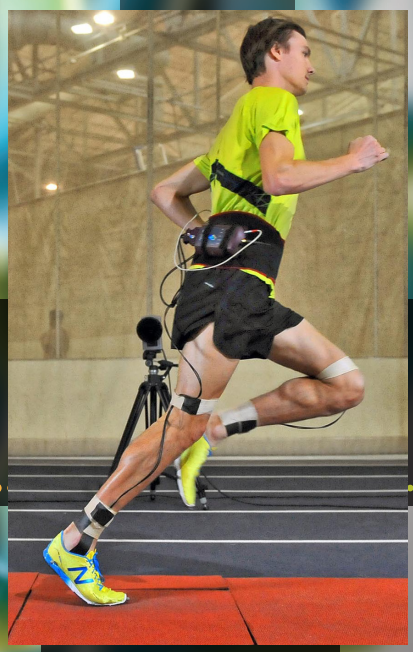
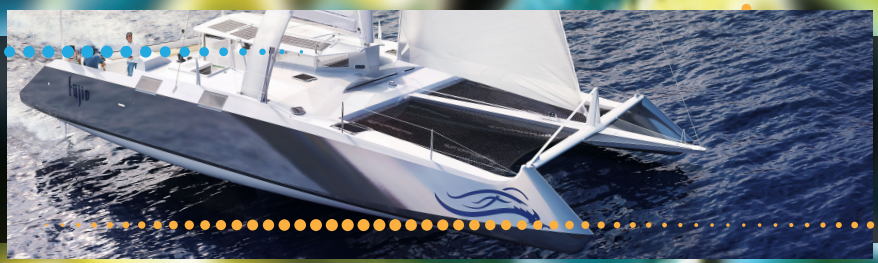
JULY/AUGUST 2015 | VOL 173 | NO 7

ADVANCED MATERIALS & PROCESSES

AN ASM INTERNATIONAL PUBLICATION





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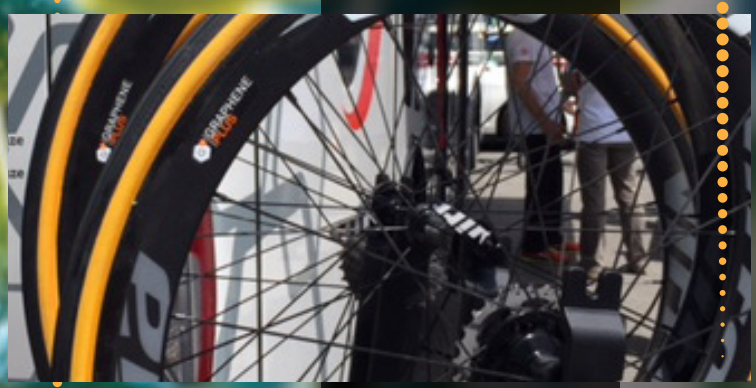
MATERIALS IN SPORTS & RECREATION

TESTING BOOSTS PERFORMANCE

P.18



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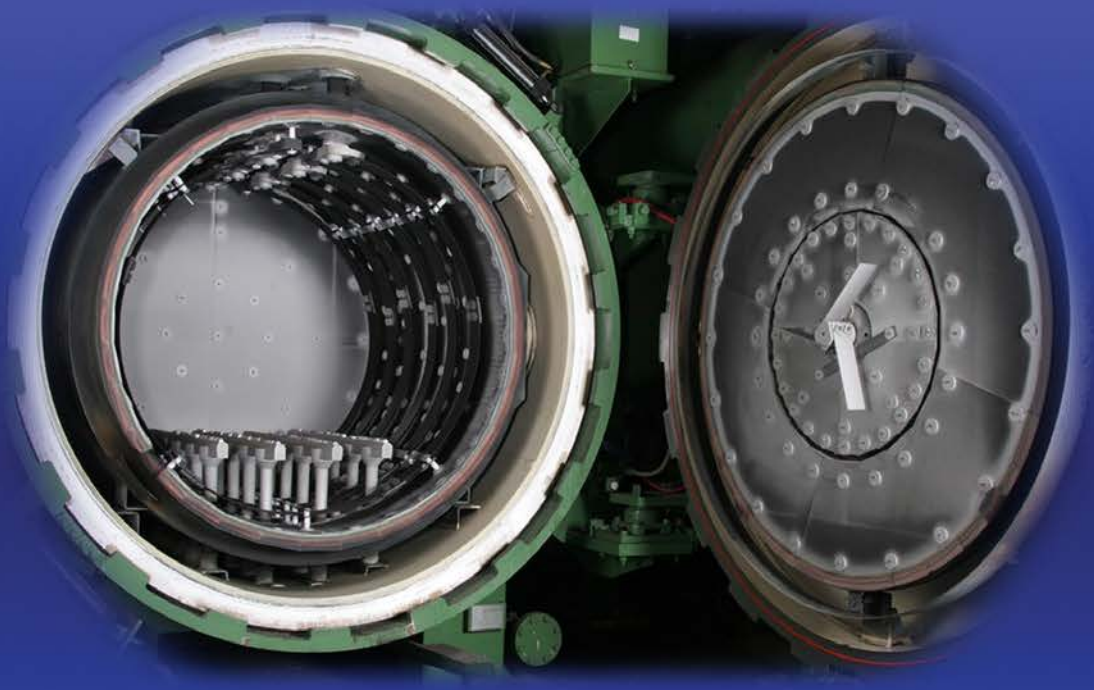

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Course	Date	Location
Practical Interpretation of Microstructures	9/1-3	ASM World Headquarters
Vacuum Heat Treating	9/9-10	ASM World Headquarters
Oilfield Metallurgy	9/9-11	ASM World Headquarters
How to Organize and Run a Failure Investigation	9/14-15	Foothill Ranch, CA
Metallography for Failure Analysis	9/14-17	Buehler Limited, Lake Bluff, IL
Metallographic Techniques	9/14-17	ASM World Headquarters
Principles of Failure Analysis	9/16-18	Foothill Ranch, CA
Introduction to Thermal Spray	9/21-22	ASM World Headquarters
Component Failure Analysis	9/21-24	IMR Test Labs, Louisville, KY
Mechanical Testing of Metals	9/21-24	ASM World Headquarters
Metallographic Interpretation	9/21-24	AQM, Provaglio D'lseo, Brescia, Italy
Scanning Electron Microscopy	9/21-24	IMR Test Labs, Lansing, NY
Superalloys	9/28-30	ASM World Headquarters
Practical Fracture Mechanics	10/19-20	IMR Test Labs, Lansing, NY
Titanium and Its Alloys	10/19-22	ASM World Headquarters
Metallurgy for the Non-Metallurgist™	10/19-22	ASM World Headquarters
Applied Techniques of Failure Analysis	10/19-22	ASM World Headquarters
Practical Fractography	10/21-22	IMR Test Labs, Lansing, NY

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On The Cover:

Materials used in sports and recreation equipment. Clockwise from left, courtesy of Gold Coast Yachts, Nitro Snowboards, EOS and New Balance, and Vittoria.

TECHNICAL SPOTLIGHT

MATERIALS TESTING PLAYS ESSENTIAL ROLE IN HIGH-PERFORMANCE SPORTING GOODS

Testing offers vital insights into product performance and enables engineers to determine a material's suitability as well as the integrity of manufacturing processes as part of quality control initiatives.

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TECHNICAL SPOTLIGHT

MULTIAXIAL MATERIALS ACHIEVE WEIGHT SAVINGS IN CARBON YACHT DESIGN

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Charles R. Simcoe

From 1988 to 2008, the minimill industry added 25 million tons annual capacity—25% of the total U.S. steel market.

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ASM NEWS

The monthly publication about ASM members, chapters, events, awards, affiliates, and other Society activities.

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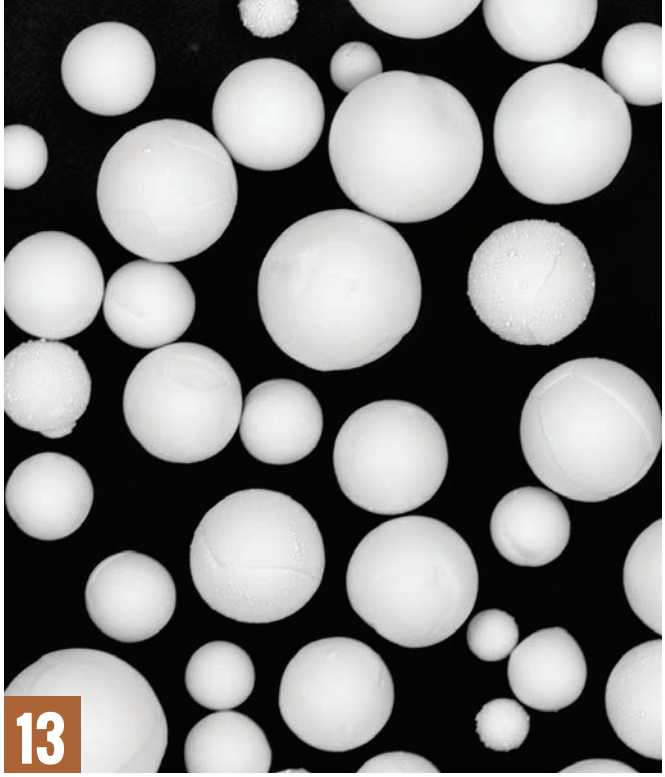
FEATURES



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

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

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

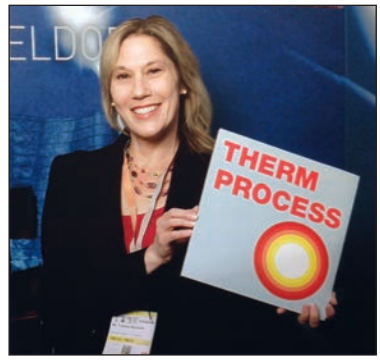
Jim Pallotta, *Creative Director*
jim.pallotta@asminternational.org

Kate Fornadel, *Layout and Design*
kate.fornadel@asminternational.org

Annie Beck, *Production Manager*
annie.beck@asminternational.org

Press Release Editor
magazines@asminternational.org

YOU SAY NIHITO, I SAY NIHATO



I was talking with one of my colleagues the other day, after we had both been away from the office at different meetings. She was telling me about a marketing seminar she attended, and her key takeaway was that she needed to get out more and speak with ASM members about their business challenges. The seminar leader emphasized the concept of NIHITO—"nothing important happens in the office." This may be an oversimplification, but the idea has merit: Talking with people one on one, attending trade shows and seminars, and visiting other businesses is vital to understanding the bigger picture, no matter what industry you're part of.

During the past few weeks, I had the opportunity to attend a few memorable events. One was an industry dinner for the Association of Women in the Metal Industries, featuring Tim Timken, president and CEO of TimkenSteel Corp. He emphasized the importance of talented people to the success of a company. "People drive progress," he said. Timken also noted that one of the major challenges for companies is to keep the talent pipeline flowing, and that attracting and retaining talent should be a top priority for every business.

On a similar note, Dave Spencer of wTe Corp. gave a great talk at the Center for Heat Treating Excellence (CHTE) spring meeting on the value of networking with peers. He began his speech with a laundry list of everything he had been asked to speak about by Diran Apelian, founder of the Metal Processing Institute at Worcester Polytechnic Institute. But he said he couldn't even scratch the surface of this request in a 30-minute talk. So he spoke about the importance of collaboration instead. He mentioned the key reason why people join CHTE and other such consortiums. "We get together and talk about things we're not allowed to talk about because we like each other. We also have fun together," said Spencer. It gets better. He emphasized the importance of staying positive and collaborative. "Try as hard as you can to be nice. And don't talk down about other people—we're all trying the best we can."

The Bright World of Metals trade show quartet in Germany was the next stop on my NIHITO journey. The event included the GIFA, Metec, ThermProcess, and NewCast shows, featuring foundry, metallurgy, thermal processing, and casting technologies. With over 78,000 visitors from 120 countries visiting 2214 booths, there was a lot to see, including several ASM member companies showcasing their latest heat treating equipment. Beyond the block-long, two-story booths featuring conference rooms and catered meals, fully functioning machinery was on display. One company, ABP Induction, had a 50-ton induction furnace set up, capable of producing 35 tons of steel in 40 minutes. The furnace was shipped to a construction facility in Saudi Arabia immediately after the show.

My favorite part about traveling is talking with other people and learning about their unique perspectives and challenges. People are a lot more candid in person than over email or LinkedIn groups. While social media certainly has its place, there's no substitute for face-to-face communication. Let the power of NIHITO work for you whenever you have the chance!

F. Richards

frances.richards@asminternational.org

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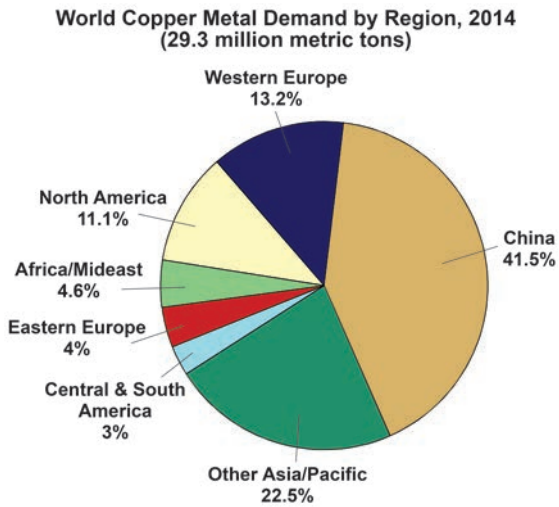
MARKET SPOTLIGHT

GLOBAL COPPER DEMAND TO REACH $261 BILLION BY 2019

According to *World Copper,* a new report from The Freedonia Group Inc., Cleveland, global demand for copper metal (produced from refined copper and recycled scrap) is projected to grow 4.2% per year through 2019 to 36 million metric tons, valued at $261 billion. Significant gains in building construction expenditures are expected to boost the use of copper wire, tube, and other mill products in applications such as building wire and plumbing. Increased infrastructure investment, particularly in developing countries, will further benefit copper suppliers as updates to national power grids drive the production of wire and cable. In addition, advances in global manufacturing output are expected to bolster copper use in transportation equipment, industrial machinery, domestic appliances, and other durable goods. However, competition from alternative materials such as plastic pipe in plumbing applications will restrain growth, say analysts.



