SEPTEMBER 2016 | VOL 174 | NO 8

ADVANCED MATERIALS & PROCESSES

AN ASM INTERNATIONAL PUBLICATION

NONDESTRUCTIVE TESTING

ELEMENTAL ANALYSIS MONITORS CORROSION

P.21

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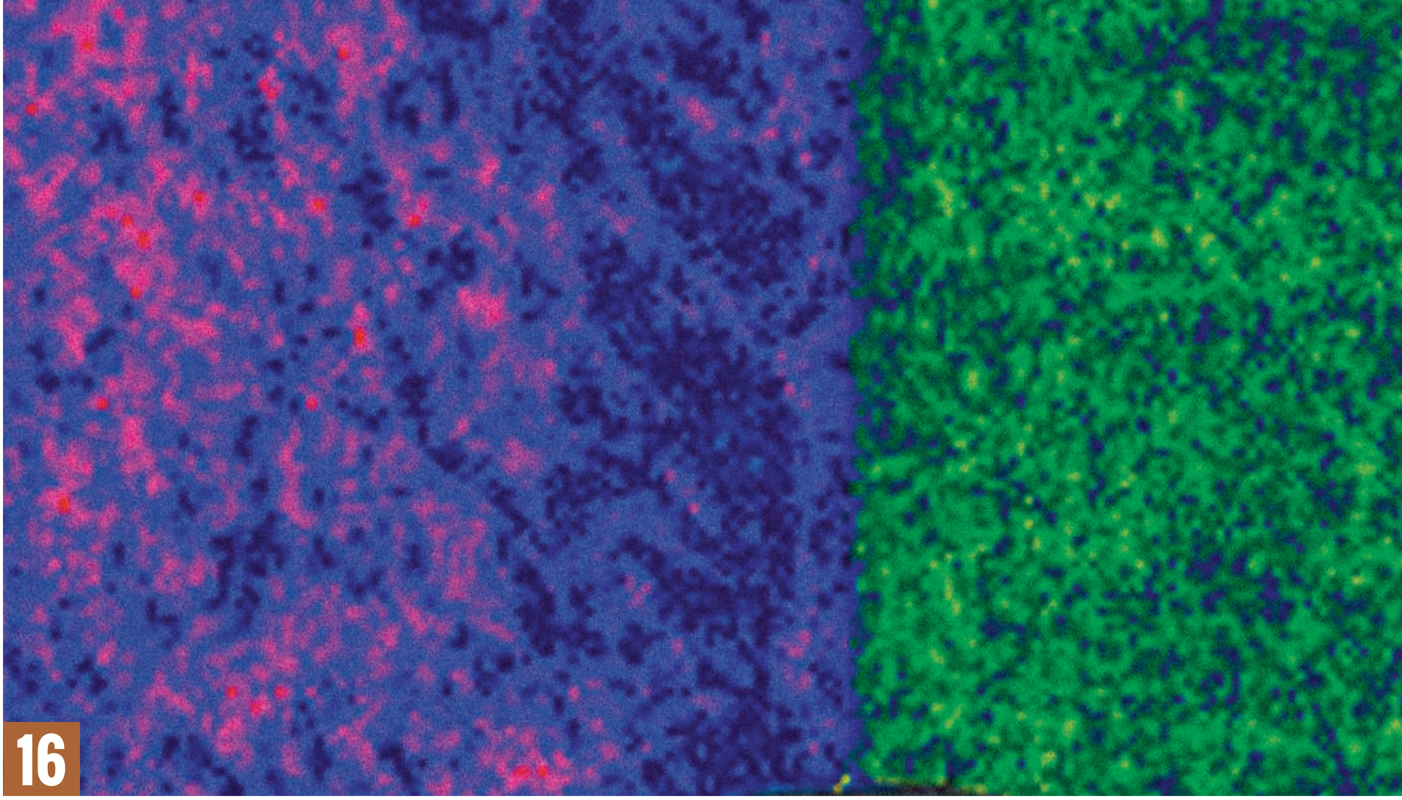

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ADVANCED MATERIALS & PROCESSES

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GOING FOR THE GOLD

The Rio 2016 Olympic Games were just as inspiring as ever, watching the human form do things that seem completely impossible and against all laws of physics and gravity. Mastering the sheer willpower, courage, and years of training it takes to compete at the highest levels of sport is beyond the grasp of most of us, and is what makes viewing these events so enjoyable. But what about the medals themselves? Now here's something that metallurgists and materials scientists of all disciplines will likely appreciate more than other people.

Interestingly, the last Olympic "gold" medal actually made of pure gold was awarded in 1912. Now, the National Olympic Committee (NOC) permits significant freedom to the host city with regard to the exact medal composition and design, although certain rules must be followed. Gold medals must be awarded for first place, measure at least 60 mm in diameter and 3 mm thick, contain a minimum of 92.5% silver, and be covered with at least six grams of pure gold. Further, although the host city is allowed to design the medals, the NOC has the final say on approval. Each host city also must mint its own medals.

2016 Olympic medals are made of mercury-free gold and recycled silver and bronze, and come with sustainable, recycled wooden cases. Courtesy of Tomaz Silva/Brazil Agency.

In Rio, the medals theme focused on sustainability with this year being the first time the awards were made with more than 30% recycled precious metal for both silver and bronze. The silver was recycled from mirrors and x-ray sheets, while the copper used in the bronze medals was salvaged and repurposed from the local mint's old, discarded machinery. In addition, the gold used in the medals is free of mercury in order to prevent pollution and to be more health-conscious for the miners. Finally, the medal cases are made of certified recycled wood that comes from a sustainable environmental management area in Brazil.

In other news regarding materials innovations, the U.S. Department of Energy announced in mid-August that it will invest $16 million to accelerate design of new materials by using supercomputers. Two four-year projects, one led by DOE's Oak Ridge National Laboratory and the other by Lawrence Berkeley National Laboratory, intend to use the superfast computers at DOE's labs by "developing software to design fundamentally new functional materials destined to revolutionize applications in alternative and renewable energy, electronics, and a wide range of other fields." Teams include experts from universities as well as other national labs.

According to the DOE, researchers are expected to develop sophisticated open-source software to capture the physics of relevant systems, which can then be used by the broader research community and industry to accelerate design of new functional materials. Who knows? Results may prove important enough to win a Nobel Prize, a medal still made of pure gold.

F. Richards

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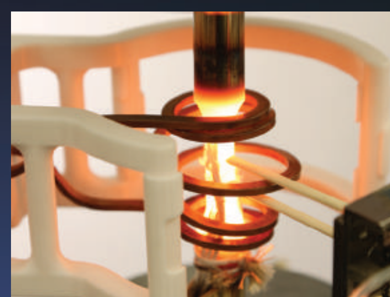

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MARKET SPOTLIGHT

POWDER METALLURGY INDUSTRY SEES STEADY GROWTH

According to analysis from the Metal Powder Industries Federation, Princeton, N.J., the powder metallurgy (PM) industry will see modest growth in 2016, following a healthy 2015. Conventional press-and-sinter companies and metal powder producers report good business levels, as do companies involved with metal injection molding, metal additive manufacturing (MAM), and hot isostatic pressing. However, refractory metal demand has continued to decline.

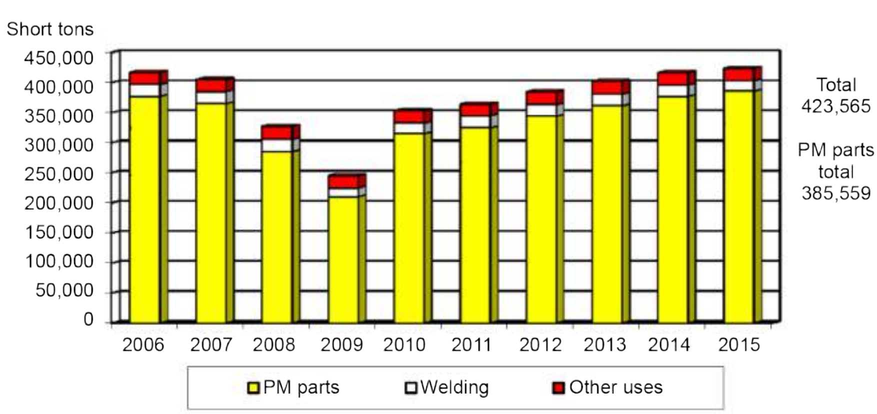
Developing metal powders for MAM via gas atomization is a new trend likely to be accelerated by most leading powder makers, say analysts. Meanwhile, successful use in the aerospace and medical sectors continues to pave the way for future applications. Although the MAM market currently remains small and limited to about 15 commercially available materials, it offers exciting promise for PM in the years ahead.

Another trend is the growing need for precision machining of PM parts. Powder suppliers are introducing high-performance lubricants and additives for the press-and-sinter PM market. Further, the aluminum powder market for PM parts applications is undergoing a new surge as automotive designers seek lighter weight parts. The use of higher-strength aluminum alloys with metal matrix composites is experiencing renewed interest to reduce mass and provide improved properties, and this focus is currently a project within the Lightweight Innovations for Tomorrow consortium.

While MAM hype has moderated, an estimated 50-100 companies and organizations are actively developing programs that use metal powders. To this end, machine sales are surging, but most MAM installations produce parts in short runs of up to 100 units. The aerospace and medical industries are leading adopters of this developing technology. So far, the main MAM powder materials include 316 and 17-4 PH stainless steel, cobalt chrome, and titanium. Other materials used in MAM include Inconel 625 and 718 alloys, platinum, molybdenum, and tungsten. Most companies in the PM industry view MAM as a complementary technology and an opportunity to enter a new technology sector.

For more information, visit mpif.org.

North American Iron Powder Shipments



Courtesy of Metal Powder Industries Federation.

FEEDBACK

The ASM Materials Education Foundation supports educators through a free materials science workshop called ASM Materials Camp–Teachers. This weeklong lab experience shows educators how to use applied engineering techniques in their classrooms. Several 2016 camps have already taken place with more scheduled throughout the year. Below are a few recent comments.

AWESOMESAUCE

I cannot overstate how awesome this camp was on a multitude of levels. I could have gone for a week and a half just so we could get to and finish composites. There was so much material and so many ideas presented that it was almost overwhelming. The instructors did a great job of explaining the material and how to present it to students.

Justin Orlando

REFRESHING WORKSHOP

The instructors were incredibly knowledgeable and accommodating. They went out of their way to help everyone understand the material, feel comfortable enough to implement it, and made adjustments to fit my schedule. I conduct professional workshops myself and am pretty demanding about my expectations for professional development. As a seasoned educator, I often find that other programs lack appropriate materials or presentation style. Not so with the ASM workshop. Instead of my usual critical attitude, I found this workshop to be a refreshing example of how one should be conducted—with pertinent lessons, excellent instructors, and practical materials to implement.

Kathleen Dwyer

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

OMG!
OUTRAGEOUS MATERIALS GOODNESS

A block of wood is made transparent at the University of Maryland.

WOOD YOU LOOK AT THAT?

Liangbing Hu and his team at the University of Maryland, College Park, removed the molecule in wood—lignin—that makes it rigid and dark in color. They left behind the colorless cellulose cell structures, filled them with epoxy, and created a version of the wood that is mostly see-through. “It can be used in automobiles when the wood is made both transparent and high strength,” says Hu. “You could also use it as a unique building material.”

Xylem and phloem pass water and nutrients up and down the tree. These vertically aligned channels in the wood are a naturally grown structure that can be used to pass light along, after the wood has been treated. The resulting 3-in. block of wood features both high transparency and high haze, the ability to scatter light. This would be useful, says Hu, in making devices comfortable to look at. It would also help solar cells trap light because the light could easily enter through the transparent function, but the high haze would keep it bouncing around near where it would be absorbed by the solar panel. *For more information: Liangbing Hu, binghu@umd.edu, www.umd.edu.*

3D-PRINTED BONES ADVANCE MEDICAL RESEARCH

Advanced Bone Technology, Fargo, N.D., is hoping to reduce cadaver use in medical research by 3D printing artificial bones. SimuBone is an artificial bone platform that can be manufactured on demand at a fraction of the cost of alternatives. It combines engineered materials with a specialized additive manufacturing process to produce what is said to be the most realistic alternative to human bone available. High-resolution manufacturing precisely reproduces every detail of the desired bone, including the contour of cortical hard bone and the intricate structure of trabecular spongy bone. SimuBone’s performance against engineered materials and processes is comparable to live bone and tailorable to a specific sex, age, disorder, or even a particular patient. By modifying the geometry and performance to customer specifications, SimuBone devices reportedly meet needs ranging from repeatable lab tests to personalized healthcare.


SimuBone could replace cadavers in medical research.

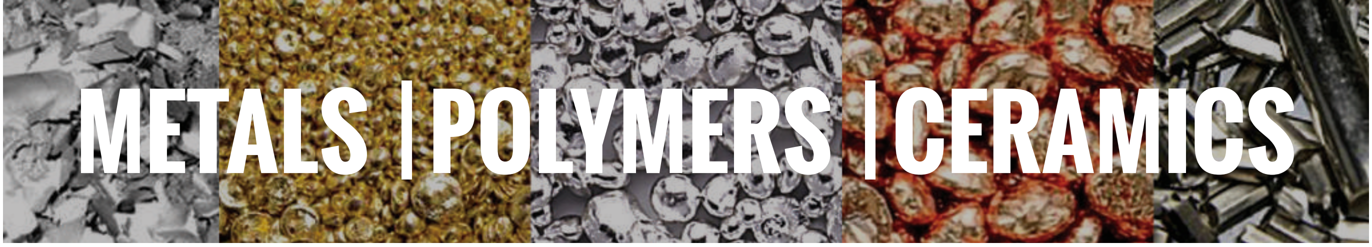
The artificial bone will also enable testing and development of medical devices and training for surgical procedures. *advancedbonetech.com.*

LIGHT-EMITTING CEMENT SAVES ELECTRICITY

José Carlos Rubio at the University of San Nicolas Hidalgo-Michoacan, Mexico, created a cement additive that absorbs solar energy during the day and then emits light for up to 12 hours after dark. The glow-in-the-dark cement—which would eliminate the need for electricity to light highways—is the latest innovation in concrete and cement products. Rubio modified the microstructure of the cement, allowing the concrete to take in solar energy and convert it into light. He says the material could last as long as 100 years and the intensity of blue or green light can be adjusted depending on need. Unlike plastic fluorescents, which have an average lifespan of three years due to decay from UV rays, Rubio explains that his cement will not degrade as a result of sunlight exposure. In addition, the only byproduct of the manufacturing process is steam. *www.umich.mx.*


Glow-in-the-dark cement.

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



Thor, a 3D-printed flying model, took off for its maiden flight in Germany last November.

PRINT ME AN AIRPLANE

Airbus, France, is using a mini aircraft project known as Thor (testing high-tech objectives in reality) as a testbed for futuristic aircraft technologies—from 3D-printed structural parts to advanced aerodynamics and even artificial intelligence. The initial Thor version weighs approximately 21 kg and can fit in a 4×4 m square. It is powered by two 1.5-kW electrically-driven propellers, and 90% of its structural components were 3D-printed from plastic polyamide powder.

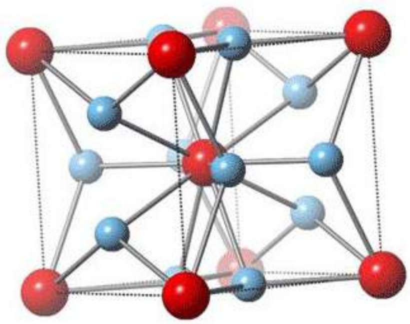
"This mini aircraft does not represent an actual airliner design Airbus is considering, rather it is a platform to enable low-risk and fast-track development of different technologies in real flying conditions," explains Detlev Konigorski, who oversees the project. "The first version was to test whether the slogan 'Print me an airplane' can be converted into reality."

A major advantage of Thor is the short lead time of 3D printing, which significantly reduces development time for producing the technology demonstrator compared to traditional manufacturing methods. Using an existing design concept, it took seven weeks to print the aircraft's 60 structural segments, followed by one week for assembly and three days to fine tune the electrical systems before it was flight-ready. *airbus.com.*

GOLD BOOSTS TITANIUM KNEE STRENGTH

Titanium is the leading material for artificial knee and hip joints because it is strong, wear resistant, and nontoxic, but adding gold might make implants even better. "It is about three to four times harder than most steels," says Emilia Morosan, a materials science professor at Rice University, Houston. The properties of a 3-to-1 mixture of titanium and gold with a specific atomic structure impart the hardness. "It's four times harder than pure titanium, which is what's currently being used in most dental implants and replacement joints." It's not clear that Morosan and former graduate student Eteri Svanidze were the first to make a pure sample of the ultrahard beta form of the compound. However, due to a couple of lucky breaks, they are the first to document the material's remarkable properties.

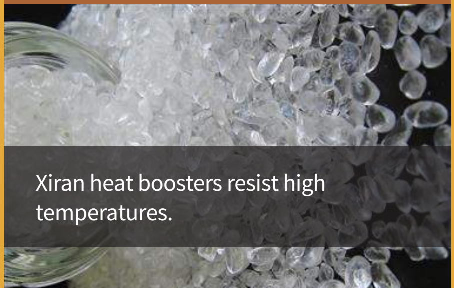
Researchers measured the hardness of the beta form of the crystal and also performed other comparisons with



Crystal structure of beta titanium-3-gold. Courtesy of E. Morosan/Rice University.

BRIEFS

Polyscope Polymers B.V., the Netherlands, expanded its Xiran heat boost range. Originally introduced to increase the high temperature resistance of acrylonitrile butadiene styrene and acrylonitrile styrene acrylate, Xiran heat boosters can now increase the heat performance of other styrenic polymers, such as polystyrene and styrene acrylonitrile, as well as polymethylmethacrylate. *www.polyscope.eu.*



Xiran heat boosters resist high temperatures.

Stainless steel rebar produced by **Outokumpu,** Finland, is being used to reinforce a spill basin at the new liquefied natural gas Gate Terminal on Rotterdam's North Sea coast. Both the basin's concrete and reinforcement must withstand the extreme conditions of a cryogenic environment and temperatures as low as -165°C. *outokumpu.com/rebar.*

titanium. For biomedical implants, for example, two key measures are biocompatibility and wear resistance. Because titanium and gold by themselves are among the most biocompatible metals and are often used in medical implants, the team believed titanium-3-gold would be comparable. In fact, tests determined that the new alloy was even more biocompatible than pure titanium. The story proved much the same for wear resistance: Titanium-3-gold also outperformed pure titanium. *rice.edu.*

Rare earth metals are used in everything from wind turbines and cell phones to electric cars and precision weapons. Courtesy of Wikicommons.

NONTOXIC METHOD EXTRACTS RARE EARTHS

Researchers from the Harvard John A. Paulson School of Engineering and Applied Sciences (SEAS), Cambridge, Mass., may have found a clean alternative to extracting rare earth metals. David Clarke, the materials professor at SEAS, and his graduate student William Bonificio, developed a method to separate rare earths using bacteria filters and solutions with pH no lower than hydrochloric acid. They immobilized a bacteria from marine algae on an assay filter and passed a solution of mixed rare earths (lanthanides) through it. The bacteria bioabsorbed all of the elements as they passed—plucking them out of the solution and fixing them to their surface.

Next, researchers pumped solutions of various pH balances through the filter. With each successive pH wash, different rare earths detached. Researchers found that lighter lanthanides, such as europium and praseodymium, desorbed with higher-pH washes while heavier lanthanides, such as thulium, lutetium, and ytterbium, desorbed with lower pH. *For more information: David Clarke, clarke@seas.harvard.edu, www.seas.harvard.edu.*

TESTING | CHARACTERIZATION

Juan Carlos Idrobo helped develop an electron microscopy technique to measure magnetism at the atomic scale.

ATOMIC-LEVEL MAGNETISM COMES INTO FOCUS

Scientists from the DOE's Oak Ridge National Laboratory (ORNL), Tenn., and Uppsala University, Sweden, developed a new electron microscopy technique that detects magnetic behavior at the atomic level. While researchers commonly correct distortions that arise in the electron-optical lens, blurring the resulting images, this team took advantage of these aberrations, purposely adding a four-fold astigmatism to collect atomic-level magnetic signals from a lanthanum-manganese-arsenic oxide material.

"Magnetism has its origins at the atomic scale, but the techniques that we use to measure it usually have spatial resolutions much larger than one atom," explains ORNL's Juan Carlos Idrobo. "With an electron microscope, the electron probes can be made as small as possible, and if you know how to control the probe, you can pick up a magnetic signature." Idrobo suggests that the new technique could ultimately lead to smaller magnetic hard drives. In addition, it can complement existing methods such as x-ray spectroscopy and neutron scattering that are considered the gold standard in studying magnetism but are limited in their spatial resolution. *ornl.gov, www.uu.se/en.*

AN EIT CHECKUP FOR STRUCTURAL HEALTH

Engineers at the University of Delaware's Center for Composite Materials, Newark, developed a new approach to assess invisible damage that can occur in structures like bridges and buildings over time or after catastrophic events. The method uses a distributed carbon nanotube composite sensor in conjunction with electrical impedance tomography (EIT). The relatively inexpensive, mechanically robust "smart skin" sensor is electrically isotropic and can adhere to virtually any shape. While carbon nanotube composites have been used as sensors before, typically a series of one-dimensional measurements are collected from a 2D area, confining possible damage locations to the grid points of the measurements. With EIT, however, a true 2D algorithm can be used.

