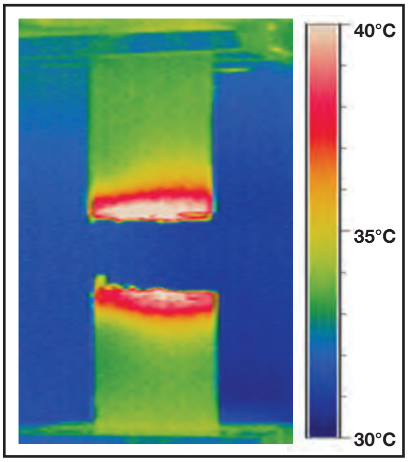


Fig.1 — *Thermal image of heating at failure of static tensile test (1 mm/min) of an impacted composite specimen.*

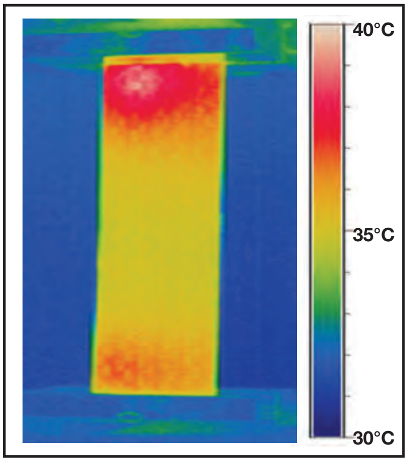


Fig. 2 — *Thermal image of self-heating of fatigue specimen 10 min into test (woven carbon fiber epoxy, 5 Hz test frequency).*

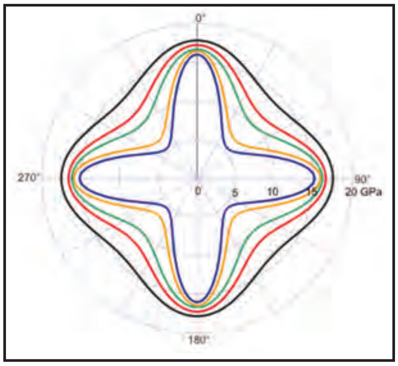


Fig. 3 — *Polar plot of tensile modulus vs. angle for a simple woven cross-ply laminate at increasing strain rate. 1) 0.00044 s^{-1}, 2) 0.044 s^{-1}, 3) 0.44 s^{-1}, 4) 4.4 s^{-1}, 5) 44 s^{-1}. Courtesy of Gude et al., Mech. Comp. Mat., Vol 45, No. 5.*

from 26° to 38°C. When an automatic system of adaptive frequency control was used, surface temperatures were controlled within ±0.5°C on all specimens and machine time was reduced by more than 27%.

Fatigue testing of composites is still evolving in terms of scientific understanding of the phenomena, but meets an urgent industrial need. A variety of failure mechanisms at a range of length scales are interacting, and are so different from those in metals that using the term *composites fatigue* might be misleading. The effects of processing (e.g., layup sequence) can be more severe than in metals, as are the results of different temperatures or strain rates. The challenges of producing representative samples are also considerable. An ongoing debate continues on how best to define specimen failure. It is agreed that specimen rupture is not a good metric, yet it remains the accepted measure because no single construction (for example, xyz% reduction in modulus) that can be used comparably across the entire, diverse family of polymer matrix composites has been identified.

Considering that metals fatigue came into being 150 years ago, it is apparent that despite numerous unsolved problems, composites fatigue is progressing rapidly after only 30 years. It is expected that industrial adoption will result in pragmatic improvements.

High-speed testing

More recently, the demand for lightweighting in the automotive sector has prompted manufacturers to investigate high-performance composites use in more critical and structural parts, as a way to reduce mass even further than what is possible with modern metals technologies.

Approximately 10 to 15 years ago, strain-rate testing of metals caused a minor revolution in automotive materials evaluation because it offered much more informative data on differences in crash scenarios. An initial phase of realization and assessment resulted in many automotive companies adopting polymer matrix composites as a worthwhile investment. Processing and designing with structural composites has significantly different challenges, but as with fatigue testing, initial work has largely employed similar models as those for metals as a starting point, so experimental data is essential. For this area of development, existing equipment and methodologies seem to have helped—a number of specialized materials test systems found further use, while many new systems are being built.

For example, Fig. 3 shows a startling picture of just how sensitive composites can be to the very high strain rates experienced by crash structures. The material modulus at high strain rate on the axes of reinforcement fibers shows a noticeable increase of around 15% compared with static loading, but in the 45° orientation this increase jumps to more than 250%.

High strain rate testing of composites (and high strength metals) is by no means trivial. All the problems that might be encountered with gripping for static tests tend to be exacerbated—such as failure at grip, effective tab bonding, or slippage of untabbed specimens. Also, the test itself is very short—often less than 2 ms. This is due to test speeds up to 25 m/s, combined with very high stiffness and low elongation at break, typical of structural composites. This requires highly specialized methods of load and strain measurement, which result in considerable data analysis.

Load is typically measured using a piezoelectric transducer within the loadstring, which converts applied stress directly to potential difference (voltage). These devices provide extremely high stiffness and nearly instant response, ideal for the necessary data acquisition rate. However, those features have a drawback in that this type of load cell offers almost no damping. Therefore, shock loading with sudden failure and recoil results in strong, but repeatable, resonances that must be filtered to accurately determine applied specimen load. Strain gauge-based load measurement is sometimes used, but it must inherently have greater mechanical compliance, ultimately raising questions about load trace reliability and signal conditioning bandwidth.

Similarly, strain cannot be measured by conventional contact methods used in low-speed tests. Applying strain gauges to the specimen and connecting them to high bandwidth amplifiers is possible, but this can lead to questions about whether the location and area are representative of specimen bulk, and if the gauges remain adhered to the specimen throughout the test. A more successful method for general strain measurement is to use a high-speed optical extensometer, which tracks a simple line of strong contrast at either end of the gauge length. The most effective method is to apply a speckle pattern directly to the whole area of interest, and then trigger a very high-speed digital camera to collect a series of images, which are post-processed using digital image correlation (DIC). Although considerably more expensive, DIC systems have great advantages in terms of understanding strain distribution during failure and the influence of edge effects.

This is also a technically demanding test, as collected data requires considerable care in interpretation, but these issues are outweighed by the importance of providing crucial insight into material behavior.

New analytical techniques

Thermography is now making a noticeable impact on dynamic testing and on composites testing in general. As previously mentioned, composites exhibit significant energetic response to loading, but this can be observed both in damaging and purely elastic conditions.

In the simplest sense, imaging the infrared emission from a specimen can provide useful qualitative information about location and evolution of heating and damage during a test, as seen in Figs. 1 and 2. With appropriate calibration, it can also be used to directly measure surface temperature, but this must be approached with caution regarding the factors that affect measurements. First, materials that are chemically or visually similar can have significantly different values of emissivity, which determine the intensity of infrared light released by the specimen. Second, emissivity can vary with temperature: This is generally a subtle change for polymers, but when monitoring metals at high temperatures, serious changes can be observed due to the formation of oxide layers. Finally, almost all specimens reflect radiation from the surrounding environment, so readings from an unshielded test area at ambient temperature can be affected simply by reflected radiation from people walking around the laboratory.

On a more advanced level, one that is rapidly gaining traction within the research sector, the University of Southampton pioneered a new technique of thermoelastic stress analysis (TSA), which can be applied to all types of materials, using cameras with much higher sensitivity. Here, the relationship between temperature and mechanical dilation analyzes the stress distribution in a system, by comparing the surface temperature difference between two load levels. Stress mapping generated in this manner can be conducted in parallel with strain mapping generated using digital image correlation, and these two independent techniques are then used for mutual verification. To date, this approach has been used most effectively with high-performance cameras, to maximize data extracted from very high speed tests. Although this research is largely academic, it is paving the way for application of less expensive equipment to more routine studies of damage evolution in the future.

Moving to higher capacity

The aerospace sector has not been mentioned thus far with regard to new areas of composites testing, and has historically been criticized by some researchers for its conservative approach. Flight-ready technology takes a long time to pass through approvals, but that does not correspond to a lack of applied research activity. A large part of aerospace manufacture's R&D development work is centered on composites. In addition to developing their production technologies, these groups are working to identify robust, repeatable approaches for dynamic performance evaluation. Meanwhile, as China and India prepare to enter the commercial aerospace market, their new research institutes have invested heavily from the beginning in a full range of dynamic testing capabilities for both metals and composites.

There is also an increasing demand for very high capacity servo hydraulic test frames. Although the tests for which these are used often do not require highly dynamic performance in terms of frequency or number of cycles, their use is not confined to high-force monotonic tests. In this case, the aerospace industry is foremost in generating this requirement, for two reasons. First, large, high-strength structures are produced from thick composite laminates with complex layups; this means that a representative test specimen must often be the full thickness, and only a finite width reduction is possible without undue influence of specimen edge effects. Therefore, if the specimen cannot be made smaller, machine capacity must be higher. Second, for similar reasons, the influence of laminate design and processing means that there is no alternative but to test entire structural elements.

True progress

There is no doubt that the structural composites market is going to keep growing for the foreseeable future. Arguably, some of the most commercially exciting developments are being achieved through industrial ac-

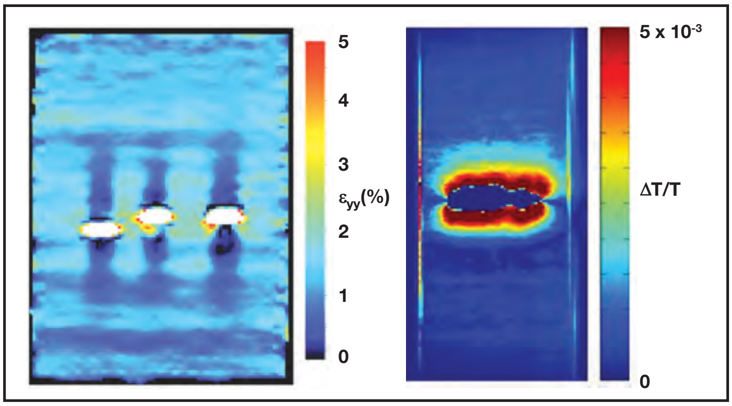


Fig. 4 — *Comparison of maps of axial strain from DIC (left) and local stress from TSA (right) on the same specimen giving complementary information. An impact-damaged composite specimen was subjected to fatigue loading. Courtesy of Crump et al., Engineering Integrity, No. 35.*

ceptance of different design needs, which in turn must be supported by even more rigorous and demanding mechanical testing techniques.

Ultimately, this commercial demand comes from the power generation and transport industries that are central to our era, because they must now evaluate various aspects of the dynamic performance of composites in order to use them in safety critical, moving structures. ❍

For more information: Peter Bailey is senior applications specialist, Instron, Coronation Rd., High Wycombe, Bucks HP12 3SY, UK, 44.1494.464646, info@instron.com, instron.us.

The Role of Materials Testing in **Vehicle Lightweighting**

Alex Koprivc
Zwick/Roell
Ulm, Germany

A mixed materials strategy calls for efficiency and flexibility, especially when it comes to testing requirements.

Consumer demand for greater fuel efficiency and a changing regulatory environment have stimulated substantial interest in alternative materials for passenger vehicles. Over the past decade, automotive manufacturers launched a series of initiatives aimed at reducing weight, improving fuel economy, and enhancing performance. Materials selection is a key factor in successfully meeting such challenges. Automotive manufacturers now have a wide variety of choices available, ranging from various grades of steel and aluminum to the most advanced lightweight composite materials (Fig. 1).

The Center for Automotive Research (CAR) created the Coalition for Automotive Lightweighting (CALM) to support collaborative efforts of auto manufacturers and suppliers to integrate mixed materials for mass reduction. Key issues addressed by CALM include identifying lightweighting technology implementation constraints, supply chain and economic issues, engineering decision analysis, and cost/benefit methodologies.

A mixed materials environment requires understanding the limitations and advantages of specific materials and the methods available to join them, according to Jay Baron, president of CAR.

Metals remain material of choice

Automotive steels, aluminum, and magnesium alloys provide high strength and have a well developed supply chain supporting quality and manufacturability. For the past century, steel and, more recently, alloys have been the automotive materials of choice. Steels are typically bonded with welds that can cost about 5 cents each. With roughly 4000 required per automobile, welds add hundreds of dollars in cost to the manufacturing process, says Baron, although they are very lightweight.

Earlier this year, Alcoa announced completion of a $300 million expansion at its Davenport, Iowa, facility dedicated to supplying aluminum sheet products to the automotive industry. As an example of aluminum's growing share of the automotive market, Ford Motor Co. announced that the body of the 2015 F-150 pickup truck will be comprised entirely of aluminum (Fig. 2). Ford expects to produce about 650,000 of the trucks next year. In the UK, Jaguar Land Rover's lightweight strategy for the Range Rover L405 involves an all-aluminum monocoque body.

According to automakers, demand for aluminum—already the material of choice behind steel for passenger vehicle manufacturing—is expected to nearly double by 2025. More specifically, the amount of aluminum body sheet content in North American vehicles is expected to quadruple by 2015 and increase tenfold by 2025 compared to 2012 levels. Aluminum is attractive for its lighter weight as well as enabling complex geometries in cases where the formability of steel has been prohibitive. Aluminum has also played an integral role in enabling part integration for cost reduction initiatives.

Despite its advantages, Al is not an ideal material for welding, says Baron, and automakers prefer redundancy in fastening solutions. Aluminum use requires new joining techniques including self-piercing rivets and adhesives. For example, each Range Rover body uses 187 yards of adhesive. Alcoa's pretreatment bonding technology, known as Alcoa 951, enables more durable bonding of aluminum components in vehicles, can reduce spot weld points, and also reduces manufacturing costs.

CFRPs for the future

Composites are following the classic adoption curve within the automotive industry.

BMW's i3 electric vehicle is the first of its kind, featuring a passenger cell comprised entirely of carbon fiber-based composites. The drive module is aluminum and must be joined to the passenger cell using specialized adhesives. Courtesy of BMW AG.

Entry occurred first in the racing and performance classes, with mainstream market applications emerging more recently. Composites also played an important role in production of mid-20th century models of General Motors' Corvette. While steel was actually lighter than fiberglass at the time, the connection between lightweight composites and high performance was cemented in the mind of the consumer.

Carbon fiber-reinforced plastics (CFRPs) deliver the benefits of high strength with ultra-low weight, but require costly technology investments. Low volume production makes it difficult to exercise economies of scale using CFRPs in select applications. Supply chain optimization, refinement of manufacturing techniques, and installation of quality assurance infrastructure are key to volume applications of CFRPs in the automotive industry (Fig. 4). BMW has invested substantially in each of these areas. Last year, the automaker announced its i3 and i8 all-electric vehicles, which both have a body consisting solely of CFRPs (Fig. 3). Vehicles are constructed of two major units—a CFRP-based passenger portion and an aluminum-based drive module.

Recognizing the challenges involved in a pure composites-based approach to lightweighting, many manufacturers are employing mixed material strategies. Applying aluminum and aluminum alloys where strength is required yet complex shapes are desirable, designers achieve weight reduction goals without sacrificing performance or form.

Joining steel, aluminum, and alloy-based components poses one set of challenges, while joining metals to composites creates new ones. Structural adhesives must be thoroughly characterized to assess their capacity to cohesively join dissimilar surfaces, manage the varying expansion rates of the materials to which they are bonded, and enable the properties profile required by the application. Adhesives create specific quality control challenges, not the least of which is environmental. Temperature control is necessary to ensure correct bonding and curing of adhesives on a tight time schedule, says Baron. Maintaining uniform adhesive thickness is also critical. However, he notes that even adhesives can be problematic with regard to lightweighting initiatives, because bonding compounds typically weigh more than rivets or spot welds.

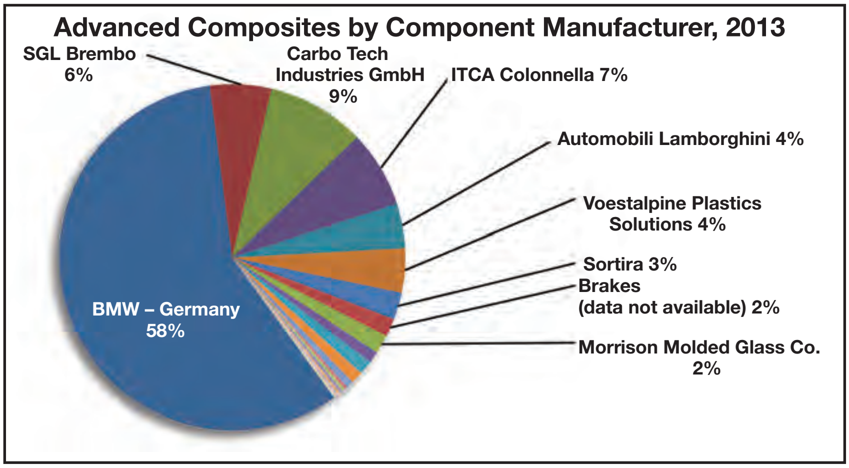


Fig. 1 — *Advanced composites drive down weight requirements, by identified component manufacturer, 2013. Courtesy of Composites Forecasts and Consulting LLC.*

Fig. 2 — *The 2015 Ford F150 boasts a body comprised of aluminum alloys, reducing truck weight by 700 lb.*

