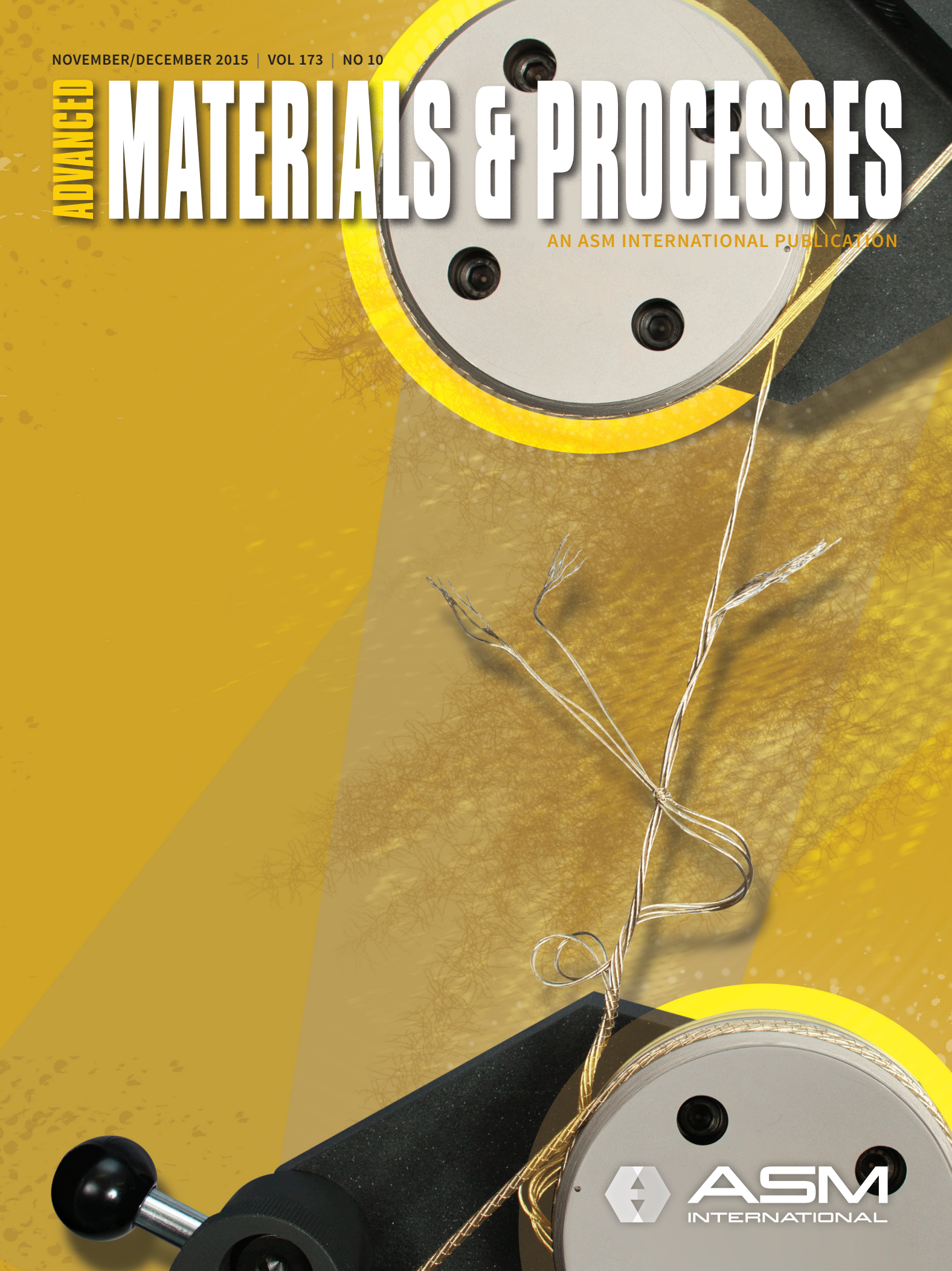
NOVEMBER/DECEMBER 2015 | VOL 173 | NO 10

ADVANCED MATERIALS & PROCESSES

AN ASM INTERNATIONAL PUBLICATION



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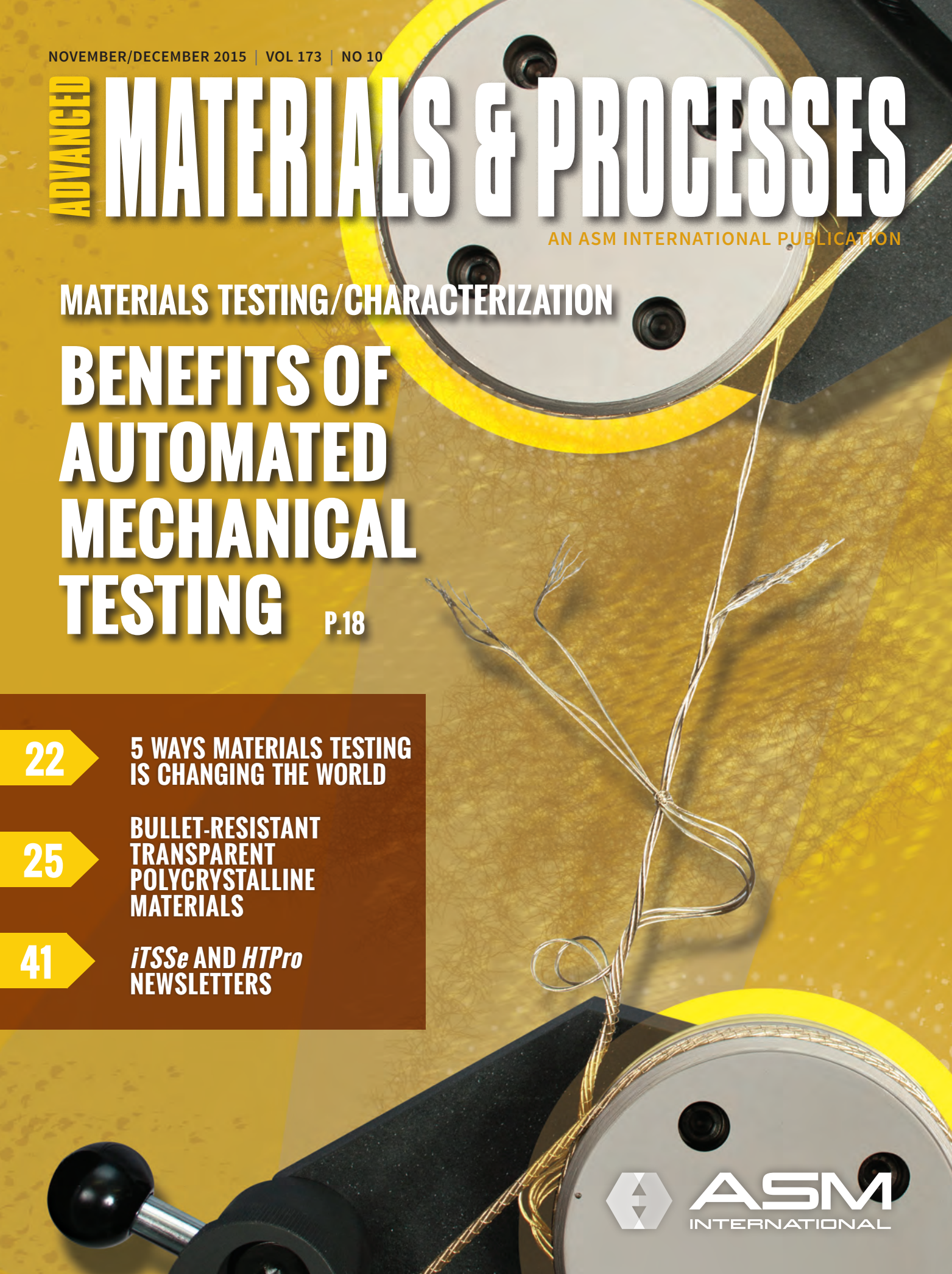
MATERIALS TESTING/CHARACTERIZATION

BENEFITS OF AUTOMATED MECHANICAL TESTING

P.18



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CALLING ALL AUTHORS

ASM INTERNATIONAL

Go for the green.

Editors are actively looking for contributors of articles, case studies, and reference information for the following handbooks:

ASM Handbook*, Volume 10: *Materials Characterization

Editors: George Vander Voort and Joseph Michael

Editors are seeking contributors on all aspects of SEM and TEM imaging and analytical techniques, electron-probe microanalysis, atom probe, Auger electron spectroscopy, XPS and more. Updated content and new applications examples are also sought for other surface analysis methods, thermal analysis (DSC, TGA, DMA, TMA), X-ray spectroscopy, and X-ray and neutron diffraction.

ASM Handbook*, Volume 17: *Nondestructive Evaluation of Materials

Editors: Aquil Ahmad, Leonard Bond, and Claudia Kropas-Hughes

ASM Handbook, Volume 17 is being updated significantly with expanded coverage on signal processing, general material-state awareness (not just cracks), in-line process control, automation, and all levels of modeling and reliability analysis. New coverage, examples, and case studies are sought for all types of NDE methods, metallic and nonmetallic materials, and product-form applications.

ASM Handbook*, Volume 18: *Friction, Lubrication, and Wear Technology

Editors: George Totten and Jeffrey Hawk

Editors are seeking contributors for updated new and expanded coverage on: solid friction; lubricants and lubrication; wear mechanics; wear testing and characterization; wear monitoring and diagnosis; friction and wear of components; friction and wear of materials; surface treatments and coatings for friction and wear control.

Wondering how to contribute?

EMAIL: handbooks@asminternational.org

TAKE THE INTEREST SURVEY: www.research.net/s/asmhandbook

On The Cover:

Tensile test using cable snubbing grips to hold steel cord, a common reinforcement material in the automotive industry. Courtesy of Instron, Norwood, Mass. instron.com.

ADVANCED MATERIALS & PROCESSES
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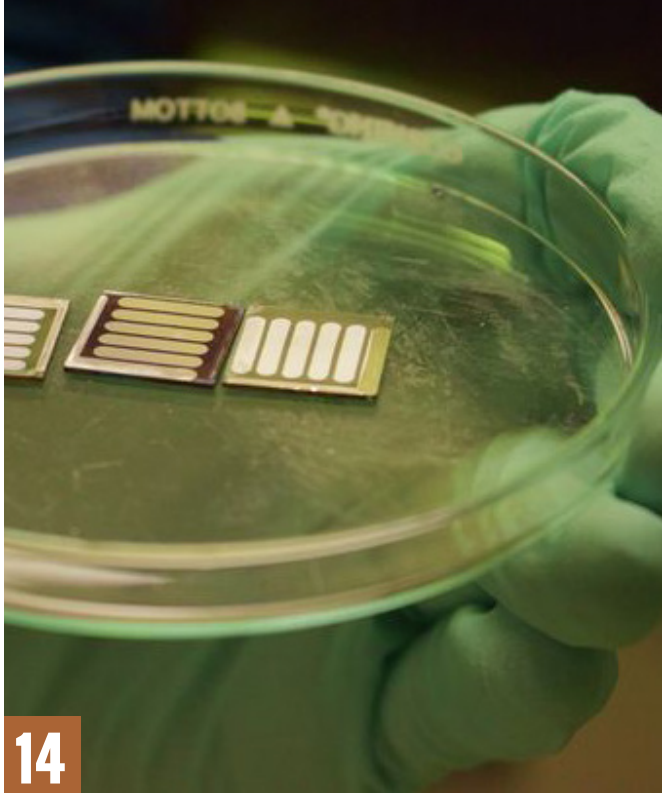
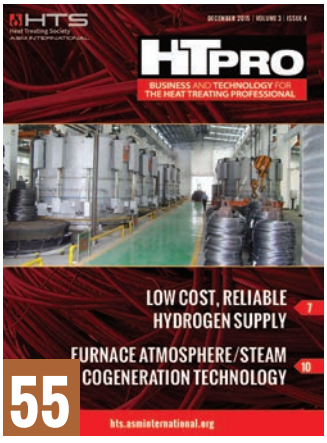
FEATURES





TRENDS

INDUSTRY NEWS

DEPARTMENTS

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FALL CONFERENCES ISSUE TALL ORDERS FOR MATERIALS ENGINEERS

Welcome to our final edition for 2015! Has the year flown by at supersonic speed or is it just me? We hope you enjoy this special double issue covering advanced testing technologies and featuring our heat treating and thermal spray quarterly supplements. We also hope that many of you had a chance to enjoy at least part of our fall conference circuit—including MS&T15, Heat Treat, and ISTFA. Look for articles in future issues of *AM&P* reporting on technology advancements presented at these meetings. For now, I'd like to share some of the most interesting tidbits and takeaways.

At MS&T, the "big picture" lectures were simply outstanding, especially the plenary session and Alpha Sigma Mu lecture. The plenary featured three speakers who talked about vastly different subjects. NASA's Sylvia Johnson discussed the urgent need for advanced materials in space applications such as Mars missions. Because these materials will face extreme pressures, temperatures, mechanical loads, and constant radiation, they must be rugged and reliable, in addition to being lightweight, flexible, and above all, affordable. A tall order! Johnson also mentioned polymer matrix composites, computationally designed materials, and the need for robust thermal protection systems as key initiatives. Harry Bhadeshia of the University of Cambridge then presented a fascinating talk on martensitic transformations in steels to a packed audience with lively questions.

Rounding out the plenary was Vincent Russo, FASM, who recently retired from Wright-Patterson AFB. He discussed the qualities that make a "splendid leader," pointing out that leadership can be learned, but it takes a lot of effort and self-awareness. He also made a distinction between a leader's IQ or intellect and their EQ or emotional intelligence. Recognizing that women in general are socialized to be more emotionally in tune than their male counterparts, he offered these words, "Women have an eight-lane superhighway for processing emotions, while men have a small country road." Despite these differences, both women and men can become more effective leaders by developing their "essence," which involves self-awareness, self-management, self-motivation, interpersonal expertise, and relationship building—another tall order!

Perhaps the most fascinating talk was the Alpha Sigma Mu lecture by Siegfried Hecker on "Metallurgy and Nuclear Diplomacy." During the past 40+ years, Hecker has visited nuclear facilities in some of the world's most volatile places, logging more than 50 trips to Russia, six to North Korea, and several others to China, India, and Pakistan, in addition to keeping close tabs on Iran. One of the greatest challenges he discussed was the collapse of the Soviet Union. Before the collapse, Soviet nuclear materials were kept safe by "guns, guards, and Gulags." After, new worries included loose nukes (40,000 weapons), loose nuclear materials (1,400,000 kg of fissile materials), loose workers (one million people employed by the nuclear complex), and loose nuclear exports. Hecker also discussed China's plan to open 80 nuclear energy reactors by 2020, North Korea's "small arsenal" of nuclear weapons, Iran's foray into nuclear power, and the powder keg known as India-Pakistan relations. He concluded with a slide on the double-edged sword of nuclear technology, with peace and prosperity on one side (through clean energy) and war and disaster on the other—a daunting balancing act without a simple solution.

In other news, it has now been a full year with *AM&P's* fresh design and feedback is encouraging. In 2016, look for new departments covering engineering primers and additive manufacturing. In the meantime, enjoy the holidays!

F. Richards

frances.richards@asminternational.org

MARKET SPOTLIGHT

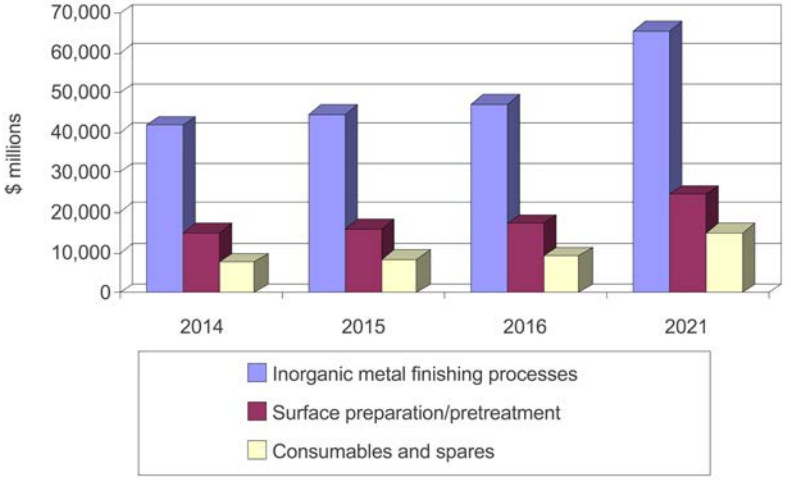
METAL FINISHING MARKET CONTINUES GROWTH

According to a new report from BCC Research, Wellesley, Mass., the world market for equipment, consumables, and spares for inorganic metal finishing processes was valued at $64.5 billion in 2014 and is expected to reach $68.9 billion in 2015. The market is further expected to increase at a compound annual growth rate of 7.4% from $73.6 billion in 2016 to $105 billion in 2021. Metal finishing is defined as the deposition of a coating, which may be metallic or nonmetallic, onto a metallic substrate. The market comprises surface preparation/pretreatment, inorganic metal finishing, and consumables and spares.

Worldwide activity in the energy production, transportation, and storage sectors is a key driver of increased sales for major companies involved in this market. Major projects related to the production and transportation of energy, including traditional and alternative power generation facilities, oil and gas drilling, pipelines, infrastructure construction, and shipbuilding are under way in all areas of the world, with a specific focus on emerging markets including the Middle East, Russia, Latin America, Asia-Pacific, and Eastern Europe.

Global Markets and Technologies for Inorganic Metal Finishing Processes examines global and regional markets for various types of inorganic metal finishing technologies. Market dynamics, growth drivers, inhibitors, opportunities, and forecasts of trends and revenue through 2021 are provided. *For more information, visit bccresearch.com.*

Global market for equipment, consumables, and spares for inorganic metal finishing processes by type, 2014-2021 ($ millions)



Source: BCC Research

FEEDBACK

RESPECT THE TECHS

Thank you for the recent news about NASA's progress on welding the Orion crew module at the Michoud Assembly Facility (*AM&P eNews,* Sept. 16). In the article, the word *engineers* is used in two places where *technicians* is more accurate. The first sentence says that "engineers have welded together the first two segments of the Orion crew module," but in truth the welding was done by highly skilled and certified technicians, as the last paragraph states.

In the engineering world, we *engineers* sometimes get credit for things we did not do at the expense of those who did, the *technicians*. Semantics for sure, yet there is a bias—ever for the engineer—with the lowly technician an afterthought. In America today, we tend to favor education and book smarts. Our schools have abandoned the old idea of trade school, where a technician's natural gifts are nurtured as a hands-on trade.

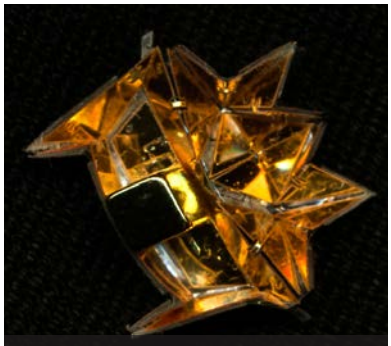
There is little cultural respect for the plumber, electrician, or welder although they are the craftsmen, artisans, and doers of what needs to be done. I hope ASM will consider this and begin to breathe respect into your readers' minds that to be a technician is to be an artisan, a vital member of the engineering team, not optional or easily interchanged—valid in their own right.

The engineer-technician skillset represents the knowing-doing capability. If wisdom is our guide, we must honor our intelligent, hands-on doers as much as our intelligent, conceptual knowers. In the Venn diagram where a technician's smarts overlap with an engineer's smarts lies a sweet spot—where getting the job done, and done right, makes the world a better place.

Dan Keenan

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

OMG!
OUTRAGEOUS MATERIALS GOODNESS



Centimeter-long origami robot. Courtesy of Christine Daniloff/MIT.

Matilda Ceesay, left, drapes muslin on an antimalarial garment worn by Sandy Mattei.

Stainless steel guitar picks feature a diamond hard coating.

MINIATURE ORIGAMI ROBOT MOVES MAGNETICALLY

Researchers at Massachusetts Institute of Technology, Cambridge, developed a printable origami robot that folds itself up from a flat sheet of plastic when heated and measures about a centimeter in length. Weighing only a third of a gram, the robot can swim, climb an incline, traverse rough terrain, and carry a load twice its weight. Other than the self-folding plastic sheet, the robot's only component is a permanent magnet on its back. Movement is controlled by external magnetic fields, which cause the body to flex. Friction between the robot's front feet and the ground is great enough that the front feet stay fixed while the back feet lift. Then, another sequence of magnetic fields causes the robot's body to twist slightly, breaking the front feet's adhesion and propelling the robot forward. *web.mit.edu.*

T-SHIRTS BATTLE BACTERIA

Juan Hinestroza and his students live in a cotton-soft nanoworld, where they create clothing that kills bacteria, conducts electricity, wards off malaria, captures harmful gas, and weaves transistors into shirts and dresses. "Cotton is one of the most fascinating—and misunderstood materials," says Hinestroza, associate professor of fiber science, who directs the Textiles Nanotechnology Laboratory at Cornell University, Ithaca, N.Y. Taking advantage of cotton's irregular topography, conformal coatings of gold nanoparticles along with semiconductive and conductive polymers were added to the cotton fibers. The technology may be embedded into shirts to measure heart rate or analyze sweat, sewn into pillows to monitor brain signals, or applied to interactive textiles with heating and cooling capabilities. Synthesizing nanoparticles and attaching them to cotton not only creates color on fiber surfaces without the use of dyes, but the new surfaces can efficiently kill 99.9% of bacteria. *For more information: Juan Hinestroza, 607.255.7600, jh433@cornell.edu, www.cornell.edu.*

PICKIN' UP GOOD VIBRATIONS WITH ROCK HARD GUITAR PICKS

Genvac Aerospace Inc., Cleveland, launched a crowdfunding campaign introducing Rock Hard Metal, a line of diamond-enhanced guitar picks. The picks are coated under high vacuum using the same techniques used to coat military grade night vision optics for the armed services.

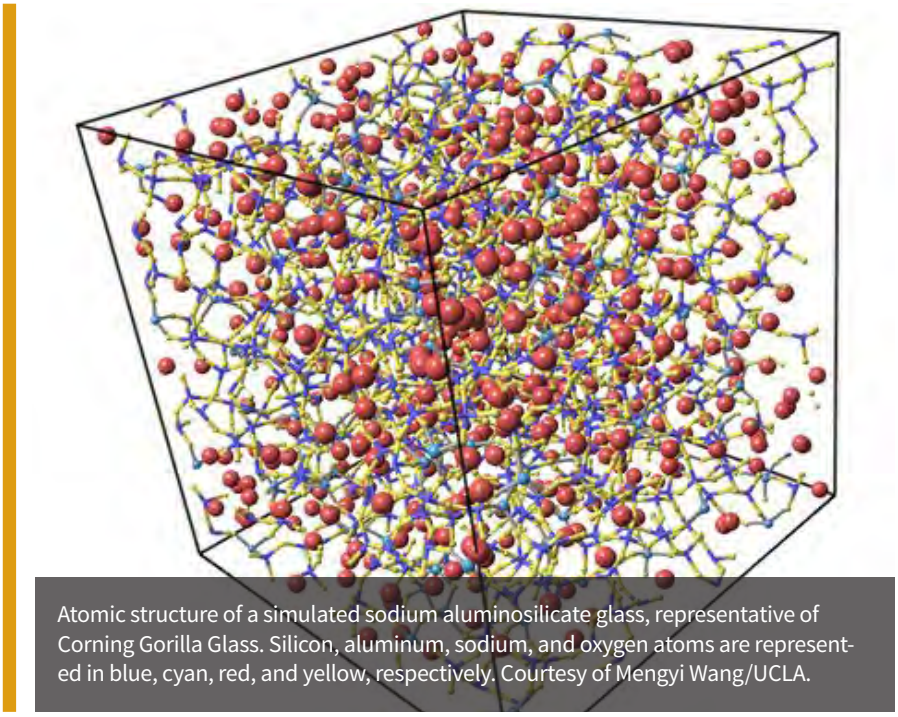
"Creating this pick was somewhat of an accident," says inventor Gerald Mearini. "I just wanted a high quality metal pick that I could use when I play my 1985 Explorer. I had my technicians make me a few metal picks, and I decided to put a layer of diamond-like carbon on it. When I tested the pick, I realized that this is the best guitar pick I have ever used."

The surface of the picks creates the lowest coefficient of friction possible, meaning it will not break the guitar strings. Wear that is typically experienced from a metal pick on metal strings will not occur.

"This pick delivers an aggressive predatory sound, and subtly generates new spectral harmonics. It sounds like you are hitting the strings with a diamond sword," Mearini explains. *indiegogo.com/projects/rock-hard-metal/x/9563023.*

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

METALS | POLYMERS | CERAMICS



Atomic structure of a simulated sodium aluminosilicate glass, representative of Corning Gorilla Glass. Silicon, aluminum, sodium, and oxygen atoms are represented in blue, cyan, red, and yellow, respectively. Courtesy of Mengyi Wang/UCLA.

GLASS FLOW DISCOVERY ENABLES LARGER SMART SCREENS

In complex, high-tech kinds of glass, like Corning Gorilla Glass, susceptibility to room-temperature deformations has been known to exist for years. Now, researchers from the University of California, Los Angeles discovered why such flowing happens and how fast. Using molecular dynamics simulations of different glasses, researchers show that high-performance glass can exhibit some long-term deformations proportional to how large the glass is.

"We found that this long-term relaxation is due to the coexistence of competitive chemical elements of different sizes in the atomic network of the glass, which is known as the mixed-alkali effect," says UCLA professor Mathieu Bauchy. The key is the use of two alkali ions, sodium and potassium, in the high-performance glass formation process. Sodium and potassium ions are typically added into the composition of glasses as their presence lowers the temperature needed to form glass, thereby saving energy. However, this process and combination of ions with different atomic sizes makes glass susceptible to long-term deformations. "The next step is to prescribe optimal glass compositions that feature little, if any, relaxation, in order to enable design of large yet stable screens," says Bauchy. *For more information: Mathieu Bauchy, 310.825.9991, bauchy@ucla.edu, www.ucla.edu.*

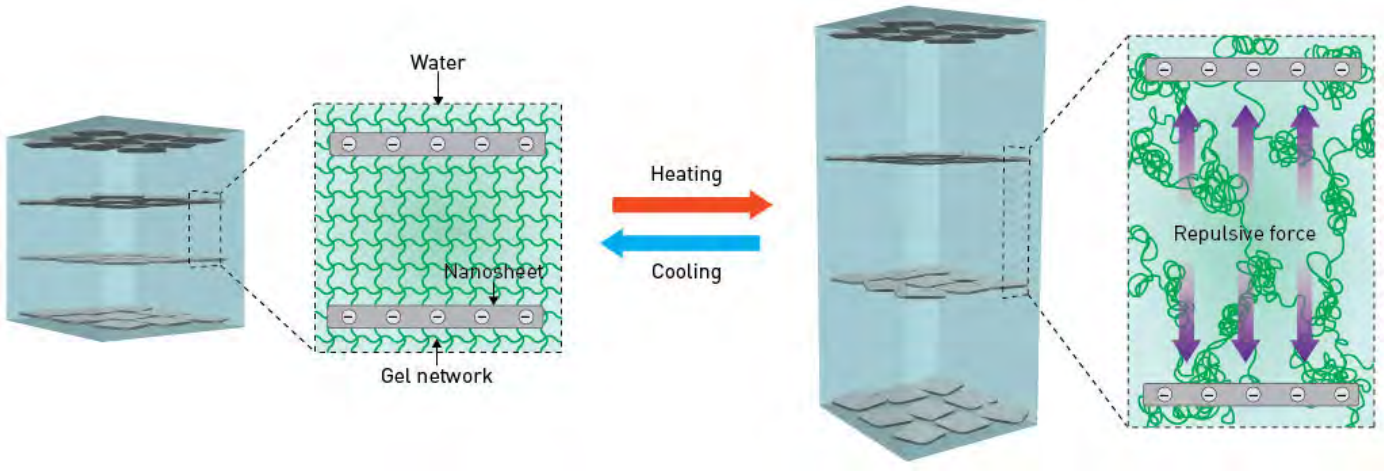
TEMPERATURE MAKES PLASTIC MUSCLES WALK

Hydrogels are translucent, squishy polymers that resemble tissues by holding large amounts of water within an interlocked molecular network. A team led by researchers at RIKEN, Japan, developed a way to cause these biocompatible materials to act like artificial muscles that rapidly expand and contract when heated and cooled. Yasuhiro Ishida and colleagues designed a hydrogel whose properties differ considerably from those of other hydrogels—their thermoresponsive material can lengthen in one direction and contract in another without absorbing or releasing water, allowing this muscle-like device to operate rapidly in an open-air environment. The secret to this behavior lies in tiny nanosheets embedded in the hydrogel that harness electrostatic

BRIEFS

Royal DSM, the Netherlands, highlighted developments in fiber visualization and low-profile characteristics of its Dyneema Purity fiber for use in the design of medical devices at the 7th International UHMWPE Meeting in October in Philadelphia. Medical-grade UHMWPE fibers enable multiple suture designs, assisting surgeons in differentiating sutures when there are multiple styles used during a procedure. *dsm.com.*

Japanese auto supplier **Yorozu Corp.** will build a $100 million metal stamping facility in Jasper, Ala., creating 300 jobs. The facility will provide suspensions and other components to several auto assembly plants. Construction is expected to start by January 2016, with operations beginning in July 2017. *www.yorozu-corp.co.jp/en.*



Researchers created a muscle-like hydrogel by trapping face-stacked inorganic nanosheets within a polymer network. The repulsive force between the charged nanosheets becomes greater with increasing temperature, causing the material to elongate in one direction.

repulsion to make the hydrogel perform like a coiled spring.