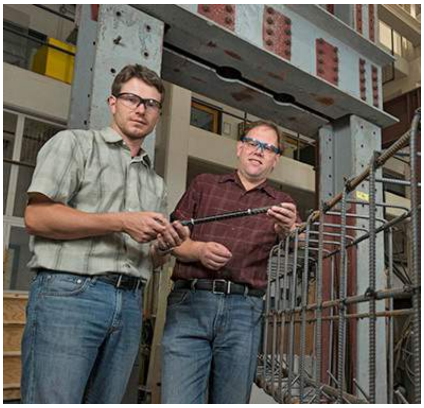
The team evaluated the methodology on composite laminate, first with well-defined damage, then with more

BRIEFS

The **King Abdullah University of Science and Technology** (KAUST), Saudi Arabia, will establish a new Center of Excellence at the KAUST Research and Technology Park on campus. KAUST purchased electron microscopy equipment from **FEI,** Hillsboro, Ore., including a Titan Themis transmission electron microscope and a Helios G4 DualBeam. Later this year, the new systems will be added to 17 FEI electron microscopes already installed at the site. *www.kaust.edu.sa, fei.com.*

Henkel, Germany, opened a new state-of-the-art testing facility in Heidelberg. At the Composite Lab, customers can perform trials using high-pressure resin transfer molding equipment, including a 380-ton press and injection equipment for polyurethanes and epoxy materials. *composite-lab.com.*

The new Composite Lab at Henkel.



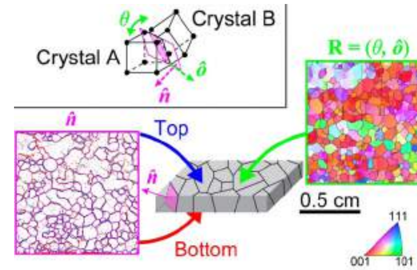
Thomas Schumacher (left) and Erik Thostenson are leading research on a new technique to monitor the health of structures such as roads and bridges.

realistic damage. While there were some discrepancies between the size and shape of cracks on the resulting EIT maps and data from visual inspection and thermograms, overall the approach detected damage well before it was visible with infrared thermography. *udel.edu.*

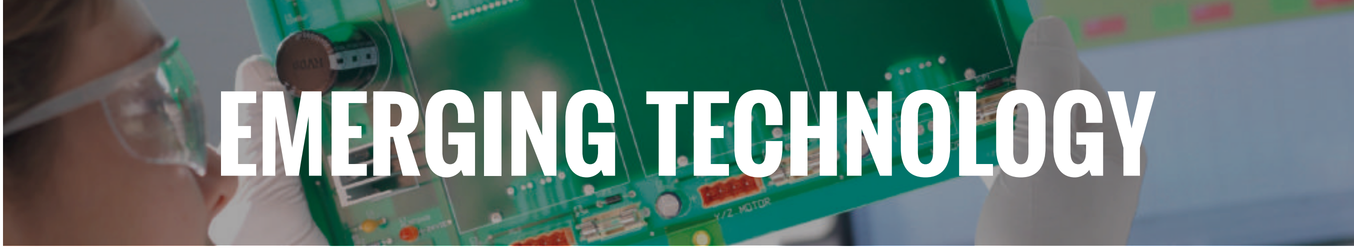
A NEW LOOK AT POLYCRYSTALLINE METALS

By combining established testing technologies in a novel way, researchers from Massachusetts Institute of Technology, Cambridge, and colleagues devised a new approach to characterize the microstructure of polycrystalline metals. The method marries optical and electron microscopy. It is also fast, affordable, accurate, and accessible—a combination not yet achieved with current testing methods for these metals, which are comprised of a random matrix of multiple small crystals rather than a single, large crystal, making them difficult to analyze.

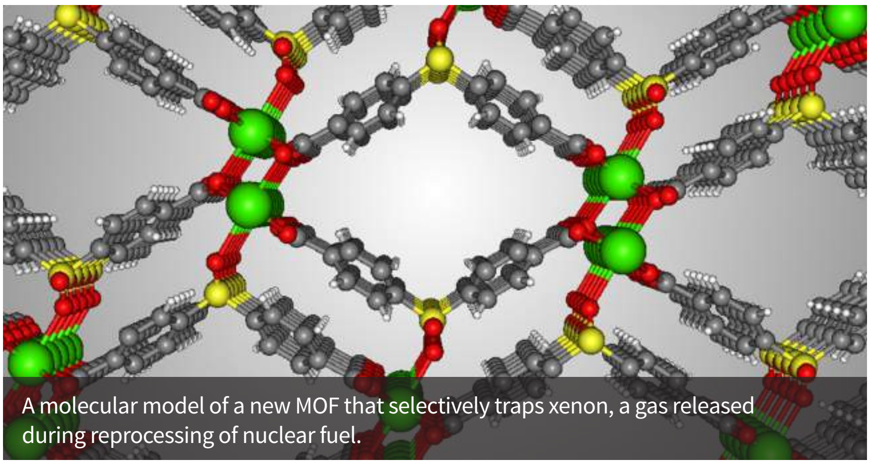
Quantifying the characteristics of interfaces between crystals in polycrystalline metals allows their material properties to be determined. To do this, researchers took optical microscope images of both sides of a sheet of polycrystalline metal foil thin enough for single grains to be seen from either side. Using software, grain boundaries were connected from one side to the other, reconstructing their 3D orientation. This data was combined with electron microscope images to show the orientation of individual crystal lattices within each grain and how they relate to those of adjacent grains. The new, nondestructive method determines all five necessary characteristics of grain boundaries, whereas previous methods achieved only two or three. *mit.edu.*



A new method combines optical microscopy (left, pink) with electron backscatter diffraction (right, green) to measure characteristics of the boundaries between crystal grains. Courtesy of Matteo Seita.



EMERGING TECHNOLOGY



A molecular model of a new MOF that selectively traps xenon, a gas released during reprocessing of nuclear fuel.

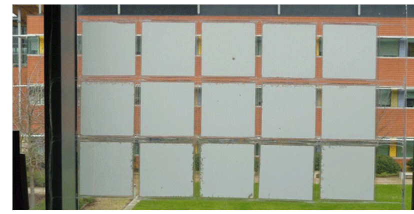
NEW MATERIAL NETS BETTER NUCLEAR FUEL RECYCLING

An international collaboration including researchers from the DOE's Pacific Northwest National Laboratory, Richland, Wash., and Lawrence Berkeley National Laboratory, Calif., is investigating whether metal organic frameworks (MOFs) could improve nuclear fuel recycling by capturing radioactive xenon and krypton at ambient temperature, avoiding the expensive, energy-intensive cryogenics necessary in current practice. MOFs contain tiny pores as small as a single molecule. When gaseous mixtures are passed through MOF walls, certain gases adsorb to the material, while the rest sift through.

To determine which MOFs out of 125,000 possibilities could be used for xenon and krypton separation, computational chemists used machine learning techniques to evaluate the materials based on seven predictive characteristics. They identified SBMOF-1 with a pore size close to that of a xenon atom as the best candidate. Laboratory tests confirmed that SBMOF-1 trapped xenon until the gas saturated the material, and in the absence of xenon it captured krypton, indicating that a mixture could be passed through SBMOF-1 twice to capture both gases. In high humidity, SBMOF-1 retained more than 85% the amount of xenon as in dry conditions, and after 10 cycles of vacuuming, it collected just as much xenon as in the first cycle, indicating a high degree of stability for long-term use. *pnnl.gov, lbl.gov.*

NOW YOU SEE IT, NOW YOU DON'T

Researchers at the University of Cambridge, UK, developed a type of smart glass that switches from transparent to opaque and back using minimal energy. The glass is embedded with Smectic A composites, which can be changed from clear to cloudy millions of times and kept in either state for as long as desired. The composites can be produced in a roll-to-roll process and printed onto plastic. The main component of Smectic A, a smectic liquid crystal, is comprised of molecules with similar directional ordering arranged in stacked layers, which confine the movement of ionic additives.

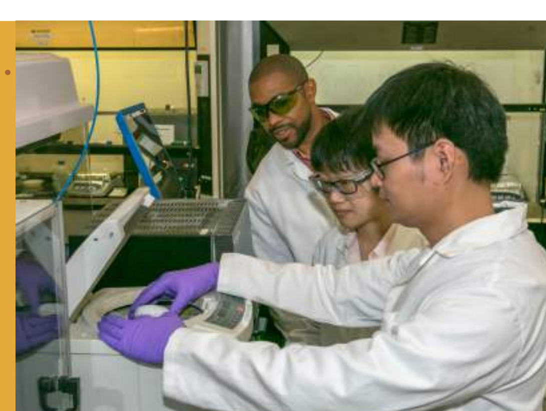


Smart glass goes from clear to opaque and back again, millions of times.

When voltage is applied, molecules align themselves with the electric field, rendering the glass transparent. When voltage direction is changed, the ionic additives disrupt the crystal layer structure, making the glass appear milky. Increasing voltage frequency freezes out ionic additive movement, reverting the pane to transparent. These transitions happen in a fraction of a second, and when the voltage is cut, the material remains in its current state until the user changes it—so unless the material is actively switching states, it requires no power. "You could have smart windows in an office building that automatically become more or less opaque, depending on the amount of sunlight coming through," explains Professor Daping Chu. The smart glass could also be used in automotive applications and advertising. *www.cam.ac.uk.*

BRIEF

A team of researchers from **Lawrence Livermore National Laboratory,** Calif., and **University of California, Santa Cruz** devised a method for doubling the performance of 3D-printed graphene-base supercapacitors. The technique involves sandwiching lithium ion and perchlorate ion between layers of graphene in aerogel electrodes, substantially improving electrode capacity while maintaining an excellent rate capability. *llnl.gov, ucsc.edu.*



Cheng Zhu mixes ink material while colleagues observe. Courtesy of Julie Russell/LLNL.

PROCESS TECHNOLOGY

Savannah Bachman explores potential retrieval of rare earth elements from water used in oil and gas production.

RECOVERING RARE EARTHS FROM INDUSTRIAL WATER

Researchers from the University of Wyoming (UW), Idaho National Laboratory (INL), and the U.S. Geological Survey (USGS) are investigating whether rare earth elements can be recovered from the high-temperature fluid byproducts associated with energy extraction. In recent years, demand for rare earths has increased—and so has their cost—stimulating interest in new recovery methods. The UW-INL-USGS collaboration is one of four groups to receive $4 million from the U.S. DOE to determine the feasibility of obtaining these critical materials from the byproducts of oil and gas production and geothermal projects.

The team aims to develop a database of rare earth elements and trace metals from oil and gas-produced waters from some of the nation's most prolific hydrocarbon basins, identify similar oil and gas reservoirs, and create a mathematical screening tool to test national geochemical databases. UW researchers recently demonstrated an accurate method to measure rare earth concentrations in highly saline fluids, paving the way for the current research. *uwyo.edu, inl.gov, usgs.gov.*

BIOADHESIVE PROCESS REVEALED

Researchers at The Ohio State University, Columbus, discovered the mechanism at work behind one of the strongest adhesives in nature—glue used by English ivy to cling to walls and trees, which is powerful enough to withstand a hurricane. Examining this glue with an atomic force microscope revealed

English ivy secretes one of the most powerful glues found in nature.

previously unknown nanoparticles, which are composed primarily of arabinogalactan proteins. "When climbing, ivy secretes these tiny nanoparticles that make initial surface contact," explains Mingjun Zhang, professor of biomedical engineering. "Due to their high uniformity and low viscosity, they can attach to large areas on various surfaces."

Investigating further, Zhang and his team found that the driving force behind the glue's curing process is a calcium-mediated interaction between these proteins and pectin in the gelatinous liquid that oozes from the ivy as it climbs, finding its way into openings invisible to the naked eye. After the moisture evaporates, a chemical bond forms. To confirm their discovery, scientists used the nanoparticles to reconstruct a simple glue that mimics ivy adhesive.

Understanding the proteins that give the glue its strength could lead to new adhesives for medical and industry products, according to Zhang, who foresees bioadhesives that could aid in wound healing. Others, notably the U.S. military, are interested in surface-coating applications that could strengthen armor systems. *osu.edu.*

BRIEFS

L&S Machine Co. LLC, Latrobe, Pa., received ISO 9001:2008 and AS9100C accreditation for the manufacture and fabrication of build-to-print metal and phenolic parts. The certifications apply to the company's precision machining, welding, waterjet cutting, and electrical discharge machining as well as prototyping and inspection services. *lsmachineco.com.*

Houghton International Inc., Norristown, Pa., acquired the metalworking fluid and industrial lubricant manufacturer **Wallover Enterprises,** Strongsville, Ohio. Wallover supplies industrial markets throughout the U.S. and Canada and provides technical expertise in electrical discharge machining fluids and cold rolling oils for stainless steel. *houghtonintl.com.*

SURFACE ENGINEERING

A steel panel with the new anti-corrosion treatment after being exposed to hundreds of hours of salt spray shows virtually no signs of corrosion. Courtesy of Patrick Dodds, Swansea University.

CORROSION-PROOF STEEL

A team from Swansea University, UK, which is developing a new smart release corrosion inhibitor for use in coated steel products, is working on an alternative to hexavalent chromate—a common corrosion inhibitor facing an EU ban in 2019. Corrosion inhibitors are commonly used in a wide range of sectors, including coated steel products used to construct industrial, commercial and other buildings; aerospace and aircraft; and the automobile industry.

The device contains a stored reservoir of corrosion inhibitor. It works by channeling aggressive electrolyte anions into the coating, triggering the release of the inhibitor on demand, thus preventing corrosion. "The system prevents the onset of corrosion for over 24 hours compared to less than two hours for the current market leader," says Professor Geraint Williams. "We have demonstrated that the rate of corrosion can be slowed down significantly once it has started. This is by far the best result seen in 15 years of research on this topic." *For more information: Geraint Williams, geraint.williams@swansea.ac.uk, www.swansea.ac.uk.*

GLAZING GLASS FOR GREENER BUILDINGS

The amount of energy needed to cool and ventilate all-glass buildings can make them extremely heavy users of resources—an expense that has both ecological and economic consequences. This is why glazing technologies play a critical role in the future of glass manufacturing and sustainable urban development.

In an effort to make all-glass buildings more sustainable and energy-efficient, assistant professor of mechanical and materials engineering Adel Gougam of Masdar Institute, United Arab Emirates, is leading a team that developed a low-cost glass coating that can significantly reduce the amount of heat that penetrates glass while minimizing manufacturing costs.

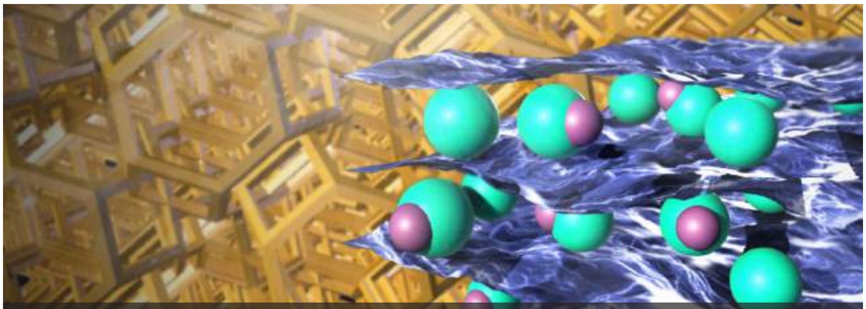
The material used to make this unique glass coating is metal oxide based, which when coated on a glass pane, lets in an ample amount of sunlight while blocking solar infrared radiation. This technique helps to maintain a neutral and natural appearance at a much lower manufacturing cost than conventional coatings. "By avoiding the need to repeat the vapor deposition technique several times, we reduced the complexity and energy requirement of the manufacturing process, as well as the manufacturing cost, contributing to a more sustainable production process and product," says Gougam. *For more information: Adel Gougam, agougam@masdar.ac.ae, www.masdar.ac.ae.*

The iconic Aldar Headquarters building in Abu Dhabi has a panoramic glass facade glazed with an energy efficient, low emissivity coating.

BRIEF

Pipe Restoration Technologies, Las Vegas, was granted its 15th U.S. patent for the ePIPE epoxy coating system. The system effectively and safely seals leaks and protects pipes from lead leaching. Pipes as small as 0.5 in. diameter can be protected from lead leaching and restored by sealing leaks in-place using the minimally invasive technique. *aceduraflo.com.*

NANOTECHNOLOGY



Researchers sandwich lithium ion and perchlorate ion between layers of graphene, substantially improving 3D-printed aerogel supercapacitor performance.

BOOSTING PERFORMANCE OF 3D-PRINTED GRAPHENE AEROGEL SUPERCAPACITORS

Researchers from Lawrence Livermore National Laboratory (LLNL), Calif., along with a team from the University of California, Santa Cruz devised a method to double the performance of 3D-printed graphene-based supercapacitors. The procedure, which involves sandwiching lithium ion and perchlorate ion between layers of graphene in aerogel electrodes, substantially improves the capacity of the electrodes while maintaining the devices' excellent rate capability.

"This is a unique process that significantly raises the performance of previous graphene aerogel supercapacitors," says LLNL engineer Cheng Zhu. "We've modified the devices and found the best recipe." The technique involves two ion-intercalation steps, followed by hydrolysis of perchlorate ion intercalation compounds.

"This two-step electrochemical process increases the surface area of graphene-based materials for charge storage, as well as the number of pseudo-capacitive sites that contribute additional storage capacity," says Zhu. "In the future, I think every device will be customized, so you need the unique architecture or shape (for the supercapacitor)," he says. "If you can 3D print it, you can make any shape you want. Everyone could design their own iPhone." *For more information: Cheng Zhu, zhu6@llnl.gov, www.llnl.gov.*

NANOMATERIALS ENHANCE WINDOW EFFICIENCY

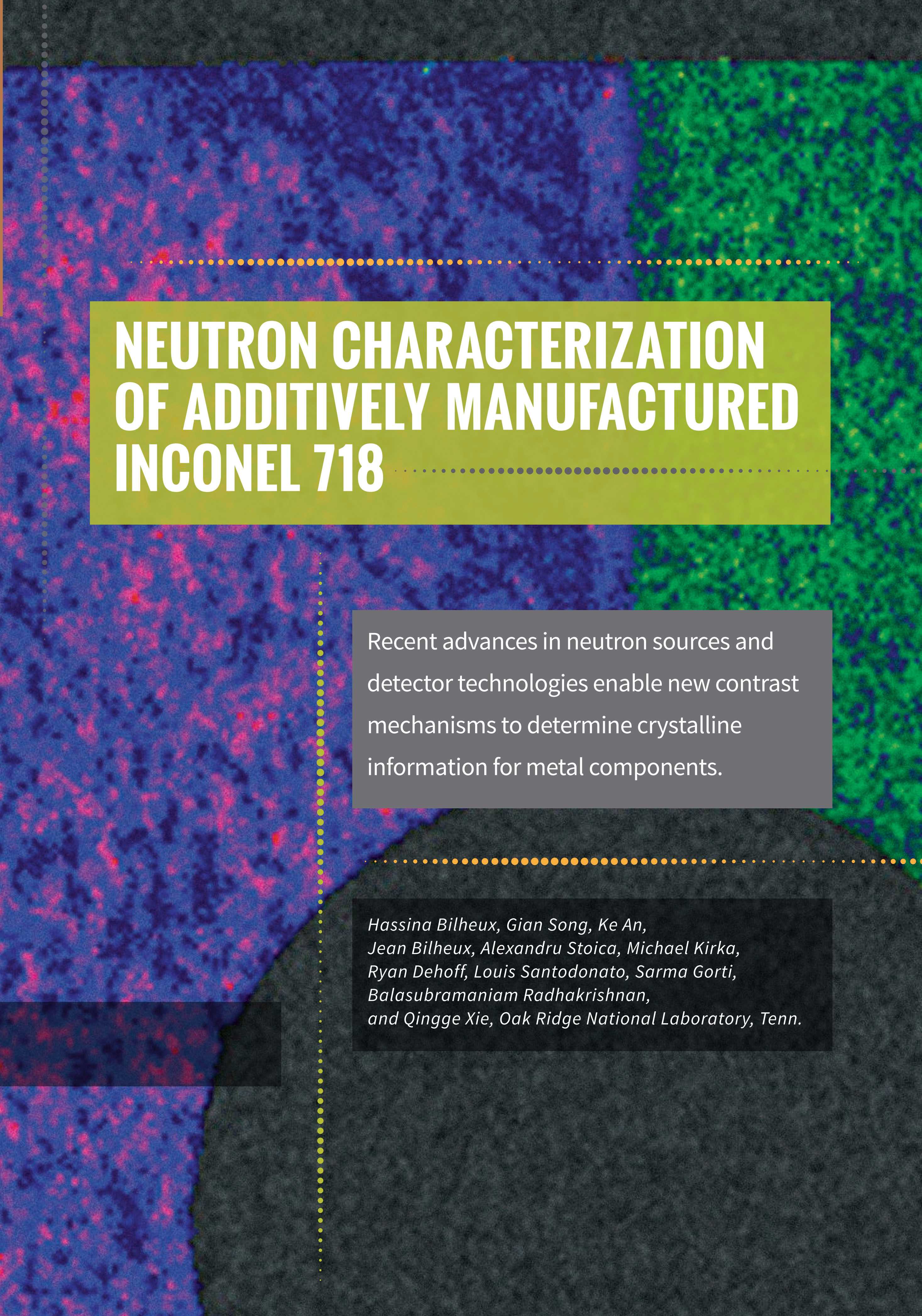
Researchers at the U.S. Department of Energy's Argonne National Laboratory, Ill., are using nanomaterials to improve the energy efficiency of existing single-pane windows in commercial and residential buildings. The team was recently awarded a $3.1 million grant from DOE's Advanced Research Projects Agency-Energy (ARPA-E) to develop a technology that could achieve that goal.

The nanofoam the team is developing—a nanocellular composite with super thermal insulation and soundproofing—uses gas bubbles less than 100 nm in diameter to block the transfer of heat and sound through glass windows while allowing visible light to pass through and maintain a clarity similar to normal windows. "That's really the trick, blocking the heat and sound transfer while maintaining transparency," says Ralph Muehleisen, principal building scientist. "It's fairly simple to develop a coating that insulates, but getting one that is thin and you can still see through is a substantial technical challenge."