Source: The Freedonia Group Inc.

China drives the global copper metal market, accounting for more than 40% of world demand in 2014. The country's massive building construction and electrical and electronic sectors consume huge volumes of copper for producing electrical wire, pipe, personal and business electronics, and telecommunications equipment. Advances in construction spending are also projected to fuel copper demand in North America, particularly in the U.S., where building construction activity will significantly accelerate compared to 2009-2014.

Global copper mine production is expected to rise 3.7% per year to 22.6 million metric tons in 2019. Rapid annual increases are forecast for countries such as Canada, Mexico, and Zambia, where ongoing development of copper projects will spur gains. In Central and South America, Peru is projected to post robust gains in copper mine output, supported by accelerated mining activity and development of additional deposits. In the refining sector, the Asia/Pacific region is expected to see the fastest annual gains in production, led by increased output in China and India. Electrolytic refining of primary copper will continue to represent the major method of production in these countries.

The top five suppliers of refined copper, Corporación Nacional del Cobre de Chile (Codelco), Freeport-McMoRan (U.S.), Jiangxi Copper (China), Glencore (Switzerland), and Aurubis (Germany), produced a combined 7 million metric tons of refined copper in 2014, accounting for 31% of global output. *For more information, visit freedoniagroup.com.*

FEEDBACK

READER SEEKS STABILITY DATA

I recently read the article "Titanium: A Metal for the Aerospace Age—Part I" (March issue) and found it very informative. I am a product engineer for a medical device manufacturer in the dental industry and one product we make uses titanium (6Al-4V-Grade 5). As part of our regulatory requirements, a component of our design history file and technical file covers the stability of materials used in our products. Can anyone recommend specific publications or other resources (such as test reports) that would help provide stability data (data that addresses negligible changes to material properties over time) to fulfill this requirement? Any pertinent information would be helpful.

Mark Albrecht

METALLURGICAL URBAN LEGEND?

Unfortunately I don't have a library-quality source for this, but somewhere in my education as a metallurgical engineer I was told that very early in Alcoa's history, their stationery was inadvertently printed with "aluminum" rather than "aluminium," and they didn't have enough money to change it. However, the company did fairly well after that and its dominance of the aluminum market in North America led to the official adoption of that spelling in the U.S.

Greg Whiting

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

OMG!
OUTRAGEOUS MATERIALS GOODNESS

Researchers working on the Architextile project, Ebba Waldhör, Benedict Anderson, and David Pigram. Courtesy of Joanne Saad.

3D-PRINTED SHELTERS HELP DISASTER VICTIMS

A pop-up, waterproof, solar-powered shelter sounds like science fiction, but a new multidisciplinary research team from CSIRO and the University of Technology, Sydney, both in Australia, and the University of the Arts Berlin, Germany, is working to make it a reality.

The shelter's architectural design is formulated by using a combination of 3D modeling, weaving, and knitting techniques. The shelter, waterproofed through coatings and additives laid into the textile fibers, is able to withstand wind, rain, and harsh elements in both hot and cold climates. A flexible design allows the shelters to be packed up and shipped out as quickly as they are erected. The Architextile project aims to build an interactive, self-sustaining, and waterproof shelter from textiles that can be flown to a disaster zone, assembled by unskilled people and, within minutes, generate its own power. *For more information: Benedict Anderson, +612.9514.8903, benedict.anderson@uts.edu.au, www.uts.edu.au.*

BULLETPROOF WALLPAPER COULD HELP PROTECT TROOPS

Soldiers often use abandoned masonry, brick, or cinderblock structures for defensive purposes instead of building their own or digging foxholes. While these materials offer a degree of protection, they are susceptible to blast impact from missiles or other large projectiles, says Nick Boone, a research mechanical engineer with the U.S. Army Corps of Engineers' Engineer Research and Development Center (ERDC), Vicksburg, Miss.

Engineers at ERDC came up with the idea of fortifying these structures with rolls of lightweight ballistic wallpaper with adhesive backing that can quickly be applied to interior walls, says Boone. The wallpaper consists of Kevlar fiber threads embedded in flexible polymer film. Without the wallpaper, a wall that is hit will "rubblize," sending shards of rock and mortar flying at the occupants inside. When the blast occurs with the wallpaper installed, it acts as a "catcher's net," containing the rubble and preventing debris from injuring soldiers. Ballistic wallpaper is still in the research and development stage, says Boone. *usace.army.mil.*

Nick Boone, at the U.S. Army Corps of Engineers, shows a section of ballistic wallpaper during DOD Lab Day at the Pentagon.

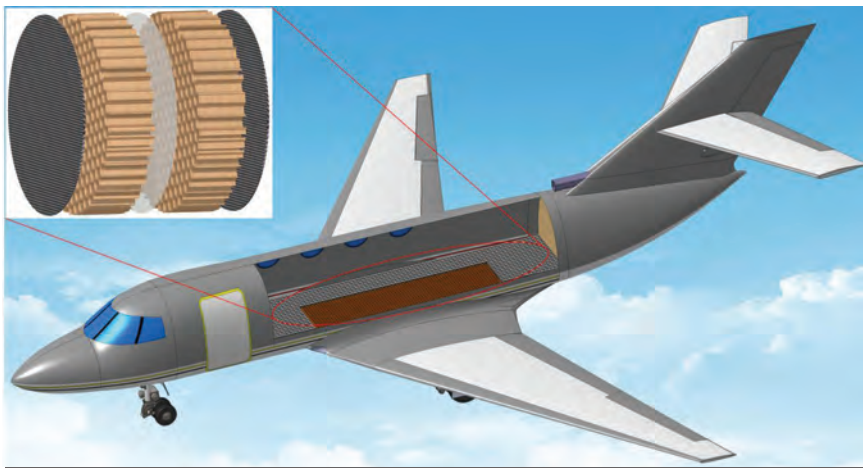
SPIDERS WEAVE SILK REINFORCED WITH CARBON

Spiders sprayed with water containing carbon nanotubes and graphene flakes have produced the toughest fibers ever measured, say researchers at the University of Trento, Italy. Fifteen Pholcidae spiders were collected and kept in controlled conditions in a lab. Researchers then retrieved samples of dragline silk produced by these spiders as a reference. Next, researchers sprayed the spiders with water containing nanotubes or flakes and measured the mechanical properties of the silk that the spiders produced. The resulting material has properties such as fracture strength, Young's modulus, and toughness modulus higher than any material ever measured, say researchers. *www.unitn.it/en.*

Pholcidae/cellar spider in West Germany. Courtesy of Wikimedia Commons/So ein Spinner.

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

METALS | POLYMERS | CERAMICS



Membranes can significantly reduce aircraft noise when inserted into the honeycomb structures used in aircraft design. Courtesy of Yun Jing, NC State.

POLYMER RESEARCH LEADS TO NEW CLASS OF MATERIALS

Macromolecular science will have to add a new giant molecule to its lexicon thanks to cutting-edge polymer research at The University of Akron, Ohio. The research team led by Professor Stephen Z.D. Cheng invented a new thinking pathway in the design and synthesis of macromolecules by creating an original class of giant tetrahedra.

The unique challenge of building macromolecules is to keep their material-specific properties. This requires the ability to create material designed and engineered at the nanometer scale for a specific task. Cheng and his team asked themselves, "What kind of structures do we need to transfer and amplify microscopic functionalities to macroscopic properties?"

Building on earlier work on giant surfactants, Cheng and his team developed a new class of giant polyhedra. These precisely functionalized nanoparticles were achieved by extending the molecular geometry from traditional 1D categories of giant surfactants to 3D of tetrahedron shapes that are the simplest to use. "It had never been done before in soft matter, where its engineering could be particularly useful," explains Cheng, "and it took three years to design and synthesize." *For more information: Stephen Z.D. Cheng, 330.972.6931, scheng@uakron.edu, www.uakron.edu.*

LIGHTWEIGHT MEMBRANE MUTES IN-FLIGHT AIRCRAFT NOISE

Researchers from North Carolina State University, Raleigh, and Massachusetts Institute of Technology, Cambridge, developed a membrane that can be incorporated into aircraft to drastically reduce the low-frequency noise that penetrates the cabin.

Aircraft designs incorporate lightweight materials with a honeycomb-like structure into their wings and cabins. The sandwiched honeycomb structure makes it strong, and the light weight makes the aircraft more fuel efficient. But these honeycomb structures are very bad at blocking low-frequency noise—like that of an aircraft engine.

The solution is a thin, lightweight membrane that covers one side of the honeycomb structure like the skin of a drum. When sound waves hit the membrane, they bounce off rather than passing through. "It's particularly effective against low-frequency noise," says Yun Jing, an assistant professor at NC State. "At low frequencies—sounds below 500 Hertz—the honeycomb panel with the membrane blocks 100 to 1000 times more sound energy than the panel without a membrane." The membrane is made of rubber that is roughly 0.25 mm thick, adding approximately 6% to the overall weight of the honeycomb panel. *For more information: Yun Jing, 919.513.4673, yjing2@ncsu.edu, www.ncsu.edu.*

BRIEF

Scientists at the **DOE's Ames Laboratory,** Iowa, created a new magnetic alloy that is an alternative to traditional rare-earth permanent magnets. The new alloy—a potential replacement for high-performance permanent magnets found in automobile engines and wind turbines—eliminates the use of one of the scarcest and most expensive rare earth elements, dysprosium, and instead uses cerium, the most abundant rare earth. *science.energy.gov.*

Cerium is used to create a high-performance magnet that is similar in performance to traditional dysprosium-containing magnets and could make wind turbines less expensive to manufacture. Courtesy of Ames Laboratory.

SEPARATING RARE EARTH METALS WITH UV LIGHT

Researchers from the KU Leuven Department of Chemical Engineering, Belgium, discovered a method to separate two rare earth elements—europium and yttrium—with UV light instead of traditional solvents. "The UV light influences the electrically charged particles known as ions. Both europium and yttrium have three positive charges per ion. When we shine UV light upon the solution of europium and yttrium, we add energy to the system. As a result, one positive charge per europium ion is neutralized. When we add sulphate, only the europium reacts with it. The result is a precipitate that can easily be filtered, while the yttrium remains in the solution," says Professor Tom Van Gerven.

The UV light does not leave behind any harmful chemicals in the liquid and the separation efficiency and purity in synthetic mixtures is very high—more than 95% of the europium is recovered from the solution. The precipitate itself is 98.5% pure, so it contains hardly any traces of yttrium. *For more information: Tom Van Gerven, +32.16.322.342, thomas.vangerven@cit.kuleuven.be, www.kuleuven.be/english.*

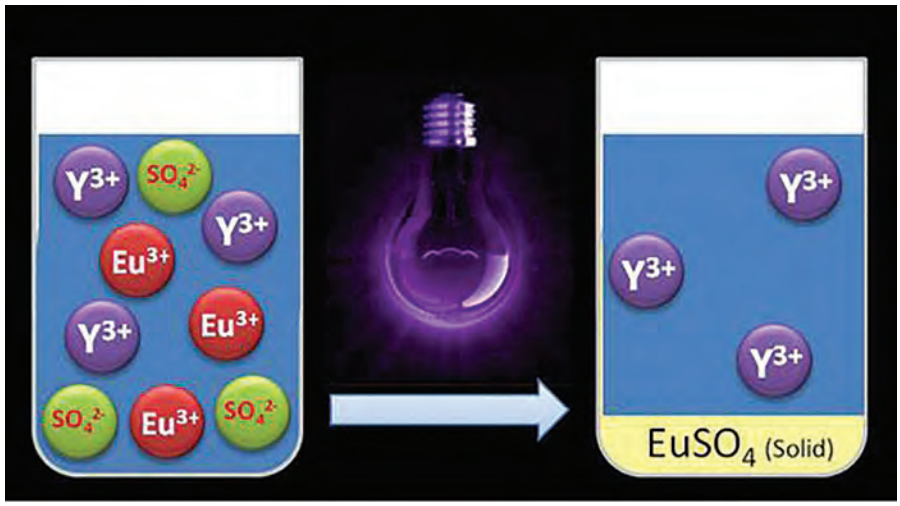
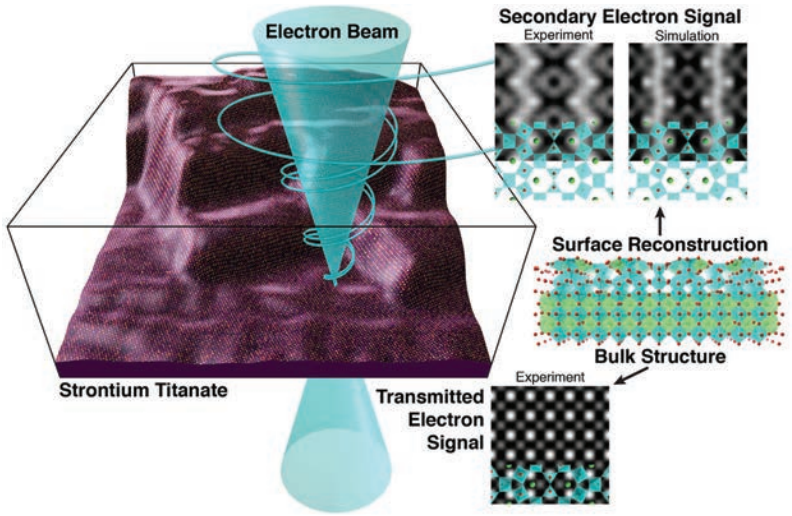


Illustration of the separation of rare earth metals with UV light. Courtesy of KU Leuven.

