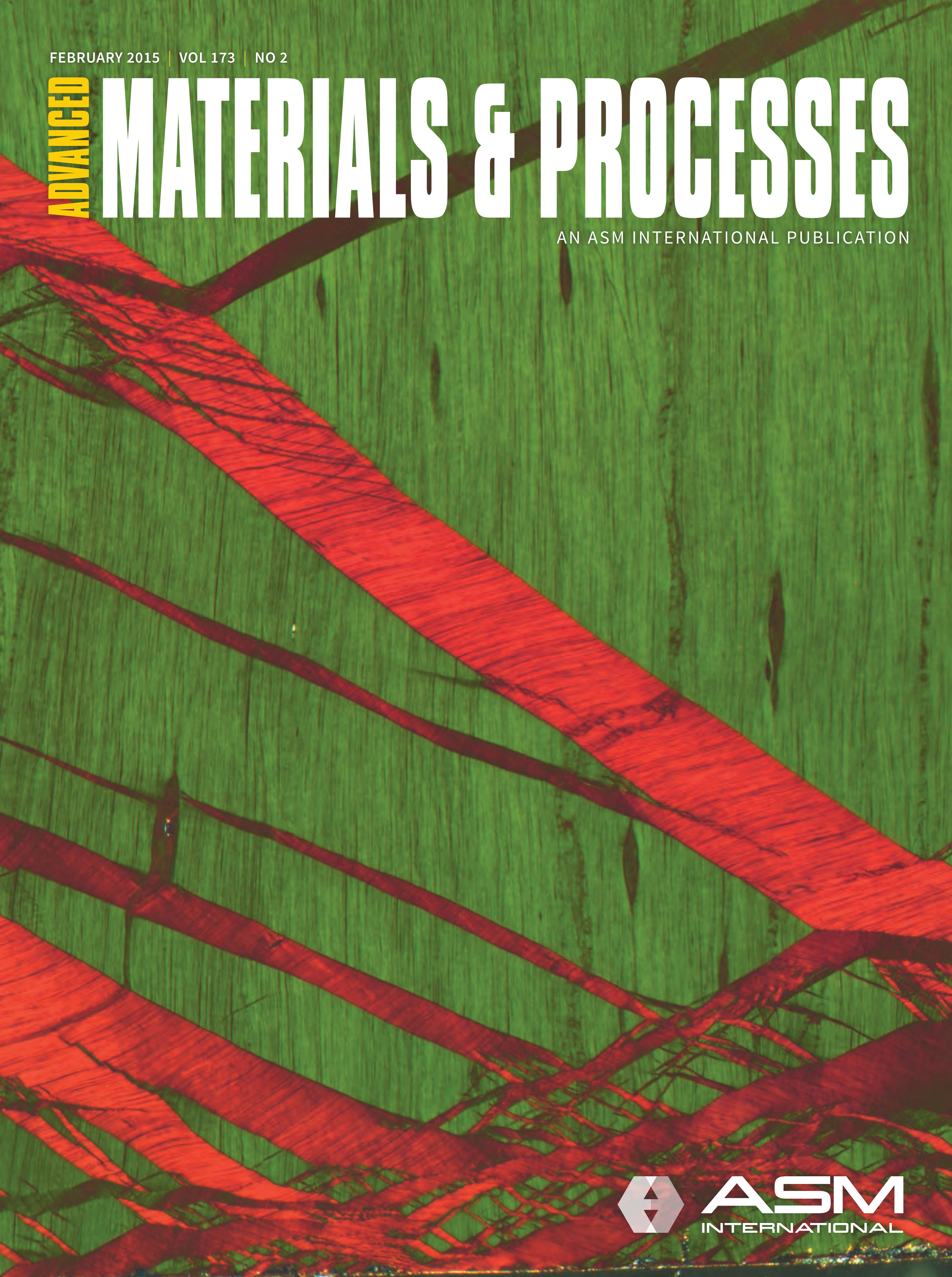
FEBRUARY 2015 | VOL 173 | NO 2

ADVANCED MATERIALS & PROCESSES

AN ASM INTERNATIONAL PUBLICATION



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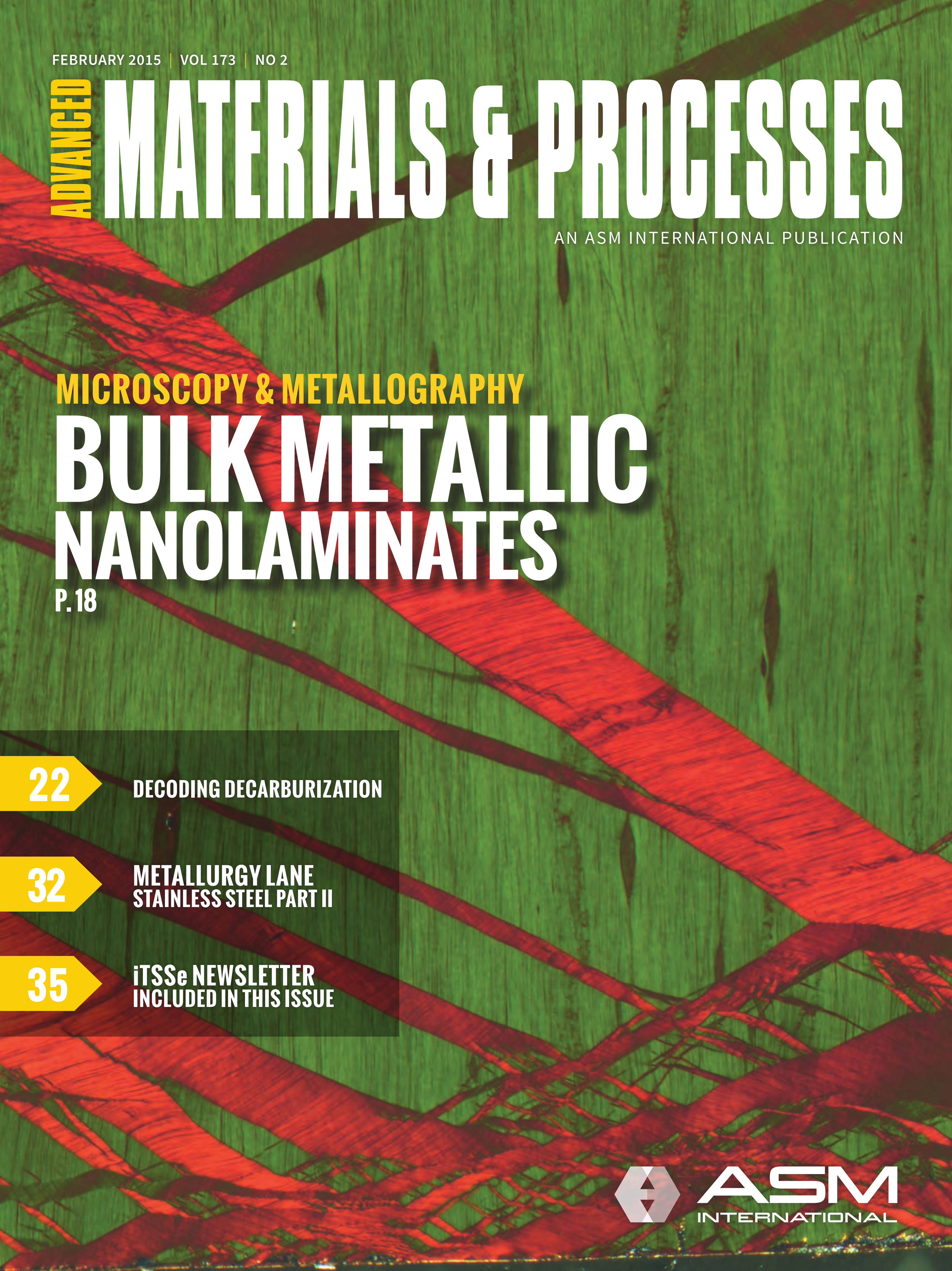

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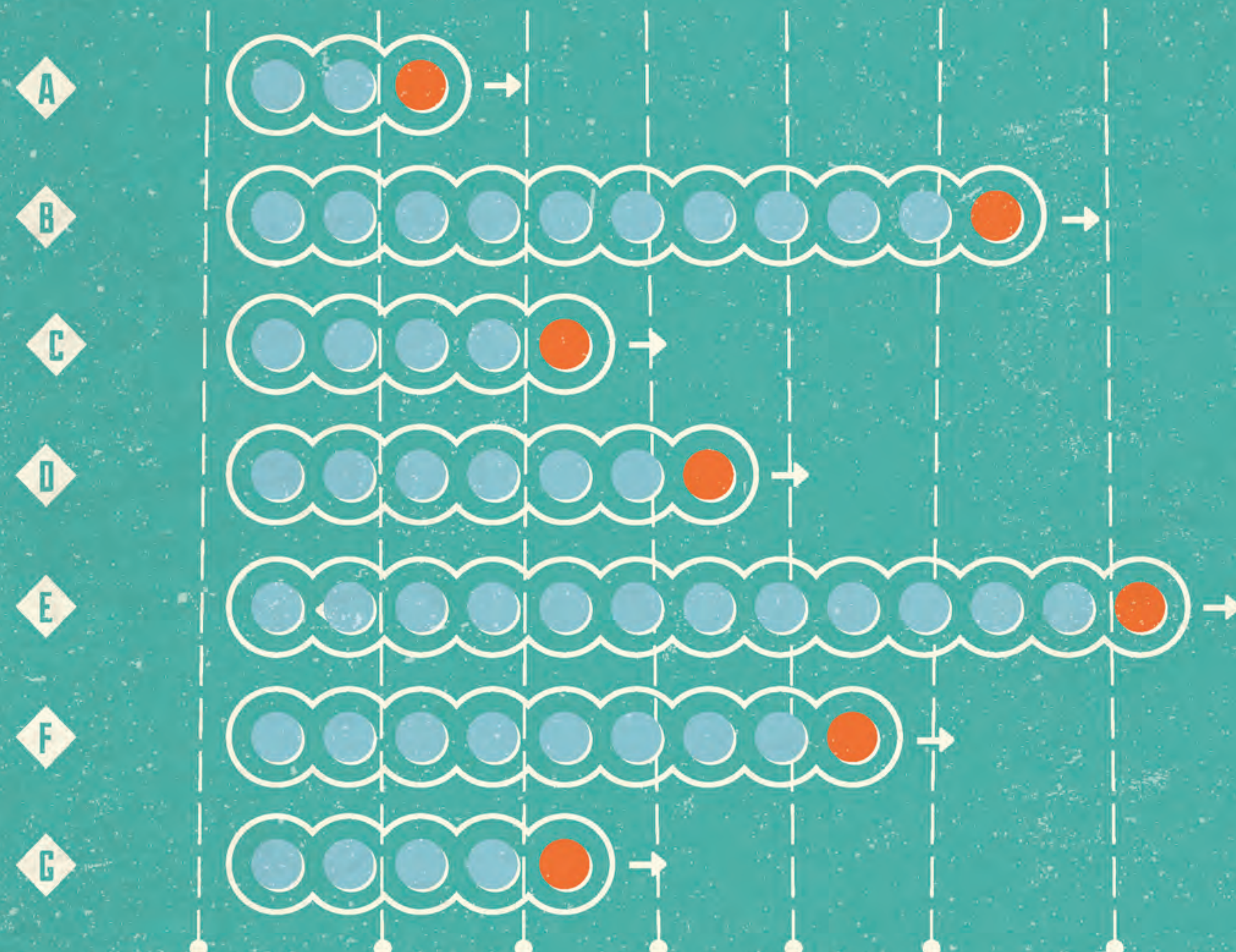
MICROSCOPY & METALLOGRAPHY
BULK METALLIC NANOLAMINATES

ASM INTERNATIONAL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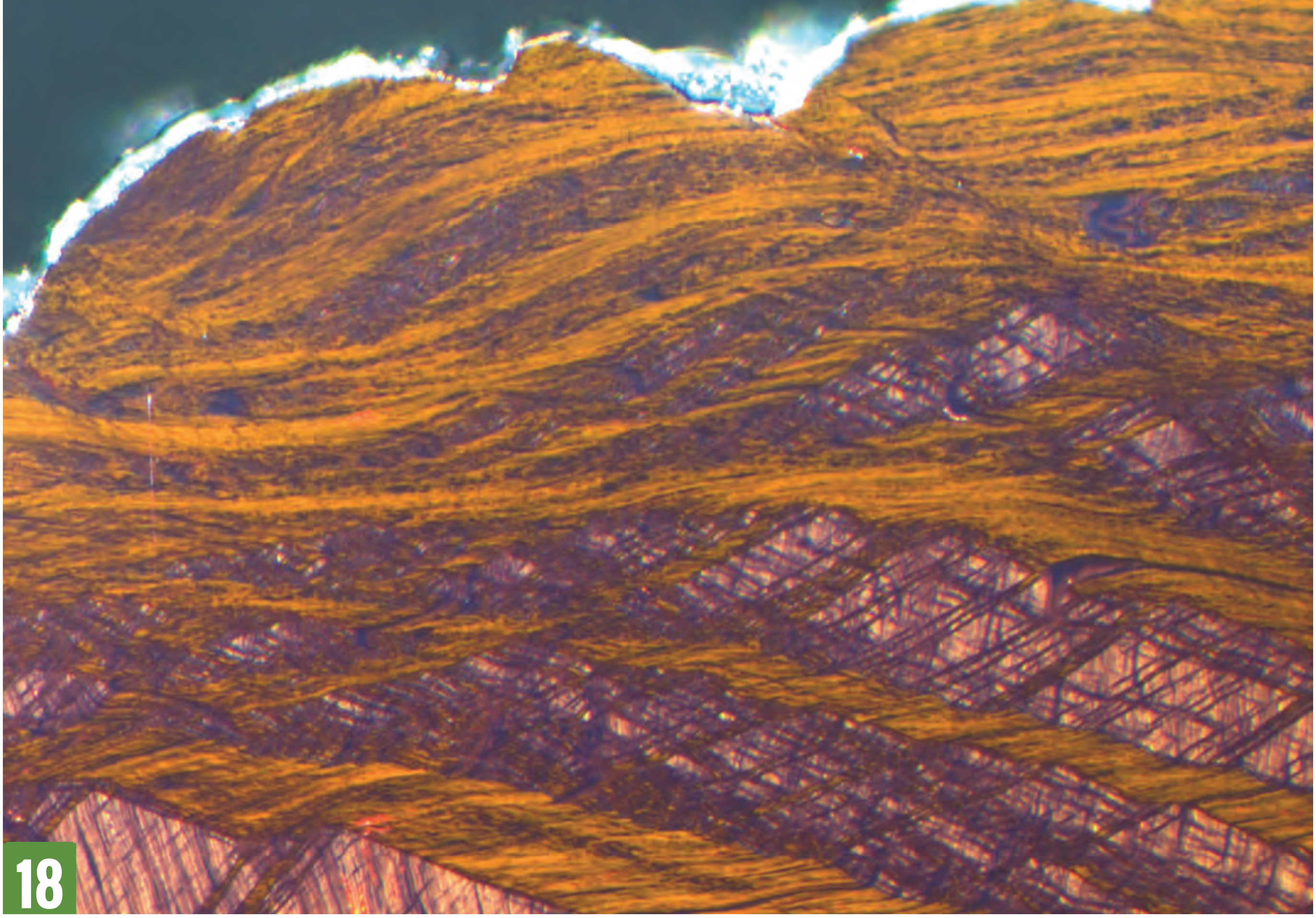

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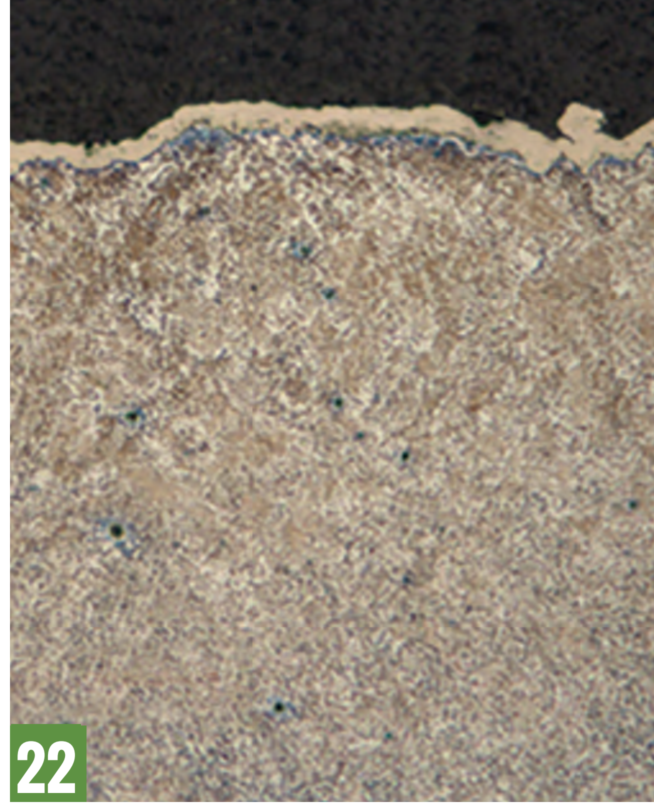
FEATURES



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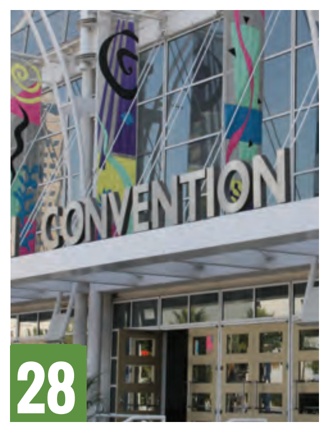

28

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TRENDS

INDUSTRY NEWS

DEPARTMENTS

ON THE COVER: Kink bands near the corner of this 15 nm compression specimen are clearly revealed using polarized light. Image courtesy of the Jacquet-Lucas Award-winning article included in this issue, adapted from a full-length feature in *Metallography, Microstructure, and Analysis* 3.6 (2014): 470-476, DOI 10.1007/s13632-014-0172-2. © Springer Science+Business Media New York and ASM International 2014.

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PARDON OUR DUST

Have you noticed? *Advanced Materials & Processes* has a bold new look, which we introduced in January. The redesign turned out to be a major undertaking, full of twists, turns, and a fair share of drama. Then, once our editorial and design staff reviewed our freshly printed copies, we decided to make numerous tweaks and subtle changes. The intended result is a significantly optimized February issue. Many readers expressed feedback on our January debut, which we took into consideration for this second issue. We now hope to hear from you about February as well. What do you like? What could we do better? Are there topics you would like to see covered more often? As ASM members, we appreciate that many of you consider *AM&P* to be "your magazine," and as such, we highly value your opinion. So please don't be shy with your comments! We consider the magazine to be a living thing that evolves over time and we count on you—our readers and members—to be part of the metamorphosis.

In a similar vein, we know that manufactured objects often evolve in a similar manner, meandering down a path of design iterations and incremental improvements. Fortunately for materials scientists and engineers, many of these modifications involve advanced materials. From using ceramic matrix composites in aircraft design to ramping up multi-material strategies in the automotive industry, the physical world of "stuff" we depend on keeps changing as well. Perhaps even more exhilarating are the new wonder materials coming down the pike—*science-fictionish* substances like mass-produced graphene, black phosphorous, and ghostlike aerogels. If you're working on any of these developments, we want to hear about it.

Likewise, we have two initiatives to share that may spur some interest and creative designs. First up is a new "Head Health Challenge" just announced by the National Institute of Standards and Technology in partnership with the NFL, GE, and Under Armour. The challenge involves an open innovation prize in search of advanced materials with enhanced energy absorption or dissipation properties. The goal: Improve the protective equipment used by athletes, military personnel, first responders, and others who face injury from impact events. Sponsors will award $2 million in prizes to those who propose and provide the best materials. A short abstract describing the proposed material is all that is needed to get started, but the deadline for submission is March 13. Visit headhealthchallenge.com for more information.

On a similar note, the BoatUS Foundation, Personal Floatation Device Manufacturers Association, and National Marine Manufacturers Association have partnered to search for the best technologies and designs for the "Innovation in Life Jacket Design Competition." A $10,000 cash prize will go to the winner. Deadline is April 15 and more information is available at boatus.org/design.

Very few participants may choose to enter either of these contests, so why not try it? Our materials science and engineering community seems to have a definite advantage in these types of competitions and it would be exciting to see someone from our world announced as a winner. In the meantime, stay warm. Spring is just around the corner.

frances.richards@asminternational.org

MARKET SPOTLIGHT

NANOTECHNOLOGY MARKET TO REACH $64.2 BILLION IN 2019

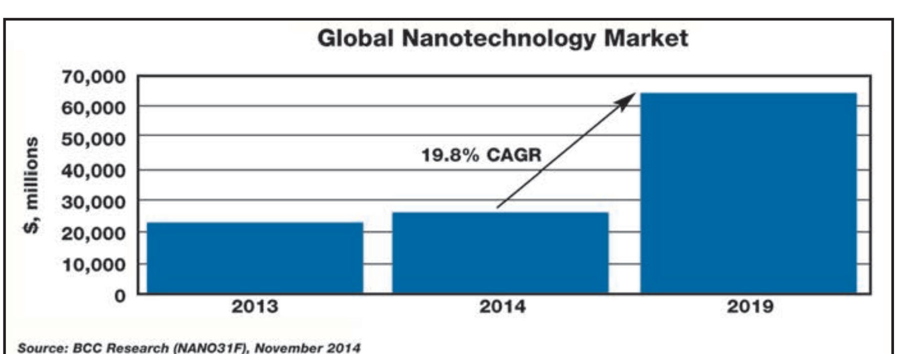
In a new report, "Nanotechnology: A Realistic Market Assessment," BCC Research, Wellesley, Mass., forecasts that the global market for nanotechnology is expected to grow to $64.2 billion by 2019, with a five-year compound annual growth rate (CAGR) of 19.8%. Nanodevices—the fastest moving segment of the overall market—are anticipated to move at an impressive 34% CAGR, say analysts. The study covers nanomaterials (nanoparticles, nanotubes, nanostructured materials, and nanocomposites), nanotools (nanolithography tools and scanning probe microscopes), and nanodevices.

Nanotechnology, defined as the creation and utilization of materials, devices, and systems through the manipulation of matter at scales of less than 100 nm, continues to have a broad and fundamental impact on nearly all sectors of the global economy, including the biomedical, electronics, energy, environmental, and pharmaceutical industries. Nanomaterials, particularly nanoparticles and nanoscale thin films, dominated the nanotechnology market in 2013, accounting for 78.8% of the market. This segment is predicted to grow to $52.7 billion by 2019 and register a 20.7% CAGR.

The nanotools category, comprised of devices used to manipulate or measure nanoscale objects or substances, accounted for 21% of the 2013 nanotechnology market. This segment is expected to reach nearly $11.3 billion by 2019 to register a CAGR of 16.2% However, the nanodevices category, which was valued at just $39 million in 2013, is projected to surge to $183.4 million in 2019. This growth will primarily be driven by increasing consumer demand for smaller and more powerful electronic devices, according to the report.

"Increased R&D spending in both the private and public sectors is driving development of commercial nanomaterials applications such as nanocatalyst thin films for catalytic converters, as well as new and emerging technologies such as nano thin-film solar cells, nanolithographic tools, and nanoscale electronic memory," says analyst Andrew McWilliams. "Rising demand for miniaturization in electronics, as well as public health and environmental concerns, are anticipated to shape significant growth in this market for the foreseeable future."