The nanofoam, which will be extruded into sheets about 3 mm thick, thermally insulates by using tiny bubbles to reduce collisions among gas molecules, thereby reducing heat energy transfer. When bubbles are reduced to that scale, super thermal insulation becomes possible. According to ARPA-E, single-pane windows make up 30-40% of windows in the U.S., depending on the region. Single-pane windows conduct at least twice as much heat as double paned, so retrofitting all those windows could save about $12 billion a year in energy costs. *For more information: Ralph Muehleisen, rmuehleisen@anl.gov, www.anl.gov.*

BRIEF

Malvern Instruments, UK, released an automated analyzer that uses dynamic light scattering to measure the size of nanoparticles in suspensions and emulsions. The Zetasizer AT provides timely and reliable data that enables tracking of processes in the sub-micron size range, such as emulsification, dispersion, milling and homogenization, while at the same time eliminating the delays and inefficiencies associated with manual analysis. *malvern.com.*



NEUTRON CHARACTERIZATION OF ADDITIVELY MANUFACTURED INCONEL 718

Recent advances in neutron sources and detector technologies enable new contrast mechanisms to determine crystalline information for metal components.

*Hassina Bilheux, Gian Song, Ke An,
Jean Bilheux, Alexandru Stoica, Michael Kirka,
Ryan Dehoff, Louis Santodonato, Sarma Gorti,
Balasubramaniam Radhakrishnan,
and Qingge Xie, Oak Ridge National Laboratory, Tenn.*

Reactor-based neutron radiography is a nondestructive, noninvasive characterization technique used extensively to characterize engineering materials[1]. It is often used to inspect[2,3], evaluate porosity, and to observe parts in-operando[4]. Neutron radiography has been flourishing at reactor facilities for more than four decades, but is relatively new to accelorator-based neutron sources[5]. Recent advances in neutron sources and detector technologies include the spallation neutron source (SNS) at Oak Ridge National Laboratory (ORNL) and the microchannel plate (MCP) detector[6-8], respectively. These advances enable new contrast mechanisms using neutron scattering Bragg features for crystalline information, such as average lattice strain[9], crystalline plane orientation, and identification of phases in a neutron radiograph[10].

This new capability can help validate emerging additive manufacturing (AM) processes. AM holds enormous potential to revolutionize manufacturing by enabling new designs with complex geometries[11] that are not feasible with conventional manufacturing processes. However, the technique lacks process optimization and control standards compared with traditional processes. Residual stresses that commonly occur when materials are machined, heat treated, hot and cold worked, and welded significantly affect mechanical properties and durability. Residual stresses can also occur during AM. For example, defects in AM parts such as internal cracks can propagate over time as the component relaxes after removal from the build plate.

Because AM parts can only be assessed after completion, it is impossible to identify defects early enough to minimize expensive reruns. Current validation of AM materials and processes occurs mainly through expensive trial-and-error experiments at the component level. By comparison, the level of confidence in predictive computational modeling in conventional processes is high enough to allow process and materials optimization through computational approaches. Thus, nondestructive characterization techniques and processing-microstructure databases are needed to develop and validate predictive modeling tools for AM.

PRINCIPLES OF NEUTRON RADIOGRAPHY

Neutron radiography (nR) measures neutron beam attenuation caused by absorption and scattering within a sample using a 2D, position-sensitive detector that measures transmitted neutron flux. Neutron computed tomography (nCT) measures neutron beam attenuation in 3D by rotating a sample to record attenuation for multiple beam paths through an object. The sample is usually rotated from 0° to 180°, assuming the beam is parallel. Data quality is improved by scanning over the full 360° range (super-sampling technique). Computational reconstruction enables virtual visualization of the sample in 3D.

Neutrons can be used to study defects, grain orientation and size, residual stress, and phase distribution using both imaging and diffraction techniques. The principle of neutron radiography is based on the Beer-Lambert law given by:

$$I(\lambda) = I_0(\lambda)e^{-\sum_i \mu_i(\lambda)x_i} \quad (1)$$

where $I(\lambda)$ is the transmitted beam intensity for a neutron of wavelength λ; $I_0(\lambda)$ is the incident beam intensity; and $\mu_i(\lambda)$ is the linear attenuation coefficient of element i, of thickness x_i, as seen by neutrons. The linear attenuation coefficient, μ_i is given by:

$$\mu_i = \frac{\sigma_i(\lambda)\rho_i N_A}{M_i} \quad (2)$$

where $\sigma_i(\lambda)$ is the neutron total cross section (sum of scattering and absorption cross sections) of element i, ρ_i is material density, $\mathbf{N_A}$ is Avogadro's number, and M_i is the element molar mass. At a time-of-flight (TOF) neutron source, such as the SNS, neutrons are produced in pulses after being kinetically cooled or moderated by light atoms, resulting in an uncertainty in the time of emission, t_e, when the neutrons leave the moderator. Neutron wavelength, λ, is determined by:

$$\lambda = \frac{h}{m_n}\frac{(t-t_e)}{L} \quad (3)$$

where t is the time of detection and L is the distance between the source and detector. Such wavelength dependent information is collected at a reactor source, for example, by using a crystal monochromator (a crystal that transmits a selected band of neutron wavelength). However, using this method reduces incident intensity by almost two orders of magnitude. All wavelengths within a pulse are collected at an accelerator-based or TOF neutron source, and wavelength (or energy) is sorted by the time each neutron is observed, reducing acquisition time from several days to a few hours. This enables acquiring neutron data at the highest TOF resolution achievable and post-processing the data in 2D and 3D images. Because neutron cross sections are wavelength dependent, the intensity of each pixel of the radiograph, I, obtained at different wavelength ranges displays a different contrast. In non-textured crystalline materials, narrow dips and abrupt edges in pixel intensity occur at precise neutron wavelengths specified by Bragg's law:

$$\lambda_{hkl} = 2d_{hkl}\sin\theta_{hkl} \quad (4)$$

where d_{hkl} is the interplanar distance for the (hkl) atomic planes and θ_{hkl} are the Bragg angles (angles between the incident neutron beam and crystalline planes). At a given (hkl) and for $\theta_{hkl} < 90°$ or $\theta_{hkl} > 90°$, neutrons scatter/diffract or transmit, respectively. At $\theta_{hkl} = 90°$, the neutron wavelength reaches $\lambda = \lambda_{hkl}$, neutrons reach the lowest transmission, and the darkest pixels are indicative of the *hkl* orientation, thus effectively creating a map of preferred crystalline plane orientations averaged through the thickness of a material.

The wavelength resolution of a neutron instrument, $\Delta\lambda/\lambda$, and the absence/presence of texture define the shape of the Bragg edge. Assuming sufficient wavelength resolution[10], sharp Bragg edges are indicative of texture-free material. The position of the Bragg edge is defined by the applied or residual stress in the sample[9,12]. The precise location of the Bragg edge as a function of spatially related applied or residual stress conditions can directly measure d-spacing of an imaged sample over the entire view area with single pixel size defining the gauge volume, leading to potentially increased spatial resolution of the strain maps.

Using neutrons to image residual stress enables nondestructive penetration deep into large components. Hard (high energy) x-rays offer similar penetration capability (depending on the material), but the relevant diffraction angles are very small, so gauge volumes are needle-like, which is problematic for measuring one component of the stress. Therefore, the two techniques are highly complementary and are increasingly used in combination. A limitation of the residual stress and Bragg-edge imaging techniques is the ability to time-stamp neutrons at a very high temporal resolution to provide a mechanism to detect Bragg shifts. Analysis of the imaging pattern using single Bragg peak fit or full pattern Rietveld refinement gives an accurate value for the interplanar spacing, d_{hkl}, from which the lattice strain, ε, can be determined by:

$$\varepsilon = \frac{d_{hkl}-d_0}{d_0} \quad (5)$$

where d_0 is the reference interplanar spacing under stress-free conditions. For tensile strain, d_{hkl} is greater than d_0, which means the Bragg's peak shifts to a smaller angle; for compressive strain, d_{hkl} is smaller than d_0.

PUTTING NCT TO WORK

A 70-mm-tall Inconel 718 turbine blade made by AM was measured using nCT at the high flux isotope reactor (HFIR) CG-1D neutron imaging beamline at ORNL[13]. Figure 1a shows the blade's rendered volume obtained from nCT using fake coloring. Virtual studies can be performed on a selected section of the part (Fig. 1b) or on a slice-by-slice basis (Fig. 1c). Figure 1c shows the nCT attenuation slice in gray scale overlapped with the outline of the component (in yellow) from the engineering drawing from which the part was printed. This direct comparison

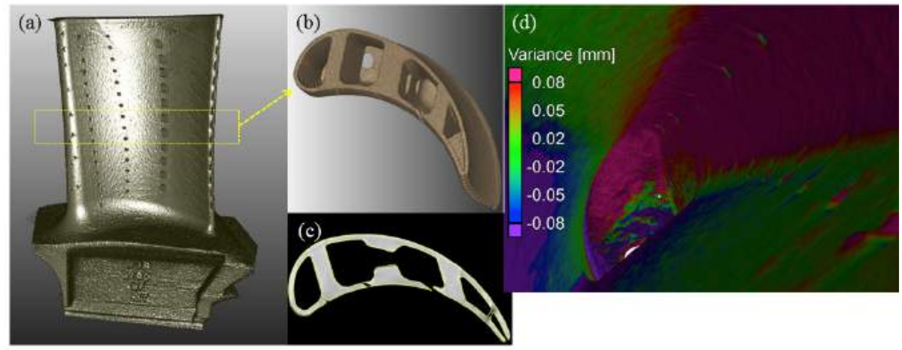


Fig. 1 — Examination of AM Inconel 718 turbine blade using neutron computed tomography: (a) nCT rendered volume; (b) virtual section from yellow outlined area in nCT data; (c) engineering drawing contours (yellow) overlapping neutron slice (gray); (d) color map of blade internal structure shows variance from engineering drawing (purple and pink).

can be performed for the complete volume. Overlapping the outline virtually enables various nondestructive measurements including:

- Dimensional accuracy (printing tolerance)
- Distortion (Fig. 1c)
- Defects and surface roughness of internal structure not reachable using conventional characterization techniques without cutting (Fig. 1d)
- Porosity

Figure 1d also shows an internal air path with acceptable deviation (±0.08 mm) from the engineering drawing (indicated from red to blue), and outside tolerance (indicated in pink and purple). A shift of the channel walls (in pink and purple) may have occurred due to the part relaxing after printing. A video of the overlap of the turbine blade design and nCT is available at https://youtube.com/watch?v=eLTJl-bqICno&feature=youtu.be.

The study is done systematically at the resolution capability of the neutron imaging system (50 μm in this case), and is fed back to modeling capabilities to optimize printing parameters. In particular, areas of material removal and surplus can be tracked down throughout the sample volume, including internal structures (Fig. 1c). In addition, it is possible to directly measure the evolution of defects by measuring a standard sample before and after removal of the build plate and overlapping nCT scans.

Figure 2 illustrates the Inconel 718 powder Bragg edges (equivalent to a

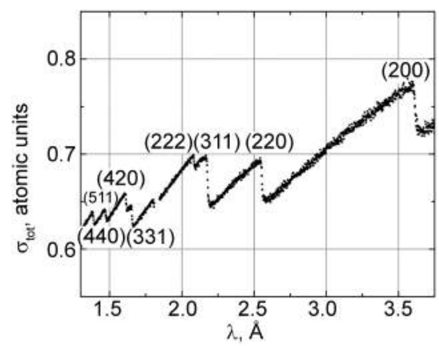


Fig. 2 — Total neutron cross section as a function of wavelength for Inconel 718 powder. Increase of statistical noise at higher wavelengths is due to the decrease of neutron flux at these wavelengths. The gap between (311) and (222) is due to a detector acquisition time-out.

nontextured sample) measured at the SNS Vulcan diffractometer. Edges are sharp (as expected for a powder sample that has no preferred grain orientation), and their respective positions correspond to theoretical Bragg edge values calculated using d-spacing (d = 3.595 Å) of Inconel 718 at the SNS Vulcan beamline. Powder data represent the ideal case and Bragg edge is drastically altered in a textured sample with a grain size distribution.

Bulk samples were prepared from the Inconel powder mentioned previously using electron beam melting at the ORNL Manufacturing Demonstration Facility. Samples were fabricated while manipulating the electron beam to form a real melt, which resulted in solidification of grains in a random manner. Figure 3a shows a representative electron back scatter diffraction

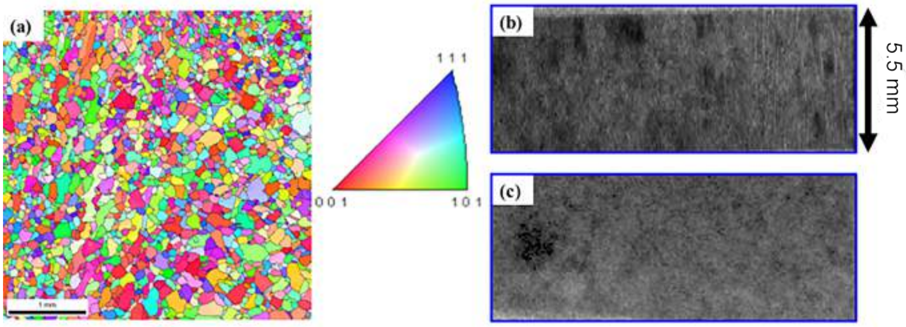


Fig. 3 — (a) Electron back scatter diffraction map and (b) neutron radiograph before compression of equiaxed sample; (c) neutron radiograph of equiaxed sample after compression.

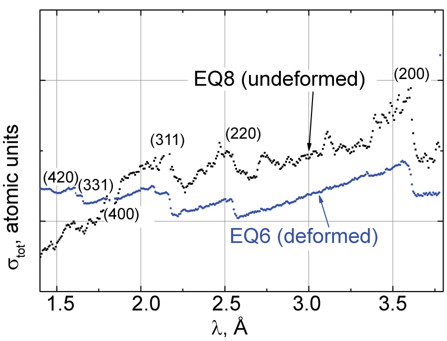


Fig. 4 — Bragg edge mapping of as-fabricated (undeformed) and compressed (deformed) EQ8 and EQ6 equiaxed samples, respectively. Bragg edges of undeformed sample show presence of preferred grain orientation (bumps between Bragg edges), whereas Bragg edges of deformed sample are similar to Inconel 718 powder, indicating a local change in grain orientation due to compression. Technique provides pixel-by-pixel mapping of preferential grain reorientation.

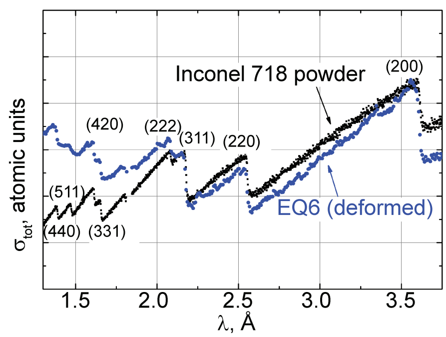


Fig. 5 — Bragg edge mapping comparison of Inconel 718 powder and equiaxed deformed sample EQ6.

(EBSD) grain orientation map for one of the equiaxed samples.

After solidification and removal from the stainless steel base plate, samples were compressed 13% and compared with their uncompressed counterpart using Bragg edge radiography (Fig. 3). Before compression, grains with the same orientation are visible in the radiograph (Fig. 3b), but they realign preferentially due to compression (Fig. 3c). These results are also reflected in Bragg edge image analysis (Fig. 4). Before compression, Bragg edges are not as pronounced as in the powder sample despite the fact that the samples were printed with no preferred grain orientation. A trend similar to that in the powder sample (Fig. 2) might be expected. The presence of "bumps" in the Bragg edges of the uncompressed sample EQ8 is likely due to the presence of grains with a preferred orientation in the sample (Fig. 3b).

After compression, sample EQ6 has greater similarity to the Inconel powder sample (Fig. 2), indicating the absence of preferred crystallite orientation—as if sample grains reoriented during compression. A direct comparison between Inconel powder and the deformed EQ6 sample is shown in Fig. 5. Bragg edges are similar for both, while the (200) edge for powder is higher, illustrating that the (200) orientation is more predominant in the deformed sample. Also, the (511) Bragg edge in the deformed sample is poorly defined, which is likely due to the preferred grain orientation in the sample rather than instrument wavelength resolution, because all measurements were performed at the SNS Vulcan diffractometer under the same beam optic configuration.

CONCLUSIONS

ORNL has recently implemented neutron radiography based on detecting Bragg edge features to complement neutron diffraction strain mapping and ESBD. Bragg edge radiography provides grain orientation average over the thickness of a sample, with differences in neutron transmission due to the Bragg edge scattering at wavelengths specific to each crystal lattice plane. This technique effectively measures crystal plane orientation, assesses single crystal quality, and quantifies Bragg edge shifts, which are indicative of average strain through the thickness of the material at a neutron pulsed source such as the SNS.

While interest in additive manufacturing is increasing, the role of processing variables on microstructure is still not sufficiently understood to enable predictive finite element modeling design. Experimental measurements were performed at the SNS Vulcan diffractometer, which revealed localized reorientation and refinement of grains due to compression. These preliminary results highlight the potential of TOF neutron radiography to contribute to the understanding of AM materials characteristics. However, a pixel-by-pixel study would provide more detailed information. Further developments are aimed at enabling a pixel-by-pixel study, with potential spatial resolution on the order of tens of microns and modeling of the Bragg edges to further understand microstructure and its evolution. **~AM&P**

ACKNOWLEDGMENT

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TECHNICAL SPOTLIGHT

USING ELEMENTAL ANALYSIS TO MANAGE INDUSTRIAL CORROSION

As industrial infrastructure continues to age, the risk of corrosion-related incidents becomes greater, increasing the need for detailed analysis of residual elements in steel framework and equipment.

In the chemical, oil and gas, fossil fuel, and nuclear power industries, pipe and equipment corrosion is a major cause of leaks and other issues that can lead to early replacements, unplanned outages, and incidents potentially resulting in plant and factory damage and injury to workers. To learn more about this topic, *Advanced Materials & Processes* spoke with Brian Wilson, business development manager, energy markets, portable analytical instruments, for Thermo Fisher Scientific, about the causes and dangers of infrastructure corrosion and how portable analysis tools can help facilities save time and improve safety.

Can you discuss the importance of analyzing element concentrations in industrial infrastructure?

Throughout the chemical, oil and gas, fossil fuel, and nuclear power industries, there is an increased focus on measuring residual elements in the carbon and microalloyed steels used in piping and components. It is imperative to understand the expected life and performance of the infrastructure. As carbon steel manufacturing has become more dependent on recycled metal scrap, residual element concentrations in materials have increased. These can significantly impact material properties—including corrosion resistance—with regard to melting and maintenance of piping and components. We have seen elemental analysis become increasingly important for both installed and newly purchased industrial framework and equipment.

Is the need for materials analysis greater today than in the past?

Industrial infrastructure across the country is aging, with many oil refining and petrochemical sites using the same pipe they did 30 or 40 years ago. As piping and components age, the ability to verify their elemental makeup is essential in order to prevent leaks and ruptures that could adversely impact worker safety and plant reliability. In the past, metals analysis primarily focused on heavy elements that made up the largest proportion of the alloy matrix. Today, we are learning more about corrosion mechanisms and the need to analyze residual, or trace elements, which require more sensitive testing technology to measure. It is critical that refineries and plants implement a material verification program (MVP) proactively—before a costly failure occurs—as infrastructure ages.

What are the main causes of corrosion across the industrial sectors?

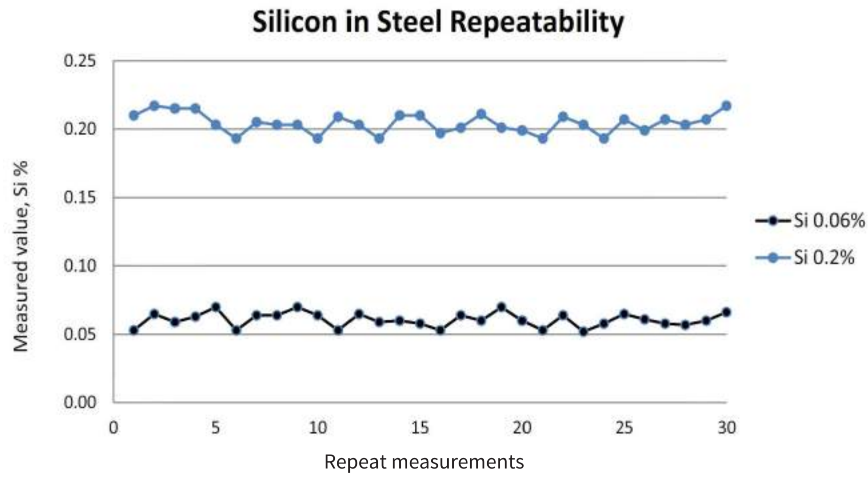
A number of variables cause corrosion at industrial sites, mainly stemming from sustained equipment use and elevated levels of residual elements. One cause, in particular, is flow-accelerated corrosion. This occurs when the protective oxide layer on the inside surface of carbon and low alloy steel pipe dissolves as iron oxides that naturally form on the pipe's exposed surface are removed by hot water flowing over it. Elevated levels of residual elements such as chromium, copper, and nickel can also cause corrosion in hydrofluoric acid alkylation units, while carbon steels with low silicon content can corrode at an accelerated rate when exposed to hydrogen containing sulfur compounds at elevated temperatures. Using materials analysis technology, technicians can measure the elemental composition of piping and components and detect the presence of alloying elements (such as silicon, vanadium, niobium, and titanium) that can reduce the rate of deterioration, in addition to residual elements that can contribute to corrosion.

Thermo Scientific Niton XL5 XRF analyzer inspects finished welds in steel piping.

Several technologies are available to analyze the elemental content of metals. Which approach do you recommend for industrial infrastructure?

For metals analysis, materials characterization is generally performed using methods such as x-ray fluorescence (XRF), optical emission spectrometry (OES), and lab analysis. Over the years, the materials characteri-

Elemental content of steel piping inspection with the Niton XL5 XRF analyzer.



Low- and high-standard silicon in carbon steel measurement results using the Niton XL5 XRF analyzer.