Researchers exploited their hydrogel's large and rapid thermally induced shape changes by designing an actuator that walks when exposed to alternating temperature cycles. Their L-shaped gel contains two "feet" in contact with a horizontal, underwater surface. On heating, the back foot elongates, propelling the gel forward. A quick plunge in temperature then draws the feet back into position for another kick forward. The team is currently working on improving material properties with a view to achieving their ultimate goal—a new generation of hydrogel-based artificial organs and muscles. *For more information: Yasuhiro Ishida, 81.048.462.1111 ext. 6351, y-ishida@riken.jp, www.riken.jp/en.*

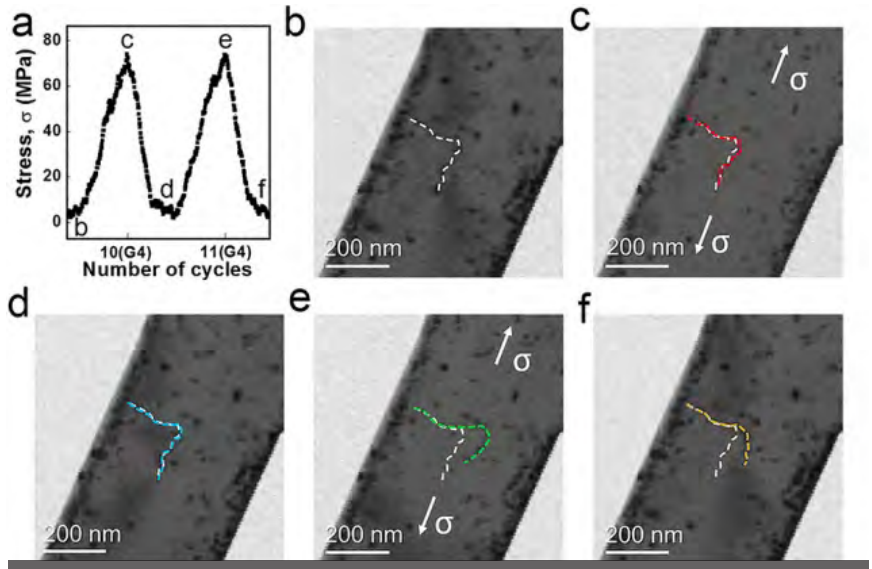
Each of the National Ignition Facility's (NIF) 192 beamlines contains two large amplifier sections. The amplifiers are designed to efficiently provide 99.99% of NIF's power and energy. Laser amplifier glass is doped with rare earth ions, which prevent external heat and noise from affecting the laser transitions.

RARE EARTHS HELP PROBE PARTICLE PHYSICS

In recent work by Lawrence Livermore National Laboratory, Calif., scientist Michael Hohensee and colleagues discovered that the properties that make rare earth elements so useful also make them great probes of physics beyond the Standard Model of particle physics—a theory concerning the electromagnetic, weak, and strong nuclear interactions, as well as classifying all the known subatomic particles.

According to Hohensee, rare earths make great magnets in part because their valence electrons have more orbital angular momentum than other elements, and because other electrons form a shield around the valence electrons. This shield also helps make them good laser media, as it prevents external heat and noise from affecting the laser transitions, maintaining the rare earths' unique properties when they are mixed (or doped) into a piece of glass or crystal. "Thanks to both these properties, the electronic states of rare earths doped in a crystal make possible an electronic equivalent of the Michelson-Morley experiment that would be more sensitive than any other yet performed, helping to validate or rule out unified theories of gravity and particle physics," says Hohensee. *llnl.gov.*

TESTING | CHARACTERIZATION



Abrupt depinning and destabilization of a line defect due to repeated cyclic loading; (a) the evolution of nominal tensile stress during two loading and unloading cycles; (b) to (f) are still frames from a video that correspond to the stress state marked in (a), where white dashed lines indicate the original defect location, and colored dashed lines represent the altered locations from cyclic loading. Direction of tensile stretching is indicated by arrows in (c) and (e).

ELIMINATING METAL DEFECTS WITH CYCLIC LOADING

Researchers from Massachusetts Institute of Technology, Carnegie Mellon University, Xi'an Jiaotong University, and elsewhere have found that under certain conditions, repeated stretching of nanoscale metal pieces can actually strengthen a material by eliminating defects in its crystalline structure. The new process is referred to as *cyclic healing.*

"While metal fatigue has been studied at larger volumes of materials, there has been little understanding of it at the atomic scale," says Ming Dao of MIT. To remedy that, the team studied metal fatigue using a transmission electron microscope to observe atomic-scale changes in defects. The primary subject of the study was small, single-crystal pieces of aluminum. Researchers aimed to reduce or eliminate microstructural imperfections—such as defects in the crystal lattice known as dislocations—through repeated, small-amplitude, cyclic deformation, rather than heat-based annealing.

Repeated small displacements of metal tend to dislodge dislocations from their pinned locations inside the crystal. The small crystal has a high surface-to-volume ratio, so dislocations are attracted to the surface, and the energy stored in the metal due to the presence of the defects could be reduced.

By "shaking" the dislocations gently and repeatedly, researchers were able to get the material relatively free of them, increasing the material's strength significantly. This phenomenon is counterintuitive, because it is the opposite of what one sees in much larger metal crystals, where repeated stretching often increases defect density and causes cracks to form. Researchers believe the process could help in the production of strong parts for nanotechnology applications, such as mechanical nanosensors, nanoelectromechanical systems, and nanorobots. *web.mit.edu, cme.edu.*

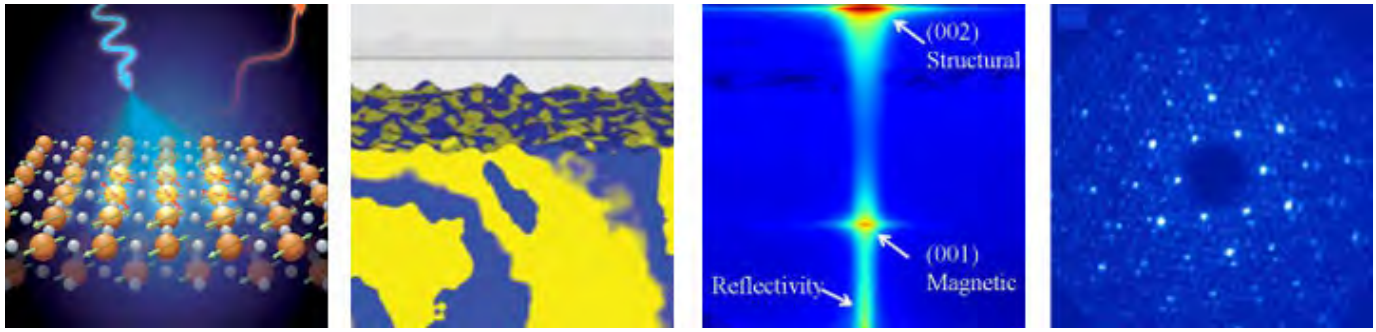
BROOKHAVEN HOSTS NEW CENTER FOR COMPUTATIONAL MATERIALS SCIENCES

The Department of Energy's (DOE) Brookhaven Lab, Upton, N.Y., will host a new center devoted to developing computational tools to advance materials science. With $12 million in funding from DOE's Office of Basic Energy Sciences over the next four years, this center will be led by Gabriel Kotliar of Rutgers University and Brookhaven,

BRIEFS

Bruker Corp., Billerica, Mass., will acquire **Jordan Valley Semiconductors Ltd.,** Israel, by the end of 2015. Jordan Valley's in-line x-ray metrology products complement Bruker's portfolio of analytical x-ray technologies, say company sources. *bruker.com.*

Boise State University, Idaho, will receive a $25 million gift from the **Micron Foundation.** It is the largest gift in the university's history, and will fund the establishment of the new Micron Center for Materials Research, operated by the College of Engineering. *go.boisestate.edu.*



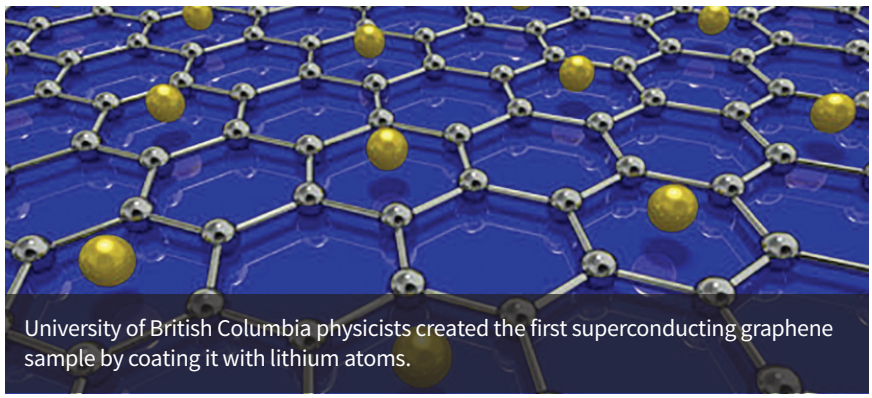
A new initiative aims to help scientists characterize and catalog material properties and develop computational tools to assess and predict them.

with additional partners from the University of Tennessee and Ames Laboratory, and make use of computing capabilities at three DOE Office of Science User Facilities—the National Energy Research Scientific Computing Center at DOE's Lawrence Berkeley National Laboratory, and the DOE Leadership Computing Facilities at Argonne and Oak Ridge National Laboratories.

The Brookhaven Center for Computational Design of Functional Strongly Correlated Materials & Theoretical Spectroscopy is one of three new efforts funded by DOE for computational materials science. The others are the Midwest Integrated Center for Computational Materials, based at Argonne, and the Computational Synthesis of Materials Software Project with Validation on Layered Low Dimensional Functional Materials and Ultra-Fast X-Ray Laser Experiments, led by University of Southern California with partners at Berkeley Lab, SLAC, and other institutions.

The mission of the Brookhaven/Rutgers team is to develop next-generation methods and software to accurately describe electronic properties in complex strongly correlated materials—such as high-temperature superconductors and high-performance thermoelectrics—along with a database to help scientists predict targeted properties with energy-related applications. *bnl.gov.*

EMERGING TECHNOLOGY



University of British Columbia physicists created the first superconducting graphene sample by coating it with lithium atoms.

SUPERCONDUCTING GRAPHENE DEBUTS IN CANADA

Physicists at the University of British Columbia (UBC), Canada, report creating the first-ever superconducting graphene sample by coating it with lithium atoms. Although superconductivity has already been observed in intercalated bulk graphite, inducing superconductivity in single-layer graphene has eluded scientists until now.

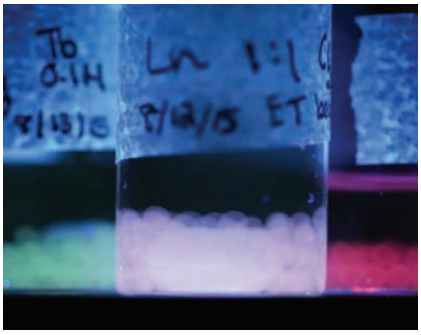
"Decorating monolayer graphene with a layer of lithium atoms enhances the graphene's electron-phonon coupling to the point where superconductivity can be stabilized," explains researcher Bart Ludbrook.

Given the massive scientific and technological interest, the ability to induce superconductivity in single-layer graphene promises to have significant cross-disciplinary impacts. According to financial reports, the global market for graphene reached $9 million in 2014 with most sales in the semiconductor, electronics, battery, energy, and composites industries. The researchers, including colleagues at the Max Planck Institute for Solid State Research, Germany, through the joint Max-Planck-UBC Centre for Quantum Materials, prepared the Li-decorated graphene in ultra-high vacuum conditions and at ultra-low temperatures of -449°F (-267°C) to achieve this breakthrough. *www.ubc.ca.*

METALLIC GELS HOLD PROMISE FOR FAILURE PREVENTION

Researchers at Massachusetts Institute of Technology, Cambridge, developed a new family of materials that can emit light of precisely controlled colors and whose output can be tuned to respond to a wide variety of external conditions. The materials could find applications in detecting chemical and biological compounds, or mechanical and thermal conditions.

These light-emitting lanthanide metallogels can be chemically tuned to emit light in response to chemical, mechanical, or thermal stimuli, potentially providing a visible output to indicate the presence of a particular substance or condition. Combining a metal from the lanthanide group with polyethylene glycol results in a material that produces tunable, multicolored light emissions. These emissions can then reflect very subtle changes in the environment, providing a color-coded output that reveals details of those conditions, says assistant professor of materials science and engineering Niels Holten-Andersen. The materials can also detect mechanical changes, and could be used to detect stresses in mechanical systems. For example, it's difficult to measure forces in fluids, Holten-Andersen says, but this approach could provide a sensitive means of doing so. The material can be made in a gel, thin film, or coating that could be applied to structures, potentially indicating a developing failure before it occurs. *mit.edu.*



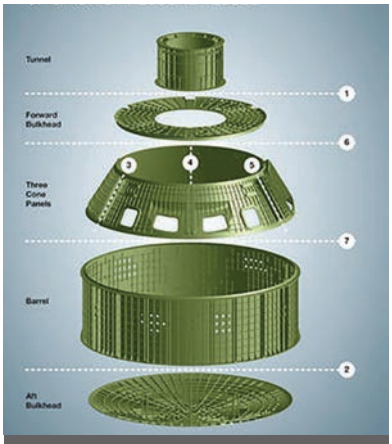
Luminescent materials produced by the MIT team shown under ultraviolet light, emitting different colors of light that can be modified by their environmental conditions. Courtesy of Tara Fadenrecht.

BRIEF

The **U.S. Department of Defense** awarded **FlexTech Alliance** a cooperative agreement to establish and manage a **Manufacturing Innovation Institute for Flexible Hybrid Electronics** based in San Jose, Calif. The Alliance is comprised of 96 companies, 11 laboratories and nonprofits, 42 universities, and 14 state and regional organizations. The $75 million award, distributed over a five-year period, will be matched by more than $96 million in cost sharing from nonfederal sources, including the City of San Jose. *flextech.org.*

FlexTech Alliance
for Flexible, Hybrid & Printed Electronics

PROCESS TECHNOLOGY



Orion's primary structure and the order in which it will be welded together. Courtesy of NASA.

ORION SPACECRAFT COMING TOGETHER

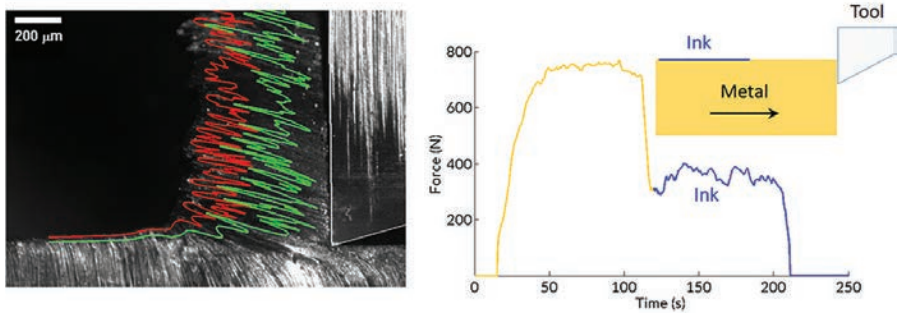
Technicians at NASA's Michoud Assembly Facility in New Orleans welded together the first two segments of the Orion crew module that will fly atop NASA's Space Launch System (SLS) rocket on a mission beyond the moon. The primary structure of Orion's crew module is made of seven large aluminum pieces that must be welded together. The first weld connects the tunnel to the forward bulkhead, which houses critical systems such as parachutes that deploy during reentry. The tunnel will allow workers to move between the crew module and other spacecraft.

To prepare for welding, technicians cleaned the segments, coated them with a protective chemical, and primed them. Next, each element was outfitted with strain gauges and wiring to monitor the metal during fabrication. Prior to beginning work on the pieces destined for space, technicians practiced their process, refined their techniques, and ensured proper tooling configurations by welding together a pathfinder, a full-scale version of the current spacecraft design. NASA's prime contractor for the spacecraft, Lockheed Martin, is working on the crew module at Michoud. The number of welds for the crew module was reduced by more than half since the first test version of Orion's primary structure was constructed and flown on the Exploration Flight Test-1 last December. The Exploration Mission-1 structure will include just seven main welds, reducing weight. *nasa.gov/orion.*

CONTROLLING SINUOUS FLOW SAVES ENERGY

Discovery of a previously unknown type of metal deformation called sinuous flow could lead to more efficient machining by reducing the force and energy required to process metals, say researchers at Purdue University, West Lafayette, Ind. The team discovered the phenomenon by using high-speed microphotography and analysis to study what happens while cutting ductile metals. They found that the metal is deformed into folds while it is being cut—contrary to assumptions that metals are sheared uniformly—and also that sinuous flow can be controlled by suppressing the folding behavior.

Results show that cutting force can be reduced by 50% simply by painting the metal with a standard marking ink. Because the painted layer is found to suppress sinuous flow, not only can energy consumption be reduced by 50%, but also machining can be done faster and with improved surface quality, says Srinivasan Chandrasekar, professor of industrial engineering. In one set of experiments, only half of a sample was inked. When the cutting tool reached the inked portion, the amount of force dropped immediately by half. *purdue.edu.*



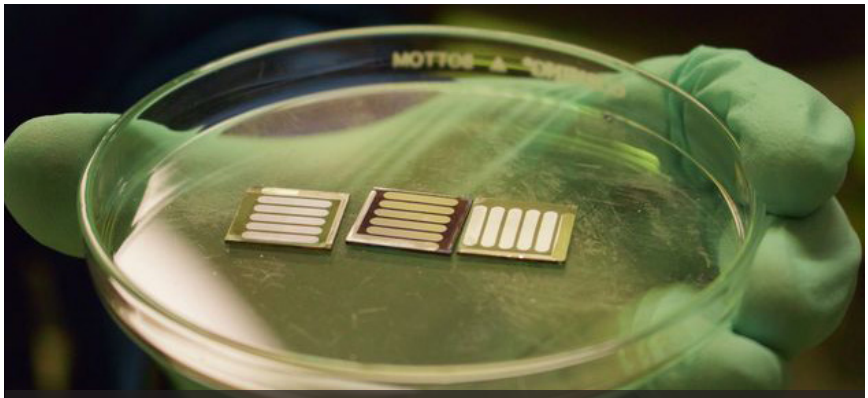
Sinuous flow, left, shows that metal is deformed into folds while it is being cut. New research, right, reveals that cutting force can be reduced 50% by painting metal with a standard marking ink. Courtesy of Purdue.

BRIEFS

H.C. Starck, Germany, acquired a minority stake in **Metasphere Technology,** Sweden. Metasphere developed a new technology for producing spherical metal powders for use in additive manufacturing and other fields. The companies will build a new production line in Lulea, Sweden. *hcstarck.com.*

United Technologies Corp., Hartford, Conn., will sell its Sikorsky Aircraft business to **Lockheed Martin Corp.,** Bethesda, Md., for $9 billion in cash. The transaction is projected to close by year-end or in the first quarter of 2016. *lockheedmartin.com.*

ENERGY TRENDS



Perovskite solar cells with metal oxide hole and electron transport layers. Courtesy of Tunde Akinloye/CNSI.

NEW TECHNIQUE STABILIZES PEROVSKITE SOLAR CELLS

University of California, Los Angeles Professor Yang Yang and his team report they have conquered the primary obstacle of perovskite by protecting it between two layers of metal oxide—a significant advance toward stabilizing perovskite solar cells. Their new cell construction extends the cell's effective life in air by more than 10 times, with only a marginal loss of efficiency in converting sunlight to electricity.

Yang says there are several factors that lead to quick deterioration in normally layered perovskite solar cells. The most significant is that the widely used top organic buffer layer has poor stability and cannot effectively protect the perovskite layer from moisture in the air, speeding cell degradation. The buffer layers are important to cell construction because electricity generated by the cell is extracted through them.

The team replaced those organic layers with metal oxide layers that sandwich the perovskite layer, protecting it from moisture. The difference is dramatic. The metal oxide cells lasted 60 days in open-air storage at room temperature, retaining 90% of their original solar conversion efficiency.

The next step is to make the metal oxide layers more condensed for better efficiency and to seal the solar cell for even longer life with no loss of efficiency. Yang expects that this process can be scaled up to production now that the main perovskite problem has been solved. *For more information: Yang Yang, 310.825.4052, yangy@ucla.edu, yylab.seas.ucla.edu.*

NANOPARTICLES IMPROVE ULTRATHIN CIGSe SOLAR CELLS

Helmholtz-Zentrum Berlin, Germany, researchers are inquiring how to use nanoparticle arrangements to improve solar cells and other opto-electronic devices. CIGSe solar cells have proven high efficiencies and are established thin film devices with active layers of a few micrometers thickness. But, because indium is a rare element, the active layer should be as thin as possible, reducing efficiency, as less light is absorbed. "It took me more than a year to be able to produce ultrathin layers of only 0.46 μm or 460 nm, which still reach reasonable efficiencies up to 11.1%," says Ph.D. student Guanchao Yin.

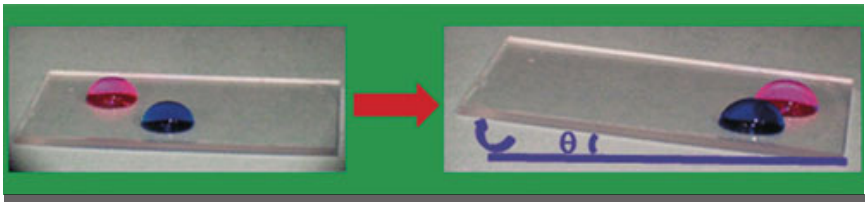
Colleagues in Amsterdam produced an array of SiO_2 nanoparticles directly on the molybdenum substrate, which corresponds to the back contact of the solar cell. On top of this structured substrate, Yin grew an ultrathin CIGSe layer, followed by all other layers and contacts needed for the solar cell. With this configuration, efficiency increased from 11.1% to 12.3%, and the short circuit current density of the ultrathin CIGSe cells increased by more than 2 mA/cm^2. With additional antireflective nanoparticles at the front, efficiencies grew to 13.1%.

Further studies indicate that the nanoarray of dielectric SiO_2 nanoparticles at the back side could also increase efficiency by reducing chances for charge carrier recombination. *For more information: Guanchao Yin, 030.8062.43721, guanchao.yin@helmholtz-berlin.de, www.helmholtz-berlin.de.*

BRIEF

Researchers from the **University of Kashan,** Iran, produced nanostructures in bar form and studied their performance in dye-sensitized solar cells. Core-shell structures made of zinc oxide and titanium oxide were grown on indium tin oxide beds in nanobar form. Results show that the nanostructures have high transparency in the visible light range and have lower electrical resistance compared to common samples. The high transparency enables adsorption of larger wavelengths in the visible light range—an important step in increasing efficiency. *www.kashanu.ac.ir/english.*

SURFACE ENGINEERING



Fluorine-free, anti-smudge polyurethane coatings are transparent and durable. Courtesy of Wiley-VCH.

NEW COATINGS RESIST STAINS

Scientists at Queen's University, Canada, introduced a new method for producing transparent, smudge-resistant coatings. The new approach is fluorine-free and based on polyurethane, an inexpensive type of plastic that adheres well to a wide variety of surfaces. The coatings remain clear at layer thicknesses of tens of micrometers and repel both aqueous and oily contaminants.

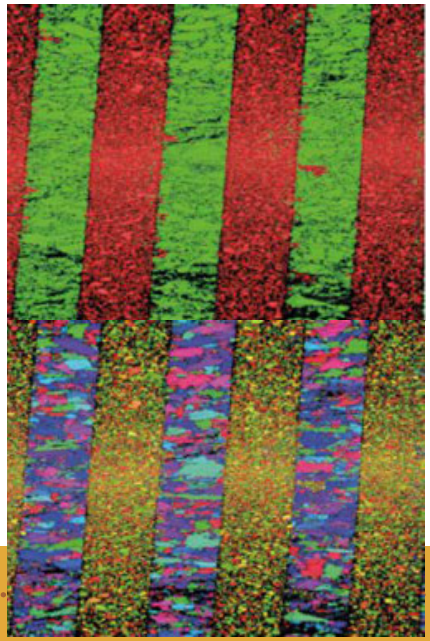
The success of this new coating stems from grafted side chains made of poly(dimethylsiloxane) (PDMS), a biocompatible silicone oil used in medicine. Individual components and conditions for the synthesis were chosen to produce a highly cross-linked polyurethane matrix in which nanodomains of PDMS are embedded. At the surface, the silicone side chains form a thin lubricating liquid film. When another liquid is dispensed on the surface, it readily slips off because the lubricating thin liquid film cannot grab the liquid. *For more information: Guojun Liu, 613.533.6996 ext. 78755, guojun.liu@chem.queensu.ca, www.queensu.ca.*

GLASSLIKE COATINGS PROTECT AND ENHANCE AUTOMOBILES

Researchers from INM—Leibniz Institute for New Materials, Germany, developed new automotive coatings that have glassy and glass-ceramic properties, reducing corrosion and wear, susceptibility to scratching or tarnishing, and other processes of oxidation on surfaces. To complement these protective properties, depending on the choice of color pigments, the method can be used to produce red, black, green, white, and blue coatings for decorative purposes with stability at high temperatures. These functional coatings are suitable for metallic substrates such as steel, aluminum, and alloys, and may be used as a protective layer for glassy components.

Special silicates are used for the coatings and are converted into a sol-gel nanocomposite in a single-step reaction. Depending on the color pigment and substrate, surfaces can be hermetically sealed from 200° to 800°C. Layer thickness ranges from 2–10 µm. Curved and flat surfaces can easily be covered with the coating in immersion chambers or spray booths. *www.leibniz-inm.de/en.*

Glasslike coatings for automotive parts offer both protection and vibrant color. Courtesy of INM.