TESTING | CHARACTERIZATION



A highly promising technique called high-resolution SEM extends scanning microscopy to the atomic scale and provides information on both surface and bulk atoms simultaneously. Courtesy of Berkeley Lab.

NEW IMAGING METHOD HOLDS PROMISE FOR CORROSION RESEARCH

Researchers from Northwestern University, Brookhaven National Laboratory, Lawrence Berkeley National Laboratory, and the University of Melbourne, Australia, developed a new imaging technique that uses atomic resolution secondary electron images in a quantitative way to determine the arrangement of atoms on the surface.

"We are excited by the possibilities of applying our imaging technique to corrosion and catalysis problems," says Laurence Marks, professor of materials science and engineering at Northwestern. "The cost of corrosion to industry and the military is enormous, and we do not understand everything that is taking place. We must learn more, so we can produce materials that will last longer."

To understand these processes, it is vital to know how atoms are arranged on surfaces. While there are many good methods for obtaining this information for flat surfaces, most tools are limited in what they can reveal when surfaces are rough. Scanning electron microscopes (SEMs) are widely used to produce images of many different materials and surface roughness is not that important. Until recently, instruments could not obtain clear atomic images of surfaces until a group at Brookhaven managed to get the first images that seemed to show the surfaces very distinctly, in 2011. However, it was not clear to what extent they were able to image the surface, as there was no theory for the imaging and many uncertainties existed.

The new work answers all these questions, says Marks, providing a definitive way of understanding the surfaces in detail. What was needed was to use a carefully controlled sample of strontium titanate and perform a large range of different types of imaging to unravel the details of how secondary electron images are produced.

"We started this work by investigating a well-studied material," says Jim Ciston, a staff scientist at Lawrence Berkeley National Laboratory who obtained the experimental images. "This new technique is so powerful that we had to revise much of what was already thought to be well known. This is an exciting prospect because the surface of every material can act as its own nanomaterial coating, which can greatly change the chemistry and behavior."

Les Allen, who led the theoretical and modeling aspects of the new imaging technique in Melbourne, notes, "We now have a sophisticated understanding of what the images mean. It will be full steam ahead to apply them to many different types of problems." *northwestern.edu.*

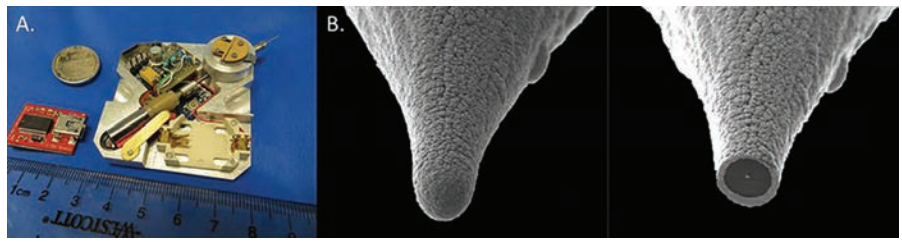
BRIEFS

Ametek Inc., Berwyn, Pa., will acquire **Cognex Corp.'s Surface Inspection Systems Division** (SISD), Hayward, Calif., for approximately $160 million. SISD develops and manufactures software-enabled vision systems used to inspect surfaces of continuously processed materials for flaws and defects. End markets include metals, paper, nonwovens, plastics, and glass. *ametek.com.*

Teledyne Technologies Inc., Thousand Oaks, Calif., acquired **Industrial Control Machines** (ICM), Belgium, a supplier of portable x-ray generators for nondestructive testing and complete x-ray imaging systems for security screening. Founded in 1993, ICM designs and manufactures lightweight x-ray sources for inspecting materials and structures, ranging from light alloy aviation parts to thick steel pipelines. *teledyne.com.*

X-RAY MICROSCOPY TECHNIQUE PROVIDES CHEMICAL FINGERPRINT

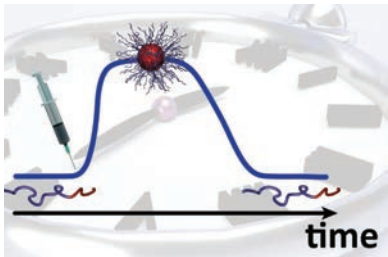
Gaining a comprehensive understanding of nanoscale systems requires tools with both the ability to resolve nanometer structures as well as direct observation of chemical composition and magnetic properties. X-ray microscopy methods provide the desired chemical and magnetic sensitivity, but their spatial resolution is limited. On the other hand, scanning tunneling microscopy (STM) achieves the requisite high spatial resolution, yet it has a fundamental drawback in that it is chemically blind. Now, scientists at the DOE's Argonne National Laboratory (ANL), Lemont, Ill., have advanced a new technology that pairs the powerful capabilities of x-ray analysis and STM.



A new patent from ANL includes a compact programmable nanorotator that allows the fabrication of smart tips (A). Coaxial smart tips serve as novel x-ray detectors, shown before (left) and after (right) nanofabrication (B). Courtesy of ANL.

This long-standing goal was achieved by developing "smart" nanofabricated coaxial multilayer probes that serve as detectors in the microscope as well as a programmable nanomanipulator to fabricate these. Further, a specialized electronic filter was invented that allows scientists to obtain simultaneous topographic and chemical information on surfaces, giving the chemical fingerprint of the material while also providing a detailed, clear image of the physical structure. Researchers expect that the new patent will ultimately enable the study of the electronic, chemical, and magnetic properties in individual atoms. *anl.gov.*

EMERGING TECHNOLOGY



Scientists at DWI-Leibniz Institute for Interactive Materials can program self-assembly, lifetime, and degradation of nanostructures consisting of single polymer strands. Courtesy of Thomas Heuser/DWI.

NANOSTRUCTURES SELF-ASSEMBLE, SELF-DESTRUCT

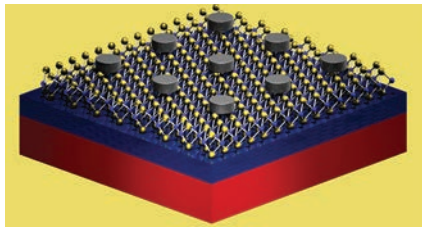
Materials that can self-assemble and self-destruct once their work is done are highly advantageous for a number of applications, such as components in temporary data storage systems or for medical devices. For example, such materials could seal blood vessels during surgery and reopen them later. Andreas Walther, research group leader at DWI-Leibniz Institute for Interactive Materials, Germany, developed an aqueous system that uses a single starting point to induce self-assembly formation, whose stability is preprogrammed with a certain lifetime before disassembly occurs without any additional external signal.

A closed system was developed, in which the precise balance between assembly reaction and programmed activation of the degradation reaction controls the lifetime of the materials. A single injection initiates the process, which distinguishes this new approach from current responsive systems that always require a second signal to trigger the disassembly. Then, pH changes are used to control the process. The reaction is initiated by the addition of a base and a dormant deactivator. This rapidly increases the pH and the building blocks—block copolymers, nanoparticles or peptides—which assemble into a 3D structure. At the same time, the pH change stimulates the dormant deactivator. Currently, a hydrolytic reaction is used to activate the deactivator. However, the team is already working on more sophisticated versions, which include an enzymatic reaction to slowly start the self-destruction mechanism. *www.dwi.rwth-aachen.de.*

ENHANCING LIGHT EMISSION IN MOLYBDENUM DISULFIDE

Molybdenum disulfide is a promising new material, but its best asset—monolayer thickness—is also its greatest challenge. MoS_2's ultrathin structure is strong, lightweight, and flexible, making it a good candidate for many applications, such as high-performance, flexible electronics. Such a thin semiconducting material, however, has very little interaction with light, limiting its use in light emitting and absorbing applications.

"The problem with these materials is that they are just one monolayer thick," says Koray Aydin, assistant professor of electrical engineering and computer science at Northwestern University's McCormick School of Engineering, Evanston, Ill. "So the amount of material that is available for light emission or light absorption is very limited. In order to use these materials for practical photonic and optoelectric applications, we needed to increase their interactions with light."



Silver nanodiscs on a sheet of monolayer molybdenum disulfide.

Aydin and his team designed and fabricated a series of silver nanodiscs and arranged them in a periodic fashion on top of a sheet of MoS_2. Not only did the nanodiscs enhance light emission, but the specific diameter of the most successful disc, which is 130 nm, was also discovered. Using the nanostructures instead of a continuous film to cover the MoS_2 allows the material to retain its flexible nature and mechanical properties. With enhanced light emission properties, MoS_2 could be a good candidate for light emitting diode technologies. The next step is to use the same strategy for increasing the light absorption abilities to create a better material for solar cells and photodetectors. *northwestern.edu.*

BRIEF

NASA selected three proposals to develop and manufacture ultra-lightweight materials for future aerospace vehicles and structures, which aim to reduce the mass of spacecraft by 40% percent for deep space exploration. The awards include **HRL Laboratories LLC,** Malibu, Calif.: Ultralight Micro-truss Cores for Space Launch Systems; **ATK Space Systems LLC,** Magna, Utah: Game Changing Technology Development Program Ultra-Light Weight Core Materials for Efficient Load Bearing Composite Sandwich Structures; and **Dynetics Inc.,** Huntsville, Ala.: Ultra-Lightweight Core Materials for Efficient Load-Bearing Composite Sandwich Structures. *nasa.gov/spacetech.*

Image courtesy of NASA.

PROCESS TECHNOLOGY

PNNL's process joins (white line) a thicker gauge of aluminum near the door hinge, where additional strength is needed, to a thinner gauge used throughout the rest of the door panel, resulting in a 62% weight reduction. Image courtesy of TWB Co.

NEW FRICTION STIR WELDING METHOD IS 10 TIMES FASTER

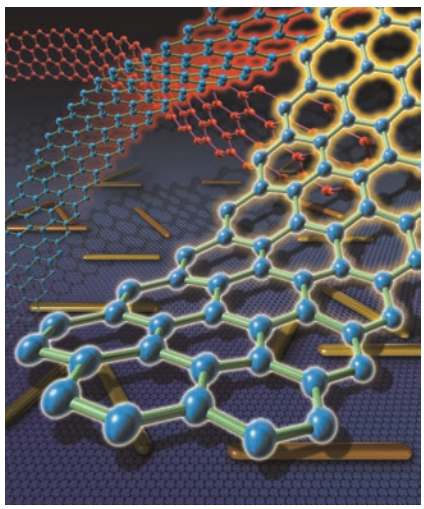
Researchers recently demonstrated a new process for the expanded use of lightweight aluminum in cars and trucks at the speed, scale, quality, and consistency required by the auto industry. The process reduces production time and costs while yielding strong and lightweight parts, for example delivering a car door that is 62% lighter and 25% less expensive than that produced with traditional manufacturing methods. In partnership with General Motors, Alcoa, and TWB Company LLC, researchers from the DOE's Pacific Northwest National Laboratory transformed the joining technique of friction stir welding (FSW). The technique can now be used to join aluminum sheets of varying thicknesses—key to producing auto parts that are light yet retain the required strength.

The new process is also 10 times faster than current FSW techniques, representing production speeds that meet high-volume assembly requirements for the first time, say researchers. The two-phase, six-year project is funded by the DOE's Office of Energy Efficiency and Renewable Energy with contributions from participating companies. With more than two years of funding left, the team continues to collaborate, with a focus on even faster weld speeds and the ability to maneuver around the contours of complex aluminum parts, for which laser welding is not commercially feasible. The team is also modifying FSW to join different alloys, such as automotive-grade aluminum alloys with light, ultra-high strength alloys currently reserved for aerospace applications. *pnnl.gov.*

GRAPHENE NANORIBBON ASSEMBLY PROCESS MAKES PROGRESS

Researchers at the University of Tokyo produced graphene nanoribbons by taking advantage of the phenomenon that inorganic nanomaterials self-assemble into regular structures on graphene. Professor Shoji Takeuchi and assistant professor Won Chul Lee found that gold cyanide nanowires grow directly on pristine graphene in aqueous solution at room temperature, the molecules aligning themselves with the zigzag lattice directions of the graphene. The team then fabricated graphene nanoribbons with zigzag-edged directions by employing the synthesized nanowires as an etching mask. Ribbons were 10 nm in width and as thin as a single carbon atom. Both the nanowires and graphene nanoribbons formed along the zigzag lattice, offering a potential method for controlling the formation direction of the ribbons.