The report includes analysis of global market trends, with data from 2013, estimates for 2014, and projections of CAGRs through 2019. *For more information, visit bccresearch.com.*

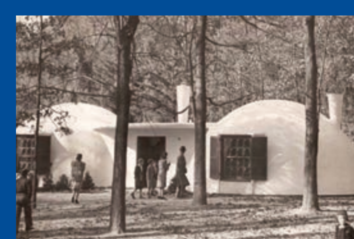


FEEDBACK

LIVING IN A BUBBLE

I enjoyed the spotlight on Vienna University of Technology's inflatable concrete construction method. ("Stress Relief," Nov/Dec 2014). It would be nice to have a more detailed explanation on how the process differs from Wallace Neff's bubble houses.

Matt Burr



Wallace Neff bubble house. Courtesy of Jeffrey Head.

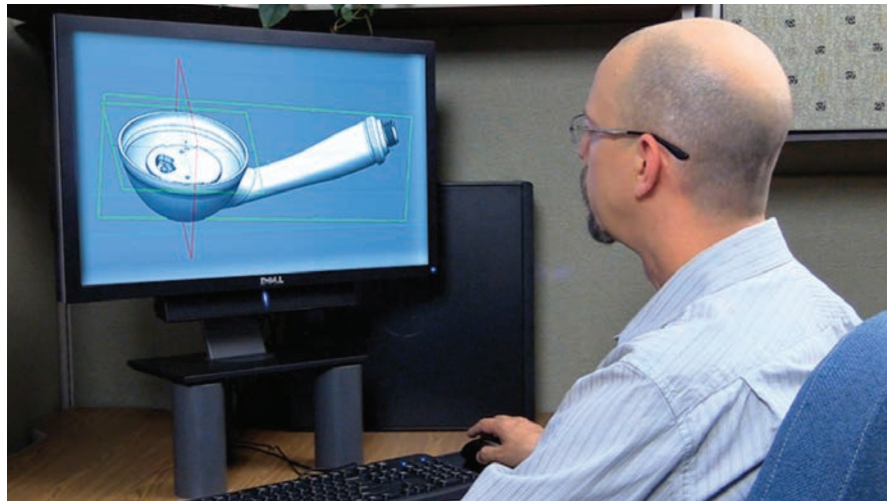
[Wallace Neff inflated a giant balloon and applied shotcrete after inflation. The main difference between Neff's approach and our technology is that we cast the concrete in a flat formwork with petal-shaped outlets lying on the ground. After the concrete is hardened, the flat plate is transformed into a double-curved shell with the aid of a pneumatic formwork and additional post-tensioning cables in the circumferential direction.—*Benjamin Kromoser*, Vienna University of Technology]

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

OMG!
OUTRAGEOUS MATERIALS GOODNESS

BETTER BAMBOO BUILDINGS

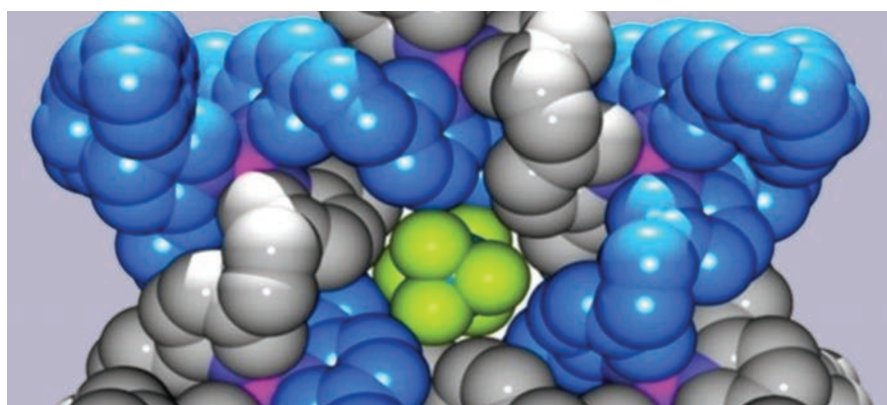
Scientists at Massachusetts Institute of Technology, Cambridge, along with architects and wood processors from England and Canada, are looking for ways to turn bamboo (shown above) into a construction material more similar to wood composites, like plywood. The idea is that a stalk, or culm, can be sliced into smaller pieces, which can then be bonded together to form sturdy blocks—much like conventional wood composites. A structural product of this sort could be used to construct more resilient buildings—particularly in places like China, India, and Brazil, where bamboo is abundant. The goal is to gain a better understanding of these materials, so bamboo can be used more effectively. Researchers have analyzed the microstructure of bamboo and found that it is stronger and denser than North American softwoods like pine, fir, and spruce, making it a promising resource for composite materials. Photo courtesy of Jennifer Chu/MIT. *web.mit.edu.*



A Waterpik shower head design is prepped for 3D printing.

3D PRINTING IS OLD HAT IN SHOWER HEADS

Water Pik Inc., Fort Collins, Colo., has been using 3D printer technology for nearly 20 years to speed design processes and create high-performance products. 3D printing allows designs to be fine-tuned and is up to 10 times faster than traditional prototyping. This gives engineers time to refine designs to meet rigorous performance requirements and address consumer needs. The company recently released a video highlighting the prototyping process, which provides an inside look at the 3D printer technology in place. The video also demonstrates how shower heads are tested to meet rigorous OptiFLOW (the power behind Waterpik shower heads) technology performance standards. *waterpik.com/shower-head/blog/3d-printer-video.*



Atoms in the Star of David molecule. Courtesy of The University of Manchester.

STAR OF DAVID SHINES AS MOLECULAR DISCOVERY

Consisting of two molecular triangles, entwined about each other three times into a hexagram, the Star of David's interlocked molecules are tiny—each triangle is 114 atoms in length around the perimeter. The molecular triangles are threaded around each other at the same time that the triangles are formed, by a process called self-assembly—similar to how the DNA double helix is formed in biology. The molecule was created at The University of Manchester, UK, by Alex Stephens. Professor David Leigh says, "It's the next step on the road to man-made molecular chainmail, which could lead to the development of new materials that are light, flexible, and very strong. Just as chainmail was a breakthrough over heavy suits of armor in medieval times, this could be a big step towards materials created using nanotechnology." *www.manchester.ac.uk.*

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.


Plastic-aluminum laminate packaging presents a technical recycling challenge that causes millions of tons of rubbish to be disposed of in landfills each year. Courtesy of Sam Stanton.

MICROWAVING TOOTHPASTE TUBES INTO ALUMINUM

Fifteen years ago, Howard Chase and Carlos Ludlow-Palafox at the University of Cambridge, UK, discovered that an over-microwaving process could be used to recover useful materials from packaging wastes. Plastic-aluminum laminate packaging is commonly used for food, drink, toothpaste, pet food, and cosmetic products. The combination of plastic and aluminum in the packaging poses a technical recycling challenge that until now has been unsolved. "In the UK, roughly 160,000 tons of laminates are used per year for packaging, which means at least 16,000 tons of aluminum is going into the ground," says Ludlow-Palafox.

The solution started in a relatively simple way—a pile of particulate carbon and some shredded laminated packaging was placed inside a conventional 1.2 kW kitchen microwave, the air inside was replaced with nitrogen, and it was set on full power until the temperature reached 600°C. When researchers opened the door two minutes later, the laminated material had been separated into clean aluminum flakes and hydrocarbon gases and oil.

Now fully commissioned, Cambridge spinoff Enval Ltd. can recycle up to 2000 tons of packaging per year—roughly the amount handled by regional waste haulers—and generate enough energy to run itself. Enval has an arrangement with manufacturers of plastic-aluminum laminates to recycle their industrial scrap at lower cost than sending it to a landfill. *enval.com.*

HIGH-PERFORMANCE PLASTICS FROM **BAYER MATERIALSCIENCE LLC,** DALLAS, HELP PROTECT BUILDINGS AND THEIR OCCUPANTS WITH PRODUCTS THAT NOT ONLY GUARD AGAINST VANDALISM AND FORCED ENTRY, BUT ALSO OFFER BULLET RESISTANCE AND BLAST MITIGATION. HYGARD SECURITY LAMINATES ARE AN ARCHITECTURAL SYSTEM FOR A WIDE VARIETY OF GLAZING APPLICATIONS WHERE SECURITY IS CRITICAL. *materialscience.bayer.com/en.*

LIGHTER, SAFER VEHICLE SEATS

Johnson Controls, Plymouth, Mich., is reducing the use of metals in vehicle seat structures by replacing them with multi-material systems in its CAMISMA (carbon-amide-metal-based interior structure using a multi-material system approach) research project. The seats are more than 40% lighter than conventionally manufactured seat structures and equally as safe.

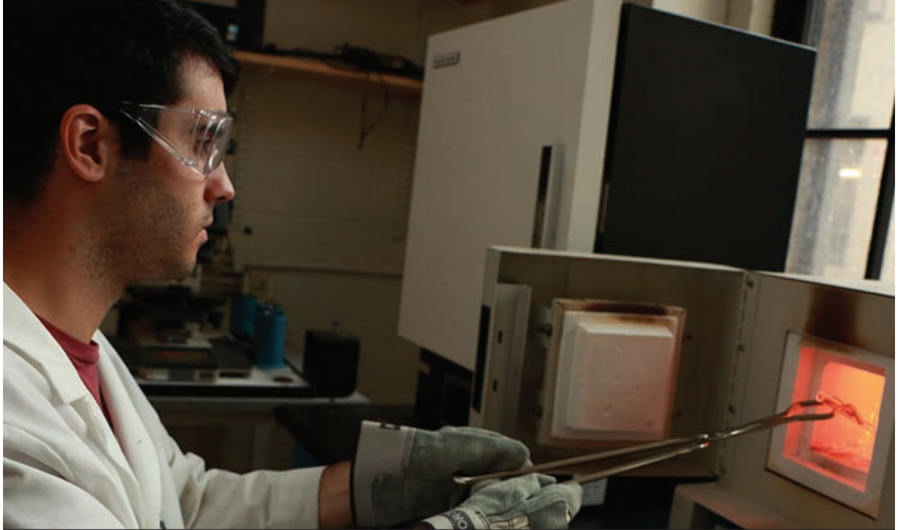
An innovative industrial manufacturing process for volume production


Recliners used in a multi-material research project are 40% lighter than conventionally manufactured seat structures and equally as safe.

BRIEFS

Aleris, Cleveland, offers a new 7017 aluminum alloy in North America for commercial plate and defense uses. After extensive review and testing, the U.S. Army Research Lab issued MIL-DTL-32505 for use in armor applications. 7017 offers high strength, good weldability, and corrosion resistance. It is currently used in Europe and Asia on combat vehicles to achieve superior ballistic protection. *aleris.com.*

with about 200,000 units per production line allows the highly concentrated, efficient use of carbon fiber, while at the same time meeting all safety requirements. Results of an initial rear-impact crash test demonstrate that the CAMISMA prototype satisfied all of the strength requirements of current seats built with a metal structure in large-scale series production. In addition to significant weight savings, CAMISMA offers a further advantage: The manufacturing steps required in assembly are substantially reduced through the number of attachment parts needed, which also saves cost. *johnsoncontrols.com.*



MIT graduate student Zack Cordero removes a vacuum-sealed glass ampoule from a box furnace operating at 1100°C used to anneal metal powders. Courtesy of Denis Paiste/Materials Processing Center.

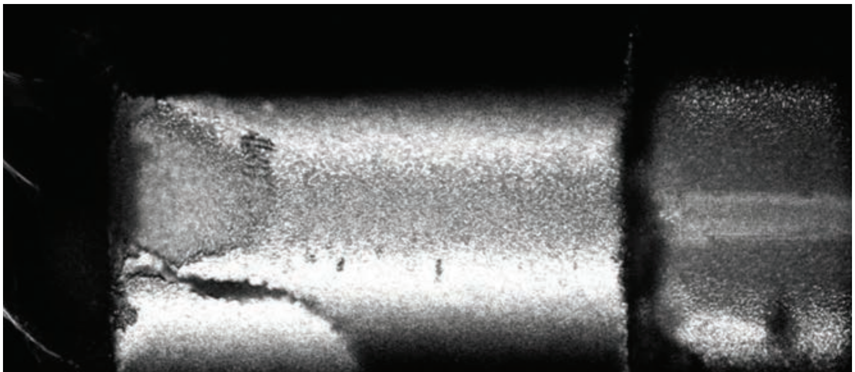
ALLOYING TOUGHER TUNGSTEN

New tungsten alloys being developed at Massachusetts Institute of Technology, Cambridge, could replace depleted uranium in armor-piercing projectiles. Depleted uranium poses a potential health hazard to soldiers and civilians.

A new alloy with chromium and iron (W-7Cr-9Fe) is significantly stronger than commercially available tungsten alloys, reports graduate student Zachary Cordero.

To achieve this, metal powders were compacted in a field-assisted sintering hot press, with the best result attained at a processing time of one minute at 1200°C. Cordero achieved ultrafine grain structure of about 130 nm in the W-7Cr-9Fe compact, confirmed by electron micrographs. "Using this powder processing route, we can make big samples up to 2 cm in diameter, or we could go bigger, with dynamic compressive strengths of 4 GPa." *For more information: Zachary Cordero, zcordero@mit.edu, www.web.mit.edu.*

TESTING | CHARACTERIZATION



Microscope image of a micropillar failing after the formation of a shear band.

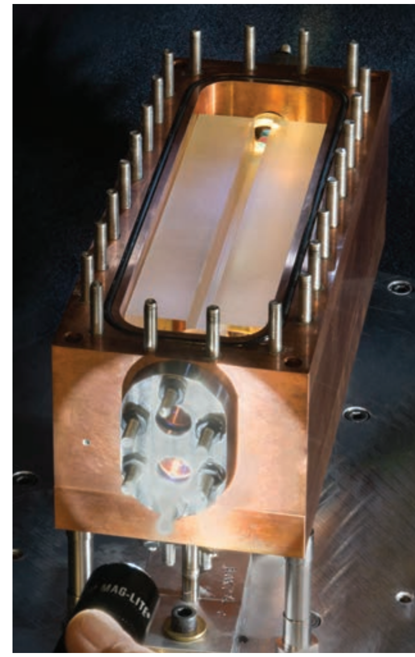
UNDERSTANDING FAILURE IN GLASSY MATERIALS

Researchers at University of Pennsylvania, Philadelphia, discovered an important commonality that seems to extend through the wide range of glassy materials. They demonstrated that the scaling between a glassy material's stiffness and strength remains unchanged, implying a constant critical strain that these materials can withstand before catastrophic failure, despite the extreme variation found among the physical properties of different glasses. This constant critical strain provides insight into the fundamental "seed" out of which glass failure grows—a small group of the glass's constituent particles or atoms that change shape in a collective way. Despite the disorder that epitomizes glass, this coordinated activity appears to be universal among many glassy systems, such as certain metals, polymers, and colloids, and is an important starting point for designing more durable materials. *For more information: Daniel Gianola, 215.898.7246, gianola@seas.upenn.edu, www.seas.upenn.edu.*

INAUGURAL PHOTONIC PRESSURE SENSOR OUTSHINES MERCURY MODEL

A unique pressure-sensing device recently surpassed the performance of the best mercury-based techniques in resolution, speed, and range at a fraction of the size, according to scientists at NIST, Gaithersburg, Md. The new instrument, called a fixed-length optical cavity (FLOC), works by detecting subtle changes in the wavelength of light passing through a cavity filled with nitrogen gas.

The FLOC system is poised to depose traditional mercury pressure sensors (manometers) as the standard used to calibrate commercial equipment, according to researchers. The new design is also a promising candidate for a factory-floor pressure instrument that could be used by a range of industries, including semiconductor, glass, and aero-

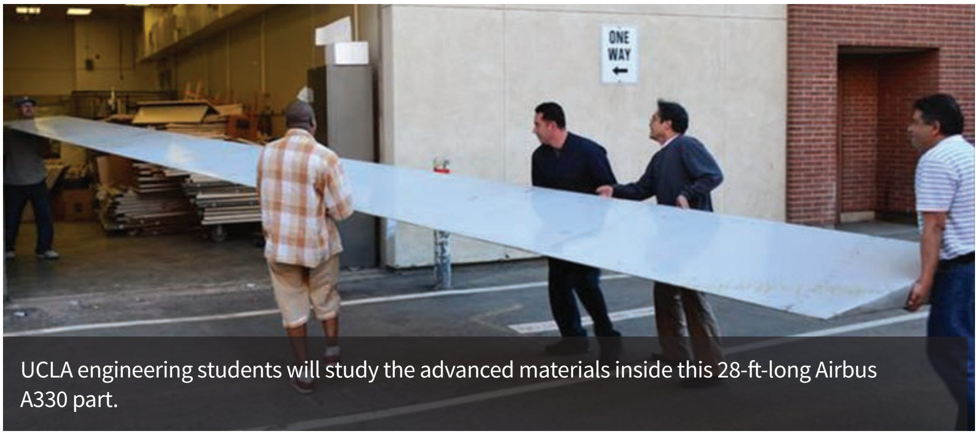


FLOC gauges pressure by detecting subtle differences in the wavelength of light resonating in two channels. Courtesy of NIST.

SIGMA LABS INC., SANTA FE, N.M., A DEVELOPER OF INSPECTION SYSTEMS FOR METAL-BASED ADDITIVE MANUFACTURING TECHNOLOGIES, RECEIVED A CONTRACT FROM HONEYWELL AEROSPACE AS PART OF A **DEFENSE ADVANCED RESEARCH PROJECT AGENCY** (DARPA) PHASE II AWARD TO DEVELOP AN INTEGRATED COMPUTATIONAL MATERIALS ENGINEERING (ICME) FRAMEWORK TO ACCURATELY PREDICT THE PROPERTIES OF METAL COMPONENTS PRODUCED USING ADDITIVE MANUFACTURING. *sigmalabsinc.com.*

BRIEFS

Nikon Instruments Inc., Melville, N.Y., entered a strategic partnership with **JEOL,** Peabody, Mass., to develop techniques to address correlative light and electron microscopy. Along with progress in super-resolution technologies, there is growing interest in correlating light microscopy data with electron microscopy data to further push the limits of resolution. The alliance plans to develop tools to combine the advantages of both methods. *nikoninstruments.com, jeolusa.com.*



UCLA engineering students will study the advanced materials inside this 28-ft-long Airbus A330 part.

space manufacturing. About the size of a travel mug, the FLOC has a resolution of 0.1 mPa, 36 times better than NIST's official U.S. pressure standard, which is a 3-m-tall column of liquid mercury that extends through the ceiling of the calibration room. The FLOC is also 100 times faster than the standard mercury manometer. *nist.gov.*

AIRBUS DONATES AIRCRAFT PART TO UCLA MATERIALS LAB

Mechanical and aerospace engineering students at University of California, Los Angeles (UCLA), will have a rare opportunity to analyze the composition, structure, thermal, and other properties of a piece of advanced commercial aircraft equipment, thanks to a donation from Airbus Americas. The part, a 28-ft-long elevator from an Airbus A330, was delivered to the UCLA Henry Samueli School of Engineering and Applied Science late last year. The elevator, used for flight control on the aircraft's tail, is valued at $750,000. The equipment will be housed at UCLA's Materials Degradation Characterization Laboratory, supervised by Ajit Mal, distinguished professor of mechanical and aerospace engineering.

"This material and this structure are very advanced," says Mal. "It is so important to have a real piece of aircraft in the lab so students can have access to new and advanced materials and structures." Mal's long-term research goal is to develop sensors that can be embedded in composite materials to communicate when a vital component of a structure is damaged by impact with a foreign object. *ucla.edu.*

PROCESS TECHNOLOGY

A metal-free atom transfer radical polymerization process uses an organic-based photocatalyst. Courtesy of Peter Allen, UCSB.

METAL-FREE CATALYST PROCESS USES LIGHT FOR RAPID POLYMERIZATION

Materials science researchers from University of California, Santa Barbara, and The Dow Chemical Co., Midland, Mich., created a novel way to overcome a major hurdle preventing widespread use of controlled radical polymerization. In a global polymer industry valued at hundreds of billions of dollars, a technique called atom transfer radical polymerization (ATRP) is emerging as a key process for creating well-defined polymers for a vast range of materials, from adhesives to electronics.

However, current ATRP methods use metal catalysts, a major roadblock for applications in which metal contamination is an issue, such as materials used for biomedical purposes. The new method does not involve heavy metal catalysts like copper. Instead, an organic-based photocatalyst—and light—serve as the stimulus for the reaction.

"We looked toward developing an organic catalyst that is highly reducing in the excited state, and we found it in an easily prepared catalyst, phenothiazine," explains Craig Hawker, director of the Dow Materials Institute at UCSB. ATRP is already used widely across dozens of major industries, but the new metal-free rapid polymerization process enables controlled radical polymerization to be used in new applications. "Many processes in use today start with ATRP. This method opens doors for a new class of organic-based photoredox catalysts. The development of living radical processes, such as ATRP, is arguably one of the biggest things to happen in polymer chemistry in the past few decades," adds Hawker. *ucsb.edu.*

AUTO SHOW FEATURES 3D-PRINTED MUSCLE CAR

The Department of Energy's Oak Ridge National Laboratory (ORNL), Tenn., highlighted its additive manufacturing research at the 2015 North American International Auto Show held in January in Detroit by showcasing a 3D-printed Shelby Cobra. The car was printed at DOE's Manufacturing Demonstration Facility at ORNL using the big area additive manufacturing (BAAM) machine, which can manufacture strong, lightweight composite parts in sizes greater than one cubic meter. The 1400-lb vehicle contains 500 lb of printed parts made of 20% carbon fiber. It took six weeks to design, manufacture, and assemble the Shelby, including 24 hours of print time. The new BAAM system, jointly developed by ORNL and Cincinnati Inc., can print components 500 to 1000 times faster than today's industrial additive machines. ORNL researchers say the speed of next-generation additive manufacturing offers new opportunities for the automotive industry, especially in prototyping vehicles. *ornl.gov.*

3D-printed Shelby Cobra. Courtesy of ORNL.

BRIEFS

Alcoa, New York, will invest $190 million in its Davenport Works, Iowa, facility to expand aerospace and industrial products. Technology to enhance performance of thick aluminum and aluminum-lithium plate in various applications, including wing ribs and fuselage frames, will be installed. The investment also includes a very thick plate stretcher for reducing stress introduced into plate during manufacturing. Company sources say the upgrades will enable production of the largest high-strength monolithic wing ribs in the industry. *alcoa.com.*

ENERGY TRENDS

A new chemical process converts cellulose in sawdust into hydrocarbon chains. Courtesy of Shutterstock.

CAN SAWDUST RUN YOUR CAR?

Researchers at the University of Leuven's Centre for Surface Chemistry and Catalysis, Belgium, successfully converted sawdust into building blocks for gasoline. Using a new chemical process, cellulose in sawdust was converted into hydrocarbon chains. These hydrocarbons can be used as an additive in gasoline or as a component in plastics.