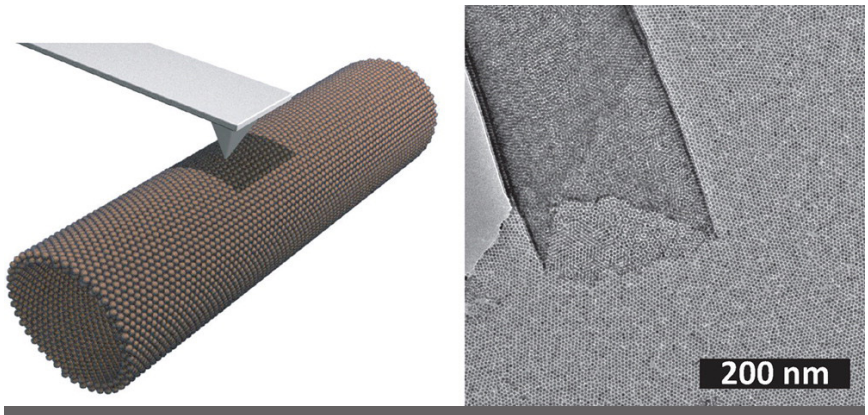


EBSD image shows local structure of a thin film: The top image shows preferred direction of the $LaSrMnO_3$-film perpendicular to the growth direction, while the bottom image shows the directions in the plane with contours of the individual nanosheets clearly visible.

BRIEF

Researchers at the **University of Twente,** the Netherlands, show that by growing magnetic layers on various 2D crystals, or nanosheets, the preferred direction of the magnetism can be locally controlled. Nanosheets can be made in less than a minute, in contrast to the traditional synthesis process, which is very slow. Magnetic films have many potential applications including the latest smartphones. *www.utwente.nl/en.*

NANOTECHNOLOGY



Scientists discovered how to measure the resistance of a nanomembrane to both bending and stretching by rolling it into a tube and measuring the tube's bending resistance along its length. Courtesy of ANL.

GOLD NANOMEMBRANES RESIST FLEXING

The first direct measurement of resistance to bending in a nanoscale membrane was made by scientists from the University of Chicago, Peking University, the Weizmann Institute of Science, and the Department of Energy's (DOE) Argonne National Laboratory. Their findings give researchers a new and simplified method to measure nanomaterials' resistance to bending and stretching, opening new possibilities for creating nanosized objects and machines by controlling and tailoring that resistance.

"Researchers around the world are seeking ways to manipulate ultrathin nanomaterials into stable 3D objects. The challenge is how to make a 2D film into a 3D shape when the film is so thin and flexible. You need something stiffer than you would expect. It turns out that many nanomembranes may already possess that property," explains Heinrich Jaeger of the University of Chicago.

"We were surprised to find that the gold nanomembrane was over 100 times more resistant to bending than we predicted, based on standard elasticity theory and our experience with thin sheets such as paper," says Xiao-Min Lin, who fabricated the gold nanoparticles in specialized facilities at the Center for Nanoscale Materials at Argonne.

Critical to the team's discovery is a new method for creating gold membranes that roll themselves into nanosized scrolls plus a new technique for measuring the scroll's resistance to bending. The nanoscrolls were self-assembled by suspending a fluid containing gold nanoparticles on a carbon screen. As the fluid dried, it left a gold membrane suspended like a nano-drumhead across the screen's circular holes. As the membranes continued to dry and tighten, one edge pulled loose from the screen, and the membrane spontaneously rolled up to form a hollow tube. Because the measurement is based only on elasticity theory and the tube's geometry, it should have general applicability across a wide range of materials and size scales, from nano and microtubules to macroscopic objects. *anl.gov.*

NANOSENSORS DETECT LEAD ELECTROCHEMICALLY

Anodized aluminum oxide (AAO) nanosensor arrays are now being used to electrochemically detect lead levels in a rapid and inexpensive manner, say researchers at Zetanostics Inc., Santa Fe, N.M. The simple electrochemical approach uses a potentiostat and does not require reagents, spectroscopy, or colorimetry. While the U.S. Environmental Protection Agency limits lead in public drinking water systems to 15 parts per billion, the AAO nanosensor method can reliably test to two parts per billion. Sandia National Laboratories, Albuquerque, N.M., filed a patent on this technology nine years ago, but the process was cost prohibitive and complex. Scientists at Zetanostics worked with Sandia's team for two years to make the technology commercially viable. Arrays can be used to test water at homes and schools, commercial buildings and plants, aquifers, storage tanks, and more. In addition, the technology can be applied to test for arsenic, hexavalent chromium, copper, and other pollutants. *For more information: Shobhan Paul, 310.721.0977, shobhanpaul@gmail.com.*

BRIEF

The **National Science Foundation** will provide a total of $81 million over five years to support 16 sites and a coordinating office as part of a new **National Nanotechnology Coordinated Infrastructure** (NNCI).The NNCI sites provide researchers from academia, government, and industry access to university facilities with fabrication and characterization tools, instrumentation, and expertise within nanoscale science, engineering, and technology. *nsf.gov.*

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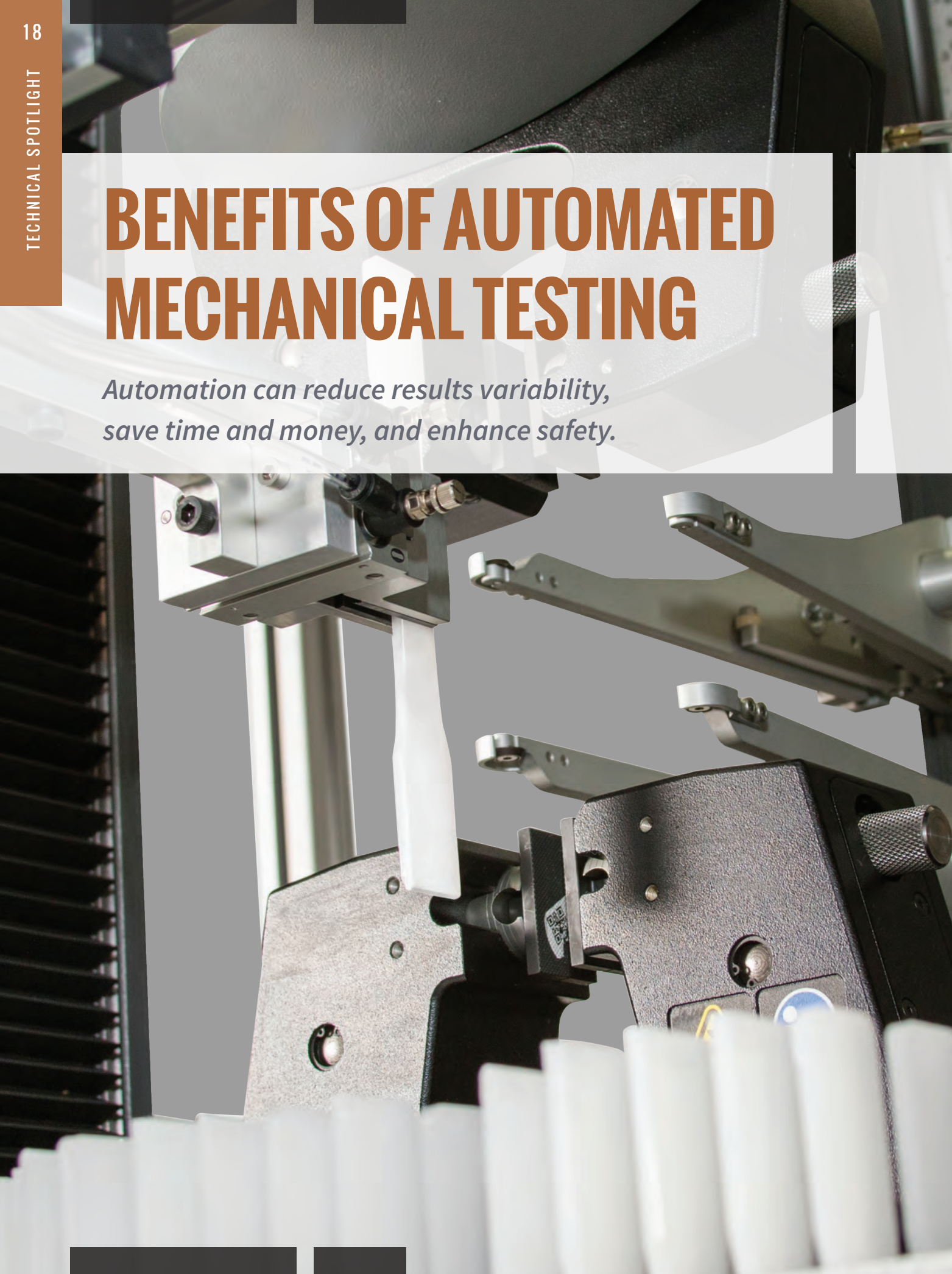
BENEFITS OF AUTOMATED MECHANICAL TESTING

Automation can reduce results variability, save time and money, and enhance safety.



Automation is commonly used in everyday life. For example, automatic doors at retail stores, car windows, ticket and toll booths, electronic devices, and online banking are among the many forms of automation that make life more convenient. Despite this, there is resistance to using automation in mechanical testing scenarios. With regard to lab automation in particular, common objections include worries about equipment cost, the time and difficulty of training operators, and the belief that automated systems are inflexible when changes are required.

Despite these fears, automation offers many key advantages in mechanical testing. For example, it reduces retesting due to data entry errors and failed tests, resulting in quicker go/no-go decisions for end users. Automation also offers a better use of skilled labor. Instead of spending time loading testing machines or waiting for tests to finish, operators can work on more valuable tasks. Companies using automation will see an increase in testing efficiency because it allows testing laboratories to keep up with increased testing demands without additional personnel, as automation can run overnight and on weekends unattended, increasing throughput. Automation also improves personnel safety, reduces repetitive motion injuries, and keeps operators clear of testing equipment and moving machinery.

TABLE 1–TYPICAL TESTING CYCLE

Step 1	Specimen ID or batch is entered by operator.
Step 2	Specimen is measured, usually in three places.
Step 3	Specimen information is manually entered into software.
Step 4	Specimen is loaded into grips.
Step 5	An extensometer is attached to the specimen (if necessary).
Step 6	Test is initiated by operator.
Step 7	Operator waits for a test to complete.
Step 8	Specimen is removed from grips.
Step 9	Operator manually transfers results to the database.

MANUAL TESTING PROCESS

Many manual and tedious steps are involved in a typical testing cycle (Table 1). All of these steps take valuable operator time, and many can potentially introduce errors and variability that might create more work due to retesting. Performing manual measurements is time consuming and cumbersome, which can lead to errors—numbers can be written incorrectly, transposed, or forgotten. In fact, some testing labs report measurement processes consuming as much as one-third of their testing process time (Fig. 1).

Loading specimens into testing equipment is operator-dependent and can have a big impact on results. This process also presents multiple opportunities for errors because specimens can easily be loaded incorrectly—too high, too low, off center, or at an angle. For example, consider two operators testing the same batch of specimens. Operator A tends to test on the high side. While most of the testing stays within the product limits, occasionally results are out of range and good product is not shipped. On the other hand, Operator B tends to test on the low side. Again, most of the values stay within product limits, but occasionally, due to lower limit testing, some product that should actually be rejected unfortunately passes and bad product is shipped. It all depends on the operator's technique, and the difference between operators could result in both lower quality and higher costs (Fig. 2).

One of the final steps in the testing process, and likely the most crucial, is transferring testing results into a LIMS or master database for analysis, tracking, and to make important product decisions. Similar to manual entry of information at the beginning of the testing process, manual results entry is time consuming and increases variability and errors.

Fig. 1 — Manual measurement performance is time consuming and often leads to errors.

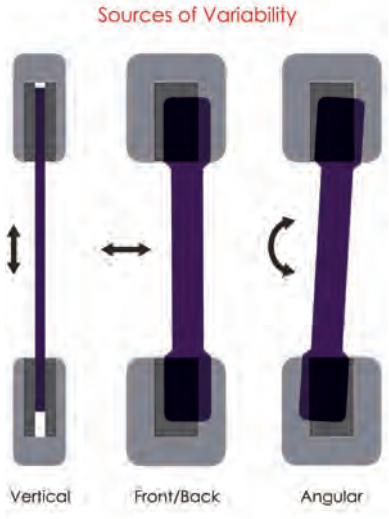


Fig. 2 — Loading specimens into testing equipment can easily be done incorrectly—too high or too low, off-center, or at an angle.

Fig. 3 — Barcode labeling and a barcode reader allow necessary batch and sample information to be loaded into a testing system or LIMS by scanning a barcode.

AUTOMATION ADVANTAGES

Automated solutions offer various levels of benefits and often do not require a full robotic testing system. This is known as the *automation continuum.* This continuum offers phases of automation and allows laboratories to automate parts of their testing process, usually starting with their greatest pain point such as data entry. By adding barcode labeling and a barcode reader, all the necessary batch and sample information can be loaded into a testing system or LIMS by simply scanning a barcode. Not only does this decrease variability, it frees up valuable operator time to perform other tasks and requires no special training (Fig. 3).

Another challenge that can be easily automated is specimen measurement. Automating measurements can be as simple as changing from a manual micrometer to a digital micrometer on a stand (Fig. 4). The specimen is loaded into the micrometer mounted on a stand. The red upload button on the micrometer is pressed and the measurement value is automatically loaded into the testing software. If further automation is desired, an automated measurement device that can measure width and thickness at the same time can also be used (Fig. 5). With this solution, the specimen is loaded into a device that measures both width and thickness and then automatically loads the values into the testing software. If multiple measurements are desired, the automatic device can store separate values and then transfer the desired measurement value into the testing software. This also saves valuable operator time and reduces variability.

Fig. 4 — Digital micrometer on a stand.

Fig. 5 — An automated measurement device measures width and thickness at the same time.

Moving through the typical testing sequence, the next step is extensometer attachment. This can be especially time consuming and requires a lot of skill and concentration to attach properly. By adding an automatic extensometer, setup time is reduced because the automatic extensometer sets the desired gauge length (Fig. 6). Results variability is decreased, as the extensometer automatically attaches properly to the specimen and in the same location for every sample. Lastly, using an automatic extensometer improves operator safety as less time is spent in the testing area, minimizing physical fatigue.

CASE STUDY

During a side-by-side experiment that compares the benefits of a semi-automated test setup to a

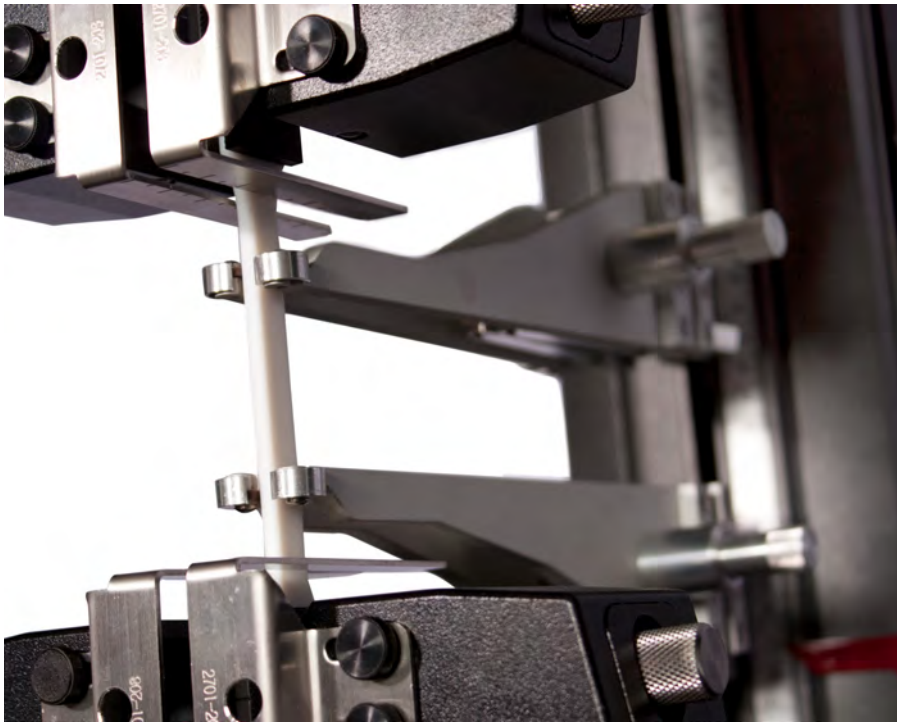


Fig. 6 — Automatic extensometers reduce setup time as desired gauge length is automatically set.

completely manual setup, manual wedge grips were replaced with pneumatic, side-acting grips, a traditional clip-on extensometer was replaced with an automatic extensometer, and an automatic, digital micrometer was used in place of manual micrometers. Making these incremental changes to the basic test setup resulted in a 38% time savings. This savings equates to an operator having three more hours per day to perform more important tasks—without adding automated specimen loading.

CONCLUSIONS

Adding automation, even in small increments, into the testing process results in reduced variability due to specimens being tested in a more consistent manner. It also improves throughput without adding labor and eliminates retests and interruptions. Automation can also enable more efficient use of skilled labor, improved repeatability and reproducibility of results, and increased safety. **~AM&P**

For more information: Suzanne Delemos-Williams is senior applications engineer at Instron, 825 University Ave., Norwood, MA 02062, 800.564.8378, suzanne_delemos-williams@instron.com, www.instron.com.

RESEARCH SPOTLIGHT

FIVE WAYS MATERIALS TESTING IS CHANGING THE WORLD

Engineering departments at universities across the U.S. are using materials testing to advance scientific research. Five of the most exciting innovations under development are presented here.

Higher education researchers are developing advanced materials that will improve building integrity, enhance medical treatment for infants, and drive biomedicine to the next level. Key to each of these developments is the testing process. Below are five ways that materials testing in being used in today's academic research environment.

1 MECHANOBIOLOGY AND REGENERATIVE MEDICINE

While biomechanics has existed for a number of years, much of the new and exciting work in the field centers on moving from classic materials testing to testing at the cellular level. "Mechanobiology has become a hot field," says Ed Sander, an assistant professor at University of Iowa's department of biomedical engineering. "You have to develop new ways to mechanically test very small things like a cell."

Sander points to the challenge of size in this work. "Classical materials testing systems are designed to test big things, strong things, and things that are linear and don't deform much," he says. "I am usually testing really small samples, like a cornea, or a sheet of cells, or a small piece of engineered tissue." In addition to size issues, testers must accommodate less than ideal geometries. "Gripping is a big issue, as is measuring low force accurately, all while doing it in a sterile environment continually over time," says Sander.

Materials used to make biomedical devices need to satisfy a range of characteristics, including withstanding fatigue and being nontoxic. "If you have a hip replacement, a heart valve, or you need a graft, the material must be in spec and meet certain requirements," says Sander. "When you get to regenerative medicine, you need materials that act like native tissue in the body."

Edward Sander, assistant professor, University of Iowa department of biomedical engineering.

Testing is where ideas are proven. "To diagnose when an aneurism might rupture, we need to go beyond current geometry-based standards. We need to see how an excised piece of tissue conforms to loads and fails, and then somehow connect that mechanical behavior to the information we can get from medical imaging devices. If we do this, a clinician could more accurately diagnose whether a risky surgery should be undertaken or not," says Sander. "All of this work leads to improving human health."

2 DEVELOPING NEW PLASTICS

Plastic compounding represents most of the research activity at University of Massachusetts Lowell (UMass Lowell), as new applications have requirements that cannot be met by existing plastics. "Everything is tested, including electrical, optical, and surface properties," says Robert Malloy, chair of the plastics engineering department. "But at the heart of each plastic are mechanical properties." Students measure mechanical properties in tension, compression, shear, and flexure; dielectric constant and dissipation factor; thermal behavior under stress; and melt rheology.

Robert Malloy, plastics engineering department chair, UMass Lowell.

Testing these newly designed materials for mechanical properties is critical to plastics research and for developing reliable design data. "We need tests to be repeatable," says Malloy. "You can follow a standard test and get good data, but that does not necessarily work for design."

One testing trend in plastics design is to subject sample material to extreme conditions. For example, when researching roof shingles made of recycled material, mechanical properties such as flame retardancy and impact resilience must withstand extreme heat and hurricane-force winds. Another example Malloy cites is snap-in hubcaps. "The material must be tested according to cold day driving, such as at -40°F, versus the temperature specified in the ASTM standard," he explains. "In plastics, this type of testing is increasing in both volume and sophistication. Testing is key to answering the 'will it work' question. There is only so much one can do with theories."

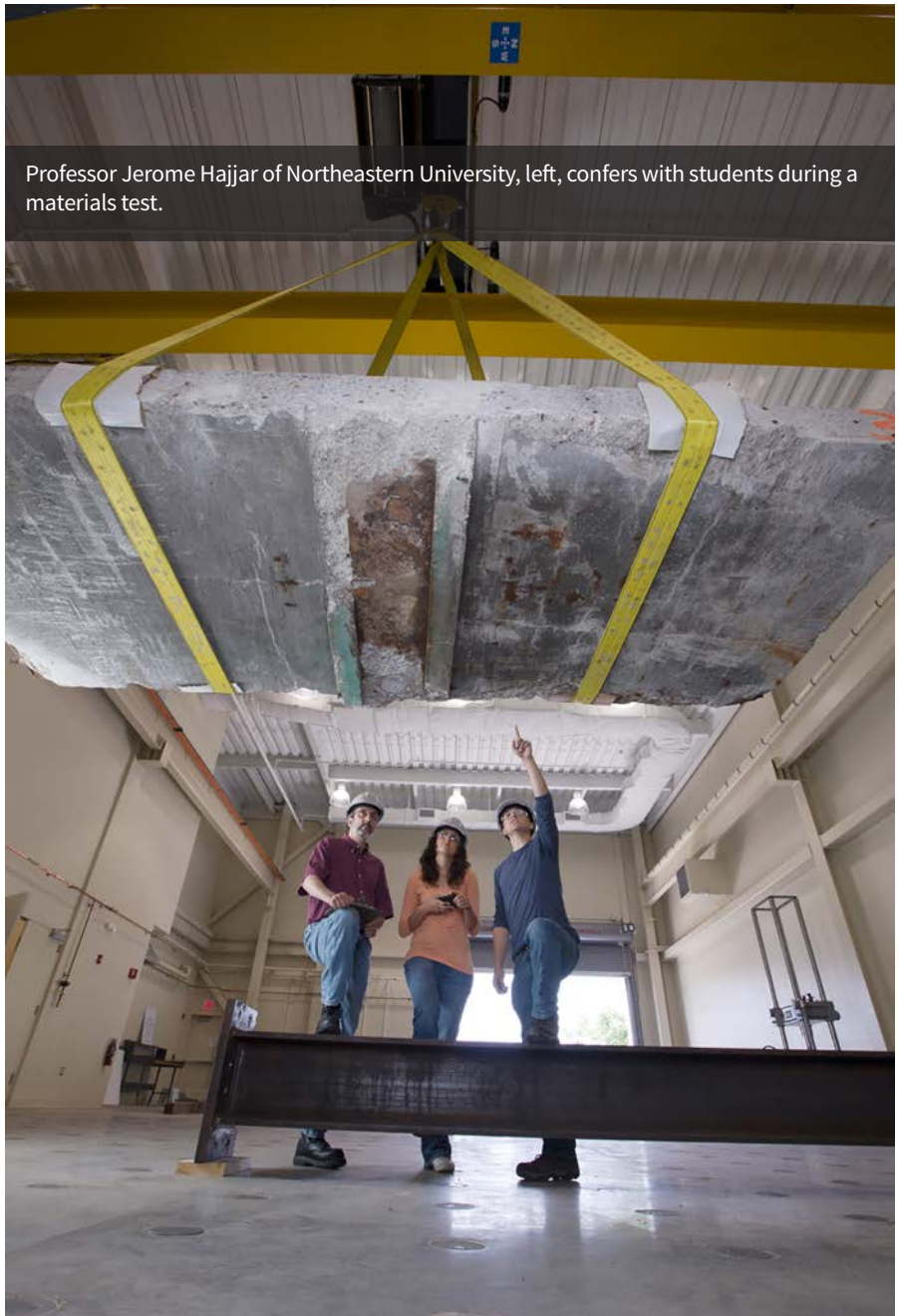
3 INNOVATIVE BUILDING MATERIALS

"In civil engineering, anything that is expected to take any reasonable level of stress and strain or be subjected to elevated temperatures or to a lot of moisture needs to be tested and characterized," says Jerome (Jerry) Hajjar, chair of Northeastern University's department of civil and environmental engineering. The school's Structural Testing of Resilient and Sustainable Systems (STReSS) lab focuses on the security and sustainability of structures against hazards and events, whether manmade or natural. Among the lab's current projects is the development of deconstructable systems for sustainable steel structures to create reusable building materials. STReSS Lab conducts large or full-scale component tests of clamping connections and experimental tests of deconstructable composite floor systems subjected to gravity and lateral loading. The team is also researching foam materials that can be used in a cladding system to harness and store energy from the sun or wind.

"One of the challenges in civil engineering is that while engineers design structures not to collapse in major events, we're not very good at mimicking collapse in simulated environments," says Hajjar. Whereas tension or shear failures can be quantified using standard test procedures, multiple forces are at play during a major event such as an earthquake or tsunami. Helping to meet this challenge is the profession's increasing capability to simulate at the atomic and molecular level.

The more microscopic the understanding of how a material behaves, the greater likelihood engineers can design new materials and associated structural systems capable of withstanding extreme loads. One example is Hajjar's research into using replaceable

Jerome Hajjar, civil and environmental engineering department chair, Northeastern University.



Professor Jerome Hajjar of Northeastern University, left, confers with students during a materials test.

components, which he calls fuses, within steel structures to absorb energy caused by a major event in a way similar to how shock absorbers prevent damage in cars.

"In civil engineering research, the whole realm of new materials is some of the most important and exciting work ever experienced in the field, and will be for many years to come," says Hajjar.

4 LIGAMENT REPAIR

At Northeastern University's department of chemical engineering, mechanical testing is essential in developing better materials for ligament repair. In biomedical polymer research, this typically involves simulating conditions in the human body such as the real-life movement of tendons and tissues in a wet test environment. For example, the department uses a micro-test system to measure mechanical properties of miniature samples and is able to measure very low forces and small displacements. The system also records microscopic material behavior while the sample is subjected to forces such as in characterizing viscoelasticity properties.

In addition to ligament repair research, faculty and students also focus on hydrogels development, a material popular in tissue engineering given its potential to mimic the body. "We use our test system to pretend we are injecting the hydrogel into bone or other tissues," says Tom Webster, chair of the chemical engineering department. "Once the hydrogel solidifies, we test the interface between it and the natural tissue."

If the interface is bad, a crack will begin and failure will occur. If the interface is good, it will withstand a lot of force. The university is testing applications including injecting into bone, ligaments, and the heart to heal damaged tissue and rebuild healthy heart tissue. "The future of mechanical testing is to tell us how new materials behave," says Webster. "The world needs better materials."

Tom Webster, chemical engineering department chair, Northeastern University.

5 IMPROVED MEDICAL ADHESIVES

Researchers at the Harvard-MIT Laboratory of Accelerated Medical Innovation at Brigham and Women's Hospital believe that innovation occurs at the interface of disciplines. "The constant is that we focus on solving medical problems and we constantly test our solutions in multiple models," says director Jeffrey Karp. Getting every solution to a human testing phase as efficiently and quickly as possible is what gives the lab its sense of urgency.

The lab is working on how to reduce injuries to the fragile skin of premature newborn babies when the adhesives holding the medical monitoring devices are removed. Lab researchers designed an adhesive with a middle thin layer of silicone etched in spider web inspired patterns that enables quick and painless release. To conduct proof of concept tests, Karp used an adhesive testing system for standard peel and shear tests, and added an innovative non-machine approach: Researchers tested the adhesive on origami paper to simulate fragile skin.

Jeffrey Karp, director, Harvard-MIT Laboratory of Accelerated Medical Innovation at Brigham and Women's Hospital.

The first priority of testing is to understand the most critical point of failure. "If we use mechanical testers in labs, we can fail fast," Karp explains. He adds that testing can help accelerate the iterative process of innovation. With regard to the lab's work on developing adhesive tissue that will attach to the heart, Karp explains the testing challenges. "We need to understand this environment and the extension, compression, and force that our material will be up against. How often will it be extending? How does the material change as it degrades?" he asks. The liquid adhesive is known as HLAA (hydrophobic light-activated adhesive), which features a combination of qualities that enable it to adhere to a constantly beating—and therefore moving—heart in the body's wet environment, and to biodegrade during the healing process.