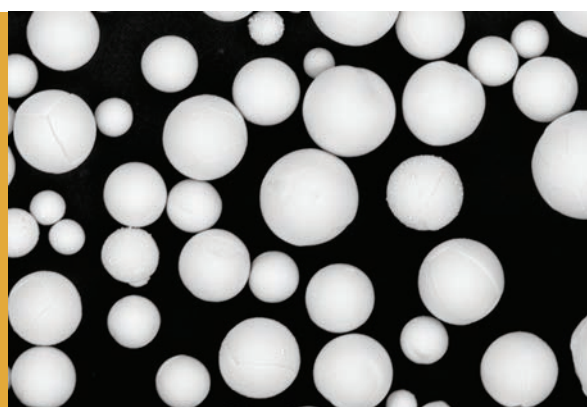
The research is a collaboration between the University of Tokyo, University of California at Berkeley, Ulsan National Institute of Science and Technology, Harvard University, Konkuk University, and Lawrence Berkeley National Laboratory. *www.u-tokyo.ac.jp/en.*



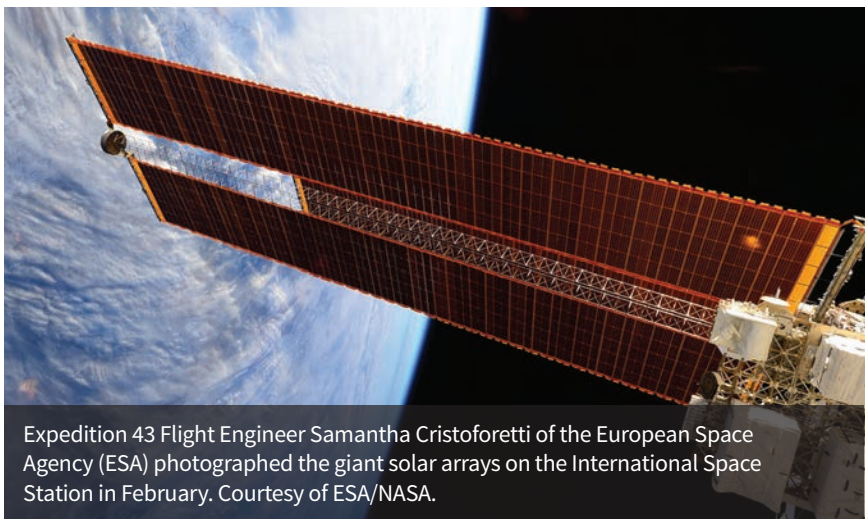
Inorganic nanowires self-assemble on graphene and graphene nanoribbons fabricated using those nanowires. Both the nanowires and the nanoribbons are aligned in zigzag-edged directions. Courtesy of Aki Sato.

BRIEF

LPW Technology Ltd. and **Metalysis,** both in the UK, will collaborate to develop an alternative supply chain for spherical tantalum and tungsten powders for quality-critical applications. It will combine Metalysis' technology, using electrolysis to make metal powder directly from oxide, with LPW's spherodization and post-processing capability. *lpwtechnology.com, metalysis.com.*



ENERGY TRENDS



Expedition 43 Flight Engineer Samantha Cristoforetti of the European Space Agency (ESA) photographed the giant solar arrays on the International Space Station in February. Courtesy of ESA/NASA.

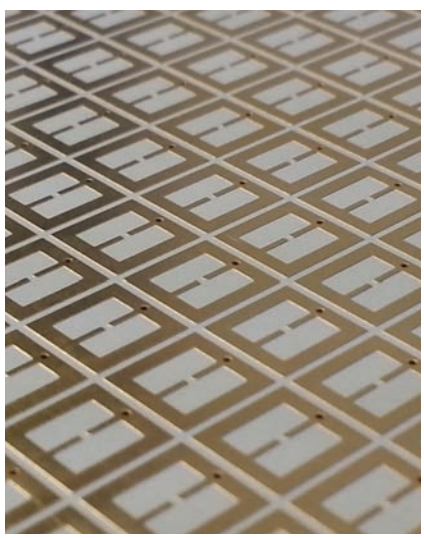
SOLAR ARRAYS POWER SPACE STATION

The International Space Station is a microgravity laboratory in which an international crew of six people live and work while traveling at a speed of five miles per second, orbiting earth every 90 minutes. Crew members spend about 35 hours each week conducting research in many disciplines to advance scientific knowledge in earth, space, physical, and biological sciences. It is powered by more than an acre of solar arrays, which contain a total of 262,400 solar cells and cover an area of about 27,000 ft^2 (2500 m^2). The solar array's wingspan of 240 ft (73 m) is longer than a Boeing 777's wingspan. Altogether, the four sets of arrays can generate 84 to 120 kW of electricity—enough to provide power to more than 40 homes. The solar arrays produce more power than the station needs at one time for systems and experiments. When the station is in sunlight, about 60% of the electricity that the solar arrays generate is used to charge the station's batteries. At times, some or all of the solar arrays are in the shadow of Earth or part of the station. The batteries power the station when it is not in the sun. *nasa.gov.*

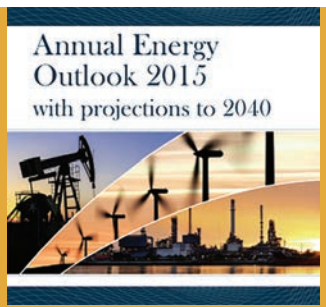
HARVESTING ENERGY FROM ELECTROMAGNETIC WAVES

Researchers from the University of Waterloo, Canada, reported a novel design for harvesting electromagnetic energy based on the full absorption concept, which involves use of metamaterials tailored to produce media that neither reflects nor transmits any power. This enables full absorption of incident waves at a specific range of frequencies and polarizations.

Since the inception of collecting and harvesting electromagnetic energy, classical dipole patch antennas have been used. "Our technology introduces *metasurfaces* that are much better energy collectors than classical antennas," explains Omar M. Ramahi, professor of electrical and computer engineering. Metasurfaces are formed by etching a material's surface with an elegant pattern of periodic shapes. The particular dimensions of these patterns and their proximity to each other can be tuned to provide near-unity energy absorption. This energy is then channeled to a load through a conducting path that connects the metasurface to a ground plane. The key significance of the researchers' work is that it demonstrates for the first time that it's possible to collect essentially all of the electromagnetic energy that falls onto a surface. *https://uwaterloo.ca.*



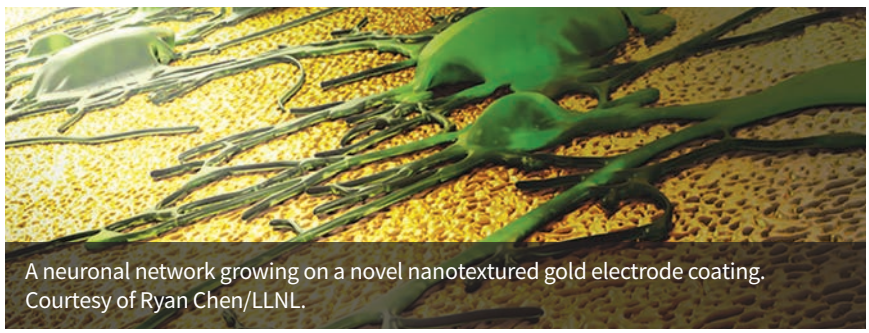
Metasurface used for collecting electromagnetic energy. Courtesy of O. Ramahi/U. Waterloo.



BRIEF

The **U.S. Energy Information Administration** released the **Annual Energy Outlook 2015** (AEO2015), which presents long-term projections of energy supply, demand, and prices through 2040. The analysis focuses on six cases: reference, low and high economic growth, low and high oil prices, and high oil and gas resources. AEO2015 is a shorter edition under a newly adopted two-year release cycle in which full editions and shorter editions will be produced in alternating years, allowing the EIA to focus more resources on rapidly changing energy markets both in the U.S. and abroad. *eia.gov.*

SURFACE ENGINEERING



A neuronal network growing on a novel nanotextured gold electrode coating. Courtesy of Ryan Chen/LLNL.

NEW FILTER COULD HELP IN OIL SPILLS

A new stainless steel mesh filter created at The Ohio State University, Columbus, could make a big difference for future environmental cleanups. The mesh coating was partly inspired by lotus leaves, whose bumpy surfaces naturally repel water but not oil. To create a coating that did the opposite, researchers covered a bumpy surface with a polymer embedded with molecules of surfactant. A fine dusting of silica nanoparticles was then sprayed onto the stainless steel mesh to create a randomly bumpy surface while the polymer and surfactant were layered on top. The silica, surfactant, polymer, and stainless steel are all non-toxic and relatively inexpensive, say researchers. They estimate that a larger mesh net could be created for less than a dollar per square foot. Because the coating is only a few hundred nanometers thick, it is mostly undetectable. To the touch, the coated mesh does not feel any bumpier than uncoated mesh. The coated mesh is a little less shiny, though, because the coating is only 70% transparent. *osu.edu.*

IMPLANTABLE ELECTRODE COATING IS GOOD AS GOLD

A team of researchers from Lawrence Livermore National Laboratory (LLNL) and University of California, Davis, found that covering an implantable neural electrode with nanoporous gold could eliminate the risk of scar tissue forming over the electrode's surface. The team demonstrated that the nanostructure of nanoporous gold achieves close physical coupling of neurons by maintaining a high neuron-to-astrocyte surface coverage ratio. Close physical coupling between neurons and the electrode plays a crucial role in recording fidelity of neural electrical activity.

Nanoporous gold, produced by an alloy corrosion process, is a promising candidate to reduce scar tissue formation on the electrode surface solely through topography by taking advantage of its tunable length scale. "Nanoporous gold reduces scar coverage but also maintains high neuronal coverage in an in vitro neuron-glia co-culture model," says Juergen Biener at LLNL. "More broadly, the study demonstrates a novel surface for supporting neuronal cultures without the use of culture medium supplements to reduce scar overgrowth." *For more information: Juergen Biener, 925.422.9081, biener2@llnl.gov, www.llnl.gov.*

SURFACE-MODIFIED NANOPARTICLES FOR MULTIFUNCTIONAL COATINGS

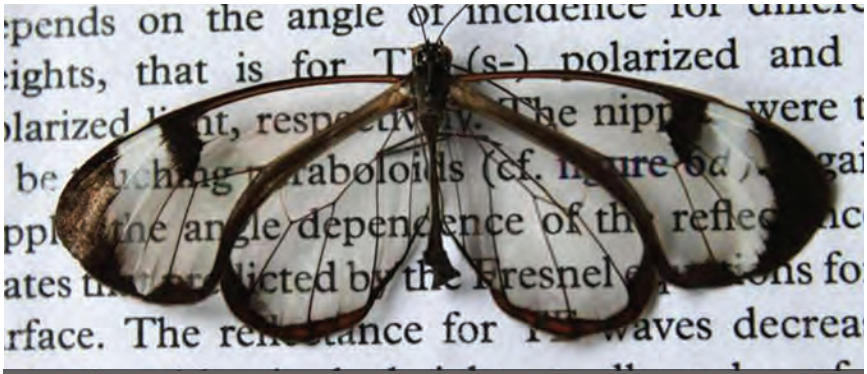
The INM – Leibniz Institute for New Materials, Germany, is using nanoparticles to create multifunctional coatings. These nanoparticles are specifically adapted by small molecule surface modification (SMSM). Depending on which property is desired, the nanoparticles can be surface modified with organic moieties. SMSM imparts specific combinations of desired properties, for example hydrophilic, hydrophobic, adhesive, anti-adhesive, acidic, basic, inert, or polymerizable.

Nanoparticles thus modified are used to develop nanocomposites—they combine the physical solid-state properties of ceramics or semiconductors, for example, with classic polymer-processing technology. Titanium dioxide, barium titanate, indium-tin oxide, or zirconium dioxide could be used as nanoparticles. In addition to the chemical intrinsic composition of the nanoparticles and their SMSM surface treatment, the properties that are attainable for the desired coatings also vary with the size and dispersal mode of the nanoparticles. *www.leibniz-gemeinschaft.de/en/institute-museen/einrichtungen/inm.*

BRIEF

Whitford Corp., Elverson, Pa., established a new medical coatings group. The company is a raw material supplier for catheter guide wire manufacturers and coaters, as well as other biocompatible devices. To service all global tiers of the medical supply chain, Whitford will implement an ISO 13485 compliant quality system, validate all levels of manufacturing, and enhance quality control testing to ensure product quality and performance. *whitfordww.com.*

NANOTECHNOLOGY



The wings of the glasswing butterfly (*Greta Oto*) do not reflect much light and could inspire new lenses or mobile device displays. Courtesy of KIT.

BUTTERFLY WINGS INSPIRE ANTIREFLECTIVE SURFACES

Hendrik Hölscher and colleagues at Karlsruhe Institute of Technology, Germany, found that irregular nanostructures on the surface of butterfly wings create low reflective surfaces. In theoretical experiments, researchers reproduced the effect, which holds potential for mobile phone and laptop displays, for example. Transparent materials such as glass always reflect part of incident light. Some insect surfaces such as moth eyes reduce reflection, but only when the view angle is vertical to the surface. Glasswing butterfly wings, however, maintain very low reflection even under higher angles.

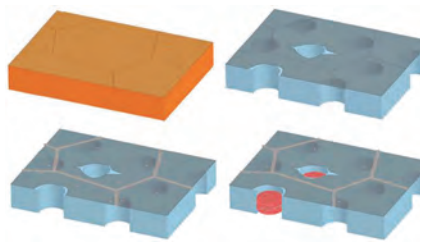
Scientists examined glasswing butterflies using scanning electron microscopy. Earlier studies show that regular pillar-like nanostructures are used by other insects to reduce reflection. Scientists also found these nanopillars on the butterfly wings, although they are arranged irregularly. In simulations, researchers mathematically modeled the irregularity of the glasswings' nanopillars and found that the estimated amount of reflected light exactly corresponds to the actual amount at variable view angles. *kit.edu/english.*

GRAPHENE ENHANCES WATER FILTERS

For faster, longer-lasting water filters, some scientists are looking to graphene to serve as ultrathin membranes, filtering contaminants to quickly purify high volumes of water. Graphene's unique properties make it a potentially ideal membrane for water filtration or desalination. But there has been one main barrier to its wider use: Making membranes in one-atom-thick layers of graphene is a meticulous process that can tear the thin material.