Repeatability Study Results of Microalloy Elements in Carbon Steel Samples
Round #1 Results Using the Niton XL5

Run Number	Nb	V	Ti	Nb+V	Nb+V+Ti
1	.063	.072	.068	.135	.203
2	.058	.075	.068	.134	.202
3	.060	.073	.069	.133	.202
4	.064	.075	.070	.139	.209
5	.063	.073	.069	.136	.205
6	.063	.074	.073	.137	.210
7	.058	.073	.072	.131	.203
8	.057	.068	.069	.125	.194
9	.060	.073	.067	.133	.200
10	.061	.073	.070	.134	.204
Material Test Report	**.054**	**.073**	**.066**	**.127**	**.193**
Niton XL5 Average Result	**.061**	**.073**	**.070**	**.134**	**.203**

Microalloy element measurements of carbon steel samples using the Niton XL5 XRF analyzer agree with laboratory test results.

zation field has seen XRF technology evolve and even match OES in terms of performance and reliability. XRF is now incorporated into much smaller instrumentation than ever before, allowing easier access to hard-to-reach areas such as corner welds, inside vessels and exchangers. Inherent to its smaller, lightweight design, it can also help reduce operator fatigue.

How is XRF technology used in plants and refineries?

The greatest advantage of XRF technology is user productivity. Modern XRF equipment can take a measurement in a few seconds with little sample preparation and produce real-time results that allow users to make immediate decisions. XRF analysis is also nondestructive. These are major advantages compared to lab testing, which often requires removing a segment of the sample and sending it to an offsite lab for results. Another advantage is ease of use. Modern XRF analyzers are smaller, faster, and smarter instruments than previous generations. This allows users without extensive materials analysis training to measure the elemental composition of a metal pipe or component onsite.

What are you seeing with regard to standards and legal requirements?

In the United States, we are seeing increased pressure from regulatory groups like the EPA (Environmental Protection Agency) and OSHA (Occupational Safety and Health Administration) demanding that asset holders know the composition of materials they have in place. Because portable analyzers are easier to use than earlier versions, employees at industrial sites are beginning to conduct materials analysis themselves. By enabling onsite workers to conduct measurements without hiring a third-party contractor or sending samples to a lab, industrial sites can prove to regulators that they have a program in place to monitor and manage corrosion. As the oil refining and petrochemical industries continue to require more inspection and data collection, we expect that use of portable XRF metal analyzers will become even more common. **~AM&P**

For more information: Brian Wilson is business development manager, energy markets, portable analytical instruments, Thermo Fisher Scientific, 2 Radcliff Rd., Tewksbury, MA 01876, 713.380.1287, brian.k.wilson@thermofisher.com, thermofisher.com/portableid.

MATERIALS SCIENCE & TECHNOLOGY 2016 OCTOBER 23-27

SALT PALACE CONVENTION CENTER • SALT LAKE CITY

The MS&T partnership brings together scientists, engineers, students, suppliers, and other professionals to discuss current research and technical applications, and to shape the future of materials science and technology. In addition to the four organizing societies, NACE International will co-sponsor MS&T16.

The Salt Palace Convention Center boasts 515,000 sq ft of exhibit space, 164,000 sq ft of meeting space including a 45,000-sq-ft grand ballroom, and 66 meeting rooms. Courtesy of Adam Barker.

PLENARY LECTURES

TUESDAY, OCTOBER 25

8:00 – 10:40 a.m.

ACerS Edward Orton Jr. Memorial Lecture
Designing Ceramics for Next-Generation Energy Systems
Bruce Dunn, professor, Department of Materials Science and Engineering, University of California, Los Angeles

The ability to design the chemistry and nanostructure of ceramics will continue to have a profound effect on the performance of electrode materials for electrochemical energy storage. One significant contribution to the lithium-ion battery field is the development of nanoscale materials whose shorter ion and electron path lengths have led to improvements in energy and power densities. The development of core-shell architectures represents another substantial advancement in the design of electrode materials. Pseudocapacitors based on transition metal oxides offer the promise of a new generation of energy storage materials that combine the high power of capacitors and the high energy density of battery materials. Key advances as well as future trends will be discussed.

AIST Adolf Martens Memorial Steel Lecture
Enhancing the Fatigue Performance of Steel: Have We Learned Anything from the Past?
David K. Matlock, University Emeritus professor, Colorado School of Mines

Fatigue failures in operating equipment continue to occur even though extensive research has been done since the mid-1800s when the important basic aspects of fatigue were identified after multiple railroad axle failures led to several catastrophic accidents in Europe. At that time, it was realized that application of cyclic loads could lead to metal failures at peak applied loads or stress levels less than required to cause permanent deformation. In this presentation, selected historical aspects of fatigue testing and failures will be presented, the fundamental basis for fatigue will be reviewed, and opportunities to increase the fatigue performance, and thus safety, of operating equipment will be discussed.

ASM/TMS Joint Distinguished Lecture in Materials and Society
Elegant Solutions: Exploration and Outcomes that Matter
Julie A. Christodoulou, FASM, Director, Office of Naval Research

New tools and new ways of using existing instruments are made available to us on a near-daily basis. Materials

Sugarhouse Park Duck Pond is a 110-acre park located at the heart of the Sugar House neighborhood of Salt Lake City. Courtesy of Adam Barker.

researchers can now explore structure at scales where chemical and physical phenomena occur, allowing more confident identification and control of ultimate properties. In-situ and in-operandi tools provide critical insight into the complicated and rapidly changing environments in which real materials perform, challenging hypotheses and assumptions and forcing the development of more rigorous analysis.

TECHNICAL PROGRAM

MS&T16 focuses on 11 major symposia themes covering the breadth of materials science and engineering. These include additive manufacturing; biomaterials; ceramic and glass materials; electronic and magnetic materials; energy; fundamentals, characterization, and computational modeling; iron and steel (ferrous alloys); materials-environment interactions; nanomaterials; processing and manufacturing; and special topics.

EDUCATION COURSES

SUNDAY, OCTOBER 23

Additive Manufacturing of Metals
8:30 a.m. – 12:00 p.m.
Instructor: Eric Bono

This course looks at some of the conditions and what impact they may have on final components as well as how to manage and control them to yield the best possible parts. Different additive manufacturing (AM) processes will be compared and contrasted as to how they manipulate the starting powder and how that affects the ultimate material properties.

A Design Mindset for Additive Manufacturing
8:30 a.m. – 4:30 p.m.
Instructor: Howard A. Kuhn

This short course focuses on a formalized approach to design for AM by briefly reviewing the materials and characteristics of AM processes, describing various research accomplishments and successful commercial applications, and summarizing these observations into a set of rules, procedures, and mindset for realizing genuine value propositions for AM in metallic and ceramic materials.

Computational Modeling of Thermal Processes for Metallic Parts
8:30 a.m. – 4:30 p.m.
Instructor: B. Lynn Ferguson

This one-day course covers a portion of the broad field of computation modeling of materials, but it will illustrate the concepts of integrated computational materials engineering (ICME). Computational modeling of thermal processing of metallic parts is the focus, with emphasis on microstructure control, dimensional change, and stress during and as a consequence of the process.

Correlative Light and Electron Microscopy of Metals
12:00 – 4:30 p.m.
Instructor: John Peppler

Light microscopy and electron microscopy each offer specific advantages and limitations when applied to the analysis of metallic materials. Correlating light microscopy images obtained with a variety of illumination and contrast techniques to SEM/EDS images at the same locations provides valuable information for interpretation of results.

Essential Microstructure Interpretation
8:30 a.m. – 4:30 p.m.
Instructor: Frauke Hogue

This one-day course focuses on practical interpretation, phase diagrams, and thermodynamics. Slides of over 200 structures will be observed to find out and discuss what each structure tells about the type of material, manufacturing methods used, heat treatment, mechanical properties, and sometimes even failure modes.

Failure Mechanisms and Analysis
8:30 a.m. – 12:00 p.m.
Instructor: Ronald J. Parrington

This half-day short course is based on the very popular ASM course: *Principles of Failure Analysis*. Whether made of metallic or nonmetallic materials, components fail by distortion, corrosion, wear, and/or fracture. Numerous examples and case studies are illustrated with photographs, fractographs, and photomicrographs.

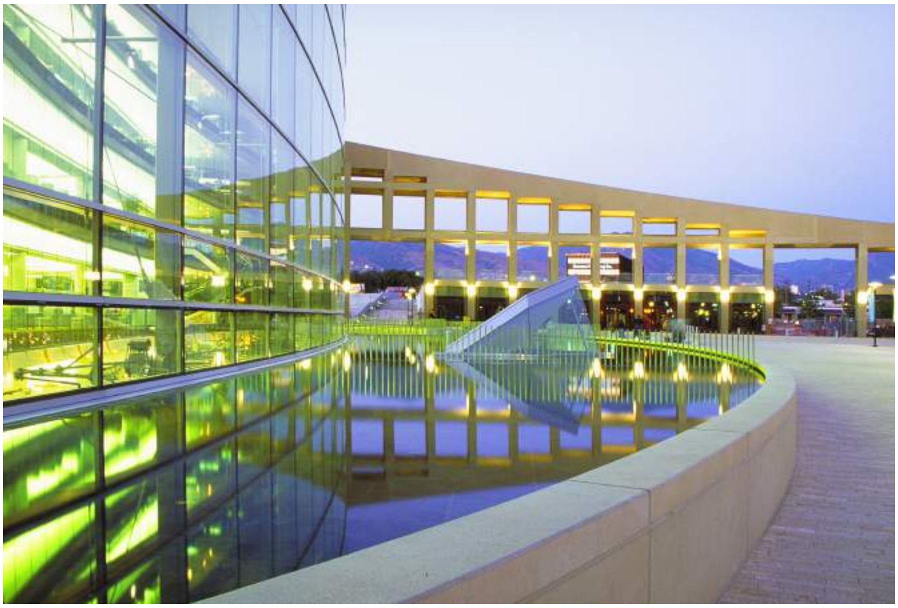
Testing and Qualification in Additive Manufacturing
8:30 a.m. – 4:30 p.m.
Instructor: Prabir K. Chaudhury

This short course will address the role of testing and qualification for industrial implementation of various AM processes.

THURSDAY, OCTOBER 27 AND FRIDAY, OCTOBER 28

Sintering of Ceramics
Instructor: Mohamed N. Rahaman

This two-day course follows key topics in the textbook, *Sintering of Ceramics*, by M. N. Rahaman (book included) and will be supplemented by



Salt Lake City's Main Library opened in February 2003 and remains one of the most architecturally unique structures in Utah. Courtesy of Dana Sohm.

detailed case studies of the sintering of specific ceramics and systems.

SPECIAL LECTURES

MONDAY, OCTOBER 24

9:00 – 10:00 a.m.
ACerS/NICE Arthur L. Friedberg Ceramic Engineering Tutorial and Lecture
Aldo R. Boccaccini
University of Erlangen-Nuremberg

Bioactive Glasses in Soft Tissue Repair: What Do We Know So Far?

2:00 – 5:00 p.m.
ACerS Alfred R. Cooper Award Session
Cooper Distinguished Lecture
G. Neville Greaves
Cambridge University and Wuhan University of Technology

Where Inorganic Meets Organic in the Glassy State: Hybrid Glasses and Dental Cements

2:00 – 4:20 p.m.
ACerS Richard M. Fulrath Award Session
Tadachika Nakayama
Nagaoka University of Technology
Ceramics/Polymer Hybrids and its Processing with Nano Pulsed Power Technology

Yoshiki Iwazaki
Taiyo Yuden Co. Ltd.
Material Design of Dielectric and Piezoelectric Materials with First-Principles Calculation

James G. Hemrick
Reno Refractories Inc.
A Future for Refractory Ceramic Technology Based on a Rich Past

Tomoyuki Nakamura
Murata Manufacturing Co. Ltd.
Development of Dielectrics for Monolithic Ceramic Capacitor

Bryan D. Huey
University of Connecticut
High Speed and Tomographic AFM of Functional Materials

2:30 – 4:00 p.m.
Alpha Sigma Mu Lecture
Alton D. Romig, Jr.
Executive Officer, National Academy of Engineering

National Academy of Engineering Grand Challenges for Engineering

TUESDAY, OCTOBER 25

12:45 – 1:45 p.m.
ASM Edward DeMille Campbell Memorial Lecture
A. Lindsay Greer
University of Cambridge

Extending the Range of the Glassy State: New Insights from the Novel Properties of Metallic Glasses

1:00 – 2:00 p.m.
ACerS Frontiers of Science and Society–Rustum Roy Lecture
Cato T. Laurencin
University of Connecticut

Regenerative Engineering: A Convergence Approach to Next Generation Grand Challenges

SPECIAL EVENTS

SUNDAY, OCTOBER 23

MS&T Women in Materials Science Reception
6:00 – 7:00 p.m.

Enjoy the chance to network with professionals and peers in a relaxed environment.

MONDAY, OCTOBER 24

Experience Salt Lake City
9:00 – 10:00 a.m.

Meet with local tour organizers who will provide information on local activities, sites, and self-guided tours in Salt Lake City. The knowledgeable local staff will assist in getting your day planned and started. Advance registration is not required.

Welcome Reception and Exhibit Opening
4:30 – 6:00 p.m.

Network with your colleagues, meet new people, and learn about the exciting membership offerings of the organizing societies.

ACerS 118th Annual Meeting
1:00 – 2:00 p.m.

Newly elected officers take their positions during the annual membership meeting. All ACerS members and guests are welcome.

ASM Women in Materials Engineering Breakfast
7:00 – 9:00 a.m.

Join colleagues and listen to a lively discussion of relevant topics with featured speakers. Tickets can be purchased via the registration form.

EXHIBITOR LIST

Company	Booth
ACerS	132
AdValue Technology	218
Advanced Abrasives Corp.	327
Agilent Technologies	506
Akrometrix LLC	105
Aldrich Materials Science	233
Alfred University (CACT)	405
Allied High Tech	400
American Stress Technologies	408
Anton Paar USA	204
Applied Test Systems	306
ASM International	100
Boise State University	524
Cameca Instruments Inc.	522
Carl Zeiss Microscopy LLC	401
Centorr Vacuum Industries	322
CM Furnaces	421
CompuTherm	321
EBSD Analytical Inc.	424
EDAX Inc.	422
Electron Microscopy Sciences	211
FEI Co.	318
FlackTek Inc.	423
Gasbarre Products Inc. (PTX)	418
Goceram	325
Goodfellow Corp.	426
Granta Design	512
Harper International	526
Heraeus Platinum Labware	121
Hitachi High Technologies America	410
HORIBA Scientific	333
Hysitron	219
International Centre for Diffraction Data (ICDD)	101
JEOL	301
Keyence Corp.	208
Leco Corp.	300
Metal Samples Co.	319
Metcut Research	213
Micromeritics Instrument	119
MSE Supplies LLC	328
MTI Corp.	500
MTS Systems Corp.	431
Nabertherm Inc.	207
Nanovea	111
Netzsch Instruments N.A. LLC	413
National Institute of Standards and Technology	419
NSL Analytical Services	430
Oxford Instruments	212
PANalytical	205
Photron USA Inc.	427
Precision Surfaces International	508
Premier Lab Supply Inc.	330
Proto Manufacturing Inc.	502
Pulstec	420
Renishaw	221
Rigaku	332
Sente Software	411
Setaram	118
Springer	407
Struers	310
TA Instruments	323
Taylor & Francis	133
TEC (Technology for Energy Group)	309
Tescan USA	201
TevTech LLC	425
Thermcraft Inc.	305
Thermo-Calc Software Inc.	432
Thinky USA Inc.	331
TMS	520
UES Inc.	223
Union Process	232
Unitron Ltd.	112
Verder Scientific Carbolite	311
John Wiley & Sons	307

Exhibitor list current as of July 11.

Salt Lake City was founded in 1847. Due to its proximity to the Great Salt Lake, the city was originally named "Great Salt Lake City"—the word "great" was dropped from the official name in 1868. Courtesy of Douglas Pulsipher.

ASM Leadership Awards Luncheon
11:30 a.m. – 1:00 p.m.

ASM's organizational unit awards, as well as awards and scholarships of the ASM Materials Education Foundation, will be presented. ASM's incoming Committee/Council chairs will also be recognized for their leadership.

ASM 103rd Annual Business Meeting
4:00 – 5:00 p.m.

Attend our annual business meeting where officers will be elected for the 2016-2017 term and other ASM business will be transacted. ASM members and guests are welcome.

ASM Canada Council Suite
9:00 p.m. – 12:00 a.m.

Experience Canadian hospitality.

ACerS 118th Annual Honors and Awards Banquet
6:45 – 10:00 p.m.

Enjoy dinner, conversation, and presentation of Society awards. Purchase tickets for $90 via meeting registration.

TUESDAY, OCTOBER 25

Salt Lake City Tour
8:30 a.m. – 2:00 p.m.

Includes visits to Temple Square; the State Capitol Building; This is the Place Heritage Park; historic districts with mansions and cathedrals; University of Utah; Pony Express Station; historic Fort Douglas; Trolley Square; Union Pacific Depot; and more. Purchase tickets at registration.

ASM Geodesic Dome Design Competition "Domesday"
10:15 a.m. – 1:30 p.m.*

Can these domes take the weight? Visit the exhibit hall for the display, judging, and selection of winners at the third ASM Geodesic Dome Design Competition. To register as a contestant and for more information, visit asminternational.org/domesday.

Ceramic Mug Drop Contest
11:15 a.m. – 12:15 p.m.*

Mugs fabricated by students from ceramic raw materials are judged on aesthetics and breaking thresholds. The mug with the highest successful drop distance wins. Visit matscitech.org/students for more information.

Ceramic Disc Golf Contest
12:30 – 1:30 p.m.*

Students create discs from ceramic or glass materials to meet certain specifications, and the discs are thrown into a regulation disc golf basket. Each disc will be judged in the categories of farthest distance achieved and artistic merit.

MS&T Young Professionals Reception
4:30 – 6:00 p.m.

Meet and network with fellow young professionals.

MS&T16 Exhibit Happy Hour Reception
4:00 – 6:00 p.m.

Network with colleagues and build relationships with qualified attendees, buyers, and prospects.

ASM Awards Dinner
7:15 – 9:30 p.m.

Celebrate the wonderful accomplishments of this year's award recipients and the 2016 Class of Fellows. Tickets can be purchased via the registration form.

EXHIBITION

MS&T16 brings together professionals from virtually every field of materials science—metals, polymers, ceramics, and composites. Almost every industry is represented including automotive, aerospace, instrumentation, medical, oil and gas, and energy. Reach potential customers from all markets in a single venue. There is also a Professional Recruitment & Career Pavilion.

EXHIBIT DATES, HOURS, AND ACTIVITIES*

MONDAY, OCTOBER 24

Welcome reception and exhibition grand opening.
4:30 – 6:00 p.m.

TUESDAY, OCTOBER 25

ASM Mini-Materials Camp:
9:00 a.m. – 2:00 p.m.
Exhibition hours: 10:00 a.m. – 6:00 p.m.
Football feature: 10:00 a.m. – 6:00 p.m.
Career pavilion: 10:00 a.m. – 6:00 p.m.
Food court: 12:00 – 2:00 p.m.
Happy hour reception: 4:00 – 6:00 p.m.

WEDNESDAY, OCTOBER 26

Exhibition hours: 9:00 a.m. – 2:00 p.m.
ASM Mini-Materials Camp: 9:00 a.m. – 2:00 p.m.
Poster viewing: 9:30 a.m. – 2:00 p.m.
Football feature: 9:30 a.m. – 2:00 p.m.
Food court: 12:00 – 2:00 p.m.

**Times are tentative and subject to change*

42ND INTERNATIONAL SYMPOSIUM FOR TESTING AND FAILURE ANALYSIS NOVEMBER 6-10

FORT WORTH CONVENTION CENTER, TEXAS

The theme of ISTFA 2016 is *Next Generation*, and it is truly infused into all levels of the program. There are opportunities to meet and discuss research with students working on various failure analysis topics, and to possibly find an engineer to fill a future job opening. However, a *Next Generation* engineer is rare—some even think there is a crisis fueled by a lack of relevant academic education. Christian Boit and Philipp Scholz address this in their keynote presentation, which proves the opposite is true.

The technical program is poised to be excellent, with papers coming from a record number of abstract submissions. For networking and relaxation, there is a lively, Texas-inspired evening event. As always, the exposition attracts top companies in the industry to demonstrate next-generation equipment and products. More than 60 companies are showcased.

Opening in 1968, the Fort Worth Convention Center is noted for its indoor arena, resembling a flying saucer.

EDUCATION SHORT COURSES

SATURDAY, NOVEMBER 5

Beam-Based Defect Localization
Instructor: Edward Cole, Jr.
Sandia National Laboratories

Fault Isolation Techniques for Failure Analysis
Instructor: David Vallett
PeakSource Analytical LLC

Electrostatic Discharge in Robotic Manufacturing Lines
Instructor: Peter Jacob
EMPA Duebendorf

MONDAY, NOVEMBER 7

Tools of the Trade Tour
5:00 – 6:00 p.m.

This tour allows select ISTFA attendees exclusive access to attend and view product demonstrations from top companies prior to the exhibit hall opening. Reception to follow.

Social event
7:00 – 10:00 p.m.

Enjoy a fun-filled evening at the iconic "Billy Bob's Texas" including food, drinks, and entertainment. Every full conference attendee receives a ticket as part of registration.

TUESDAY, NOVEMBER 8

Plenary session
9:00 – 10:30 a.m.

Christian Boit, professor at the Technische Universität Berlin, former director of failure analysis at Infineon Technology, and general chair of ISTFA 2002 demonstrates, together with Philipp Scholz, that it is possible for a university to equip engineers with great skills and knowledge. His students successfully find internships and employment in failure analysis at tier one semiconductor companies not only in Europe, but also in the U.S.