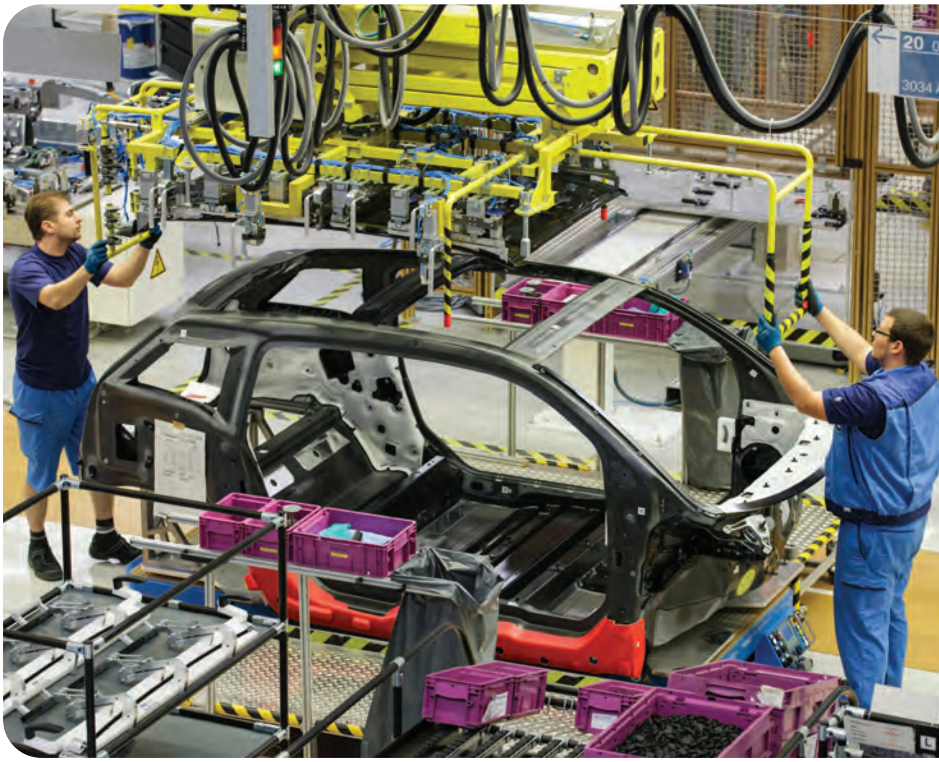


Fig. 3 — *Final assembly of the BMW i3 electric vehicle at the manufacturer's Leipzig, Germany, site. Courtesy of BMW AG.*

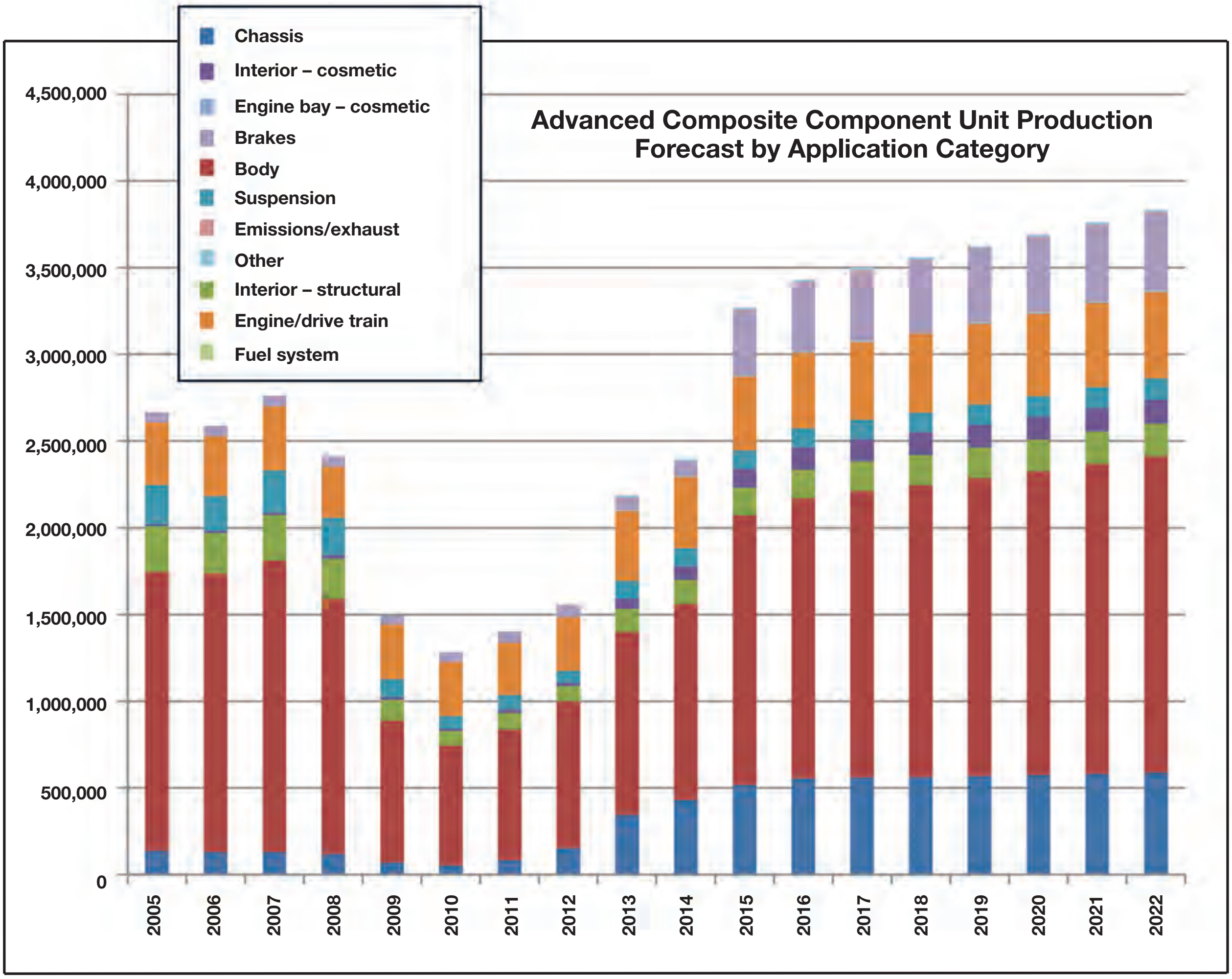


Fig. 4 — *Advanced composite component unit production forecast by application category. Courtesy of Composites Forecasts and Consulting LLC.*

Adhesive quality control begins with the supply chain, emphasizes Baron. Adhesive properties need to be standardized to ensure consistency and integrity in the bonding process. Testing of joints between materials usually requires destructive testing and knowledge of mechanical engineering. As new adhesives are developed, quality control will require greater knowledge of chemical engineering.

Assessing the properties of materials on an individual basis—as well as collective performance within a joined system—supports the realization of design goals. With materials selection processes complete, manufacturers must then assess the quality of inbound products from suppliers as well as performance of components in joined systems. The capability to accurately determine crucial properties, such as percent elongation at failure, modulus, shear strength, and flexure in a manner that supports high throughput is paramount. Materials testing equipment has traditionally been used to evaluate small samples. As quality assurance moves from the lab to the manufacturing floor, capacity to handle high volume is the key to large scale implementation of quality testing.

Solutions for mixed materials strategies

One company making headway in mixed materials qualification is Zwick/Roell, a testing equipment supplier based in Germany. The company has developed solutions that support both R&D (materials selection and design validation) and quality control testing applications for aluminum/aluminum alloys and composites. Its new-generation Allround-Line testing system is well suited to the high throughput test environment mandated by both materials selection routines and quality management processes for lightweighting initiatives (Fig. 5). Rapid test and positioning speeds, coupled with fast return, reduce cycle times for testing. Intelligent features such as integrated adaptive control with automatic setting of all control parameters, sophisticated strain-rate control, and online compensation for changes in specimen properties enable lab managers to spend more time focusing on results analysis than test setup. For example, applications such as buckling tests on lightweight vehicle door components demonstrate the flexibility of the new system.

"The Allround-Line systems contain dual testing areas that minimize changeover time between tests and deliver the flexibility that R&D labs require, as well as the throughput that quality control environments demand," says Helmut Fahrenholz, composites industry manager for Zwick.

Composite testing challenges

Composites are anisotropic and therefore present challenges. In addition, the properties of fiber-reinforced composites greatly depend on fiber and matrix materials, alignment of fibers, and the fiber-matrix interface. Materials testing must therefore employ a variety of tests in order to characterize all properties. These tests are described in international standards (ISO) as well as national and regional standards such as ASTM, EN, and DIN. Automotive manufacturers also have established their own standards, which set performance criteria for suppliers and ensure manufacturing quality.

Because robust composites characterization requires conducting a wide range of tests, manufacturers and suppliers used multiple testing systems with varying test arrangements. In contrast, Zwick's Allround-Line system enables testing of specimens with loads to 100kN and 250kN. The system covers 21 different types of tests, representing approximately 115 standards, while a temperature chamber enables testing from -70° to 250°C. Tests with the new system range from determining interlaminar shear strength and fracture toughness to characterizing static compression.

"This means that some highly complex tests can be performed with the new machine in addition to the usual tensile, compression flexure, and shear tests," says Fahrenholz. ❍

Fig. 5 — *Zwick's Allround-Line system supports testing of aluminum, magnesium, specialized alloys, and composites. Dual testing areas improve efficiency by reducing changeover time.*

For more information: Alex Koprivc is automotive industry manager for Zwick/Roell. Zwick USA, 2125 Barrett Park Dr., Suite 107, Kennesaw, GA 30144, 770.420.6555, info@zwickusa.com, zwickusa.com.

Naval Academy Attacks Corrosion with Education and Research

Joel J. Schubbe
U.S. Naval Academy
Annapolis, Md.

The U.S. Naval Academy is expanding awareness about corrosion-related material degradation, its effects on force readiness, and efforts to manage it.

Founded in 1845 and now the undergraduate college of the Navy, the U.S. Naval Academy (USNA), Annapolis, Md., prepares young men and women to lead naval forces as commissioned officers after four years of classes and training. Because the naval fleet has changed dramatically since its early days, the classes and topics students must master in order to maintain ships have also evolved. Many organizations within the Department of Defense (DoD) recognize the importance of the next generation of leaders and their ability to address material degradation and corrosion in the aging—and sometimes irreplaceable—systems that the armed forces rely on.

The Office of the Secretary of Defense through the Technical Corrosion Collaboration, the Naval Research Laboratory, the Air Force Research Laboratory, the Air Force Institute of Technology, the Naval Air Systems Command, and others, have all implemented efforts to address expanded education efforts and technical understanding of materials degradation. One of the goals of the Naval Academy's corrosion efforts and corrosion-related STEM activities is to educate students to understand materials degradation processes and prevention methods for aging defense systems. The USNA has a robust undergraduate engineering program with many research opportunities.

Recent corrosion research

Corrosion, corrosion fatigue, fracture and fatigue, surface treatments, hybrid materials, and composites are central subjects of the mechanical engineering faculty for materials and mechanics, and have inspired many summer internships and research projects in recent years. For example, Peggy LeGrand, as a Bowman Scholar, with professor Michelle Koul pursued "Environmentally Assisted Cracking Evaluation of UNS N06686 Using Constant Extension Rate Testing" and presented results at the 2010 NACE Conference.

Fig. 1 —*Professor Patrick Moran teaches high school students about corrosion testing.*

In addition, Jennifer Jones produced "An Evaluation of the Corrosion and Mechanical Performance of Interstitially Surface Hardened Stainless Steel" and is currently a graduate student at University of Virginia studying with Jimmy Burns. Eric Arnold, an independent research student, with associate professor Joel Schubbe and professor Patrick Moran presented work at the 26th ICAF Symposium and published in the *Journal of Materials Engineering and Performance* with "Comparison of SCC Thresholds and Environmentally Assisted Cracking in 7050-T7451 Aluminum Plate." Follow-up work was performed by Martin Bennett, a recent graduate of the Naval Postgraduate School.

U.S. Naval Academy, Annapolis, Md., founded in 1845.

Battling corrosion fatigue

Corrosion is the most insidious form of damage commonly present in DoD weapon systems and infrastructures and has many facets. One of the most dangerous and prevalent is *corrosion fatigue,* damage that occurs due to cyclic stresses combined with corrosive environments. It reduces the operational life of many systems and infrastructures, such as aerospace structures, ships, submarines, and bridges. Catastrophic consequences can result when corrosion fatigue is not prevented or corrected.

Midshipmen (MIDN) Sabrina Reyes and Scott Bolstad, members of the USNA Bowman Scholar program fostering nuclear expertise officers, were recently featured in *CorrDefense*

Fig. 2 — *Trident Scholar and former Brigade Commander Jennifer Jones demonstrates strain rate testing to her mentors.*

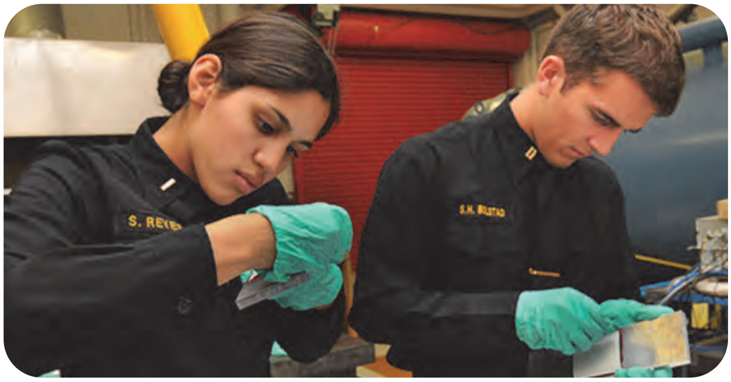


Fig. 3 — *MIDN Sabrina Reyes and Scott Bolstad conduct corrosion fatigue research on composite repairs of aluminum alloys for aerospace and naval ship applications. Courtesy of CorrDefense DoD News.*

DoD News (Fig. 3) displaying their ongoing corrosion fatigue research on composite repairs of aluminum alloys for aerospace and naval ship applications. These experiments continue Schubbe's work with boron-epoxy repairs and expand the research into four different alloy systems and two composite repair applications. Preliminary experiments in 2013 showed a significant increase in fatigue rates of cracks in corrosion-resistant aluminum alloys when simulated seawater was applied to the repair area. In addition, durability testing was done through the Naval Research Laboratory's Key West facility, coordinated by Robert Bayles and Sean Olig, to examine repair bonds over time and when subjected to seawater immersion. Only minor bonding degradation was observed due to some biofouling of the repair systems. Seawater exposure to these repair systems was tested on cracked and repaired specimens of 7050, 7075, 6061, and 5083 aluminums; data is now being reviewed.

Standard flat aluminum specimens with an electro-discharge machined (EDM) pre-notched center hole were tested. Specimens were pre-cracked to a specified length then repaired using one of two composite combinations. Boron-epoxy with AF-163-2 adhesive or graphite-epoxy with an electrically insulative fiberglass layer was applied and cured at elevated temperature and vacuum bagged to simulate a field repair scenario. Specimens were then subjected to tension-compression sinusoidal fatigue loading at R = -0.3 to grow the crack in either ambient lab air or subjected to a saltwater solution simulating seawater in the crack damage. Results were promising, showing the patches extend life. However, some indications still show a negative effect from a potential galvanic couple between the graphite patch and the aluminums.

Preliminary results were presented at the USNA Student Research Fair on May 1 and final results will be presented at the TCC (Technical Corrosion Collaboration – OSD) Program Review meeting in August at The University of Akron. One of the goals of the TCC is to enhance the education of potential DoD employees in the area of corrosion and expand the workforce involved in repairing aging systems for the nation's naval forces.

The USNA program continues to grow and attract interested students with the help of the TCC and other naval organizations. The ultimate goal is to expand awareness relative to corrosion and corrosion-related material degradation, its effects on force readiness, and efforts to manage it. ❍

For more information: Joel J. Schubbe is an associate professor at the U.S. Naval Academy, 590 Holloway Rd., Annapolis, MD 21402, 410.293.6426, schubbe@usna.edu, usna.edu.

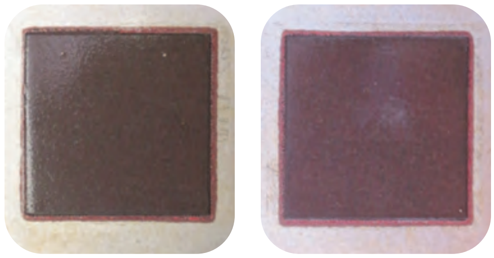


Fig. 4 — *Corrosion test samples from the Key West NRL facility.*

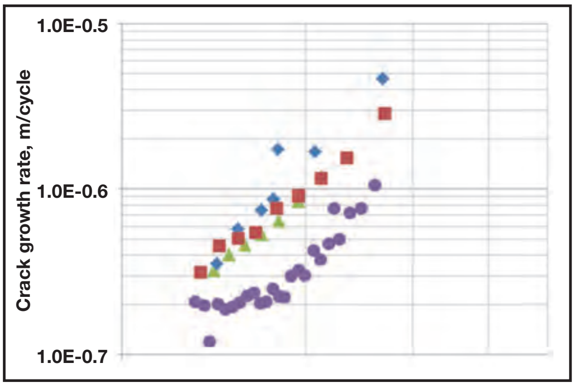


Fig. 5 — *Research results.*

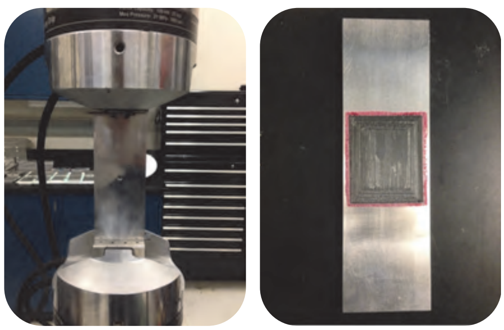


Fig. 6 — *U.S. Naval Academy testing of composite repair for corrosion fatigue.*

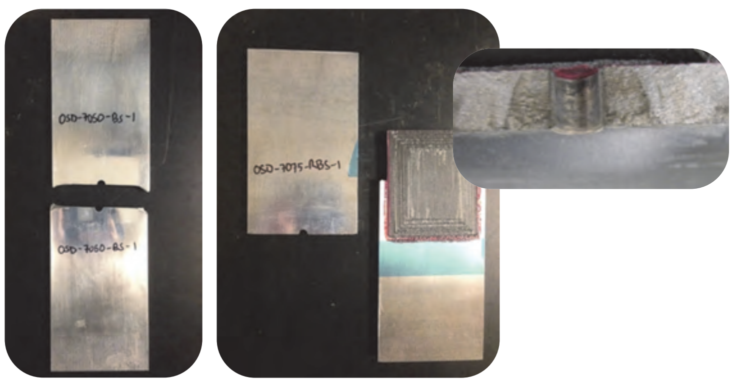


Fig. 7 — *Exposed failed test specimens.*

Full Spectrum Infrared Light Analysis Enhances Web Gauging Applications

Accurate multi-component thickness and moisture data is critical to the productivity and efficiency of producers of plastic films, extrusion coatings, blown films, and nonwoven fabrics. Collecting this data on production lines in real-time ensures that raw materials are not wasted and that all products meet relevant specifications. This becomes even more important as polymer material costs rise. Several different noncontact online analysis techniques exist, which primarily measure thickness by passing either nuclear or electromagnetic radiation through the web and measuring its absorption patterns via a detector on the other side of the material.

Nuclear web gauging instruments are some of the earliest online measurement technologies. Using sources like Krypton 85 and Promethium 147 to emit a directed beam of particles at test materials, these instruments can provide valuable and accurate thickness data but are limited in measurement capabilities and cost. In addition to obtaining a regulatory license to operate and incurring maintenance costs associated with replacing the source, users of nuclear web gauging instruments often need to hire a radiation safety officer and submit to annual inspections. Depending on the country where the instrument is operated, users may be subject to additional regulatory and licensing requirements.