Now engineers at Massachusetts Institute of Technology, Cambridge, Oak Ridge National Laboratory, Tenn., and King Fahd University of Petroleum and Minerals, Saudi Arabia, devised a process to repair these leaks, fill cracks, and plug holes using a combination of chemical deposition and polymerization. Combining these techniques, researchers engineered a defect-free graphene membrane about the size of a penny.

Membrane size is significant: To be used as a filtration membrane, graphene would have to be manufactured at a scale of centimeters or larger. In experiments, water was pumped through a graphene membrane treated with both defect-sealing and pore-producing processes. Water flowed at rates comparable to current desalination membranes. Graphene filtered out most large-molecule contaminants, such as magnesium sulfate and dextran. *For more information: Rohit Karnik, 617.324.1155, karnik@mit.edu, www.web.mit.edu.*



In a two-step process, engineers successfully sealed leaks in graphene. Graphene was fabricated on a copper surface (top left)—a process that can create intrinsic defects, shown as cracks on the surface. After lifting the graphene and depositing it on a porous surface (top right), the transfer creates further holes and tears. Atomic layer deposition (bottom left) was used to deposit hafnium (in gray) to seal intrinsic cracks, while remaining holes (bottom right) were plugged with nylon (in red) via interfacial polymerization.

BRIEF

Researchers at the **University of Arkansas,** Fayetteville, received a $438,317 grant from the **National Science Foundation,** Arlington, Va., to identify and characterize the fundamental mechanisms of a core-shell nanoscale structure. Discovered by Min Zou, professor of mechanical engineering, the structure is a new type of material that can be used to improve the mechanical integrity of electro-mechanical systems in computer hard-drive discs and a wide range of other electronic devices. *mzou@uark.edu, www.uark.edu.*

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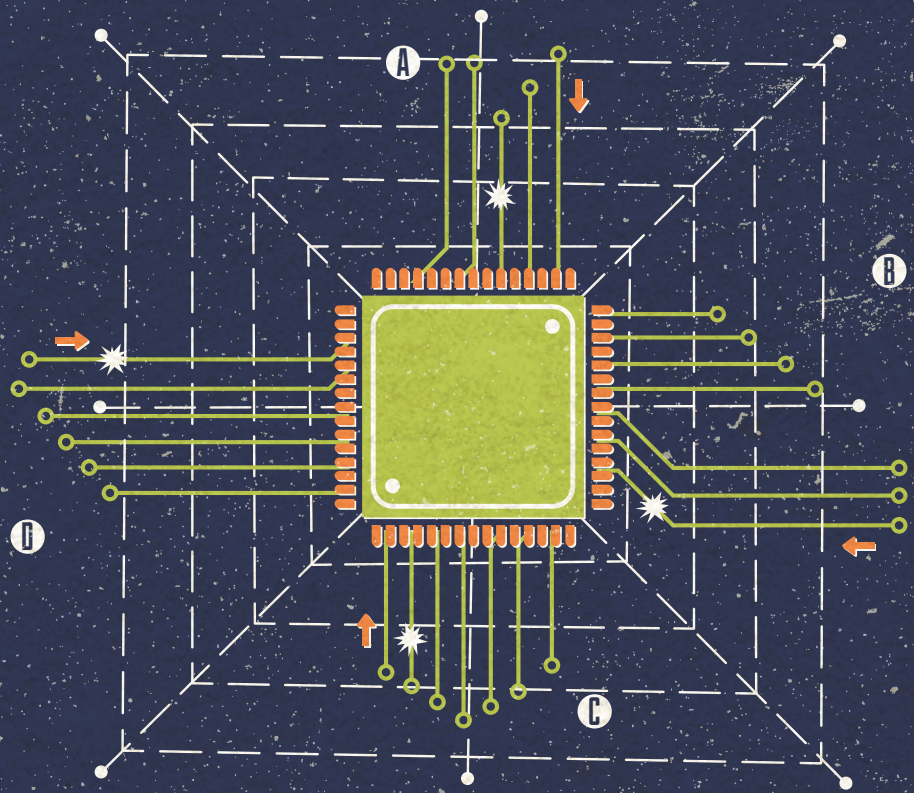

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TECHNICAL SPOTLIGHT

MATERIALS TESTING PLAYS ESSENTIAL ROLE IN HIGH-PERFORMANCE SPORTING GOODS

Testing offers vital insights into product performance and enables engineers to determine a material's suitability as well as the integrity of manufacturing processes as part of quality control initiatives.

In the sport and leisure industry, performance sets products apart and connects companies with consumers. In both cases, testing represents a vital element in product enhancement. In addition to classical materials testing, component testing is now an integral part of product engineering due to the continuous development of sports equipment and the ever-increasing role of technology. Investigation of mechanical properties is of particular importance, with companies such as Oakley, Nitro Snowboards, and Alpinestars using sophisticated testing machines for this purpose. This article provides a snapshot of what these leading sports equipment companies do regarding materials testing initiatives.

OAKLEY SETS SIGHTS ON ADVANCED EYEWEAR

Oakley Inc., Foothill Ranch, Calif., continues to develop cutting-edge sports eyewear and apparel with a focus on both performance and design. The company takes a unique approach to design, translating the functional requirements demanded by each sport into products that offer security as well as visual appeal. Oakley has long emphasized technology, employing novel molding techniques to optimize lens stiffness and curvature for various applications. Perhaps less widely known is the priority Oakley places on safety and the connection it draws between product integrity and performance. The company's testing laboratory assesses a wide range of properties to support new product design. Among the characteristics explored are impact resistance and compressive strength, according to Wayne Chumbley, vision performance testing manager.

Maintaining a close connection with the sports to which it supplies vision solutions, Oakley set out to design a goggle for motocross applications that addresses issues associated with lens penetration, ejection, and collapse. As the design team evaluated materials as well as prototypes, testing played a significant role in the process. Oakley manufactures motocross lenses with a specific thickness and molded arc that impart both safety and visual acuity. The company then tests the resulting product to standards such as those developed by ANSI and the U.S. military. ANSI Z87 standards prescribe the testing procedures to quantify high velocity impact resistance. These tests involve shooting a quarter-inch steel ball at the lens and frame at a velocity of 250 ft/s from a distance of just under 10 in. The U.S. military standard MIL-PRF-31013 calls for using an irregularly-shaped projectile that more closely simulates operational conditions. The projectile is shot at the lens at a velocity of 650 ft/s, substantially higher than that prescribed by ANSI.

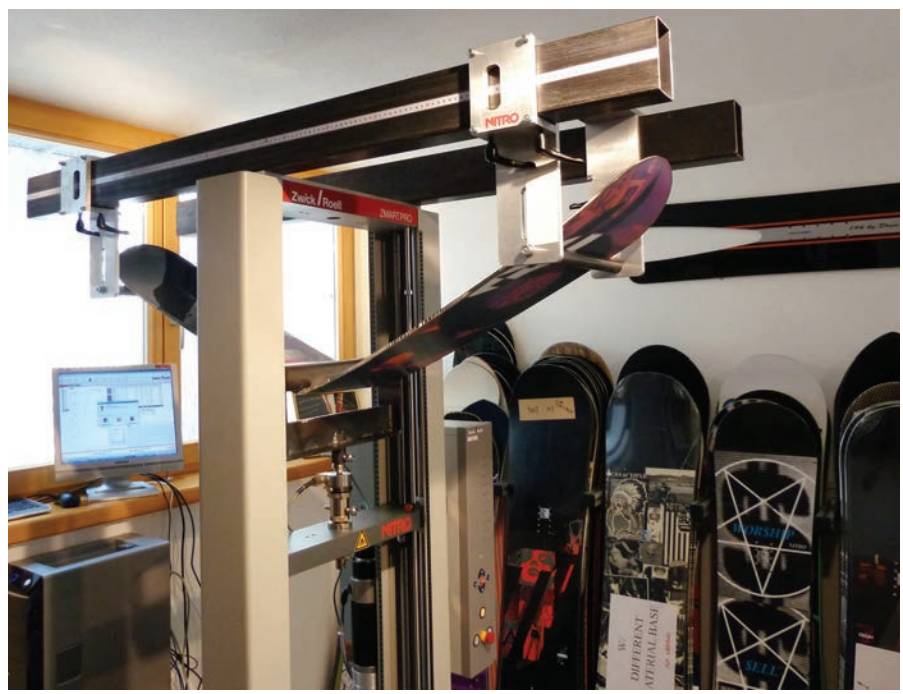
When commercializing its line of Mayhem Pro goggles, Oakley evaluated impact resistance and compressive strength to simulate performance in the rugged, off-road conditions faced by motocross riders.

Oakley also uses a compression testing procedure that quantifies the force required to cause the lens to impact the rider's face. For this test, Oakley uses testXpert II measurement and control software from Zwick/Roell, Germany, which compares results for the Oakley Mayhem Pro goggle with a competing product. "This is something we use the data from to support the design of our goggles—to improve chassis design and to use better materials in our products," says Chumbley.

The compression test not only evaluates the compressive strength of the lens, but the performance of the lens and chassis together. Reviewing the data in the software, Chumbley confirms that the strength value of more than two times that of the competing product and the shape of the curve both indicate how well the Mayhem Pro goggle performs as a unit. "We are designing goggles and lenses to truly work together. We see a really consistent lens-frame interface throughout the curve in the test results," adds Chumbley.

A Nitro snowboard undergoing a 3-point flexural test.

Nitro's unique camber designs determine the amount of surface area in contact with the mountain, rail, or halfpipe, enabling the rider to control the board. Flexural strength and flexural modulus are key performance elements that influence ride quality and can be validated through testing.



Nitro snowboards are comprised of multiple materials, enabling higher flexural strength and strain to failure. Layup processes layer the traditional element, wood, with glass and carbon fiber to create a board that matches modern riding styles. Carbon fiber imparts strength at high levels of strain, enabling riders to develop new tricks.

NITRO SNOWBOARDS CARVES OUT NEW LEVELS OF QUALITY

From the company founder to members of the design team, at Nitro Snowboards, Seattle, there is recognition that being part of the culture supports product development that will perform in demanding environments. It is this commitment that motivates company investment in a global team of riders. Dispersed in locations from Chile in the southern hemisphere to some of the most challenging mountains in Europe, Nitro boards are field tested year round.

Snowboarding as a sport continues to evolve as riders explore new horizons. These explorations continue to drive changes in board design, introducing new materials based on high-tech engineering principles. In addition to the board's primary element—wood—new combinations of composite materials such as glass and carbon fiber were introduced to offer greater stability and better handling characteristics. The emergence of new types of riding such as high speed, powder, and unique forms of freestyle have tremendous influence on materials as well as shape. Another factor contributing to the level of engineering involved in commercializing new snowboards is the availability of novel manufacturing processes. In each case, testing offers quantifiable results that support critical decision making.

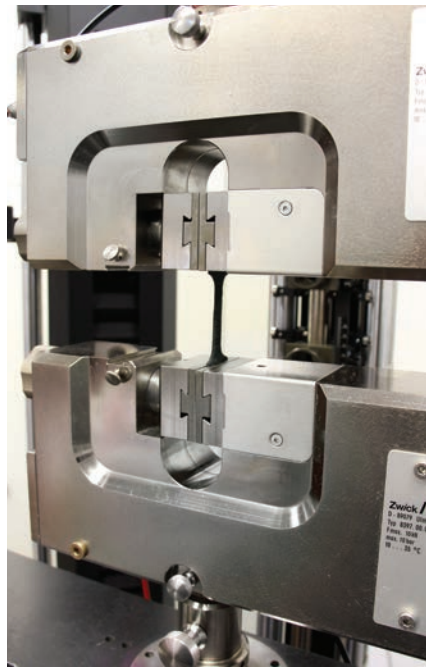
The quality of the ride in snowboarding is directly related to the board's capacity to move and respond to rider-initiated direction. Control and response are important features that may be assessed through testing procedures as Nitro seeks to design products that offer optimized flexural strength as well as torsional flexure. The company uses a Zwick two-column test machine to assess this, as well as other properties, in its snowboards. According to Florian Lang, Nitro's head developer, customers look for boards with varying degrees of flexure that match their riding style. "Riders want a certain level of control and at the same time, the board has to return energy. When a board is flexed, it absorbs a great deal of energy and that energy must be returned. This is what we look to quantify in testing," says Lang.

A three-point flexure test is used to examine the flex and shape properties of snowboards. The board is loaded to breaking point in a special flexure test kit and the characteristic values obtained are channeled directly into product development. The test is also used to monitor current production batches. In addition to snowboards, Nitro also performs a wide range of tests on bindings, boots, and laces. Peel tests on composite materials and fabric tear tests also represent areas of interest. Applying the dual testing areas of the Allround-Line, Nitro is able to perform these other types of tests in addition to flexure testing.

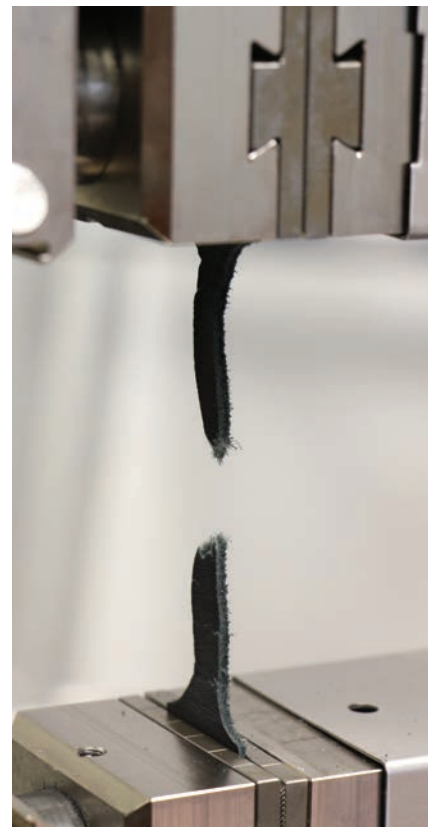
"We find that the testXpert II software offers value in support of the design cycle as well as our quality control programs. We have set up a routine that allows us to test certain product specifications with a high degree of reliability," says Lang.