Other innovations the lab has developed using its accelerated processes include a micro-needle based adhesive that results in minimal tissue damage. The needle's cone-like structure enables easy insertion into skin and locks into place as the tip swells from absorbing water in the body. Researchers in the lab tested the adhesive properties of the micro-needles and conducted tensile and force pull-out tests. **~AM&P**

For more information: Rich Gedney is CEO of Admet Inc., 51 Morgan Dr., Norwood, MA 02062, 781.769.0850, sales@admet.com, www.admet.com.

TRANSPARENT POLYCRYSTALLINE MATERIALS RESIST BULLETS

Capable of stopping 50-caliber, armor-piercing rounds, ALON and Spinel are hard and durable transparent polycrystalline materials manufactured using powder based processes.

Mohan Ramisetty, Suri Sastri, FASM*, *Surmet Corp., Burlington, Mass.*

A new class of advanced polycrystalline materials with a cubic crystal structure—including aluminum oxynitride (ALON) and magnesium aluminate (Spinel)—is making its way into many advanced applications. Due to their unique combination of mechanical, optical, and chemical properties, along with recent advances in manufacturing, these materials are now being used for critical defense, industrial, and civilian applications.

ALON has attracted considerable media attention lately, based on its ability to stop 50-caliber armor-piercing rounds, coupled with night vision capability, and crystal clear transparency. Sometimes referred to as "transparent aluminum," the material appears regularly in movies, documentaries, and popular fiction. For example, the movie *Jurassic World* used ALON for its gyrospheres, ALON Armor was featured in an episode of Discovery Channel's *How Stuff Works,* and the material also appeared in Lee Child's best-selling novel *Personal.*

Fig. 1 — Engineer inspects a 19 × 36 in. ALON window.

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CHEMISTRY AND PROPERTIES

Although both ALON and Spinel exhibit a cubic spinel crystal structure, the lattice constants and chemical bonds vary and result in significant property differences. Table 1 summarizes the key properties of these materials.

ALON is significantly harder and stronger than Spinel, primarily due to the slightly increased covalent nature of its bonding versus a predominantly ionic bond in Spinel. ALON is the hardest transparent polycrystalline material available for commercial use[1]. Compared to ALON, Spinel's lattice structure features a slightly expanded unit cell and transmits further into the mid-wave infrared (MWIR) region (Fig. 2), making it desirable in many midwave infrared sensor applications.

MANUFACTURING PROCESSES AND CHALLENGES

Manufacturing both ALON and Spinel involves many of the steps required to make any technical ceramic material. However, attaining crystal-clear

TABLE 1–KEY PROPERTIES OF ALON AND SPINEL[1,2,3]

Property	ALON	Spinel
Chemical formula (nominal)	$Al_{23-1/3X}O_{27+X}N_{5-X}$	$MgAl_2O_4$
Crystal structure	Cubic, spinel	Cubic, spinel
Lattice parameter/constant (nm)	0.794-0.796	0.8085
Density (g/cc)	3.69	3.58
Strength (MPa)	300-700	70-300
Hardness (kg/mm2, Knoop)	1800-1870	1550-1650
Young's modulus (GPa)	323	277
Refractive index (at wavelength 0.5 μm)	1.80	1.723
Transmission wavelength range (at 2 mm thick)*	0.25 to 6	0.25 to 6.5
Refractive index in-homogeneity (~4" aperture, RMS)	~5	<10
Transmittance in the visible (no AR coating)* (%)	84-85	80-86
Haze* (%)	<2	<10
Clarity* (%)	>98	>95

**Varies depending on processing conditions and thickness.*

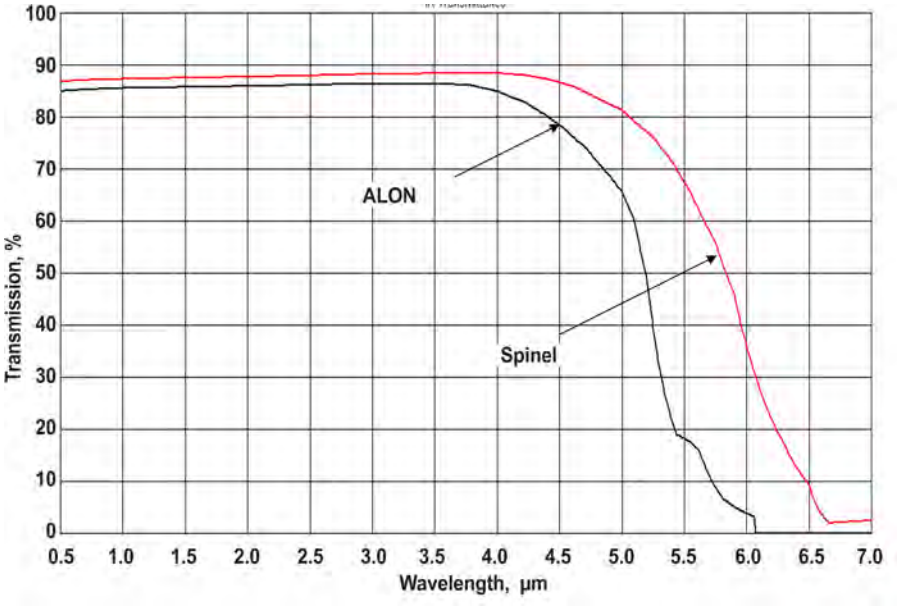


Fig. 2 — Transmission spectra of ALON and Spinel; 2-mm-thick sample with no anti-reflection coatings.

transparency presents several challenges that require additional critical steps. Certain physical and chemical requirements must be met in order to achieve full transparency. For example, transparent materials cannot have any features that are large enough to scatter light in the wavelengths of interest, mainly in the visible range. Some of these requirements include:

1. >99.9% density—Porosity that is larger than roughly 40 nm causes light to scatter.
2. Ultra high purity—The presence of impurities, such as a few ppm of transition metals, imparts color or tint into the part.
3. Clean microstructure—No secondary phases at the grain boundaries. Microstructural defects such as pores or bubbles also result in inclusions.

To get an idea of the difficulty of achieving these requirements for ceramics, first consider a powder metallurgy example: Imagine starting with micron to submicron size metal or alloy powder, compacting it into a shape, and then heat treating it to nearly full density with absolutely no microstructural defects on the scale of tens of nanometers. This is quite challenging even for metals, in which plastic deformation takes place and less complex chemistries and diffusion mechanisms are involved. In addition, much lower sintering temperatures are needed for metals versus ceramics. The process is orders of magnitude more complex for transparent ceramic materials, requiring tens of millions of dollars and more than a decade of effort to transform it from a laboratory invention into a viable commercial product.

Figure 3 depicts the key steps involved in transparent ceramics manufacturing. In any powder-based method, a robust process begins with a consistent and reliable powder supply with the appropriate characteristics. The manufacturing process for ALON is reliable and repeatable, so it can be produced with consistently higher quality and in larger quantities and larger sizes than Spinel.

One of the contributing factors to ALON's robust manufacturing process is that Surmet Corp. synthesizes its own powder with consistent characteristics. In contrast, Spinel powder is sourced from an outside supplier and exhibits inconsistent quality and reliability, which has inhibited its progress in terms of reproducibility and scalability. Although Spinel has been available for nearly 50 years, manufacturers still struggle to consistently produce parts as small as 12 × 12 in. with reasonable

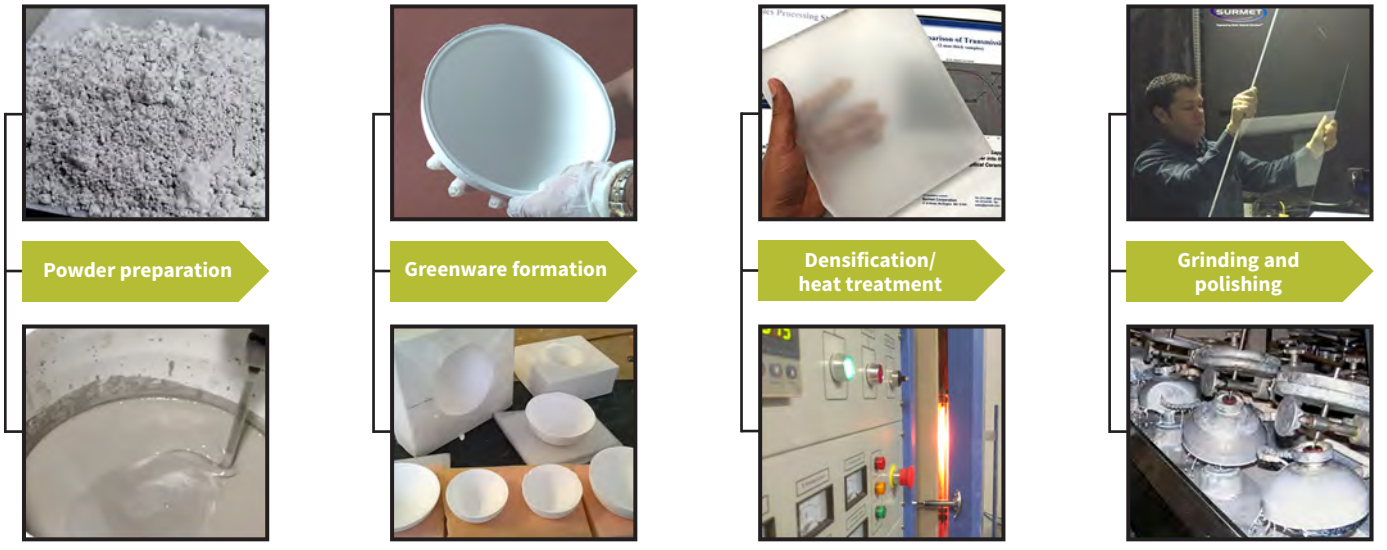
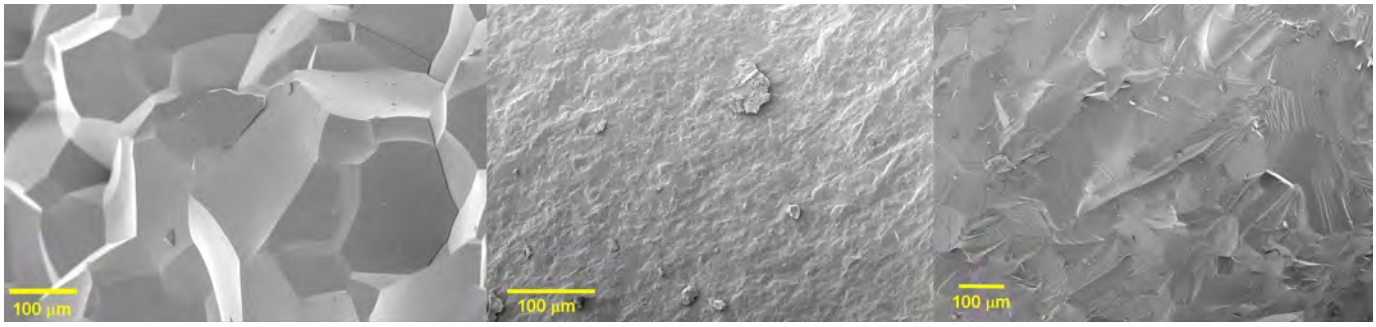


Fig. 3 — Key steps in manufacturing transparent polycrystalline ceramics.



(a) (b) (c)

Fig. 4 — Typical SEM micrographs: (a) Spinel processed using the LiF-based hot pressing approach; (b) Surmet's Spinel; and (c) Surmet's ALON produced via solid-state pressureless sinter followed by HIP.

TABLE 2–PROPERTIES AND APPLICATIONS FOR ALON AND SPINEL

Featured Properties	Applications
Mechanical: • Hardness • Strength • Durability	**Transparent armor systems for ground vehicles and aircraft:** ALON provides superior ballistic performance against multiple advanced threats such as 50-caliber armor-piercing bullets.
	Durable windows: Because ALON is the hardest polycrystalline transparent material, it offers significant environmental durability (rain and sand erosion resistance) and scratch resistance. Common applications include windows for laser communications (airborne laser data links, counter manpads, laser rangefinders, laser target designators, laser radars), protective covers for sensors, pressure vessels, and laser igniter windows.
	Windows/covers for harsh environments: Oil and gas drilling, scratch-resistant covers for electronic devices, and windows on chemical reactors.
Optical: • Highly transparent • Visible midwave infrared transmission • High Abbé number/ low dispersion	**Domes for infrared optics:** Hemispherical and hyper-hemispherical domes for infrared guided missile systems, reconnaissance and sensor windows, and lenses for targeting pods.
	Reconnaissance and sensor windows: ALON offers the highest refractive index homogeneity over large areas, a key requirement for sensor and reconnaissance applications. ALON windows are now in use on various helicopters and aircraft.
	Night vision systems: In addition to its mechanical performance, ALON's higher transmittance in the 0.6 to 1 micron wavelength range offers significant night vision advantages over glass-based systems. **Gradient index optics (GRIN):** ALON GRIN optics have low chromatic aberrations (due to low dispersion) and GRIN lenses are possible with Δn of >0.05 (axially and radially).
Processability: Powder processing allows manufacturing of complex geometries, embedded features, and large sizes	**Large monolithic transparent armor, large area optics, and curved/conformal optics:** Unlike single crystal, which is melt-based and grown as a boule and then fabricated into a shape, ALON and Spinel are made from powder and hence can be made into very large sizes and to near-net complex geometries. This enables applications such as large monolithic transparent armor windows in flat as well as conformal shapes.
Chemical resistance (ALON): • To acids and bases • To halogen plasma	**Tools and components for harsh environments:** Examples include semiconductor equipment, plasma etching chambers, reaction chambers, chemical reactors, and reaction vessels.
High temperature resistance	**Windows for furnaces and other equipment operating at elevated temperatures:** ALON has a melting point of >2000°C and can withstand temperatures of roughly 1500°C in inert atmospheres.
Biocompatibility	**Bio-ceramics such as load-bearing prosthetic implants and components of diagnostic tools and equipment:** ALON is nontoxic and has been shown to have both in-vitro and in-vivo biocompatibility, as well as outstanding wear resistance and low coefficient of friction.

yields. In addition to these powder issues, densification of Spinel green bodies is still plagued by unpredictable chemistry and complex diffusion mechanisms and requires further lab studies.

Two main techniques exist for making fully dense and transparent Spinel. The most widely used approach is vacuum hot pressing, where powder is typically blended with lithium fluoride (LiF) as a liquid phase sintering aid followed by uniaxial pressing at elevated temperatures. LiF melts at relatively low temperatures and forms a eutectic composition, which then wets and reacts with Spinel grains, resulting in liquid-phase assisted densification. LiF is highly volatile and ideally should evaporate at or below the hot pressing temperature regime of Spinel (roughly 1600°–1700°C). However, a sufficient amount of LiF remains at the grain boundaries, resulting in severe grain-boundary embrittlement and intergranular weakness[4]. Weak grain boundaries are depicted in Fig. 4(a), a scanning electron micrograph of a

fractured surface of conventionally hot pressed Spinel with LiF doping.

Surmet uses a different approach, which includes solid-state pressureless sintering followed by hot isostatic pressing (HIP). This method is not without challenges, but the overall result is mechanically superior and more reliable on many counts than hot pressed Spinel (Fig. 4). Pressureless sintering followed by HIP is also used to produce ALON.

CURRENT AND POTENTIAL USES

Both ALON and Spinel have enormous potential in a broad range of applications. However, ALON appears to be at the forefront primarily due to its robustness and superior properties in addition to large-scale and reliable manufacturability. Table 2 summarizes some of the key properties and applications for ALON and Spinel although the majority of the list is mainly applicable to ALON.

COMMERCIALIZATION AND FUTURE APPLICATIONS

Scaling up ALON manufacturing from laboratory to production quantities has required more than a decade of dedicated process development and tens of millions of dollars. Work is now underway to bring down the cost so that these materials can find a role in cost-sensitive applications such as consumer products, semiconductor equipment, and energy-related uses. ALON is now available in large sizes (up to 18 × 35 in.) and large quantities. Spinel remains a work in progress. For its efforts, Surmet was recently awarded the American Ceramic Society's Corporate Technical Achievement Award in 2013. Surmet acknowledges funding support from the U.S. Department of Defense in this effort. **~AM&P**

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EDUCATION SPOTLIGHT

MATERIALS SUSTAINABILITY APP SERVES AS TEACHING TOOL

A new mobile application could successfully incorporate sustainability education into every school in the U.S.

Today's students use digital tools in all aspects of their lives—for communicating, socializing, entertaining, organizing, and learning. Even computers are fading in popularity among the younger crowd in favor of cell phones, tablets, and other devices. Due to this communications revolution, researchers are now aiming to harness flexible mobile technology for materials education purposes.

In the classroom, use of mobile applications or *apps* by middle and high school students could trigger interest in materials science and engineering. As one recent example, a new app was designed as an interactive *sustainability game* where students learn without realizing it. The idea behind the app development is that learning about sustainable materials and environmental awareness could be enhanced if such information was readily available on cell phones and other mobile devices.

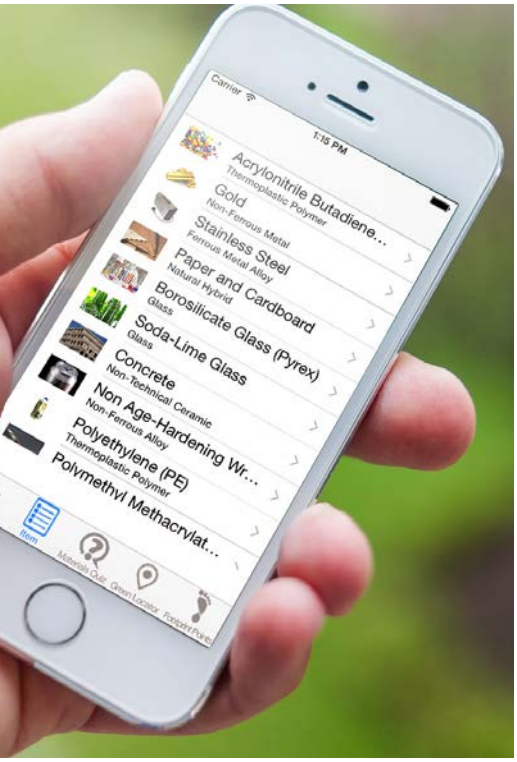

Fig. 1 — Sustainable materials list screen.

Because environmental concerns are such an important topic, the EPA began making recommendations in 1994 about how institutions can teach sustainability in schools[1]. Today, the Center for Green Schools and the U.S. Green Building Council has its own recommendations on how sustainability can be taught, in hopes that every school in the U.S. will require each student to graduate with an understanding of this topic in the near future[2].

Sustainability education needs to influence students in order to modify their attitudes, behaviors, and thoughts on being environmentally friendly. The earlier students are exposed to sustainability education, the easier it will be to instill environmentally friendly habits and opinions[3].

However, there has been debate as to whether technology use in the classroom enhances education or if it is a distraction[4]. Recent studies show positive results regarding technology use in the classroom to achieve educational goals. For example, in one study[5], a control group was given permission to use the technology under teacher guidance to assist learning while another group learned the same material without technology. Students were given the same test after the lesson and students who used technology achieved an overall score 16% higher than the control group who did not.

Researchers then developed a new sustainability app, which aims to incorporate sustainability education into U.S. classrooms in a fun way. It consists of five major functions and screens, which can be accessed at any time from any screen with a navigation bar at the bottom. The screens include:

- Welcome/Home screen.
- Materials Quiz, which includes 35 questions.
- Materials List/Material Details screen, which provides more details about material cost per unit, common uses, date of first use, and CO_2 emissions. All information used to compile this list is referenced from CES EduPack, Granta Design, UK (Figs. 1 and 2).
- Footprint Points Counter, which shows how many points a user has earned, depending on environmental friendliness.
- Green Locator Map—*app map* illustrates 10 locations in the Pittsburgh area that are known as "green" buildings and what makes them so notable (Fig. 3).

The app was developed on an Apple computer with XCode software (Objective-C programming). Alpha testing using the simulation component of the software ensured all functions were working properly. Each question was reviewed to make sure answers were appropriately marked and also to ensure every question could be viewed.

This application is still in the development stage and more work is needed before it can be used in schools. When it is further refined, the app will be available in the Apple store for beta testing. After it is downloaded, students who are part of the testing phase will evaluate it and feedback will be used to further enhance the application. When

the app is finally approved, it will be released in the Apple store for use in schools as an educational tool.

Sustainability has become a hot topic over the past few years and the U.S. education system will soon begin implementing sustainability into its curriculum. With the rise of Internet and cell phone use, it seems to be more of an advantage than a disadvantage to use mobile technology effectively to enhance student education. Creating an interactive, rewarding, and informative mobile app to aid in this endeavor is a logical answer to these calls. Further, because younger students learn more effectively the earlier they are introduced to information, aiming this proposed mobile app toward younger students is perhaps the best approach. Ideally, the mobile application described in this work will be the beginning of successfully incorporating sustainability education into every school in the U.S. **~AM&P**

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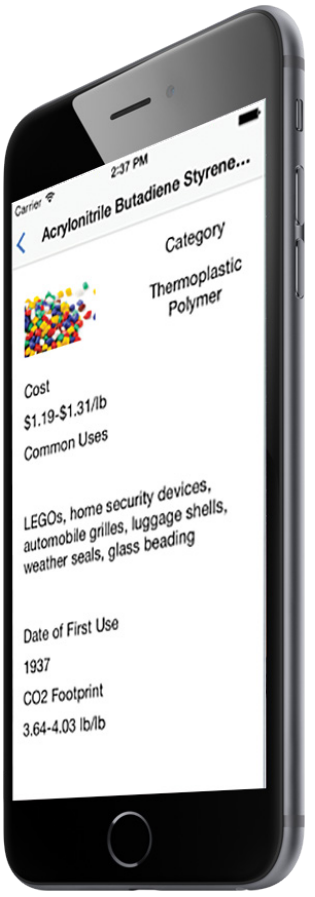

Fig. 2 — Material details screen provides additional properties.

Fig. 3 — Green building locator screen.

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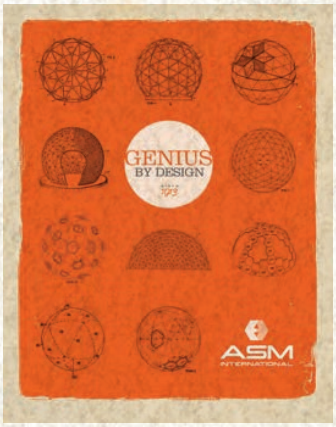

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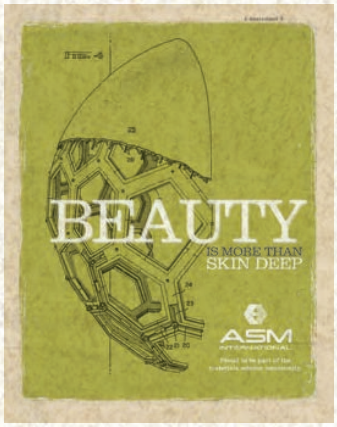

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METALLURGY LANE

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PIONEERS IN METALS RESEARCH–PART III

METALS PIONEER PAUL DYER MERICA AND HIS ASSOCIATES AT THE NATIONAL BUREAU OF STANDARDS DISCOVERED THE PRINCIPLES THAT GOVERNED THE AGE HARDENING OF DURALUMIN.

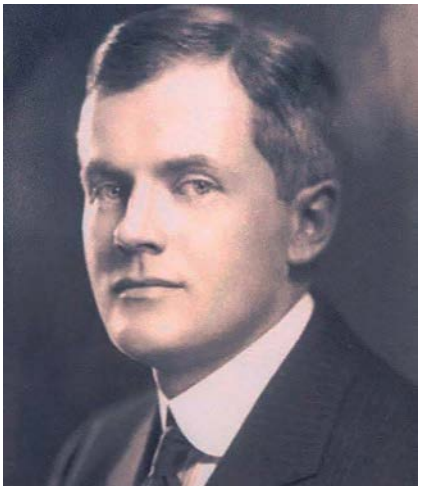
Duralumin, the Al-4Cu-0.5Mg alloy invented by Alfred Wilm in the early 1900s, was in production during World War I in Germany, France, and England. Germany built nearly 100 giant Zeppelins using duralumin for the framework, while France and England used it for limited aircraft parts. The U.S. was behind in both military aircraft and duralumin development, so it did not use the alloy in these early days.

Duralumin was believed to be a unique alloy, which could not be duplicated in any other alloy system. The manner in which it aged to high strength was a complete mystery. In this atmosphere, the National Bureau of Standards initiated a research program to study the alloy's behavior. Paul Dyer Merica was selected to head a small group of researchers studying duralumin behavior during age hardening. Results showed that aging in duralumin was not unique, but was the basis for a new strengthening mechanism in metal alloys that could be applied to many alloy systems. The principle of age hardening is widely considered the most important metallurgical discovery in the first half of the 20th century.

EARLY LIFE AND EDUCATION

Paul Dyer Merica was born in 1889 to Charles and Alice Merica. He was raised and educated in Warsaw, Indiana, and attended DePauw University in Greencastle where his father had preceded him some 20 years earlier. After three years, Merica transferred to the University of Wisconsin where he received a degree in physics. He taught physics at Wisconsin for one year and then left the U.S. for two years to teach at Zhejiang University in China.

After a brief return to the U.S. in 1911, he moved to Germany to enroll in graduate studies at the Royal Institute of Technology in Charlottenburg. Here he was classmates with Samuel Hoyt, an American who had entered metallurgy at Columbia University in a course taught by William Campbell. What we know about Merica during his time in Germany was written by Hoyt in his book, *Men of*

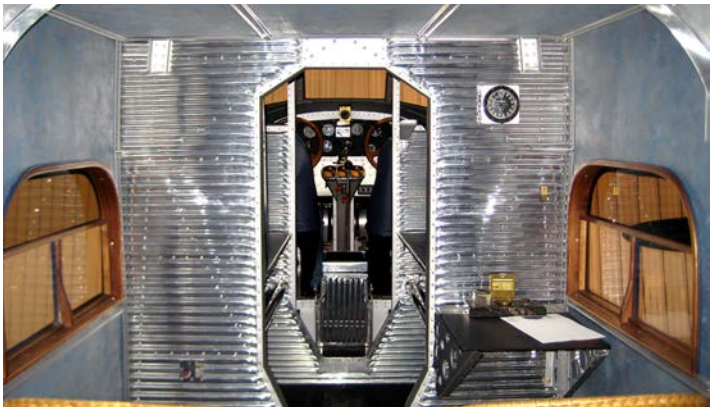


Paul Dyer Mercia led the team that discovered the principles governing precipitation hardening.

The first major use of duralumin was in the frame of the Zeppelins built in Germany for bombing London during World War I.

A wrecked Zeppelin brought down by British aviators near the coast of Essex, September 23, 1916.

The Ford Trimotor was the first commercial plane built in the U.S. with a duralumin type alloy produced by Alcoa. Courtesy of goldenwingsmuseum.com.



Interior of the Trimotor, which only held a dozen passengers. Courtesy of goldenwingsmuseum.com.

Metals. Hoyt describes Merica's appearance when he arrived: "One day a young man presented himself at the laboratory and announced he might be joining us. His attitude seemed to say that he might just possibly if he liked what he saw. He wore a straw hat obviously too small worn on the side of his head." Merica and Hoyt had a number of classes together including one taught by Adolf Marten for whom Floris Osmond named martensite after. Here they met Guillaume Kroll, also known as William Kroll of titanium fame.

Upon his return, now with a Ph.D. in physics and metallurgy, Merica worked for a brief time at the University of Illinois. He then joined the National Bureau of Standards where he worked for an older physicist and metallurgist, George Burgess, a Massachusetts Institute of Technology graduate who also studied under the famous Henry-Louis Le Chatelier at the Sorbonne in Paris. Merica led a group of metallurgists in studying the mechanism responsible for age hardening in duralumin. His colleagues included Howard Scott, R.G. Walthenberg, and J.B. Freeman.