"At the molecular level, cellulose contains strong carbon chains. We sought to conserve these chains, but drop the oxygen bonded to them, which is undesirable in high-grade gasoline. Our researcher Beau Op de Beeck developed a new method to derive these hydrocarbon chains from cellulose," explains professor Bert Sels. The result is an intermediary product that requires one last simple step to become fully distilled gasoline, says Sels. "Our product offers an intermediate solution for as long as our automobiles run on liquid gasoline. It can be used as a green additive—a replacement for a portion of traditionally refined gasoline." *For more information: Bert Sels, bert.sels@biw.kuleuven.be, www.kuleuven.be/english.*

HEAT-REFLECTIVE BUILDING MATERIAL SAVES ENERGY

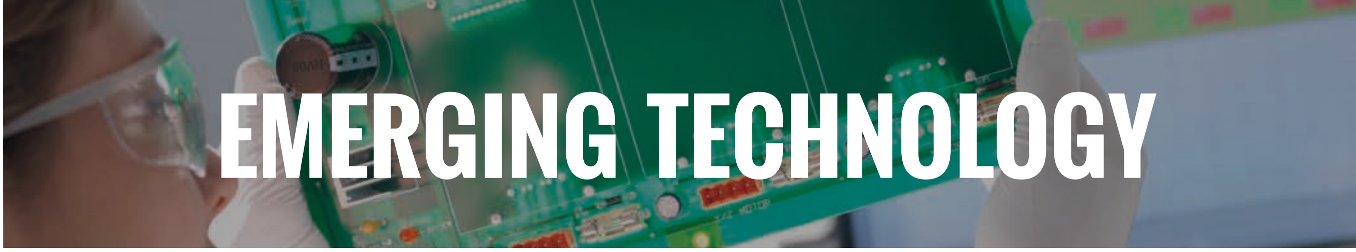
Stanford University, Calif., engineers invented a material designed to help cool buildings. The heart of the invention is an ultrathin, multilayered material that handles light, both invisible and visible, in a new way. The novel material, in addition to dealing with infrared light, is also a highly efficient mirror that reflects virtually all of the incoming sunlight that strikes it. The result is referred to as photonic radiative cooling—a one-two punch that offloads infrared heat from within a building while reflecting the sunlight that would otherwise warm it up.

The coating radiates heat-bearing infrared light directly into space and sends it away from buildings at the precise frequency that allows it to pass through the atmosphere without warming the air. Together, the radiation and reflection make the photonic radiative cooler material nearly 9°F lower in temperature than the surrounding air. The material is just 1.8 μm thick and is made of seven layers of silicon dioxide and hafnium oxide on top of a thin layer of silver. *For more information: Professor Shanhui Fan, 650.724.4759, shanhui@stanford.edu, www.stanford.edu.*

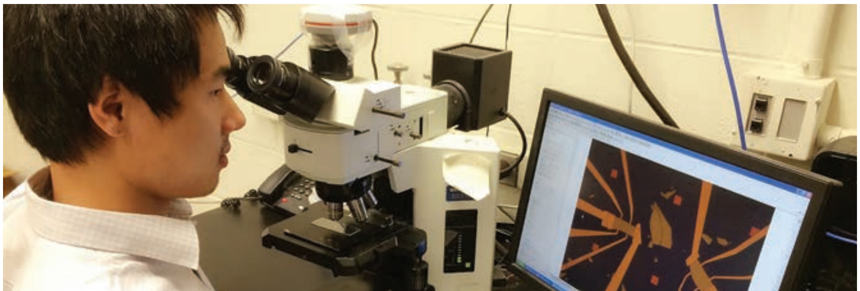
A new material reflects incoming sunlight while dispersing heat from inside the building directly into space as infrared radiation (represented by reddish rays).

BRIEFS

A new electrode design for lithium-ion batteries could potentially reduce the charging time from hours to minutes by replacing the conventional graphite electrode with a network of tin-oxide nanoparticles. Researchers at **Purdue University,** West Lafayette, Ind., performed experiments with a "porous interconnected" tin-oxide based anode, which has nearly twice the theoretical charging capacity of graphite. The experimental anode can be charged in 30 minutes and still have a capacity of 430 milliamp hours per gram (mAh g−1), which is greater than the theoretical maximum capacity for graphite when charged slowly over 10 hours. *purdue.edu.*



EMERGING TECHNOLOGY



Doctoral student Yang Xu inspects devices made from topological insulators. Courtesy of Purdue University/Ting-fung Chung.

NEW EVIDENCE CONFIRMS PRINCIPLES OF TOPOLOGICAL INSULATORS

Researchers at Purdue University, West Lafayette, Ind., report they have uncovered "smoking gun" evidence to confirm the workings of an emerging class of materials called topological insulators that could enable spintronic devices and quantum computers far more powerful than those now available. The materials are insulators inside, but conduct electricity via the surface. More specifically, the team reports the clearest demonstration of such seemingly paradoxical conducting properties to date and observed the "half integer quantum Hall effect" on the insulator's surface.

Yong P. Chen, associate professor of physics and astronomy and electrical and computer engineering, led a team of researchers from Purdue, Princeton University, and the University of Texas at Austin in studying the bismuth-based material. By further combining topological insulators with a superconductor, researchers may be able to build a practical quantum computer.

Researchers demonstrated a 3D material with an electrical resistance not dependent on material thickness for the first time. Whereas electrons usually have a mass, in the case of topological insulators the conducting surface electrons have no mass and are automatically "spin polarized," leading to the unique half-integer quantum Hall effect observed. *For more information: Yong P. Chen, 765.494.0947, yongchen@purdue.edu, www.purdue.edu.*

NASA AWARDS GRANTS TO 11 EMERGING TECHNOLOGY PROPOSALS

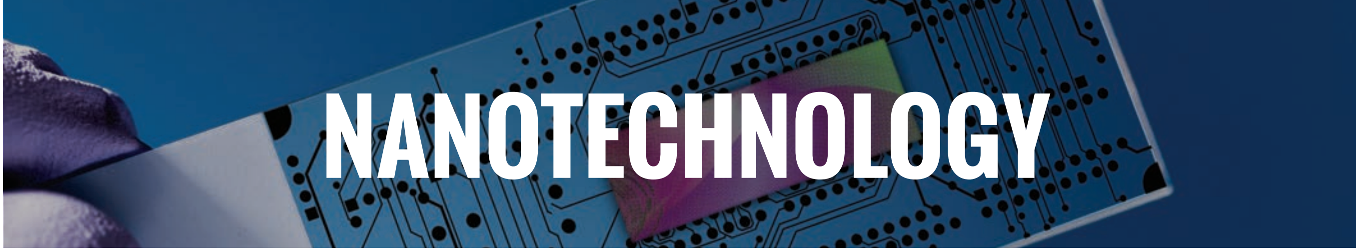
NASA chose 11 university-led proposals for studying early stage technologies that address high priority needs within America's space program. The proposals address unique, disruptive, or transformational technologies, including: advanced thermal protection materials modeling, computational materials, in situ utilization of asteroid materials, mobile robotic surface probe concepts for planetary exploration, and kinetic penetrators for icy planetary moons. Among the selected projects are: Iowa State University, Ames: Computational Modeling of Nondestructive Evaluation, Defect Detection, and Defect Identification for CFRP Composite Materials; Stanford University: Asteroid Surface Resource Characterization Through Distributed Plasma Analysis of Meteoroid Impact Ejecta; and Texas A&M University, College Station: Control of Variability in the Performance of Selective Laser Melting (SLM) Parts through Microstructure Control and Design. The awards from NASA's Space Technology Research Grants Program are worth as much as $500,000 each, with technology research and development efforts taking place over two to three years. *go.usa.gov/X9eP.*

RESEARCHERS AT THE **UNIVERSITY OF ARKANSAS, FAYETTEVILLE AND PINE BLUFF,** RECEIVED A $725,000 GRANT FROM THE **U.S. AIR FORCE OFFICE OF SCIENTIFIC RESEARCH** TO FURTHER DEVELOP A NEW MATERIAL FOR ADVANCED ELECTRONICS DEVICES. *uark.edu.*

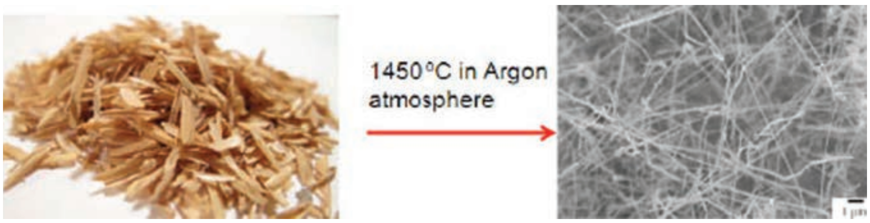
BRIEFS

A car powered by its own body panels may soon become a reality, based on a nanotechnology breakthrough at **Queensland University of Technology (QUT), Australia.** Researchers developed lightweight supercapacitors that can be combined with regular batteries to dramatically boost power. The supercapacitors were made into a thin film with high power density that could be embedded in a car's body parts, storing enough energy to turbocharge an electric vehicle battery in minutes. *www.qut.edu.au.*

Professor Nunzio Motta with one of QUT's powerful nanotechnology microscopes.



NANOTECHNOLOGY



For U.S. Naval Research Laboratory scientists, the conversion of rice husks to high value SiC nanowires may provide new materials for electronic and structural applications.

CORN HUSKS CONVERTED TO SILICON CARBIDE

Scientists at the U.S. Naval Research Laboratory (NRL), Washington, are exploring ways to convert agricultural waste into high-value silicon carbide that can be used for a variety of electronic and structural applications. Agricultural waste products have significantly high silica content in a molecular state, similar to hydrocarbons. Armed with that knowledge, Syed B. Qadri and his team discovered that these agricultural waste products can be economically transformed into silicon carbide (SiC) consisting of nanostructures and nanorods in various polytypes.

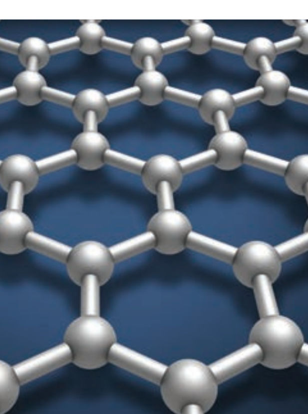
The team accomplished this by pyrolysis of the agricultural waste to produce the crystalline phases of silicon carbide, a highly stable compound, in various shapes of nanocrystals, nanorods, and nanowires. By selectively heating and cooling the agricultural waste products, they were able to systematically investigate the role of temperature rise and cooling rates. They observed that this heating and cooling process directly impacts the extended defect formation mechanisms that help in modifying the optical, electrical, and structural properties of these nanoparticles. *nrl.navy.mil.*

NEW UNDERSTANDING OF NANOCRYSTALS

Nanocrystals exhibit unprecedented properties that intrigue scientists and engineers. To apply these materials in emerging nanotechnologies, scientists need to better understand their structure, corresponding functions, and how they pack together. Collaboration between Cornell High Energy Synchrotron Source (CHESS), Ithaca, N.Y., and materials scientists has yielded greater understanding of what particular nanocrystals look like individually and how they fit together as they form larger structures called supercrystals. This discovery could lead to effective bottom-up engineering of new materials for applications ranging from solar cells to electronic components.

The team used innovative x-ray crystallography methods at the B1 CHESS beamline led by Zhongwu Wang. Data was simultaneously collected on the ordering and orientation of lead sulfide nanocrystals and supercrystals using both wide-angle (WAXS) and small-angle (SAXS) x-ray scattering, which are typically done one at a time. The new method provides insights into the unexpected complexity of the arrangement of nanocrystals within the supercrystal. The discovery could result in new methods for growing supercrystals and how to optimize their properties. *chess.cornell.edu.*

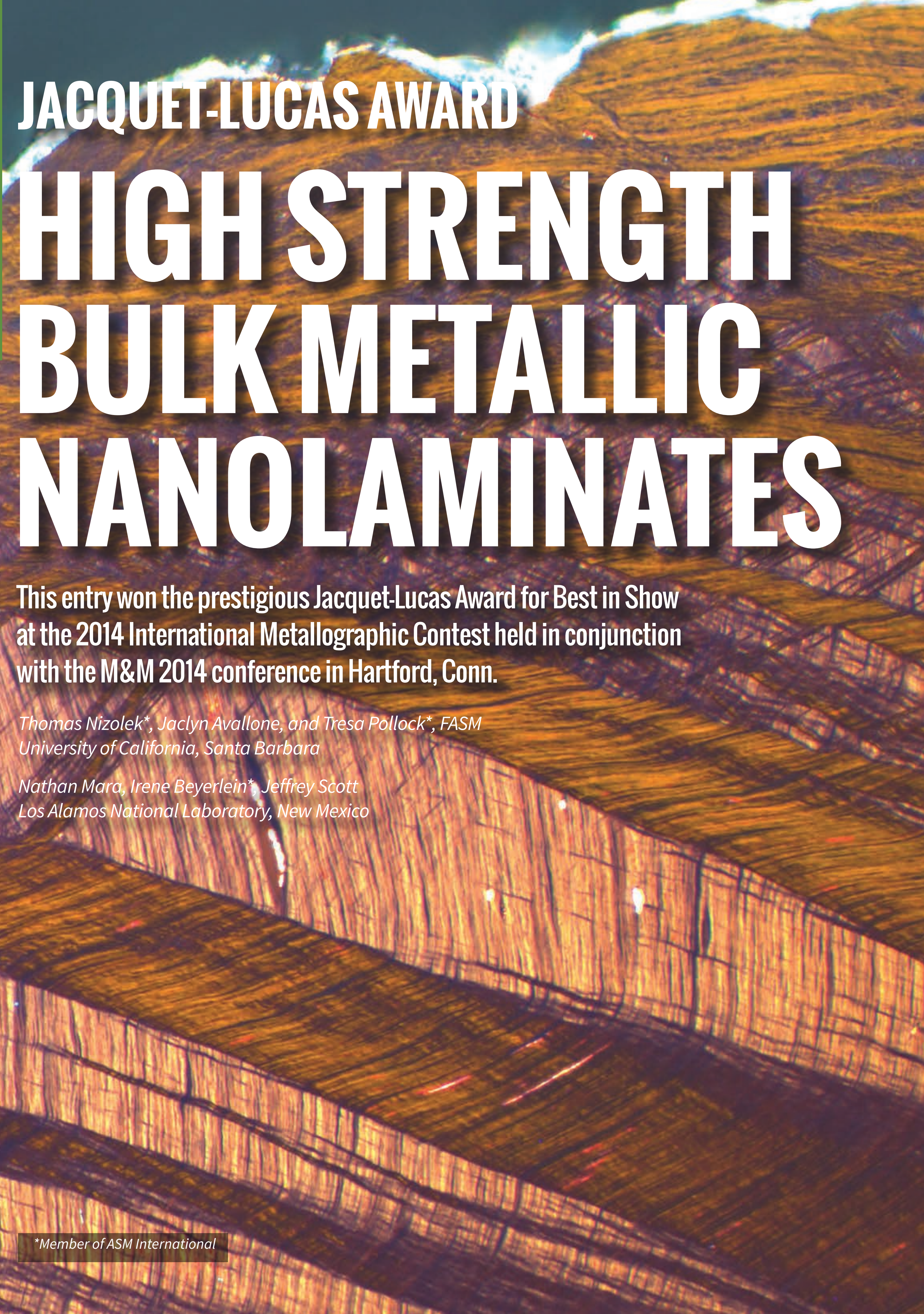
NORTHWESTERN UNIVERSITY, EVANSTON, ILL., PROFESSOR MARK HERSAM WON A "GENIUS GRANT" FROM THE MACARTHUR FOUNDATION FOR HIS INVESTIGATIONS INTO HOW THE TINIEST MATERIALS CAN IMPROVE ELECTRONICS, MEDICAL DEVICES, AND RENEWABLE ENERGY. HERSAM IS USING GRAPHENE TO FASHION NOVEL DEVICES THAT CREATE NEW POSSIBILITIES IN SUPPORT OF THE OFFICE OF NAVAL RESEARCH PLAN TO ENHANCE THE NAVY'S ASYMMETRIC CAPABILITIES ACROSS THE PHYSICAL DOMAIN, CYBERSPACE, AND ELECTROMAGNETIC SPECTRUM. *onr.navy.mil.*



BRIEFS

Perpetuus Carbon Group, UK, a producer of purified and functionalized graphene, received independent verification of its graphene production. An independent work-study using a measurement study compliant with BS 3138:1992, concluded that the annual theoretical capacity, running 30 kg batches of raw graphite, is 140 tons per year from a single reactor. *perpetuuscarbon.com.*

Graphene has incredible intrinsic properties, showing great potential for industrial and commercial applications across a wide range of industries. Courtesy of Haydale Ltd.



JACQUET-LUCAS AWARD

HIGH STRENGTH BULK METALLIC NANOLAMINATES

This entry won the prestigious Jacquet-Lucas Award for Best in Show at the 2014 International Metallographic Contest held in conjunction with the M&M 2014 conference in Hartford, Conn.

Thomas Nizolek, Jaclyn Avallone, and Tresa Pollock*, FASM*
University of California, Santa Barbara

Nathan Mara, Irene Beyerlein, Jeffrey Scott*
Los Alamos National Laboratory, New Mexico

**Member of ASM International*

Copper-niobium nanolaminates, composed of alternating layers of Cu and Nb, display high strengths (>1 GPa) and intriguing properties due to their highly oriented nanocrystalline microstructure. Compared to either pure Cu or Nb, these composite materials have superior hardness, flow strength, and radiation damage resistance[1-2]. While nanolaminates were previously only available in thin-film form (<40 µm thick), recent advances in the severe plastic deformation process of accumulative roll bonding (ARB) have enabled production of bulk nanolaminates (Fig. 1). Four-mm thick Cu-Nb nanolaminates containing more than 200,000 individual layers (layer thickness of <20 nm) are now routinely synthesized for research purposes.

The ability to produce bulk metallic nanolaminates has greatly expanded the potential structural applications for these materials, motivating investigations into formability, joining techniques, and deformation behavior. This article presents an overview of both the ARB process and the materials' deformation behavior.

SYNTHESIS METHOD

The ARB process uses an iterative sequence of cleaning, stacking, cold roll bonding, and cutting to create and refine a lamellar microstructure. Starting materials consist of coarse-grained single-phase sheets of Cu and Nb which are degreased, wirebrushed, and alternately stacked. Materials are bonded together using a single-pass 50% rolling reduction. Next, the roll bonded sheet is cut in half, cleaned, and re-stacked in preparation for the next cycle. Iterating these steps increases the number of layers exponentially while decreasing layer thickness (Fig. 2). Sheet thicknesses remain nearly constant during processing, and can be increased by cutting and bonding three or more pieces together.

This processing technique allows extreme strains to be imparted to the material while maintaining the desired sheet thickness. Strains exceed those typically encountered during conventional rolling. For example, synthesis of 15 nm Cu-Nb nanolaminates requires a rolling strain of 11.8. Imagine a U.S. nickel coin (nearly the same thicknesses as the sheets used for ARB). If it were conventionally rolled to a strain of 11.8, the length of the rolled strip would exceed 2 km.

While ARB has been applied to several different bimetal systems[3-5], the Cu-Nb system offers low solid solubility as well as similar flow stresses for the two phases. These characteristics result in excellent microstructural stability during ARB processing, allowing production of nanolaminates with continuous layers and individual layer thicknesses as small as 10 nm[6].

Fig. 1 — A 4-mm-thick piece of Cu-Nb nanolaminate material synthesized using the ARB process held by Thomas Nizolek. For comparison, a thin-film Cu-Nb multilayer synthesized using physical vapor deposition is shown in the bottom right.

DEFORMATION BEHAVIOR

The large dimensions of ARB Cu-Nb nanolaminates have facilitated a wide variety of bulk mechanical tests (i.e., tensile tests, miniature Charpy impact tests, and fatigue tests) that are difficult, if not impossible, to perform on traditional thin film nanolaminates. In many cases, these tests confirm the extraordinary properties of metallic nanolaminates. For example, tensile specimens of ARB Cu-Nb nanolaminates with a 30 nm layer thickness have a strain-to-failure of approximately 8% and a flow strength of 1200 MPa (a 5× increase in strength compared to pure Cu or Nb)[7]. However, bulk mechanical testing also reveals an unusual deformation mode during compression.

During layer-parallel compression of nanolaminate specimens with layer thicknesses below 100 nm, a pronounced inhomogeneous shape change occurs

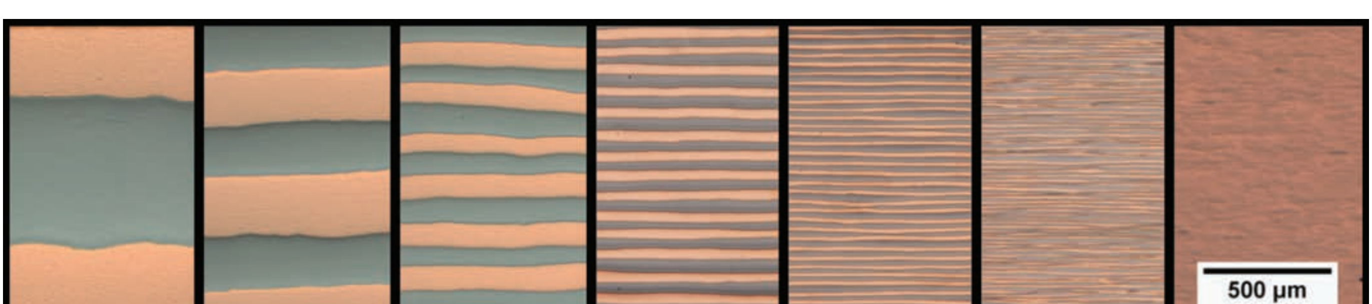


Fig. 2 — Optical micrographs show cross-sections of Cu-Nb laminates at various stages during the ARB process.

as seen in Fig. 3. In situ imaging shows that bands of localized deformation form shortly after yield, but do not lead to failure. Post-test metallographic characterization reveals that the dark bands evident during in situ imaging do not correspond to cracks or microstructural damage, as demonstrated using bright-field light optical microscopy (LOM) in Fig. 4a. Instead, these bands are kink bands in which the lamellar structure remains continuous but has been uniformly sheared and rotated (Figs. 4b and 4c). While these deformation structures lack sufficient contrast when imaged using bright-field LOM (Fig. 5a), polarized light microscopy clearly reveals that complex networks of kink bands can form in these specimens (Fig. 5b).

In addition to forming during uniaxial compression tests, kink bands also occur during bending, Charpy impact tests, and even high strain rate ballistic tests where local compressive strains occur. Kink band formation in a wide range of both quasi-static and dynamic mechanical tests suggests that it is an important deformation mode, likely to occur during many forming operations and potential structural applications.

While strain localization is almost universally viewed as detrimental to a metal's mechanical properties, kink band formation in Cu-Nb nanolaminates may be an exception to this rule. Unlike other forms of strain localization, such

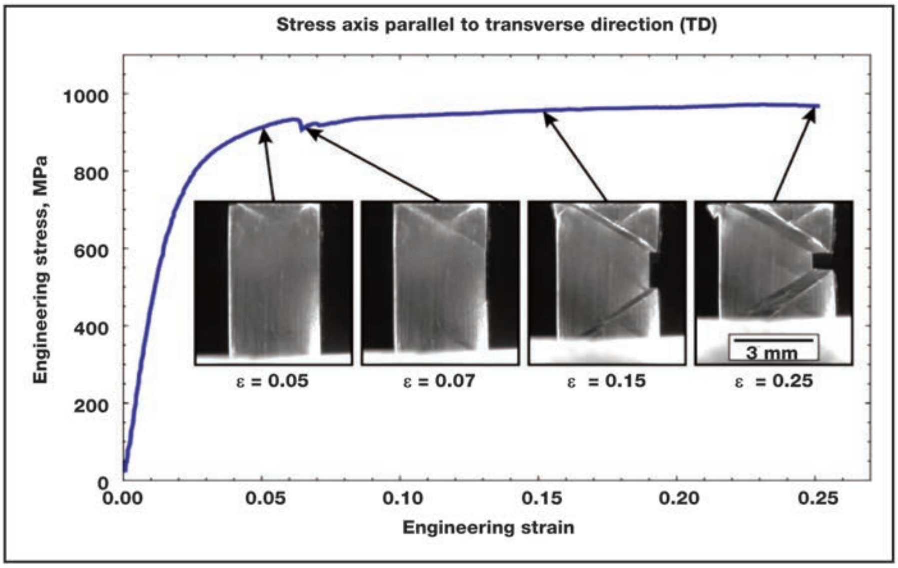


Fig. 3 — Stress strain curve from a 65 nm layer thickness Cu-Nb nanolaminate displays a perturbation at 7% engineering strain. In situ video recording of the compression specimen reveals that this point corresponds to pronounced inhomogeneous deformation due to kink band formation.