ALPINESTARS INTEGRATES STYLE AND FUNCTION

While Alpinestars, Torrance, Calif., began as a manufacturer of footwear for motorcycle racing, the company has expanded to become a complete provider of protective gear and apparel in motorsports. Leather remains a primary material in a large number of the company's products. The demands of racing and the drive to increase safety motivate the designers and engineers at Alpinestars to devote ample time to materials testing.



Alpinestars designs protective gear for motorcycle racing and action sports, using leather as a primary material in the company's jackets, pants, gloves, and boots. Pigments can influence material performance, so testing determines the ultimate tensile strength of treated leather and supports design decisions.



A sample from a leather road racing suit is tested to failure on an Allround-Line testing system.

Assessing the suitability of various types of leather is a chief consideration, as treatments during the tanning process can have a dramatic impact on material properties. Among the assessments conducted at the company's development laboratory in northern Italy are UV exposure tests, abrasion tests, tensile, compression, and tear strength tests. Alpinestars uses a Zwick testing machine to conduct compression tests on boots in accordance with EN13634. The test assesses the amount of force required to compress the portion of the boot that surrounds the ankle.

Leather testing represents a major share of the analyses performed at Alpinestars' development laboratory. Grades of leather that have undergone the addition of brightly colored pigments exhibit reduced strength due to weakening of the fibers. Tensile and tear strength tests are performed on all forms of leather and on all fabrics the company incorporates into finished products. The Zwick testing machine is one of the busiest machines in the laboratory because every fabric and every type of leather must be evaluated by it. Offering valuable insight into application suitability, materials testing plays a vital role in the development of sporting gear, protective wear, and apparel. As high performance sports continue to grow in popularity, it is anticipated that demand for testing and the insights it offers will increase as well. **~AM&P**

For more information: Boris Plach is product manager, testing machines, Zwick/Roell, August-Nagel-Str. 11, D-89079 Ulm, Germany, +49.7305.100, info@zwick.de, www.zwick.com.

TECHNICAL SPOTLIGHT

MULTIAXIAL MATERIALS ACHIEVE WEIGHT SAVINGS IN CARBON YACHT DESIGN

CUSTOM MULTIAXIAL FABRICS ENABLE USE OF RESIN INFUSION TO ACHIEVE CHALLENGING WEIGHT SPECIFICATIONS.

From naval ships to recreational sailboats, materials play a significant role in vessel design and performance. This article provides a case study of how one materials supplier worked with a yacht builder to achieve weight and cost savings by using both innovative materials and a unique manufacturing process. For the B53 all-carbon racer/cruiser, Formax, UK, partnered with Gold Coast Yachts (GCY), U.S. Virgin Islands, to develop custom multiaxial fabrics that enable resin infusion use.

The B53 was designed by Paul Bieker of Bieker Boats LLC, known for engineering the AC72 foils for the 2013 America's Cup winner, Oracle Team USA. The B53 is complete and was successfully launched in June. In addition to serving as a competitive racing boat, the B53 is also a modern, well-equipped cruiser. It has an overall length of 16.3 m, is 8 m wide, and has a draft of 0.4 m to 3 m with foils down. It has a displacement of 5500 kg, including most of the equipment. GCY built the main structure, with the mast, rigging, and foils—also made of carbon—supplied by other companies.

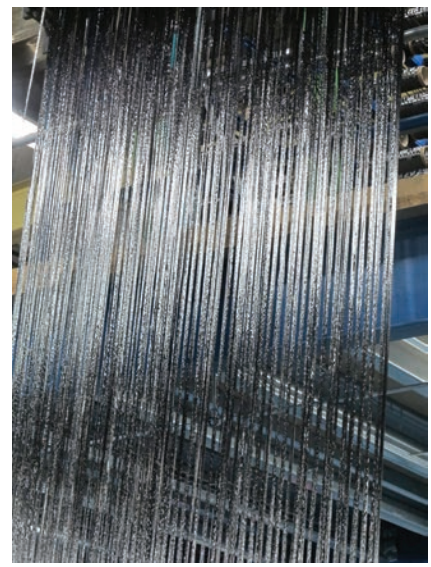
Since its inception in 1985, Gold Coast Yachts has built 113 custom one-off multihulls for the private yacht, commercial ferry, and day charter markets with many models in the 12-30 m range. Over the years, the company has transitioned from wood/epoxy construction, to E-glass/foam core/epoxy composites using either resin infusion or wet bagging (vacuum bagging) techniques, and more recently, has been incorporating more carbon composite parts. The B53 was GCY's first all-carbon build.

INFUSION-OPTIMIZED FABRICS

The B53's development team considered a number of composite build techniques. They did not think it was possible to meet the weight and panel engineering requirements of the boat using wet bagging, but they were concerned that carbon could not be vacuum-infused successfully. Carbon fiber is significantly more difficult to infuse with resin than glass due to its smaller fiber diameter, which means carbon fibers pack together more tightly, reducing fabric permeability. However, prepreg (a fabric reinforcement method that uses pre-impregnation with a resin system) is very expensive, requiring costly materials, tooling, and production equipment, plus higher labor costs.

Formax's director of business development for North America, Philip Steggall, helped Gold Coast Yachts decide which manufacturing process could best deliver the laminate properties (weight, strength, and stiffness). This effort involved a collaborative, three-month testing program. Formax fabrics were used to build identical laminate panels with wet bagging and infusion techniques. A typical laminating resin was used for the wet bag test panels, and an infusion-specific resin for the infusion samples. Panels were tested at laboratories in the U.S. and Canada and results demonstrated the superior properties of the infused panels, including a 15% increase in compression strength.

With this data, GCY was able to prove it could meet the B53's weight and engineering specifications using infusion, with relatively low-cost molds and lower post-curing temperatures than required for prepreg. Key to this success was Formax's ability to develop custom multiaxial fabrics optimized for the infusion. For the B53, it engineered new infusion-specific versions of its +45°/-45° biaxial carbon fiber fabrics of 400 g/m^2 and 300 g/m^2 and a 0°/90° biaxial of 300 g/m^2.

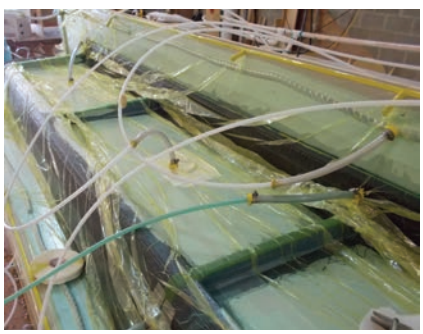


Formax carbon fabric.

Stitched multiaxials perform better in infusion than woven or hot-melt bonded fabrics because they offer a *z* axis for air to escape through the thickness, resulting in fewer voids. Formax also stitched "microweb" between the plies of the biaxial carbon fabric, which enhances the infusion and overall mechanical properties. Microweb is a polyamide random monofilament web that offers a path for air to escape and resin to flow between multiple layers of carbon reinforcement.

Gold Coast Yachts' B53 carbon structure.

B53 under construction.



B53 during resin infusion.

Launch day, June 5.

Unlike a surface flow medium where the laminate is flooded with resin, microweb (at approximately 3 g/m^2 per 100 g/m^2 of carbon) allows for an even flow rate of resin through the thickness and across the laminate surface. The web also boosts impact resistance, and improves shear, compression, and flexural strength. Further, the weight gain is minimal. While the B53's strength, stiffness, and weight specifications could have been met with prepreg construction, the cost would have been much higher. GCY co-founder, Roger Hatfield, believes that while a boat like this might normally cost $4 million in prepreg, the B53 came in around $2.5 million.

"It was the new fabric that allowed us to get air out ahead of the resin front, instead of entrapping it within the laminate, as is done with wet bagging, and even with prepreg. That's how we hit the weight target as well as the strength requirement for this boat," says Hatfield.

BOAT-BUILDING PROCESS

Steggall also assisted in the next production stage—defining the manufacturing process for the boat building. He helped the Gold Coast staff identify risks that could cause a failure in every step of the process, from monitoring and verifying equipment to controlling the temperature of parts and resin to optimize viscosity and flow rate.

The improved build process started out with the validation of smaller, less highly structurally-loaded panels before moving on to larger components. Some parts were male-molded, with others using female molds. Some parts were produced in a one shot process with skin-core-skin all infused together. To save weight, parts with a complicated geometry were built in a three-stage process: The outer skin was resin infused first, then the core was installed, and finally the inner skin was infused. **~AM&P**

For more information: Philip Steggall is director of business development, North America, at Formax, Cutters Close, Narborough, Leicester, LE19 2FZ, UK, +1.401.965.5387, philip.steggall@formax.co.uk, www.formax.co.uk.

MODERN MATERIALS FOR SPORTS AND RECREATION

Beyond automotive, aerospace, and medical materials innovations, research and development of advanced materials and processes for sports and recreation activities is one of the most exciting areas for today's materials scientists and engineers.

Compiled by Frances Richards and Julie Lucko

The following news department is part of our special summer issue highlighting materials used in sports and recreation. This compilation is not meant to be comprehensive, but rather provide a lively snapshot of some of the most interesting developments and wide variety of efforts taking place in the modern sports arena. From competitive sailing and fishing to running and cycling, materials matter in sports. Whether it's a slight performance edge for elite athletes or a practical effort to make sports equipment safer, today's materials scientists and engineers are busy working on some amazing innovations. Warning: If you're a sports enthusiast, these stories might make you want to change your day job.

Sir Bradley Wiggins sets World Hour Record with the help of lightweight 3D-printed handlebars. Courtesy of Radu Razvan/The University of Sheffield.

3D-PRINTED HANDLEBARS HELP CYCLISTS PUT THE PEDAL TO THE METAL

On June 7, Sir Bradley Wiggins broke the World Hour Record with the help of 3D-printed, super lightweight, and aerodynamic handlebars developed at The University of Sheffield's Mercury Centre, UK, in conjunction with Italian bicycle manufacturer Pinarello. Wiggins broke the world record for the longest distance that a cyclist has ridden within an hour on the track, after spanning 218 laps—54.53 km—of the Lee Valley VeloPark in London. The record-breaking bicycle was produced by Pinarello Lab, part of the technical department of Pinarello, and designed by Dimitris Katsanis, an aerodynamics and composites expert who works for British Cycling.

3D printing was used to develop the titanium handlebars because it enabled the developers to create complex designs and quickly produce a number of versions in order to test which handlebars best matched the body size and cycling style of Sir Bradley. The handlebars were the only component of the bike not made of carbon fiber, due to a compressed timetable for bike production and need for several prototypes. Designers used an Arcam electron beam additive manufacturing machine to make slight modifications quickly, without having to build new molds to fabricate individual pieces. This saved time and allowed designers to thoroughly test parts and make necessary adjustments to the handlebars prior to the world record attempt. *www.sheffield.ac.uk.*

ITALIAN CYCLISTS RACE AHEAD WITH GRAPHENE-BASED WHEELS

A wheel produced by Vittoria, an Italian supplier to the cycling industry, is now available in three different sizes, 46, 60, and 84 mm. By incorporating an

Graphene-based wheels. Courtesy of Directa Plus.

innovative material made of pristine graphene nanoplatelets provided by Directa Plus, Vittoria has rapidly transformed from a traditional manufacturer to a high-tech innovation company. Graphene increases material strength, flexibility, and lateral stiffness. The advantages for a wheel include heat dissipation (15°-30°C lower), an increase in lateral stiffness (more than 50%), and puncture reduction—especially around the valve area. Two wheels weigh 1250 grams together and cost around $1800. At Giro d'Italia, an international cycling competition held in June, several professional cyclists tried out the new wheels. *vittoria.com.*

INTERNATIONAL CONSORTIUM CHAMPIONS CARBON COMPOSITES

Nanyang Technological University (NTU), Singapore, set up an international consortium to develop innovative materials and processes for sports products. Besides NTU's Institute for Sports Research (ISR), the four founding members include Arkema (France), textile and composites company Chomarat (France), tennis racquet maker Babolat (France), and bicycle manufacturer Topkey (Taiwan). The new consortium, known as the Innovative Composites for Sports Products (I-Comp Sports), will benefit from ISR's research and testing facilities housed at NTU's School of Mechanical and Aerospace Engineering. It will also leverage ISR's strong industry links, including NTU's plans to invest millions in specialized machinery for manufacturing composite materials using automated fiber placement. The consortium will jointly develop new carbon composites materials, parts design, and manufacturing technology for sports products such as racquets and bicycle frames. The research will benefit not only the sports product industry, but also industries such as aerospace, renewable energy, and materials engineering, say NTU sources.