DURALUMIN RESEARCH PROGRAM

The Bureau's study was designed to examine the role of Cu and Mg independently and then combine them in various amounts to determine how they interacted to cause age hardening. Sample alloys were made at the New Kensington plant of the Aluminum Company of America. They were rolled, annealed, and rerolled until reduced to a 0.032-in. thickness in the cold-rolled condition. They were tested in the cold-rolled condition and after annealing to soften them to form a baseline measurement. Other samples were solution-treated at temperatures to 520°C, water-quenched to room temperature, and aged for 11 days at room temperature or for three days at 100°C. All samples were tested for hardness, ultimate tensile strength, and elongation.

Merica and his team concluded that this supersaturated solid solution formed a pre-precipitate that hindered plastic deformation until higher stress was applied to the material. Over-aging at higher temperatures where $CuAl_2$ could be seen removed the pre-precipitate, and also decreased hardness. The work showed that duralumin might not be unique, but a mechanism for hardening in other alloy systems fitting the conclusions of Merica. Any alloy with decreasing solid solubility with decreasing temperature when quenched to form a supersaturated solid solution could form pre-precipitates at some aging temperature. The authors stated, "If the temperature of the alloy is raised to 100°C, or even to ordinary room temperature, according to the theory which the authors propose, the mobility of the molecules becomes sufficiently great that precipitation of the $CuAl_2$ takes place in the form of very fine particles of colloidal dispersion."

The authors finally concluded, "Upon aging a quenched sample at 200°C, the hardness first increases to a maximum and afterwards decreases. During that aging there has been first a formation of fine nuclei of $CuAl_2$ followed by coalescence of these particles into ones of larger size. There is, therefore, a certain average size of particle of $CuAl_2$ for which the hardness is a maximum; atomic dispersion of the solute is not the dispersion that produces the maximum hardness but some intermediate one between it and that at which the particles become visible by ordinary means. To this dispersion is due the hardening of duralumin."

Results of this study by Paul Dyer Merica, et al., were quoted by Zay Jefferies as "the shot heard around the world." If duralumin could be hardened by precipitation of a compound, then this new hardening mechanism could be applied to many other alloy systems. The resulting developments opened the door to a whole new world of strong alloys.

AWARDS AND HONORS

Merica received many awards for his work on precipitation hardening in duralumin including the John Fritz Medal, the Platinum Medal from the British Institute of Metals, ASM's Gold Medal, The Franklin Institute's Franklin Medal, and AIME's James Douglas Gold Medal. Merica joined the International Nickel Co. in 1919 after his five years at the National Bureau of Standards. During the next 38 years, he advanced from research metallurgist to president of the parent company, the largest nickel company in the western world. Merica died of a heart attack in 1957 at the age of 68.

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

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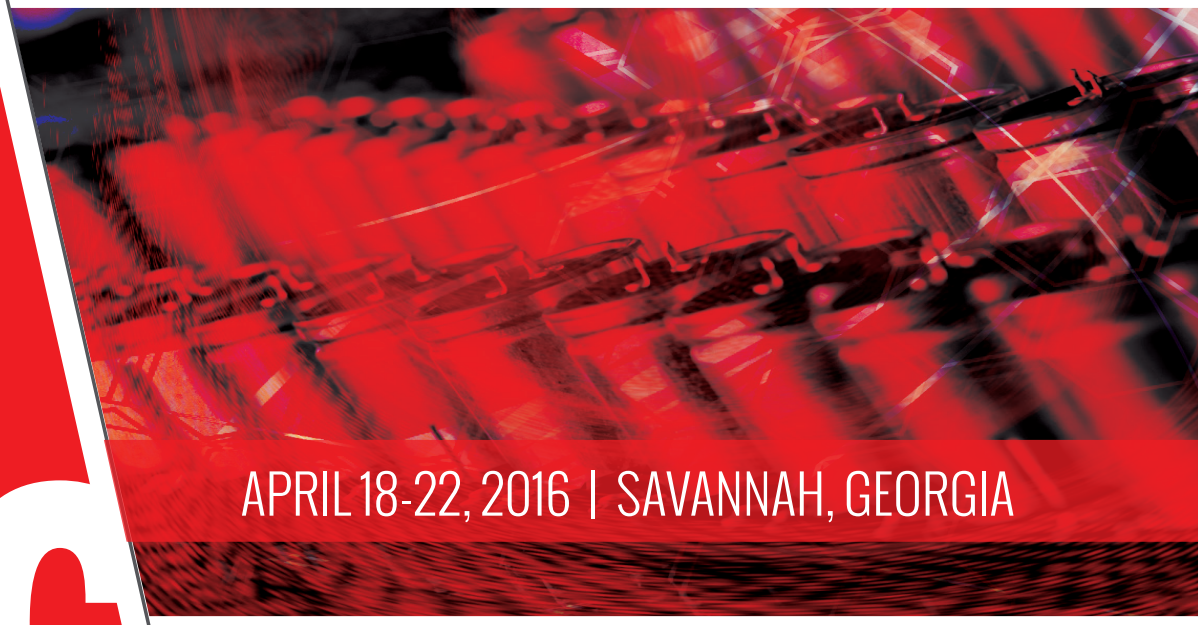

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MATERIALS TESTING PRIMER

SELECT TEST METHODS FOR MATERIALS TESTING

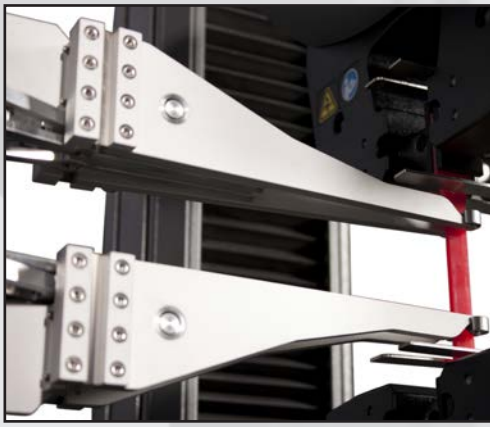
For engineers and scientists who need to know if a certain testing technique or analytical method might be capable of providing answers to their materials properties questions, this special section describes two important techniques in simplified terms and emphasizes the most common applications and limitations of each method.

Articles include a summary of general uses, applications, types of samples for testing, limitations of the method, typical time required for analysis, and capabilities of related techniques. The summary is designed to provide readers with a quick overview of the technique and to help them decide whether the technique might be applicable to their problem.

Techniques included in this section are:

- Tensile Testing
- Fatigue Testing

Contact the sponsors of these pages if you are looking for testing equipment/instruments or more information about testing capabilities. To find more information about testing primers and materials information, go to asminternational.org/materials-resources/online-databases.



TENSILE TESTING

William Mankins, *Metallurgical Services Inc.*

Tensile testing is used to quantitatively measure the strength and ductility of materials, to provide engineering design data, and to determine the mechanical properties of materials subjected to axial loading and deformation. It is also used as a tool for quality assurance of supplied engineering materials.

Applications include alloy research and development, determination of the conformance of materials to customer specifications, failure analysis, and the design of engineered components of construction, or machine assemblies subjected to load and deformation.

SAMPLES

- *Form*: Solids (metals, polymers, ceramics, composites, elastomers).
- *Size/shape*: Round or rectangular cross sections with lengths up to approximately 24 in. (~ 60 cm); actual components may be tested full size.
- *Preparation*: Specimens are machined in conformance with requirements of standard test procedures, or actual parts or components are used (e.g., threaded fasteners) per standard test procedures.

LIMITATIONS

The range of testing capabilities is limited by the load capacity of the specific universal testing machine. Testing is destructive to material tested.

ESTIMATED ANALYSIS TIME

- Sample preparation time of up to one hour if extensive cutting/machining is required.
- Approximately five minutes per test to measure sample gage length and cross-sectional area.
- Up to approximately 10 minutes testing time per test in the tensile testing machine, which varies depending on the loading rate.
- Up to approximately five minutes to perform test measurements and analyze data after testing.

RELATED TECHNIQUES

Use of the universal testing machine to perform *compression, bending, and shear tests.* Extensive tensile test databases allow comparisons with other mechanical tests (e.g., hardness), other alloys, and materials in other heat treated conditions.

FATIGUE TESTING

William Mankins, *Metallurgical Services Inc.*

Fatigue testing is used to predict the service life of components subjected to cyclic loading as a function of applied stresses and cycles to failure and to determine the fatigue-crack propagation rate of a cyclic-loaded component after a crack or flaw has been identified or produced in testing. It is also used to evaluate actual machine components that undergo cyclic loading service and measure the crack-growth characteristics after initial cracking.

Applications include the determination of metallurgical effects (processing, heat treatments, and defects) on the fatigue life of components, determination of fatigue life of components resulting from design errors, determination of the effects of welding/joining processes on the fatigue life of components, and simulation of failure conditions for failure analysis.

SAMPLES

- *Form*: Solids (metals and alloys, polymers, composites, glasses, and ceramics).
- *Size and shape*: Machined test specimens per requirements of standard procedures; actual machine components and large fully operational equipment (e.g., aircraft).
- *Preparation*: Specimens can be machined without a defect to determine time/cycles to initiate a crack or cause failure. Specimens can also be pre-cracked with the crack growth time to create a critical or fatal flaw being measured.

LIMITATIONS

- Creating a fatigue test specimen to duplicate actual practice is a challenge.
- Metallurgical variables in fatigue samples make it difficult to duplicate testing results.
- Metallurgical processing history (heat chemistries, mill processing, or heat treatments) cause variability in fatigue test results.
- Material variations and processing variables make it difficult to achieve statistically significant reproducible fatigue data.

ESTIMATED ANALYSIS TIME

- Preparation time for machined samples is estimated to be a few hours (six to eight hours maximum).
- Testing time is a function of the applied stress and number of cycles; to determine an endurance limit of 10^{6+} cycles (or orders of magnitude greater) requires an extended period of time.
- State-of-the-art electromechanical and servohydraulic fatigue testing systems are capable of high cyclic loading rates and can shorten test times to a few hours.

RELATED TECHNIQUES

Corrosion fatigue and *thermal fatigue testing* procedures, which are realistic problems encountered in actual applications and exacerbate the problem of obtaining accurate fatigue data.

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[ATTEND TS4, THE PREMIER EVENT FOR THE THERMAL SPRAY COMMUNITY!]

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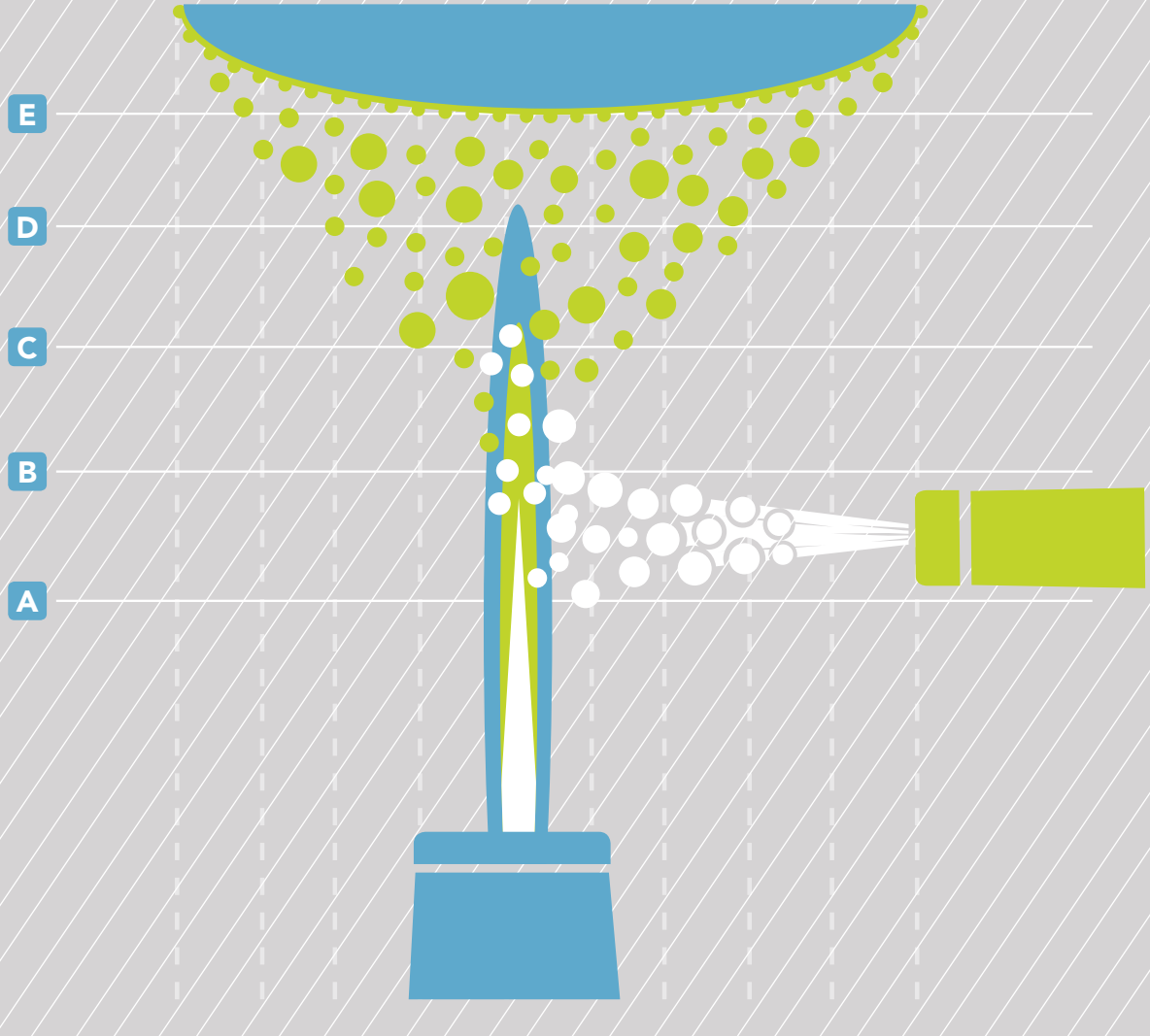
Looking for innovative solutions to improve coating performance in the aerospace, energy generation, and transportation industries? Join us for the latest information on emerging S&STS technologies at the Thermal Spray of Suspensions & Solutions Symposium (TS4) in Montreal, Canada.



FOR MORE DETAILS, VISIT ASMINTERNATIONAL.ORG/SUSPENSION2015

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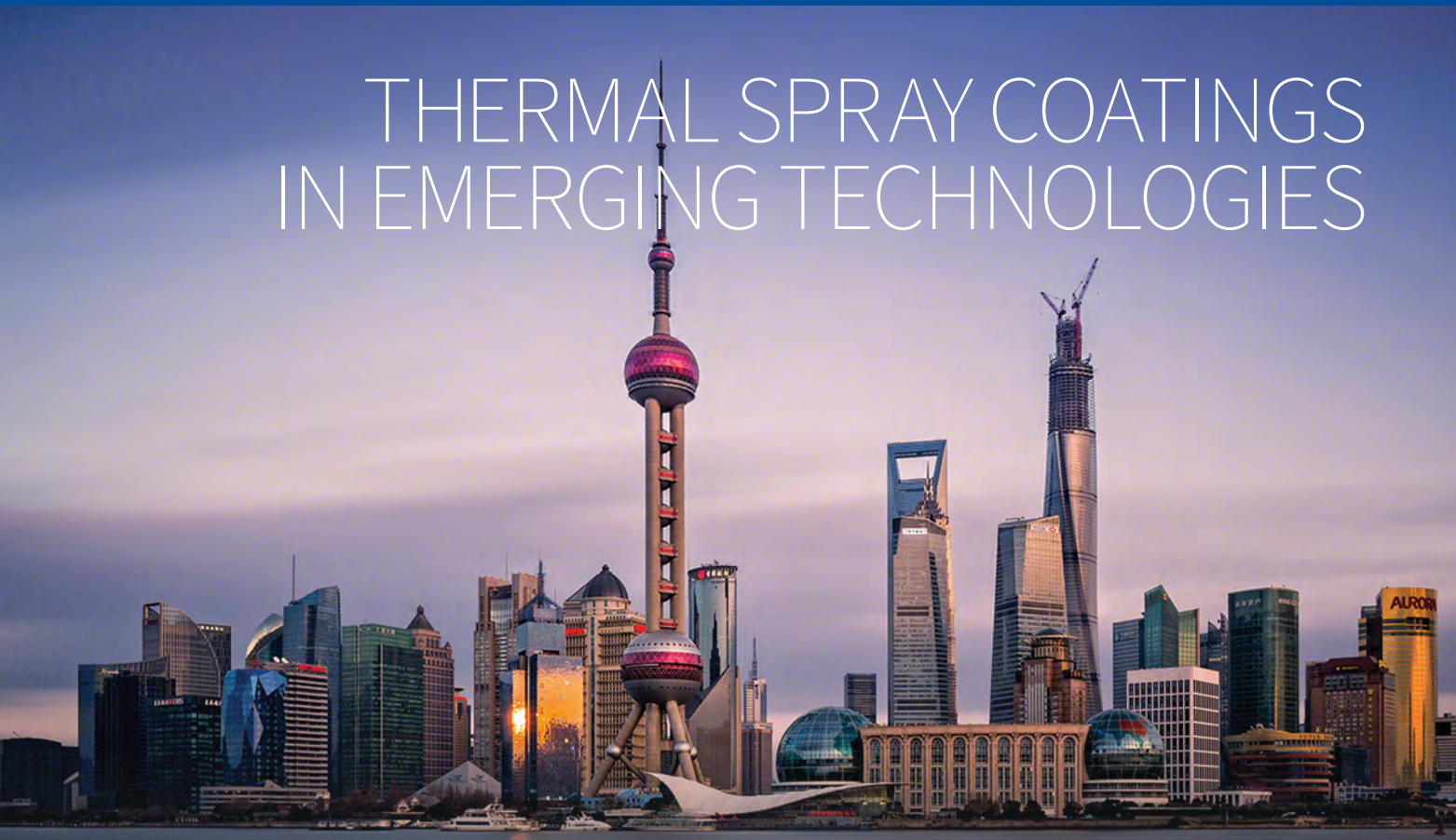
NOVEMBER/DECEMBER 2015 | VOL. 10 | ISSUE 4

iTSSe

INTERNATIONAL THERMAL SPRAY & SURFACE ENGINEERING

THE OFFICIAL NEWSLETTER OF THE ASM THERMAL SPRAY SOCIETY

THERMAL SPRAY COATINGS IN EMERGING TECHNOLOGIES



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EDITORIAL OPPORTUNITIES FOR *iTSSe* IN 2016

The editorial focus for *iTSSe* in 2016 reflects established applications of thermal spray technology such as power generation and transportation, as well as new applications representing the latest opportunities for coatings and surface engineering.

February: Aerospace Industry/Military Applications
May: Energy & Power Generation
August: Automotive & Industrial Applications
November: Emerging Technologies/Applications & Case Studies

To contribute an article to one of these issues, please contact the editors c/o Julie Lucko at julie.lucko@asminternational.org.

To advertise, please contact Kelly Thomas, kelly.thomas@asminternational.org.

DEPARTMENTS

ABOUT THE COVER

Shanghai is a popular tourist destination renowned for its historical landmarks such as the Bund, City God Temple, and Yu Garden as well as the extensive Lujiazui skyline and major museums. It has been described as the "showpiece" of the booming economy of mainland China. Come and enjoy the countless wonderful experiences Shanghai has to offer at next year's International Thermal Spray Conference and Exhibition May 10–12. See page 5 of this issue to learn more.

CONFERENCES OFFER VALUABLE WAYS TO CONNECT WITH THERMAL SPRAY COMMUNITY

Gansert

I was fortunate enough to attend the International Thermal Spray Conference and Exhibition that took place last spring in Long Beach, Calif. The show offered a wide variety of technical information as it was co-located with both AeroMat and Microstructural Characterization of Aerospace Materials and Coatings hosted by ASM's International Metallographic Society. My co-technical editor on *iTSSe*, Rajan Bamola, presented a talk on emerging thermal spray techniques for coating dental implants. It outlined the evolution of surface texturing of dental implants from plasma spray titanium and hydroxyapatite to acid etching and RBM blasting. The benefits and deficiencies of each technique pointed to a roadmap for future surface treatment requirements.

Another opportunity to explore thermal spray technology is coming up December 2-3 at the Thermal Spray of Suspensions & Solutions Symposium (TS4) in Montreal. This symposium offers a chance for scientists and engineers interested in the emerging S&STS technologies to address both research challenges and development of industrial applications. The symposium will comprise a balanced group of speakers from industry, academia, and national laboratories. Visit asminternational.org/web/suspension-2015/home for the complete schedule and to register.

Of course, ITSC 2016 is another great opportunity for the global thermal spray community to meet, exchange information, and conduct business. Next year, it takes place in Shanghai—the largest Chinese city by population and the largest city proper by population in the world. Shanghai sits on the south edge of the mouth of the Yangtze River in the middle of the Chinese coast. We hope to see you there next May!

Finally, the 7th Rencontres Internationales sur la Projection Thermique is taking place December 9-11 in Limoges, France. Topics include spray processes, cold spray, coatings properties, nanotechnology, and much more. Don't miss out on your chance to keep up with the latest happenings in the vast area of thermal spray technology. And don't forget to publish your work—right here in *iTSSe*. We're always looking for articles and need your help to keep this publication going strong. Contact Julie Lucko, managing editor, at julie.lucko@asminternational.org to get published here.

Sincerely,
Robert Gansert, Ph.D.
President, Advanced Materials & Technology Services Inc.

NOMINATIONS SOUGHT FOR ASM THERMAL SPRAY SOCIETY BOARD

The ASM TSS Nominating Committee is currently seeking nominations to fill three board member positions. Candidates for these director positions can be from any segment of the thermal spray community. Nominees must be a member of the ASM Thermal Spray Society and must be endorsed by five TSS members. Board members whose terms are expiring may be eligible for nomination and possible reelection on an equal basis with any other nominee. Nominations must be received no later than **March 1, 2016.** Forms can be found at tss.asminternational.org. For more information, contact Luc Pouliot at lpouliot@tecnar.com.

SEEKING SOLICITATIONS FOR TSS STUDENT BOARD MEMBERS

The ASM Thermal Spray Society is seeking applicants for its two student board member positions. Nominations are due by **April 1, 2016.** Students must be a registered undergraduate or graduate during the 2015-2016 academic year and must be studying or involved in research in an area closely related to thermal spray technology. For more information on eligibility and benefits, visit tss.asminternational.org.

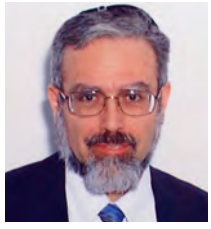
TSS ANNOUNCES NEW BOARD MEMBERS

Moreau

TSS President **Christian Moreau, FASM, TS-HoF,** professor, Concordia University, announced the new appointments to the TSS Board. New board members elected for a three-year term include: **Eric Irissou,** team leader, Thermal Spray Group at NCR, and **Julio Villafuerta,** corporate product strategist, Centerline Windsor Ltd. **Robert A. Miller,** senior materials engineer, Kennametal Stellite, was reappointed to the Board for a three-year term. In addition, **Dr. Ann Bolcavage,** FASM, Associate Fellow, Materials—Coatings, Rolls-Royce Corp., was reappointed secretary/treasurer for a one-year term. Two student members were reappointed to the Board for a one-year term: **Yoanna Shams,** University of Cambridge, and **Jeremy M. Schreiber,** Pennsylvania State University.

Irissou

Villafuerta



Miller

Bolcavage

Shams

Schreiber

TSS MEMBERS HONORED AT MS&T 2015

ASM President Sunniva R. Collins, FASM, welcomed three new TSS members to the 2015 Class of Fellows and presented a TSS member with the Distinguished Life Membership Award at MS&T15 in Columbus, Ohio, in October.

TSS President Christian Moreau also presented the TSS Meritorious Service Award at the event.

ASM FELLOWS

Victor K. Champagne, FASM, leader of ARL Center for Cold Spray, U.S. Army Research Laboratory, Aberdeen, Md. His citation reads, "For serving as the international champion of cold spray technology through exemplary research, development, qualification, and persistent dedication toward transition and implementation throughout all sectors of industry and the Department of Defense."

Petri Vuoristo, FASM, professor, Tampere University of Technology, Finland. His citation reads, "For continuous and dedicated contributions toward the advancement of thermal spray, cold spray, and laser cladding technologies worldwide through education and practice."

Zbigniew Zurecki, FASM, senior research associate**,** Air Products & Chemicals Inc., Allentown, Pa. His citation reads, "For conceptualization and sustained development of cleaner, safer, and environmentally-friendlier alternatives to many conventional methods of processing metals resulting in improved product quality and increased productivity of industrial operations."

DISTINGUISHED LIFE MEMBERSHIP

Richard L. Wilkey, president, Fisher-Barton Group, Waukesha, Wis., received this year's Distinguished Life Membership award "for the entrepreneurial drive in business creation and growth and persistent and aggressive advancement in materials science and engineering and the people and industries who use them." This award was established in 1954 and is conferred on leaders who have devoted their time, knowledge, and abilities to the advancement of the materials industries.

PRESIDENT'S AWARD FOR MERITORIOUS SERVICE

Mitchell R. Dorfman (left) was presented the 2015 TSS President's Award for Meritorious Service by TSS President Christian Moreau, FASM, TS-HoF (right). Dorfman's plaque reads, "in sincere and grateful appreciation for exemplary service to the ASM Thermal Spray Society."

THERMAL SPRAY SOCIETY EDUCATION COURSES

Visit asminternational.org/learning to find out more about these valuable courses.

Introduction to Thermal Spray
Date: March 21-22, 2016
Location: ASM World Headquarters, Materials Park, Ohio
Instructor: Richard A. Sayman

As the thermal spray profession has changed, so has the need to ensure safe and consistent methods for thermal spray operators. ASM International brought together the leaders in the Thermal Spray Society to compile their knowledge and experience in a comprehensive, easy to understand course.

Thermal Spray Technology
Date: July 26-27, 2016
Location: ASM World Headquarters, Materials Park, Ohio
Instructor: Chris Berndt, FASM

Coating reliability and effectiveness requires overlay coatings to be selected, engineered, and applied correctly. This course provides a thorough grounding and understanding of thermal spray processes, depicts complex scientific concepts in terms of simple physical models, and integrates this

knowledge into practical engineering applications and commonly accepted thermal spray practices.

Advanced Thermal Spray Technology
Date: July 26-27, 2016
Location: ASM World Headquarters, Materials Park, Ohio
Instructor: Chris Berndt, FASM
Thermal spray is increasingly used to manufacture net shapes, advanced sensors, and materials for the biomedical and energy/environmental industries. These and a vast array of emerging applications take advantage of the rapid and cost-effective capabilities of thermal spray technology in the OEM and repair industries.

REGISTER NOW FOR THERMAL SPRAY OF SUSPENSIONS & SOLUTIONS SYMPOSIUM (TS4)

Thermal Spray Suspensions & Solutions Symposium (TS4) takes place December 2-3 in Montreal. This symposium is a chance for scientists and engineers interested in the emerging S&STS technologies to address both research challenges and development of industrial applications. The symposium will comprise a balanced group of speakers from industry, academia, and national laboratories. Visit asminternational.org/web/suspension-2015/home for the complete schedule and to register.

ITSC 2016, "THERMAL SPRAY: FOSTERING A SUSTAINABLE WORLD FOR A BETTER LIFE"

Mark your calendars for May 10-12, 2016, in Shanghai. This annual event is jointly organized by the German Welding Society (DVS), ASM International's Thermal Spray Society (TSS), and the International Institute of Welding (IIW). This year, the organizers are proud to be supported by their Chinese partners as Host Organizers of ITSC 2016: TSCC—Thermal Spray Committee of Chinese Surface Engineering Association and SICCAS—Shanghai Institute of Ceramics, Chinese Academy of Sciences. Visit asminternational.org/web/itsc-2016-expo/home for the complete schedule and to register.

THERMAL SPRAY ALUMINUM COATINGS FOR SPLASH ZONE STRUCTURES—PART I

Recent advances in thermal spray techniques enable thermal spray aluminum coatings to reliably protect offshore structures in splash zones.