Infrared (IR) instruments avoid these burdens by using infrared light to measure layer thickness. Because every component in a multilayer web has a specific pattern of infrared absorption unique to its chemical structure, web composition, multilayer thickness data, moisture, and other parameters can be found by measuring the absorption and reflection of a light source through a multilayer web. Two primary types of IR web gauging sensors exist: Spinning filter wheel and solid-state full spectrum.

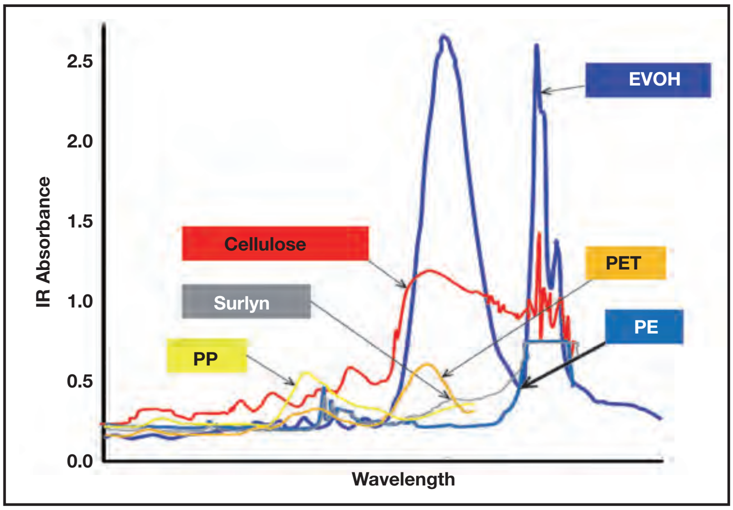


Fig. 1 — *Full spectrum absorption patterns for common web materials, taken using the Thermo Scientific PROSIS sensor.*

Spinning filter wheel sensors

The spinning filter wheel offers the simplest design, which determines moving web thickness using a ratiometric measurement technique that compares two IR absorption readings. These readings are taken through two different light filters, attached to a spinning wheel positioned near the web. The first filter is called the reference filter (R) and it selects a wavelength with very low absorption for the analyzed material. The second filter is known as the measurement filter (A) and uses a high absorption wavelength. After readings are taken, the A/R ratio provides a result proportional to web thickness.

Spinning filter wheel sensors present several challenges. Because each material in a multilayer web has its own absorption pattern, these sensors cannot measure multiple materials simultaneously without additional A and R filters. These filters increase upfront instrument costs, require more maintenance, and compound the risk of failure. Additionally, any changes to the composition of the web being measured require new filters. Spinning filter wheels require a finite amount of time to rotate, so measurements suffer from spatial displacements between readings. Further, each filter measures a slightly different spot on the web, making precise measurements difficult. While design improvements have incrementally increased filter wheel speed over time, they are unable to overcome this limitation.

Spatial displacement and the limited number of wavelengths measured by filter wheel sensors also make them prone to error in certain circumstances. Moving webs that include printed substrates, pigmentation, or nonuniform base substrates have different absorption patterns than those that do not, especially when variations are not uniform across the entire web (i.e., printed text and paper board). Sheet flutter can also cause errors, as it can alter absorption for one or both of the A and R readings. The same is true for varying light conditions in the area surrounding the instrument.

Solid state full spectrum sensors

Full spectrum IR web gauging instruments were developed to overcome the regulatory and technical issues of nuclear and spinning filter wheel IR sensors. Unlike spinning filter wheel sensors, which use only one wavelength of IR light per filter at a time to take measurements, full spectrum IR instruments emit the entire spectrum of near infrared (NIR) light and take absorption measurements for all wavelengths simultaneously. These instruments are able to continuously measure the complete absorption pattern of a given material rather than just a single wavelength.

Full Spectrum IR sampling eliminates many of the problems that come with filter wheel IR web gauging sensors. Because the entire NIR spectrum is sampled simultaneously, inaccuracies caused by spatial displacement are

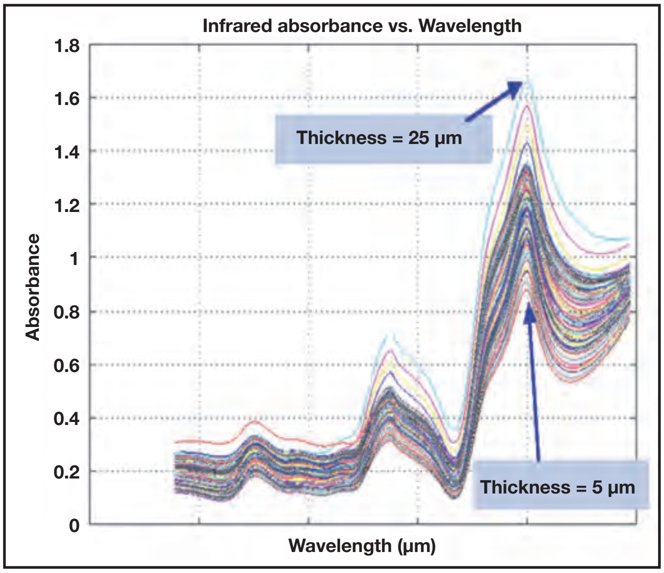


Fig. 2 — *Absorbance levels for various material thicknesses.*

completely eliminated. Taking all measurements from the exact same point on the web prevents measurement errors caused by nonflat base substrates, sheet flutter, and ambient light change.

Because full spectrum IR web gauging sensors lack the moving parts of a filter wheel, they have significantly fewer possible failure points. This makes them more reliable and less likely to require maintenance. They can also be easily recalibrated for new material measurements via software and require no hardware or filter changes.

Chemometrics software like that offered by Thermo Scientific, Waltham, Mass., called EZCal, offers easy recalibration for maximum product measurement flexibility. Using a broad set of mathematical manipulation techniques, this software can analyze complex sets of overlapping spectra to provide accurate measurements of mono- and multi-component webs. It also eliminates the effects of printing and additives, which can cause spinning filter wheel sensors to provide inaccurate measurements.

In a full spectrum measurement, web component thickness is determined by measuring total absorption across the material's unique fingerprint. Figure 2 shows an example of the absorption pattern for a given material, with thicknesses varying from 5-25 µm. Typically, graphs like this are only seen in an FSIR instrument's output in diagnostic mode. Most of the time, the chemometrics software performs thickness analysis on its own and provides an easy-to-read figure for each web component. Accurate multi-component analysis offered by full spectrum IR web gauging instruments makes them well suited for both simple and complex web process monitoring applications, including cast film, biax film, extrusion coating and laminating, blown films, and nonwovens.

A typical multilayer blown film may contain skin layers of polyethylene (PE), a barrier layer of ethylene vinyl alcohol (EVOH) or Surlyn, and tie layers. For this application, a full spectrum IR sensor analyzes the spectra of the multilayer structure and is able to separate the thicknesses of each material across the entire web. Full spectrum IR sensors also excel in multilayer extrusion coating and lamination applications, as they are capable of accurately

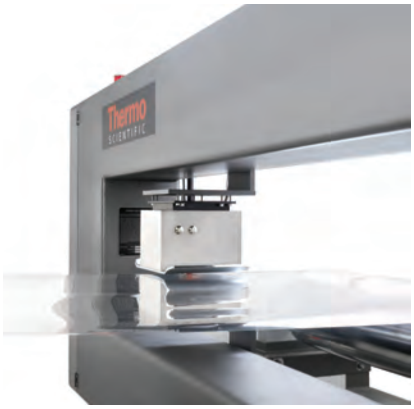


Fig. 3 — *PROSIS IR process analysis thickness sensor.*

measuring thin layers of polyethylene terephthalate (PET), PE, and polyacetylene (PA) simultaneously, for example.

Applications

Production of nonwovens, including spunbond, spunlace, spunlaid, and airlaid webs, is a good application for full spectrum IR web gauging technology. Applicable materials measurements for analysis of nonwovens include polyethylene (PE) or polypropylene (PP) fibers, latex binders, superabsorbent polymers/materials, and total basis weight. Full spectrum IR instruments can also continuously monitor the moisture content of nonwoven materials—important for nonwovens with personal hygiene, medical, and geotextile purposes.

In addition to a transmission mode that measures web absorption of the NIR spectrum, full spectrum IR sensors such as Thermo Scientific's PROSIS can be configured to measure a web in reflection mode. This configuration excels at measuring coating thickness on metal sheets or other opaque substrates. Typical measurements for coated metal sheets include top and bottom paint thickness, oil film thickness, and primer or lacquer layers. Reflection measurements are also useful for tandem extrusion coating and aseptic packaging production.

Another important application of full spectrum IR sensor technology is lithium ion battery (LIB) production. Complex multilayer separator films, which separate the cathode and anode in all LIBs and facilitate the flow of charged ions, are critical to battery efficiency and lifetime. Full spectrum IR instruments can help improve thickness consistency and ensure a more homogenous distribution of pores in the separation film to maximize performance. Essentially any web production industry could benefit from the versatility, ease of use, increased precision, and reduced maintenance costs of full spectrum IR web gauging instruments. In certain cases, nuclear sensors can also be switched to full spectrum IR sensors, to reduce regulatory burdens. Through their full spectral response measurement capabilities and advanced chemometrics analysis technique, full spectrum IR thickness sensors enable production of more on-spec products and reduce material waste without compromising profitability. ❍

For more information: Tam Nguyen is product marketing manager – web gauging, Thermo Fisher Scientific Inc., 81 Wyman St., Waltham, MA 02451, 978.663.2300, tam.nguyen@thermofisher.com, thermofisher.com.

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Inform. Connect. Inspire. Evolve. These are the actions that ASM has always stood for. Today, our new brand emphasizes that we stand together stronger than ever.

Thom Passek, *Managing Director*

Metallurgy Lane

The Toolmakers: Part II

Modern society has evolved and progressed in no small part due to the availability of cutting tools made of high-speed steel.

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

A shortage of tungsten during World War I forced many high-speed steel users to fall back to carbon steel, a 50-year technology regression. After the war, a major research effort in high-speed steels at Watertown Arsenal, Mass., looked at substituting molybdenum—tungsten's sister metal—in J.A. Mathews' successful T-1 alloy. This work was done during the late 1920s and early 1930s, and substituted approximately 9.5% Mo for the 18% W in the T-1 alloy—a roughly 1:1 atomic replacement. Major accomplishments included using a borax coating during heat treating to protect the surface and incorporating molten salt baths to heat the steel during hardening. A significant drawback of all previous high-molybdenum tool steels was the excessive loss of surface carbon during heating.

99.99% pure molybdenum crystal. Courtesy of Jurii/Wikimedia Commons.

It was widely known that large deposits of Mo were present in the Colorado Rocky Mountains. Within a few years, consumption rapidly increased partially due to the growing adoption of Mo in engineering alloy steels. With increased supply from the Climax Molybdenum Co., the price finally became competitive with tungsten for use in high-speed steel. Price alone, however, was not the main driver for replacing W with Mo: Technical acceptance in the industrial marketplace among tens of thousands of tool makers, tool room foremen, and machinists was the final hurdle. The Watertown Arsenal work was interesting, and many applications were discovered for the new tungsten-free, molybdenum high-speed steel within various arsenals around the country. However, it never gained acceptance in industry as a T-1 competitor.

99.98% pure tungsten rods with evaporated crystals, partially oxidized with colorful tarnish; high-purity tungsten cube for comparison. Courtesy of Alchemy-hp/Wikimedia Commons.

Major breakthrough

The first significant breakthrough regarding commercial development of Mo high-speed steels was discovered by Joseph V. Emmons at the Cleveland Twist Drill Co. In 1933, he received his patent and published a technical paper in which he briefly reported that all-molybdenum steels (tungsten-free) were inferior to T-1. Emmons also pointed out that substituting small amounts of Mo for some of the W was not worthwhile. His major discovery was that a Mo-W ratio of roughly 4:1, for a total of 10% of the steel, offered a critical composition that could compete against T-1's 18% tungsten recipe. His paper, "Some Molybdenum High Speed Steels," won the coveted Henry Marion Howe Medal in 1933, an annual award still presented by ASM International.

Beautiful bits from Cleveland Twist Drill Co., circa 1933, the first company to commit to Mo high-speed steel.

Cleveland Twist Drill significantly boosted the manufacture of Mo high-speed steel by ordering more than $1,000,000 worth, based solely on confidence in Emmons and his 15-year quest for the best T-1 replacement. Many modern high-speed steel compositions still fall under various patents issued to Emmons.

Industrial practices, however, die hard and at the time of America's entry into World War II, more than 80% of high-speed steels were still of the tungsten type. The War Production Board provided encouragement for the massive technological shift to molybdenum by denying the tool steel industry the tungsten it required to maintain production. Thus, Mo high-speed steels became the dominant type during World War II and beyond.

Scientific understanding progresses

Fast forward 40 years past Taylor and White's discovery of high-speed steel heat treatment, and 15 years since Bain and Jeffries published their theory of secondary hardening. While practical development of Mo high-speed steels steadily progressed during this time, little was done to develop a more fundamental understanding of the materials. A young metallurgy professor at Massachusetts Institute of Technology, Morris Cohen, set out to develop an understanding of the nature of high-speed steel tempering. Beginning in 1939, several studies were published by Cohen and a series of graduate students who wrote their doctoral theses on high-speed steel.

The first paper, by M. Cohen and P.K. Koh in 1939, set the tone for many that followed. They reviewed the literature on secondary hardening, which showed that most researchers believed the high-speed phenomenon was caused by transformation of residual austenite to martensite during tempering. A considerable amount of residual austenite was always seen in the microstructure of as-cooled high-speed steel, but it was replaced by martensite after tempering. Cohen and Koh studied changes in properties after heat treating at various temperatures and times. The variable of time at tempering temperature had never been examined adequately. In addition to x-ray diffraction of solid samples, they studied changes in electrical and magnetic properties, length, volume, and hardness. They concluded there were four stages to the reactions in high-speed steel during tempering:

1. Formation of iron carbide (Fe_3C)
2. Precipitation of carbide in retained austenite
3. Transformation of retained austenite to martensite
4. Precipitation of alloy carbides in martensite

Cohen and Koh's paper showed for the first time in American technical literature that retained austenite did not transform to martensite at the tempering temperature, but rather on cooling. Time spent at the tempering temperature conditioned residual austenite for its subsequent transformation. The basic conclusion was that stages two and three contributed the secondary hardening. This conclusion continued the conventional wisdom that somehow the transformation of retained austenite was the cause of secondary hardening, or *red hardness,* and that the eventual formation of alloy carbides upon long exposure to temperatures of 1100°F or higher was insignificant.

During World War II, the War Production Board rationed commodities such as gasoline, metals, rubber, paper, and plastics, enabling the massive technological shift to molybdenum by denying the tool steel industry the tungsten it required to maintain production.

During the next decade, Cohen and his students continued their research studies on steel. Some of the work pertained directly to high-speed steel, while other research applied more broadly to steels in general. The work on tempering of high-speed steel showed that little was understood about the tempering of all hardenable steels. Such a study was undertaken by Antia, Fletcher, and Cohen and reported in 1944. One of the last papers in the high-speed steel series, by Cohen and Blickwede, explored the effects of vanadium and carbon on 6% tungsten, 5% molybdenum high-speed steel. This new steel was becoming very popular in industry under the M-2 designation.

Walter Crafts and John Lamont of Union Carbide and Carbon Research Laboratories published another paper in 1948 of great importance to high-speed steel. They studied the effects of alloying elements on ordinary engineering steels, so they increased the amount of alloy until it approached the level found in tool steels. Secondary hardening peaks were found after tempering, even though these steels did not contain residual austenite from quenching. This work finally killed the retained austenite theory, stubbornly held since the days of H.C. Carpenter more than 40 years earlier. Tiny carbide particles were found forming at tempering temperatures corresponding to the high-speed steel hardening peak. These small carbides were found by x-ray refraction to be alloy carbides of Mo_2C, W_2C, or VC in various Mo, W, and V steels. This research supported the now 25-year-old theory of Bain and Jeffries, which stated that alloy carbides were the direct cause of secondary hardening in high-speed steels.

Morris Cohen was educated and served his career at MIT. He was awarded the ASM Gold Medal in 1968, the National Medal of Science presented by President Carter in1976, and elected to the National Academy of Science, Engineering Division. Courtesy of MIT.

Hats off to the tool makers

It is now nearly 150 years since the first alloy tool steel was invented by Robert Mushet and more than a century since Taylor and White's discovery of specialized heat treatment. In this brief historical time, our modern technological society came into being in no small part due to the availability of advanced cutting tools made of high-speed steel. The early pioneers who contributed to these special steels will forever be known as the "tool makers."

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

ASM International Heat Treating Society
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JUNE 2014 • VOLUME 2 • ISSUE 2

HTPRO

BUSINESS AND TECHNOLOGY FOR THE HEAT TREATING PROFESSIONAL

SIZING QUENCH TANKS

PAGE 6

FLOWMETER OVERVIEW

PAGE 10

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ASM International Heat Treating Society
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JUNE 2014 • VOLUME 2 • ISSUE 2

HTPRO
BUSINESS AND TECHNOLOGY FOR THE HEAT TREATING PROFESSIONAL

TABLE OF CONTENTS

DEPARTMENTS

Editorial Opportunities for *HTPro* in 2014

The editorial focus for *HTPro* in 2014 reflects some key technology areas wherein opportunities exist to lower manufacturing and processing costs, reduce energy consumption, and improve performance of heat treated components through continual research and development.

September	Surface Engineering
November	Atmosphere/Vacuum Heat Treating

To contribute an article to one of these issues, please contact Frances Richards at frances.richards@asminternational.org. To advertise, please contact Erik Klingerman at erik.klingerman@asminternational.org.

ABOUT THE COVER:
Hot furnace charge prior to immersion into a quench bath. From "Houghton on Quenching," Houghton International Inc., Valley Forge, Pa., houghtonintl.com.

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ASM to Lead Thermal Manufacturing Industries Advanced Technology Consortium

Thermal manufacturing, consisting of heat treating, melting, and other process heating methods, is used in nearly every manufacturing facility in the U.S. It affects the employment of an estimated 8.3 million Americans at more than 262,000 companies, according to the U.S. Census Bureau. The Bureau says these companies (98% of which are small and medium enterprises) produce $3.4 trillion in total value of annual shipments.