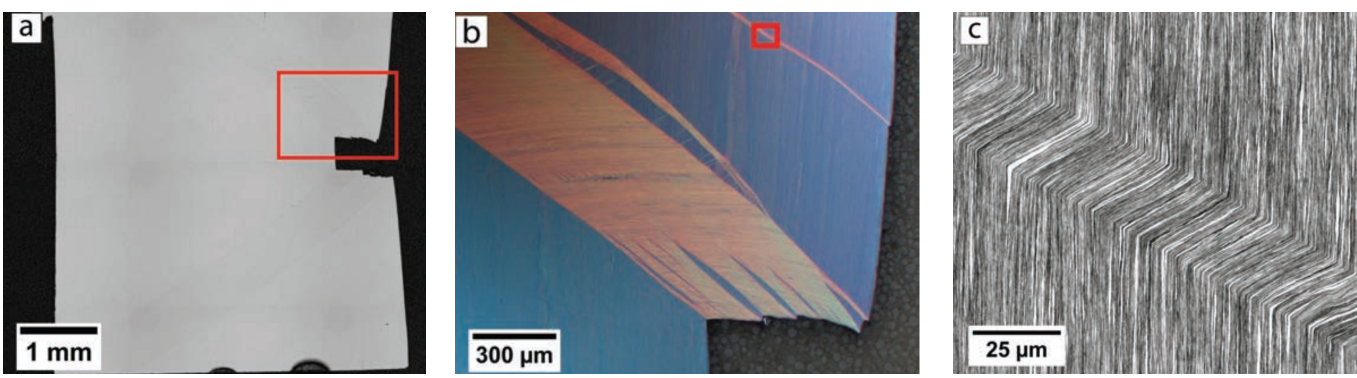


Fig. 4 — Optical and scanning electron microscopy reveal that kink bands are responsible for the pronounced shape change that occurred during compression of the 65 nm specimen. Bright-field microscopy shows the absence of cracks along the kink bands (a). Sub-region of (a) imaged using circular differential interference contrast (b). Sub-region of (b) imaged using backscatter scanning electron microscopy (c)[7].

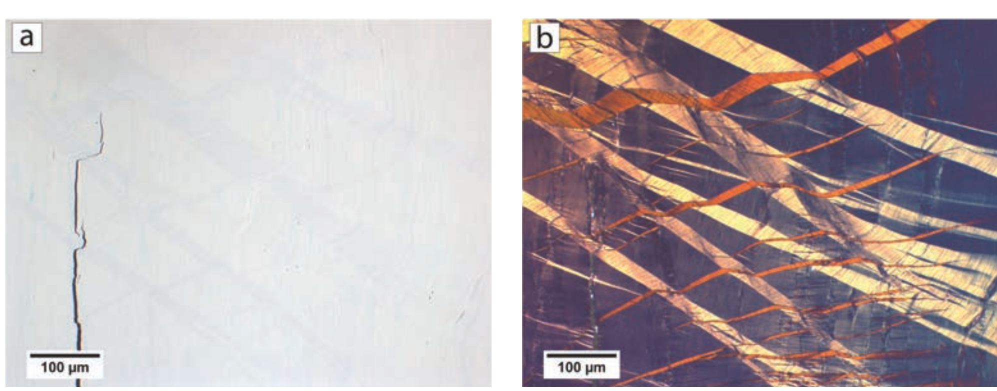


Fig. 5 — Bright-field image of kink bands in the 65 nm specimen showing poor kink band contrast (a). Same field of view as (a) imaged using polarized light microscopy (b). Polarized light allows the complex network of kink bands to be clearly revealed and highlights many small kink bands not evident in (a).

as shear bands, kink bands result in large but limited local deformation, do not cause microstructural damage, and may even provide a beneficial mechanical response. Kink band formation allows for very large deformations at a constant stress, with neither a load drop nor an increase in engineering stress that would occur during homogenous deformation[7]. Therefore, kink bands may prove beneficial for the design of energy absorbing structures where large strain deformation at a constant reaction force is a highly desirable mechanical response.

SUMMARY

Cu-Nb nanolaminates can be produced in bulk form using the industry scalable ARB process. These materials display high strengths (>1 GPa) and show a strong propensity for kink band formation during layer parallel compression. The combination of microstructural stability, high strength, and unusual deformation behavior make metallic nanolaminates intriguing candidate materials for structural applications. ~AM&P

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Acknowledgment
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UNDERSTANDING AND MEASURING DECARBURIZATION

Understanding the forces behind decarburization is the first step toward minimizing its detrimental effects.

George F. Vander Voort, FASM, Struers Inc. (Consultant), Cleveland*

Decarburization is detrimental to the wear life and fatigue life of steel heat-treated components. This article explores some factors that cause decarburization while concentrating on its measurement. In most production tests, light microscopes are used to scan the surface of a polished and etched cross-section to find what appears to be the greatest depth of total carbon loss (*free-ferrite depth,* or FFD) and the greatest depth of combined FFD and partial loss of carbon to determine the *maximum affected depth* (MAD).

In some cases, there is no free ferrite at the surface. In research studies, this may be supplemented with a Knoop hardness traverse to determine the depth where hardness becomes constant. The Knoop-determined MAD is often somewhat deeper than the visually determined MAD, as variations in the microstructure of carbon contents close to the core may be difficult to discern. The MAD determined by hardness traverse may be slightly shallower than that determined by quantitative carbon analysis with the electron microprobe. This is especially true when the bulk carbon content exceeds about 0.45 wt%, as the relationship between carbon in the austenite before quenching to form martensite and the as-quenched hardness loses its linear nature above this carbon level.

DECARBURIZATION BASICS

Decarburization occurs when carbon atoms at the steel surface interact with the furnace atmosphere and are removed from the steel as a gaseous phase[1-8]. Carbon from the interior diffuses towards the surface, moving from high to low concentration and continues until the maximum depth of decarburization is established. Because the carbon diffusion rate increases with temperature when the structure is fully austenitic, MAD also increases as temperature rises above the Ac_3. For temperatures in the two-phase region, between the Ac_1 and Ac_3, the process is more complex. Carbon diffusion rates in ferrite and austenite are different, and are influenced by both temperature and composition.

Decarburization is a serious problem because surface properties are inferior to core properties, resulting in poor wear resistance and low fatigue life. To understand the extent of the problem, two characteristics that may be present at a decarburized steel's surface can be measured: Free-ferrite layer depth (FFD, when present) and partial decarburization depth (PDD, when free-ferrite is

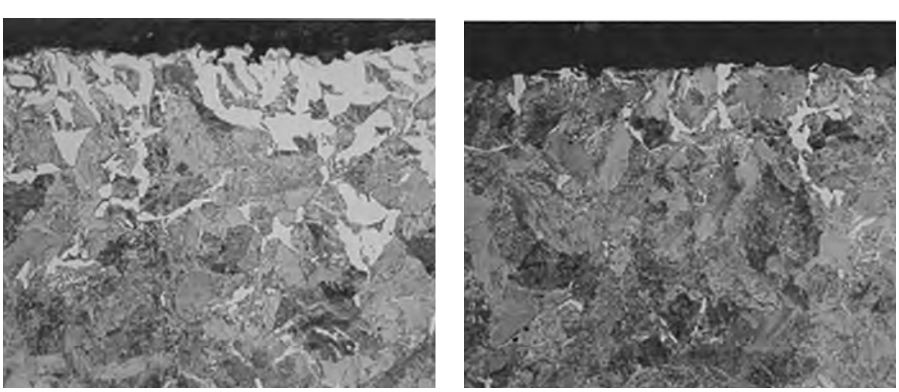


Fig. 1 — Decarburized surface of as-rolled, eutectoid carbon steel (Fe-0.8% C-0.21% Mn-0.22% Si) at two different locations around the periphery show a substantial variation in the amount and depth of ferrite at the surface. The matrix should be nearly all pearlite (4% picral etch, 500×).

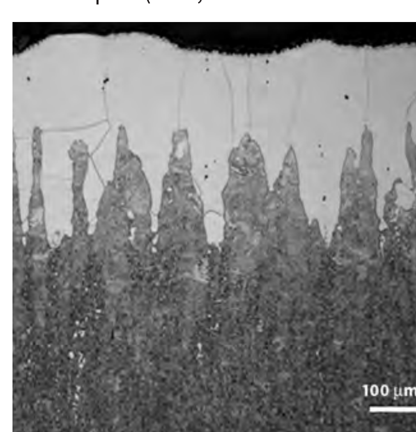


Fig. 2 — Erratic depth of free ferrite at the surface of a bar of 440A martensitic stainless steel after quenching from 2000°F (1093°C); etched with Vilella's reagent.

*Life Member of ASM International

not present). If free ferrite is present, the free-ferrite layer's maximum depth (often variable) plus the depth of partial decarburization to the unaffected core is measured. This total—FFD + PDD—is called maximum affected depth (MAD). These depths are not uniform and can vary substantially, leading to measurements of average FFD, PDD, and MAD, as well as maximum values for each. ASTM E1077 covers decarburization measurement.

In practice, decarburization should be evaluated on a plane transverse to the hot working axis, as depth variation is greater around the bar on the transverse plane than at a specific constant position along a longitudinal plane. Decarburization depth can vary substantially around the periphery of a bar, as shown in Fig. 1. Qualitative measurements can be subjective and biased. Free-ferrite depth can also be erratic, even over a small surface area, as shown in Fig. 2. Corners of square or rectangular sections normally exhibit greater decarburization depths than planar surfaces. Sampling schemes for large cross-sections are also illustrated in ASTM E1077.

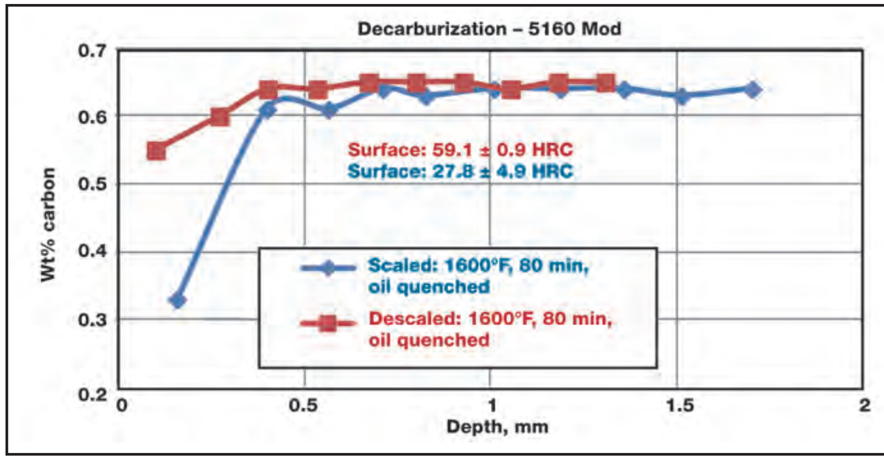


Fig. 3 — Decarburization of 5160 modified spring steel defined by surface hardness and incremental turnings analyzed chemically for carbon content as a function of whether or not the surface was descaled or was covered by mill scale, and austenitizing at 1600°F for 80 minutes.

To obtain good data, edge retention must be perfect—the surface must be perfectly flat to the extreme edge. If edges are rounded, the exact location of the outer surface is difficult to define with precision and depth measurement accuracy suffers. Good edge retention requires mounting of the specimen in a resin, such as DuroFast, that does not exhibit shrinkage gaps between the mount and specimen after polymerization. Grinding and polishing procedures must emphasize maintaining flatness. While

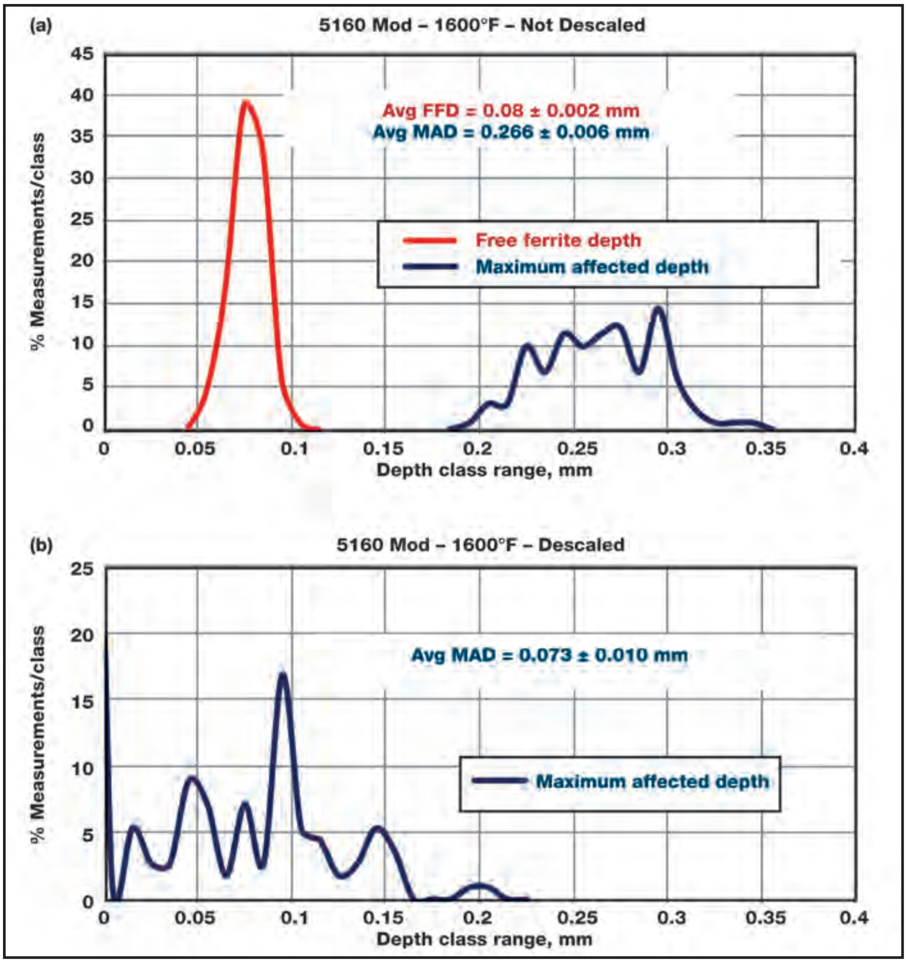


Fig. 4 — Frequency histograms of decarburization measurements made around the periphery of 5160 modified bars after heat treatment. a) 1600°F specimen with a mill scaled surface has an average FFD of 0.08 mm and average MAD of 0.266 mm for 132 measurements. Note the narrow, peaked distribution of the FFD measurements and broad distribution of MAD measurements. b) 1600°F specimen with a descaled surface does not exhibit any free ferrite. No decarburization was observed for almost 19.5% of the measurements and distribution of MAD values is broad.

SiC abrasive paper can be used for grinding, resin-bonded diamond discs such as MD-Piano provide excellent flatness and long life. Napless cloths are used for diamond polishing while low-nap clothes are used to polish with alumina or colloidal silica abrasives. In most cases, a reticule is used to make the measurement. Alternatively, many image-capture software programs allow operators to make point-to-point distance measurements. However, these systems must be properly calibrated.

Hot working temperatures can produce ferrite at the surface with the amount and size of the ferrite grains growing as carbon loss increases at the surface. The upper critical temperature, Ac_3, of these grains could be above 1600°F, as alloy composition and residual elements influence the Ac_3 of the steel grade. Spring steels are used as an example. If a decarburized specimen is induction hardened, the heating rate to the austenitization temperature is extremely fast. To put all of the carbon in solution (assuming that the steel has a carbon content of 0.60-0.65%), it is heated to roughly 1700°-1750°F. As the holding time is short, perhaps no more than 10 s, there is little time for appreciable carbon diffusion and the decarburization depth after heat treatment is a function of the as-rolled mill decarburization depth.

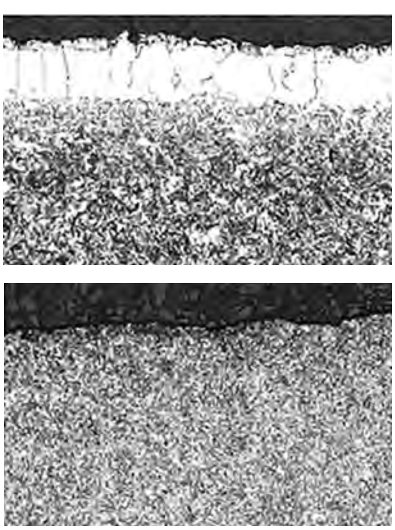


Fig. 5 — Decarburized surfaces of 5160 Mod austenitized at 1600°F for 80 min. and oil quenched. Free ferrite on the scale covered specimen, top. No free ferrite present on the specimen that was descaled before being austenitized (2% nital, 200×), bottom.

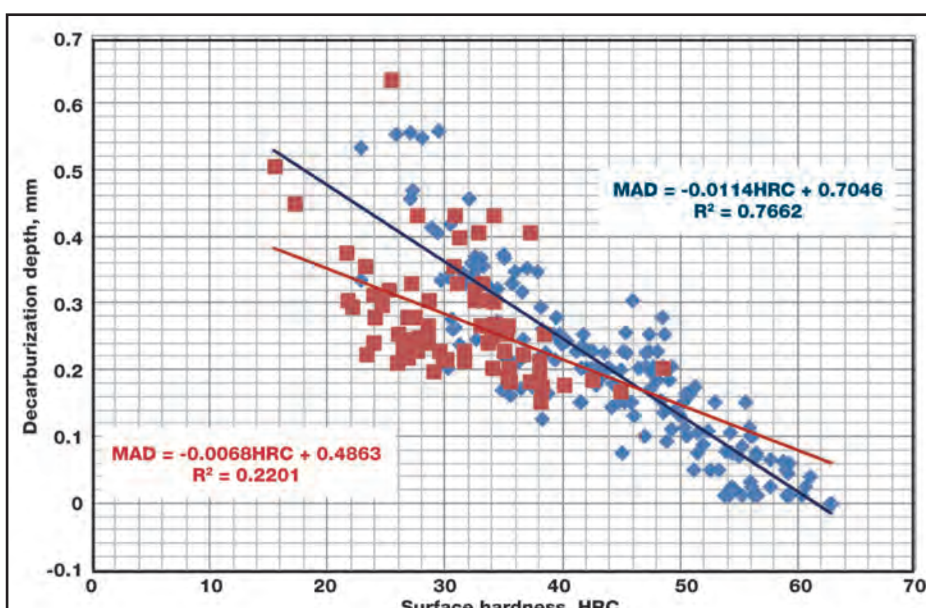


Fig. 6 — Rockwell C hardness tests on the surface of 5160H, 5160M, and 9260M (after glass bead blasting) is a simple screening test to determine if the surface is decarburized or free of decarburization. The correlation is much better when there are no free-ferrite grains at the surface (blue data points) than when free ferrite (red data points) is present.

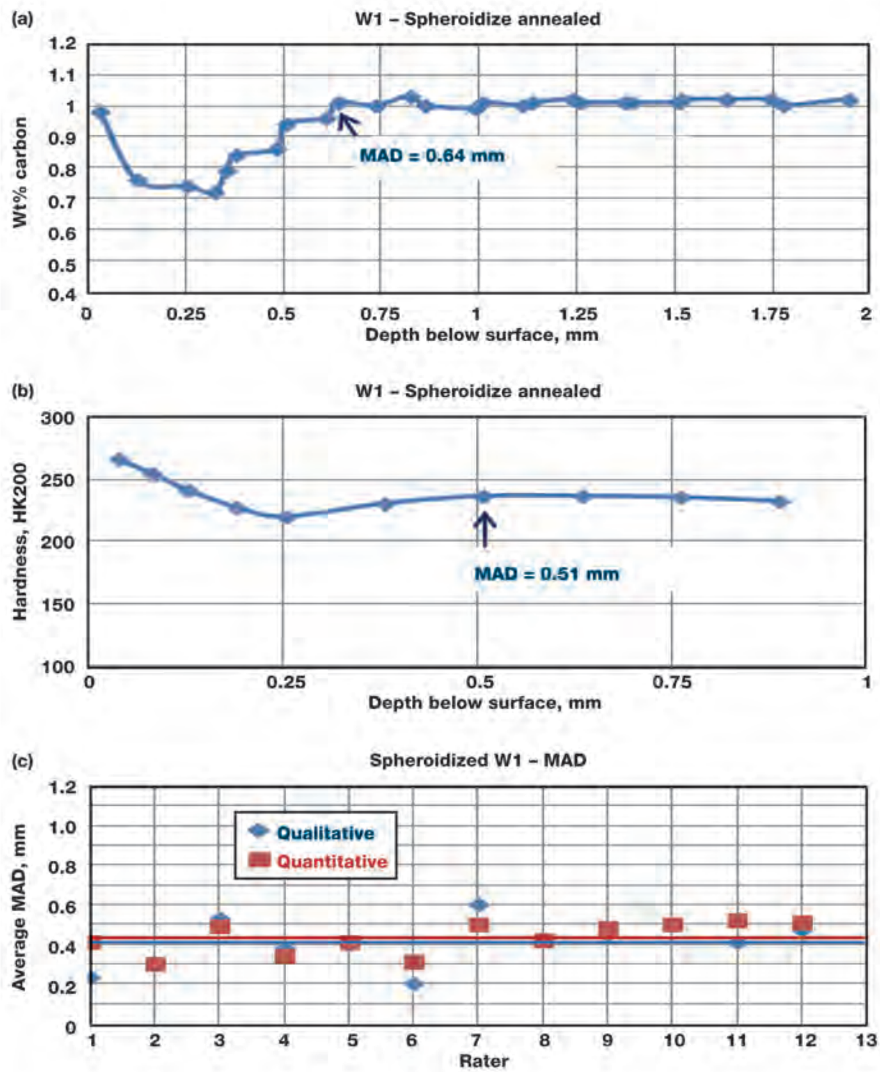
EXPERIMENTAL DATA

If spring steels (typically ~0.6% carbon) are heat treated in gas-fired furnaces, operating conditions can either increase or decrease the as-rolled depth of decarburization after heat treatment, relative to the starting point. Austenitizing of these grades is typically performed in the 1600°-1650°F range and holding times, which depend upon bar diameter, are usually at least 20 minutes. In many cases, a protective atmosphere is not employed.

An experiment was conducted using round bars of 5160 modified spring steel. Specimens were austenitized either with the as-rolled mill scale present or removed by sand blasting. Specimens were austenitized at 1600°F (871°C) for 80 minutes, then oil quenched. Part of each bar was incrementally machined (after scale removal by glass-bead blasting) and the carbon content was determined. Surface hardness readings were also recorded and results are shown in Fig. 3. Note that the specimen austenitized at 1600°F exhibits a large difference between surface carbon content and surface hardness, compared to the bar covered with mill scale to the descaled one.