Deepashri D. Nage, *L&T Hydrocarbon Engineering Ltd., Mumbai, India*

Offshore oil and gas platforms are subjected to hostile, corrosive marine environments and require continuous operational and preventive maintenance to ensure safe operation. These platforms face significant exposure to seawater immersion, splash zone, and salty, moist air. Steel corrosion in these environments can be greater than 100 mils per year[1]. The intensity of corrosion of an unprotected steel structure in seawater varies noticeably relative to the mean high and low tide level as shown in Fig. 1.

Submerged zones have a corrosion rate as low as 0.015 mm per year due to lack of oxygen and do not usually require protection. Immersed and tidal zones rely on cathodic protection for corrosion control. However, splash zones typically range from -3 to 6 m of mean sea level (MSL). This is the most severely attacked region due to continuous contact with highly aerated sea water and the erosive effects of spray, waves, and tidal actions. Cathodic protection in this area is ineffective due to intermittent contact with seawater.

CORROSION PROTECTION IN THE SPLASH ZONE

The corrosion rate of unprotected steel in the splash zone can exceed 30 mils per year. As a result, an exotic protection method is required. Traditionally, Monel sheathing in the splash zone was used and a typical system consisted of vinyl or chlorinated rubber coatings in multiple layers with a total build of 250–300 µm (10–12 mils). Over time, inorganic zinc silicate primers were incorporated into the systems as well as epoxy intermediate coats. These systems were used for several decades with good results, and inorganic zinc/epoxy/urethane systems are still used today. Current technologies include use of organic zinc-rich primers, higher build epoxies, and polysiloxane coatings. Glass flake reinforced epoxies and polyethylene are also prevalent for abusive conditions with thicknesses up to 1500 µm.

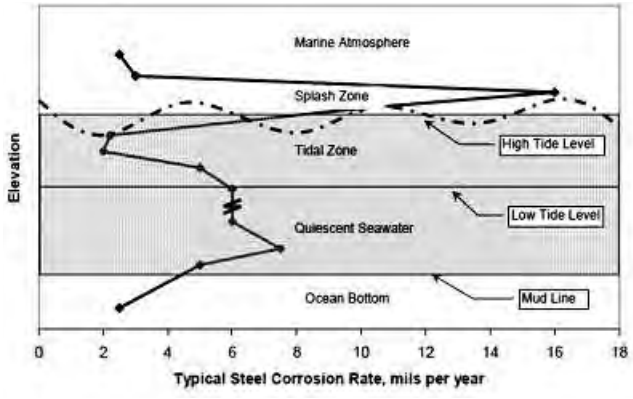


Fig. 1 — Steel corrosion rate relative to sea level.

Recently, the oil and gas industry has begun using thermal spray aluminum (TSA) coatings to protect steel structures in the splash zone. Extensive testing and industry experience in marine environments indicate that TSA coatings are a long-term solution for protection of hot risers in submerged, splash zone, and atmospheric service environments[1]. TSA is recommended in NORSOK (M-501-surface preparation and protective coating) and in NACE RP-0176-2003.

Thermal spray coatings are generally used to hardface seats and valve balls, refurbish rollers for high temperature and/or wear resistance, and are usually used in confined areas. Thermal spray application in open yards on very large structures is challenging. TSA coatings are one of the most successful protective coatings for splash zone of offshore structures, and their performance is well documented by the American Welding Society (AWS), U.S. Navy, British standards, Norwegian offshore studies, and The Welding Institute (TWI).

A recent AWS study evaluated various parameters such as coating thickness, surface preparation, and sealer coatings in long-term exposures in several environments. Sealed TSA-coated panels (80 µm) at Wrightsville Beach, N.C., exhibited no damage to the underlying steel after 19 years of exposure[2]. In addition, the main result of a study conducted by the U.S. Navy shows successful performance of a 125-micron unsealed TSA coating after 15-years of exposure and a 100-micron TSA coating after 18.5 years (Port Hueneme Harbor, Calif.)[3].

Further, a 1977 British Standard (BS 5493) states that a sealed TSA will protect steel from corrosion for 20 years or longer without maintenance in seawater splash-zones[4]. It should be noted, however, that TSA coatings from 1977 are the same quality as those used today. Based on these studies and the current scenario of protective coatings, TSA coatings are considered the most appropriate protective coatings for the splash zone and have even been used on a project with six legged jackets.

Fig. 2 — Surface profile measurement.

Fig. 3 — Thermal spray aluminum coating application in progress on test panel.

TABLE 1–SUMMARY OF REQUIREMENTS FOR TSA COATINGS

Spray parameters	Methods of Application	
	Arc wire spray	Flame wire spray
Arc voltage	27 V	—
Air pressure	60–80 psi	60–80 psi
Steel surface cleanliness	NACE-1 white metal/SSPC-SP5 or NACE-2 near white metal/SSPC-SP10	
Steel surface profile	65 µm (min.)	65 µm (min.)
Arc current	150 A0200A	—
Coating adhesion	225 µm (nominal)	225 µm (nominal)
Coating Porosity	>2000 psi (total coatings) >4000 psi (initial body coat)	>1000 psi
Spray distance	6–8 in.	5–7 in.
Spray pass width	1.5 in. (40 mm)	0.75 in. (20 mm)

CASE STUDY

A customer's specifications for application and performance of TSA coatings are listed in Table 1. Note that these specifications are relatively stringent. Per the protective coating requirements in this case, the following components were coated with TSA but ran into practical and technical difficulties in the application process.

All structural parts in the -3 to 6 m MSL range including jacket structures, jacket legs, braces, nodes, conductor guide framing, launch trusses, mud mat risers, boat landings, barge bumpers and guides, riser clamps, boat fenders, stairways and cross supports, sump cassion/pump, and cassions were coated with TSA by twin arc spray. This method was selected due to its anticipated quality in the most susceptible and critical zone.

Successful implementation of TSA depends on several factors, and both relative humidity and dew point can affect coating quality. In very humid environments, blast cleaned steel may re-rust or exhibit a rust bloom more rapidly than under normal ambient conditions. Thermal spray coatings should never be applied after rust bloom appears on the surface. Because of this, the ambient temperature is required to be at least 3°C (5°F) above the dew point. As in painting, surface preparation is the most crucial part of the TSA coating process. Pre-blasting and blasting operations should be carefully monitored.

Pre-blasting operations include grinding of sharp edges, fillets, corners, and welds, washing weld flux and residues with clean water, and removing oil and grease contamination per SSPC/SSPM Volume 2, grade SP1. Blasting should be done with abrasives that are dry, clean, and free from contaminants[5]. In addition, surfaces to be coated should be clean, dry, free from oil/grease, and have the specified roughness and cleanliness when the first coat is applied. The blasted surface should be coated within four hours after blasting. The surface finish needs to be minimum white metal (SSPC SP 5) with a sharp anchor profile greater than 63 µm[5].

Proper technique is critical to the success of thermal spray coatings. Poor spray technique may result in early coating failure due to poor coating adhesion or de-cohesion, excessive coating porosity, or high oxide content. Poor spray technique may also result in highly variable coating thicknesses, including areas that are deficient. It is essential to engage skilled operators and experienced applicators.

The spray pattern, stand-off distance, and spray angle are the most important factors and should be continuously monitored during arc spray. Each type and source of thermal spray equipment should be set up and operated in accordance with the manufacturer's recommended procedures. Spray parameters should be optimized primarily for coating quality and secondarily for production rate. With respect to these parameters, the operations sequence is as follows:

1. Preparatory
   - Blasting media (16-24 mesh size)
   - Blasting air (no dust or oil)
   - Comparator-test sample of 18 × 18 in.
   - Mandatory for every shift or applicator: Sample of 50 × 150 × 1.3 mm thick sheet for bend test
   - Degreasing agent (per SSPC SP1)
   - Al wire purity
   - Calibrated inspection gadgets
   - Certified operators and inspectors
   - SHE considerations
2. Surface preparation
   - Inspection: Surface temperature >10°C, relative humidity (<85%), dew point (>3°C), blasting media (20-40 mesh size garnet) for oil and salt content, blasting air for oil and contamination (less than 20 µg/cm^2)
   - Degreasing inspection: Surface grade, presence of oil and grease
   - Blasting inspection: Surface finish (SA3), surface profile (>65 µm) angular sharp profile is preferred to extent of 90-100 microns, surface contamination (Rating 2), salt content (Bresle patch, less than 10 Kg/cm^2)

3. Thermal spray application

- Inspection: Wire purity and diameter, current, voltage, air pressure (<100 psi), DFT, adhesion bond strength, certified applicator
- Intervals between blasting and sealer application is important
- DFT (dry film thickness) of the TSA is achieved with cross spray application with roughly 75-100 µm in single spray coat
- Maintain recommended spray width and gun distance
- Bond strength shall average 1800-2000 psi
- Sealer coat of Al-silicone application (theoretical coverage of >38 µm)
- Visual

General inspection and panel coating procedures are shown in the images on the previous page. Figure 2 shows surface profile measurement after blasting according to ASTM D4417. As per the customer's specification, the surface profile should be more than 65 µm. However, the actual profile was maintained on the higher side (75-90 µm) to obtain better adhesion values. Figure 3 shows preparation of the test panel (comparator) for adhesion, DFT, finish, and porosity test (ASTM E2109), which was mandatory for every applicator for qualification.

Look for Part II of this article in the February 2016 issue of *iTSSe*. **iTSSe**

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ENHANCED DIAMOND-LIKE COATINGS BOOST FUEL EFFICIENCY

A new laser arc method is being used to apply a hard carbon coating to engine components on the production line.

Scientists already know how to coat components with diamond-like carbon to minimize friction. But researchers at Fraunhofer Institute, Germany, have now developed a laser arc method that applies layers of carbon almost as hard as diamond at high coating rates and with high thicknesses. By applying the carbon coating to engine components such as piston rings and pins, fuel consumption can be reduced.

"Systematic application of our new method could save more than 100 billion liters of fuel each year over the next 10 years," says Andreas Leson, a professor at the Fraunhofer Institute for Material and Beam Technology IWS.

Although carbon-based coatings are already used in volume production, the Fraunhofer team succeeded in producing hydrogen-free ta-C coatings on an industrial scale with consistent quality. These tetrahedral amorphous carbon coatings are significantly harder and thus more resistant to wear than conventional diamond-like coatings. "Unfortunately, you can't just scrape off diamond dust and press it onto the component. So we had to look for a different method," says team member Hans-Joachim Scheibe.

PULSED LASER CONTROLS LIGHT ARC

In a similar style to old-fashioned film projectors, the laser arc method generates an arc between an anode and a cathode (the carbon) in a vacuum. The arc is initiated by a laser pulse on the carbon target. This produces a plasma made of carbon ions, which is deposited as a coating on the workpiece in the vacuum. To run this process on an industrial scale, a pulsed laser is vertically scanned across a rotating graphite cylinder as a means of controlling the arc. The cylinder is converted evenly into plasma due to the scanning motion and rotation. To ensure a consistently smooth coating, a magnetic field guides the plasma and filters out any dirt particles.

Fig. 1 — Volker Weihnacht, Andreas Leson, and Hans-Joachim Scheibe (left to right) developed a new laser arc method of depositing friction-reducing, wear-resistant coatings on components. Courtesy of Dirk Mahler/Fraunhofer.

The laser arc method can be used to deposit very thick ta-C coatings up to 20 μm at high coating rates. "High coating thicknesses are crucial for certain applications—especially in the auto industry, where components are exposed to enormous loads over long periods of time," says researcher Volker Weihnacht.

One of the early adopters of this promising technology is BMW. The auto manufacturer is working intensively on industrial-scale implementation of ta-C engine components in its various vehicle models with the aim of reducing fuel consumption. Leson views this as the first major step in using the laser arc method to save resources. And as a motorcycle aficionado himself, he sees another positive effect stemming from this development. "The fact that our research is helping to make motorcycling more environmentally friendly eases my conscience every time I go for a ride," he says. **iTSSe**

For more information: Andreas Leson, Fraunhofer Institute for Material and Beam Technology IWS, 49.351.83391.3317, Winterbergstr. 28, 01277 Dresden, www.fraunhofer.de/en.html.

JTST HIGHLIGHTS

The *Journal of Thermal Spray Technology* (*JTST*), the official journal of the ASM Thermal Spray Society, publishes contributions on all aspects—fundamental and practical—of thermal spray science, including processes, feedstock manufacture, testing, and characterization. As the primary vehicle for thermal spray information transfer, its mission is to synergize the rapidly advancing thermal spray industry and related industries by presenting research and development efforts leading to advancements in implementable engineering applications of the technology. Articles from the October and December issues, as selected by JTST Editor-in-Chief Christian Moreau, are highlighted here.

The October issue focuses on suspension and solution thermal spraying. The first four articles highlighted below are from this issue. The December issue is also a special issue, featuring the 6th Asian Thermal Spray Conference (ATSC-6). The last article highlighted below is from that issue. In addition to the print publication, *JTST* is available online through springerlink.com. For more information, visit asminternational.org/tss.

"DEMANDS, POTENTIALS, AND ECONOMIC ASPECTS OF THERMAL SPRAYING WITH SUSPENSIONS: A CRITICAL REVIEW"

Filofteia-Laura Toma, Annegret Potthoff, Lutz-Michael Berger, and Christoph Leyens

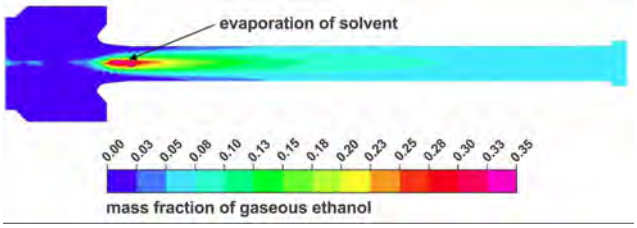
Advantages of ceramic coatings by using fine powder suspension as feedstock in APS and HVOF processes include direct feeding of fine nano- and submicron-scale particles to avoid special feedstock powder preparation, the ability to produce coating thicknesses in the 10-50 µm range, a homogeneous microstructure with less anisotropy and lower surface roughness compared to conventional coatings, and retention of initial crystalline phases. This paper discusses the main aspects of thermal spray with suspensions in order to economically produce these coatings. The efficiency of the process depends on availability of suitable additional system components (e.g., suspension feeder, injectors), development and handling of stable suspensions, and high process stability for use at the industrial scale. There is special focus on the development and processability of highly concentrated water-based suspensions. While costs and operational safety clearly require water as the liquid media for preparing suspensions on an industrial scale, its use is often critically discussed due to the required higher heat input during spraying compared to alcoholic suspensions.

Color of the HVOF flame during spraying of suspensions starting from an Al_2O_3 powder with alkali impurities.

"WHAT DO WE KNOW, WHAT ARE THE CURRENT LIMITATIONS OF SUSPENSION HVOF SPRAYING?"

A. Killinger, P. Müller, and R. Gadow

Suspension spray has evolved during the past decades and now is at the threshold of commercial use. Compared to standard powder spray methods, mainly DC plasma spray and high velocity flame spray, it is clear that suspension spray will not replace these well-established technologies. However, it can extend them by adding new coating properties. But first, many issues need to be solved. Suspension interaction with the hot gas stream is much more complex than in ordinary powder spray processes. In the case of HVOF, when an axial is injected into the combustion chamber, it is not possible to directly observe the liquid flame interaction. This paper discusses the current status of high velocity suspension flame-spray including torch concepts, torch configuration in case of a TopGun system, and different injector concepts and their influence on suspension atomization. The role of suspensions regarding their rheological and thermodynamic properties is examined, mainly given by the solvent type and the solid content. An overview of different available diagnostic methods and systems and their respective applicability is provided. Coating properties are shown and discussed for several oxide ceramics in respect to their possible applications.

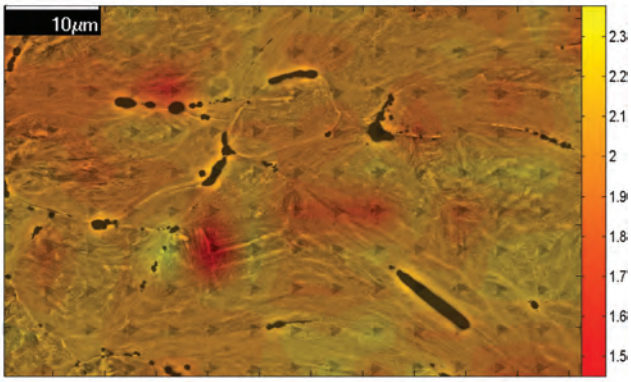


CFD simulation of mass fraction contour of gaseous ethanol in HVSF-spray process using a standard combustion chamber geometry of a TopGun. Evaporation occurs at the expansion barrel entrance.

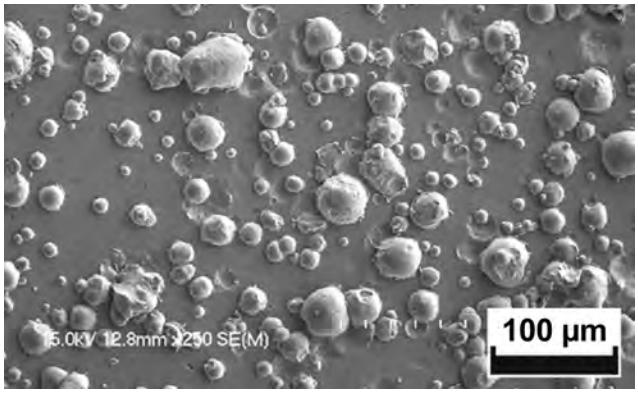
"MICROSTRUCTURAL ANALYSIS OF COLD-SPRAYED TI-6AL-4V AT THE MICRO- AND NANO-SCALE"

A.M. Birt, V.K. Champagne Jr., R.D. Sisson Jr., and D. Apelian

The microstructure of cold sprayed Ti-6Al-4V is different than any structure resulting from any other processing technique. The unique characteristics are derived from the solid



Nanohardness in GPa shown as 2D heat maps overlaid on microstructures for nitrogen sprayed sample C1.



Morphology of substrates observed at center of sprayed region, deposited particles on mirror-polished substrate.

state thermomechanical processing of predominantly martensitic feedstock powders. During deposition, these powders undergo high strain rate deformation, leading to shear band induced transformation of martensitic grains into nanoscale martensite, equiaxed alpha structures, and nanostructured alpha grains. The resulting microstructure evolution depends on the magnitude and direction of shear undergone by the particles. The specific structure and mechanism for formation of these regions is discussed in detail using nanohardness mapping, scanning electron microscopy, and transmission electron microscopy.

"INFLUENCE OF SUBSTRATE SURFACE OXIDE FILM THICKNESS ON THE DEPOSITION BEHAVIOR AND DEPOSITION EFFICIENCY IN THE COLD SPRAY PROCESS"

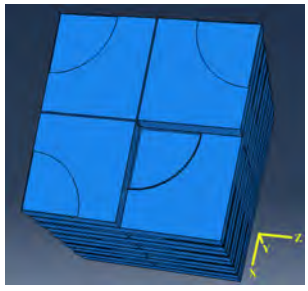
Yuji Ichikawa and Kazuhiro Ogawa

Cold spray deposition accelerates particles by means of a supersonic gas jet at a gas temperature that is usually lower than the melting point of the powder material, solving oxidation and phase transformation problems. Accordingly, it is expected that an alternative technique of MCrAlY coatings is used for high-temperature oxidation and hot corrosion protection. Thus far, MCrAlY coatings have been deposited by thermal spraying techniques (e.g., LPPS or HVOF). Cold spray deposition for MCrAlY coatings has been demonstrated and, while the mechanism of this process has been studied with various approaches, it is not yet completely understood. A previous study shows that a nascent surface created during the high-velocity impingement of particles affects the deposition process. Large scale plastic deformation of the metallic substrate and particles easily occurs during impact. In contrast, covered thin oxide films cannot deform plastically. Unfollowable large plastic deformation breaks the oxide film. During this deformation process, the native oxide film on the substrate disintegrates; subsequently, the newly formed surface may cause direct contact and initiate deposition. Therefore, the surface oxide layer is expected to affect the quantity of generating newly formed surface formation and consequently the cold spray deposition process. Clarification of the oxide film influence for deposition phenomenon is beneficial for understanding the deposition mechanism. Moreover, it is invaluable in the decision of spray condition optimizing and pretreatment.

"RELATIONSHIP BETWEEN LAMELLAR STRUCTURE AND ELASTIC MODULUS OF THERMALLY SPRAYED THERMAL BARRIER COATINGS WITH INTRA-SPLAT CRACKS"

Guang-Rong Li, Bo-Wen Lv, Guan-Jun Yang, Wei-Xu Zhang, Cheng-Xin Li, and Chang-Jiu Li

The elastic modulus of plasma-spray top coatings plays an important role in the thermal cyclic lifetime of thermal-spray thermal barrier coatings (TBCs) because thermal stress is determined by the substrate/coating thermal mismatch and the elastic modulus of the top coating. Consequently, it is critical to understand the relationship between the elastic modulus and lamellar structure of the top coating. However, neglecting the intra-splat cracks connected with inter-splat pores often leads to poor prediction in the in-plane modulus. In this study, a modified model taking account of intra-splat cracks and other main structural characteristics of plasma-sprayed yttria-stabilized zirconia (YSZ) coatings was proposed. Based on establishing the relationship between elastic modulus and structural parameters of the basic unit, effects of structural parameters on the elastic modulus of coatings were discussed. Predicted results are consistent with experimental data on coating the elastic modulus in both out-plane direction and in-plane direction. This study benefits the further comprehensive understanding of the failure mechanism of TBCs in thermal cyclic conditions.



Structural model of this study: The reverse side of uniform distribution with one part missing.

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HTPRO

BUSINESS AND TECHNOLOGY FOR THE HEAT TREATING PROFESSIONAL

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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.

March: Thermal Processing in the Aerospace Industry

June: Testing and Process Control

October: Thermal Processing in Automotive Applications

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.

UNIQUE GAS GENERATOR PROVIDES LOW COST, RELIABLE HYDROGEN SUPPLY

Goutam Shahani, Kyle Finley, Nick Onelli, and Grzegorz Moroz

Gas generator combines steam methane reforming with an integrated heat recovery system to reduce the cost and improve the reliability of hydrogen gas supply.

REDUCING THE COST OF HEAT TREATING ATMOSPHERES

Bud Weiland

Conserving utilities is the simplest, most practical way for heat treaters to reduce costs and remain competitive.

DEPARTMENTS

ABOUT THE COVER

Bell-furnace heat-treating installation. Courtesy RAD-CON Inc., Cleveland. www.rad-con.com.

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HTS CONFERENCES AND EXPOS KEEP HEAT TREATERS UP TO DATE

Pressure on heat treaters continues to come from all directions including becoming more energy efficient, meeting increasingly stricter environmental regulations, providing faster turnaround times, producing higher quality parts, and keeping better records.

To ensure that your skills and talents match your company's and customer's needs, it's important not to fall behind as new developments are continually brought on stream. How can you keep up? Some methods to stay on top of the rapidly changing technical horizon include on-the-job training, continuing education, refresher courses, and self-learning through technical materials such as reference books and engineering magazines.

Conferences and expositions are also available, which focus on either a full range of heat treating topics or one specific technology area. In addition, technical conferences and expos are a proven, efficient way to bring new products and services directly to target audiences. Equipment suppliers and service providers are continually working to offer the tools required to help heat treaters stay on the leading edge of technology and survive in the globally competitive market. Expos are highly visible and interactive forums where you can meet face-to-face with hundreds of users and potential clients, assess the competition, and network with colleagues.

That these conferences are considered to be very important was evident in the more than 2100 attendees at Heat Treat 2015 in October in Detroit. Along with the 144 high quality technical presentations, nearly 200 companies highlighted their equipment, products, and services. Put a note on your calendar to mark Heat Treat 2017, taking place October 24-26, 2017, in Columbus, Ohio.

ASM's Heat Treating Society will continue to sponsor events that help raise the bar of heat treating expertise. If you are interested in helping to plan these events, consider joining the HTS Technology and Programming Committee. Contact Joanne Miller at 440.338.5151 ext. 5513, joanne.miller@asminternational.org.

Ed Kubel
Contributing Editor

IFHTSE
23RD IFHTSE CONGRESS

23rd IFHTSE CONGRESS

April 18-22, 2016
Savannah, Ga.

The 23rd IFHTSE Congress sponsored by the ASM Heat Treating Society and the International Federation of Heat Treatment and Surface Engineering (IFHTSE) brings together international experts from around the globe to present some of the latest developments in thermal processing, heat treating, and surface engineering. Technological advancements in these areas are crucial to cost-effective manufacturing of products in nearly all industries.

The technical program covers a wide range of topics including computational fluid dynamics as applied to thermal processing; atmosphere prediction and processing including traditional and vacuum processing; vacuum processes and technology; thermochemical treatment (e.g., carburizing, nitriding, nitrocarburizing); hardening and hardenability; coating technology including surface modification and thin film deposition for corrosion and tribology requirements; and much more.

For more information, visit asminternational.org/web/ifhtse.

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CONFERENCE AND EXPOSITION

27TH AEROMAT CONFERENCE AND EXPOSITION

May 23-26, 2016
Meydenbauer Center, Bellevue, Wash.

AeroMat, sponsored by ASM International, is the premier aerospace materials conference in the world. The event includes a highly informative technical program with a plenary session featuring presentations by leading players in the aerospace field and technical sessions with more than 150 presentations covering some of the latest developments in aerospace materials and processes. The event also includes an exposition of aerospace products and services from over 80 companies and organizations, as well as education workshops and a host of networking functions.

For more information, visit asminternational.org/web/aeromat-2016.

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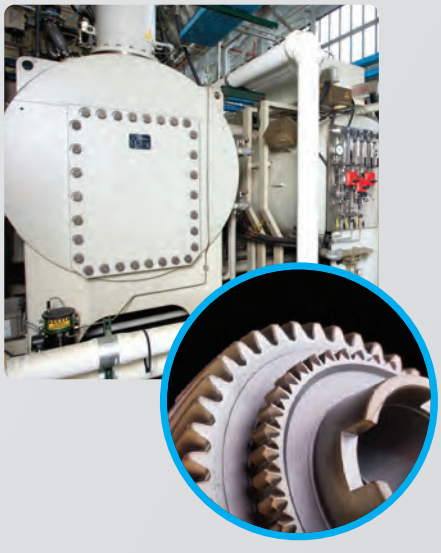

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HTS MEMBERS INDUCTED INTO ASM'S CLASS OF FELLOWS AT MS&T15

Dr. Joseph W. Newkirk, associate professor, Missouri University of Science and Technology, Rolla, was inducted as ASM Fellow at the MS&T15 Awards Ceremony on October 6 in Columbus, Ohio. Newkirk (right) accepts his citation from ASM President Sunniva Collins, FASM.

Prof. Yongho Sohn, professor, University of Central Florida, Orlando, was inducted as ASM Fellow at the MS&T15 Awards Ceremony on October 6 in Columbus, Ohio. Sohn (left) accepts his citation from ASM President Sunniva Collins, FASM.

Prof. Chester J. Van Tyne, FIERF professor, Colorado School of Mines, Golden, was inducted as ASM Fellow at the MS&T15 Awards Ceremony on October 6 in Columbus, Ohio. Van Tyne (left) accepts his citation from ASM President Sunniva Collins, FASM.

Mr. Zbigniew Zurecki, senior research associate, Air Products & Chemicals Inc., was inducted as ASM Fellow at the MS&T15 Awards Ceremony on October 6 in Columbus, Ohio. Zurecki (left) accepts his citation from ASM President Sunniva Collins, FASM.

HTS MEMBERS RECEIVE ASM AWARDS AT MS&T15

Mr. Richard L. Wilkey, president, Fisher-Barton Group, Waukesha, Wis., was awarded Distinguished Life Membership at the MS&T15 Awards Ceremony on October 6 in Columbus, Ohio. Wilkey (right) accepts his award from ASM President Sunniva Collins, FASM.

Dr. Frederick E. Schmidt, FASM, senior managing consultant and director, materials technology, Engineering Systems Inc., Aurora, Ill., received the William Hunt Eisenman Award at the MS&T15 Awards Ceremony on October 6 in Columbus, Ohio. Schmidt (right) accepts his award from ASM President Sunniva Collins, FASM.