Advanced thermal manufacturing technologies potentially can improve the efficiency, productivity, and global competitiveness of many U.S. materials manufacturing and value-added, end-user industries. However, technical challenges identified in previous roadmapping efforts (such as the Heat Treating Technology Road Map) are still preventing development and deployment of these technologies. The main reason is because these roadmaps were developed independently from one another by different industries that rely on or supply thermal equipment and processes as a critical part of their operations. Understandably, these thermal manufacturing industries focused primarily on their specific areas of interest. As a result, there has been a lack of the necessary coordination and critical mass needed to address the technical challenges facing these industries. In addition, there has been an incomplete transfer of available technologies to the small and medium enterprises that make up a large segment of the thermal manufacturing industries.

To address these issues, the proposed Thermal Manufacturing Industries Advanced Technology Consortium (TMI ATC) will be formed to lead and coordinate a national effort to develop and deploy advanced manufacturing technologies across the broad thermal manufacturing community, including equipment manufacturers and end users. Specifically, TMI ATC will lead the development of a comprehensive R&D roadmap that identifies common thermal manufacturing needs across industries and solicits the input from key stakeholders in highly interactive, action-oriented technology roadmapping workshops. The results of these sessions will identify advanced manufacturing technologies ready for implementation in thermal manufacturing industries as well as high-priority areas for development. This 18-month process will generate a final roadmap in the first year, and will then begin to implement the recommendations during the remaining months.

The proposed structure of the consortium will facilitate technology implementation and sustainability. TMI ATC will be led by ASM International through a federal grant. ASM, from its founding roots, and now primarily through its affiliate Heat Treating Society, is a leader in collecting and disseminating thermal-manufacturing information, and has many relationships with industrial companies.

The ASM Heat Treating Society has been involved for the past 15 years in identifying and prioritizing key initiatives in heat treating-related areas of equipment and hardware materials technology, processes and heat treated materials technology, and energy and environment technology. This puts the society in a prime position to extend this work with the cooperation of other consortium participants.

Ed Kubel
Contributing Editor

New Face for Heat Treating Society Website

The Heat Treating Society (HTS) website joined the ASM International website on the new technology platform. What can you expect with this new development?

One ID, One Password – If you login to the ASM website, you will automatically be signed in if you navigate to the Affiliate website (and vice-versa). One ID/email address and one password for the ASM and ASM Affiliate websites.

Fast Checkout – The new, overhauled checkout process is designed after well-known Internet commerce vendors. When you add a purchase to your shopping cart on your Affiliate website, you can also take advantage of adding products through the ASM website "Store." In addition, you can "Checkout as Guest," which speeds up and minimizes the time to register on the website.

Find Content Easier – New ability to find content by Subject, Resource Type, Publication Date, and Author to find exactly what you are looking for to solve materials problems quickly and easily.

Easier Reading – Enlarged text adds to a simplified look and feel.

More Connections – Profile pictures can now be uploaded to the Member Directory, which can help with recognition at networking events.

Universal Content Management – One database, one version of the entire collection of ASM content.

**It is an entirely new look and feel.
Be sure to check it out!
http://hts.asminternational.org.**

2014 HTS/Bodycote Best Paper in Heat Treating Awarded

The winner of the 2014 HTS/Bodycote Best Paper in Heat Treating Award is a paper entitled "Development of Methodology to Improve Mechanical Properties of 319 Al Alloy Engine Blocks through Cost-Effective Heat Treatment Optimization," by Anthony Lombardi. Mr. Lombardi is a third year Ph.D. candidate in mechanical engineering at Ryerson University (Toronto) under the supervision of Dr. C. (Ravi) Ravindran, ASM President. Lombardi is the recipient of the prestigious NSERC Alexander Graham Bell Canada Graduate Scholarship - Doctoral (CGS-D). The HTS/Bodycote award will be presented at the ASM Leadership Awards Luncheon, Monday, October 13, 2014, during MS&T in Pittsburgh.

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 some substantial way, or represents a clear advancement in managing the business of heat treating. The award includes a plaque and $2500 cash prize endowed by Bodycote Thermal Process-North America. Visit asminternational.org/hts to read the winning paper.

Winner of the HTS/Bodycote 2014 Best Paper in Heat Treating Award, Anthony Lombardi.

HTS Looking for Volunteers for Committees

Whether you are a seasoned professional or just beginning your career in the heat treating industry, HTS members are encouraged to become more deeply involved in the society through committee membership.

HTS committees capture key directional shifts in member needs and translate those needs into action items for potential development. Their input and recommendations enable the HTS Board of Directors to establish effective policies, set meaningful budgets, and oversee society operations.

HTS Directors and committees meet on a regular basis. As the eyes and ears of the HTS Board, society committees are invaluable for improving service to HTS members and customers. Volunteers are needed to grow HTS permanent committees to meet these objectives. The committees include:

HTS Awards and Nominations Committee, whose mission is to nominate candidates who are representative of commercial and captive heat treaters; users of heat treating; suppliers of materials and equipment; researchers, educators and government agencies involved in heat treating for the positions of president, vice president, and members of the Heat Treating Society Board as well as the development and recommendation of awards to be given by the Heat Treating Society.

HTS Finance Committee, whose mission is to supervise the financial affairs of the Society under the direction and with the approval of the HTS Board. It reviews the financial plan of the Society and recommends it to the Board for action.

HTS Membership Committee, whose mission is to understand current, past, and potential HTS member needs, refocusing efforts to provide improved member value. The committee is charged with understanding and interpreting member needs as well as achieving the financial contribution for HTS.

HTS Technology and Programming Committee, whose mission is to develop programming and technical information that provides practical, leading-edge global technology; and to foster the exchange, education, understanding, and exposure of technology within the heat treating industry.

HTS Research and Development Committee, which is charged to work with the heat treating community, the Center for Heat Treating Excellence, and other research institutions, to identify, monitor, and provide updates on worldwide research and technology development relevant to the industry.

HTS Education Committee, which is charged to research, develop, and support education programs that best respond to the needs of the heat treating industry. The committee reviews courses and revises them as necessary, and develops new educational services related to heat treating.

To express your interest, or for more information, contact Sarina Pastoric at Sarina.pastoric@asminternatinal.org.

Ferguson receives IFHTSE Fellowship 2014 Award

Dr. B. Lynn Ferguson, FASM, president, Deformation Control Technology Inc., Cleveland, was honored at the 21st IFHTSE Congress, recently held in Munich with an IFHTSE Fellowship 2014 Award.

The citation reads: In recognition of globally acknowledged leadership in the development and practical implementation of principles and practices of mathematical modeling and their application to the benefit and advancement of heat treatment industry and surface engineering. Ferguson is a longstanding member of the ASM Heat Treating Society, and past member of HTS Board of Directors.

Improving the Service Life of Furnace Materials

Heat treating companies spend a significant amount of time and money replacing furnace parts and furnace fixtures. Extending the service life of these components and reducing the time to heat them up and cool them down could result in considerable savings. The Alloy Life Extension Project currently under way at the Center for Heat Treating Excellence (CHTE), Worcester Polytechnic Institute (WPI), is aimed at solving those problems.

The focus of the project is identifying and testing alloys and coatings that can improve the service life of parts like fans, burners, rollers, tubes and mesh belts, as well as fixtures like wire baskets that carry the parts to be heat treated.

Researchers are also analyzing fixture design and material selection to reduce the energy needed to repeatedly heat fixtures. The goal is to find alloys for use in the heat treating industry that will last twice as long as current materials, resulting in significant savings.

According to Rick Sisson, George F. Fuller professor of mechanical engineering at WPI and director of CHTE, "Manufacturers are spending lots of money for alloy fixtures that go into carburizing furnaces. The goal of this study is to explore options that will allow industry to work more efficiently, lessening fixture replacement costs, reducing energy consumption, and improving product quality."

The project has already produced some interesting findings. For example, the main reason for alloy failure is excessive carburization, which causes furnace parts and fixtures to become brittle and easily fracture. Based on this information, a series of carburization-resistant alloys have been identified for commercial furnace testing, including RA602CA, Inconel 625, and Stellite 250. Samples of these alloys are being tested at the facilities of CHTE member companies Sikorsky Aircraft and Bluewater Thermal Solutions.

Different alloys are being assessed for their resistance to oxidation and carburization at two Bluewater facilities in Illinois. Multiple sets of each alloy are run for different times in test furnaces, and one of each set is removed periodically to evaluate the extent of alloy degradation. Based on visual inspection, samples are removed for metallographic characterization.

Another test being carried out at Bluewater is aimed at determining whether an aluminized section of an industrial furnace mesh belt holds up better than regular mesh belts. Craig Zimmerman, technical director at Bluewater, explains, "Mesh belts last only nine months and they are extremely expensive to replace. We are hopeful that this study will help us and everyone in the industry to identify which materials can drive down costs. If we can make any of the parts and fixtures last longer, it will be a huge savings."

Furnace fixtures at various levels of degradation.

Rick Sisson (right) and Anbo Wang work together to identify ways to extend the life of alloy parts and fixtures. Mei Yang also contributed to the study.

Part of the research is looking at ways to extend the life of mesh belts so that companies don't have to replace them every nine months at significant expense.

About CHTE

The CHTE collaborative is an alliance between the industrial sector and university researchers to address short-term and long-term needs of the heat-treating industry. Membership in CHTE is unique because members have a voice in selecting quality research projects that help them solve today's business challenges.

Member research process

Research projects are member driven. Each research project has a focus group comprising members who provide an industrial perspective. Members submit and vote on proposed ideas, and three to four projects are funded yearly. Companies also have the option of funding a sole-sponsored project. In addition, members own royalty-free intellectual property rights to precompetitive research, and are trained on all research technology and software updates.

CHTE also periodically undertakes large-scale projects funded by the federal government or foundations. These endeavors keep members informed about leading edge technology.

CHTE current research portfolio

Other projects now in progress include:
Nondestructive Testing for Hardness and Case Depth, Induction Tempering, Gas Quench Steel Hardenability, Enhancements to CHTE software (CarbTool, CarboNitrideTool, and NitrideTool), and Cold Spray Nanomaterials (supported by ARL).

For more information about CHTE, its research projects, and member services, visit wpi.edu/+chte, call 508.831.5592, or email Rick Sisson at sisson@wpi.edu, or Diran Apelian at dapelian@wpi.edu.

SIZING QUENCH TANKS FOR BATCH IMMERSION QUENCHING

A QUENCH TANK MUST CONTAIN SUFFICIENT FLUID TO QUENCH THE LOAD WITHOUT AN EXCESSIVE RISE IN TEMPERATURE OF THE QUENCHING FLUID.

D. Scott MacKenzie,* FASM, Houghton International Inc., Valley Forge, Pa.

The size of a batch immersion quench tank depends on the dimensions of the workload, as well as the allowable temperature rise. The temperature rise permitted is dependent on whether the quenchant is oil, water, or polymer.

In a batch operation, care should be taken to ensure that a sufficient amount of quenchant covers the top of the workload. The physical dimensions of the tank should be large enough to ensure full immersion of the quench load and fixtures, and, at the same time, should allow enough space for agitators and manipulators. Depending on the size of the workload, it is generally appropriate to have at least 150–300 mm (6–12 in.) of fluid over the top of the workload, and preferably more.

When using hot quenching oils, it is necessary to make an allowance for thermal expansion of the oil, either by making provision for an overflow system, or by manual adjustment of the fluid level.

Tank capacity

A quench tank must contain sufficient fluid to quench the load without an excessive rise in temperature of the quenching fluid. In an uncooled tank, the quantity of quenchant required can be calculated from the basic equation:

$$M_m Cp_m DT_m = M_q Cp_q DT_q$$

Where M_m is the mass of metal, Cp_m is the specific heat of the metal, DT_m is the decrease in temperature of the metal being quenched, M_q is the mass of quenchaant, Cp_q is the specific heat of the quenchant, and DT_q is the increase in temperature of the quenchant. Typical values for specific heat at 20°C (70°F) are:

- Steel — 0.17 cal/g/C (0.17 Btu/lb/F)
- Aluminum — 0.23 cal/g/C (0.23 Btu/lb/F)
- Quench Oil — 0.50 cal/g/C (0.50 Btu/lb/F)
- Polymer Quenchant — 0.95 cal/g/C (0.95 Btu/lb/F)
- Water — 1.0 cal/g/C (1.0 Btu/lb/F)

A general guideline for steel quenching (for a single quench) is that 10 liters of oil is required for each kilogram of total charge weight (1 gal/lb). This rule of thumb results in about a 40°C (70°F) temperature rise under nominal conditions, which is recommended to prevent the oil from reaching the flashpoint of the fluid. It is recommended that the maximum temperature during quenching using oils always should be at least 55°C (100 °F) below the flash temperature, which mitigates the potential for a fire if a hung-up load occurs. This is illustrated in the following example:

Flash temperature of the oil:
175°C (350°F)
Recommended temperature
cushion: 55°C (100°F)
Temperature rise during quenching:
40°C (70°F)
Maximum recommended operating
temperature: 80°C (180°F)

However, with successive quenches, some form of cooling is necessary to prevent the oil from overheating. The heat exchanger should be sized to recover the heat produced by the quenched load within one heat treating cycle.

For example, in quenching 2270 kg (5000 lb) of steel from 870°C (1600°F), a heat treater wants to remove the parts from the oil at 65°C (150°F). The "cold quench" oil used has a flash temperature of 175°C (350°F) and operates at a temperature of 60°C (140°F). Based on these process parameters, the maximum peak temperature of the oil (considering the flash point of 175°C), would be 120°C (250°F). What should the minimum size of the quench tank be? Using the equation given above:

$$M_m Cp_m DT_m = M_q Cp_q DT_q$$

or

$$M_q = M_m Cp_m DT_m / Cp_q DT_q$$

therefore

$$M_q = 5000 \text{ lb } (0.17 \text{ Btu/lb/F})$$

$$(1600 - 150\text{F})/0.50 \text{ Btu/lb/F } (110\text{F})$$

$$M_q = 22{,}409 \text{ lb } (10{,}185 \text{ kg}) \text{ oil}$$

At a weight of 6.8 lb/gal (0.8 kg/liter), approximately 3300 gal (12,500 liters) are required for these conditions. However, this temperature rise is a bit excessive and could lead to premature oxidation of the oil. Alternatively, rearranging the equations using a fixed size quench tank allows solving for the temperature rise during quenching.

Water and polymer quenchants have a different limitation on temperature. This is not related to safety, as with quench oils, but effective cooling for water, and maximum operating temperatures for polymer quenching. For water, the maximum temperature is 100°C (210°F). However, this limit is rarely used as the cost of make-up and cooling becomes excessive. For polymer quenchants and water used in quenching aluminum, aerospace standards specify a maximum

Hot charge ready to be quenched

**Member of ASM International and Heat Treating Society.*

temperature rise of 5°C (10°F) with a maximum temperature of 45°C (110°F). For polymer quenchants, it is somewhat more difficult. The maximum temperature for polyalkylene glycol (PAG) quenchants cannot exceed the cloud point temperature. This is between 60° and 75°C (135° and 170°F) for most PAG quenchants, depending on the molecular weight of the polymer. It is also recommended that the maximum bulk temperature rise be at most 10°C (20°F) below the cloud point temperature. Polymer quenchants, besides being sensitive to agitation, are strongly affected by temperature. The cooling rate decreases significantly with increasing temperature. Small temperature rises during quenching reduce variations in cooling rate and quench rate effectiveness. This also reduces drag-out, produces more uniform quenching, and prolongs the life of the quenchant. Limiting the temperature rise greatly increases the quench tank size.

For PVP-type quenchants, there is no cloud point temperature. However, the maximum peak temperature is generally limited to 65°C (150°F) or lower to prevent destructive oxidation of the quenchant. This also reduces the amount of drag-out and chemical consumption in the system.

As an example, consider the design of a quench tank containing Aqua-Quench 3699, a hybrid polymer quenchant that does not have a cloud point. Steel parts will be quenched from 1095° to 205°C (2000° to 400°F), with a maximum load weight of 2270 kg (5000 lb). The quench tank operates at 45°C (110°F) nominally. What volume of quenchant is required in gallons?

To solve this, the maximum allowable temperature rise must first be determined. For this quenchant, the maximum temperature is 65°C (150°F). Because the quench tank is operating at 150°F, the temperature rise of the quenchant (ΔT_q) is 40°F (i.e., 150°–110°F). From the equation above, and rearranging to determine the mass of water required:

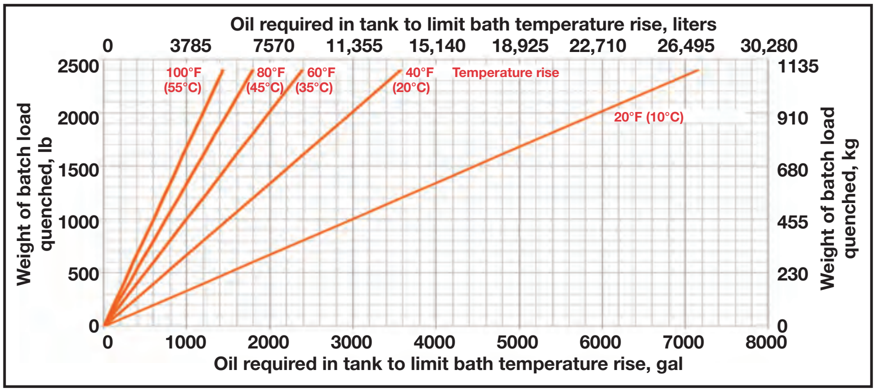


Fig. 1 — *Relationship of volume of oil quenchant and weight of quenched workload to prevent specific temperature rise of quench bath when quenched from 1600° to 140°F (870° to 60°C).*

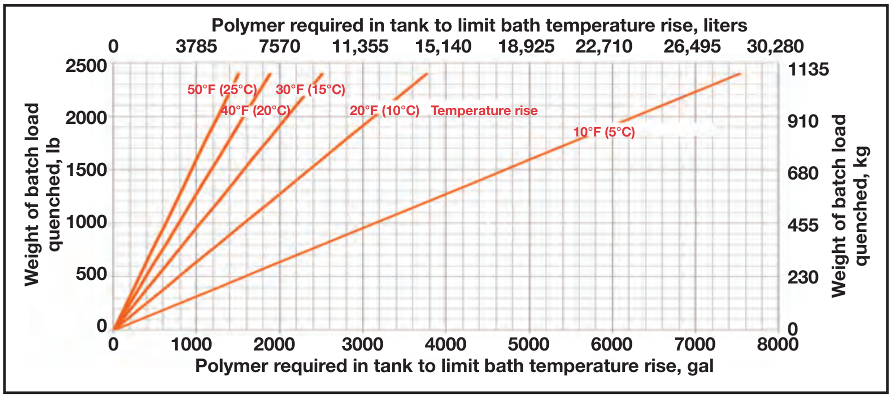


Fig. 2 — *Relationship of volume of polymer quenchant and weight of quenched workload to prevent specific temperature rise of quench bath when quenched from 1600° to 140°F (870° to 60°C).*

$$M_m Cp_m DT_m = M_q Cp_q DT_q$$

or

$$M_q = M_m Cp_m DT_m / Cp_q DT_q$$

therefore

$$M_q = 5000 \text{ lb } (0.17 \text{ Btu/lb/F})$$

$$(1600)/0.95 \text{ Btu/lb/F } (40F)$$

$$M_q = 35{,}800 \text{ lb } (16{,}270 \text{ kg})$$

polymer quenchant

A gallon of water weighs 8.33 lb/gal (1 kg/liter), so the number of gallons required to quench 5000 lb of steel is 4296 gal (16,260 liters). Temperature rise for polymer and oil quenchants are shown in Figs. 1 and 2.