EXHIBITOR LIST

Company	Booth
Advanced Circuit Engineers	122
Advantest Corp.	504
Akrometrix LLX	125
Allied High Tech	201
Analytical Solutions	505
Anasys Instruments	114
Angstrom Scientific Inc.	231
Applied Beams	419
Attolight AG	423
Balazs Nanoanalysis	222
Barnett Technical Services	421
Bruker	313
BSET EQ	321
Carl Zeiss Microscopy	211
Checkpoint Technologies	301
Control Laser Corp.	502
Electron Microscopy Sciences	409
Evans Analytical Group	117
EXpressLO LLC	126
FEI Co.	106
Gatan	208
Hamamatsu Corp.	207
HDI Solutions - Hitachi	223

Company	Booth
Hi-Rel Laboratories	524
HiLevel Technology Inc.	224
Hitachi High Technologies	305
ibss Group	118
Imina Technologies SA	113
IXRF Systems Inc.	414
JEOL USA	200
Jiaco Instruments	103
Keysight Technologies	411
Kleindiek Nanotechnik	330
LatticeGear	420
Left Coast Instruments/RKD	212
Materials Analysis Technology	120
Mentor Graphics	306
Mesoscope Technology Co. Ltd.	518
Muegge GmbH	124
Nanolab Technologies	322
Nikon Metrology	501
Nippon Scientific Co. Ltd.	416
Nisene Technology Group	311
Neocera LLC	111
Nordson Dage	127
Olympus	412

Company	Booth
Oxford Instruments	401
Park Systems Inc.	101
Quantum Focus Instruments	225
Quartz Imaging	121
Robson Technologies Inc.	415
Sage Analytical Lab	500
Samco International	216
Sela USA Inc.	331
Semicaps	324
Sonoscan	210
South Bay Technology	115
SPI Supplies	204
Synopsys	109
Ted Pella	425
Tescan USA Inc.	317
TMC Ametek	105
ULTRA TEC	221
XEI Scientific	427
Yxlon FeinFocus	116
Zurich Instruments AG	112

Exhibitor list current as of July 11.

Expo Welcome Reception
5:00 – 6:40 p.m.

Attendees are encouraged to mingle on the exhibit floor with exhibitors while enjoying an assortment of appetizers and beverages.

WEDNESDAY, NOVEMBER 9

EDFAS General Membership Meeting and Luncheon
12:15 – 1:30 p.m.

SPECIAL CONTESTS

EDFAS Video Contest—Winners will be showcased with their three-minute films about failure analysis results or interesting artifacts.

EDFAS Photo Contest—The best images in optical microscopy, ray/UV micrographs, photon emissions, and more will be displayed.

EXHIBITION HOURS

Tuesday, November 8
9:00 a.m. – 6:40 p.m.

Wednesday, November 9
9:30 a.m. – 3:30 p.m.

Fort Worth was established in 1849 as an army outpost on a bluff overlooking the Trinity River. Today, the city still embraces its Western heritage and traditional architecture and design.

METALLURGY LANE

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

THE INTEGRATED STEEL INDUSTRY–PART III

THE ADVENT OF "LITTLE STEEL" AND THE STRIKE OF 1937 HAD A LASTING IMPACT ON THE DOMESTIC STEEL INDUSTRY AND LABOR RELATIONS IN PARTICULAR.

Founded in 1936, the Congress of Industrial Organizations (CIO) achieved victory when it forced the "Little Steel" companies to finally recognize the Steel Workers Organizing Committee as the bargaining agent for its steelworkers in 1942. Courtesy of explorepahistory.com.

Steel companies that emerged in the Midwest to serve the growing manufacturing markets in Ohio, Illinois, and Michigan were much smaller than United States Steel Corp. (USS), and therefore referred to as "Little Steel." These companies included Youngstown Sheet and Tube Co. (YS&T) in Ohio, Inland Steel Co. in Chicago, Jones & Laughlin Steel Co. (J&L) in Pittsburgh, The American Rolling Mill Co. (ARMCO) in Middletown, Ohio, Republic Steel Co. in Cleveland, and National Steel Corp. in Detroit. These six companies—combined with Bethlehem Steel who joined them in their crusade to prevent employees from forming a union—gained notoriety by displaying the worst reaction to organized labor in the history of American steelmaking.

Labor unrest was common in the steel industry. Low wages, a hot and dirty work environment, unsafe conditions, and poor treatment of workers lead to strikes. One serious strike occurred at YS&T in 1916 where workers were fired on by company guards, killing two and wounding more than 100. The incident resulted in a riot that burned down part of the city of Youngstown. These isolated strikes were often limited to one company or one plant and were therefore never successful. Steelworkers were unable to form an organization that would lead to industry-wide action and there was no legal basis for workers to join a union like those that protected corporations. Therefore, company officials could call on the police or the National Guard to break up a strike and protect their property. This lack of legal protection for workers was corrected during the Franklin D. Roosevelt administration.

NATIONAL LABOR RELATIONS ACT

Congress passed a labor bill written by Senator Robert F. Wagner of New York that became known as the National Labor Relations Act, signed by President Roosevelt on July 5, 1935. The Act gave workers the right to organize and bargain with management for wages, hours, and other benefits. The Act also established a National Labor Relations Board (NLRB) to oversee elections and examine company labor policies. Forty-five years after the worker struggle at Homestead—where Henry Frick faced down strikers with 300 armed guards—labor finally had the backing of the federal government for the right to form unions to negotiate with management.

However, the immediate problem was finding an organization that could assist steelworkers with organizing a nationwide union movement. John L. Lewis, president of the national United Mine Workers union for coal miners, formed a Steel Workers Organizing Committee (SWOC). Using officials from his own union, he recruited workers from the steel industry. He selected Philip Murray to head the activity. The SWOC demanded a $5 per day, 40-hour work week, plus time and a half for overtime.

Lewis's first goal was to organize the largest steel companies, believing that the smaller firms would follow. His breakthrough came in March 1937 when he and Myron Taylor, president of USS, signed an agreement to recognize the SWOC for its 225,000 workers. However, Lewis had misjudged the reaction of the Little Steel companies and Bethlehem Steel. With regard to Taylor, Lewis was working with an individual with a background in law and finance as well as experience in industries other than steel. However, with Little Steel and Bethlehem, Lewis faced two of the most anti-union men in the history of steel—Eugene Grace and Tom Girdler.

GRACE AND GIRDLER

Eugene Grace began work as a crane operator at Bethlehem in 1898 right out of Lehigh University. Under Charles Schwab, he advanced to president within 16 years. He adopted his attitude toward labor from Schwab who had been superintendent of the Homestead plant during the 1892 strike. From that event, Schwab formed his extreme attitude toward unions.

Tom Girdler was another enemy of the labor unions. He became president of J&L, but left to take over the newly formed Republic Steel Co. in 1930. To protect their companies during the unrest of the 1930s, Bethlehem and Republic Steel

Senator Robert F. Wagner of New York, author of the Wagner Act that allowed workers to organize unions. Courtesy of Library of Congress.

Tom Girdler, president of Republic Steel, testifying before the Senate Post Office Committee in June 1937. Courtesy of Library of Congress.

along with other Little Steel companies began stockpiling guns, ammunition, clubs, and tear gas. Management's contentious attitude toward labor had not changed since the Homestead strike.

However, after the Wagner Act, which legalized recruitment of union members and encouraged elections, the companies ignored the law against worker resistance just as they had in the past. The SWOC asked for a meeting with Grace and Girdler to discuss an agreement on holding elections to determine if the majority of their workers wanted a union or not. Girdler's answer was to close a plant in Canton, Ohio, and lay off the workers. The SWOC then met with Philip Murray where both parties agreed to bargain over wages and hours, but Murray refused to hold elections or sign to recognize a union. Grace, Girdler, and Murray were all in violation of the Wagner Act.

The SWOC was prepared to act at the Republic plant in South Chicago. There were already 33,000 steelworkers on strike at other Little Steel plants. The company had prepared by trucking in food and cots to house the workers to be replaced with supervisors, managers, and imported stand-ins for the strikers. Republic intended to keep operating during the strike.

MEMORIAL DAY MASSACRE OF 1937

Toward the end of May 1937, SWOC members attempted to demonstrate at the gates in front of the plant and each time they were turned away by the police. On Sunday, May 30, the men made a new attempt to reach the gates. It was Memorial Day and wives and children joined them along with workers from other steel plants and volunteers from the public. They were met by a line of 200 police to prevent them from reaching the gates. Strike leaders tried to bargain with the police to let them through for a peaceful picket line. When talks broke down, things started to escalate. As the crowd began to press forward, they were met with tear gas and gunshots into the air. As people in the back kept pushing forward, the police responded by throwing more tear gas and firing into the crowd. Everyone turned to escape as the gunfire continued along with beatings by police clubs. The police continued to chase the crowd, clubbing and shooting as men, women, and children ran for their lives.

Ten men were killed and over 100 strikers needed medical attention. Afterward, the police, newspapers, and Republic Steel all blamed the workers for the massacre. Later investigations by Congress found that all of the dead were shot in the back or side while trying to flee the area. It was Congress that finally published the true and detailed facts of what happened during the Memorial Day Massacre.

The strike failed and workers returned to their jobs. Many were fired for their union activities and some were blackballed so they could never find work in their communities. But the SWOC did not accept the situation. They turned to the federal government and the courts for help. In the spring of 1938, the NLRB found that Republic Steel had violated the Wagner Act. They ordered the company to rehire thousands of workers with back pay, and to award payment to the injured and the families of those killed. The company appealed the order but the court ruled in favor of the NLRB.

During the next several years, the union added enough workers to reach its goal of more than 50% membership. The NLRB supervised the election and certified that the company had to sign a contract with the union. Republic appealed to the courts again, but in 1942 the Supreme Court handed down the decision that Republic was in violation of the Wagner Act. The Little Steel industry finally had to give up its fight to avoid union shops. The workers won, but at a price they would never forget. The whole affair would poison management-labor relations for years to come.

The Memorial Day Massacre in 1937 killed 10 men and wounded more than 100.

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

HTS
Heat Treating Society
ASM INTERNATIONAL

SEPTEMBER 2016 | VOLUME 4 | ISSUE 3

HTPRO

BUSINESS AND TECHNOLOGY FOR THE HEAT TREATING PROFESSIONAL

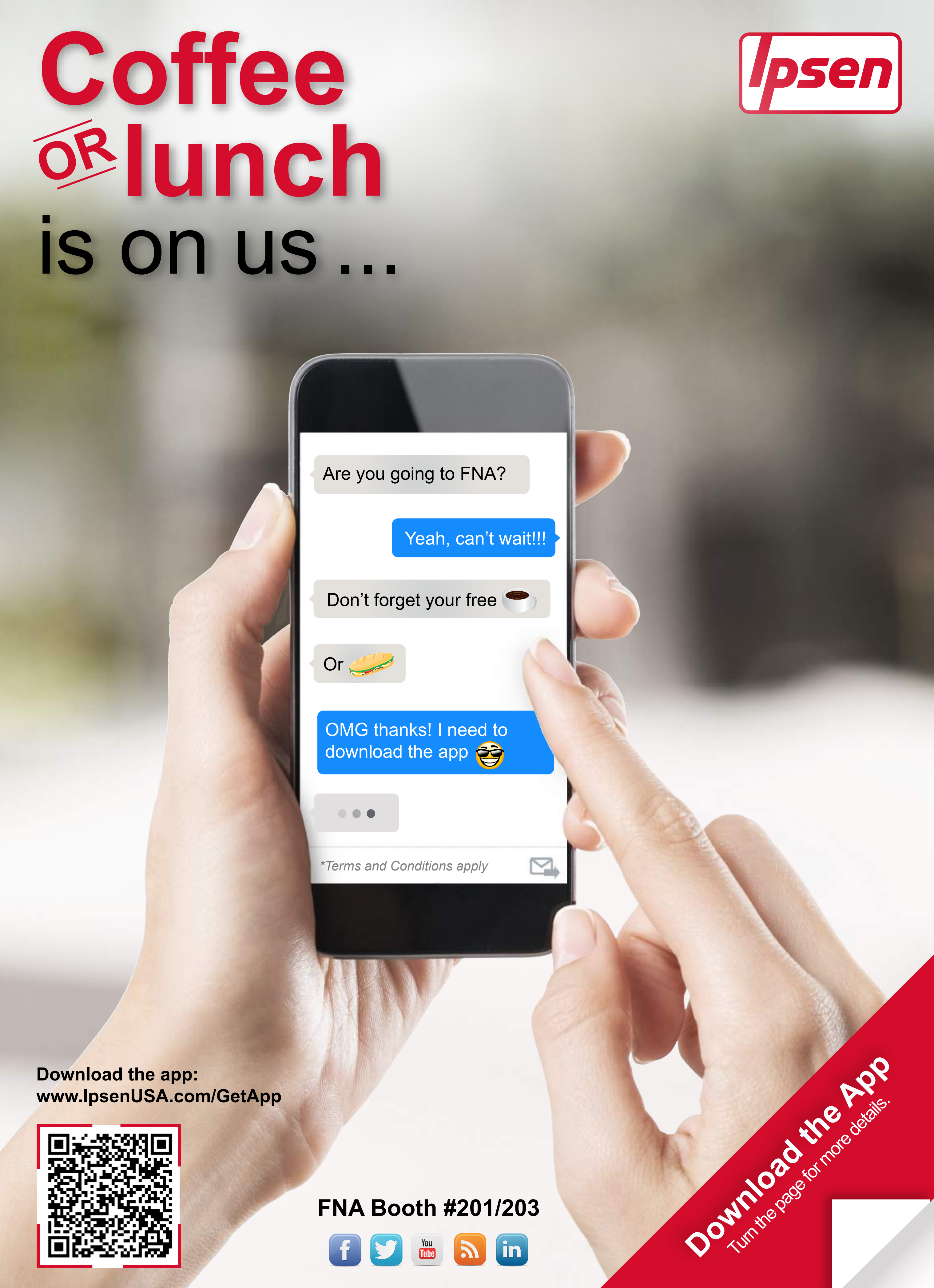
PASSING YOUR NADCAP AUDIT: PART II
6

BORONIZING 3D-PRINTED INCONEL
14

INNOVATION
at your fingertips

Industry Resources

Ipsen was founded with a vision of creating products and technologies that continuously push the boundaries of innovation to create a future of thermal processing excellence. From *The Ipsen, Harold* blog to industry-leading technical articles, Ipsen is committed to continuing this legacy of innovation by providing valuable, expert-created resources that cover a wide range of industry topics.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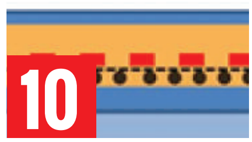

DEPARTMENTS

ABOUT THE COVER

During an internal audit, it is important to review past leak tests and maintenance logs as well as past surveys, system accuracy tests, and industry specifications for heat treatment. Courtesy of Ipsen, ipsenusa.com.

EDITORIAL OPPORTUNITIES FOR HTPro IN 2016

The editorial focus for *HTPro* in 2016 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.

November Atmosphere/Vacuum Heat Treating

To contribute an article to one of the upcoming issues, contact Frances Richards at frances.richards@asminternational.org.

To advertise, contact Erik Klingerman at erik.klingerman@asminternational.org.

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GUEST EDITORIAL

Heat treating is an important topic wherever you travel in the world. Like it or not, today's heat treating industry is global. This is reflected in the number of recent conferences and events taking place around the globe. Last April, the ASM/IFHTSE 23rd Heat Treatment and Surface Engineering Congress was held in Savannah, Ga. This event attracted attendees from 22 different countries and virtually every continent to discuss heat treating. In May, the IFHTSE European Conference on Automotive Heat Treatment and Surface Engineering took place in Prague. In Russia, a large tradeshow and conference on Innovation Technologies of Heat Treatment will be held September 13-14. Next, ASM has its own event in Queretaro, Mexico, from September 20-23. Another event in September is the IFHTSE 3rd Mediterranean Conference on Heat Treatment and Surface Engineering in Portoroz, Slovenia. Following shortly thereafter is the Furnaces North America tradeshow in Nashville. Finally, the 5th Asian Conference on Heat Treatment and Surface Engineering will take place November 12-14 in Hangzhou, China.

In addition to the sheer number of conferences, the industry itself is expanding and much activity is taking place. In fact, demand for heat treating equipment and services is growing at 2-4% while the global economy is growing at 1%. Globally, there is a strong demand for consistent specifications. For example, a heat treating specification written in France through collaboration with captive and commercial heat treaters resulted in the French Standard NF A 02-053. A new working group is now creating a draft of a new ISO document based on this French standard to replace CQI-9. In addition, standards once perceived as strictly for aerospace specifications, such as AMS 2759 or AMS 2750, are now being adopted into the realm of automotive heat treatment.

In the U.S., it is sometimes said that the various heat treating conferences are too theoretical and not practical. However, a recent paper in Savannah from CHTE described the practical benefits of extending the life of furnace and fixture alloys by surface engineering. In Prague, Thomas Lubbens provided practical examples of distortion mitigation and control of distortion in heat treated components. Methods to increase production in carburizing and reduce intergranular oxidation were also presented. These are all useful topics that directly impact a heat treater's bottom line, whether commercial or OEM.

Without our participation in these events as either speakers or attendees, and learning from the global community of heat treaters, the U.S. heat treating industry will fall behind.

D. Scott MacKenzie, Ph.D., FASM
Houghton International Inc.

HTS NAMES NEW BOARD MEMBERS FOR 2017

The Heat Treating Society (HTS) board, at the recommendation of the HTS Awards and Nominating Committee, named new board members including **Robert Cryderman** and **Joseph Powell** to serve on the HTS Board for the 2016-2019 term, and **Blake Whitley** to serve as student board member for the 2016-2017 term. **Olga Rowan,** who served a partial term on the board, has been reappointed to serve a full term during 2016-2019 and **Hannah Noll** has been reappointed to serve a second term from 2016-2017 as a young professional board member. Terms begin September 1. Continuing on the board are **Stephen Kowalski** (president), **Jim Oakes** (vice president), **Roger Jones** (past president), **Timothy De Hennis** (member), **Eric Hutton** (member), **Nathan Chupka** (member), **Michael Pershing** (member), and **Craig Zimmerman** (member). Leaving the board are **Stephen Mashl, FASM** (member), **Jin Xia** (member), and **Zbigniew Zurecki, FASM** (member). **Rachel Sylvester,** who has completed a one-year term as a student board member, will stay on as ex officio for one year.

Robert Cryderman is research associate professor of the Advanced Steel Processing and Products Research Center at the Colorado School of Mines. He received BSE and MSE degrees in metallurgical engineering from the University of Michigan and has over 45 years of experience in the steel producing industry. While employed at Climax Molybdenum Co., he was the first to publish a paper that characterized the martensite-austenite constituent in low carbon sheet steels using transmission electron microscopy. Cryderman worked at LTV Steel in Pittsburgh and Aliquippa, Pa., before moving to CF&I Steel in Pueblo, Colo. There he started up production of head hardened rails. At Gerdau Special Steels in Monroe, Mich., he was the technical leader in developing and commissioning a new, world class bar heat treating and inspection facility. Cryderman has published over 30 technical papers, has been awarded nine patents, and has served HTS as a technical reviewer and session chair.

Joseph Powell is president and owner of Akron Steel Treating Co. (AST) in Ohio and president and part owner of IQ Technologies Inc. He has over 32 years of experience in commercial heat-treating operations. Powell is one of the developers of the IntensiQuench process for 3D heat treating processes for steels, as well as IQDI for intensively quenched ductile iron and DFIQ for "direct from the forge IntensiQuench." AST performs Nadcap heat-treating services in vacuum, controlled atmosphere, and molten salt furnaces for over 1200 different metalworking companies. Powell has a B.S. in industrial management and a J.D. degree in law (both from University of Akron, Ohio). In addition to his membership with HTS, he is also an active member of the Metal Treating Institute and the Forging Industry Association Technical Committee and serves as a STEM school advisor with Akron City Schools.

Blake Whitley is pursuing a Ph.D. in metallurgical engineering in the Advanced Steel Processing and Products Research Center at the Colorado School of Mines. His research focuses on the effects of advanced thermomechanical processing and heat treatment on the microstructure and properties of steel. He also earned a B.S. in metallurgical and materials engineering at the University of Alabama. His industrial background includes consulting work with General Motors and serving as a metallurgical engineering intern at Alstom in Chattanooga. Whitley received the Alpha Sigma Mu Outstanding Undergraduate Student Award (2012) and numerous fellowships and scholarships. He served as a student board member on the ASM International Board of Trustees and president of his local Material Advantage Chapter in 2012. In addition, Whitley is a member of the ASM Rocky Mountain Chapter Executive Committee (2012-2016), junior mentor at the ASM Eisenman Materials Camp, and team captain of the 1st place Materials Bowl Team at the TMS Annual Meeting in 2015.

Olga Rowan is senior engineer in Advanced Materials Technology, Caterpillar Inc. Rowan received her Ph.D. in materials science and engineering from Worcester Polytechnic Institute in 2007, where she was an active member of the Center for Heat Treating Excellence. She joined Caterpillar in 2007 working in heat treat R&D, gear heat treat production support, and supplier development. Areas of expertise include gas atmosphere and vacuum heat treat, energy and business case analyses for new capital introduction, and heat treat process control and optimization. She is a member of ASM, active in the Peoria chapter and on the national level. She served as a co-chair of the ASM Emerging Professionals Committee and as a member of the ASM Education Committee. She has also been an active volunteer and workshop mentor in the ASM Materials Camp, Central Illinois area, since 2008. Rowan co-authored two articles in the *ASM Handbook*, Vol 4A, *Steel Heat Treating Fundamentals and Processes*, and has published 18 peer-review journal articles and conference publications.

Hannah Noll earned her B.Sc. in metallurgical engineering from Missouri University of Science and Technology in 2010, and her M.E. in materials science and engineering at North Carolina State University in 2015. After graduating

from Missouri S&T, she joined ATI Specialty Materials as product engineer and later served as process engineer at ATI Specialty Materials Richburg Operations where she was responsible for Ni/Ti/Fe-base alloy heat treatment, continuous bar rolling, and coil processing. She recently accepted the position of superintendent at the new ATI Bakers Powder Operations in Monroe, N.C., which will make powder for the aerospace industry. Noll has been a member of the executive board of the ASM Carolinas Southern Piedmont Chapter since 2012 and is currently chapter chair. She is a contributing member of engineergirl.org, directed the first Union County JobReady Partnership "Women in Engineering" summer camp for middle school girls in 2014, and also directed the camp in 2015.

HTS MEMBERS RECEIVE ASM AWARDS

Three HTS members have been named as recipients of 2016 ASM Awards. The awards will be presented at ASM's annual Awards Dinner, taking place October 25 in Salt Lake City, during MS&T16.