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 the Heat Treating Society website at hts.asminternational.org/portal/site/hts/HTS_Awards.

Paper submission deadline is December 11. 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.

MPI AND CHTE TO DIRECT ROADMAP IMPLEMENTATION FOR ADVANCING THERMAL MANUFACTURING

Thermal manufacturing plays a major role in the U.S. economy, employing more than five million people and producing nearly $3 trillion in value of product shipments annually. It promises to play an even greater role in the near future with the launching of a new roadmap, *Advancing Thermal Manufacturing: A Technology Roadmap to 2020*, developed by a consortium of experts from industry and academia.

Its purpose is to accelerate the development, adaptation, and implementation of advanced technologies throughout the thermal manufacturing community. These advances will drive greater efficiency and productivity in manufacturing, resulting in improved sustainability and global competitiveness.

The roadmap was developed over the past year by the Thermal Manufacturing Industries Advanced Technology Consortium (TMI ATC), a working group under the direction of ASM International including the Metal Processing Institute (MPI) and the Center for Heat Treating Excellence (CHTE), both located at Worcester Polytechnic Institute (WPI). Other group members include the Industrial Heating Equipment Association (IHEA), Metal Treating Institute (MTI), Association for Iron and Steel Technology (AIST), Oak Ridge National Laboratory (ORNL), Forging Industry Association (FIA), and the ASM Heat Treating Society (ASM HTS). Through facilitated workshops, TMI ATC gathered input for the roadmap from trade associations, professional societies, academic researchers, and companies who conduct thermal manufacturing processes. TMI ATC is funded by an 18-month planning grant from the National Institute of Standards and Technology (NIST) Advanced Manufacturing Technology Consortium (AMTech).

The benefits of thermal manufacturing have a far reaching impact. Courtesy of Nexight Group.

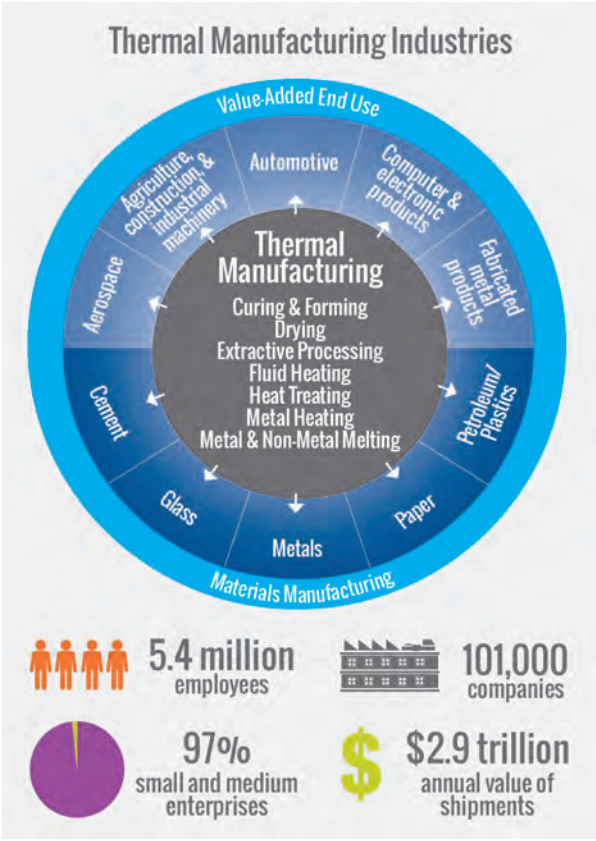
Up to now, various manufacturing sectors like heat treating, drying, curing and forming, extractive processing, metal casting, and technology transfer worked independently to enhance thermal manufacturing processes. Because these groups were acting alone, attracting the resources necessary to implement their plans was difficult. Thus, many challenges to developing and deploying advanced manufacturing technologies highlighted in earlier studies remain unaddressed today.

"This is the first time a thermal manufacturing group representing various sectors is working together to pool resources and knowledge," explains Terry Mosier, managing director of ASM International. "Collaboration is critical, and ASM is pleased to lead this initiative with help from MPI, CHTE, and many others."

ROADMAP PRIORITIES

There are seven priority action items in TMI ATC's roadmap. Four that require research and development work that will be carried out by MPI and CHTE staff and resources at WPI include:

- Increasing the robustness of materials used in thermal-processing equipment



Thermal manufacturing consists of a wide range of heat-driven processes used in nearly every manufacturing industry. Courtesy of Nexight Group.

- Advancing tools to model and simulate entire thermal manufacturing processes
- Improving understanding of performance requirements and development needs of thermal-manufacturing sensors
- Identifying and implementing hybrid thermal processes and novel applications for existing thermal manufacturing

WPI will also take the lead in establishing a thermal manufacturing demonstration facilities network.

"WPI is uniquely qualified to work on this initiative," explains Diran Apelian, director of MPI. "Under the umbrella of MPI, we not only have CHTE, but also the Advanced Casting Research Center (ACRC) and the Center for Resource Recovery and Recycling (CR3), and the Center for Advanced Research in Drying (CARD), incredible knowledge and expertise that will come together to further progress in thermal manufacturing. We are thrilled to be a part of this work," says Apelian.

The impact of thermal manufacturing on the industry is significant. According to Nexight Group, a technical and management consulting group located in Silver Springs, Md., the benefits of advanced manufacturing technologies are far reaching. About 5.4 million people work in the industry and are employed by about 101,000 companies. Of this group, 97% are small and medium enterprises, which is why it is critical to the U.S. economy to secure funds to implement TMI ATC's roadmap. Nexight was hired by ASM to lead the TMI ATC roadmap development and facilitate implementation planning for priority actions that resulted.

ASM and WPI jointly launched *Advancing Thermal Manufacturing: A Technology Roadmap to 2020* to the industry at the ASM Heat Treat Society Conference and Exposition in Detroit in October.

It is anticipated that NIST will provide additional funds for implementation through the AMTech program in FY 2016, with additional financial support for implementing this five-year plan being sought through various approaches. To learn more, visit tmiatc.org.

CHTE is located in Worcester, Mass., on WPI's New England campus. The university was founded 150 years ago this year. For more information about CHTE, visit wpi.edu/+chte, call 508.831.5592, or email Rick Sisson at sisson@wpi.edu, or Diran Apelian at dapelian@wpi.edu.

UNIQUE GAS GENERATOR PROVIDES LOW COST, RELIABLE HYDROGEN SUPPLY

A Hyrdroprime gas generator plant offers a flexible hydrogen supply solution to the powder metallurgy industry.

Goutam Shahani, Kyle Finley, Nick Onelli, and Grzegorz Moroz, Linde Group, Blue Bell, Pa.

Hydrogen furnace atmospheres in conjunction with nitrogen or argon, carbon monoxide, and methane provide protective and oxide-reducing characteristics, which enhance the physical and chemical properties of heat treated metal products. Gas mixtures containing hydrogen are used as a protective atmosphere in many heat treating processes including annealing, brazing, and sintering. This article provides an overview of Hydroprime, a unique steam methane reformer that uses an integrated heat recovery system to reduce the cost and improve the reliability of hydrogen gas supply.

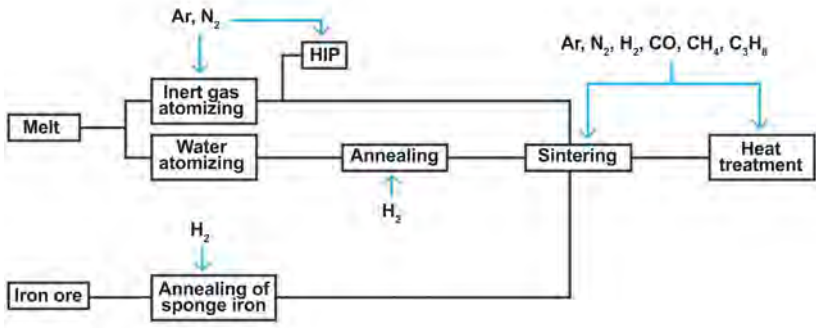


Fig. 1 — Gas atmospheres are used in the production of metal powders and in the sintering and heat treatment of powder metallurgy parts.

Hydrogen and nitrogen atmospheres are used in the sintering and annealing of powder metallurgy (PM) parts to enhance the physical and chemical properties of these products as shown in Fig. 1. Relatively small volumes of hydrogen (<1095 Nm^3/h, or 1 MMSCFD, million standard cubic feet per day) are supplied in bulk by trailer, or produced on site by electrolysis, methanol, and ammonia dissociation, as well as steam methane reforming (SMR). Steam methane reforming is the dominant method used to produce hydrogen at a relatively large scale (>1095 Nm^3/h), but the technology has not been widely adopted at a small scale due to cost and reliability considerations. Linde's Hydroprime plant is an innovative hydrogen generator based on proven steam methane-reforming technology. The plants are compact, efficient, and flexible. Figure 2 shows a representative plant.

Fig. 2 — Representative Hydroprime plant.

HYDROPRIME PROCESS TECHNOLOGY

Steam methane reforming is the predominant method used to produce hydrogen on an industrial scale. Hydroprime plants use a unique heat integration concept combined with SMR. In the process, desulfurized natural-gas feed is mixed with preheated water and fed into tubes filled with nickel catalyst. Reactions that occur at elevated temperature and pressure include:

- Reforming: $CH_4 + H_2O \leftrightarrow CO + 3H_2$ (1)
- Shift reaction: $CO + H_2O \leftrightarrow CO_2 + H_2$ (2)

Approximately 75% of the conversion to hydrogen occurs in reaction (1). Reaction (2) drives the equilibrium balance further to yield a hydrogen-rich gas. Reforming is an endothermic reaction, while shift conversion is an exothermic reaction. Both reactions (1) and (2) occur in the reformer. However, only reaction (2) occurs in the shift converter. The shift reaction uses a promoted iron-oxide catalyst. Both reactions are equilibrium limited based on outlet temperature and pressure. Reaction products are a mixture of H_2, CO, CO_2 and H_2O. A simplified block flow diagram of the SMR process is shown in Fig. 3.

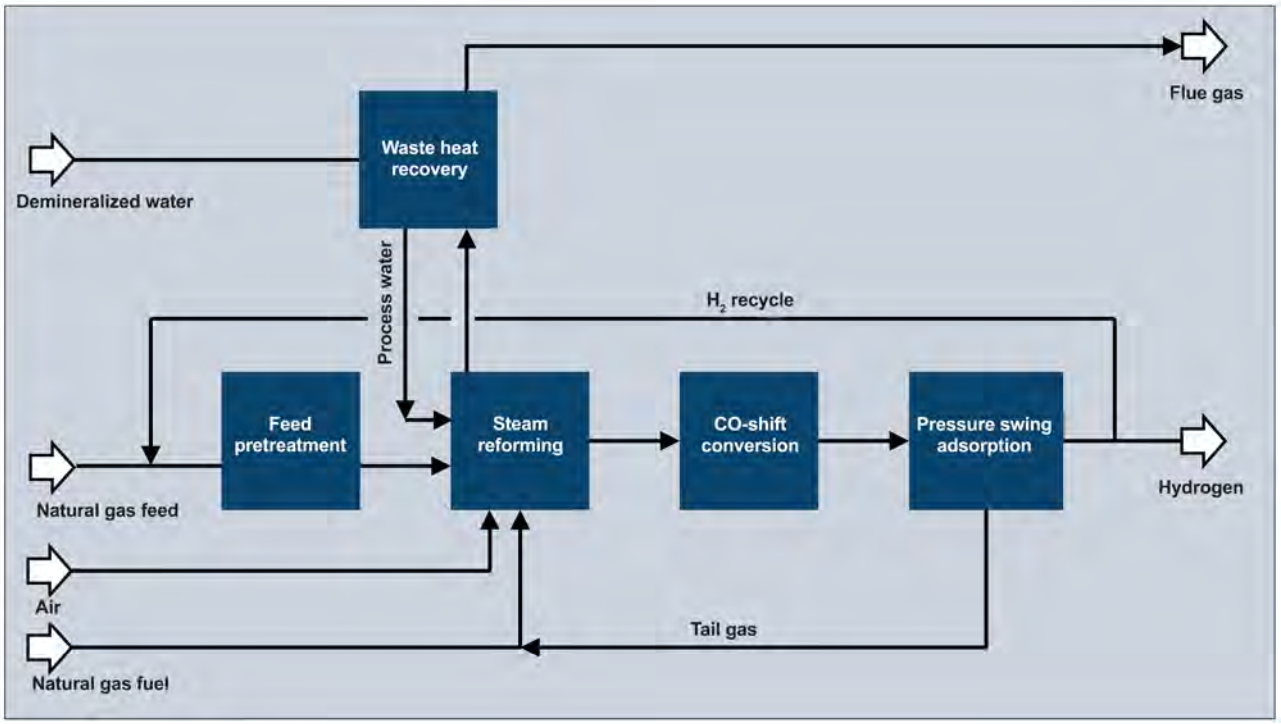


Fig. 3 — Flow diagram of steam methane reforming (SMR) process.

The overall reforming reactions are endothermic (require heat), which is supplied by the combustion of fuel. Tail gas from the pressure swing adsorption (PSA) system meets most of the fuel requirement with the rest being supplied by natural gas.

The hydrogen-rich stream is purified using pressure swing adsorption. PSA is a physical process that depends on selective physical binding of gas molecules. Hydrogen is essentially not adsorbed by the proprietary adsorbent material, a mixture of carbon molecular sieve and zeolites, because it is nonpolar and highly volatile. The system operates on a repeated cycle consisting of two basic steps: adsorption and regeneration. Regeneration consists of depressuring, purging, and repressuring.

PLANT DESIGN

Inputs to the modular plant are natural gas, demineralized water, and electric power. Outputs are high purity, gaseous H_2. There is no export steam. This plant produces H_2 with the following specifications:

- Flow rate: 165-330 Nm^3/h
- Purity: 99.999+%
- Pressure: 13.8 barg

The plant is designed to be easily shipped all over the world. It can be hauled on a flatbed truck, thereby simplifying logistics and transportation. Figure 4 shows a 14 m long by 3 m wide by 4 m high partly assembled plant module in transit.

Plants are heat integrated for high thermal efficiency. Typical operating characteristics for a 330 Nm^3/h (0.3 MMSCFD) plant are:

Operating parameter	
H_2 capacity, Nm^3/h	330
H_2 purity, %	99.999
$CO + CO_2$, ppm	<1
Pressure, barg	13.8
Natural gas /H_2 MM cal/Nm^3 H_2 (HHV)	4.4
Power, kW	60
Demineralized water, kg/h	550

These results were achieved in actual commercial operation over an extended time.

Advantages of the Hydroprime plants include:

- Simple, quick site installation
- Outdoor installation
- Excellent accessibility for maintenance
- Small footprint

The plants are standardized with fully automatic failsafe controls, allowing unattended operation with remote start-up and 24/7 monitoring. This enables quick response to

Fig. 4 — Hydroprime plant in transit.

even the slightest production interruption. Furthermore, the system provides virtually 100% uptime for H_2 product supply with the addition of a simple liquid backup tank.

USER BENEFITS

Hydroprime plants offer a viable alternative for relatively small (<1095 Nm^3/h) hydrogen requirements. The plants are shop fabricated with efficient use of labor in a controlled environment, ensuring high quality control. Modular design reduces field construction, minimizes risk, and provides a faster project schedule. The plants also provide superior environmental and safety performance based on low emissions and reduced truck deliveries. Furthermore, the combination of low utility consumption and high reliability offers a cost-competitive solution for relatively small, industrial hydrogen consumers. Linde can provide "over-the-fence" supply of H_2 molecules. In this arrangement, the end-user purchases the molecule under long term contract, eliminating the need for any capital investment and responsibilities related to ownership such as installation, operation, maintenance, repair, insurance, manning, and back-up of product in case of plant stoppage. Alternatively, these plants can also be owned and operated by the end user.

CONCLUSIONS

A Hydroprime gas-generator plant is a standardized steam methane reformer developed to reduce the cost of and improve the reliability of hydrogen supply for relatively small industrial consumers, offering advantages over traditional supply modes such as electrolytic plants, conventional steam methane plants, and truck-delivered bulk hydrogen. Hydroprime plants are highly heat integrated, which translates into low operating cost, and they offer high reliability and both superior environmental and improved safety performance. The modular units are fully automatic with fail-safe controls, allowing unattended operation with remote start-up and monitoring. Modular open-skid design provides easy site installation and accessibility for maintenance. Ten units have been built, nine of which have been in commercial operation for a long time, demonstrating performance in a variety of applications worldwide.

For more information: Goutam Shahani, Linde Group, 5, Sentry Parkway East, Blue Bell, PA 19422; 267.992.4364, goutam.shahani@linde-le.com, www.linde-engineering.com.

REDUCING THE COST OF HEAT TREATING ATMOSPHERES

Conserving utilities is the simplest, most practical way for heat treaters to reduce costs and remain competitive.

Bud Weiland, ERC International Inc., Cleveland

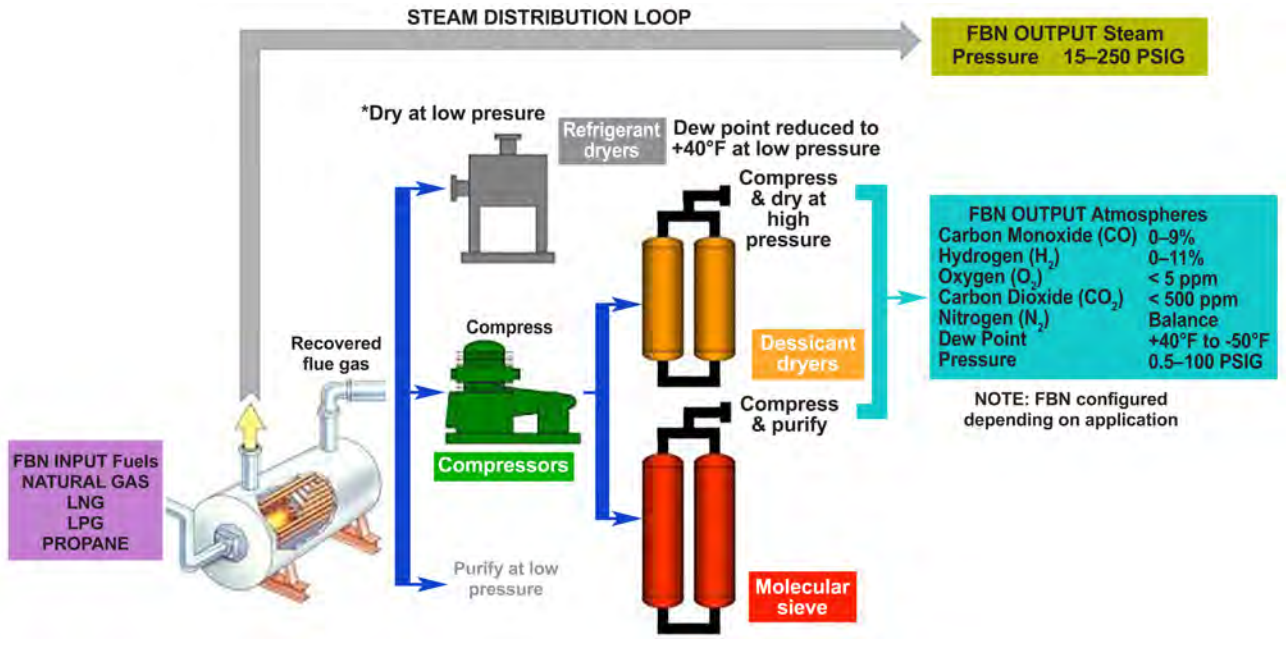
While natural gas costs have been declining since 2014, bulk nitrogen costs have not followed the same track. As nitrogen supply becomes an increasing portion of the total cost to process metal products, technologies to generate nitrogen on-site become viable. Many of the largest industrial gas suppliers will install on-site air separation plants for producing nitrogen for their larger consumers, but these arrangements typically come with high-commitment take-or-pay contracts. For consumers in the middle range (e.g., 10-60,000 scfh nitrogen requirements), bulk liquid nitrogen is the least expensive among expensive options. By comparison, cogeneration technology, producing two utilities using one process, has the potential to greatly reduce costs at facilities that can fully use both utilities.

BENEFITS OF COGENERATION TECHNOLOGY

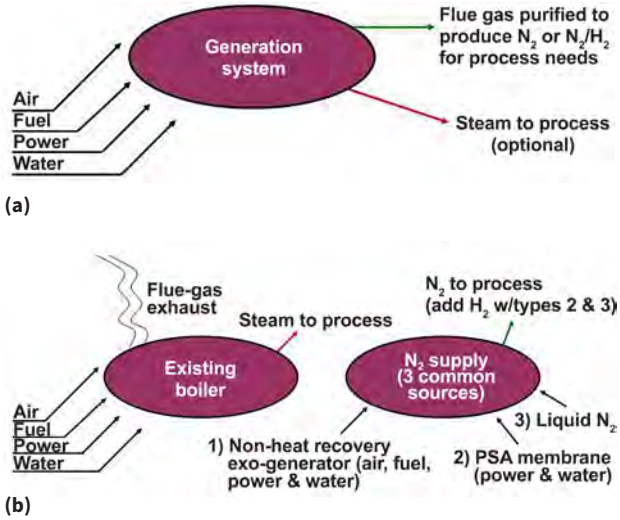
ERC International supplies cogeneration equipment to manufacturing facilities that consume both nitrogen and steam, with the largest market presence in the metals processing industries. The fastest return on investment is seen by facilities using delivered liquid nitrogen and plant steam. There is also added value to facilities generating their own endothermic gas, a carbon-intensive atmosphere used in the heat treating industry. The typical ERC user is a metal processor that has large heat treating furnaces, consumes nitrogen in the range of 10-60,000 scfh, and uses steam (or hot water) for heating acid pickling tanks. For bright annealing and annealing of medium carbon alloy steels, endothermic gas is sometimes blended with nitrogen. All of these utilities (nitrogen, steam, and the total supplies for the endothermic generator) are delivered by one ERC cogeneration unit.

ECONOMIC BENEFIT

The economic benefit comes from replacing the cost of nitrogen and endothermic gases with just the cost to run the purification section of the cogenerator. The fuel to run the steam section of the cogenerator (natural gas or propane) is equal to the fuel being used to generate plant steam and, thus, is cost neutral. The difference is that the cogenerator products of combustion are carefully controlled to be suitable for purification into a very good atmosphere gas compared with conventional plant boilers that are just venting their products of combustion. Users keep their



Schematic of ERC International fuel-based nitrogen cogeneration system.



Facility with a traditional atmosphere-generation system (a) and facility with the "atmosphere advantage" ERC cogeneration system (b).

existing boilers to fulfil excess steam demand. Therefore, the cogenerator stays at full steam, maximizing the "free" nitrogen delivered. ERC users include steel and copper-tube manufacturers, aluminum manufacturers and many other metal processing companies. Typical payback for supplied ERC units ranges from six months to one year. ERC conducts surveys at prospective plants to determine the potential economic value.

PROTECTIVE ATMOSPHERE

The high purity atmosphere produced by ERC cogenerators is well suited for annealing and many other metal-processing applications. The output contains not only nitrogen (N_2), but also the required reducing gases (H_2 and CO) necessary for successful processing of metals to produce a superior bright finish. For annealing medium- and high-carbon steels where decarburization must be avoided, enhanced purification is provided to further reduce CO_2, H_2O and O_2 to levels approaching those of 99.999% liquid nitrogen. The atmosphere is much more robust than straight nitrogen due the presence of H_2 and CO, and tolerates furnace leaks and other sources of CO_2, H_2O and O_2, while still producing a superior metal finish.

GREEN TECHNOLOGY

Besides the direct economic benefit from nitrogen savings, the ERC unit can result in reduced emissions. Given that the products of combustion from steam boiler operation are not vented, but instead are recycled to the heat treating furnace, total emissions of the heat treating facility are minimized. Especially when replacing nitrogen/endothermic systems, a study should be conducted to determine the magnitude of a reduced carbon footprint, and the value of potential credits to the facility.

Steam/exo gas cogenerator for processing alloy-steel tubes at PTC Alliance in Fairbury, Ill.

CASE STUDY: QUALITY/COST UPGRADE

In 2010, a steel-tube manufacturer (PTC Alliance, Fairbury, Ill.) upgraded an existing furnace to enable processing medium-carbon steel tubes, producing a bright finish without decarburization on the inside or outside of the tubes. Prior to the upgrade, the furnace was used to process low-carbon steel tubes, and did not have the capability to produce tubes free of decarburization (which was not a problem for the market they were serving). The goal of the project was to convert the furnace to enable processing high-strength automotive products.

The company consulted the furnace manufacturer about making the necessary furnace conversion, and it was recommended to take the traditional approach of converting to nitrogen/endothermic atmosphere. Instead, the tube processor selected an ERC cogenerator with enhanced purification and RAD-CON atmosphere control system. The resulting bright finish on the steel tubes exceeded expectations, and met all decarburization specifications on the inside and outside of the tube. Today, the plant continues to successfully produce tubes for this application.

OTHER APPLICATIONS

Other manufacturers that installed ERC cogenerators over the past two decades include carbon-steel tube manufacturers, steel-coil producers, companies producing steel laminations for motors, aluminum producers, steel rod and bar suppliers, steel golf-shaft manufacturers, copper and brass tubing manufacturers, and producers of sheet steel.

For more information: Christopher J. Messina, president, RAD-CON Inc., Cleveland, OH, 440.463.4224 (mobile), chris.messina@rad-con.com, www.rad-con.com, or Bud Weiland, ERC International Inc., part of the RAD-CON Group, Cleveland, 440.610.6239 (mobile).

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... tell you that you are at risk of experiencing discoloration in the next cycle?

... tell you that you will not pass the leak back test in three weeks?

What if your furnace could warn you about a heating element failure, order the part and schedule the service needed to install it?

These *what ifs* are the motivating drivers pushing predictive maintenance technology to the forefront of product development and maintenance strategies for industries across the globe. And, in the near future, customers are going to expect all heat treatment furnaces to be capable of leveraging the Internet of Things to perform such analysis.

Currently in the thermal processing industry, when a heat treatment furnace breaks, the result is clear: production comes to a grinding halt and the personnel necessary to resolve the issue might not be readily on hand. As a result, companies are faced with unplanned downtime until the problem is resolved, potential overtime wages for the necessary personnel, the cost of rushing critical part shipments and more.

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ASMNEWS

ASM AFFILIATE SOCIETIES ANNOUNCE NEW OFFICERS AND BOARD MEMBERS

In accordance with their Rules of Governance, four ASM Affiliate Societies have completed their elections for officers and board members for 2015. Please join us in welcoming the following appointments.

ASM Electronic Device Failure Analysis Society

Cheryl Hartfield, business manager, Omniprobe Products, Oxford Instruments Co., EDFAS president, announced the reappointment of **Christopher Henderson,** president, Semitracks, as finance officer for one year. **Martin Keim,** engineering manager, Mentor Graphics, was appointed to the board for a two-year term in his role as ISTFA General Chair.

ASM Heat Treating Society

Stephen G. Kowalski, president, Kowalski Heat Treating Co., succeeds as president of HTS, while **Roger A. Jones,** corporate president, Solar Atmospheres Inc., remains on the board as immediate past president. **James P. Oakes,** vice president business development, Super Systems Inc., is elected vice president. Officers serve a two-year term.

In addition, the following new members were elected to the HTS board for a three-year term: **Nathan J. Chupka,** manufacturing engineering supervisor, John Deere Waterloo Works; **Michael A. Pershing,** senior technical steward, Caterpillar Inc.; and **Craig Zimmerman,** director–technical, Bluewater Thermal Solutions. **Olga K. Rowan,** senior engineer, Caterpillar Inc., was elected for one year, to complete the unexpired term of James Oakes.

Hannah M. Noll, process engineer, ATI Specialty Materials, was appointed young professional board member and **Rachel M. Sylvester,** The Ohio State University, was appointed student board member. Both appointments are for one year.