System temperature control

Maintaining the temperature of the quench bath is as important as the size of the quench tank, which requires a means of temperature control.

Quenchant heating is achieved using several methods, including electrical resistance heating elements, gas- and oil-fired radiant tubes, and waste heat from the furnace exhausts. In some systems, the quenchant is heated by quenching a "dummy" hot load of parts. The energy density of radiant tubes and electrical heating elements should not exceed 1.5 W/cm^2 (10 W/in.^{2}). This prevents heaters from preferentially oxidizing the oil and depleting the oxidation additive package. This energy density guideline should also be followed for polymer quenchants, with the additional provision that maximum heater temperature should be about 70°C (160°F) to prevent exceeding the cloud point of the material. Heaters should also be interlocked with the agitation system so they shut off if the agitation system is shut off or fails. The system should also be designed to make it impossible to turn on the heating system without the agitation operating.

Quenchant cooling. Various methods are available to cool quenchants including:

- Submerged water-cooling pipes
- Cooling jackets
- External water-cooled heat exchangers
- Forced air-cooled radiators
- Refrigeration systems

Submerged water-cooling pipes and jackets are suitable only for small systems, and there is always the risk of water contamination of oil quenchants, which should be avoided at all costs. Water contamination of polymer quenchants is not critical. External water-cooled heat exchangers and air-cooled radiators are very efficient and widely used for cooling large quenching systems. For oil quenchants, air-cooled heat exchangers are nearly always used in the U.S. to prevent potential fires from water in quench oil. For polymer quenchants, water and chillers are predominately used. Air-cooled heat exchangers are generally limited to cool a quenchant to approximately 10°C (20°F) above ambient temperature. Because most polymer quenchants should be used around room temperature, the use of chiller water or other means is mandated by temperature and heat exchanger constraints.

To obtain maximum efficiency from cooling systems, the direction of circulation should be such that hot quenchant is removed from the top of the tank and then passed through the heat exchanger. Once cooled, the oil is returned to the bottom of the tank. Generally, the heat exchanger should be sized to recover the heat within one quench cycle. The equations above can be used to determine the size of the heat exchanger:

$$Q = M_m Cp_m DT_m$$

where Q is the total heat that must be extracted from the quenchant. This is the total heat given up by the quenched metal to the quenchant. To properly size the heat exchanger, the heat from the workload should be completely recovered prior to the next load. For instance, assume that an integral quench furnace is quenching an 1820 kg (4000 lb) charge into a 15,140 liter (4000 gal) quench tank at 60°C (140°F). The load is quenched from a temperature of 870°C (1600°F) and extracted from the quench at 65°C (150°F). The cycle time from one load quenching until the next load quenching is 90 minutes. The heat exchanger must recover this heat from the quench oil to return the temperature of the quench back to the original temperature of 60°C. Substituting and solving the equation gives:

$$Q = M_m Cp_m DT_m = 4000\ (0.17)\ (1600 - 150) = 986{,}000\ \text{Btu}$$

The heat exchanger must extract nearly one million Btu from the oil in 90 minutes to recover the oil temperature. In other words, the heat exchanger must be rated for at least 660,000 Btu/hr (194 kW). There also must be an adequate safety factor to compensate for different heat treating cycles and ambient conditions.

Conclusions

This brief article describes the basics of sizing quench tanks for immersion quenching and offers a methodology for sizing the temperature-control system. It is recommended to contact your quenchant supplier or heat-exchanger supplier for more detailed, precise determinations for specific applications. HTPRO

For more information: D. Scott MacKensie is research scientist – metallurgy, Houghton International Inc., Valley Forge, PA 19482, 610.666.4007, smackenzie@houghtonintl.com, houghtonintl.com.

TOOL FOR ATMOSPHERIC CARBON POTENTIAL ANALYSIS

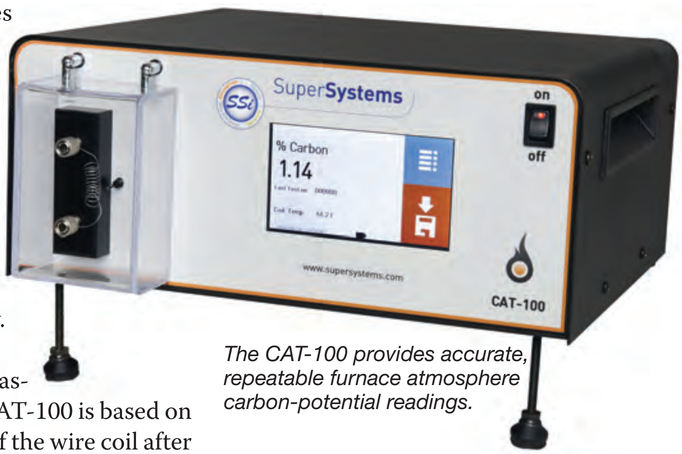
A question frequently asked by heat treaters is: "What is the actual carbon in my furnace?" There are many tools for continuous atmosphere monitoring, verification, and troubleshooting. They address standard heat treating practices and industry requirements, such as AMS or CQI-9, to ensure continuous control and periodic verification of the furnace atmosphere used for the heat treatment process.

Heat treaters regularly seek ways to prevent and reduce rework and scrap loads by implementing procedures and tools to make sure the heat treating process meets customer expectations and specifications. One process parameter requirement is to ensure consistent atmosphere carbon content. Measuring carbon absorption into steel is commonly done to verify atmosphere consistency. Super Systems's CAT-100 instrument is an atmosphere carbon potential analyzer that provides a cost-effective way to measure carbon using a wire coil that functions in a way similar to using shim stock.

Working principles

The CAT-100 measures carbon potential in a positive-pressure atmosphere. The value is determined by measuring specific properties of a steel wire coil inserted into an atmosphere made up of a carbon-bearing gas for a predefined time. The concept behind the instrument is similar to that behind the company's Shim Port method. Both use metal pieces "soaked" in a carbon-containing atmosphere as the basis for carbon analysis. Two important differences between the instrument testing method and the shim-stock method are the time required to generate a carbon-potential reading and the cost associated with the measuring instruments.

CAT-100 is capable of providing on-site carbon-potential measurement in less than one hour, while the shim-stock method requires specialized equipment that many heat treaters do not have on site. This requires having an off-site laboratory measure the shim stock, adding several days to the process. Wire coils are available for use with the CAT-100, and instrument calibration is relatively easy.



The CAT-100 provides accurate, repeatable furnace atmosphere carbon-potential readings.

Carbon potential measurement using the CAT-100 is based on the carbon content of the wire coil after soaking in the furnace, which is measured by analyzing changes in the metallurgical properties of the coil. For example, metallurgical changes caused by carbon diffusing into the coil affect its electrical resistance. Measurements are made on the coil after removing it from the furnace (at ambient temperature). Measurement accuracy is dependent on the coil temperature.

Measured carbon potential is also dependent on changes in surface metal properties. The steel surface eventually reaches equilibrium with a given gas composition and furnace temperature. Electrical resistance is directly proportional to the amount of carbon present in the fine-wire coil. Using the baseline electrical resistance and carbon content for the untreated wire, the addition and/or depletion of carbon in the heat treated wire can be accurately measured. The instrument provides a direct reading of percent carbon without the influence of gas composition.

The measurement can be influenced by nitrogen absorption into the coil from the furnace atmosphere. Because this results in erroneous readings, the instrument should not be used for carbonitriding processes.

Operating procedure

The instrument must be calibrated for use with a specific wire coil. The reason is that different lots of coils could have different carbon content, and the presoak carbon content of the coil is crucial for accurate carbon potential measurement. Before the testing process begins, the furnace atmosphere must be verified as suitable for a coil soak. Furnace temperature should be generally uniform before the coil is introduced to the atmosphere, and should not change greatly during the soak. A special insertion rod is used to place the coil into the furnace atmosphere; it must not be inserted within a furnace charge or in a basket. The coil soaks in the atmosphere about 30 to 40 minutes depending on the temperature, and is removed after the soak is completed.

When the coil cools sufficiently (quenching must not be used), it is attached to testing posts on the instrument and a carbon potential value is displayed after about 30 seconds. Readings can be stored in the instrument's internal memory and can be downloaded to a computer using included software. Following proper procedures, carbon-potential readings are accurate and repeatable. The CAT-100 is designed to provide results within 0.03% of the carbon in an atmosphere containing 0.1 to 1.3% carbon (the effective testing range of the instrument). HTPRO

For more information: Jim Oakes is vice president, Business Development, Super Systems Inc., 7205 Edington Dr., Cincinnati, OH 45249, 513.772.0060, email: joakes@supersystems.com, supersystems.com.

OPERATIONAL PRINCIPLES OF FLOWMETERS

ONCE A "SET IT AND FORGET IT" TECHNOLOGY, FLOW MEASUREMENT IS AN INCREASINGLY IMPORTANT PART OF QUALITY CONTROL SYSTEMS IN THE HEAT TREATING INDUSTRY.

Daniel H. Herring*, The Herring Group Inc., Elmhurst, Ill.

In most heat treating applications, important flowmeter selection criteria include reliability, accuracy, ruggedness, ease of calibration, and ease of maintenance. Given the high accuracy and reliability of today's instruments, users can run their processes more economically. This article discusses the most commonly used flow measurement instruments and compares their operating principles (Table 1).

Types of flowmeters

Flowmeters typically measure either volumetric or mass flow. *Volumetric flow measurement* looks at the flow of a given volume of the medium over time (e.g., ft^3/h). This technology uses either mechanical flow rate indication or electronic output (Fig. 1).

Fig. 1 — *Typical volumetric flowmeter. Courtesy of Atmosphere Engineering Inc.*

*Member of ASM International

Mass flow measurement looks at the flow of a given mass over time (e.g., lb/h). Industrial thermal mass flowmeters are often equipped with electronic output (Fig. 2). Conversions between the two measurements can be made if the pressure, temperature, and specific gravity of the flowing medium are known.

Flowmeters can be further subdivided into several general types. Of these, variable-area and thermal-mass flowmeters are most often used in heat treating applications:

- *Variable area*: Fluid flow rate is measured as the flowing medium passes through a tapered tube. The position of a float, piston, or vane placed in the flow path changes as higher flows open a larger area to pass the fluid, providing a direct visual indication of flow rate.

- *Differential pressure*: Calculating a fluid flow rate from the pressure loss across a pipe restriction is the most commonly used flow measurement technique in industrial applications. The pressure drops through these devices are well understood, and a wide variety of configurations are available, each having specific strengths and weaknesses. Variations on the theme of differential pressure flow measurement include the use of pitot tubes.

- *Mechanical*: In these instruments, flow is measured either by passing isolated, known volumes of a fluid (gas or liquid) through a series of gears or chambers (positive-displacement type) or via a spinning turbine or rotor. Measurements using a positive-displacement flowmeter are obtained by counting the number of passed isolated volumes.

- *Electronic*: Magnetic, vortex, and ultrasonic devices are available, all of which have either no moving parts or vibrating elements and are relatively nonintrusive.

- *Thermal mass*: In contrast to volumetric flow devices, thermal mass flowmeters are essentially immune to changes in gas temperature and pressure. Because measurements can be very accurate and repeatable, these devices are used in critical flow measurement applications.

Fig. 2 — *Typical mass flowmeter. Courtesy of MKS Instruments.*

Variable-area types

Variable-area flowmeters are simple, versatile devices that operate at a relatively constant pressure drop and measure the flow of liquids, gases, and steam. The popularity of this type of flowmeter in the heat treating shop is their direct-view design, where flow is indicated mechanically, which makes it easy to understand the operating principle. Several different designs of variable-area flowmeters are used throughout the heat-treating industry (Fig. 3).

TABLE 1 — COMMONLY USED FLOW MEASUREMENT INSTRUMENTS BY TYPE

Industrial flowmeter type	Style	Manufacturer (a)	Disassembly without repiping	Sensitivity to dirty fluids	Robust spare parts
Variable area, including rotameters	Metal tube	Waukee Engineering Co. Inc.	Yes	Moderate	Delicate
	Metal cylinder tube	Meter Equipment Mfg. Inc.	Yes	Low	Moderate
	Glass or plastic tube	Fisher-Porter Brooks Instrument King Instrument Co. Dwyer Instruments Inc. Key Instruments	No	Sensitive	Moderate
	Vane type	Universal Flow Monitors Inc. Erdco Engineering Corp. Orange Research Inc.	No	Moderate	Moderate
	Moving orifice	Hedland, Div. Racine Federated Inc.	No	Moderate	Robust
	Piston (with spring)	Insite (Universal Flow Monitors Inc.)	No	Moderate	Delicate
Differential pressure/ Orifice	Orifice	Lambda Square Inc. Flowell Corp.	No	Moderate	Robust
	Venturi	Flowell Corp. Fox Valve Development Corp.	No	Moderate	Robust
Turbine/Impeller	Rotary impeller	Roots (BNC Industrial Co. Ltd.) TokicoTechno Ltd.	No	Sensitive	Moderate
	Turbine	Hoffer Flow Controls Inc. Sponsler Inc. Great Plains Industries Inc.	No	Sensitive	Delicate
Thermal mass	Thermal mass	Sierra Instruments Inc. MKS Instruments Brooks Instrument	No	Sensitive	Delicate

(a) Not all-inclusive

Rotameter types

The glass or plastic rotameter (Fig. 3a), is the most widely used because of its low cost, low pressure drop, relatively wide range, linear visual flow indication, and simplicity of operation. To pass through the tapered tube, fluid flow must raise the float. The greater the flow rate, the higher the float is lifted. In liquid service, the float rises due to a combination of the liquid's buoyancy and its velocity. With gases, buoyancy is negligible, so the float responds mostly to velocity.

The float moves up and down in proportion to the fluid flow rate and the annular area between the float and the tube wall. As the float rises, the size of the annular opening increases. As the area increases, the differential pressure across the float decreases. The float reaches a stable position when the upward force exerted by the flowing fluid equals the weight of the float. Thus, every float position corresponds to a specific flow rate for a particular fluid's density and viscosity.

Features and advantages

Advantages of variable-area flowmeters include:

- Mechanical flow measurement with just a single moving part, ensuring measurement reliability
- Application versatility and availability of a variety of construction materials, inlet and outlet sizes, and types
- Easy installation with generally no straight pipe requirements
- Low pressure drops
- Linear scales, allowing easy flow measurement interpretation
- Electronic output availability, preserving the mechanical flow measurement

Advantages of tapered-tube rotameters include:

- Low instrument cost (when glass or plastic metering tube is used)
- Can be used for very low flow rates

Advantages of slotted-cylinder flowmeters include:

- Flow measurement accuracy determined by the precision of the slot manufacturing operation; good flow range of 25:1 results
- Instrument specifications can be changed by field replacement of the slotted tube and float without having to re-pipe the flowmeter vessel
- Ability to handle high flows and pressures
- Improved immunity to pulsating flows, with no minimum backpressure

Limitations common to both tapered-tube and slotted-cylinder variable-area flowmeters include the requirement of vertical mounting aand the fact that they contain moving parts.

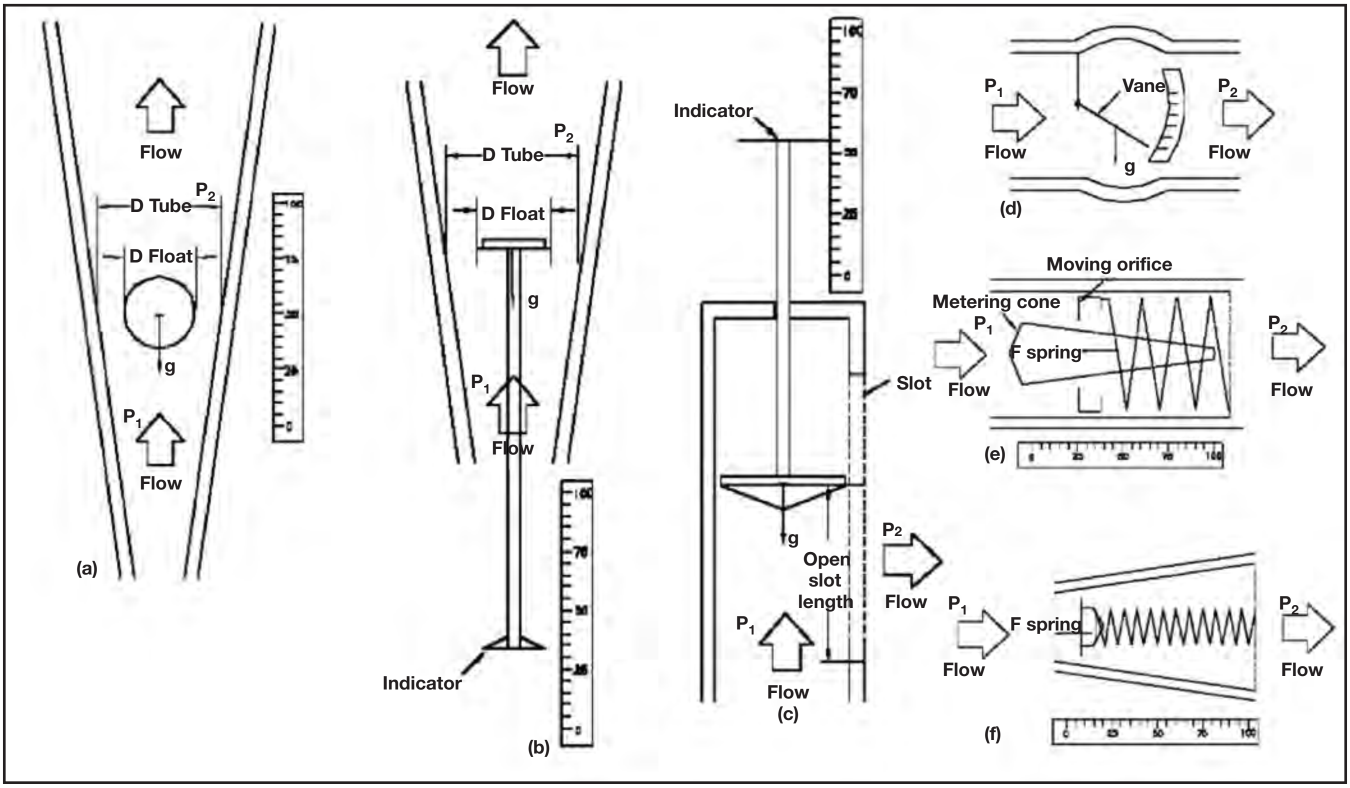


Fig. 3 — *Variable-area flowmeters: (a) glass/plastic tapered tube rotameter, (b) metal tapered tube rotameter, (c) slotted metal cylinder, (d) vane type, (e) piston meter with spring-loaded orifice piston over a tapered plug, and (f) tapered tube with spring.*

This is why it is necessary to size the rotameter for each application. When sized correctly, flow rate can be determined by matching the float position to a calibrated scale on the outside of the instrument. Many rotameters come with a built-in valve to manually adjust flow. Several shapes of floats are available for various applications.