Distinguished Life Membership

Mr. William R. Jones, FASM, owner/CEO, Solar Atmospheres Inc., Souderton, Pa., will receive this year's award "for innovations in the field of vacuum furnace technology and applying this technology to enhance metallurgical thermal processes around the world."

Prof. Diran Apelian, FASM, Alcoa-Howmet professor of mechanical engineering, Worcester Polytechnic Institute, Mass., will receive this year's award "for his leadership and vision for establishing and executing a model for industry-university collaborative research, and for his pioneering work in metal processing."

The medal was established in 1943 to recognize outstanding knowledge and great versatility in the application of science to the field of materials science and engineering, as well as exceptional ability in the diagnosis and solution of diversified materials problems.

Allan Ray Putnam Service Award

Mr. Robert J. Gaster, senior staff engineer, Deere & Co. Technology Innovation Center, John Deere, Moline, Ill., will receive this year's award "for continuous and enthusiastic promotion of ASM membership and volunteerism at the local chapter and national society level, as well as his longstanding volunteerism for the Heat Treat Society." Established in 1988, the award recognizes the exemplary efforts of various outstanding members of ASM International on behalf of the Society to further its objectives and goals. The purpose of this award is to recognize those individuals whose contributions have been especially noteworthy and to whom the Society owes a particularly great debt of appreciation.

CAI RECEIVES 2016 ASM HTS/BODYCOTE BEST PAPER IN HEAT TREATING AWARD

Xiaoqing Cai (center) received the 2016 ASM HTS/Bodycote Best Paper in Heat Treating Award from **Dean Hoffmann** of Bodycote (left) at Worcester Polytechnic Institute's Center for Heat Treating Excellence on June 15 during their spring meeting. She received assistance on her winning paper entitled, "Microstructure Development in AISI 4140 Steels During Tempering" from her advisor, **Dr. Richard D. Sisson, Jr., FASM** (right). Cai is a Ph.D. student in materials science and engineering at WPI. She is currently working on a research project focused on furnace and induction tempering of steel. The award includes a plaque and $2500 prize endowed by Bodycote Thermal Process-North America.

SOLICITING PAPERS FOR ASM HTS/BODYCOTE BEST PAPER IN HEAT TREATING CONTEST

The ASM HTS/Bodycote award was established by HTS in 1997 to recognize a paper that represents advancement in heat treating technology, promotes heat treating in a substantial way, or represents a clear advancement in managing the business of heat treating. The award is endowed by Bodycote Thermal Process-North America.

The contest is open to all students, in full-time or part-time education, at universities (or their equivalent) or colleges. It is also open to those students who have graduated within the past three years and whose paper describes work completed while an undergraduate or post-graduate student. The winner receives a plaque and check for $2500.

To view rules for eligibility and paper submission, visit hts.asminternational.org, Membership & Networking, and Society Awards.

Paper submission deadline is March 1, 2017. Submissions should be sent to Joanne Miller, ASM Heat Treating Society, 9639 Kinsman Rd., Materials Park, OH 44073, 440.338.5151 ext. 5513, joanne.miller@asminternational.org.

OBTAINING NADCAP ACCREDITATION: HELPFUL GUIDELINES FOR PASSING YOUR AUDIT, PART II

Learn how to simplify the process of obtaining Nadcap accreditation for your heat treating facility by paying heed to some of the challenges others have experienced.

Nathan Durham, Ipsen USA, Cherry Valley, Ill.

Aerospace Material Specification (AMS) standards and the Nadcap accreditation process play key roles in ensuring that manufacturers performing heat treating and other special processes adhere to consistent, high-quality standards for producing aerospace products. While preparing for a Nadcap audit can seem daunting, a series of articles has been developed that discusses some of the recommended resources for obtaining a better understanding of how to prepare for and execute a successful audit. The first part of this series (June 2016, *HTPro*) looked at preparing for and scheduling an audit. This article looks at the internal audit process, nonconformances, and completing the internal audit.

UNDERSTANDING THE INTERNAL AUDIT PROCESS

It is necessary to understand exactly what is required when preparing for an official Nadcap audit. Internal audits involve performing quality system audits (e.g., AS9001 or AC7004) and real job audits, as well as reviewing past temperature uniformity surveys (TUS), system accuracy tests (SAT), leak back tests, maintenance logs, and industry specifications. It is required that audit checklists (available on eAuditNet) are used during an internal audit to ensure adherence to key specifications, as well as to help identify any potential findings.

Prior to submitting internal audit results to Performance Review Institute (PRI) as proof of completion, some recommend performing additional internal audits to become more familiar with the process of going through an audit, as well as to work through the implementation of any necessary corrective actions. An alternative approach is to hire an outside consultant to perform the internal audit, which could provide a more realistic perspective of what might occur during the official audit.

Throughout the audit, you must record where system requirements are met and where there is objective evidence of compliance. Examples of objective evidence include notes that refer the auditor to a specific section in the Quality Manual, reference training files in the production manager's office, or direct the auditor to the sales manager for customer satisfaction surveys.

A key step for performing a successful Temperature Uniformity Survey is ensuring the survey fixture is carefully placed within the hot zone. Courtesy of Ipsen.

While discussing best practices for performing an internal audit, we found that the requirement of conducting live job audits (with either real or sample aerospace parts) makes it easier to identify potential nonconformances that the auditor might find during the official Nadcap audit. It is also required to review a balance of live and historical job audits; specifically, you must perform a minimum of 10 job audits, with at least two job audits for each Prime. However, regardless of which audits are performed or prepared, it is essential to make sure all records are in order for the official audit as the auditor could ask to see anything—from paperwork for a job that occurred three months ago to TUS results for initial surveys from several years ago.

PREPARING FOR JOB AUDITS

There are some recommended best practices for performing job audits during the internal and official audit that can help contribute to a successful audit process.

Do you know the instrumentation type? As part of the job audit, auditors will verify that you are meeting all the requirements of AMS 2750. Therefore, it is essential to have records on hand that clearly demonstrate you are meeting the requirements. It is also required that you define your instrumentation classes and types, work zones, etc., and have proper documentation available. Thus, during the internal audit, you must review this information when performing job audits to ensure everything is in order for the official audit.

Do you know the soak time requirements? During the job audit, the auditor will review the heat-treat cycle data to ensure the cycle complies with customer requirements for the beginning and end of the soaking time. Therefore, you must review your cycle data during the internal audit process. Another important step is to verify your customer's initial soak requirements prior to running a cycle and listing this information on the process sheet in the job traveler. If there is any uncertainty about start- and end-time requirements, you must refer to the guaranteed soak-in table (available on eAuditNet in Section 12.3.3 of AC7102), or to other industry and customer specifications that provide this information.

Do you understand flowdown procedures? It is required that you understand how flowdown procedures work when reviewing production cycles during job audits, whether it is for the internal or official audit. First, you must have all material testing parameters listed on the PO and internal documents, such as the job traveler. In addition, if material testing is outsourced, these specifications need to be provided to the calibration service provider, who should document the specifications on their test reports.

Another required aspect of flowdown procedures is knowing the Prime and/or end user of the part. For example, a supplier could run more than 400 production orders in one day, but they are still required to know the Prime (i.e., find out if any of the components will be used for a specific aerospace Prime and which one). This is important because, depending on who the end user is, the requirements for the parts could change.

However, knowing how to perform job audits correctly—from verifying instrumentation type to understanding flowdown procedures—is just one aspect of performing an internal audit. It is also required that you review commonly experienced nonconformances as part of your internal audit process. This assists with identifying nonconformances that will require root-cause analysis and corrective actions before the scheduled official Nadcap audit.

REVIEWING NONCONFORMANCES

Reviewing PRI's list of common nonconformances is a valuable step prior to starting your internal audit, as well as for confirming you are in compliance while going through the internal audit process. PRI creates this list every year, which highlights the most common nonconformance reports (NCR) written during the previous year. The list, as well as other NCR-related materials (e.g., ineffective NCR responses), are available on eAuditNet. Reviewing these lists before starting your internal audit makes it easier to determine the extent to which you might need to make adjustments, implement additional training, etc., before the official audit occurs.

Two common nonconformances that frequently occur from year to year are:

1. Not having a documented procedure in place, or not correctly following documented procedures
2. Not providing intervals for retraining and evaluations

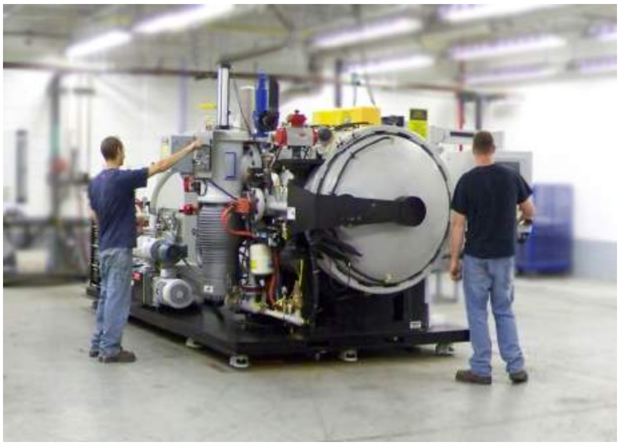
Being familiar with common nonconformances helps you to avoid them during the accreditation process, and helps to refine and improve other aspects of your heat treatment processes. We will discuss some best practices for avoiding nonconformances, including knowing which specifications to take note of and understanding why you are required to define retraining intervals.

Incorporating documented procedures. Reviewing audit checklists during the internal audit is another required step. For example, it allows you to know how to correctly document procedures and know exactly what needs to be done. One of the questions on the audit checklists touches on this, asking, "Does the supplier have an internal procedure or procedures for pyrometry addressing all the aspects of AMS 2750E and other customer specifications applicable to their operations?"[1]. The question essentially asks whether you have procedures in place that (1) state what you do to fully comply with AMS 2750E and (2) incorporate any additional Prime specifications to which you are required to adhere.

Occasionally, this requirement leads to a nonconformance as some suppliers might forget to note any additional applicable Prime specifications, which can be found in AC7102/S. It is also required that you know which specifications take precedent over others (i.e., Prime or AMS 2750E) so when it is time to conduct the official audit, you can be sure you are adhering to the strictest applicable requirements. Not having any documented procedures in place will result in a nonconformance. In addition, not documenting how SAT or TUS are performed as part of the procedures followed to comply with AMS 2750E will also lead to a nonconformance.

We found that some suppliers only present the auditor with the SAT and TUS reports submitted by their calibration service provider. However, it is required that you also include and submit the internal procedure's form number on the SAT and TUS reports, as well as have the calibration service provider's procedures readily available. This common nonconformance illustrates the importance of preparing for the audit process and going through each relevant audit checklist to make sure you fully understand and adhere to each listed requirement.

Implementing training and retraining intervals. Another common nonconformance involves advancing employees'



During performance of the internal audit, it is important to review past leak tests and maintenance logs, as well as past surveys, System Accuracy Tests, and industry specifications for heat treatment. Courtesy of Ipsen.

general knowledge of the processes that are run within their company's equipment, as well as having a procedure in place for training, retraining, and periodic employee evaluations. The checklist question asks, "Do records indicate that training is scheduled and attended in accordance with procedures and documented … Do records indicate that the evaluations are performed at documented frequencies and the results reviewed with employees in a program of continuous improvement of personnel?"[2]. When reviewing this question during a typical official audit, the auditor not only wants to confirm that procedures for training, retraining, and evaluations are in place, but also verify that procedures state the rate at which retraining and evaluations will occur.

Our experience with companies striving to receive Nadcap accreditation shows that not having documentation of these events, or not having a procedure in place, will result in a nonconformance as they are both major findings. Therefore, when creating procedures for training, retraining, and evaluations, it is not only required that you include intervals for retraining and retesting employees, but that you also define these intervals and provide documentation.

Overall, nonconformances can result from a range of oversights, from noncertified overtemperature thermocouples to not documenting the uniformity tolerance at each surveyed temperature. This is why it is imperative you evaluate every item referenced on the applicable Nadcap audit checklists, AMS specifications, and PRI's list of common nonconformances prior to the official audit.

FINISHING THE INTERNAL AUDIT

After concluding the internal audit, the proper steps outlined by PRI must be followed in preparation for the official audit, including:

- Reviewing findings (i.e., nonconformances)
- Performing root-cause analysis
- Implementing corrective actions

Reviewing findings. A finding is essentially a nonconformance identified during the internal audit, or that the auditor identifies during the official audit. Nonconformances are classified as minor and major. A minor nonconformance is "any single system failure or lapse in conformance with the applicable standard or audit criteria"[3]. A major nonconformance is either "the absence of, or systemic breakdown of, the process control and/or quality management system" or "any nonconformance where the effect impacts or has the potential to impact the integrity of the product"[4]. In other words, a minor nonconformance is a small deviation from Nadcap/AMS specifications or customer standards that does not impact the product (e.g., a typographical error). By comparison, a major nonconformance can imply a lack of control over the process or product quality, or that the safety of the product is significantly compromised. However, if a minor nonconformance could affect the product (e.g., not having a thermocouple calibration document on hand), then it becomes a major nonconformance.

When reviewing findings of the internal audit, you should prioritize the findings and establish the order in which they should be addressed. Once this step is complete, the root cause of each nonconformance should be determined. The recommended approach is to starting with the most drastic finding(s), e.g., major nonconformance so as to immediately ensure basic product safety and quality.

Performing root-cause analysis. Determining a root cause (i.e., the reason why a nonconformance occurred) requires defining the "5-Whys" noted by PRI[5]. This helps identify chronological events that led to the ultimate root cause. If answers to the "why" questions are "as a result of" or "because," then the true root cause has not yet been identified and further investigation is required.

A common misconception concerning appropriate root causes is that you can list the immediate contributing factors or simply list human error (e.g., the operator did not adhere to the correct process when positioning the load thermocouples in the furnace). However, the root cause was not human error. Rather, a more acceptable root cause might be that a procedure was not in place to provide the operator with appropriate training and retraining at regular intervals.

Consider how a root cause of an issue might be determined. For example, if the problem is that you were late to work, you might ask yourself, "Why was I late?" An answer of "the car wouldn't start," is a contributing cause, meaning the true root cause has not yet been identified. As such, more "why" questions are required (e.g., "why didn't the car start") until the answers are no longer "as a result of" or "because" and you discover the true root cause, such as "the battery was old." The true root cause has been found when continuing to ask "why" no longer adds value, meaning any further possible answers would not help prevent a recurrence, reduce erratic results, or provide cost savings[6].

Applying corrective actions. After determining root causes for all internal audit findings, the corrective action taken to address the issue must be defined and the timing of the implementation cited. If a corrective action implemented as a result of an internal audit has not yet been fully applied due to time constraints, the Nadcap auditor might not write an NCR for the same finding as long as you are working to apply corrective actions. This depends on the exact finding, as well as the auditor's ability to later verify that the corrective action was truly implemented.

For example, if a nonconformance was identified in relation to a typographical error that had no product impact in the calibration report for the overtemperature controller, the root cause might be a lack of quality resources for reviewing calibration reports. However, if the calibration service provider is not available to correct the root cause within the 30 days before the scheduled audit, it should be noted in the internal audit report that the corrective action will be fully implemented and verified during the next calibration with the future date. After the official audit, the auditor will verify that the corrective action was implemented by the aforementioned date. Documenting the implementation of any corrective actions after the internal audit is required as auditors will verify that the corrective actions are still in place during the official Nadcap audit. Generally, implementing corrective actions for internal audit findings is one of the final steps in performing an internal audit. After that, ensure that all proper documentation from the internal audit is submitted to PRI at least 30 days before the official audit.

The final part of this series will discuss the official audit, auditor interaction, and finishing the audit process.

For more information: Nathan Durham is an electrical solutions manager at Ipsen. For technical information, contact technical@ipsenusa.com or 844.464.7736 (select 1). Ipsen USA, 984 Ipsen Rd., Cherry Valley, IL 61016, ipsenusa.com.

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CONTINUOUS DEW POINT MONITORING SYSTEM FOR A SINTERING FURNACE

Accurate dew point measurement is key to maintaining the atmosphere composition required to achieve high quality and consistency of sintered products.

Liang He,* Zbigniew Zurecki, FASM,* Donald Bowe, and Ranajit Ghosh,*
Air Products & Chemicals Inc., Allentown, Pa.

Common powder metallurgy (PM) techniques involve compacting a blend of metal powder with lubricant and graphite (for ferrous parts) into a green part in a press, and sintering the part in a batch or continuous furnace. Continuous mesh-belt furnaces are widely used for mass production of PM parts[1]. They typically have at least three zones—a preheating (or de-lubrication) zone, a hot (or sintering) zone, and a cooling zone. In addition, some continuous sintering furnaces have a specially designed rapid-cooling zone between the hot and cooling zones for sinter hardening steel parts. Figure 1 shows a typical continuous sintering furnace design.

WHY DEW POINT IS IMPORTANT

Atmosphere quality plays a key role in the final properties of a sintered part. Dimensional accuracy as well as characteristics such as hardness, ductility, carbon content, microstructure, and magnetic properties are influenced not only by time and temperature, but also by furnace atmosphere composition, flow rate, and stability. Different furnace zones require varying degrees of oxidizing or reducing power to develop optimum final sintered part properties[2]. Generally, a reducing and carbon-neutral atmosphere is desired in the hot zone for ferrous parts.

The *reducing potential* determines the rate at which powder particle surface oxides are reduced, which directly influences sintering bonding between particles in the compact. A dry or slightly humidified[1] nitrogen-hydrogen blend is used for steel PM operations. The hydrogen-to-moisture ratio in the hot zone determines reducing capability. Moisture is simply a product of powder oxides reduced by hydrogen introduced into the furnace, as well as belt reduction and air ingression. Properties of sintered parts, such as surface hardness and strength, are affected if uncontrolled carburization or decarburization occurs. In a carbon-neutral atmosphere based on nitrogen with hydrogen addition, the actual hydrogen-to-moisture ratio in the sintering zone can be used as the control parameter. For example, in nitrogen and hydrogen sintering atmospheres, maintaining an atmosphere dew point (DP) below −30°F ensures a reducing and carbon-neutral hot zone for common steel grades used in gear manufacturing[3].

Thus, monitoring and controlling hot-zone atmosphere DP is necessary for better sintering process control and production cost control[4]. Continuously measuring DP enables real-time monitoring of the furnace condition. For example, a sudden, extremely high (wet) DP reading may indicate a leak in the muffle or cooling zone inside the furnace.

SELECTING THE CORRECT DP SENSOR

Ceramic and polymer-based capacitance DP sensors are popular in the heat treating industry due to their low cost, fast response, and long service life. Alumina (Al_2O_3) is a preferred ceramic sensing material for DP sensors, and current Al_2O_3 DP sensors are fabricated by an anodization process. One limitation of these sensors is that significant degradation in sensitivity and drift in capacitance characteristics occur after long exposure to high humidity. This is attributed to the gradual decrease of effective surface area and porosity caused by water absorption[5].

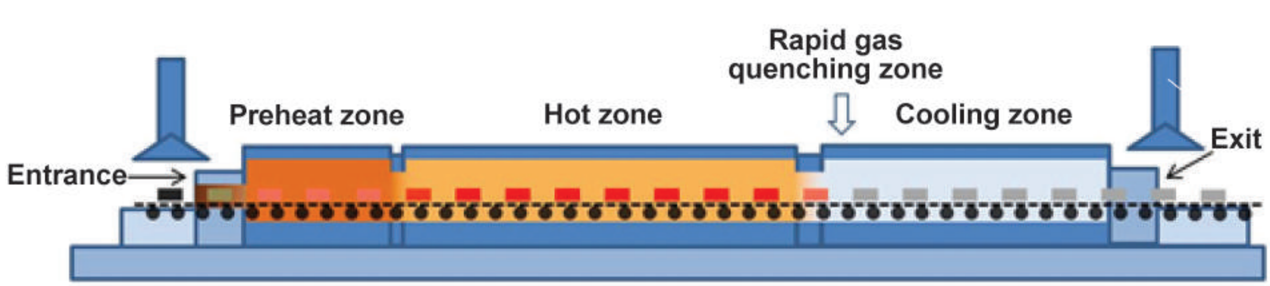

Fig. 1 — Typical design of a continuous sintering furnace.

**Member of ASM International*

In polymer-based DP sensors, a polymer film is filled with micropores for water vapor condensation, and its physical properties change with the amount of water absorption[5]. The hot-zone atmosphere in a sintering furnace is very complicated upon reaching equilibrium with the steel parts, belt, and trace hydrocarbon gas additions that are occasionally used to adjust carbon potential. This could include water vapor, metallic or organic vapors of green-body lubricant and carbon particles (soot), carbon monoxide, carbon dioxide, and methane[6]. Polymer-based DP sensors have been developed to resist particulate contamination, oil vapors, and most chemicals. This type of thin-film polymer DP sensor ensures continuous, reliable DP measurements.

CASE STUDY: CONTINUOUS DP MONITORING SYSTEM

Although a thin-film polymer sensor is resistant to particulate contamination, condensation, and most chemicals, it can still be permanently damaged after long exposure in the hot, toxic sintering atmosphere. Thus, a special sampling and monitoring system was designed to reliably and continuously measure the DP of a hot-zone atmosphere with less maintenance.

The Air Products DP measurement solution enables sampling hot-zone atmosphere from the point of interest using a vacuum pump. Passing the gas sample through a temperature-controlled filtering system conditions the gas before entering the DP sensor. DP measurements and other information are collected and sent to a cloud server, and are easily accessed by visiting webpages using a computer or smartphone. A schematic of the continuous dew point monitoring system is shown in Fig. 2.

TEMPERATURE CONTROL AND FILTRATION

A change in DP sensor temperature affects the DP reading due to the intrinsic physical properties of the sensor material. Thus, maintaining a stable sampled gas temperature and sensor temperature is the initial challenge in considering the complicated operating environment of the system to achieve continuous, reliable DP measurement. The new system incorporates an air conditioning system designed for the filtration unit and DP sensor container, which enables continuous, precise control of the sampled gas and DP sensor temperatures.