ASM International Metallographic Society

Jaret J. Frafjord, laboratory director, IMR KHA Portland, succeeds as president of IMS, while **Richard Blackwell, FASM,** country manager, Buehler Canada, remains on the board as immediate past president. **James E. Martinez,** materials scientist, NASA, was elected vice president. **David Rollings,** vice president, business development, Advanced Abrasives Corp., was reelected finance officer and **Judith L. Arner,** senior metallographer, Struers Inc., was reelected secretary. Officers serve a two-year term.


Gliebe

George Abraham IV, supervisor, technical services, Allied High Tech Products, was elected a director for four years. **Daniel P. Dennies, FASM,** senior managing engineer, Exponent, and **Coralee McNee,** senior metallurgical engineer, United Technology Co., were reelected directors for four years. **Laura C. Gliebe,** Wright State University, was appointed student board member for one year.


Hartfield, Henderson, Keim, Kowalski, Jones
Oakes, Chupka, Pershing, Zimmerman, Rowan
Noll, Sylvester, Frafjord, Blackwell, Martinez
Rollings, Arner, Abraham, Dennies, McNee

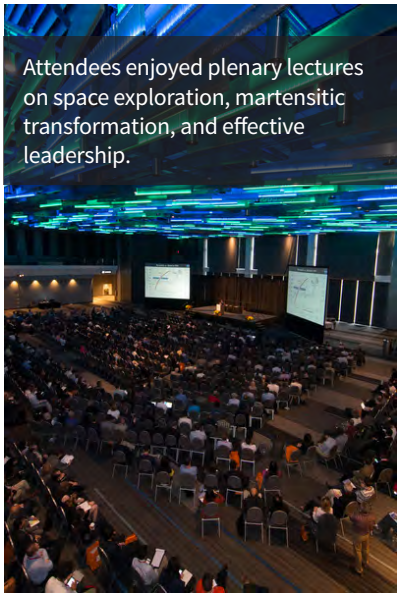
ASM Thermal Spray Society

The TSS electorate elected two members to the board and reelected one member; and the TSS Executive Committee reappointed the secretary/vice president and two student board members to the board. See page 3 of *iTSSe* in this issue for the full story.

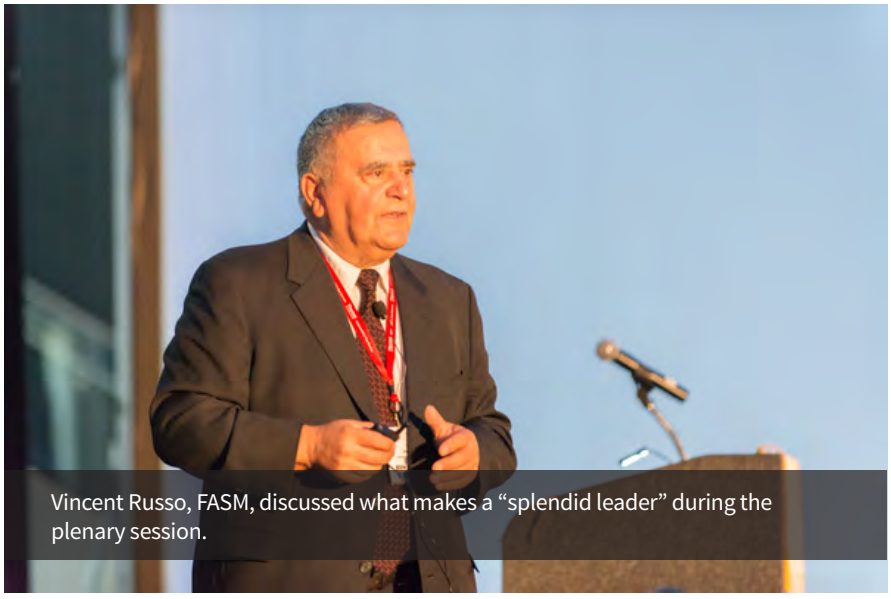
In This Issue

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

COLUMBUS HOSTS MS&T15: PHOTO GALLERY OF CONFERENCE HIGHLIGHTS



Attendees enjoyed plenary lectures on space exploration, martensitic transformation, and effective leadership.



Vincent Russo, FASM, discussed what makes a "splendid leader" during the plenary session.

Mary Juhas, FASM, gave a talk on "inclusive excellence" at the Women in Materials Engineering Breakfast.

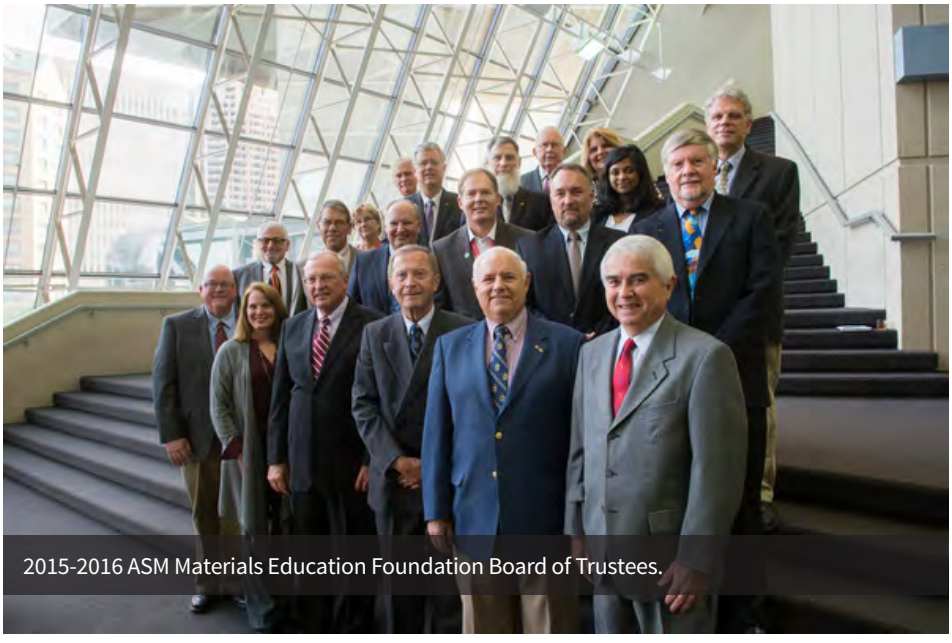
Frederick Schmidt, FASM, gives his acceptance speech for the William Hunt Eisenman Award.

Conference attendees enjoyed networking at both the exhibit hall and awards dinner.

Student poster session in the exhibit hall.

A DomesDay winner proudly displays his entry.

Incoming ASM President Jon Tirpak, FASM.



2015-2016 ASM Materials Education Foundation Board of Trustees.

HIGHLIGHTS MS&T15

Honorary Membership is bestowed on Siegfried Hecker, FASM.

Steven May accepts the Bradley Stoughton Award for Young Teachers.

Raymond Decker, FASM, of Thixomat Inc., receives the Medal for the Advancement of Research.

2015-2016 ASM Board of Trustees.

2015 Class of ASM Fellows.

Jana Šmilauerová receives the Acta Student Award from Rusty Gray.

Incoming ASM President Jon Tirpak, FASM, presents the Canada Council G. MacDonald Young Award to John Wolodko.

Outgoing ASM President Sunniva Collins, FASM, with Gold Medal winner James C.M. Li, FASM, Silver Medal winner Ryan Deacon, and Bronze Medal winner Emily Kinser.

Sunniva Collins, FASM, and Kathryn Dannemann visit the Case Western Reserve University team.

SECOND ANNUAL DOMESDAY A SMASHING SUCCESS

Eleven teams from eight different schools came to MS&T15 this year to compete in the 2nd annual ASM Geodesic Dome Design Competition, DomesDay. Virginia Tech's VT Composites Team won first place with $1000. Virginia Tech's Metals Team came in second, winning $750. Third place went to the Sun Devil Dome from Arizona State, with $500. Teams were judged based on an elevator speech, aesthetics, and mechanical strength, the last of which saw the dome being compression tested in front of a live audience on the convention floor.

DomesDay was established in 2014 by the ASM Student Board Members. It is intended to familiarize Material Advantage students with a piece of ASM culture, the Dome, by involving them in a design and materials selection competition. For more information, visit asminternational.org/students/domesday-competition. Special thanks to our sponsors, NSL Analytical and MTS.

Nominations Due for 2016 ASM Nominating Committee

ASM International is seeking members to serve on the 2016 ASM Nominating Committee. The committee will select a nominee for 2016-2017 vice president (who will serve as president in 2017-2018) and three nominees for trustee. Committee candidates may only be proposed by a Chapter through its executive committee, an ASM committee or council, or an affiliate society board. Nominations are due **December 15.** For more information, contact Leslie Taylor at 440.338.5151, ext. 5500, leslie.taylor@asminternational.org, or visit www.asminternational.org/about/governance/nominating-committee.

Nomination Deadline for the 2016 Class of Fellows is Fast Approaching!

The honor of Fellow of the Society was established to provide recognition to 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 ASM membership

Deadline for nominations for the class of 2016 is **November 30, 2015.** View rules and past recipients at asminternational.org/membership/awards. To receive a unique nomination form link, contact Christine Hoover at christine.hoover@asminternational.org.

Nominations Sought for ASM-IIM Visiting Lecturer and the ASM-IIM North American Visiting Lecturer for 2016

The cooperative Visiting Lecturer Program of ASM International and the Indian Institute of Metals (IIM) is seeking lecturers for 2016. Nominations are due **February 15, 2016.** View rules, past recipients, and criteria at asminternational.org/membership/awards. To receive a unique nomination form link, contact Christine Hoover at christine.hoover@asminternational.org.

Annual ASM Award Nominations Due Feb. 1, 2016

The deadline for the majority of ASM's awards is **February 1, 2016,** and we are actively seeking nominations for all of these awards, a sampling of which is listed below:

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

View rules and past recipients at asminternational.org/membership/awards. To receive a unique nomination form link, contact Christine Hoover at christine.hoover@asminternational.org.

FROM THE FOUNDATION

Dear Friends,

As this year comes to an end, we reflect on what we have been able to accomplish thanks to the energy and efforts of our members and volunteers. It is my pleasure to present to you some highlights of the 2014-2015 year at ASM Materials Education Foundation. This year the Foundation:

- Conducted two specialty Materials Camps focused on additive manufacturing
- Established a partnership with LIFT (Lightweight Innovations For Tomorrow) to incorporate a lightweight materials module into Materials Camp
- Enjoyed greater involvement and participation in information and education programs, which reflects the organization's mission of exciting young people in STEM careers
- Established a new scholarship in memory of David J. Chellman
- Organized a Materials Camp for Teachers in Brazil—scheduled for January 2016
- Kicked off a new award titled "Materials Choice"

The Foundation has a committed team and involved Board of Trustees eager to not only continue the work, but also improve upon and invest in the programs and services that we provide.

A big thank you goes to the Board and staff for their commitment to the mission and purpose of the Foundation, and to all of our donors, partners, and volunteers for their incredible contributions. Without your support, none of this work would be possible! Because of you, the ASM Materials Education Foundation is financially stronger and able to provide more programs and services than at any other time in our 63-year history. In the years ahead, with your continued generosity and support, we will continue to respond effectively to the needs of the STEM community.

As we pause this holiday season to recognize the goodness in our lives, we offer special thanks to each and every one of you who contributed time, knowledge, resources, and funding to our programs. And to ALL who make our work possible, we offer wishes for a healthy and happy holiday season!

Sincerely,

Michael Campana

VOLUNTEERISM COMMITTEE

Profile of a Volunteer

Nate Eisinger, Staff Metallurgist, Perryman Co.

How do you inspire high school students to study materials science? Capture the imagination. That's what happened to Nate Eisinger when he read about Hank Rearden, the fictional character who invents a stronger-than-steel superalloy in *Atlas Shrugged.* "The book may have an 'out there' philosophy, but the character and the metal stuck with me," says Eisinger, a 36-year-old metallurgist working for Perryman Co., a Pittsburgh-area company manufacturing titanium products for aerospace and medical markets.

While at Cornell University, Eisinger joined the ASM student chapter and then the Twin Tier Chapter. He was encouraged to apply for—and won—an ASM scholarship, and was sent to a life changing ASM conference. "I intended to go to grad school, but at the career fair, I met the president of Special Metals. He said it was a great place to work and asked for my resume," he recalls. The rest is history, as it opened the door for a position in research without requiring a Ph.D.

Since joining Perryman, Eisinger has inspired student involvement in the Pittsburgh Chapter by coordinating ASM high school scholarship competitions. "It's very rewarding to help students and see them pursue a similar track," he says. Eisinger has organized demos for kids at Pittsburgh's Carnegie Science Center and spearheads the Materials Camp at MS&T, introducing about 400 students to materials science each year. "There aren't a lot of new metallurgists coming up, so we need to educate young people to take up the mantle," he adds.

As a husband and father of two young children, Eisinger understands the challenge of volunteering with ASM. Seeing both personal and professional benefits, he works hard to attract new members and appreciates Perryman's encouragement of employee involvement. He hopes to see ASM put together a package at the national level to show employers the value of participating in local chapters.

CHAPTER NEWS

Milwaukee Hosts Annual Students Night

The Milwaukee Chapter held its annual Students Night reception and meeting on October 13 at Element Materials Technology in New Berlin, Wis. Tescan USA sponsored the meeting. The evening included a tour of Element's lab facilities as well as a talk by Craig Brown on "Metallurgical Failure Analysis: Overview and Case Studies." The Ernie Guenther Memorial Fund (EGMF) committee awarded both teacher grants and university scholarships to several teachers and students.

From left to right, Professor Ben Church, Emily Gerstein, Steven Acker, and Susan Kerber.

Los Angeles Chapter Hosts Tirpak, Hogue

Jon Tirpak, FASM, ASM incoming president, spoke to the Los Angeles Chapter on "Additive Manufacturing vs. Forging" at the September meeting. In October, the Chapter hosted Frauke Hogue, FASM, who gave a talk on "Microstructures of Iron Meteorites."

From left to right, Matt Aggleton, Jon Tirpak, and Chris Do.

From left to right, Jon Tirpak with Connor Knowles, Verenice Botello, and Shay McCarthy, officers of the Cal Poly Pomona Material Advantage Chapter.

Frauke Hogue receives a certificate of appreciation from Michael Hahn.

ASM INTERNATIONAL Emerging Professionals

Do you know an Emerging Professional deserving of recognition?

Nominate someone for the Emerging Professional Achievement Award today!

The EPAA was introduced to honor individuals in our Society who make an impact on ASM International shortly after graduation from school. The Emerging Professionals Committee would like to invite you to nominate an outstanding member of your chapter who has completed their degree (either baccalaureate or post-baccalaureate) within the last 0-5 years.

The link to the rules and nomination form is listed below.

Nominations are due by February 1

Scan the QR code to view the award rules and nomination form or visit asminternational.org/membership/awards

Please direct any questions to drew.fleming@asminternational.org

CWRU Hosts Engineering Standards Workshop

Case Western Reserve University (CWRU), Cleveland, recently held its debut Engineering Standards Workshop, which included representatives of six standards organizations along with CWRU faculty, staff, and students. The event drew over 150 attendees and provided an interactive forum for a variety of majors to learn about standards. The workshop was opened by Ph.D. candidate Janet Gbur and moderated by Bradley Lerch from NASA Glenn Research Center. In attendance were several members of the Cleveland Chapter.

From left to right, Mohsen Seifi, Sunniva Collins, John Lewandowski, and Bradley Lerch.

ASM INTERNATIONAL | Emerging Professionals

Attention Young Professionals and Recent Material Advantage Graduates!

Are you looking for a way to become more involved with ASM International?

Feel ready to take on a challenging and exciting new role in the professional society?

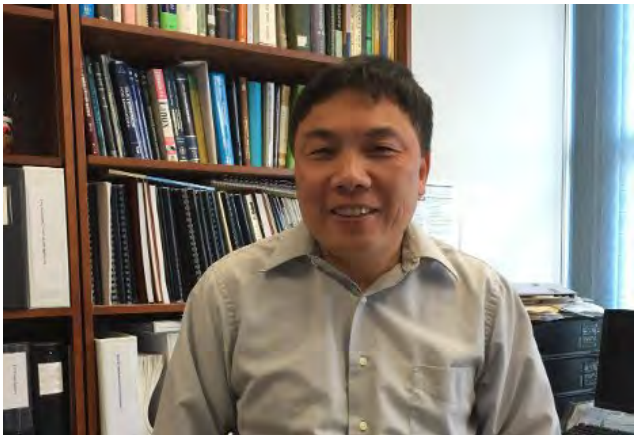
The Emerging Professionals Committee is for You!

ASM International is currently seeking applicants (up to 5 years post-graduation) for the Emerging Professionals Committee to serve a three-year term with the program.

For more details on the program and application information, contact Drew Fleming, drew.fleming@asminternational.org

Be sure to click the "Emerging Professionals" member type under the "Membership" tab at asminternational.org for more information!

MEMBERS IN THE NEWS



Hu Elected Fellow of AIChE

Yun Hang Hu, the Charles and Carroll McArthur Professor of Materials Science and Engineering at Michigan Technological University, Houghton, was elected as a Fellow of the American Institute of Chemical Engineers (AIChE). Hu is internationally recognized for his accomplishments in energy, materials, catalysis, and novel processes.

Elsayed

Lombardi

Elsayed, Lombardi Earn Doctoral Degrees

Abdallah Elsayed and **Anthony Lombardi,** both of Ryerson University, recently completed all the requirements for their doctoral degrees with flying colors. Elsayed was a 2014-15 student board member of ASM's International Metallographic Society. He is now a research and development engineer with Nemak Canada in Windsor. Lombardi was a 2014-15 student member of ASM's Board of Trustees. He is now a Natural Sciences and Engineering Research Council of Canada Postdoctoral Fellow at the University of Toronto.

IN MEMORIAM

John F. "Jack" Smith, FASM, died on September 26 at age 92. He was born on May 9, 1923, in Kansas City, Kansas. Smith enlisted in the Navy in 1942 and spent his service years as a fighter pilot on the carrier USS Suwannee in the South Pacific during WWII. In 1948, Smith began a 40-year career at Iowa State University (ISU) and Ames Laboratory where he was a professor of metallurgy and a senior scientist. He served as chairman of ISU's Department of Metallurgy from 1966 through 1970, and was a section chief for the Metallurgy and Ceramics department at Ames. With a background in metal behavior, Smith co-developed an ultrasonic method for measuring bolt tension, which improved on the traditional torque-wrench method of measurement. Smith retired from ISU and the Ames Laboratory in 1988, at which time he became an associate scientist and professor emeritus. He was elected a Fellow of the American Institute of Chemists in 1969 and the American Society for Metals in 1984. Smith served for 24 years as editor of ASM's *Journal of Phase Equilibria and Diffusion*. Donations to the John F. Smith Scholarship Fund may be made in his honor by contacting the ISU Department of Materials Science and Engineering.

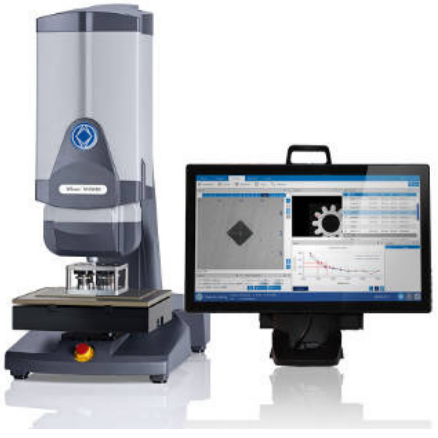
Robert Peh-Ying (Bob) Wei, FASM, passed away on September 28. He was born in Nanjing, China, on September 16, 1931, and emigrated from China to the U.S. in 1947. Upon completing his Ph.D. at Princeton University, he worked at the US Steel Research Center in Monroeville, Pa., until 1966. He then joined the Mechanical Engineering and Mechanics department at Lehigh University, where he served for over 40 years as a professor and department chair. He was a leading international authority on the fracture mechanics, fatigue, and corrosion failure of aircraft materials, helping develop current predictive models for aircraft component life and safety. Wei received ASM's Henry Marion Howe Medal in 1979.

John Beverley Clark, FASM, died on September 16. Born on July 13, 1924, in Port Dalhousie, Ontario, Clark was a metallurgical engineer and researcher educated at the University of Toronto and Carnegie Institute of Technology. After earning his doctorate, Clark pursued research at Dow Chemical Co. in Midland, Mich., Ford Motor Co.'s basic research laboratory in Dearborn, Mich., and the University of Missouri-Rolla. On several leaves of absence from the university, he served at the National Science Foundation and the National Institute of Standards and Technology. In 1960, he received ASM's Henry Marion Howe Medal.

PRODUCTS & LITERATURE

Rigaku Analytical Devices, Wilmington, Mass., launched Katana, **a handheld laser-induced breakdown spectroscopy (LIBS) analyzer.** It enables durable and accurate alloy identification for use in scrap metal sorting, quality assurance in metal fabrication, and positive material identification in petrochemical operations. The device was engineered to address analysis and usability gaps that similar handheld metal analyzers do not meet. Katana provides an alternative for more accurate identification of a larger number of alloys in a ruggedized form. The device has an IP54 rating, protecting against dusty and harsh work environments encountered in scrap recycling yards. *rigakuanalytical.com.*

Buehler, Lake Bluff, Ill., announces the Wilson VH3300 system, which complements the Wilson VH3100 system and expands the company's range of **automatic Vickers/Knoop hardness testers.** The new system excels in accurately measuring both very high and/or very low test loads. The VH3300 features an extensive variety of scales and magnifications and is suitable for advanced heat treatment processes found in the aerospace, energy, construction, and transportation industries. The system is equipped with patent-pending collision protection technology, a high-speed sample stage, and DiaMet universal testing software. *buehler.com.*



TMC, Peabody, Mass., a division of Ametek Inc., introduces Everstill K-400, a compact, **benchtop active vibration cancellation system.** The unit is well suited for small, lightweight, ultra-precision instruments, including optical microscopes, scanning probe microscopes, and metrology instruments, and helps those tools achieve superior resolution. The system starts to isolate at 0.7 Hz and delivers dramatic vibration cancellation, especially in the critical 1-10 Hz range. Everstill achieves this performance through an active "hard-mount" with serial-type architecture. *techmfg.com.*

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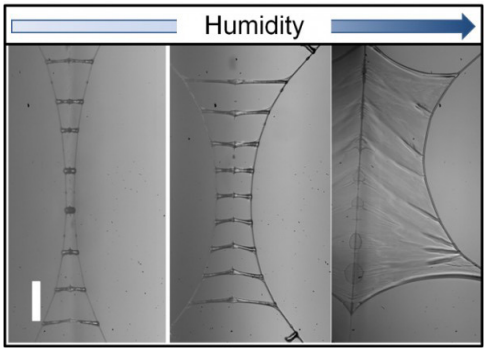
STRESS RELIEF

SPIDERWEB GLUE SHAPES NEXT GENERATION ADHESIVES

Most spiderwebs are made of spiral-like strands of "capture silk" that play a key role by retaining prey, freeing spiders to hunt. This special silk consists of an axial fiber coated with glue droplets at regular intervals. Spider glue is unique because its adhesion increases in response to humidity, and for some species, adhesion continues to increase up to 100% relative humidity—the exact opposite of how synthetic adhesives act on human skin in response to higher humidity.

Researchers from the University of Akron, Ohio, and Virginia Polytechnic Institute, Blacksburg, explored the properties underlying the spider glue's humidity-responsive adhesion. Scientists measured the adhesion of capture threads from five different species. "The habitats of these species range from dry to wet and humid, so we measured the adhesion as a function of humidity and used high-speed imaging to quantify the spreading rate of the glue droplets," explains Gaurav Amarpuri of Akron. The spreading of a liquid droplet follows the "spreading power law," in which low viscosity droplets spread faster than high viscosity droplets. The group used the spreading power law to calculate glue viscosity as a function of humidity. "We discovered maximum glue adhesion at the humidity levels at which the spider usually forages," says Amarpuri. *uabiomimicry.org.*



Larinioides cornutus capture threads peeled from a glass substrate, under low, medium, and high humidity conditions. At medium humidity, glue droplets form a suspension bridge structure where adhesion is maximum. Scale is 100 µm. Courtesy of Yizhou Chen/U.Akron.

HITCHHIKING TO MARS

Could some of the hardiest bacteria on Earth hitchhike on a Journey to Mars and survive after landing in a new world? NASA researchers intend to find out. A helium-filled scientific balloon will soon carry bacteria to the edge of space—Earth's stratosphere—exposing them to conditions similar to those found on the surface of Mars. Researchers will measure how long the bacteria can endure, and will also study the biological underpinnings of bacterial survival in harsh conditions. A specialized hardware system that will be used for the study, Exposing Microorganisms in the Stratosphere (E-MIST), was developed last year at NASA's Kennedy Space Center in Florida. *towerfts.csbf.nasa.gov.*

The 2014 test of the E-MIST system is prepared for flight on August 24 at NASA's Columbia Scientific Balloon Facility in Fort Sumner, N.M.

STAND-UP COMEDY GETS NEW MATERIAL

"I was once asked what kind of music stem cells would like best. Classical, I decided, because they're cultured." This was just one in a string of tales Laura McNamara unraveled at the debut Glasgow Bright Club a few years ago, where science meets humor. Bright Club is a comedy-club-style event featuring scientists and academics, which started at University College London. Academics brave the spotlight to vent about anything from Greek mythology to neuroscience. Researchers who perform at Bright Club span all ages, career levels, and disciplines. McNamara, who was culturing stem cells on nanopatterned titanium surfaces at the time of her first stand-up routine, is now the science education coordinator at the Glasgow Science Centre. *brightclub.org.*

Researcher Laura McNamara performs stand-up comedy about materials for Bright Club in Scotland.

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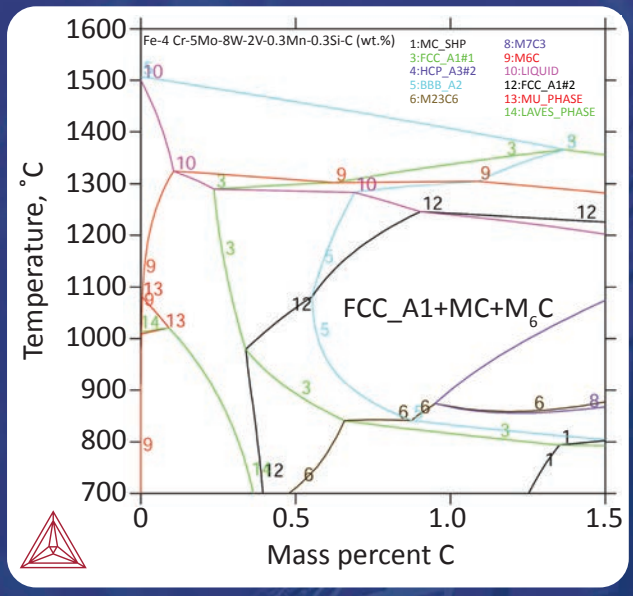

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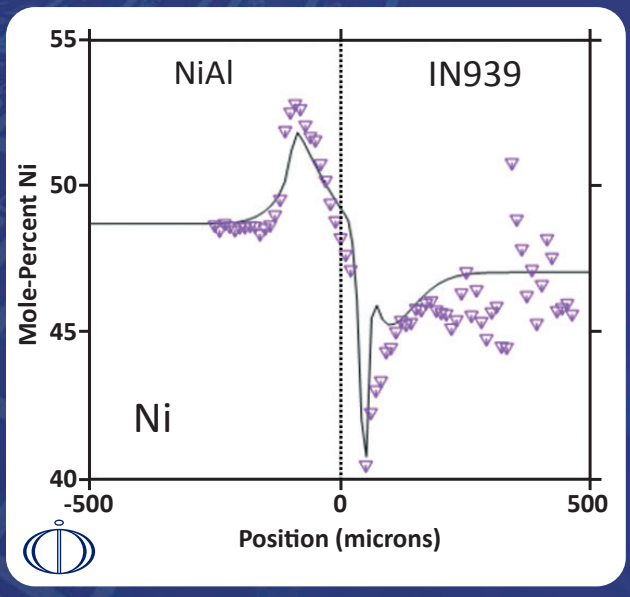

Diffusion in ordered phases

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