Both glass and metal rotameters are available. Glass and plastic rotameters cost less and are more accurate than metal tapered-tube rotameters (Fig. 3b), but may not be able to provide the durability and reliability needed in a manufacturing environment. Metal rotameters are reliable, but the machined tapered tube limits the flow measurement range (turndown). Another limitation is that metal rotameters typically have brass or aluminum bodies, which can make them unsuitable for use in certain gases (ammonia, for example).

Slotted-cylinder types

The flowmeter most commonly used in the process industries substitutes a slotted cylinder for the tapered tube (Fig. 3c). Compared with a metal rotameter, a greater selection of construction materials and a flow turndown of at least 25:1 (vs. 3.6:1) are provided. The lower portion of the float is a piston that can "plug" the slot in the cylinder wall. The float rises until enough of the slot has opened to create equilibrium between the two upward-acting flow forces and the single downward-acting force. As for rotameters, when in this equilibrium position, float height is proportional to flow rate. The basic equations for tapered tube and slotted cylinder flowmeters are similar, with their flowmeter coefficients (K factors) accounting for any differences.

Flowmeter accessories

Regardless of the design of variable-area flowmeters, flow measurement is taken at some equilibrium point where the fluid flow force is balanced by an opposing force exerted by a "flow element" (such as a float). Either the force of gravity or a spring is used to return the flow element to its resting position when the flow lessens. Gravity-operated flowmeters (Fig. 3a–c) must be installed in a vertical position, while vane or spring-operated devices (Fig. 3d–f) can be mounted in any position.

Some variable-area flowmeters can be provided with position sensors and transmitters (pneumatic, electronic, digital, and fiber optic) for connecting to remote displays or controls. Most flowmeters have only flow alarm output signals, although some provide a continuous signal that represents the flow rate.

A variable-area flowmeter or rotameter is typically provided with calibration data and a direct-reading scale for air or water (or both). To size a meter for other service, the actual flow must be converted to a standard flow. Instrument manufacturers use different standard flow units. For liquids, the standard flow is the water equivalent in gal/min at 70°F and 10 psi (20°C, 69 kPa); for gases, it is the air equivalent in standard cubic feet per minute (scfm) at 70°F and atmospheric pressure. Tables listing standard water and/or air equivalent values are available from flowmeter manufacturers, who also might provide slide rules, nomographs, and computer software for flowmeter sizing. **HTPRO**

Look for Part 2 of this article in the September 2014 issue of HTPro covering selection basics, sizing, mass flowmeter overview, and FAQs about flowmeters.

For more information: Daniel H. Herring (The Heat Treat Doctor) is president, The Herring Group Inc., P.O. Box 884, Elmhurst, IL 60126-0884, 630.834.3017, dherring@heat-treat-doctor.com, heat-treat-doctor.com.

ASMnews

Board Nominees Announced

Tirpak for VP; Clauser for Treasurer; Dannemann, Sudarshan, and Williams for Trustees


Collins


Tirpak


Clauser


Dannemann


Sudarshan


Williams

The ASM Nominating Committee, chaired by **Richard Blackwell, FASM,** announced the nominees for ASM vice president and trustee for 2014-15 and three members of the Board of Trustees for 2014-17.

In accordance with the ASM Constitution, these nominees will be voted on at the ASM Annual Business Meeting on October 13, during MS&T14 in Pittsburgh. Once elected, the vice president will automatically become ASM president for 2015-16.

In accordance with Article IV, Section 3 of the ASM Constitution, the ASM Board of Trustees has also announced its nominee for ASM Treasurer for 2014-15.

Officers and members of the Board who will continue serving in 2014-15 are: Dr. Sunniva R. Collins, FASM, who will become president in October, Prof. C. Ravi Ravindran, FASM, who will serve as immediate past president; and trustees Dr. Iver Anderson, FASM, Mitchell Dorfman, FASM, Dr. James C. Foley, Jacqueline M. Earle, John Keough, FASM, and Dr. Zi-Kui Liu, FASM.

Retiring from the Board at this year's Annual Business Meeting will be immediate past president, Dr. Gernant E. Maurer, FASM, Robert J. Fulton, FASM, treasurer 2011-14, and trustees Dr. Jeffrey A. Hawk, FASM, William J. Lenling, FASM, and Dr. Linda S. Schadler, FASM.

About the President-Elect and Board Nominees

Dr. Sunniva R. Collins, FASM
President-Elect

Sunniva Collins joined the faculty of the Case School of Engineering at Case Western Reserve University (CWRU) in March 2013, where she teaches Materials, Design, and Manufacturing courses in the Department of Mechanical and Aerospace Engineering. She is also contributing to the university's initiatives in advanced manufacturing. Prior to CWRU, she was employed by Swagelok Co. for 18 years. As senior research fellow at Swagelok, Collins was responsible for coordinating the company's academic and governmental research partnerships. She joined the company in 1995 as a research metallurgist and served in engineering management positions, including manager, materials technology; and manager, standards and product regulatory compliance.

Collins received her doctorate and master's degree in materials science and engineering from CWRU and her bachelor's degree from the University of Michigan. From 2003 to 2006, she was Swagelok's Principal Investigator (PI) on a DoE-funded project to evaluate surface hardening of austenitic stainless steels by low temperature carburization. On this project, she was responsible for program management of collaborative research with CWRU, Oak Ridge National Laboratory (ORNL), and other industry partners. Results of this research were recognized with the 2006 ASM Engineered Materials Achievement Award and a 2008 R&D 100 Award. She was also PI for Swagelok on an Ohio Department of Development commercialization proj-

...in this issue

Submit news of ASM and its members, chapters, and affiliate societies to
Joanne Miller, editor, *ASM News* | ASM International | 9639 Kinsman Road | Materials Park, OH 44073
P 440.338.5151 ext. 5662 | **F** 440.338.4634 | **E** joanne.miller@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)*
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ect from 2008 to 2012; and on a DARPA project led by the NRL from 2008 to 2010.

Collins worked to develop key standards on welding, surface finish requirements, and corrosion test methods for the semiconductor equipment industry. She also instructed courses for ASME on Bioprocessing Equipment (BPE) and for the International Society of Pharmaceutical Engineers (ISPE). Collins is a Fellow of ASM International and served on the ASM Board of Trustees from 2008 to 2011. She was the Cleveland Chapter Chair from 2000 to 2001, and received the Cleveland Chapter's Award of Distinction in 2009 and the Distinguished Service Award in 2013. In 2011, she was named a fellow of Alpha Sigma Mu, the national honor society for materials scientists. She is the 2014 recipient of the Cleveland Technical Societies Council (CTSC) Technical Educator Award.

Collins has been a member of ASM since 1988 and credits her graduate school experience for getting actively involved in the Cleveland Chapter. She is also a member of ASM affiliate societies IMS and HTS, and has focused on STEM initiatives throughout her career. She has served as a Materials Mentor for the ASM Materials Camp for Students and organized the Cleveland Materials Camp for Teachers, now entering its seventh year.

Jon D. Tirpak, P.E., FASM
Nominee for Vice President

Since studying metallurgical engineering at Lafayette College, ASM International has supported Jon Tirpak, FASM, throughout his entire career. After being commissioned as 2nd Lieutenant in the Air Force, he landed at the Materials Laboratory in the Birthplace of Aviation, Ohio. In 1982, attendance at his first ASM Dayton Chapter meeting launched his professional association with the organization. Between assignments at Wright Patterson AFB and special projects in Washington, Tirpak earned a master's degree in materials engineering. Captain Tirpak was assigned to the Ballistic Missile Office at Norton AFB in Southern California. He was tasked with integrating the Air Force's nuclear testing requirements, which exposed him to the Defense Nuclear Agency, Department of Energy, and the Nevada Test Site. Tirpak attended several Westec and Aluminum Lithium Conferences, and through associations at one of those events, was invited to help found AeroMat with many other dedicated ASMers.

Departing the Air Force in 1988, he returned to Dayton as a contractor with the Air Force Materials Laboratory and Manufacturing Technology Directorate. The Dayton Chapter welcomed him back with plenty of leadership opportunities, including an invitation to Washington to participate in the Federal Affairs Committee of ASM, introducing him to the national operations of the Society. After a brief stint in Ann Arbor, Mich., with a fluid power company, Tirpak moved to Charleston, S.C., at the request of SCRA Applied R&D, a technological and economic engine for the Palmetto State. For the past 12 years, he has served as executive director of the Forging Defense Manufacturing Consortium leading multiple, million-dollar R&D programs. Tirpak's ASM volunteerism includes service on committees that oversee New Products and Services, Federal Affairs, Finance, Investment, Web, Student Trustee Selection, and 100th Anniversary Awards. He received the Hammer Award from Vice President Al Gore for "reinventing government" and is a Licensed Metallurgical Engineer in S.C.

Official ASM Annual Business Meeting Notice

The Annual Business Meeting of members of ASM International will be held in conjunction with MS&T14 on:
Monday, October 13
4:00 – 5:00 p.m.
David L. Lawrence Convention Center, Pittsburgh
The purpose of the ASM Annual Business Meeting is the election of officers for the 2014-15 term and transaction of other society business.

Craig D. Clauser, P.E.
Nominee for Treasurer

Craig D. Clauser is the president and owner of Craig Clauser Engineering Consulting Inc., which he founded in 2005. The company provides metallurgical engineering services nationwide, primarily in failure analysis and process improvement.

He is a magna cum laude graduate of Lehigh University with a B.S. and M.S. in metallurgical engineering and materials science and a registered professional engineer. Clauser joined Westinghouse Electric Power Generation as a metallurgical engineer in the Materials Engineering Laboratory after graduating and subsequently became Laboratory Manager. The laboratory serviced the Steam Turbine, Gas Turbine, and Heat Transfer Divisions at Lester, Pa. In 1977, Clauser joined Phoenix Steel Corp. where he served as technical director. Phoenix produced carbon and alloy plate in Claymont, Del., and heavy wall, pilger forged tubing in Phoenixville, Pa., and was a leader in clean steel technology. In 1986, he joined Consulting Engineers and Scientists Inc. in Malvern, Pa., where he was an engineer and senior vice president until starting his own firm.

Clauser joined ASM in 1967 and was Philadelphia Chapter Chairman in 1983. He also served as chairman of the ASM Chapter Operations Committee and the Handbook Committee. He is currently a member of the ASM Content, Failure Analysis, and Handbook Committees as well as the ASM Finance and Investment Committees. He was the Delaware Valley Metals Man of the Year in 1993 and Philadelphia Liberty Bell Chapter Albert Sauveur Lecturer in 2001. Clauser is also a member of NSPE, ASTM, NACE, ASME, and AWS.

Dr. Kathryn A. Dannemann
Nominee for Trustee

Kathryn Dannemann is principal engineer in the Engineering Dynamics Department at Southwest Research Institute (SwRI). Her professional experience includes the mechanical behavior of materials, materials characterization and structure, and the interactive effects of microstructure and processing on materials performance. At SwRI, Kathryn directs technical programs investigating materials response in various engineering systems. Since 2000, her work has focused on the high strain rate behavior of materials (metals, ceramics, composites, glass). Prior to joining SwRI in 1996, Dannemann worked at General Electric where her contributions to high-temperature materials were most recognized. Her career began at Bethlehem Steel Homer Research Laboratories where she led coatings development activities.

She earned a Ph.D. in materials engineering from the Massachusetts Institute of Technology in 1989, and B.S. and M.S. degrees in materials engineering from Rensselaer Polytechnic Institute. Dannemann has been actively involved with ASM for 34 years. She currently serves on the Materials Property Database Committee, is Scholarship/ Student Affairs Chairperson for the Alamo Chapter, and was on the organizing committee for the inaugural Teachers Materials Camp in San Antonio. She served the Eastern NY Chapter in various executive board positions, including chairperson in 1995-96. Recognized as an outstanding young metallurgist, she was the 1995 recipient of the chapter's ASM Alfred H. Geisler Memorial Award.

Dannemann also held numerous leadership positions in other technical societies including TMS, the Society for Experimental Mechanics (SEM), and the Society of Women Engineers (SWE). She was chairperson of the TMS High Temperature Alloys Committee (1998-99), chairperson of the SEM Dynamic Behavior of Materials Technical Division (2008-10), executive board member of SEM (2012-14), Treasurer for SWE Region C (2008-9), and counselor to the SWE student section at Trinity University (2004-present).

Dr. T.S. Sudarshan, FASM
Nominee for Trustee

Dr. T.S. Sudarshan, FASM, is the president and CEO of Materials Modification Inc. He received his B.Tech. in metallurgy from the Indian Institute of Technology in Madras, and his M.S. and Ph.D. in materials engineering science from Virginia Tech. He worked with Ashok Leyland in the Truck and Bus division as a senior metallurgist and later as director of R & D at Synergistic Technologies. For the past 28 years, Sudarshan has been responsible for the management and technical development of innovative materials and the development of new technologies related to surface engineering and nanotechnology. His affiliation with ASM began in 1984. He has actively served on various committees and is currently chair of the ASM-IIM lectureship committee. He also chaired the Surface Engineering Critical Technology sector and has been a member of IMR, JMEP, *AM&P*, and Awards committees.

Sudarshan is the recipient of numerous awards including the *Design News* Award, the R&D 100 Award for the microwave plasma technique "Nanogen" and the Plasma Pressure Compaction technique, and the SAE Outstanding Young Manufacturing Engineer award. He served on numerous committees of the NSF, NIH, U.S. Army, Michigan Economic Development Council, National Research Council, as well as technical advisory boards of numerous companies. Sudarshan is editor of the journals *Materials and Manufacturing Processes* and *Surface Engineering.* He is a Fellow of ASM, the International Federation for Heat Treatment and Surface Engineering, and the Institute of Mining, Metals and Materials, UK. A Distinguished Alumnus of IITM, he was a member of the National Materials Advisory Board and served on numerous NRC committees. He is coauthor of 175 publications and coeditor of 28 books on surface modification technologies.

Prof. David B. Williams, FASM
Nominee for Trustee

Dr. David B. Williams, FASM, is the Monte Ahuja Endowed Dean's Chair, Executive Dean of the Professional Colleges, and Dean of the College of Engineering at The Ohio State University. Williams oversees the education of more than 10,000 students, leads a $120M research program, and oversees the administration of 950 faculty, research scientists, and staff.

Williams serves on the Boards of the State of Ohio's Third Frontier Advisory Board, the American Lightweight Materials Manufacturing Innovation Institute, Columbus 2020, Metro High School, EWI, Ohio Aerospace Institute, Ohio Aerospace & Aviation Council, and the Transportation Research Center. A member of the Global Engineering Dean's Council, the American Society for Engineering Education, and the Ohio Engineering Dean's Council, Williams is also a fellow of several national and international professional societies in the areas of materials and microscopy.

Williams served as the fifth president of the University of Alabama in Huntsville from 2007 to 2011. Prior to that role, he spent 31 years at Lehigh University in Bethlehem, Pa., as professor of materials science and engineering. His activities were supported by many federal agencies, including NSF, DOE, NASA, and the U.S. Army. From 1980 to 1998, he directed Lehigh's Electron Microscope Laboratory and the Microscopy School. He chaired Lehigh's Materials Science and Engineering Department from 1992 to 2000, and was vice provost for research from 2000 to 2007.

Williams co-authored and edited 11 textbooks and conference proceedings, including the world's leading text on transmission electron microscopy. He published more than 220 journal papers and 200 conference proceedings in the areas of analytical and transmission electron microscopy. He has given 280 invited presentations in 28 countries. Williams holds B.A., M.A., Ph.D., and Sc.D. degrees from the University of Cambridge.

Nominations and the ASM Constitution

The ASM International Constitution provides that members of the society may submit additional nominations after the Nominating Committee has made its official report. Article V, Section 6 of the ASM Constitution reads: "After publication of the Nominating Committee's report on nominees, and the Board report on its nominee for Treasurer, and at any time prior to July 15 of the same year, additional nominations for any or all of the vacancies may be made in writing to the Secretary at Headquarters. Such nominations must be signed by at least five individuals or Chapter Sustaining Members, each from any combination of at least 10 Chapters and/or ASM Committees. Such nominees shall be processed by the Secretary for compliance with Section 4 of this Article. This shall be the only way in which additional nominations may be made. The membership of ASM International shall be duly notified of such additional nominations." Section 7(a), a related provision, states: "If no additional nominations are received prior to July 15, the nominations shall close automatically. At the next succeeding annual business meeting of ASM, the Secretary shall cast the unanimous vote of all members for election of nominees of the Nominating Committee and the nominee for Treasurer as presented by the Board even though a quorum may not be present."

From the Foundation
"Materials Matter" New after-school program

Lyle Schwartz
ASM Materials Education Foundation Board of Trustees

Numerous studies over many years have consistently revealed an achievement gap in STEM knowledge and low STEM career interest among middle school students. Using content from the ASM Materials Camp for Teachers, ASM Materials Education Foundation is launching a trial program that focuses on engaging middle school children and exciting them about pursuing STEM education. The program will encourage students to see the world around them as one in which science is transformed into technology through engineering. The primary goal of the program is to stimulate an interest in learning more about STEM as students move to high school.