Figure 4 shows results of quantitative FFD and MAD measurements for the two specimens austenitized at 1600°F—including 132 measurements around the periphery of the scaled bar and 113 measurements for the descaled sample. The scaled bar austenitized at 1600°F exhibits a consistent free-ferrite layer around its periphery with an average depth of 0.08 ± 0.002 mm (95% confidence interval). Note that FFD measurement distribution is very narrow, or *peaked*. The MAD, however, shows an average depth of 0.266 ± 0.006 mm and distribution is broad. In contrast, for the descaled bar, no free ferrite was seen and 19.47% of the 113 measurements indicate no decarburization was present. The remaining measurements exhibit an average depth of 0.073 ± 0.010 mm, slightly lower than the scaled bar's average FFD. The MAD distribution curve appears to be bimodal. Figure 5 shows typical microstructures observed at the specimens' two surfaces.

Visual estimates of the maximum affected depth of decarburization generally produce more conservative estimates than the incremental carbon analysis procedure or microindentation hardness traverses. This is because it is difficult to detect the final minor loss in carbon as the unaffected core is reached. Color etchants are likely to perform better for this purpose than black and white etchants such as nital or picral, but comparative tests have not been performed. For annealed microstructures, the visual estimate of the average MAD is generally about 50-70% of the MAD determined by incremental carbon analysis or microindentation tests. This depth, however, can be considered an effective depth where carbon content is usually within about 10-25% of the matrix carbon content and responds reasonably well to heat treatment. If the maximum observed MAD is used as criteria for stock removal, the surface's carbon content will be close to the matrix carbon content after machining.



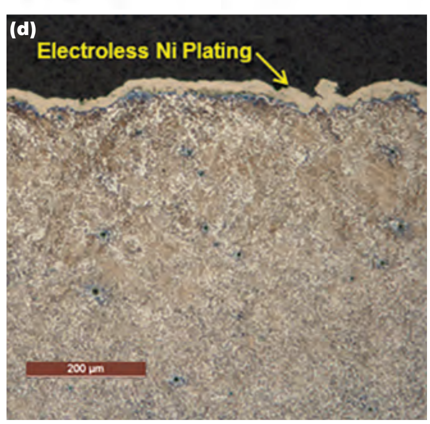


Fig. 7 — Decarburization measurements on a spheroidize annealed bar of W1 carbon steel. a) Carbon analysis of incremental turnings reveal a MAD of 0.64 mm. b) A 200 gf Knoop hardness traverse reveals a MAD of 0.51 mm. c) Qualitative and quantitative visual LOM estimates yield MADs of 0.406 and 0.433 mm, respectively. d) LOM image of a typical surface area.

Additionally, a simple screening test was used to detect decarburized specimens of 5160H, 5160M, and 9260M spring steel lots used for front wheel drive automobile springs. As the design loads on these springs increased throughout the 1970s, no free ferrite and almost no MAD could be permitted or spring life would be reduced. Mill processing helped minimize the MAD to less than the amount removed in the final processing step of turning and burnishing. Figure 6 shows data for a number of specimens where the surface scan was removed by glass-bead blasting after hardening and bulk Rockwell C tests were made on the OD surfaces at a number of locations and averaged. Bars were sectioned, metallographically prepared, and rated for maximum free-ferrite depth (when present) and maximum affected depth of decarburization. The plot shows a much better correlation between HRC and MAD when free ferrite was not present versus when it was present.

Examples of the variation in decarburization ratings by three methods—carbon analysis of incremental turnings, microindentation hardness traverses, and visual qualitative or quantitative estimates by light microscopy—are shown in Fig. 7. The spheroidize annealed microstructure of W1 carbon tool steel (~1% C), a typical specimen rated by mill metallurgists in plants that make tool steel, is shown in Fig. 7d at 100×. The carbide in the decarburized surface zone exhibits a significantly lower volume fraction than the interior. At the extreme surface, individual carbides can be seen. Note the seemingly unusual carbon distribution at the surface in Fig. 7a. The lowest carbon content is only to about 0.7%, roughly a 30% loss. So, free ferrite is not present. Examination at 1000× shows that the cementite in the decarburized zone is not well spheroidized but tends to be lamellar. This is because the annealing cycle cannot spheroidize cementite in the lower carbon surface area compared to the bulk carbon content. Note that the hardness at the surface of the decarburized zone is actually greater than in the core, a result that may seem counterintuitive. However, as some tool steel metallurgists are aware, coarse lamellar carbide structure—even with a lower volume fraction than the spheroidized core—is harder and less ductile.

Carbon analysis of the incremental turnings provides the best estimate of the maximum affected depth. The MAD estimate is more accurate using the Knoop traverses than LOM measurements, but is still rather conservative compared to the MAD from actual carbon analysis. However, this is not a major problem because the hardness became essentially constant at a shallower depth than shown by the incremental carbon analysis. The qualitative estimates, based on a simple visual estimate going around the bar's periphery, are slightly lower than the quantitative average, which was based on 25 random measurements around the periphery. If it was assumed that the visual estimate of the greatest MAD around the bar periphery would be deeper than the mean MAD of 25 randomly chosen locations, then the actual result would be rather surprising.

CONCLUSIONS

Decarburization of steel parts is a serious problem as the weaker surface layer reduces wear resistance, enabling fatigue failures to occur more easily. A simple screening test was discussed, which can be used for certain shapes and high production runs. If the surface hardness is below some predetermined limit, which varies with grade, then a microstructural examination is required. Chemical analysis of carbon on incremental turnings (or millings) can be performed, although this is more applicable to research than production. Metallographic rating of decarburization depth requires properly prepared specimens with good edge retention. This can easily be achieved with modern equipment and is reasonably fast. Qualitative measurements of the free-ferrite depth (when present) and the maximum affected depth of decarburization are usually adequate. But such measurements are subject to bias and the reproducibility is not as good as when quantitative measurements are made using at least 25 randomly selected locations around the bar periphery. Microindentation hardness traverses are excellent for defining the MAD. The FFD is easily observed by light microscopy and adequate inspection of the periphery is needed to detect the deepest amount present. ~AM&P

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INTERNATIONAL THERMAL SPRAY CONFERENCE AND EXPOSITION 2015

Plan now to attend the foremost international conference and exposition for thermal spray technologists, researchers, manufacturers, and suppliers. This year ITSC is co-located with AeroMat and Microstructural Characterization of Aerospace Materials and Coatings.

Whether you are an expert, an experienced engineer or scientist, or new to the thermal spray field, the 2015 ITSC technical program features the latest in advanced technology, research and development, and a wealth of resources where you can learn about processes that can be applied immediately to impact critical issues such as corrosion, wear, tear, and abrasion.

PLENARY SPEAKERS

John Grotzinger
Chief Scientist and Head of Strategic Planning for Mars Rover Mission

Humberto Luiz de Rodrigues Pereira
Vice President, Engineering, Embraer Executive Jets

Robert Vassen
Professor, Ruhr-University Bochum, Germany, and Researcher, Forschungszentrum Jülich GmbH

EDUCATION COURSES

All education courses will be held at the Hyatt Regency Long Beach. Visit asminternational.org/web/itsc-2015/education to register.

Introduction to Thermal Spraying
Instructor: Chris Berndt
Date/time: Saturday, May 9 and Sunday, May 10 from 8:30 a.m. – 4:30 p.m.

Leaders in the Thermal Spray Society were brought together to compile their knowledge and experience in a comprehensive, easy to understand course.

Thermal Spray Safety Management
Instructor: Gregory Wuest
Date/time: Sunday, May 10, 8:30 a.m. – 4:30 p.m.

This course focuses on key elements of a comprehensive health and safety system using the U.S. Occupational Safety and Health Standard 29 CFR 1910 as a basis.

Robotics for the Thermal Spray Industry
Instructor: Nick McDonald
Date/time: Sunday, May 10, 8:30 a.m. – 4:30 p.m.

Students will gain an understanding of robot coordinate systems, basic robot configuration, and critical elements of robot path instructions.

EXHIBITORS

3M Abrasives Systems Division
Above Material Technology Co. Ltd.
AIM MRO
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AMETEK Specialty Metal Products
AMS
AMT AG
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Ardleigh Minerals Inc.
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Metallizing Equipment Co. Pvt. Ltd.
MILLIDYNE OY Surface Technology
Montreal Carbide
Nakayama Amorphous
North American Höganäs
Oerlikon Metco
Oseir Oy
Plasma Giken USA
Polymet Corp.
Powder Alloy Corp.
Praxair Surface Technologies
Precision Surface International Inc.
Progressive Surface Inc.
ProjectSoft HK a.s.
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Saint-Gobain
Sewon Hardfacing Co. Ltd.
Tapeworks
TECNAR Automation Ltd.
Thermach Inc.
Treibacher Industrie Ag
Uniquecoat Technologies LLC
Wall Colmonoy
Watson Grinding & Manufacturing
Zhengzhou Ruite Diamond Belt Co. Ltd.
ZL Diamond Technology Co. Ltd.

Exhibitor list current as of January 28.

ITSC 2015 SCHEDULE-AT-A-GLANCE

The preliminary schedule included here is subject to change. ITSC conference attendees will also have access to the technical programming offered through AeroMat 2015 and Microstructural Characterization of Aerospace Materials and Coatings Conference at no additional charge.

Date	Time	Event
Saturday, May 9	8:30 a.m. – 4:30 p.m.	Education course: Introduction to Thermal Spraying (Two-day course)
Sunday, May 10	8:30 a.m. – 4:30 p.m.	Education course: Introduction to Thermal Spraying (Two-day course)
	8:30 a.m. – 4:30 p.m.	Education course: Thermal Spray Safety Management
	8:30 a.m. – 4:30 p.m.	Education course: Robotics for the Thermal Spray Industry and Thermal Spraying for the Oil and Gas Industry
	11:00 a.m. – 12:30 p.m.	ASM Thermal Spray Society – Expo Committee Meeting (invitation only)
	12:30 – 6:00 p.m.	ASM Thermal Spray Society – Board of Directors Meeting (invitation only)
	6:00 – 8:00 p.m.	Conference registration open
Monday, May 11	7:00 a.m. – 6:00 p.m.	Conference registration open
	8:00 a.m. – 12:10 p.m.	ITSC technical programming
	10:00 – 10:30 a.m.	Refreshment break
	10:15 – 11:15 a.m.	Private demo tours (ITSC and IMS)
	12:00 – 7:00 p.m.	Exhibit hall open
	12:10 – 1:15 p.m.	Lunch on show floor (included in registration)
	1:30 – 3:00 p.m.	Combined plenary session with ITSC/AeroMat/IMS, featuring John Grotzinger
	3:00 – 3:30 p.m.	Refreshment break (show floor)
	3:30 – 5:30 p.m.	ITSC technical programming
	5:30 – 7:00 p.m.	Expo welcome reception (included in registration)
Tuesday, May 12	7:00 a.m. – 5:00 p.m.	Conference registration open
	8:00 – 11:50 a.m.	ITSC technical programming
	9:00 a.m. – 5:00 p.m.	Exhibit hall open
	10:00 – 10:30 a.m.	Refreshment break (show floor)
	12:00 – 1:00 p.m.	Lunch on the show floor (included in registration)
	1:00 – 3:30 p.m.	Combined plenary session with ITSC/AeroMat/IMS, featuring Robert Vassen and Humberto Luiz de Rodrigues Pereira
	3:30 – 4:00 p.m.	Refreshment break (show floor)
	4:00 – 5:40 p.m.	ITSC technical programming
	7:00 – 9:30 p.m.	Networking event on Queen Mary (additional fee)
Wednesday, May 13	7:30 a.m. – 5:00 p.m.	Conference registration open
	8:00 – 10:00 a.m.	ITSC technical programming
	9:00 a.m. – 4:00 p.m.	Exhibit hall open
	10:00 a.m. – 12:00 p.m.	Coffee break, Oerlikon Metco Sulzer young professionals competition, and poster session (show floor)
	12:00 – 1:00 p.m.	Lunch (concessions available on the show floor)
	1:00 – 4:50 p.m.	ITSC technical programming
	3:00 – 3:30 p.m.	Refreshment break
Thursday, May 14	7:30 a.m. – 12:00 p.m.	Conference registration open
	8:00 a.m. – 12:10 p.m.	ITSC technical programming
	10:00 – 10:30 a.m.	Refreshment break
	12:10 p.m.	Conference adjourns

2014-2015 PRESIDENT OF ASM INTERNATIONAL

SUNNIVA R. COLLINS

Diana Essock, FASM, Metamark Inc., Moreland Hills, Ohio

It is my great pleasure to introduce ASM International's new president, Professor Sunniva R. Collins, FASM. Sunniva and I have known each other for more than 20 years through our involvement in the ASM Cleveland Chapter. I have also enjoyed working with her on ASM's national activities. We developed the nomination for ASM Headquarters as an ASM Historic Landmark, awarded in 2009, and we both served as ASM Trustees in 2010 and 2011. Sunniva has been a great supporter of the new ASM Women in Materials Engineering Committee and helped us kick off a wonderful inaugural breakfast event at MS&T 2014.

BACKGROUND AND CAREER

Sunniva was born and raised in Cleveland. Her mother was a journalist and newspaper reporter, and her father, a Norwegian sea captain, was the superintendent for the Port of Cleveland, just after the opening of the Saint Lawrence Seaway brought oceangoing vessels to the Great Lakes for the first time. She is the middle of three children and remembers field trips to ASM to see the fantastic Buckminster Fuller geodesic dome, the largest structure of its kind. Always academically inclined, she earned a scholarship to the University of Michigan, where she studied mechanical engineering and English. After university, she made an extended visit to Norway to visit her father's side of the family.

Upon graduation, Sunniva worked as a technical editor for the American Society for Metals, editing articles for ASM Handbooks and developing manuscripts for technical monographs. After a few years, she was ready for a new challenge and began pursuing a graduate degree in materials science and engineering at Case Western Reserve University (CWRU).

At Case, Sunniva studied under Professor Gary Michal, working on steel metallurgy projects for her thesis and dissertation, studying inclusions in steel and their effects on fatigue properties. Graduate school was a lot of fun as well, as she learned to brew beer so she could bring it to the department happy hours (a long-standing Friday tradition), and participated in student government and a soccer team in the local co-ed league. Sunniva started attending ASM confer-

VISION FOR ASM

Sunniva's constant compass has always been her interest in materials technology and what it can do to make the world better. ASM has been integral to her career, from her first job on the publications staff, through graduate school, and throughout her experiences at Swagelok and Case. Her vision for ASM stems from its vital networking function: ASM serves a critical role in the technology-based economy as a connector of people, ideas, and information. As ASM president, Sunniva's priorities are to build on the strategic plan, creating better connections and synergies among key initiatives, as she discusses here.

Content is Everything Material

ASM is widely recognized as a fair broker of reliable technical information about materials. ASM should position itself as the source and repository for technical information on many emerging trends, including materials for fuel cells, hydrogen storage materials, green processes, and reduction of hazardous substances (RoHS), to name a few. Additionally, we need to protect and preserve our core content through review and revision to keep the information current and timely, and better understand how we generate and capture materials content.

Partnerships are synergistic relationships where both parties benefit.

For ASM, strategic partnerships can be a source of materials content generated by a related discipline, as well as new members who need materials information, but for whom materials are not the main focus of their job. A smart strategy developed around partnerships could have significant influence on all of ASM's initiatives.

Flashback: Sunniva with daughter Kristina and Prof. Arthur Heuer at CWRU after receiving her Ph.D.

Graduation Day 2014 at CWRU. Prof. Collins with Prof. Heuer, research collaborators since 2000.

ences and giving presentations on her research work. She also got involved in ASM Cleveland Chapter activities, judging science fairs, attending meetings, and planning events.

After graduate school, Sunniva found a position as a research metallurgist at Nupro Co., now Swagelok, a manufacturer of high-purity valves for the semiconductor equipment market. It was a great time to be there, with many materials-based questions to answer and issues to solve as the semiconductor equipment market matured. She was recognized by SEMI International for her work in the development of standards for the semiconductor equipment industry, in particular welding procedures and inspection criteria for high purity welding; surface chemistry and surface finish requirements and test methods; and materials specifications and corrosion test methods for semiconductor gas delivery systems and components. She also remained active in ASM. At the chapter level, Sunniva served as Cleveland Chapter Chair, and in national activities, she chaired the Technical Books Committee and organized conference sessions.

In 2000, Sunniva attended ASM's inaugural Materials Camp as an observer. The excitement of the students and their mentors was infectious. In the following years, she served as a mentor at the Eisenman Camp and in Canada. From 2008 to 2014, she headed the ASM Cleveland Chapter Committee that planned and ran Materials Camps for teachers at CWRU.

Swagelok continued to grow, manufacturing fluid system components and engineering solutions for industries including oil and gas, nuclear, semiconductor, and biopharm. Sunniva kept up with her research, presenting and publishing on a variety of topics, and took on management positions at Swagelok as well. She became actively involved in Swagelok's research on low temperature carburization of stainless steel, and was the principal investigator on two government-sponsored projects concerning this technology. She also initiated Swagelok's materials science research collaboration with Case that continues to this day. Swagelok's patented SAT12 process won the ASM Engineered Materials Achievement Award in 2006. Sunniva became an ASM Fellow in 2008 and served on the Board of Trustees from 2008 to 2011.

Sunniva is very proud of her family and grateful for their support—husband Michael, daughter Kristina, and son William. Michael and Sunniva celebrated their 25th wedding anniversary in July 2014. Michael is a business economist and writer, and a stay-at-home dad. Kristina studies electrical engineering at Case, and William is a sophomore in high school. They have been great ASM supporters too, wrapping family vacations around ASM conferences and helping out at Materials Camps.

In March 2013, Sunniva left her position at Swagelok after 18 years and became a professor in mechanical and aerospace engineering at Case. She teaches undergraduate and graduate courses in design, manufacturing, and materials, and assists with manufacturing research initiatives. The driver for her return to campus was an opportunity to serve as a role model and mentor for the next generation of engineers. She is particularly interested in supporting women in STEM professions for the benefit of workforce development and economic opportunity.

I hope I've given you a sense of who Sunniva is and how she functions. She is a good listener and a great communicator, and I look forward to her leadership of our Society. ~AM&P

International Impact

Although ASM became "international" in the 1980s, we have not developed a truly global view. ASM has opportunities in countries all over the world, English-speaking and otherwise. With an expanded web presence, and an understanding of how to deliver value to people in China, India, and South America—anywhere there is a potential member—we can fulfill our international promise.

Volunteerism

This initiative addresses a very special portion of our membership, those who are engaged in chapter participation and as volunteers. The ASM Chapters form a wonderful base for the Society. We need to determine what works well in the chapter model and how to improve it for the next generation of members. Our volunteers also need support and a new generation of volunteers needs to be cultivated. We must make the benefits of ASM membership and volunteerism obvious and transparent, and make membership easy and valuable to both members and their companies.

METALLURGY LANE

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

STAINLESS STEEL: THE STEEL THAT DOES NOT RUST – PART II

FROM WARTIME USE TO CUTLERY AND BUILDING FACADES, THE STAINLESS STEEL INDUSTRY BEGAN TO EXPERIENCE DYNAMIC GROWTH FROM THE 1920s ON, ESPECIALLY FOLLOWING WWII.

Before World War I began, a small amount of stainless steel cutlery and tableware was produced in Sheffield, England. Meanwhile in the U.S., the first heat of stainless steel was melted at the Pittsburgh plant of the Firth-Sterling Steel Co., a subsidiary of Thomas Firth and Sons, headquartered in Sheffield. However, the decade from 1910-1920 saw little progress in stainless steel production mainly because throughout World War I, all available metal was used to make exhaust valves for aircraft engines in both the U.S. and England. During the war, one of the major stainless producers was Carpenter Steel Co., a manufacturer of steel for Liberty aircraft engines.

Most production processes of this era used the heat-treatable martensitic grade—13% chromium and 0.30% carbon. These general martensitic grades were covered in the U.S. by patent applications in March 1915 from both Elwood Haynes and Harry Brearley. Rather than fight the conflict in court, Brearley and Thomas Firth and Sons formed a syndicate named The Stainless Steel Co. to hold all patents. Haynes agreed to a 30% share in the company and Brearley and Firth held 40%. Several other U.S. companies held the remaining 30%. This solved the problem for ferritic and martensitic grades of stainless, although Krupp—in Germany—held patent rights for the austenitic grades.

EARLY APPLICATIONS

Throughout the majority of the 1920s, only ferritic and martensitic stainless steels were made in the U.S. This was extremely limiting because during the next few years, the austenitic grades were required for major stainless steel applications. The commercial dilemma was corrected when patents were exchanged between England and Germany in 1923, with a royalty paid in 1928 to import or produce austenitic grades in the U.S.

The top seven stories of the Chrysler Building are covered with austenitic stainless steel. Courtesy of Petri Krohn and Leena Hietanen.

After the war ended, initial uses for stainless steel again involved cutlery and tableware. By 1923, this had expanded to surgical and dental instruments and then to containers for nitric acid. New applications throughout the decade included milk handling equipment, surgical implants, cookware, golf clubs, and automotive trim. Perhaps the most spectacular was the curtain wall for the upper seven stories of the brand new Chrysler Building in New York, including the huge gargoyles that serve as its architectural trademark. This building used 48 tons of austenitic stainless steel, from a total of 53,000 tons produced in 1929. The industry was just getting started with these new austenitic stainless offerings, with steel companies like Allegheny, Ludlum, Carpenter, Crucible, Lukens, Latrobe, and others as the major pioneers and producers.

Burlington Zephyr stainless steel passenger train, circa 1935. Courtesy of Roger Wollstadt.

Meanwhile, in England, W.H. Hatfield had modified the German austenitic alloy containing 20% chromium plus 7% nickel to the now familiar 18% chromium plus 8% nickel (18-8) that became AISI 302 in the U.S. He also added titanium to combine with the carbon for AISI 321, greatly improving weldability. 18-8 went on to become the single most important alloy in stainless steel because it offers the ideal combination of corrosion and acid resistance, formability, and the ability to be polished to a beautiful finish.

1930s AND 1940s

The Great Depression of the 1930s impacted stainless steel as it did all metal making. Production decreased from 58,000 tons in 1929 to 23,000 tons in 1932. Only a few applications saw increased stainless steel consumption during the decade, mainly in the trans-

Socony-Mobil Building, the first high-rise to use a stainless steel exterior. Courtesy of SebasTorrente at en.wikipedia.

Walt Disney Concert Hall, Los Angeles, designed by architect Frank Gehry. Public domain image.

portation industry. Automobiles used more trim and trucks were lined to carry milk, food, and acid. However, the most interesting use was on trains. Budd Manufacturing Co. designed the Zephyr, a passenger train made of stainless steel. It consisted of a locomotive, baggage car, and two passenger cars. From 1935 to the start of WWII, 47 stainless steel trains were manufactured using aircraft construction methods. The original Zephyr is now on display at the Museum of Science and Industry in Chicago. During the war, stainless steel was used extensively for aircraft exhaust systems and engine valves, ship galleys, and hardware wherever corrosion was a problem.

ALLOY DEVELOPMENT

Following WWII, several stainless steel producers developed alloys that respond well to precipitation hardening. Success was first achieved by The American Rolling Mill Co. (Armco). They kept the chromium content at 17%, but reduced the nickel to 4% and added 3.5% copper (17-4 PH) or 7% nickel with 1% aluminum (17-7 PH) and, a third alloy with 7% nickel, 2.5% molybdenum, and 1% aluminum. These alloys have design strengths of 200,000 to 220,000 psi after heat treatment. Another alloy system in development during this time was duplex stainless steels, which feature a microstructure of roughly 50% austenite and 50% ferrite to improve strength and corrosion resistance.