ISR's first product made its debut at the Sochi Winter Olympics 2014. ISR worked with Skis Rossignol, France, to develop its new Infini range of dynamic compression garments for cross country skiing. Apart from collaborating with multinational companies, ISR is also partnering with international sports federations. For example, together with the International Table Tennis Federation, ISR engineered a unique prototype machine to test the bounce of table tennis racquets to ensure they meet competition standards. At the same time, ISR is also working with the Badminton World Federation on equipment, especially in shuttlecock development. *www.ntu.edu.sg.*

SMART BLADES SHED LIGHT ON FIGURE SKATING FORCES

An ice skating blade that informs figure skaters of the stresses imposed on their joints was developed by a group of researchers at Brigham Young University, Provo, Utah, and Ithaca College, N.Y. The lightweight device is built to measure the force that figure skaters exert on the ice when performing jumps and spins and could be used by skaters and their trainers to avoid injuries, as well as help to design new skating boots. Figure skaters are continually putting their body under stress, performing anywhere between 50 and 100 jumps per daily practice session. Simulations outside of the ice rink suggest that skaters exert a force magnitude of up to six times their body weight when taking off and landing from a jump.

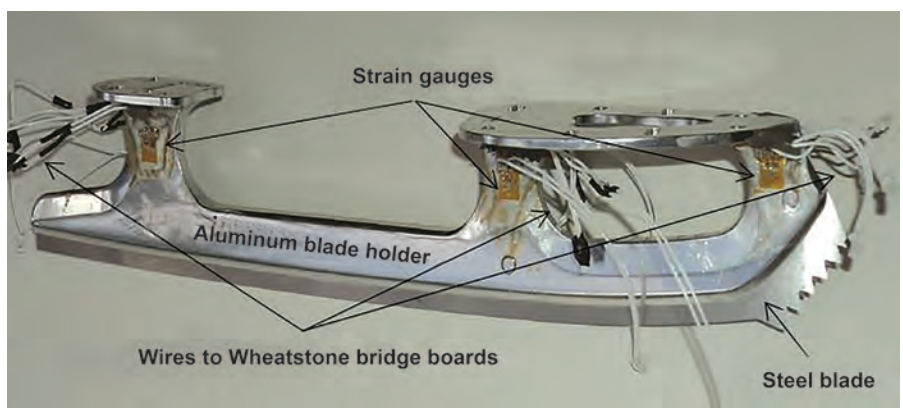
Researchers created a special blade and fitted it with strain gauges, which are attached directly to the stanchions where the blade connects to the boot, and when the stanchions deform due to the force induced by the ice skater, the strain gauges deform as well. Once deformed, the electrical resistance of the strain gauge changes. This change is measured by a device called a Wheatstone bridge and a central control system is used to calculate the overall force that was imparted.

To test the device, researchers mounted an instrumented blade onto an artificial leg and foot and applied 14 vertical loads between 0 and 236 kg to the leg. The instrumented blade was then fitted to an experienced skater who was asked to jump from a 20 cm high box onto the floor while measurements were taken from the device. These results were then compared with measurements from a different experiment, where the skater wore a normal ice skating blade and landed onto a force plate.

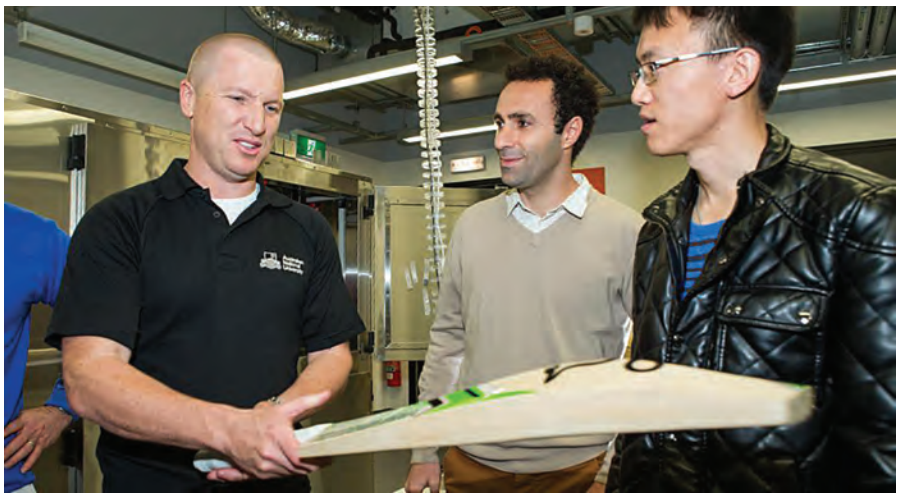
"It was encouraging to see that the device performed very well for vertical loads, which is where our initial focus has been," says professor Deborah King of Ithaca College. "We also worked on the wire packaging. So far it all looks promising and we are planning to collect data to study the forces at take-off and landing of double jumps at the end of the summer." *byu.edu, ithaca.edu.*

WILLOW WORKS WONDERS FOR CRICKET BATS

Scientists from the Australian National University (ANU) sought advice



Hybrid skate with strain gauges and wires leading from gauges to Wheatstone bridge boards. Courtesy of IOP Publishing.



Brad Haddin with Mohammad Saadatfar and Ph.D. student Jin Tao. Courtesy of ANU.

from wicket-keeper Brad Haddin for high-tech research into cricket bats. Researchers are studying English willow at the cellular level to understand what makes a top quality bat and to see if other types of wood might one day rival the legendary performance of willow.

Haddin, who played for the ANU cricket club in the 1990s, tested an English willow bat and then one made of Kashmir willow, considered to be an inferior bat material. After hitting a number of balls, he sawed one of the bats in half and gave it to the researchers. Willow samples were analyzed using an extremely accurate CT scanning technique and processed by a National Computational Infrastructure supercomputer.

Top quality bats are made from only one particular female species of English willow tree. The team examined the cellular structure of the wood to unlock the secrets of the willow's success as a light and strong bat material. "We would love to find an alternative to English willow, which would make top quality bats more accessible to kids in developing countries," says lead scientist Mohammad Saadatfar. "There is no reason why every kid in the world shouldn't play with a top quality cricket bat." *For more information: Mohammad Saadatfar, mohammad.saadatfar @anu.edu.au, www.anu.edu.au.*

IF THE SHOE FITS, WEAR IT

A consortium of European Union-funded project Demo ShopInstantShoe developed a novel, modifiable female shoe using a unique shape memory composite made of Nitinol and leather. The material is adjusted using a machine called Shoptool, which finishes the shoemaking process in the store. The compact tool is lightweight and can be assembled onsite for immediate customization. InstantShoe comes with the shaping system, smart configuration software, a sophisticated machine featuring three different lasts for every size range, and the foot scanner DOME, constructed by the Biomechanics Institute of Valencia, Spain.

The shoe's upper part is made from a shape memory composite that maintains the final shape. Customers confirm the fit and then decide to purchase the footwear or not. If they choose not to purchase, shoes are heat treated in a customization box to regain their shape. The whole process can be repeated many times on a particular shoe. The critical components of the shape memory material are Nitinol wires, which are inserted into the material in a specific pattern. Because metallic filaments are much stiffer than textile yarns, they cannot be used in a conventional knitting process. Machinery is required to operate the loom due to the metal wires. *instantshoe.com.*

3D PRINTING PUTS RUNNERS ON FAST TRACK

No two runners are the same, and this is especially true for athletes competing at the highest levels. Their foot-strike patterns, degrees of pronation, and braking and propulsion forces are all unique. However, the extent to which most running shoe models vary is limited. As a result, there are some who believe that personalizing a runner's shoes, specifically the spike plate that provides traction on the shoe's underside, can help these athletes become faster on the track.

One proponent of this trend is New Balance Athletic Shoe Inc.,

InstantShoe combines Nitinol and leather to find the perfect fit. Courtesy of Biomechanics Institute of Valencia.

Boston. The company is using design-driven manufacturing to 3D print custom spike plates, based on an individual runner's biomechanics. Using a proprietary process to collect race simulation data from Team New Balance runners, the company's research lab applies advanced algorithms to translate this information into an optimized design that can be additively manufactured on an EOSINT P 395 system. This plastic laser-sintering technology from EOS of North America Inc., Novi, Mich., allows designers to produce complex geometries that cannot be created using traditional manufacturing techniques.

Long before the spike plates are additively manufactured, or even designed, the lab collects each runner's biomechanical data using a force plate, in-shoe sensors, and a motion-capture system. The motion-capture system helps determine the relationship of the foot to the force plate, creating a 3D vector recreation of the foot strike. The in-shoe sensors show discrete pressure information over the course of the runner's foot strike and how the runner's foot interacts with the shoe. When a particular part of the foot exhibits high pressure values, it generally indicates that the associated 3D vector is important to that area of the shoe at a specific moment.

"A simple example is in the toe area. Generally, when you see high pressure there, it corresponds to a force that is pushing toward the heel to create a propulsive force forward. We use parametric modeling software to process this data and distribute the position of the spike plate traction elements, calculate the orientation and adjust the size of the elements, and incorporate specific runner preferences into the design," says Sean Murphy, senior manager of innovation and engineering.

The designer is then responsible for performing the CAD cleanup necessary to create the final product, including touching up model surfaces and making adjustments to accommodate the full-size range of the spike plate. Once the final geometry has been verified, CAD files are converted to .stl files and uploaded to the EOSINT system for production. With traditional manufacturing, each spike-plate style requires several injection molds for various sizes, each costing thousands of dollars. These molds run thousands of plates before being retired or replaced, often annually, by a new mold indicating a new model. Currently, the laser-sintered batch sizes produce around four unique plate pairs and take five to six hours to manufacture.

While traditional track spikes are commonly made of thermoplastic polyurethane and polyether block amide, New Balance worked with high-performance materials manufacturer Advanced Laser Materials, Temple, Texas, part of the EOS family, to develop a proprietary nylon blend. Spike plates are grown in the EOS system from the custom-blend nylon powder, coupled with tailored laser conditions, and yield maximum engineering properties such as tensile and flex moduli while minimizing build time.

New Balance uses design-driven manufacturing for 3D printing of custom spike plates for elite athletes, based on an individual runner's biomechanics.

Runner-specific spike plates are currently only available for Team New Balance athletes, but this will eventually change. "Design-driven additive manufacturing holds promise for more on-demand production and more customized design," says Katherine Petrecca, business manager. "These spike plates are the first step we've taken with our athletes to prove that out. As material options and our proficiency with the technology expands, and as capacities for additive manufacturing grow, we believe we will be able to bring 3D-printed products, in some format, to the everyday consumer." *newbalance.com.*

HUT, HUT, HIKE A 3D-PRINTED FOOTBALL

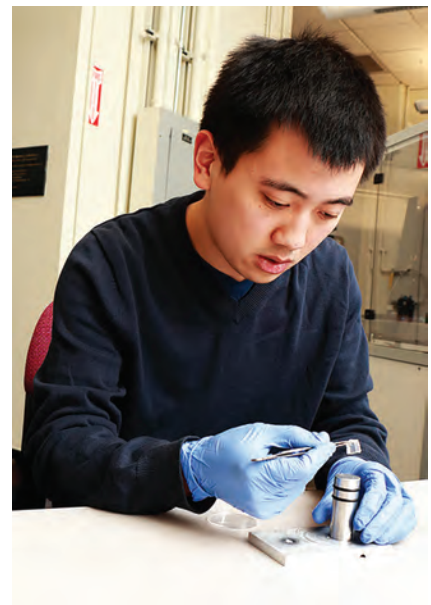
Before the North Carolina State University home football game last April in Raleigh, engineers at the Edward P. Fitts Department of Industrial and Systems Engineering (ISE) presented NC State Chancellor Randy Woodson with a 3D-printed titanium football replica. The full-size football, bearing the NC State logo, was created in ISE's Center for Additive Manufacturing and Logistics by Professor Tim Horn. It is made of medical-grade titanium and took 24 hours to produce. The titanium football is now displayed in Chancellor Woodson's office alongside three real footballs presented to him by Wolfpack head coach Dave Doeren and former coach Tom O'Brien commemorating gridiron victories over rival UNC-Chapel Hill. *camal.ncsu.edu.*

Titanium football replica produced via 3D printing. Courtesy of NC State.

MIMICKING NATURE TO PROTECT THE BRAIN

Designing gear to better protect against severe impacts requires a detailed understanding of how soft tissues in the body respond to such impacts, whether from concussions, ballistic attacks, or blast wounds. Massachusetts Institute of Technology, Cambridge, researchers are developing new synthetic polymer-solvent gels, called tissue simulant gels, which mimic the response of natural tissue.

Biological engineering graduate student Bo Qing is studying the impact of traumatic force on brain tissue from rodents and modeling synthetic substitutes to enable better insight into preventing such injuries. "If we can design a material that mimics this impact response, it would be very helpful to serve as an injury model to assess new protective equipment that can minimize this harm," says Qing.

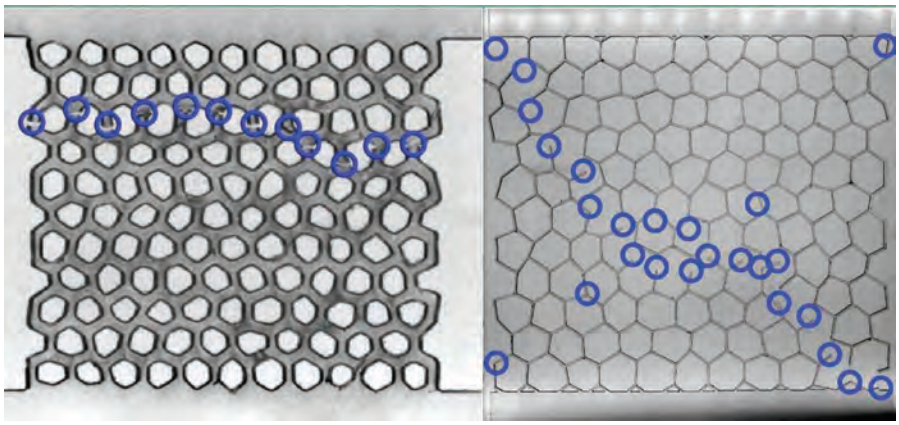


Bo Qing loads a polydimethylsiloxane gel onto a post used in a nanoindenter to measure the gel's impact response. Courtesy of Denis Paiste.