Over a two-year timeframe, the ASM Materials Education Foundation will organize, test, and evaluate the materials-based STEM after-school program designed to be readily replicated in many locales. The new program will be centered on existing ASM developed content and has been designated as the "Materials Matter" Program. Working in small groups, students will use hands-on experiments to explore concepts of physical science while learning to independently draw generalizations and apply basic engineering principles. This model STEM program will focus on common materials such as metals, ceramics, polymers, and composites. These structural materials are ideal as examples to assist STEM learners in linking science to application. Research has documented this approach to be a proven pathway that will engage and excite students about STEM subjects and ASM has effectively demonstrated this premise at the high school level over the past 14 years.

The program development strategy requires engaging an institution as a partner to host the after-school program and participate fully in its development, advertising, fielding, and evaluation. ASM Materials Education Foundation has been fortunate in identifying two ideal partners, each bringing unique expertise and experience to the project. Together, these two demonstrations of "Materials Matter" will provide the basis for extension to most after-school environments.

As the ASM Materials Education Foundation continues to expand their suite of programs, it is imperative to garner support. The Foundation needs your help to continue advancing their mission "to excite young people in materials, science, and engineering careers." Please consider making a tax-deductible donation today. Contact us at foundation@asminternational.org or 800.336.5152 ext. 5538.

Congratulations to the **2014 Winners of the Student Chapter Grants!**

Grants of $800 each were awarded to these Material Advantage Chapters for their winning projects:

- Rensselaer Polytechnic Institute
- Georgia Tech
- University of Washington
- University of Minnesota
- University of Puerto Rico-Mayaguez

To date, 67 Material Advantage Chapter activities have received financial support from the ASM Foundation through the Student Chapter Grants Program. We are confident that these Material Advantage Student Chapter leaders will utilize the grants to the fullest with their strong commitment to attract and excite young minds in the field of science and engineering.

Winning proposals may be viewed online at asmfoundation.org.

For more information about the Student Chapter Grants program, contact Jeane Deatherage at 440.338.5151 ext. 5533 or jeane.deatherage@asminternational.org.

HISTORICAL LANDMARK
Delhi Iron Pillar

The ASM board selected the famous Delhi Iron Pillar as a 2013 Historical Landmark Winner with input from the Indian Institute of Metals, the Indian National Academy of Engineering, and the Archaeological Survey of India (ASI). The Iron Pillar, located in Delhi, was constructed during early 400 CE and is 7.21 meters tall, and weighs more than 6 tons. Made of wrought iron, it stands—without any corrosion or degradation despite the highly tropical climate—as pristine as when it was built more than 1600 years ago. Modern studies began in 1861 with the establishment of ASI. A major advancement occurred in 1912 in a study by Sir Robert Hadfield that determined the composition of the pillar and its microstructure. He noted that the monument, made by the tribes of India for their emperor in the 5th century, was beyond the capabilities of European iron masters until the end of the 18th century. Its corrosion resistance has intrigued many, with the first paper on the rust-less wonder published in *Nature* by Hudson in 1953.

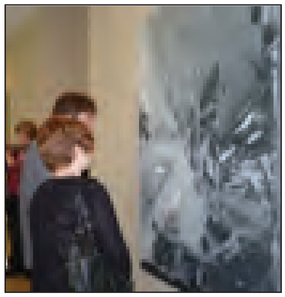
For a list of upcoming ASM Training Courses, see our ad on page 34 of this issue.

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

KSU Art Shines at the Dome

The 2nd Annual ASM and Kent State University (KSU) Art Show is on display at ASM headquarters between May 14 and January 2015. The venue's views, lighting, and sense of balance—important to architect John Terence Kelly and still valued more than 50 years later—create the ideal space for artwork. ASM hosted an opening reception on May 14 with more than 40 guests present. The top 20 pieces on display were selected from 158 submissions by 37 artists.

Christine Havice, director, KSU School of Art, Kathryn Shinko, graduate assistant to the gallery director, KSU School of Art, John Crawford, dean, College of Arts, at the opening reception.



Artists Stephanie Mote and Hunter Elliott enjoy the art exhibit.

HANDBOOK EDITOR SPOTLIGHT
Dr. Valery Rudnev, FASM

As volume co-editor, Dr. Valery Rudnev, FASM, was instrumental in developing *ASM Handbook* Volume 4C: *Induction Heating and Heat Treatment*. As a leading global figure in the induction heating industry, Rudnev undertook the ambitious challenge to compile an all-new, comprehensive ASM Handbook resource on induction thermal process technologies and applications. With more than 30 years of experience in induction heating, he took on the immense commitment and effort of organizing and recruiting an international team of volunteer editors, authors, and peer reviewers for Volume 4C. The new volume represents a significant expansion of *ASM Handbook* coverage on heating and heat treatment, and *ASM Handbook* Volume 4C would not have occurred without Rudnev, who is director of science and technology, Inductoheat Inc., an Inductotherm Group Company. An ASM member for 19 years, and a member of many other industry, scientific, and engineering committees and editorial boards, Rudnev acknowledges co-volume editor Dr. George Totten, FASM, and all contributing authors for their support and devotion during this challenging project.

Do you have an idea for a book? Would you like to share your knowledge and expertise with the engineering community? ASM can help you in such an endeavor. Contact Karen Marken at 440.338.5151 ext. 5545 or karen.marken@asminternational.org to discuss your ideas and details of the process.

EMERGING PROFESSIONALS
Aluminum Industry:
Game-changing Technological Development Needed

Behzad Majidi
Aluminum Research Centre – REGAL
Université Laval, Québec, Canada

In 1886, Charles Martin Hall and Paul Héroult independently developed the method of reduction of aluminum in electrolysis cells. Thanks to Thomas Edison's brilliant work and his dynamo invention—which made low cost electrical power available—the first large scale aluminum production plant was opened by Hall in 1888 in Pittsburgh.

Technology improvements in the 20th century raised the current efficiency of Hall-Héroult cells to 96%. However, issues such as the price of electricity and greenhouse gas emissions from the smelting process forced aluminum industry experts to consider modifications to this old process.

Consumable carbon anodes—made by mixing petroleum pitch and calcined coke—have been a priority research focus for the aluminum community in the last three decades. The need for nonconsumable or inert anodes for the Hall-Héroult process is widely accepted. A successful inert anode technology is estimated to increase the energy efficiency of the process by 25%, reduce operating costs by 10%, and lower greenhouse gas emissions by 6.5 million metric tons.

Electrochemical and thermodynamic stability, electrical conductivity, and mechanical properties at 930°-1100°C are essential parameters for candidate materials for inert anodes. Purity of metal output of the cell is also a critical point and the inert anodes investigated in the past failed to meet this criterion. Anode materials are the most critical barriers to development of industry-scale inert anodes.

Hall gave us a wise start, but it seems we are reaching a turning point: Without advanced, low cost materials for anodes (and cathodes), it will be very difficult for the aluminum industry to hold its current position in technology development.

Industrial aluminum production started with innovations and state-of-the-art designs from engineers. Once again, there is a critical need for a new game-changing design that can provide high-quality inert anodes. So, go materials scientists. Go!

Chapter News

President Ravindran in Ontario

ASM president Ravi Ravindran, FASM, visited the Ontario Chapter on April 2. From left: Francesco D'Elia, Diana Facchini, Brick Kung, Paul Okrutny (chapter vice chair), ASM president Ravindran, Abdallah Elsayed, Anthony Lombardi, and Eric Ambros. D'Elia, Elsayed, and Lombardi are University of Toronto MAdvantage Chapter members and secretaries of the ASM 100th Canada Fundraising Committee. The participation of youth on the Executive Committee is impressive and includes members Facchini, Kung, and Ambros.

Southern CT Honors Professor and Funds Foundation

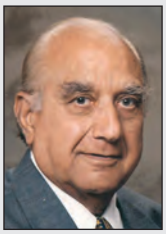
Christine C. Broadbridge, professor and chairperson of physics at Southern Connecticut State University, was named Connecticut Materials & Manufacturing Professional of the Year. The award was presented in April during the Chapter's Materials and Manufacturing Week. The event was co-sponsored by the New Haven Manufacturers Association (NHMA). Broadbridge was honored for multiple contributions to STEM education and for unique collaborations with area manufacturing.

The Chapter also announced their donation of $5000 seed money to the NHMA Workforce Enhancement Education Foundation dedicated to growing skilled workers for Connecticut's manufacturing industry. The check was presented in New Haven at an April 24 dinner during the Connecticut Materials and Manufacturing Week.

ASM Southern CT chapter's Christine Broadbridge (center) is congratulated by Bob Klancko (left) and Harold Brody.

Jim Steele, Chapter chair (left), presents a $5000 check to Bill Neale, NHMA president.

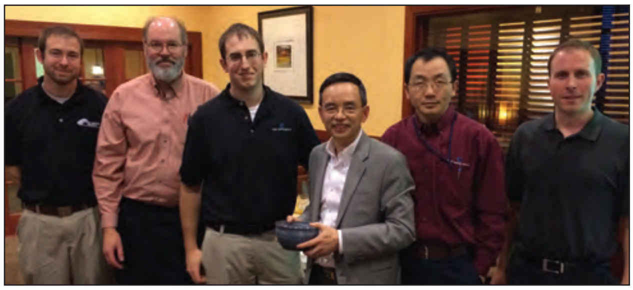
IN MEMORIAM



Bal Raj Nijhawan, FASM, of Sun City Center, Fla., and formerly of Kokomo, Ind., passed away on April 6 at age 98. He was the first Indian Director of the CSIR-National Metallurgical Laboratory (NML) in Jamshedpur, India, an internationally acclaimed institute. He left in 1966, to become the Senior Inter-Regional Advisor (Metallurgical Industries) with UNIDO (United Nations Industrial Development Organization), based in Vienna, Austria. In 1986, he retired from the United Nations and moved to the U.S. Nijhawan was renowned for his work in ferrous metallurgy with contributions to armor plate technology, nickel-free austenitic stainless steel, grain size control, low-shaft iron and steelmaking, and sponge-iron techniques in steelmaking. During his tenure in the United Nations, he led development of 25 Centers of Metallurgical Technology in many developing countries.

Nijhawan received his bachelor's degree in metallurgy from Banaras Hindu University in India in 1936 and Ph.D. from the University of Sheffield, UK, in 1941. He held 55 patents, authored nearly 500 technical publications, and edited two books. He was honored with the Padma Shri (1958) presented by the President of India and the Bhatnagar Award (1964). He received gold medals and other citations from the Japanese Iron And Steel Institute and governments of Poland, Czechoslovakia, and Yugoslavia. Nijhawan served as the President of Indian Institute of Metals and Institute of Indian Foundrymen.

Word has been received at ASM Headquarters of the death of Life Member **T.J. Bodner** of Plymouth, Mich. (Detroit Chapter).



Fort Wayne Hosts Trustee Liu

ASM Trustee Dr. Zi-Kui Liu visited the ASM Fort Wayne Chapter at their April 16 dinner meeting held at Wu's Fine Chinese Cuisine. Liu (center) holds a gift from the Fort Wayne Chapter, which is a ceramic bowl made by a local artist. He is flanked by Chapter Committee Board members (left to right): Webber Darryl, Barry Dupen, Austin Lucas, Adam Griebel, Song Cai, and David Snider.

Hartford Honors Christy

At a special meeting on May 1, the ASM Hartford Chapter recognized Dr. Sam Christy for his splendid service as chairman of the chapter during the years 2007-2014. Christy, who works for Pratt & Whitney, recently accepted a three-year assignment in Izmir on a joint venture between his company and Turkey. Past Chapter chairmen gathered for the presentation of a plaque to Christy. Shown from the left, are Jack Woodilla (1978-79), incoming chairman Rainer Hebert (2014-15), Sam Christy, Arnie Grot (2001-02, 2003-06) and Harley Graime (2001-02).

Members in the News

Muzyka Receives Liberty Bell's Eisenman Award

The ASM Liberty Bell Chapter announced the selection of **Donald R. Muzyka, FASM,** as recipient of its 2014 William Hunt Eisenman Award. The award, announced at the May 16 Award and Past Chairman's Meeting in Hosham, Pa., was given in recognition of his service to ASM, foresight, dynamic management, leadership, and promotion of the materials industry and materials education. Muzyka is an ASM past president and has served as ASM Foundation trustee and treasurer. He will address the Philadelphia Chapter meeting on October 16 with a discussion on the history of the ASM Foundation's Materials Camps and his thoughts on issues in technical education.

Lados Honored by SAE and TMS

Diana Lados, associate professor of mechanical engineering at Worcester Polytechnic Institute (WPI) and founding director of the university's Integrative Materials Design Center, recently received two major career achievement awards from leading engineering societies. At its annual congress in Detroit, SAE International presented Lados with the 2014 Ralph R. Teetor Educational Award "in recognition of significant contributions to teaching, research, and student development." In February, TMS awarded her the Brimacombe Medal at its annual meeting and exhibition in San Diego. The award, presented to mid-career professionals, recognizes sustained excellence and achievement in business, technology, education, public policy, or science related to materials science and engineering.

Diana Lados, left, receives the 2014 TMS Brimacombe Medal from TMS president Elizabeth Holm at the society's 2014 annual meeting and exhibition in San Diego.

IFHTSE Fellowship Awarded to Ferguson

B. Lynn Ferguson, FASM, president, Deformation Control Technology Inc., Cleveland, was honored at the 21st IFHTSE Congress in Munich, held in May, with an IFHTSE Fellowship 2014 Award. The citation reads: In recognition of globally acknowledged leadership in the development and practical implementation of principles and practices of mathematical modeling and their application to the benefit and advancement of the heat treatment industry and surface engineering. Ferguson is a longstanding member of the ASM Heat Treating Society.

Heller Award to Maurer

Russ Maurer, a science teacher at Hawken School in Gates Mills, Ohio, received the Irene C. Heller Award from the Cleveland section of the American Chemical Society (ACS). The award recognizes an outstanding high school chemistry teacher who teaches in the Cleveland area. Maurer received the award at the April 9 meeting of the Cleveland ACS. A graduate of Princeton University, Maurer earned his Ph.D. in biochemistry from Harvard University and started his teaching career at Case Western Reserve University School of Medicine in 1982. He transitioned to high school teaching at Hawken School in 2001. He is also an ASM Master Teacher with the ASM Foundation's Materials Camps program.

Furnace Awarded during Master Teachers Training

Sherri Rukes of Libertyville High School, Ill., was awarded the seventh furnace from the Michael Connelly "Furnace Project" during a Master Teachers Training weekend in April at Materials Park, Ohio. **Michael C. Connelly, FASM,** started the project in 2008 with a mission to get furnaces into as many classrooms as possible. "A small donation can have an immediate impact on a student's future as they experience materials, science, and engineering for the first time." Rukes plans to try various labs with her students that incorporate the furnace, such as glass fusing, slumping, Nitinol wire, and Raku.

Senior Master Teachers Debbie Goodwin and Andy Nydam presented the furnace award to Sherri Rukes (center) while instructing at a teacher training session at ASM headquarters.

Narayan Wins Max Gardner Award

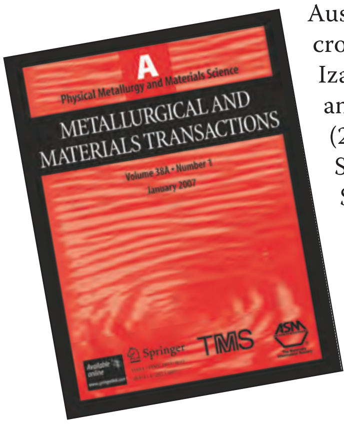
The President and Board of Governors of the University of North Carolina System have announced **Prof. Jagdish (Jay) Narayan, FASM,** as the winner of the 2014 O. Max Gardner Award. He is the John Fan Family Distinguished Chair Professor in the Department of Materials Science and Engineering at North Carolina State University. The O. Max Gardner Award is the highest faculty honor of the system comprising of 17 universities, given annually to one faculty member whose academic and research contributions made the maximum impact on the human race. The winner receives a medallion and prize of $35K. Narayan is recognized for his groundbreaking contributions in nanoscience and nanotechnology leading to useful products for society at large. This is a first for the field of materials science in the award's 66-year history.

Knovy Receives "Next Generation" Award from AGMA

Scott Knovy (right), vice president of German Machine Tools of America in Ann Arbor, Mich., was recognized as being a rising star in the industry by being awarded AGMA's Next Generation Award. Lou Ertle, chairman of Overton Gear Chicago and the AGMA Board of Directors, made the presentation at the association's annual meeting on April 11 in St. Petersburg, Fla.

MetTrans A Paper Wins the 2014 Charles Hatchett Award

Metallurgical and Materials Transactions A: Physical Metallurgy and Materials Science is pleased to announce that the two part paper "Precipitation of Nb in Ferrite after Austenite Conditioning Part I: Microstructural Characterization," by A. Iza-Mendia, M.A. Altuna, B. Pereda, and I. Gutierrez, *MetTrans A*, Vol. 43, (2012), 4553-4570 and "Part II: Strengthening Contribution in High-Strength Low-Alloy (HSLA) Steels," by M.A. Altuna, A. Iza-Mendia, and I. Gutierrez, *MetTrans A*, Vol. 43, (2012), 4571-4586 won the 2014 Charles Hatchett Award. The award will be presented at the Institute of Materials, Minerals and Mining (IOM3) 2014 Premier Awards Dinner on July 15 in London.



The Charles Hatchett Award is presented for work related to niobium. The prize includes a minted medal of pure niobium and funding to go to Companhia de Metalurgia e Mineração–CBMM in Brazil, the world's largest niobium producer. CBMM initiated and has sponsored the Charles Hatchett Award since 1979 in association with IOM3.

The winning paper was selected from a collection of journal and proceedings papers over a two-year period and chosen by an international panel of renowned metallurgists.

ASM members receive free online access to the entire suite of Metallurgical and Materials Transactions Journals including *MetTrans A.* Log in to asminternational.org, click on My Subscriptions, and select *Metallurgical & Materials Transactions A.*

VOLUNTEERISM COMMITTEE

Profile of a Volunteer

Bob Gaster
Sr. Staff Engineer
John Deere Moline Technology Innovation Center

Career choices often seem to happen by chance, but Bob Gaster sees a design to his. It began in his 1969 high school physics class when the teacher invited seniors to visit Iowa State University's metallurgy department. While other students laughed at the idea, Gaster raised his hand. That decision led to a bachelor's degree in metallurgy and a successful 40-year career with John Deere.