THE ARGON OXYGEN DECARBURIZATION (AOD) PROCESS WAS THE GREATEST TECHNOLOGICAL ADVANCE IN THE HISTORY OF PROCESSING STAINLESS STEEL.

AOD PROCESS

The major problem in ferritic and austenitic stainless steels production was the requirement for very low carbon content to avoid precipitation of chromium carbides, which lower the chromium content needed for corrosion resistance. This was a particular problem during welding, where a region in the heat-affected zone sits at the ideal temperature for carbide formation. Union Carbide Corp. (UCC) tried using an oxygen lance to reduce the carbon level, but was unsuccessful due to the uncontrolled temperature of the bath. They hired a recent MIT graduate named William A. Krivsky to work on improving the oxygen process. Krivsky tried adding the inert gas argon with the oxygen to control the bath temperature and carbon reaction. He successfully decreased the carbon to very low levels without excessive chromium loss. Following his laboratory success, UCC looked for a stainless producer to scale up the process to production levels. Only one company was interested—Joslyn Steel, a small producer in Fort Wayne, Ind.

Over many years and many heats of steel, Joslyn was unable to produce a satisfactory result. They had tried introducing oxygen and argon into the electric arc furnace using lances coated with ceramics. Joslyn and UCC finally realized that the refining was going to need a separate vessel where argon was blown through the bottom, but oxygen was still introduced with a lance. The new vessel was similar to the old Bessemer converter and the technique became the successful argon oxygen decarburization (AOD) process. Union Carbide started offering licenses in 1970. As industry began to learn about the new process, more than 100 vessels were installed within a dozen years with 75% of world production eventually using AOD. This was the greatest technological advance in the history of processing stainless steel.

Modern kitchen with stainless steel appliances. Public domain image.

NEW AND NOVEL APPLICATIONS

A major use for stainless steel after WWII was for the exterior walls of high-rise buildings. The austenitic grade with 18% chromium and 8% nickel was selected for its corrosion resistance, formability, and added strength when cold rolled. The first design was the Socony-Mobil Building in New York. Within a few years, it was common practice to clad skyscraper buildings with stainless steel.

It was also used for kitchen sinks in the late 1930s, later expanding to the exteriors of refrigerators, stoves, dishwashers, and other appliances. Although stainless has largely disappeared as auto trim and hubcaps, its current automotive use is for exhaust systems with catalytic converters and fuel injection systems. The chemical, pharmaceutical, and electrical power industries also use large amounts of stainless in piping, tanks, pumps, and other equipment. Stainless steel is the ideal metal alloy for designs requiring steel that does not rust. ~AM&P

For more information: Charles R. Simcoe can be reached at crsimcoe1@gmail.com. For more metallurgical history, visit metals-history.blogspot.com.

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INTERNATIONAL THERMAL SPRAY & SURFACE ENGINEERING

THE OFFICIAL NEWSLETTER OF THE ASM THERMAL SPRAY SOCIETY

THERMAL SPRAY COATINGS IN AEROSPACE AND MILITARY APPLICATIONS

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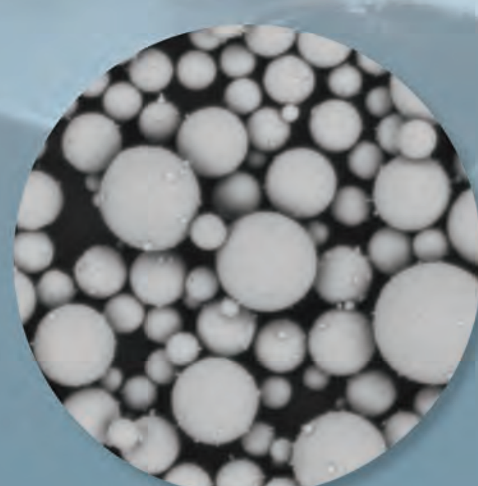
NEW!

High Purity Yttria Thermal Spray Powder

- High density yttria coatings with less than 1% porosity
- Improved erosion resistance
- 20% higher productivity = cost savings
- Perfect for dry etch chambers



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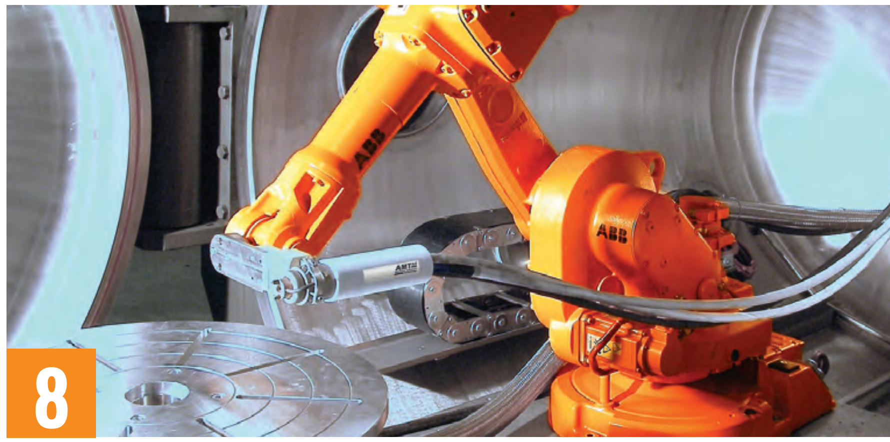
EDITORIAL OPPORTUNITIES FOR iTSSe IN 2015

iTSSe's editorial focus reflects established applications of thermal spray technology as well as emerging applications.

May	Energy & Power Generation
August	Automotive & Industrial Applications
November	Emerging Technologies/ Applications and Case Studies

To contribute an article, contact Julie Lucko at julie.lucko@asminternational.org. To advertise, contact Kelly Thomas, kelly.thomas@asminternational.org.



DEPARTMENTS

ABOUT THE COVER

The Orion Multi-Purpose Crew Vehicle is intended to carry a crew of up to four astronauts to destinations at or beyond low Earth orbit. During re-entry into Earth's atmosphere, the Orion heat shield protected the vehicle from external temperatures of 4000°F. Courtesy of NASA. nasa.gov.

ALL FOR ONE AND ONE FOR ALL!

CHRISTIAN MOREAU
TSS PRESIDENT

It's not *The Three Musketeers* cry; it's the 2015 International Thermal Spray Conference and Exposition! This year, for the price of one registration fee, ITSC attendees will gain access to technical programming for three conferences: ITSC 2015, AeroMat 2015, and an IMS topical event. The theme of AeroMat 2015 is "Shape the Future of Your Industry," while IMS focuses on the "Microstructural Characterization of Aerospace Materials and Coatings." Between all three conferences, attendees will have access to more than 400 technical presentations.

Attendees will also learn about the latest research and development efforts in their specific field while gaining a global perspective from leading scientists and engineers from around the world. AeroMat and ITSC are working together to present a special joint symposium on advanced coatings for the aerospace industry. Topics include thermal barrier coatings (TBCs); engineering, protection, and repair of aircraft structural parts; bond coat development for TBCs, engineering TBCs and abradables, and much more. A special combined plenary session is also being planned on the expo show floor.

The opening keynote session features Dr. John Grotzinger, chief scientist and head of strategic science planning for NASA's $2.5 billion Curiosity rover mission to Mars. Dr. Grotzinger is the lead scientist for Curiosity's mission to explore the past climate and geology of Mars. He will describe what the rover has discovered since landing on the Red Planet, and how the Mars Science Laboratory onboard Curiosity will continue the search for signs of extraterrestrial life.

The show also features a special event on the historic Queen Mary where attendees will have the opportunity to build business relationships and network with key contacts. Crowds will gather on the show floor to learn the latest industry trends across the thermal spray, aerospace, and metallurgy industries. New products and services will be discovered, while business relationships are built.

On top of all of that, the show is taking place in beautiful Long Beach, California, May 11-14—a prime West Coast location that is part of the Southern California aerospace corridor—and is sure to attract a large cohort of aerospace engineers and researchers. We hope to see you in Long Beach in May! To learn more and to register, visit asminternational.org/web/itsc-2015.

POULIOT

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TSS COMMITTEE CHAIRS NAMED FOR 2014-2015 TERM

The ASM Thermal Spray Society Board appointed chairs to each of its committees for the 2014-2015 term. **Christian Moreau, FASM,** Concordia University, Montreal, was elected as president of TSS. **Luc Pouliot,** Tecnar Automation Ltd., Quebec, Canada, currently serves TSS as immediate past president and chair of the Nominating Committee. **Robert C. Tucker, Jr., FASM,** The Tucker Group, continues as chair of the Journal of Thermal Spray Technology Committee. **Atin Sharma,** Oerlikon Metco, Westbury, N.Y., serves as chair of the Membership, Marketing and Outreach Committee. **Douglas Puerta,** Elementals Materials Technology, Portland, Ore., serves as vice president of TSS and chair of the TSS Program Committee. **Greg Wuest,** Oerlikon Metco, continues to serve as chair of the TSS Safety Committee while **Andre McDonald,** University of Alberta, Edmonton, Canada, continues as chair of the TSS Training Committee. **Timothy N. McKechnie, FASM,** Plasma Processes Inc., Huntsville, Ala., continues to serve as chair of the TSS Awards Committee. **Shari Fowler-Hutchinson,** Saint-Gobain, Boston, serves as chair of the Exposition Committee and **Marcel van Wonderen,** KLM Royal Dutch Airlines, Amsterdam, was named chair of the Accepted Practices Committee. If you are interested in serving on an affiliate society committee, contact the respective committee chair or email joanne.miller@asminternational.org.

PRESIDENT'S PROFILE: CHRISTIAN MOREAU

Christian Moreau, FASM, Ph.D., has advanced the understanding and development of thermal spray technology through his significant role in the development of optical systems for the measurement of the plasma effluent and particle temperature, velocity, and size distribution. Dr. Moreau is currently a professor in the Department of Mechanical and Industrial Engineering at Concordia University in Montreal. He has been an active member of the Thermal Spray Society and a member of the TSS Nominating Committee from 2010 to 2012. In addition, he has been a member of both the TSS Publications and Communications Committee as well as the TSS Program Committee from 1999 to 2013.

He was a TSS Board Member from 2006 to 2012, and also a member of TSS Information Development/Delivery. He became an ASM Fellow in 2006 and was inducted into the Thermal Spray Hall of Fame in 2013. He is presently Editor-in-Chief of the *Journal of Thermal Spray Technology* and has been a member of the JTST Committee since 1999.

"I am much honored to have the opportunity to contribute to the TSS as the newly elected president. In this capacity, I will invest my efforts to make sure our Society continues providing members with high quality publications, conferences, and services in the most efficient and pertinent manner possible," says Moreau. "I would like to recognize the exceptional job my predecessor Luc Pouliot has done over the last two years and thank him on behalf of all TSS members and on my own behalf. I would also like to thank all volunteers who contributed and will continue to contribute to the life of our Society by their dedicated work and efforts. Nothing would be possible without you. A special welcome to the new members of the TSS Board and Committees! I look forward to working with all of you in the coming years."

NOMINATIONS SOUGHT FOR ASM THERMAL SPRAY SOCIETY BOARD

The ASM TSS Nominating Committee is currently seeking nominations to fill two board member positions. Candidates for these director positions may come from any segment of the thermal spray community, but ideally will have a focus on the service or government research segments.

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 candidate. Nominations must be received no later than March 1. Forms can be found at tss.asminternational.org. Contact Luc Pouliot, ASM TSS Nominating Committee Chair, at lpouliot@tecnar.com for more information.

ASM HANDBOOK, VOLUME 5A: THERMAL SPRAY TECHNOLOGY

Volume 5A is a replacement for the *Handbook of Thermal Spray Technology*, edited by J.R. Davis (2004) and provides an introduction to modern thermal spray processes including plasma spray, high velocity oxy-fuel, and detonation gun deposition, as well as a description of coating properties and their wear, corrosion, and thermal barrier characteristics. Principles, types of coatings, applications, performance, and testing/analysis are also covered. A greatly expanded selection of applications includes examples and figures from various industries, including electronics and semiconductors, automotive, energy, and biomedical. Emerging thermal spray market sectors such as aerospace and industrial gas turbines, and important areas of growth such as advanced thermal barrier materials, wear coatings, clearance control coatings, and oxidation/hot corrosion resistant alloys are also reviewed. Visit asminternational.org to learn more.

JULY THERMAL SPRAY EDUCATION COURSES

Please look for these upcoming courses at ASM Headquarters, Materials Park, Ohio, in July. Visit asminternational.org/education for more information.

Introduction to Thermal Spray
July 6-7
Instructor: Richard A. Sayman
This course focuses on the five critical areas of thermal spray: Safety, preparation, troubleshooting, spraying, and keeping records. Safety standards for thermal spray operators and the evaluation process required in various practical applications are an important part of the course.

Thermal Spray Technology
July 8-9
Instructor: Christopher C. Berndt, HoF, FASM
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. Participants also receive the *Handbook of Thermal Spray Technology*.

Thermal Spray for Gas and Oil Industries
July 10
Instructor: André McDonald
Given the special needs of the oil and gas sector for wear and corrosion-resistant coatings with high longevity, the certification and validation process differs significantly from other industries. This course includes training and testing information that applies specifically to the oil and gas sector.

JOIN THE TSS DISCUSSION GROUP

The TSS email discussion group is an email-based discussion list, where only subscribers may post messages to the group. Messages are relayed as they come in, or subscribers may choose a once-daily digest instead. Individuals may subscribe and unsubscribe as they wish. Visit asminternational.org/web/tss/membership/forum to learn more.

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LOW PRESSURE AND VACUUM PLASMA SPRAY BUILD BETTER COATINGS FOR ENGINE APPLICATIONS

Ludwig Guggenheim, Ralph Herber, and Silvano Keller, AMT AG, Dottingen, Switzerland
Robert Gansert, Advanced Materials & Technology Services Inc., Simi Valley, Calif.*

Low pressure and vacuum plasma spray technologies are making headway in many emerging industries, along with their primary use in commercial and military aerospace gas turbine engine applications. Vacuum plasma has also been implemented in biomedical and electronics applications. Figures 1 and 2 show a vacuum plasma system, while Figs. 3 and 4 show a low pressure coating system (LPCS) manufactured by AMT AG.

Both systems pump down the atmosphere to <0.1 torr and backfill to processing pressure in a short time. Stable atmospheric pressure regulation and reliable part handling are critical for proper coating quality. Therefore, state-of-the-art control software and hardware is used as well as a new robotic and computer numerical control (CNC) technique.

LOW PRESSURE AND VACUUM PLASMA SPRAY COATING PROPERTIES

Low pressure and vacuum plasma spray produce coatings with better performance properties than those made by traditional air plasma spray (APS). By carefully controlling the processing environment, exceptional coating properties with regard to microstructure (porosity, oxide content, density), phase composition, and mechanical attributes may be achieved. It is also possible to hold oxide content to less than 1% and reach coating densities near 99%.

Plasma coatings of NiCrAlY, shown in Fig. 5, are produced in a low pressure plasma spray atmosphere. These coatings exhibit enhanced oxidation protection and increased resistance to spallation in gas turbine engines.

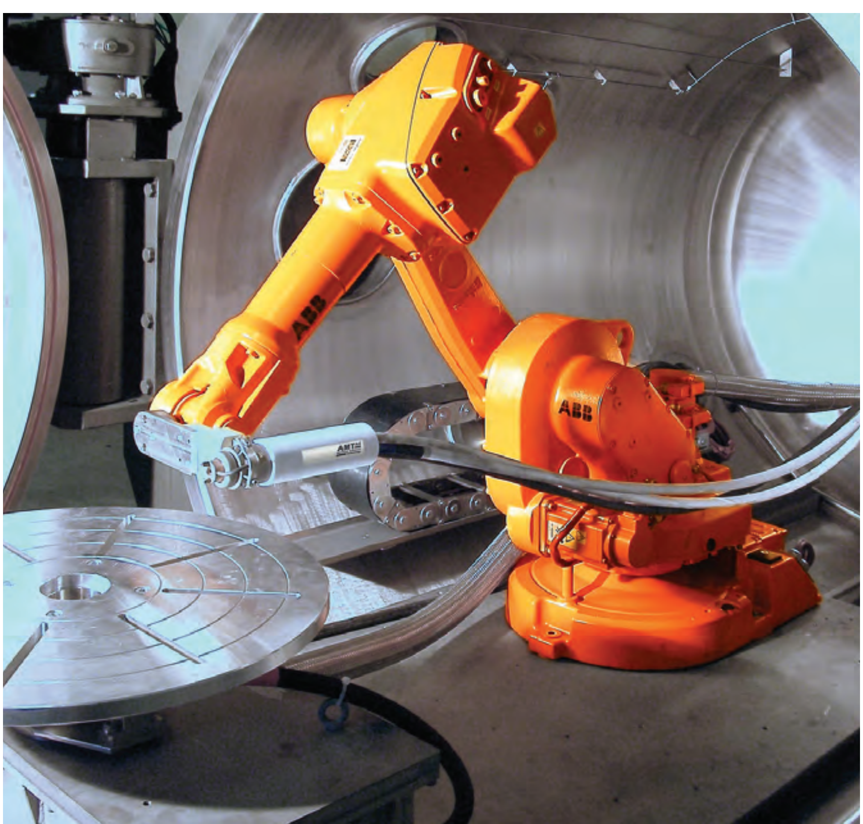


Fig. 1 — Vacuum plasma spray system.

Fig. 2 — Vacuum plasma spray in operation.

Fig. 3 — Low pressure coating system (LPCS).

**Member of ASM International and ASM Thermal Spray Society*

A range of coating operations and system configurations are possible using low pressure and vacuum plasma spray. Figure 1 illustrates a vacuum plasma spray process during a batch operation where parts (ranging from IGT turbine components to titanium implants) are coated using a vacuum rated turntable and robot system located inside the chamber.

With LPCS, continuous production is performed in contrast to a batch operation. This is common in high-volume production spray of thermal barrier coatings, such as NiCrAlY for aerospace turbine engine components. Figure 3 shows a main process low pressure chamber located between two load-locks, which enable part loading and unloading for spraying coatings in the main chamber. The main process chamber is able to maintain low pressure, while parts (e.g., turbine blades) are loaded into the load-locks and pumped down to match the pressure of the process chamber for the coating operation. Two work-piece manipulators (stings) move parts into and out of the main process chamber and manipulate components to be coated in the plasma process stream. A gun drive (sting) further enables gun motion for coating all desired surfaces of a component, in addition to the two stings already mentioned. In LPCS, a higher-power

Fig. 4 — LPCS plasma plume (dummy part).

Fig. 5a — NiCrAlY, 200x.

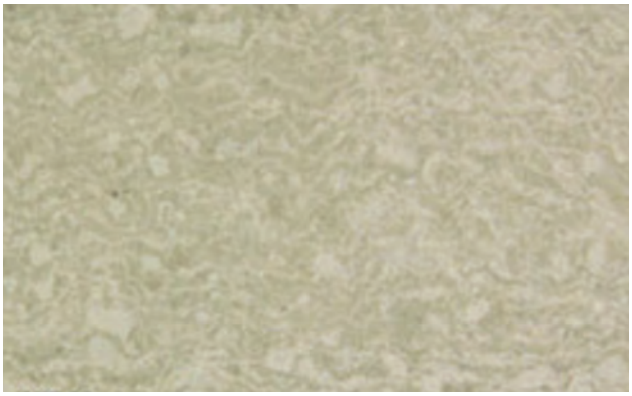


Fig. 5b — NiCrAlY, 500x.

plasma gun is enabled with the use of 2000 amperage power supplies in contrast to the type of gun typically used in a vacuum plasma spray process.

CONCLUSIONS

Vacuum plasma and low pressure plasma spray technologies each provide unique solutions for achieving superior properties in metallic coatings that require low oxide content and high density. Applications include various turbine engine components, as well as biomedical and electronics components.

For more information: Robert Gansert is president of Advanced Materials & Technology Services Inc., 67 W. Easy St., Simi Valley, CA 93065, 805.581.6045, rgansert@adv-mts.com, www.adv-mts.com.

ORION HEAT SHIELD HANDLES EXTREME TEMPS

Have you ever imagined how hot it would be at the Earth's core? What about stepping on molten lava? The Orion spacecraft built by Lockheed Martin endured those temperatures (and higher) when re-entering the terrestrial atmosphere late last year. Boosted to an altitude of 3604 miles, Orion fell back to Earth on December 5 at nearly 20,000 mph. During re-entry, Orion's heat shield protected the vehicle from external temperatures of 4000°F—nearly half the heat of the sun's surface.

The heat shield is the forebody or wind-facing side of an aeroshell system. Due to its size, the aeroshell experiences tremendous entry loads as a result of dynamic pressures from the atmosphere and the high velocity of vehicle descent. Lockheed Martin constructed all eight of the aeroshells that have protected NASA's Mars-bound spacecraft—but Orion is unique.

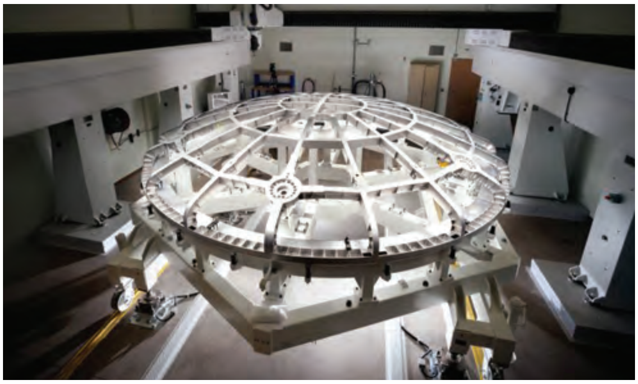


Fig. 1 — At 16.5 ft in diameter, the Orion heat shield is the largest composite version ever made.

At 16.5 ft in diameter, it is the largest composite heat shield ever made. Orion is also designed for long-duration, human exploration of deep space. That means the shield will play a critical role in protecting future astronauts on their return to Earth.

Fig. 2 — Engineers attach the heat shield to the Orion spacecraft.

Not only is the new heat shield the largest ever built, it also features a unique resin system that can withstand higher temperatures and landing impact. After testing in extreme environments and simulating re-entry, engineers verified that the thermal insulator on the outside of the composite material could be thinner, making the spacecraft lighter and allowing more payload to join the mission. The resin was developed by the Lockheed Martin Orion thermal protection system team in partnership with TenCate Advanced Composites, Morgan Hill, Calif.

The heat shield is built around a titanium skeleton and carbon-fiber skin that gives the shield its shape and provides structural support for the crew module during descent and splashdown. A fiberglass-phenolic honeycomb structure fits over the skin, and each of its 320,000 cells is filled with a material called Avcoat. The surface is designed to burn away, or ablate, as the material heats up, rather than transfer heat back into the crew module. At its thickest, the heat shield is 1.6-in. thick, and about 20% of the Avcoat will erode as Orion travels through Earth's atmosphere.

TEST PARAMETERS

During the high orbital test flight, Orion traveled a total of 60,000 statute miles and as far out as 3600 statute miles

ORION HEAT SHIELD DETAILS:

- The Orion heat shield is the largest ever made.
- The melting point for titanium is about 3000°F and the surface temperature of the sun is about 10,000°F. Orion can handle temperatures around 5000°F.
- Orion must withstand landing loads of 300,000 to 400,000 lb, roughly equivalent to the mass of a school bus crashing into the ocean at 20 mph.