Reliable, accurate DP measurement of the complex hot-zone atmosphere requires a well-designed filtering system. If contaminants in the sampled gas are not removed, they affect the measurement by permanently poisoning the instruments, especially the DP sensor, and shortening the service life of the entire system. The Air Products system incorporates a staged filtration unit designed with several sintered stainless steel filters to completely remove different kinds of contaminants.

REDUCED MAINTENANCE

Integrating a periodic self-cleaning function into this system eliminates frequent (sometimes monthly) calibrations of the DP sensor as well as sampling system maintenance. This function ensures the cleanliness of the filtering system and DP sensor itself. Drifts/changes of DP readings on the calibration gas were not observed after more than six months of operation. It is recommended that the DP sensor is calibrated once a year. The filtration system can be replaced or regenerated in a few minutes at minimal cost.

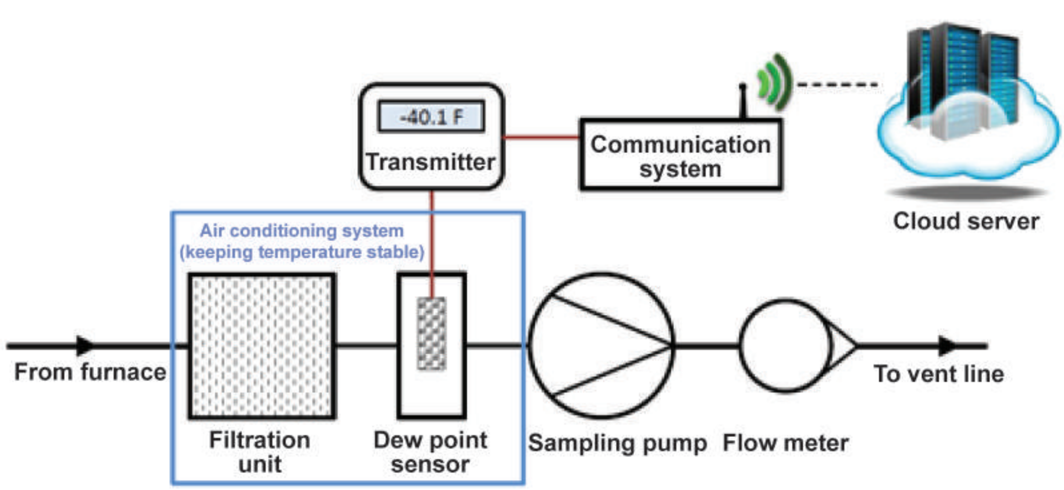

Fig. 2 — Schematic of continuous dew point monitoring system.

COMMUNICATION SYSTEM AND CLOUD SERVER

The new system also features a wireless data storage function. DP readings and operating parameters are recorded and sent to a cloud server every two minutes, and can be adjusted to meet user requirements. Process engineers can observe the DP reading locally in front of the system interface and check historical data by accessing a customized website. Stored historical data can help identify and address furnace operation issues quickly and proactively. For example, analysis of DP readings could facilitate planning furnace shutdowns and scheduling preventive maintenance, which saves the cost of unnecessary maintenance work and reduces the possibility of unexpected downtime.

SUMMARY

In the sintering industry, continuous monitoring and control of furnace atmosphere is increasingly important to improve quality control and reduces costs. Air Products' continuous dew point monitoring system is designed to overcome common obstacles to analyzing sintering atmospheres. The system can also be upgraded with an atmosphere control function to automatically adjust flow rates of nitrogen and hydrogen.

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BORONIZING ADDITIVELY MANUFACTURED INCONEL 718

Boronizing 3D-printed Inconel 718 produces results similar to those obtained for wrought 718.

Craig Zimmerman,* Bluewater Thermal Solutions, Chicago

Additive manufacturing (AM) is becoming an increasingly popular production method for making metal parts with complex geometries. AM offers a solution for producing components with geometrical features that are difficult to create through traditional casting, forging, forming, and machining methods. One example is a 3D-printed Inconel 718 component used in fluid flow control. The component has many small, intricate internal passageways that control and moderate the flow of an abrasive fluid. The small holes, internal twisting passageways, and openings would be very difficult to machine from a solid piece of material. Traditionally, investment casting would be used to produce a near-net-shape part, but some machining is still required to add intricate features. AM offers an alternative production method to near-net-shape casting, post machining, and grinding.

BORONIZING FOR IMPROVED WEAR RESISTANCE

Erosion wear of flow control unit internal surfaces from abrasive fluid flow affects flow rates, which in turn affects the proper function of the unit. Increasing wear resistance is therefore necessary to improve the unit's service life. Boronizing is a proven method for reducing wear and erosion of metal surfaces on parts produced using traditional manufacturing methods. However, it was unknown how an AM part would respond to boronizing. To explore this idea, Bluewater Thermal Solutions investigated what effects, if any, AM Inconel 718 material had on its boronizing process.

Boriding tests were conducted on a sample of 3D-printed Inconel 718, which represented a portion of a 3D-printed component (Fig. 1). The investigation was performed to determine if a 3D-printed surface has a negative effect on boronizing results compared with typical results for boronized conventional wrought Inconel 718 material.

Because the as-printed surface was fairly rough, the smaller end of the sample was ground using a belt sander to remove some as-printed surface material (Fig. 2). This enabled a determination to be made regarding whether surface roughness or surface defects from the printing process negatively affect boride layer formation.

The test sample was packed in Bluewater's proprietary boronizing powder inside a sealed retort and processed in a furnace at a temperature of 1475°F for 8 hours to prevent laves phase or grain boundary carbide precipitation during simultaneous boronizing and aging.

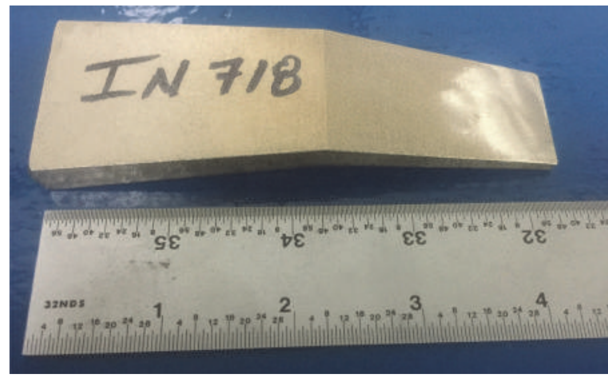


Fig. 1 — Test segment of 3D-printed Inconel 718.

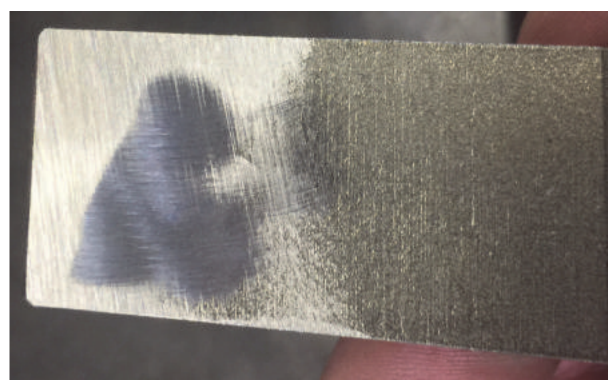


Fig. 2 — Ground surface on small end of test segment.

TEST RESULTS

Figure 3 shows the boronized as-printed and ground surfaces. The ground surface remained smoother than the unground surface, and it was difficult to visually identify the ground surface. Sectioning the sample provided a cross section containing both the boronized ground and unground surfaces. The cross section was mounted and examined metallographically to determine boride layer depth. Vickers microindentation hardness (50 g load) of the boride layer was measured in three locations. Core hardness (HRC) was measured in four locations on the cross section in the mount. No difference was observed between the ground and unground sides of the part. Both sides had a boride layer with similar appearance (Fig. 4). Figure 5 shows the core microstructures.

*Member of ASM International

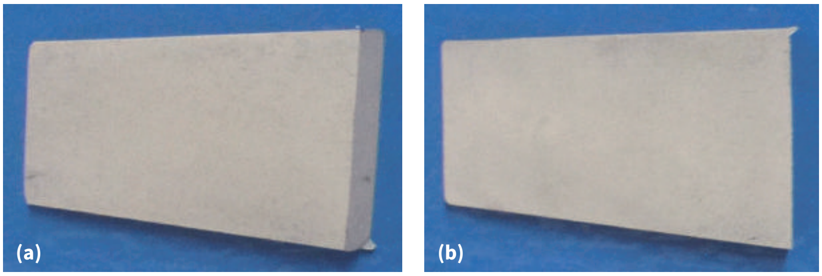


Fig. 3 — Boronized surfaces: (a) unground and (b) ground.

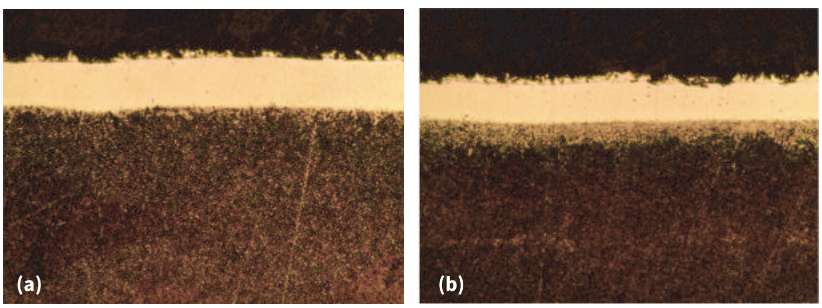


Fig. 4 — Boride layer on (a) ground and (b) as-printed surfaces. Boride layer depth range: 0.0010-0.0011 in. Boride layer hardness (three locations): 2670, 2778, and 2892 HV (50 g load). Core hardness (four locations): 36.5, 39, 39, 39 HRC. Etchant: Marble's reagent. Original magnification 200x.

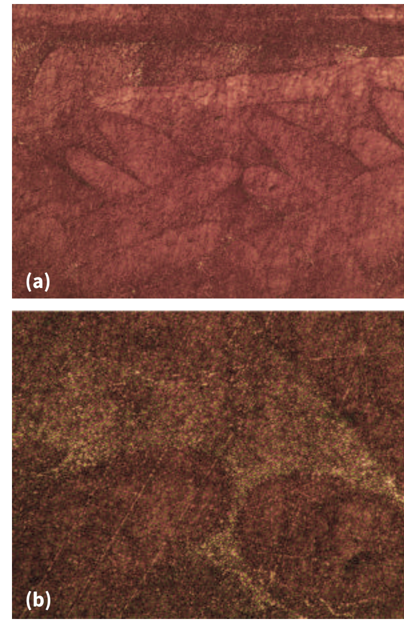


Fig. 5 — Core microstructures. Etchant: Marble's reagent; (a) original magnification 50x and (b) original magnification 200x.

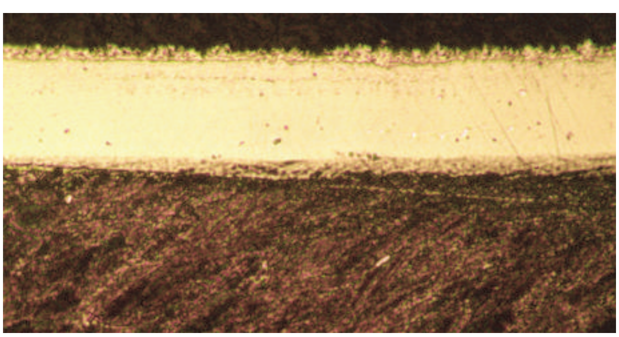


Fig. 6 — Boride layer on wrought Inconel 718 test bar. Boride layer depth range: 0.0012-0.0013 in. Boride layer hardness (three locations): 3014, 2778, and 2892 HV (50 g load). Etchant: Marble's reagent. Original magnification 200x.

COMPARING WROUGHT AND AM MATERIALS

A sample of Inconel 718 bar stock material was also processed to compare results with those of the 3D-printed material. Figure 6 shows the microstructure of the boride layer on the bar stock test bar. It was concluded that boronizing of 3D-printed Inconel 718 is possible, and boride layer depth, hardness, and microstructure are similar to results for wrought Inconel 718.

For more information: Craig Zimmerman is technical director, Bluewater Thermal Solutions, 414.573.2832, czimmerman@bluewaterthermal.com, www.bluewaterthermal.com.

ASMNEWS

ASM ANNOUNCES 2016 CLASS OF FELLOWS

In 1969, ASM established the Fellow of the Society honor to provide recognition to members for their distinguished contributions to materials science and engineering and to develop a broadly based forum of technical and professional leaders to serve as advisors to the Society. Following are the members recognized by their colleagues for 2016. Additional Fellows may be elected to this distinguished body in subsequent years. The solicited guidance, which the Fellows provide, will enhance the capability of ASM as a technical community of materials science and engineering in the years ahead. Awards will be presented at ASM's annual Awards Dinner, Tuesday, October 25, in Salt Lake City, during Materials Science & Technology 2016.

Dr. Beverly J.M. Aikin, FASM
R&D Engineer
Los Alamos National Laboratory, N.M.

For advancing microstructure, property, and processing relationships in metals and intermetallics; enhancing the safe handling, security, and recycling of beryllium; and for commitment to K-12 student outreach in STEM.

Dr. Michael P. Brady, FASM
Distinguished R&D Staff
Oak Ridge National Laboratory, Tenn.

For innovative development of novel alloy design principles for the control of surface chemistry in structural and functional materials with widespread scientific, engineering, and societal impact.

Dr. Ellen Cerreta, FASM
Group Leader
Los Alamos National Laboratory, N.M.

For outstanding contributions in the fields of dynamic and shock behavior of materials, as well as structure/property effects on mechanical behavior and damage evolution in materials.

Dr. Kathryn Dannemann, FASM
Principal Engineer
Southwest Research Institute,
San Antonio, Texas

For advancing the understanding of dynamic response of materials in metals, ceramics, and glasses; and for mentoring students in materials science and engineering, especially as an advocate of materials education and the materials profession.

Dr. Rollie Dutton, FASM
Chief, Manufacturing and Industrial Technologies Division
Air Force Research Laboratory, Materials and Manufacturing Directorate
Wright-Patterson AFB, Ohio

For outstanding scientific and engineering achievements in the processing of metallic and composite materials, and for national leadership in the development of integrated computational materials science and engineering.

Mr. Joe Epperson, FASM
Senior Metallurgist
National Transportation Safety Board, Washington

For outstanding contributions and advancements in the field of failure analysis, including leadership and service to transportation safety with high professional and societal impact.

Dr. James Hall, FASM
Senior Principal Engineer, Retired
Honeywell Engines, Phoenix

For outstanding contributions and leadership in the research, development, and commercial application of titanium and other heat resistant alloys; and as a generous and profoundly influential teacher and mentor of materials scientists and engineers.

In This Issue

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

HIGHLIGHTS CLASS OF FELLOWS

Dr. Susan E. Hartfield-Wunsch, FASM
Technical Fellow
General Motors, Livonia, Mich.

For advancing the state-of-the-art in aluminum sheet technology and implementation of same in the automotive industry.

Dr. Peggy E. Jones, FASM
Senior Project Engineer
General Motors, Saginaw, Mich.

For the application of ICME and fracture mechanics based design to aluminum automotive castings, including creation of the Virtual Cast Component Design system.

Dr. Lee Knauss, FASM
Chief, Technology Transition
IARPA, Washington

For the development and advancement of magnetic current imaging fault isolation techniques used in microelectronics failure analysis.

Dr. Manish Mehta, FASM
President and CEO
M-Tech International LLC, Ann Arbor, Mich.

For sustained contributions in materials and process technology transfer programs to accelerate global commercialization.

Prof. Matt O'Keefe, FASM
Professor and Chair
Missouri University of Science &T echnology, Rolla

For distinguished contributions in materials science related to understanding corrosion mechanisms, leading to the development and use of sustainable rare earth based coatings for lightweight metallic alloys.

Dr. Philippe Perdu, FASM
Microelectronic Senior Expert
CNES, Toulouse, France

For outstanding leadership and technical contributions towards the development of novel defect localization and failure analysis techniques applied to microelectronics and microsystems devices.

Dr. Thomas A. Siewert, FASM
Group Leader, Retired
National Institute of Standards and Technology, Wylie, Texas

For leadership in the development of consumable weld wire enabling austenitic stainless steel welding for cryogenic applications and expertise in nondestructive evaluation.

Dr. Dileep Singh, FASM
Group Leader
Argonne national Laboratories, Ill.

For pioneering contributions and global leadership in the science and technology of advanced ceramic materials and systems for energy generation, efficiency, storage, and environmental applications.

Prof. Raman Singh, FASM
Professor
Monash University, Melbourne, Australia

For outstanding contributions in understanding and mitigating material degradation through novel/disruptive approaches, and for successfully establishing and leading interdisciplinary teams advancing science and technology.

Prof. Marcel A.J. Somers, FASM
Professor
Technical University of Denmark, Kgs. Lyngby

For sustained, innovative, and outstanding contributions to the field of thermochemical surface engineering through fundamental and applied research, teaching, and transfer of technology to practice.

Dr. Donald Susan, FASM
Principal Member of Technical Staff
Sandia National Laboratories, Albuquerque, N.M.

For sustained contributions in the areas of physical metallurgy and joining research, materials characterization, and failure analysis.

Mr. David Vallett, FASM
Owner
PeakSource Analytical LLC, Fairfax, Vt.

For sustained outstanding technical contributions, leadership, dissemination of knowledge, and education in microelectronic IC fault isolation and failure analysis technology and magnetic imaging applications, and for articulating and publicizing major analytical technology hurdles and challenges throughout the industry.

Prof. Yunzhi Wang, FASM
Professor
The Ohio State University, Columbus

For pioneering foundational work on phase field modeling with seminal achievements in diffusive molecular dynamics, and for the application of these methods to challenging problems in the structure-properties-processing of materials.

Dr. George G. Wicks, FASM
CTO
Applied Research Center, Aiken, S.C.

For international leadership in materials science and technology research that benefits safe nuclear waste containment and storage, energy, and medical innovations.

Prof. Wendelin Wright, FASM
Associate Professor
Bucknell University, Lewisburg, Pa.

For developing and conducting high temporal resolution studies of deformation mechanisms in bulk metallic glasses and for contributions to our understanding of the fundamental nature of shear banding processes in these materials.

Official ASM Annual Business Meeting Notice

The Annual Business Meeting of members of ASM International will be held in conjunction with MS&T16 on:

Monday, October 24
4:00 - 5:00 p.m.
Salt Palace Convention Center,
Salt Lake City

The purpose of the ASM Annual Business Meeting is the election of officers for the 2016-17 term and transaction of other Society business.

Nomination Deadline for the 2017 Class of Fellows is Fast Approaching

The honor of Fellow of the Society was established to provide recognition to ASM members for distinguished contributions in the field of materials science and engineering, and to develop a broadly based forum for technical and professional leaders to serve as advisors to the Society.

Criteria for the Fellow award include:

- Outstanding accomplishments in materials science or engineering
- Broad and productive achievement in production, manufacturing, management, design, development, research, or education
- Five years of current, continuous membership

Deadline for nominations for the class of 2017 is **November 30, 2016.** Complete information including rules and user-friendly nomination forms is available at asminternational.org/membership/awards/asm-fellows or by contacting Christine Hoover 440.338.5151, ext 5509 or christine.hoover@asminternational.org.

ASM Indian Institute of Metals Announces Recipients of 2016 ASM/IIM Visiting Lectureship

The cooperative Visiting Lecturer program of ASM International and the Indian Institute of Metals (IIM) is pleased to announce the five distinguished individuals named to participate in the 2016 Visiting Lecturer program: **Prof. Antonello Astarita,** University of Naples; **Prof. Surojit Gupta,** University of North Dakota; **Prof. Federico Rosei, FASM,** Centre for Energy Materials and Telecommunications; **Prof. Fiorenzo Vetrone,** Institute National de la Recherche Scientifique, University of Quebec; and **Prof. Jingyang Wang,** Shenyang National Laboratory. The award includes an $800 honorarium to be used for travel expenses within India during the lecturer's visit.

Astarita

Gupta

Rosei

Vetrone

Wang

Mukopadhyay

Raja

Upadhyaya

Chatterjee

ASM is also pleased to announce two distinguished individuals who have been named to participate in the 2016 ASM-IIM Visiting Lecturer North American Program: **Prof. Amartya Mukopadhyay,** Indian Institute of Technology, and **Dr. V.S. Raja,** Indian Institute of Technology. **Prof. Anish Upadhyaya,** Indian Institute of Technology, and **Prof. Kaushik Chatterjee,** Indian Institute of Science were awarded the Lectureship in 2015 and will be recognized along with the 2016 lecturers. The award includes a $2000 honorarium to be used for travel expenses within the U.S. and Canada during the lecturer's visit. All recipients will receive a certificate of recognition to be presented at the ASM Leadership Awards Luncheon scheduled for October 24 in Salt Lake City during MS&T16.

Seeking Applicants for SMST Fellowship

The International Organization on Shape Memory & Superelastic Technologies (SMST), an affiliate society of ASM International, is seeking applicants for the 2017 SMST Fellowship. The intent of the fellowship is to provide a current use gift to a deserving graduate student(s) with the purpose of initiating interest in a unique path of research for shape memory materials such as Nitinol. The award, which is financially supported in 2017 by Edwards Lifesciences, includes a stipend of up to $50,000. The recipient will present research results at the 2019 SMST Conference to be held in Constance, Germany. Application deadline is **January 9, 2017.** For more information, visit http://bit.ly/29pjIkD or contact sarina.pastoric@asminternational.org.