Active in ASM since 1973, his primary expertise is in heat treat technology. He served in leadership roles with the Quad Cities chapter, is a founding member of the ASM Heat Treating Society, and served as member and chair of the national Volunteerism Committee. "I'm a firm believer in serving others," says Gaster. "I try to use the skills I've been blessed with—to have an impact at John Deere and in the heat treating industry." He is also committed to reaching students as he co-leads the local chapter's ASM Materials Camp and volunteers with Project Lead the Way and at a Saturday Science middle school program—all STEM pre-collegiate programs.

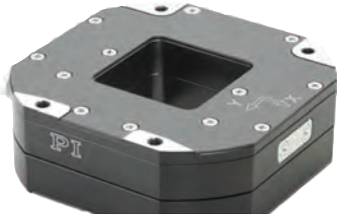
Gaster worked at the John Deere factory level for 19 years before transferring to the corporate technology center. He credits his volunteer service with ASM for helping develop his career, particularly his work with the R&D committee, which strengthened his understanding of research. That role led to publication of the ASM Heat Treating Society's 1999 R&D Plan and recognition by the U.S. Department of Energy for "Turning Industry Vision into Reality."

Most of all, Gaster treasures his relationships with ASM and industry colleagues. "I have immediate access to experts because of the extensive network I've been privileged to develop by volunteering," he reflects. "It's really multiplied when you serve at the national level. Volunteering at ASM offers opportunities to impact the materials industry while enabling both personal and professional growth!"

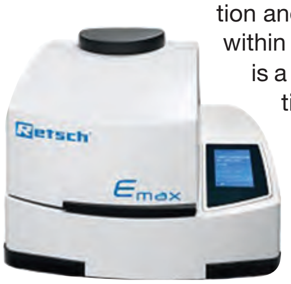
products & literature

AXT Pty. Ltd., Australia, launched a new **website dedicated to x-ray tubes.** The site focuses on replacement x-ray tubes for analytical, industrial, and medical applications. AXT supplies tubes from various manufacturers for a range of applications such as x-ray diffraction, x-ray fluorescence, nondestructive testing including baggage inspection, and many others. The site contains detailed information about these applications as well as the various x-ray tubes that are available as replacement parts for leading x-ray instrument manufacturers such as Bruker, Thermo, Shimadzu, and PANalytical. axtxraytubes.com.

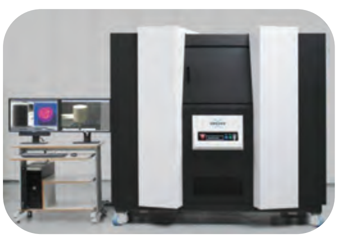
PI (Physik Instrumente), Germany, introduced a new P-763 XY nanopositioning stage, an affordable **piezo stage positioner.** The compact P-763 flexure-guided stage has a footprint of less than 3 × 3 in. (70 × 70 mm) while providing a 30 × 30 mm aperture. With a travel range of 200 × 200 µm, the piezo positioning system is suitable for demanding applications such as image stabilization, microlithography, nano-alignment, surface metrology, super-resolution microscopy and bio-nanotechnology, and photonics and datacomm. pi-usa.us.



The Emax from Retsch, Germany, is a new type of **ball mill** for high energy milling. The combination of high friction and impact results in extremely fine particles within a short amount of time. High energy input is a result of a speed of 2000 min^{-1} and innovative jar design. Thanks to the revolutionary water cooling system, high energy input is effectively used for grinding without overheating the sample. Due to the special grinding jar geometry, samples are thoroughly mixed resulting in a narrow particle size distribution. retsch.com.



Bruker Corp., Billerica, Mass., introduced the SkyScan TM 2211, a new **high-resolution x-ray nano-CT (computed tomography) system** with a wide range of object sizes and spatial resolutions. The system is capable of nondestructive scanning and 3D reconstruction of internal microstructures of large objects, as well as submicron resolution for small samples. SkyScan TM 2211 allows scanning objects up to 200 mm in diameter, where high accuracy of <50 nm for samples up to 25 kg is achieved by high-precision air-bearing rotation. Combining a 600-nm c-ray source with two c-ray detectors—a 3Mp flat-panel and an 11 Mp cooled CCD detector—8000 × 8000 × 2300 pixels can be reconstructed after a single scan. The smallest detectable detail (smallest pixel size) is 100 nm. bruker.com/skyscan2211.



Materion Performance Alloys, Mayfield Heights, Ohio, added nickel aluminum bronze (AMS 4881 C95520) **continuous cast hollow bars** to its line of high performance alloys. AMS 4881 C95520 is a martensitic nickel aluminum bronze that offers higher strength and hardness than other nickel aluminum bronze alloys. Using patented technology called EquaCAST, an extremely uniform, fine-grained microstructure with more consistent mechanical properties is produced with better machinability to ensure surface finish. AMS 4881 C95520 is used primarily for aircraft landing gear and brake systems as well as heavy equipment bearings, bushings and wear plates, and oil and gas components. materion.com.

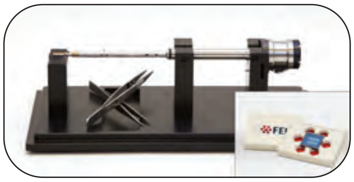
Instron, Norwood, Mass., offers VisualRHEO software, which **manages and analyzes data from rheological tests** with steps at constant piston speed or shear rate, enables full control over gathering data including viscosity, Bagley, and Rabinowitsch corrections, and non-Newtonian index calculations. Software is compatible with Windows 2000/XP/Vista/7/8.1 and features a real-time graphic display of the measured quantity; post-process graphs of rheological quantities (apparent and corrected values); password-protected operator access levels; ability to export to spreadsheets, text files, and LIMS systems; test comparison and reference viscosity curves; and an advanced database search. instron.us.

Agilent Technologies Inc., Santa Clara, Calif., introduced its **AFM-enabled scanning electrochemical microscopy (SECM) mode,** a seamlessly integrated technology package that enables scientists to perform scanning electrochemical microscopy on conductive and insulating samples. This unique mode of AFM operation allows scanning electrochemical microscopy to be performed quickly and reliably with nanoscale resolution. The SECM mode can be used to investigate homogeneous and heterogeneous electron transfer reactions, image biologically active processes, analyze thin films (e.g., pinhole detection, conformality), screen catalytic material (e.g., fuel cell catalysts), and study corrosion processes. home.agilent.com.

FEI, Hillsboro, Ore., introduced the NanoEx **sample holder** for in situ transmission electron microscopy (TEM). Its use of an innovative micro-electro-mechanical system (MEMS)-based heating element enables

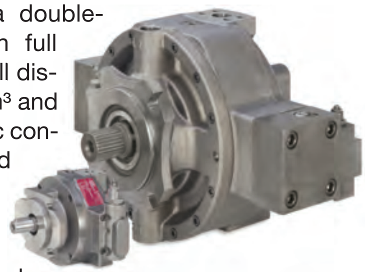
products & literature

faster, more precise heating, reduced thermal drift, and improved image resolution during in situ experiments, overcoming thermal stability limitations inherent in conventional furnace-based TEM heating holders. The holder also includes contacts to allow application of electrical bias to the sample and is optimized to accept a variety of sample geometries, from nanoparticles to thin FIB-prepared lamellae. fei.com.



NPXY60-258 and NPXY60Z20-257 **nanopositioners** from nPoint Inc., Middletown, Wis., are piezo driven, flexure guided stages, designed for high speed and nanometer precision. With a position noise of 0.4 nm in *X* and *Y* axis and 0.2 nm in the *Z*, both stages are accurate enough for advanced applications. Both stages also have a travel of 60 µm in both the *X* and *Y* axis and there is an optional *Z* with 20 µm stroke. The aperture (30 mm in diameter), creates a great deal of flexibility for incorporation in optics and nanotechnology systems. A resonant frequency of 750Hz in *XY* and 2000 Hz in *Z* allows for fast scanning and settling times less than 5 ms. Both stages are designed to be UHV compatible and have non-magnetic properties, allowing researchers to test under specialized conditions. npoint.com.

Moog Inc., East Aurora, N.Y., extended its range of variable-displacement **radial piston pumps,** with RKP 250 for displacements up to 250 cm³ per revolution. It is capable of delivering continuous pressures up to 350 bar (5000 psi). For machine applications where even higher displacements are required, the pump can be configured in a double-pump arrangement with full torque available across all displacements up to 500 cm³ and it provides highly dynamic control of hydraulic flow and pressure. Designed to be used in open-circuit systems, its large suction port and flow-optimized suction path ensure robust suction behavior, a high speed limit, and low noise emission. RKP 250 has a maximum speed of 1800 rpm at an inlet pressure of 0.8 bar absolute, enabling it to operate in machines at high altitudes without the need for a pre-load pump. moog.com.



classifieds

ad index

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editorial preview

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- Powder Compaction Manufacturing
- Cooling Rate, Weld Size, and Ferrite Content in Duplex Stainless Steels

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Failure Analysis

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- Corrosion Solutions and Case Studies

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Subscriptions/Customer Service:
800.336.5152, ext. 0
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Sales Staff:
Skip Wolfe, *Director, Sales and Marketing*
440.338.5151 ext. 5226
Fax: 440.338.8542
skip.wolfe@asminternational.org

***AM&P*/ASM Web Media**
Erik Klingerman,
National Sales Manager
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Fax: 440.338.8542
erik.klingerman@asminternational.org

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STRESS RELIEF

Bees are now incorporating plastics into nest construction. Courtesy of Albert Herring/Wikimedia Commons.

Plastic bee hives create buzz

A new study reveals that some bees use bits of plastic bags and plastic building materials to construct their nests. The discovery shows bees' resourcefulness and flexibility in adapting to a human-dominated world, says Scott MacIvor, a doctoral student at York University and graduate of University of Guelph, both in Ontario. Although researchers have shown adverse impacts of these materials on various species and ecosystems, few scientists have observed insects adapting to a plastic-rich environment.

Determining that bees are using plastics in place of natural materials was accomplished by Andrew Moore, supervisor of analytical microscopy at Laboratory Services. He analyzed grey "goo" discovered in the nests of one kind of bee, *Megachile campanulae,* which uses plant resins to build its nests. A scanning electron microscope identified the polymers. The bees also occasionally replace plant resins with polyurethane-based exterior building sealant, such as caulking, in their brood cells—created in a nest to rear larva.

Researchers also discovered that another kind of bee, *Megachile rotundata,* uses pieces of polyethylene-based plastic bags to construct brood cells. The glossy plastic replaced almost 25% of the cut leaves normally used to build each cell. Markings show that the bees chew plastic differently than leaves, suggesting intentional plastic collection. *For more information: Scott MacIvor, jsmacivor@gmail.com, www.uoguelph.ca.*

Chickens see new state of matter

The unusual arrangement of cells in a chicken's eye constitutes the first known biological occurrence of a potentially new state of matter known as "disordered hyperuniformity," according to researchers from Princeton University, N.J., and Washington University, St. Louis. Research in the past decade has shown that disordered hyperuniform materials have unique properties when it comes to transmitting and controlling light waves. These findings add a new dimension called multi-hyperuniformity, meaning that the elements that make up the arrangement are themselves hyperuniform. While individual cones of the same type appear to be unconnected, they are actually subtly linked by exclusion regions, which are used to self-organize patterns. Multi-hyperuniformity is crucial for the avian system to evenly sample incoming light, say researchers. It is speculated that this behavior could provide a basis for developing materials that can self-assemble into a disordered hyperuniform state. *princeton.edu, wustl.edu.*

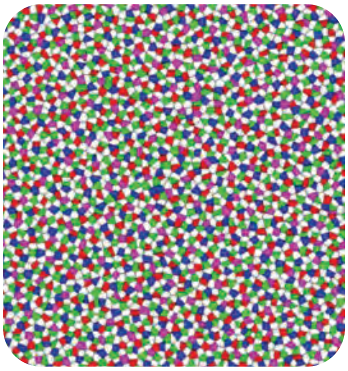
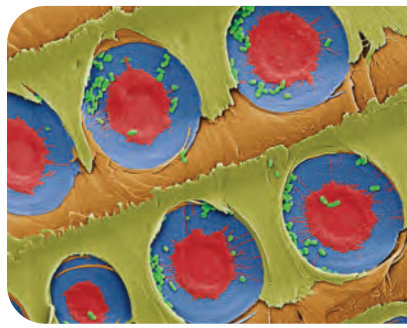


Diagram depicts the spatial distribution of the five types of light-sensitive cells known as cones in chicken retinas. Courtesy of Joseph Corbo and Timothy Lau, Washington University.

Sapwood filters bacteria from contaminated water

Need a simple solution to make drinking water? Simply break a branch off a pine tree, peel away the bark, and slowly pour water through it. The improvised filter should trap any bacteria, producing fresh, uncontaminated water. A team at Massachusetts Institute of Technology, Cambridge, discovered that this low-tech filtration system can produce up to four liters of drinking water per day—enough to quench the thirst of a typical person. Researchers demonstrate that a small piece of sapwood can filter out more than 99% of the bacteria *E. coli* from water. They say the size of the pores in sapwood—which contains xylem tissue evolved to transport sap up the length of a tree—also allows water through while blocking most types of bacteria.



A false-color electron microscope image showing E. coli *bacteria (green) trapped over xylem pit membranes (red and blue) in the sapwood after filtration.*

To study sapwood's water-filtering potential, branches of white pine were collected and the outer bark was stripped off. Small sections of sapwood measuring about 1 x 1 in. were cut and mounted in plastic tubing, sealed with epoxy, and secured with clamps. Before experimenting with contaminated water, water mixed with red ink particles ranging from 70 to 500 nm in size was used. After the liquid passed through, researchers sliced the sapwood in half lengthwise and observed that much of the red dye was contained within the very top layers of the wood, while the filtrate, or filtered water, was clear. *web.mit.edu.*

Specimen Name: Materials Research Data Management Pilot Project

A sample of wrought Mg alloy AZ31 sheet, before (top) and after high-temperature tensile testing, shows the effect of heat as well as strain. Results are being used to help build open data repositories where researchers can easily distribute and share data.

Vital Statistics:

A new collaborative effort among materials researchers and computer scientists shows how test data can be captured and shared in an open repository, an important first step toward achieving the goals of the Materials Genome Initiative (MGI). Doubling the speed at which new materials are developed and deployed—MGI's central objective—requires two things, neither of which exist today. One is a data infrastructure linking multiple repositories; the other is an incentive to fill it with data. However, the value that resides in data—along with the incentive for sharing it—cannot be realized without a fully functioning data infrastructure. This impasse hasn't deterred everyone from pursuing the goals of MGI, as evidenced by several ad hoc projects paving the way toward a new era of materials development.

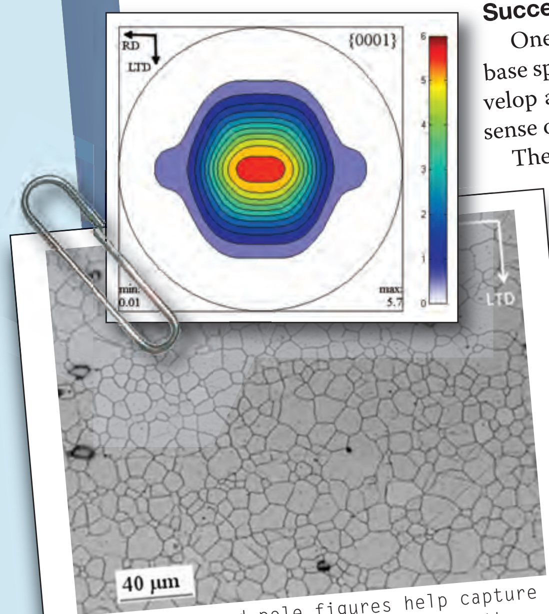
One such effort, the Materials Research Data Management (MRDM) Pilot Project, addresses the issue of how to capture, organize, and share existing test data. "There's a huge amount of data in labs that no one, outside the lab, has access to," says Eric Taleff, a mechanical engineering professor at the University of Texas (UT) at Austin. These "data islands," as Taleff calls them, are a largely untapped resource, and he and others are working diligently to change that.

Success Factors:

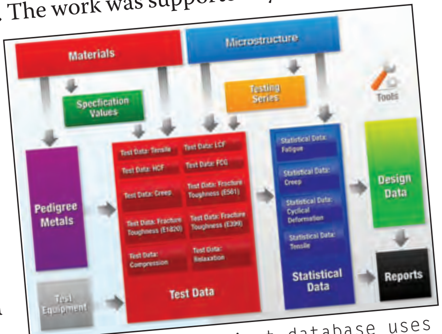
One of Taleff's collaborators on the MRDM project is Tom Searles, a materials database specialist with Materials Data Management Inc., Carmel, Ind. "Our goal was to develop a sample database to assess the level of effort required to fill it and get a better sense of the value potential of the data itself," says Searles.

The data that Searles and others used to populate the database was derived from test results acquired by Taleff and one of his graduate students. "Our original objective was to improve our understanding of plasticity in wrought Mg alloy AZ31 sheet at high temperatures," says Taleff. The work was supported by General Motors, which, along with UT, agreed to allow the data to be used in the Pilot Project.

According to Searles, the data includes specimen details, testing information, and tensile results. Related crystallographic and micrograph data has also been uploaded along with data citations that provide a record of project credits and ancillary information.



Micrographs and pole figures help capture microstructural details relevant to the Mg alloy test samples used to collect tensile data.



The MRDM Pilot Project database uses Granta MI software to accommodate tensile test data, microstructural information, pedigree and citation records, test setup details, and computational results.

About the Innovators:

Eric Taleff is a professor with the Department of Mechanical Engineering at the University of Texas at Austin. Tom Searles is a materials engineer and database specialist with Materials Data Management Inc., Carmel, Ind. Other members of the MRDM Pilot Project team include Stuart Dyer from Granta Design, and Scott Henry and Larry Berardinis from ASM International's Computational Materials Data Network.

What's Next:

The Pilot Project database is nearly complete and is expected to be open to the public sometime this month. Access is free, requiring only basic registration. The database will be accessible at cmdnetwork.org. The consensus among the MRDM project team is to keep expanding the database and begin linking it to other such repositories.

Contact Details:

Eric M. Taleff
Department of Mechanical Engineering, The University of Texas at Austin
204 E. Dean Keeton St., Stop C2200
Austin, TX 78712-1591
512.471.5378, taleff@mail.utexas.edu