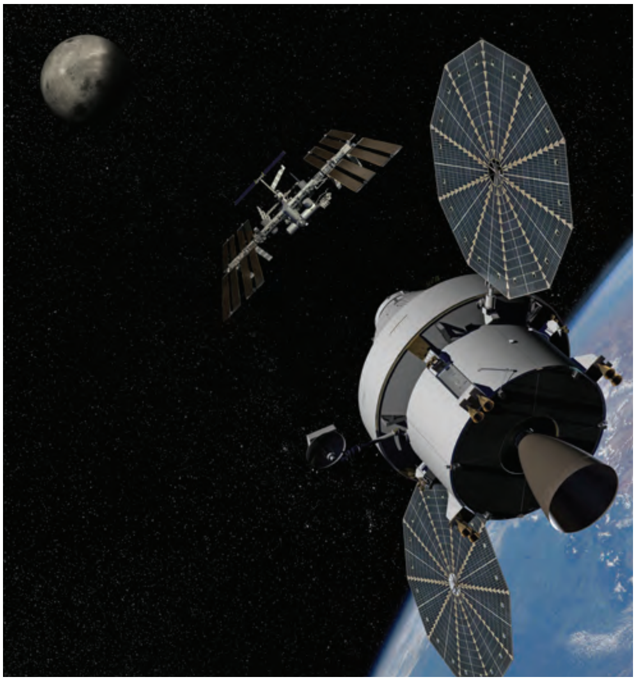


Fig. 3 — The Orion Multi-Purpose Crew Vehicle is intended to carry a crew of up to four astronauts to destinations at or beyond low Earth orbit.

Fig. 4 — During re-entry into Earth's atmosphere, the Orion heat shield protected the vehicle from external temperatures of 4000°F.

above the Earth's surface. This generated a re-entry velocity exceeding 20,000 mph. For extra strength and stiffness, the heat shield features a titanium backbone structure enabling Orion to withstand landing loads of 300,000-400,000 lb. The December flight tested all of Orion's re-entry systems—including testing the heat shield, jettisoning the forward bay cover, and deploying parachutes—and gauged the effectiveness of the software driving numerous functions across multiple systems.

Data collected from Exploration Flight Test-1 provides engineers with information about fluctuations between the temperatures and pressures across the heat shield during re-entry, Avcoat performance, and accelerations and strain during splashdown.

Even with deployment of 11 parachutes to help slow the spacecraft to a safe splashdown, the heat shield must protect the crew and capsule from landing loads and turbulent sea conditions, which could vary significantly during different missions. Comprehensive test flight data, including information about the heat shield, will guide design decisions most critical to crew safety, ultimately lowering risks and costs for future space missions.

For more information: Allison Rakes is Orion public relations officer, Lockheed Martin Space Systems Co., 6801 Rockledge Dr., Bethesda, MD 20817-1803, 303.977.7135, allison.m.rakes@lmco.com, lockheedmartin.com.

SURFACE COATINGS OFFER PROTECTION IN HARSH ENVIRONMENTS

Plasma spray coatings are increasingly used to solve a range of engineering issues for military suppliers, including heat, wear, electrical insulation, and the replacement of more harmful coatings. Plasma spray coatings now offer the potential to solve electro-mechanical interference on composites.

Novel surface technology derived from experience in the nuclear industry is enabling engineers to solve many performance issues in a range of harsh environments. Zircotec Ltd., UK, originally developed its technologies for use in nuclear reactors. During the last decade, its coatings have been used in several other applications, including orthopedic implants, and the company has expanded into the defense sector with a greater emphasis on heat protection. Anti-abrasive coatings, electrically insulating formulas, and cadmium-free options are also available.

PROCESS CAPABILITY

Plasma spray technology works by injecting powder particles into a nitrogen or argon plasma with a flame temperature of roughly 20,000K and a gas velocity of Mach 2-3. Therefore, particles spend a short time in the flame while spray parameters are adjusted, and an extensive range of materials may be sprayed. These range from nylon at the lower end of the temperature spectrum to beryllia at the top. Provided the material does not sublime nor is transparent to UV, particles will melt and quench as splats onto the substrate. Control of overall spray parameters to predefined tolerances ensures that coatings are evenly built-up in multiple thin layers—a method that helps to reduce stress in the final coating.

A range of plasma spray coatings is already being successfully applied to metallic components, reducing metal surface temperatures by more than 170°C in some applications such as automotive exhaust systems. Zirconia has a thermal efficiency of less than 1.7 W/m K (compared with 4 W/m K for alumina), enabling coatings that are highly effective at inhibiting surface heat radiation. This coating is also a suitable choice for thermal management.

The defense sector has adopted another technology—a flexible ceramic supplied on an aluminum foil. ZircoFlex solves heat issues without components needing to be removed from service for spraying, making it easy to retrofit, even during use. ZircoFlex is a flexible ceramic heat shield material, offering superior thermal barrier performance at minimal weight and thickness. Supplied in sheets, it can be cut, folded, and bent to fit any shape and offers surface temperature reductions of 64%. The newest derivative, ZircoFlex FORM, will enable structural heat shields to be made from a flexible and bendable sheet.

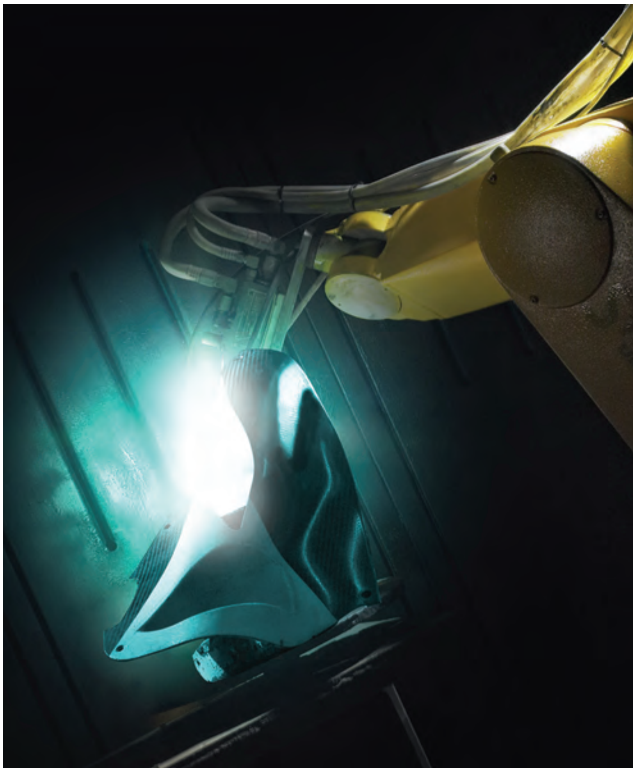


Fig. 1 — Zircotec's plasma spraying process safely coats composites, enabling use in high temperature environments.

The material is produced as a thin aluminum or gold backed foil that is easily bent and manipulated to suit different geometries, and can even be folded tightly through 180° without damaging the thermal barrier. It weighs only 0.46kg/m^2 (0.23kg/m^2 for ZircoFlex Gold). The material is extremely thin—at 0.25 mm overall, it requires only minimal space for installation. In addition, the metal backing makes it robust, easy to handle and cut, and simple to install by hand or machine.

ENABLING GREATER USE OF COMPOSITES

Zircotec has pioneered the use of plasma spray coatings on composite substrates to enable use in environments where they would have previously failed due to delamination or heat damage. Formula One racing is an area where these coatings are increasingly popular to prevent such

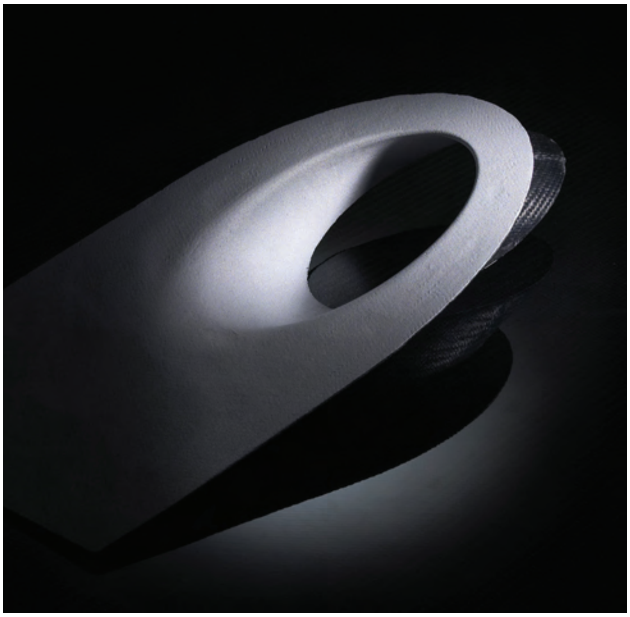


Fig. 2 — Coatings can reduce the heat and electrical signals emitted from vehicles.

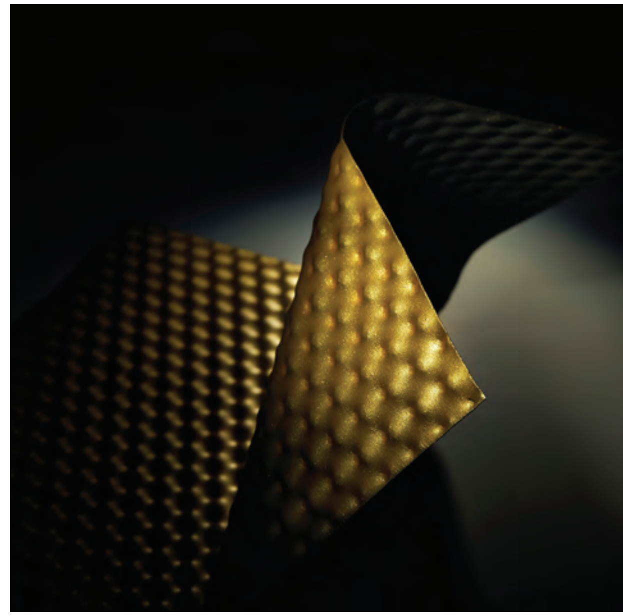


Fig. 3 — ZircoFlex is used in the field in defense applications to solve heat issues without removing vehicles from duty.

failures. In fact, 85% of the F1 grid is now using a Zircotec coating to protect composite parts.

These coatings could also boost composites growth in electrical applications. Electromagnetic interference (EMI) can interrupt or degrade transmitted data signals. Carbon-composite materials, known to be relatively transparent to radio frequency signals, require bulky metal heat shields to provide the right level of shielding. However, the added weight and bulk has deterred composite use in such applications. Zircotec addressed this problem with a highly conductive aluminum-based material that is lightweight yet thin—typically applied at less than 0.3 mm. Because carbon is an excellent electrical conductor, a less conductive sub-layer is applied before the EMC top coating to prevent electrical contact with the components themselves.

For design engineers, this means considerably more scope for positioning electrical or electronic parts within a vehicle and the option to use more composites in vehicle design as well. Zircotec's research suggests that engineers would like to use composites for housing electronics, but poor EMC performance has restricted usage due to the bulky metal shielding required to protect electrical components.

LOOKING FORWARD

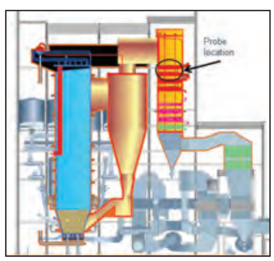
In defense applications, heat management coatings from Zircotec could be used reduce the thermal footprint of vehicles, lowering the temperature emitted and making them less detectable.

For more information: Peter Whyman is sales director at Zircotec Ltd., 22 Nuffield Way, Abingdon Oxon, OX14 1RL, +44 1235 546050, zircotec.com.

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 January issue, as selected by *JTST* Editor-in-Chief Christian Moreau and Lead Editor Armelle Vardelle, are highlighted here. This issue features papers based on presentations at ITSC 2014. In addition to the print publication, *JTST* is available online through springerlink.com. For more information, visit asminternational.org/tss.

"Thermal Spray Coatings for High-Temperature Corrosion Protection in Biomass Co-Fired Boilers"
M. Oksa, J. Metsäjoki, and J. Kärki

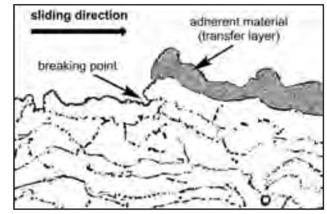
There are over 1000 biomass boilers and roughly 500 plants using waste as fuel in Europe, and numbers are increasing. Many encounter serious problems with high-temperature corrosion due to detrimental elements such as chlorides, alkali metals, and heavy metals. HVOF spray produces very dense and well-adhered coatings, which can be applied for corrosion protection of heat exchanger surfaces in biomass and waste-to-energy power plant boilers. Four HVOF coatings and one arc sprayed coating were exposed to actual biomass co-fired boiler conditions in a superheater area with a probe measurement installation for 5900 h at 550° and 750°C. Coating materials include Ni-Cr, IN625, Fe-Cr-W-Nb-Mo, and Ni-Cr-Ti. CJS and DJ Hybrid spray guns were used for HVOF spray to compare the corrosion resistance of Ni-Cr coating structures. Reference materials were ferritic steel T92 and nickel super alloy A263. The circulating fluidized bed boiler burnt a mixture of wood, peat, and coal. Coatings show excellent corrosion resistance at 550°C compared to ferritic steel. At higher temperature, NiCr sprayed with CJS had the best corrosion resistance. IN625 was consumed almost completely during exposure at 750°C.



550 MWth circulating fluidized bed boiler test facility with the probe measurement location.

"In Situ Wear Test on Thermal Spray Coatings in a Large Chamber Scanning Electron Microscope"
Weifeng Luo, Wolfgang Tillmann, and Ursula Selvadurai

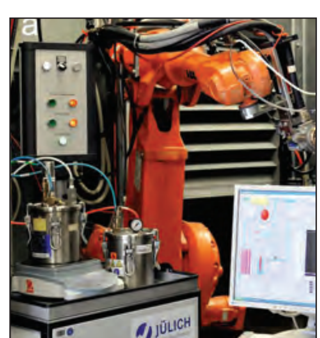
Currently, mass loss determination is usually used for quantitative evaluation of wear tests, while analysis of wear tracks is used for qualitative evaluation. Both evaluation methods can only be used after wear testing and results can only be presented in the final outcome of wear tests. However, changes during the wear test and time-dependent wear mechanisms are also of great interest. A running wear test in a large chamber scanning electron microscope (SEM) offers the first opportunity to observe the wear process in situ. Different wear mechanisms, such as the adhesive, abrasive wear, surface fatigue, and tribochemical reaction, can be recorded with high magnification. A special pin-on-disk testing device was designed for a vacuum environment. Using this device, arc-sprayed NiCrBSi coatings and HVOF-sprayed WC-12Co coatings were tested in a large chamber SEM with Al_2O_3 ceramic balls as wear counterparts. During wear testing, different wear mechanisms were determined and processes were recorded in short video streams.



Schematic representation of the surface fatigue around a pit on a coating's surface.

"Columnar-Structured Mg-Al-Spinel Thermal Barrier Coatings (TBCs) by Suspension Plasma Spraying (SPS)"
N. Schlegel, S. Ebert, G. Mauer, and R. Vaßen

Suspension plasma spray (SPS) was developed to permit feeding of sub-micrometer-sized powder into the plasma plume. In contrast to electron beam-physical vapor deposition and plasma spray-physical vapor deposition, SPS enables cost-efficient deposition of columnar-structured coatings. Due to their strain tolerance, these coatings play an important role in the field of thermal barrier coatings (TBCs). Yttria partially stabilized zirconia (YSZ) is commonly used as TBC material. However, its long-term application at temperatures higher than 1200°C is problematic. At these high temperatures, phase transitions and sintering effects lead to the degradation of the TBC system. To overcome those deficits, Mg-Al-spinel was used as a TBC material. Even though it has a lower melting point (~2135°C) and higher thermal conductivity (~2.5 W/m/K) than YSZ, Mg-Al-spinel provides phase stability at



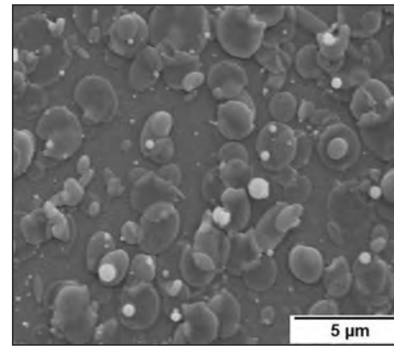
Suspension-feeder developed at Forschungszentrum Jülich GmbH (Germany), showing the monitoring and control unit (a), and injection of suspension into the plasma jet with a two-phase atomizer (b).

high temperatures in contrast to YSZ. Mg-Al-spinel deposition by SPS results in columnar-structured coatings, which were tested for their thermal cycling lifetime. The influence of substrate cooling during the spray process on thermal cycling behavior, phase composition, and stoichiometry of Mg-Al-spinel was also investigated.

"Tailoring the Spray Conditions for Suspension Plasma Spraying"

A. Joulia, W. Duarte, S. Goutier, M. Vardelle, A. Vardelle, and S. Rossignol

Plasma spray using suspensions as liquid feedstock allows deposition of finely structured coatings with improved properties compared to that of coatings deposited by conventional plasma spray techniques. The evaporation of the solvent, acceleration, heating, and melting of fine solid particles within the plasma jet take place in a shorter time, as the substrate is located closer to the plasma torch when a mono-cathode mono-anode plasma torch is used, while liquid material processing globally consumes more energy than powder materials. In this study, a large range of plasma spray conditions were used to achieve yttria-stabilized zirconia coatings by suspension plasma spray. The properties of the plasma jet (velocity, enthalpy, and stability) as well as those of droplets (trajectories, number, and size) and particles (velocity) were measured and correlated to the coating microstructure. The operating conditions necessary for obtaining disk-shape splats and achieving homogeneous coatings are described including plasma jet properties and substrate parameters.

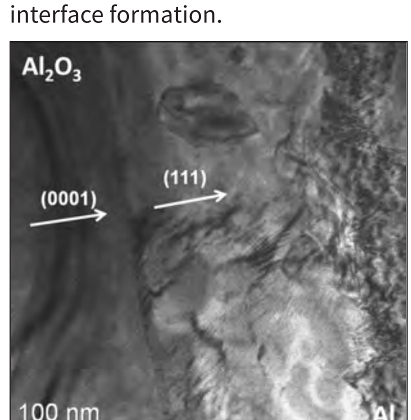


SEM micrograph of YSZ splats collected at 30 mm from nozzle exit. Arc current: 600 A. Plasma gas composition: Ar (77%)-He (33%). Substrate: 400°C.

"Interface Characterization and Bonding Mechanisms of Cold Gas-Sprayed Al Coatings on Ceramic Substrates"

R. Drehmann, T. Grund, T. Lampke, B. Wielage, K. Manygoats, T. Schucknecht, and D. Rafaja

Research aims to contribute to the understanding of adhesion mechanisms, which take effect at the interface of cold gas-sprayed metallic coatings on ceramic substrates. Former investigations reveal the possibility to deposit well-adhering metallic coatings on atomically smooth ceramics, meaning that mechanical interlocking is not always a necessary precondition for bonding. A combination of recrystallization processes induced by adiabatic shear processes and heteroepitaxial growth might explain high observed adhesion strengths. The present work examines the interface area of cold gas-sprayed aluminum on various ceramic substrates using SEM and HRTEM. Besides sintered corundum plates, single-crystalline sapphire substrates with defined lattice orientations were used as substrates for coating deposition. In addition to Al2O3 substrates, aluminum coatings were also deposited on AlN, Si3N4, and SiC to investigate whether different amounts of ionic bonds in these substrate materials influence the substrate/coating interface formation.



Interface of (0001)-oriented sapphire with (111)-oriented PVD Al coating (TEM image). Directions normal to the lattice planes (determined by XRD pole figures) are indicated by arrows.

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ASMNEWS

Affiliate Societies Name Committee Chairs for 2014-2015 Term

The Boards of the Electronic Device Failure Analysis Society (EDFAS), Heat Treating Society (HTS), International Metallographic Society (IMS), and Thermal Spray Society (TSS) have appointed chairs to each of their committees for the 2014-2015 term. Chairs for ASM Society and General Committees and Councils appeared in the January 2015 issue of *ASM News*. The purpose of each committee is stated on the ASM website, asminternational.org. Click on Membership and Committees, followed by Committee Involvement, and then Affiliate Committees.

ELECTRONIC DEVICE FAILURE ANALYSIS SOCIETY (EDFAS)

Cheryl Hartfield, business manager-Omniprobe Products, Oxford Instruments Co., Dallas, was elected president of EDFAS.

Jeremy A. Walraven, technical staff, Sandia National Laboratories, Albuquerque, N.M., serves as immediate past president and chair of the EDFAS Nominating Committee.

Susan Li, device analysis lab manager, Spansion Inc., Sunnyvale, Calif., continues to serve as chair of the Education Committee. **Leo G. Henry,** managing engineer, ESD TLP Consulting, Fremont, Calif., continues to serve as vice chair.

Tom Moore, president, Waviks Inc., Dallas, continues as chair of the EDFAS Membership Committee. **Efrat Moyal,** co-founder, LatticeGear LLC, serves as vice chair.

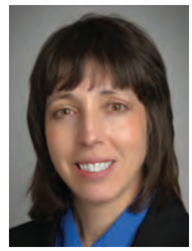
Felix Beaudoin, functional characterization engineer, IBM Corp., Hopewell Junction, N.Y., is chair of the *Electronic Device Failure Analysis* Magazine Committee.

James J. Demarest, advisory engineer, IBM Corp., Albany, N.Y., was named chair of the Events Committee and is general chair of ISTFA 2015.

Philippe Perdu, senior expert, CNES, Toulouse, France, continues to serve as chair of the International Growth Committee.

HEAT TREATING SOCIETY (HTS)

Roger A. Jones, corporate president, Solar Atmospheres Inc., Souderton, Pa., continues to serve as president of HTS.



Hartfield

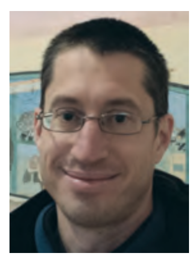
Walraven

Li

Henry

Moore

Moyal



Beaudoin

Demarest

Perdu

Thomas E. Clements, Engineering Manager-Metals and Thermal Processes, Caterpillar Inc., is currently serving as HTS immediate past president, as well as chair of the HTS Awards & Nominations and the HTS Finance Committees.

Michael J. Schneider, FASM, general manager, Prod. Materials and Metallurgy, The Timken Co., North Canton, Ohio, was named chair of the HTS Education Committee.

Aquil Ahmad, retired senior principal engineer, Eaton Corp., West Bloomfield, Mich., continues as chair of the HTS Research and Development Committee.

Rozalia Papp, business development specialist, Air Liq-

In This Issue

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

HIGHLIGHTS AFFILIATE COMMITTEE CHAIRS


Jones


Clements


Schneider


Ahmad


Papp


Rollings


Faulkner


Blackwell


Saenz


Frafjord


Abraham


McNee


Leftwich

uide US LP, was named chair of the HTS Technology & Programming Committee.

David Rollings, VP business development, Advanced Abrasives Corp., Pennsauken, N.J., serves as chair of the HTS Membership Committee.

Chuck Faulkner, marketing manager, Heat Treatment, Houghton Intl., Valley Forge, Pa., continues as chair of the HTS Expositon Commtitee.