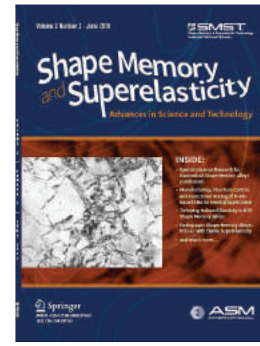
SMST
Shape Memory & Superelastic Technology
ASM INTERNATIONAL

Edwards

Seeking Nominations for Thermal Spray Hall of Fame

The Thermal Spray Hall of Fame, established in 1993 by the Thermal Spray Society of ASM International, recognizes and honors outstanding leaders who have made significant contributions to the science, technology, practice, education, management, and advancement of thermal spray. For a copy of the rules, nomination form, and list of previous recipients, visit tss.asminternational.org or contact joanne.miller@asminternational.org. Nominations are due **September 30.**

New Members Join Shape Memory and Superelasticity Editorial Advisory Board



The latest exceptional individuals to join the editorial advisory board of the *Shape Memory and Superelasticity* journal include **Gunay Anlas,** Bogazici University, Turkey; **Samantha Daly,** University of California, Santa Barbara; **Ken Gall,** Duke University; **Reginald Hamilton,** Penn State University; **Ryosuke Kainuma,** Tohoku University, Japan; **Ibrahim Karaman,** Texas A&M University, **Christian Lexcellent,** University of Besancon, France; **Alan Pelton,** G. Rau Inc., and **Aaron Stebner,** Colorado School of Mines. To view the full announcement and the first two years of *Shape Memory and Superelasticity* for free, visit http://link.springer.com/article/10.1007/s40830-016-0071-2.

ASM CHAPTER HONOR ROLL

The ASM Volunteerism Committee proudly announces the 2016 Chapter Volunteer Honor Roll recognizing individuals whose performance is exemplary and essential for ASM's success. All Chapters were invited to nominate one person and Chapter Executive Committees were encouraged to select a member who serves as a volunteer in an ongoing capacity. Submissions for the 2017 Honor Roll will open in March 2017. Join us in recognizing the following 2016 Chapter Honor Roll volunteers who will receive an ASM MVP tie or scarf.

Buffalo Chapter—Lee Gearhart

Lee Gearhart has been involved in the Buffalo Chapter in a big way for more than 35 years. He has served in every position of responsibility and has willingly and graciously orchestrated many memorable meetings and events over the years. His spirit and good will are exemplary to all he encounters and he always works to keep the Chapter energized and vital.

Central Massachusetts—Frank Blanchard

Frank Blanchard is the backbone of this Chapter's executive committee, having served on it for 32 years, with over 20 as treasurer. He has also served as chairman, vice chair, social activities chair, and sustaining membership chairman. He resurrected the Chapter's annual golf outing by creating a friendly team competition and ensuring it was financially sound for the past 23 years. Blanchard is a huge asset due to his infectious enthusiasm for ASM participation and his willingness to help whenever needed, including volunteering at the Materials Experience camp for local high school students. His professionalism as treasurer has helped the Chapter remain financially solvent, even in tough times. Nominating Blanchard for the Chapter Honor Roll was a unanimous decision. The fact that he became an ASM Life Member this year makes it that much more appropriate for 2016.

Chicago Regional Chapter—John Hasier

John Hasier, a graduate student member of the Chapter through Material Advantage, inherited the treasurer position under tough circumstances. His dedication while also working to complete his Ph.D. has proven invaluable. Hasier's efforts have kept finances in order and helped take the Chapter to the next level in terms of updating policies and recordkeeping, as well as guiding the Chapter toward a more streamlined financial system for the next season. Hasier is nominated for his diligence, dedication, and efforts in making the Chapter a better place by serving in one of its most time consuming roles.

Edmonton Chapter—Connie Williams

Connie Williams is currently the secretary and technical dinner meeting chair for the Chapter. She has been an active volunteer for ASM Edmonton, ASM Canada Council, and for a number of other technical societies in the Edmonton region over the past several years. Williams has gone above and beyond to recruit speakers and organize monthly dinner meetings. She is one of the most active members of the Chapter's executive team and often plays host to invited guests and speakers from out of town. She also participates in other Chapter activities including helping with award nomination packages, general communications, and outreach.

Houston Chapter—Leo Vega

Leo Vega has been a loyal member and volunteer to the Chapter's executive committee for at least 10 years. He has been a valuable contributor and resource to the education committee as well, providing course locations, speakers, and countless hours.

Lehigh Valley Chapter—Mark Burton

Mark Burton has filled numerous roles in the Chapter over the years. He was instrumental in revitalizing educational offerings, which comprise a large portion of the Chapter's income. Burton transitioned from education chair to vice chair, and then to chair. Currently, he is filling in as interim chair due to the previous chair moving away. Additionally, he has participated in Materials Camps as a chaperone and guest speaker. He brings enthusiasm to his roles and has volunteered for numerous positions within the Chapter.

Milwaukee Chapter—Susan Kerber

Susan Kerber has supported the Chapter for many years. She leads the summer Materials Camp for students and has founded outreach programs at area high schools. She has an additional leadership role for the EGMF committee for student scholarships at Wisconsin universities. Kerber actively participates in Chapter board meetings as well as monthly meetings. Her strength and determination are essential to leading the organization.

Minnesota Chapter—Kurt Schenk

Kurt Schenk has served as Chapter treasurer for over nine years. He created the Chapter's website and now maintains it—a volunteer job all by itself. He has also been a full-time mentor at the Chapter's Materials Camp since its inception 10 years ago. In addition, he helps select students for the camp, not an easy task with almost 100 applications and only 30 spaces available. As treasurer, the Chapter counts on Schenk to remember past costs and keep a sound budget. It is great to have a long-term officer in such a key role. The Chapter is indebted to Schenk for all of his support and knowledge.

Oak Ridge Chapter—Dongwon Shin

Dongwon Shin has served admirably as treasurer for many years and provides much needed continuity in that position. His efforts and attention to detail are greatly appreciated by the Chapter.

Pittsburgh Chapter—Timothy Hosch

Timothy Hosch did an outstanding job of organizing the Chapter's annual Young Members Night in February, drawing more than 120 participants. He created a team of student volunteers who solicited funding from local industries to organize this event. The area businesses and sustaining member companies were very interested in this event as they had the opportunity to directly interface with students from local universities. This turned out to be a great platform for both students and industry representatives as some of the students ended up securing internships at local companies.

Quad Cities Chapter—Sara Moser

Sara Moser has been a key enabler of the Chapter's Materials Day Camp for a number of years. She has faithfully and tirelessly developed the camp schedule, recruited volunteers, arranged transportation for factory tours, ordered food for students and volunteers, and worked with volunteers to buy supplies for experiments. It would be a huge challenge to replace the work and enthusiasm that Moser brings to the camp experience.

EMERGING PROFESSIONALS

EPC Announces Emerging Materials Professionals Symposium at MS&T

The Emerging Professionals Committee (EPC) is organizing the 9th annual "Perspectives for Emerging Materials Professionals" symposium at MS&T16 in Salt Lake City, October 23-27. The Symposium is an excellent opportunity for new professionals in the field of materials science and engineering (MSE) to see what career paths are available. Given the variety of fields that MSE encompasses—everything from medical devices and instrumentation to heavy industrial equipment, consumer electronics devices, and more—finding the right spot within the materials world can be unclear. The symposium will bring speakers and panelists together to share insights from years of experience in a variety of sectors including military, aerospace, medical devices, and more across academia, industry, and national labs.

Speakers and panelists will also share tips on professional development, ways to meet goals, the importance of diversity, emerging opportunities in computational modeling, and taking on management roles. ASM's incoming president, Dr. William Frazier, FASM, will deliver the keynote presentation and highlight opportunities that exist for MSE professionals. For more information or to get involved in future symposia, contact Andrew DeVillier at andrew.devillier@integralife.com.

WOMEN IN ENGINEERING


Reigel

This new profile series introduces leading materials scientists from around the world who happen to be females. Here we speak with Marissa Reigel, principal engineer for Savannah River National Laboratory (SRNL).

What is your engineering background?

I have my B.S. and Ph.D. in metallurgical and materials engineering from the Colorado School of Mines. During undergrad, I had internships at a Chevron gas refinery and NASA Glenn Research Center, both of which verified that I had made the right choice of majors. However, I guess you could say that my engineering background goes back even further since I was always helping my dad with his business, which required creative technical solutions to get telephone and computer wiring from one place to another.

What attracted you to engineering?

I really like the problem solving and continual learning aspects of engineering. I have always been interested in learning how and why things behave the way they do, so in that sense, being a materials engineer is the perfect fit for me. Every project I work on, I have had to learn something new, which is another thing that is so appealing about engineering. There is always something new to learn or gain a deeper understanding of.

What are you working on now?

My work centers on the processing, immobilization, and disposition of legacy nuclear waste. This year, my primary project is establishing erosion and corrosion wear allowances for a nuclear waste processing facility being built in Washington State. I am also working on two additional projects: The first is using additive manufacturing to assist with tritium processing at the Savannah River Site and the second is investigating novel methods to better retain problematic contaminants in immobilized nuclear waste.

What does your typical workday look like?

I'm not sure that I have a typical workday. Currently I am doing a lot of traveling but when I am back at SRNL, I am either in the laboratory, writing reports, or attending meetings. It depends on the stage of the projects I am working on.

What part of your job do you like most?

I like that the challenge and diversity of my job requires me to expand outside my comfort zone. I am involved with several different projects that keep my day-to-day technically interesting and challenge me to learn new things.

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

Go for it! There are so many opportunities in science and engineering that you can define your own career path. I would encourage them to talk to experienced people in the field they are interested in. There is so much you can learn in school, but do not underestimate the knowledge gained from hands-on experience and learning through mentoring.

Hobbies?

Volleyball, softball, hanging out with my dogs and husband, hiking, and renovating my house.

Last book read?

I am in the middle of "Skunk Works" by Ben Rich and Leo Janos. I highly recommend it for anyone with an interest in engineering and spy novels.

ASM's Women in Materials Engineering Committee is actively seeking candidates for award nominations. Contact vicki.burt@asminternational.org.

CHAPTERS IN THE NEWS

Canton-Massillon Hosts Student Night

In May, the Canton-Massillon Chapter held its annual Student Night to end the year's technical programming. Special guest speaker Laurie Moline of United Way of Stark County Women's Leadership Council spoke about some of the student programs she coordinates. One such program, GetConnected, is a mentoring program established to connect students with professionals and local industry through tours and other types of interactive events.

The evening was filled with networking, student project displays, presentations, and a panel discussion. The panel was composed of students, mentors, and local Project Lead the Way instructors, who shared about their program experiences and the effect that the mentoring relationships have had on them. Feedback was also requested on how to utilize these kinds of partnerships. During the discussion, members shared their own mentoring advice with the students as well. It was a great opportunity for students to experience a professional meeting and practice networking skills.

Canton-Massillon Chapter members enjoy Student Night.

MEMBERS IN THE NEWS

Jandeska Receives Lifetime Achievement Award

William Jandeska, Jr., FASM, president, Midwest Metallurgical Ltd., received the Kempton H. Roll PM Lifetime Achievement Award from the Metal Powder Industries Federation (MPIF) during Powdermet2016 in Boston. The award was established in 2007 to recognize individuals with outstanding accomplishments and achievements who have devoted their careers to the field of PM and related technologies.

William Jandeska (right) accepts the Kempton H. Roll PM Lifetime Achievement Award from Patrick McGeehan, president of MPIF.

Vander Voort Honored by Drexel University

From left, George Vander Voort and Fred Schmidt at the bust of Anthony J. Drexel.

On May 7, **George Vander Voort, FASM,** was honored by Drexel University at its annual alumni weekend when they gave him the school's top alumnus honor, the Service to the Profession Award. George was accompanied by his wife, Elena, and by Phyllis and **Fred Schmidt, FASM.** Schmidt also received his B.S. in metallurgical engineering from Drexel. Vander Voort then traveled to Chennai, India, for the 2nd International Conference and Exhibition on Heat Treatment and Surface Engineering organized by ASM's Chennai Chapter, where he gave the first keynote

Vander Voort receives a plaque from the Baroda Chapter of the Indian Institute of Metals after his lecture in Vadodara, India.

lecture and another talk after lunch on the opening day. Later in May and early June, Vander Voort presented seminars on metallography and failure analysis at various locations throughout India, Italy, Poland, and Russia.

Anderson, Choquette Win Outstanding Technical Paper Award

The Howard I. Sanderow Outstanding Technical Paper Award was presented to **Iver Anderson, FASM,** senior metallurgist, Ames Laboratory, and **Stephanie Choquette,** graduate research assistant, for their paper, "Liquid-Phase Diffusion Bonding: Temperature Effects and Solute Redistribution in High-Temperature Lead-Free Composite Solders." They were officially recognized during the industry luncheon held during Powdermet2016 in Boston. The award was established in 1993 to recognize authors of excellent manuscripts submitted for publication at the annual technical conference organized by the Metal Powder Industries Federation (MPIF) and APMI International.

Iver Anderson, center, and Stephanie Choquette, right, receive the Howard I Sanderow Outstanding Technical Paper Award from James Trombino of MPIF.

Henein Named 2016 Distinguished Lecturer

Hani Henein, FASM, professor, department of chemicals and materials engineering, University of Alberta, was selected by the Canadian Institute of Mining, Metallurgy and Petroleum (CIM) as a Distinguished Lecturer for 2016. Speakers are chosen based on accomplishments in scientific, technical, management, or educational activities related to the minerals industry, and speak at CIM branch and student chapter meetings across Canada. Founded in 1898, CIM is the leading not-for-profit technical society of professionals in the Canadian minerals, metals, materials, and energy industries.

Hillman Named Rockwell Collins Fellow

David Hillman is among six Rockwell Collins engineers honored for leadership, innovation, and technical expertise as well as dedication to mentoring others. He was named to the company's third annual class of Fellows during a special ceremony on July 19 in Cedar Rapids, Iowa. Hillman is a principal material and process engineer in advanced operations engineering. He is also the recognized Rockwell Collins enterprise technical expert and leading authority for matters related to soldering materials and processes, solder joint reliability, lead-free materials and processes, and metallurgy and finishes.

Murty Appointed Progress Energy Distinguished Professor

K.L. Murty, FASM, professor and director of graduate programs for the nuclear engineering department at NC State University, was recently appointed Progress Energy Distinguished Professor in the department of nuclear engineering. Murty joined NC State in 1981 following industrial experience at Westinghouse Research Center and Lynchburg Research Center of Babcock & Wilcox Co. Prior to that, he was an AINSE Research Fellow at the University of Newcastle and a research metallurgist in the Inorganic Materials Research Division of Lawrence Berkeley Laboratory at the University of California, Berkeley.

IN MEMORIAM

John T. Venard passed away May 11 at age 78. Born in Indianapolis on July 10, 1937, he grew up near Zionsville, Ind. In 1961, Venard began graduate training in metallurgical engineering at Oak Ridge and Knoxville, Tenn. He was the first of his family to attend college and trained as a metallurgical engineer at Purdue University and the University of Tennessee, with a master's degree conferred in 1967. In 1978, he earned an MBA through the Executive Program at the University of Chicago. Before his 1999 retirement, Venard spent his professional career as a research engineer, manager, and technology transfer program administrator at both Oak Ridge and Argonne National Laboratories, and later at Fermi National Accelerator Laboratory. In addition to ASM, he was a member of Sigma Xi, Aircraft Owners and Pilots Association, Sigma Gamma Epsilon, Technology Transfer Society, Licensing Executives Society, and the Association of University Technology Managers. Venard joined ASM in 1957 and was a Life Member.

Man H. Yoo, FASM, passed away on August 12, 2015, at 80 years old. After graduating from the famous Kyunggi High School in Korea, he traveled to the U.S. in 1956 to advance his studies, earning multiple degrees from Michigan State University. After receiving his Ph.D. in materials science, he joined Oak Ridge National Laboratory in 1967 and retired in 2003. His accomplishments include significant contributions to the fundamental understanding of plastic deformation, radiation damage, and high temperature flow and fracture. His pioneering achievements substantially increased the understanding of both intermetallic materials and hexagonal close-packed metals and alloys. Yoo received the Humboldt Research Award for senior U.S. scientists and the Mathewson Gold Medal in 2002. After retirement, he finally satisfied his desire to teach by joining the faculty at KAIST in Daejon, South Korea, and later received an appointment to Seoul National University in 2005.

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STRESS RELIEF

COFFEE CUP TAKES ON WHOLE NEW MEANING

3DomFuel, Fargo, N.D., created specialty 3D-printing filaments by adding value to waste byproducts. Buzzed is the first beer filament, made using byproducts from the brewing process. The outcome creates visible grain fragments and natural color gradients on the finished 3D-printed products.

There is also a filament made partially with coffee waste, called Wound Up. It has a distinct coffee color, and even smells like coffee while printing. The filament generates products with a rich brown color and a noticeable natural grain. Using Wound Up, c2renew, also in Fargo, created a 3D-printed coffee mug, so people can literally drink coffee out of a "coffee" cup.

Finally, 3DomFuel released a hemp filament called Entwined, which uses no dyes, allowing it to maintain a natural brown hue. It is almost iridescent in its ability to showcase different shades and densities within the same printed object. *3dfuel.com.*

Wound Up, a 3D-printing filament made partially from coffee waste, was used to 3D print this coffee cup.

COIN TOSS COULD CURE POLITICAL UNCERTAINTY

Etched likeness of Democratic candidate Hillary Clinton facing left and Republican candidate Donald Trump facing right. Courtesy of Business Wire.

At Long-Stanton Manufacturing Co., West Chester, Ohio, the similarity of the presidential race of 1860 and 2016 lies not in the issues but in the name of the company's founder, John Stanton. Records show that before Stanton started Long-Stanton Manufacturing in 1862, he owned a company in Cincinnati that provided the illustrations, made the stamping die, and minted many of the campaign coins of the 1860 presidential candidates. The coins contained the etched, illustrated likeness of each candidate and were handed out to voters asking for their support.

Today, the company honors this legacy by minting an "Indecision 2016" campaign coin. One side features an illustrated likeness of Republican nominee Donald Trump and the other features Democratic challenger Hillary Clinton. But don't take this coin into the voting booth—it could be distracting to those who have already made up their mind, or they may ask to borrow it. *longstanton.com.*

3D PRINTING OVERCOMES HAIRY CHALLENGE

Researchers in Massachusetts Institute of Technology's Media Lab, Cambridge, found a way to bypass a major design step in 3D printing, to quickly and efficiently model and print thousands of hairlike structures. Instead of using conventional computer-aided design (CAD) software to draw thousands of individual hairs on a computer—a step that takes hours to compute—the team built a new software platform called cilllia that lets users define the angle, thickness, density, and height of thousands of hairs, in just a few minutes.

Using the new software, researchers designed arrays of hairlike structures with a resolution of 50 µm. Playing with various dimensions, they designed and then printed arrays ranging from coarse bristles to fine fur, onto both flat and curved surfaces, using a conventional 3D printer. Could the technology be used to print wigs and hair extensions? Possibly, say researchers. But that is not their end goal. Instead, they are seeing how 3D-printed hair could perform useful tasks such as sensing, adhesion, and actuation. *news.mit.edu.*

MIT researchers attached 3D-printed hairs to a ring.


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3D PRINTSHOP

BAMBOO BOOSTS SUSTAINABILITY

Researchers at Oak Ridge National Laboratory, Tenn., are using bamboo fiber in 3D-printing experiments to determine whether bio-based feedstock materials are feasible in additive manufacturing. Chopped bamboo fibers were added to a bio-polymer resin to create bamboo-based pellets, resulting in a more sustainable material that can be used for manufacturing molds, prototypes, appliances, and furniture. In one experiment, a table that contains 10% bamboo fiber composite was 3D-printed. “We are investigating the use of different types of cellulose fibers to develop feedstock materials with better mechanical performance that can increase the number of available composites and opportunities for sustainable practices,” explains Soydan Ozcan, R&D scientist. *For more information: Soydan Ozcan, 865.241.2158, ozcans@ornl.gov, www.ornl.gov.*

A 3D-printed table was manufactured using 10% bamboo fiber, an initial step toward sustainable practices using bio-derived materials.

Alcoa opened a state-of-the-art, 3D-printing metal powder production facility located at the Alcoa Technology Center near Pittsburgh. Courtesy of Business Wire.

ALCOA OPENS METAL POWDER FACILITY

Alcoa Inc., Pittsburgh, recently opened a state-of-the-art, 3D-printing metal powder production facility. Located at the Alcoa Technology Center near Pittsburgh, the company will produce titanium, nickel, and aluminum powders optimized for 3D-printed aerospace parts. Alcoa has also invested in a range of technologies to further develop additive processes, product design, and qualification. The facility will form part of Arconic following separation from Alcoa’s traditional commodity business in the second half of 2016. The plant is part of a $60 million investment in advanced 3D-printing materials and processes that builds on the company’s capabilities in California, Georgia, Michigan, Pennsylvania, and Texas. In addition to producing powders, Alcoa is focused on advancing a range of additive techniques, including its Ampliforge process that combines additive and traditional manufacturing. With this new technique, a nearly complete 3D part is printed then finished with another process such as forging. *alcoa.com.*

PARTNERSHIP TO DEVELOP COMPUTING TOOLS

A new collaboration between Ansys Inc., Pittsburgh, and the University of Pittsburgh (Pitt) aims to solve some of the industry’s toughest additive manufacturing (AM) problems. Printing metal is particularly challenging because it involves lasers, which optimize density but can also melt metal in unexpected ways. In addition, rapid heating and cooling creates stresses that can deform the end product. Ansys and Pitt are working together to simulate those deformations before printing to ensure products have the desired shape and perform as expected. As part of the collaboration, the university is opening a 1200-sq-ft Ansys Additive Manufacturing Research Laboratory in the Swanson School of Engineering. The new facility will also support faculty and students conducting collaborative research with Ansys and other industry partners, including those in the biomedical, aerospace, and defense industries. Lab workers will have access to a variety of Ansys software, enabling them to explore, simulate, and analyze solutions for stress and fatigue on critical components designed for the automotive, aerospace, and medical device industries. *ansys.com.*

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Reverse Engineering: A Material Perspective	10/10-12	ASM World Headquarters
Heat Treating for the Non-Heat Treater	10/10-12	ASM World Headquarters
Metallurgy for the Non-Metallurgist™	10/10-13	ASM World Headquarters
Vacuum Heat Treating	10/13-14	ASM World Headquarters
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Scanning Electron Microscopy	10/17-20	IMR Test Labs, NY
Metallurgy of Steel for the Non-Metallurgist	10/31-11/2	ASM World Headquarters
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