INTERNATIONAL METALLOGRAPHIC SOCIETY (IMS)

Richard Blackwell, FASM, general manager, Buehler Canada, serves as president of IMS.

Natalio T. Saenz, technologist, Pacific Northwest National Laboratory, Richland, Wash., serves as IMS immediate past president and chair of the IMS Nominating Committee.

Jaret J. Frafjord, technical director, IMR KHA Portland, Portland, Ore., serves as chair of the Publications Committee and IMS vice president.

George Abraham, IV, materials engineer, Allied High Tech Products Inc., Compton, Calif., continues to serve as chair of the IMS Education Committee.

Coralee McNee, Sr. metallurgical engineeer, UTC Buildings & IndustrialSystems, Syracuse, N.Y., is chair of the IMS Technology Committee.

Jim Leftwich, business developoment, PSI, Skokie, Ill., continues to serve as chair of the Membership, Marketing and Outreach Committee.

THERMAL SPRAY SOCIETY (TSS)

See page 39 of *iTSSe* in this issue for the TSS committee chairs.

If you are interested in serving on an Affiliate Society committee, contact the respective committee chair directly or email joanne.miller@asminternational.org.

IMC: Fewer Classes, Larger Prize Money Deadline July 18

The International Metallographic Contest (IMC), an annual event cosponsored by the International Metallographic Society (IMS) and ASM International to advance the science of microstructural analysis, continues to offer fewer classes and larger prize money. These updates, initiated last year, were designed to encourage participation and to simplify the process for participants to submit entries. There are now just five different classes of competition covering all fields of optical and electron microscopy:

Class 1: Optical Microscopy—All Materials

Class 2: Electron Microscopy—All Materials

Class 3: Student Entries—All Materials (Undergraduate or Graduate Students Only)

Class 4: Artistic Microscopy (Color)—All Materials

Class 5: Artistic Microscopy (Black & White)—All Materials

All of the classes offer increased prize money, as established last year. Best-In-Show receives the most prestigious award available in the field of metallography, the Jacquet-Lucas Award, which includes a cash prize of $3000.

For a complete description of the rules, tips for creating a winning entry, and judging guidelines, visit metallography.net.

IMS Joins ASM, HTS, and TSS in Seeking Student Members

We're looking for Material Advantage student members to provide insights and ideas to the ASM, HTS, TSS, and IMS Boards

We are pleased to announce the continuation and expansion of our successful Student Board Member Programs. In addition to ASM, HTS, and TSS, IMS is also seeking student board members. Each Society values the input and participation of students and is looking for their insights and ideas.

An opportunity like no other!

- All expenses to attend meetings paid for by the respective Society
- Take an active role in shaping the future of your professional Society
- Actively participate in your professional Society's Board meetings
- Gain leadership skills to enhance your career
- Add a unique experience to your resume
- Represent Material Advantage and speak on behalf of students
- Work with leading professionals in the field

Application deadline is **April 1.**

Visit asminternational.org/students3 for complete form and rules.

Opportunities Specific to each Society:

ASM International
- Attend four Board meetings (June 17-19, October 5-7 during MS&T15, and March and June 2016)
- Term begins June 1

ASM Heat Treating Society
- Attend two Board meetings (October 19 during HTS Conference and Exposition and spring 2016)
- Participate in four teleconferences
- Term begins in September

ASM Thermal Spray Society
- Attend one Board meeting in the U.S. in November or December
- Participate in two teleconferences
- Receive a one-year complimentary membership in Material Advantage
- Term begins in October

International Metallographic Society
- Attend one Board meeting (August 2-6)
- Participate in monthly teleconferences
- Term begins in August

ASM Appoints Interim Managing Director


Mosier

In December, Thomas S. Passek stepped down as managing director of ASM International to pursue other opportunities after 27 years with the Society. Passek will continue in a consulting capacity with ASM through June. "The Board of Trustees, staff, volunteers, and members all wish Thom well and thank him for his dedication and service," said ASM President Sunniva Collins, FASM. Terry F. Mosier, director of finance, will serve as interim managing director.

Mosier earned a B.S. degree in industrial engineering from Marietta College and an M.B.A. with a concentration in finance and information systems from Case Western Reserve University. Since graduation, he has worked as a financial analyst, controller, and chief financial officer for Millennium Inorganic Chemicals, Nestlé, Metal Foils LLC, DCS, and Pentair. Mosier joined ASM in 2008 and has served as director of finance for the past five years. For more information, contact sunniva.collins@asminternational.org or terry.mosier@asminternational.org.

ASM Board of Trustees Nominations due March 15

It's time to nominate candidates for ASM vice president and trustee. Qualifications include: Materials professionals with broad experience in ASM, business, and management; experience with ASM committees and ASM chapter work; managerial experience (budgets and policy making) is most desirable; is an individual or chapter sustaining ASM member; understands the duties and responsibilities required and is willing to serve if elected; understands ASM's strategy and objectives; has knowledge of the field of materials and information technology. Vice presidential nominees must have previously served on the ASM Board of Trustees. Contact Leslie Taylor at 440.338.5151 ext. 5500, or leslie.taylor@asminternational.org. Visit website for rules and nomination form at asminternational.org/vp-board-nominations.

HIGHLIGHTS SEEKING NOMINATIONS

2015 Bradley Stoughton Award for Young Teachers


2014 Bradley Stoughton Award for Young Teachers, Amber Genau.

Nominate a colleague for the 2015 award!

Winner receives $3000

Deadline March 1

This award recognizes excellence in young teachers in the fields of materials science, materials engineering, design, and processing.

Do you know a colleague who:

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

2015 ASM International Student Paper Contest

Deadline April 1

The ASM International Student Paper Contest recognizes the best technical paper with a graduate or undergraduate student as first author that is published in an ASM sponsored publication during the year. The winner will receive their award during the ASM Leadership Awards Luncheon in Columbus, Ohio, during the week of October 5-8, in conjunction with MS&T15. The award consists of a certificate, $500 cash prize, and up to $500 toward expenses to attend MS&T15. The paper will also be published in one of ASM's publications.

Engineering Materials Achievement Award


2014 Engineering Materials Achievement Award, Marie Cole and her IBM team.

Deadline March 15

The Engineering Materials Achievement Award recognizes an outstanding achievement in materials or materials systems relating to the application of knowledge of materials to an engineering structure or to the design and manufacture of a product. The purpose of this award is to seek out and recognize outstanding developments in the application of materials in products or in engineering structures and to honor the organization or individuals responsible for them.

Do you know of an innovative, cutting-edge scientific achievement that has distinctly impacted industry, technology, and society within the past 10 years? If so, consider submitting a nomination for the 2015 award!

Honorary Membership


2014 Honorary Membership, Chandra Shekhar Pande.

Deadline Extended to March 1

Honorary Membership in the Society was established in 1919. It recognizes distinguished service to the materials science and engineering profession, ASM's strategic plan and initiatives, and the progress of mankind.

Honorary Membership is among the most prestigious awards of the Society. It is expected that all nominees will be outstanding individuals who have significantly furthered the purposes of the Society through an evidenced appreciation of the importance of the science of materials and through distinguished service to the profession.

New! ASM Bronze Medal Award Seeks Nominations

Deadline April 1

The ASM Board of Trustees is pleased to announce the establishment of a new ASM Award, the Bronze Medal. The honor of Bronze Medal of the Society recognizes ASM members who are in early career positions, typically with 0 to 10 years of experience, for significant contributions to the field of materials science and engineering through technical content and service to ASM and the profession.

The Bronze Medal encourages both individual development and further contributions to the growth of the profession as well as the Society. Candidates will have made significant technical contributions to the Society, might be beyond their eligibility period for the Emerging Professional Achievement Award, and are not yet considered experienced enough to be eligible for the Silver Medal Award. The Bronze Medal serves to recognize and encourage members no more than 35 years of age on January 1 of the year in which the award is given. The award consists of a bronze medallion plus a $500 travel stipend. The first Bronze Medal Award will be presented at MS&T15 in Columbus, Ohio, during the week of October 5-8.

NOMINATION FORMS & RULES

Applications, nomination forms, and rules for all of these awards can be found at asminternational.org/membership/awards.

For more information, contact Christine Hoover at 440.338.5151 ext. 5509 or christine.hoover@asminternational.org.

FROM THE FOUNDATION

Materials Education Foundation Seeks Your Wisdom & Advice

David B. Spencer

Chairman of the Board, wTe Corp.

As we begin the new year, your ASM Materials Education Foundation is working hard on your behalf "to excite young people in materials, science, and engineering careers." Under Dr. Steve Copley's distinguished leadership, our Board of Trustees developed a strategic plan for 2013-2017 and the Foundation has been working hard to execute this plan and meet all of its goals. Copley set forth our Foundation achievements in a previous column (*AM&P,* April 2014). While congratulations are in order for the accomplishments achieved to date, the Foundation now finds itself facing the need to develop a new strategic plan—one year earlier than anticipated. We would like your help in providing critical feedback. Are we doing the right things and are we doing them correctly? What new ideas could be implemented? What should we consider that would be helpful to your profession, company, and the Society?

We would like to hear your views regarding whether our existing programs could be improved. Do we seek to give more scholarships of the same size or fewer scholarships of larger size? Should our scholarship program be based on academic excellence, financial need, or a combination? Would our student camp program (which targets high school students) be better off focused at an earlier stage in the education pipeline, say at the junior high or elementary school level? Should our programs be expanded or should some be reduced or even eliminated? Do we focus on training community college students for advanced manufacturing jobs? How can we leverage our programs and enhance communications through better use of the Internet?

These are the questions we are asking within the Materials Education Foundation. Surely we will continue to advance the programs of the past, but changes in emphasis and consideration of new directions will need to be evaluated as we embark on a new strategic planning process. Please provide your feedback and share your wisdom. Send comments to nichol.campana@asminternational.org.

POWER OF ONE | MEMBERSHIP DRIVE

You Cannot Out-Give ASM

Frederick Schmidt, PE, FASM, aka Mur Doc

President, Alpha Sigma Mu

Today we are highly focused on materials and energy for the future of our Society. As I reflect on my personal ASM journey, it all started when I was a co-op commuter student at Drexel University, then an Institute of Technology in Philadelphia. Much has changed, but some things are remarkably the same.

George Dieter, Head of Metallurgy, personally greeted us during orientation to challenge us and provide a few pointers. After welcoming everyone to Drexel, circa 1963, he said to join the student ASM chapter on campus, get totally involved, and read *Metal Progress* cover to cover every month even though we would not understand much at this point. I did, and after 40+ years I must say it was the best advice. I still read *AM&P* cover to cover.

After college, my assignments with DuPont, Remington Arms, and now Engineering Systems Inc. have required numerous and diverse database sources. ASM International's extensive resources, coupled with my ever expanding network from local chapters and committee projects, have enabled the solution of mission-impossible engineering challenges. Peer review and critical analysis is a must in our complex, get-it-right-the-first-time work environments.

I have learned that you simply cannot out-give ASM! Allan Ray Putnam, past managing director, liked to say that ASM means, "Always Serve Members." His message was to ASM staff and volunteers alike. I got totally involved and continue to leverage the size and scope of my professional family through ASM. The bottom line is that when you invest in your professional network, the synergy is profitable to everyone. Embrace "The Power of One" and remember there is strength in numbers and diversity of experience. It takes a team to solve problems and implement economic solutions. "Just ask" others to join so we can build the team!

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

MEMBERS IN THE NEWS

Yun Hang Hu Becomes AAAS Fellow

Yun Hang Hu, professor at Michigan Technological University, was elected a Fellow of the American Association for the Advancement of Science (AAAS), the world's largest general scientific society and publisher of the journal *Science.* Most recently, Hu has received international recognition for his development of 3D graphene, which could replace the platinum in solar cells without degrading their efficiency.

CHAPTER NEWS

Ravindran visits Bengaluru

As part of his recent trip to India to meet with several ASM Chapters and dedicate the Delhi Iron Pillar as an ASM Historical Landmark, immediate past president Ravi Ravindran enjoyed a visit with the Bengaluru Chapter on November 28, 2014.

Haiyan Wang Wins O'Donnell Award

Haiyan Wang, FASM, professor at Texas A&M University, was named one of four recipients of the 2015 Edith and Peter O'Donnell Award. Presented by The Academy of Medicine, Engineering & Science of Texas, the award recognizes researchers who address the essential role that science and technology play in society. Wang was honored for research into nanostructured materials in the areas of high temperature superconductors, microelectronic and optoelectronic devices, solid oxide fuel cells, nuclear materials, in situ TEM characterizations, and for exceptional potential in inspired education and future leadership.

NAE Names Romig Executive Officer

Alton D. Romig, Jr., FASM, a member of the National Academy of Engineering (NAE) since 2003, will join the NAE leadership team as executive officer (EO) on March 2. The EO is the chief operating officer of the Academy reporting to the president. Romig served in several positions at the Lockheed Martin Aeronautics Co., Advanced Development Programs, including vice president and general manager of the Skunk Works. Among other honors, Romig won the ASM Silver Medal for Outstanding Materials Research in 1992.

EMERGING PROFESSIONALS

Teaching is a Matter of Learning

Mark Atwater, Millersville University

Being a new professor is actually pretty strange. In most jobs I can think of, when you're new, you're expected to be somewhere at the beginning of the learning curve. As an assistant professor, I have the duality of being the guy that knows the least and the most all at the same time. Senior faculty members expect me to need some guidance, but students expect me to provide the guidance. Add to this a diverse range of departmental and campus responsibilities and it can be quite a balancing act.

The way I've managed this dichotomy is to be honest about it. I ask for guidance from my colleagues and I try to be proactive in seeking their input before I run into problems. After all, if they've made it through the labyrinth of tenure and promotion, there is something for me to gain by their experience. I am deeply grateful for the willingness of my fellow faculty members to share their ideas, challenges, and solutions.

I am straightforward with my students as well. Because I am early in my career, everything I do in class is still new, but if I'm going to try something out of the ordinary, I warn them. They are surprisingly resilient and willing to engage in new ways of learning. I believe it is important, however, to emphasize that there may be some rough patches and we'll make adjustments as needed. In that same spirit, I ask for feedback so I can gauge how effective I am. The open dialogue ensures that they know my intentions are good.

So maybe it isn't really all that strange being a new professor. Much of life involves being somewhere between an expert and ignorant. The important thing is to keep learning, no matter where you are on this continuum.

Mathaudhu to Receive Norm Augustine Award

Suveen Mathaudhu, assistant professor at University of California Riverside, will receive the Norm Augustine Award for Outstanding Achievement in Engineering Communications from the American Association of Engineering Societies on April 20. Mathaudhu studies mechanisms that make metallic materials and composites lighter and stronger, but he also has an interest in comics. This hobby led him to help create a museum exhibit called Comic-Tanium, which has traveled to San Diego, Washington, and Pittsburgh. Comic-Tanium combines practical materials science with the fictional worlds of comic book heroes. The exhibit is being enhanced to include video and other modules that could be used by elementary school math and science teachers.

Berndt Awarded Doctor of Engineering Degree

Christopher C. Berndt, FASM, TS-HoF, was awarded the Doctor of Engineering (DEng) degree in December 2014 from Monash University, Melbourne, Australia. This is the highest academic degree that may be conferred by the university and is awarded for work that makes an original, substantial, and distinguished contribution to knowledge in a field with which the faculty is concerned. Berndt's DEng thesis was titled "Thermal Spray Coatings: Processing, Microstructural Architecture and their Materials Engineering Design."

In Memoriam

James Michael Rigsbee, FASM, Life Member, passed away on January 8 in Raleigh, N.C. He was born on December 6, 1947, in Durham, N.C., and attended Southern High School there. He graduated from North Carolina State University (NCSU) in 1974 with a Ph.D. in metallurgical engineering. Rigsbee completed a post doctorate at Michigan Technological University, Houghton, worked for Republic Steel in Cleveland, taught at University of Illinois at Urbana-Champaign, was department head at The University of Alabama at Birmingham, and came back to NCSU in 1998 as department head and professor of materials science and engineering. He was also an active and current member of the *AM&P* Editorial Committee and a past member of the International Reviews Committee.

Thomas Leo Kablach, Life Member, passed away on January 2 in Murrieta, Calif. He was born on July 4, 1925, in Mt. Troy, Pa., and earned a B.S. in metallurgical engineering from Carnegie Tech in 1950. He enlisted in the Army in April 1943 and served as a Private First Class in the Intelligence branch of the Army Air Corps. His career began at Mesta Machine Co. and included management positions at Struthers Wells, Erie Forge, Pittron, Meehanite, and Johnstown Steel. He served as director of The Roll Manufacturing Institute and president of Techmart Inc. He was chairman of ASM's Calumet Chapter and served on numerous committees. He also taught metallurgical classes for ASM and consulted for a number of companies.

Stephen E. Chehi, Life Member, of Bethlehem, Pa., died on January 12 at age 90. He served in the U.S. Army during World War II. In 1952, he received a B.S. in industrial engineering from the Pennsylvania State University where he also worked as a mechanical designer with the Navy's Ordnance Research Laboratory. He then completed a 30-year career with Bethlehem Steel Corp. During his tenure, he was granted a U.S. patent for processing methods for specialty metals and developed improved manufacturing practices for NASA's Titan IIIC rocket motor hardware and the Navy's deep submergence rescue vehicle pressure hull. Chehi joined ASM in 1953.

STRESS RELIEF

Self-folding lamp.
Courtesy of Martin Dee.

SHAPE-SHIFTING PAPER HOLDS PROMISE FOR PACKAGING

A student at The University of British Columbia, Canada, is developing self-folding paper that transforms into multidimensional figures when heated. The technology can be used for everything from origami-like decorations to sustainable packaging and insulation. A computer program is used to make small cuts and creases in a sheet of paper. A special thermoplastic polymer is then attached to pre-cut and pre-creased paper and heated to about 110°C for 10 to 20 seconds. As the polymers heat up, they shrink and lift the paper into various angles, turning it into a 3D shape.

When paper is folded into 3D structures, it is light and strong, and inexpensive to make. It is also easy to transport and has less environmental impact than other materials. Compared to plastic, less energy is used to make self-folding paper. One day it could be used for noise and heat insulation, toys, folding beds, step stools, and even mattresses, although the most promising application is packaging. *www.ubc.ca.*

BIRDSNAP: A NEW APP FOR BIRDWATCHERS

Columbia University, N.Y., researchers developed Birdsnap, a smartphone app that uses computer vision and machine-learning techniques to produce an electronic field guide featuring 500 of the most common North American bird species. Birdsnap, which enables users to identify bird species through uploaded photos, is linked to a website that includes about 50,000 images. Birdsnap also features birdcalls for each species, and offers users several ways to organize species. “Our goal is to use computer vision and artificial intelligence to create a digital field guide that will help people learn to recognize birds,” says Professor Peter Belhumeur.

Birdsnap works like facial-recognition technologies in that it detects parts of a bird so it can examine the visual similarity of comparable parts. The app automatically finds visually similar species and makes suggestions about how they can be distinguished. “What’s really exciting about Birdsnap is that not only does it do well at identifying species, it can also identify which parts of the bird the algorithm uses to identify each species,” says Belhumeur. *columbia.edu.*

Birdsnap provides access to an electronic field guide to 500 of the most common North American bird species.

BEER BREWING WASTE MAKES BIOMATERIALS FOR BONES

Researchers from the Centre for Biomedical Technology of Universidad Politécnica de Madrid (UPM), the Institute of Materials Science, and the Institute of Catalysis and Petrochemistry of Consejo Superior de Investigaciones Científicas (CSIC), in collaboration with the Mahou and Createch Co., all in Spain, developed biocompatible materials to support bone regeneration from the food industry—mainly bagasse (residue) from beer brewing. The new materials are an alternative to prosthesis made from processed sheep bones or synthetic materials. *www.upm.es.*

A biomaterial used as a matrix for bone regeneration was made from a 1-cm-high porous block obtained from the beer bagasse treatment. Courtesy of CSIC.

ADVANCED MATERIALS & PROCESSES

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MARCH 2015

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CLASSIFIEDS

AD INDEX

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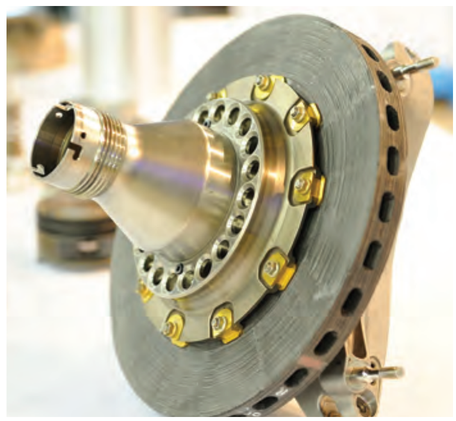
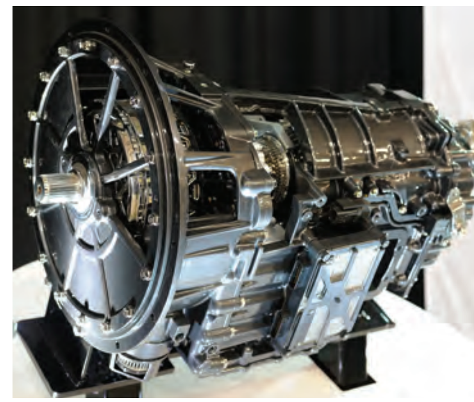
SUCCESS ANALYSIS

SPECIMEN: LIFT – LIGHTWEIGHT INNOVATIONS FOR TOMORROW


ALMMII's chief technical officer Alan Taub (left) and executive director Lawrence Brown.


Rotor made of lightweight materials.


Transmission designed using modern metals for weight savings.

VITAL STATISTICS

In January, the American Lightweight Materials Manufacturing Innovation Institute (ALMMII) opened its new 100,000-sq-ft "innovation acceleration center" in Detroit by showcasing technologies that use lightweight metals and announcing its new program name, LIFT—Lightweight Innovations for Tomorrow. The $148 million center will build partnerships among research institutions and manufacturers to accelerate the transfer of new manufacturing technology from the research stage to actual production processes.

SUCCESS FACTORS

LIFT members will work with metals such as aluminum, magnesium, titanium, and advanced high-strength steels and focus on new technologies to cast, heat treat, form, join, and coat them. Activities will build on the Materials Genome Initiative (MGI) and incorporate breakthroughs in integrated computational materials engineering (ICME), materials modeling, theory, and data mining to speed deployment of advanced materials. Launched in 2011 by the Obama Administration, MGI is a multi-agency effort designed to create a new era of policy, resources, and infrastructure to support U.S. institutions in developing materials twice as fast and at a fraction of the cost of traditional methods. LIFT, operated by ALMMII, was selected by the U.S. Department of Defense under the Lightweight and Modern Metals Manufacturing Innovation (LM3I) solicitation issued by the U.S. Navy's Office of Naval Research.

ABOUT THE INNOVATORS

ALMMII is a nonprofit organization founded by the University of Michigan, The Ohio State University, and EWI, along with a 60-member consortium of leading metals manufacturers, universities, and research labs. ASM is part of the consortium and will assist with education and workforce development initiatives.

WHAT'S NEXT

"Our industry partners, with input from government agencies, will set the priorities of our effort," explains Alan Taub, chief technical officer and ASM member. "We will create collaborations to focus on the opportunities manufacturing companies identify to take breakthroughs from the best research institutions across the country and commercialize them as certified, production-level processes. Our work will cross-fertilize developments in several industries—including defense and commercial applications in aerospace, automotive, marine, and railroad."

Contact Details

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