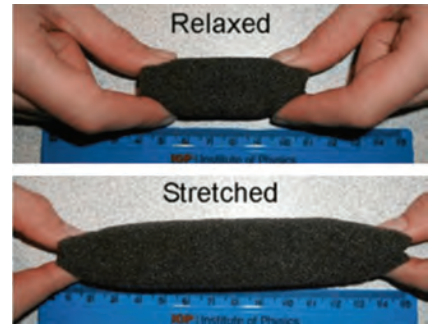
He is studying multilayered polydimethylsiloxane-based (PDMS) gels, which are stretchy and transparent, as models for brain tissue. The group previously identified specific cross-linked PDMS gel compositions that closely matched the impact response of heart tissue. "These are, essentially, a PDMS chemically cross-linked network that's loaded with a PDMS solvent. There are a lot of different variations of these gels where we can basically tune the cross-linker-to-polymer-base stoichiometric ratio, the molecular weight of the PDMS solvent, and the amount of solvent that's used for these different type of gels," explains Qing. *For more information: Krystyn Van Vliet, 617.253.3315, krystyn@mit.edu, www.web.mit.edu.*

HEAD HEALTH CHALLENGE BATTLES BRAIN INJURIES

In January, the NFL, GE, and Under Armour joined with the National



By fine-tuning the thickness of the connecting spokes in a sheet of acrylic, scientists change how it transmits force when fractured. With thick spokes (left), fractures propagate in a straight line and concentrate the impact. Thin spokes (right) divert the fracture across the sheet, diffusing the impact. Courtesy of Center for Hierarchical Materials Design.



Auxetic foams covered by a rigid outer shell display an average of six times the reduction in peak acceleration under the impact typical of many sporting applications. Courtesy of Andy Alderson.

Institute of Standards and Technology (NIST) to launch Head Health Challenge III, an open innovation competition to advance materials that better absorb or dissipate energy. Winners will be announced in September. It is hoped that these new materials will improve performance of protective equipment for athletes, military personnel, and those in dangerous occupations.

The challenge, which will award up to $2 million for innovative materials, is part of the $60 million Head Health Initiative, a multiyear collaboration between GE and the NFL. Launched in March 2013, the initiative includes a four-year, $40 million research and development program from GE and the NFL to develop next generation imaging technologies to improve diagnosis of mild traumatic brain injury. The initiative also includes $20 million open innovation challenges to address better ways to improve diagnosis, prognosis, and protection from brain injury.

Head Health Challenge III aims to support the discovery, design, and deployment of advanced materials that can protect people from brain injuries by better absorbing and mitigating force. Additionally, NIST will work to refine measurement approaches, convene the research and industry communities to assess the state of performance testing for impact energy absorbing/dispersing materials, and identify gaps in these measurements. The ultimate goal will be to develop standard testing methods for these materials systems over the next several years.

Entries will be judged by leading experts in the field of materials science who will select six winners to receive a $250,000 award each to advance their work in developing technologies that can help prevent mild traumatic brain injury. The judging panel includes three longstanding ASM members, Alton Romig, FASM, Tresa Pollock, FASM, and Alan Taub. One overall winner will be selected from the six and will receive an additional $500,000 to further develop their innovation. Previously, Head Health Challenge I focused on discovering imaging and algorithms that will be able to better detect and analyze subtle changes in the brain. Challenge II focused on new materials and technologies that can protect the brain from traumatic brain injury and new tools for tracking head impacts in real time. *headhealthchallenge.com.*

SHE(FFIELD) SELLS SEASHELLS BY THE SEASHORE, FOR SPORTS SAFETY

The Australian Cricket Board inquiry into the 2014 death of cricketer Phillip Hughes, two days after he was struck on the neck where his helmet offered no protection, could result in newly-designed safety helmets being made mandatory. Sheffield Hallam University, UK, is working to develop improved materials for impact protection in sports. The materials have the fascinating and unusual auxetic property that can be used in helmets, pads, guards, gloves, mats, and barriers. Instead of becoming thinner when stretched, an auxetic material actually gets fatter. When compressed, the material becomes thinner. At first glance this fascinating property of auxetic materials may appear highly unusual, but is actually being discovered to be a key feature of a growing number of natural materials. Examples include certain forms of skin and other soft biomaterials, and inorganic silicates such as quartz and cristobalite.

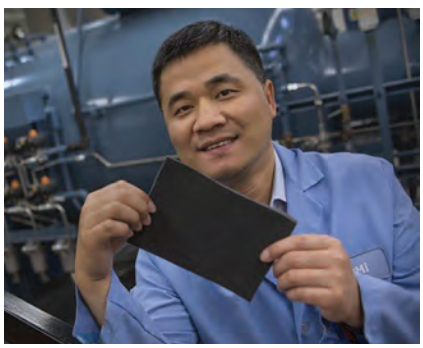
Inspiration for the current work on auxetic materials comes from the ultimate natural armor protection system—seashells. The inner layer of the two-tier armor protection system found in seashells—nacre, also known as mother of pearl—provides high stiffness, strength, and toughness. This exceptional combination of properties enables the seashell to avoid catastrophic failure and maintains shell integrity in the event that the hard and brittle outer layer becomes cracked. Nacre is also an auxetic material.

Unlike conventional materials that adopt a saddle shape when bent out of plane, an auxetic material naturally adopts a convex dome curvature similar to the overall shape of the seashell. This characteristic dome-like double curvature for auxetic materials is ideal for sports protective equipment such as helmets and shoulder or elbow pads to ensure a close fit of the equipment to the body for maximum comfort and performance. *www.shu.ac.uk.*

AWESOME AUXETIC FOAM BOOSTS COMFORT OF ATHLETIC GEAR

Whether it's in a football helmet, hospital bed, knee pad, or body armor, foam plays a critical role in making products both comfortable and safe. But can that foam be transformed into something significantly better, safer, and *more* comfortable? Changchun "Chad" Zeng with Florida State University's High Performance Materials Institute, Tallahassee, says yes, and his brand new, high-performing auxetic foam is proving the point as it heads to the marketplace through a license agreement with Auxadyne LLC.

"We know what is not working with current products and technology, and what it is going to take to make it better," says Zeng. "For example, the socks that amputees currently use to attach prosthetic devices do not adjust to limb shape and volume, creating problems. My invention solves those issues."



Chad Zeng developed a unique foam that can be used to make better football helmets and more comfortable prosthetics. Courtesy of Florida State University.

Part of what makes Zeng's auxetic foam truly unique is its ability to get thicker, rather than thinner, when stretched. In practical terms, this counterintuitive behavior—totally opposite that of conventional foam—leads to many enhanced materials properties including a better and more comfortable fit that adjusts on the fly. The sports equipment industry in particular could take advantage of the new foam technology to improve impact absorption and overall comfort of various protective gear that athletes must wear, says Zeng. *For more information: Changchun Zeng, 850.410.6273, zeng@eng.fsu.edu, www.fsu.edu.*

COMPOSITES SOFTWARE SUPPORTS SMOOTH SAILING

Artemis Racing, Alameda, Calif., chose Altair Engineering Inc., Troy, Mich., to serve as a technical supplier in its bid to win the 35th America's Cup in 2017. Areas of focus for this new era of wingsail foiling catamaran design include composites development, aerodynamics simulation, structural optimization, and fluid-structure interaction. Altair OptiStruct composite optimization technology helps companies efficiently design composite structures and has been used for more than 20 years in multiple industries.

The foils and rigid wings greatly improve the speed, stability, and maneuverability of racing yachts. Rigid wingsails provide more lift than traditional soft sails as well as a better lift-to-drag ratio. Composite materials are used extensively for yacht construction due to their lightweight properties, stiffness, and strength. America's Cup yachts are built primarily using laminated honeycomb sandwich structures, which are efficient load carriers.

Optimization of hulls, structures, appendages, sail sets, and other elements is performed using specialized design software. In parallel, the team may interact with a virtual product prototype to refine hull shape and overall design proportions to improve performance. This type of analysis can provide a significant competitive advantage. *artemisracing.com, altair.com.*

YACHT RACING TEAM SETS SAIL WITH GRAPHENE NANOPLATELETS

Haydale Ltd., UK, signed a collaborative agreement with Alex Thomson Racing (ATR)—the Hugo Boss sponsored extreme sailing team. Alex Thomson is the youngest yachtsman to ever win a round-the-world race. When he won the Clipper Round the World Race in 1998/99, he set a record he still holds to this day.

Haydale developed a patent-pending, proprietary scalable plasma process to modify the surface of graphene and other nanomaterials. Surfaces are modified through a low-pressure plasma process that treats both mined, organic fine powder, and other synthetically

Accurate prediction of composite behavior is critical when designing a sailboat for elite competition. Courtesy of Artemis Racing.

By incorporating new graphene-enhanced materials in future boat designs, ATR is seeking to keep vessels light to ensure optimum speed without compromising strength. Courtesy of ATR.

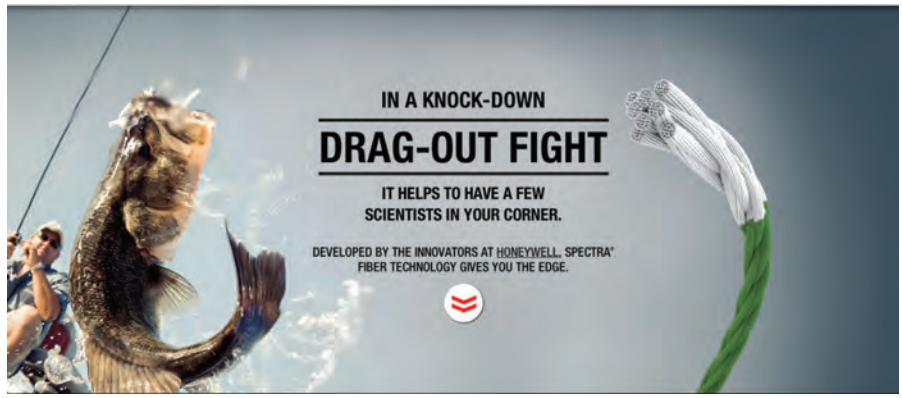
produced nanomaterial powders, producing high quality, few layered graphene and graphene nanoplatelets. The process does not use wet chemistry, nor does it damage the material being processed. Instead, it can clean up any impurities inherent in the raw material. The technology is also energy-efficient and environmentally friendly.

Initial work in the agreement will ascertain weight saving opportunities. In particular, ATR plans to incorporate Haydale's functionalized HDPlas graphene nanoplatelets (GNPs) into both carbon fiber reinforced plastic and epoxy resins. Through its newly acquired subsidiary, EPL Composite Solutions Ltd., Haydale will work with ATR to use graphene-enhanced materials to improve overall strength and stiffness of a number of key structures within the ATR boat. *alexthomsonracing.com, haydale.com.*

SUPER-STRONG FISHING LINE PROMISES GREATEST CATCH

Honeywell, Morris Township, N.J., launched Spectra HT high tenacity fiber, high-strength Spectra fiber said to be the world's strongest fishing-line material of its size, according to company sources. Shimano, makers of the popular PowerPro brand of fishing-line products, is the first manufacturer to use Spectra HT in its PowerPro Maxcuatro.

Spectra HT is 25% stronger than equivalent-size competitive materials, enabling up to 30% thinner braided fishing lines so anglers can cast more easily, get more line onto reels, or use a lighter reel without sacrificing line strength or length. Fishing lines made with Spectra HT are also abrasion-resistant and less visible under water. Spectra HT is reportedly more than 80% stronger than nylon or fluorocarbon-based fishing line materials. Pound-for-pound, Spectra fiber is 15 times stronger than steel, but is light enough to float, which helps fishing line manufacturers develop stronger, more durable, and more sensitive braided fishing lines so anglers can cast more easily and hold onto prize catches. *honeywell-spectra.com.* **~AM&P**



Spectra fiber is highly resistant to chemicals and ultraviolet light, and is made from ultra-high-molecular-weight polyethylene using a gel-spinning process.

METALLURGY LANE

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

STEEL MINIMILLS: PART II

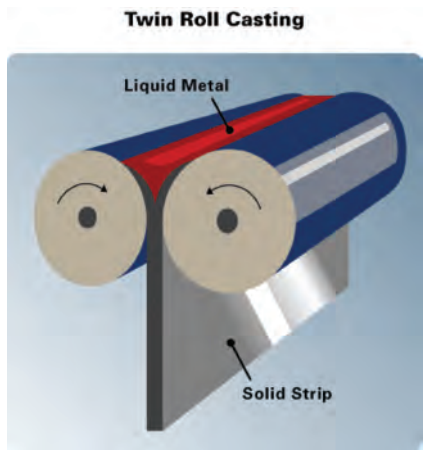
FROM 1988 TO 2008, THE MINIMILL INDUSTRY ADDED 25 MILLION TONS ANNUAL CAPACITY–25% OF THE TOTAL U.S. STEEL MARKET.

During the 20 years between 1988 and 2008, the minimill industry added 25 million tons annual capacity. Competition for raw materials and markets eventually led to industry consolidation that resulted in just three major domestic minimill producers.

INDUSTRY GROWTH

Nucor named Daniel DiMicco as its new CEO in 2000, a role he took on after working in several company positions since 1982. DiMicco continued the momentum that had been established by F. Kenneth Iverson. Nucor built a new continuous casting machine at their Crawfordsville, Ind., plant to produce what they call *Castrip.* Molten metal enters between two counter-rotating rolls where it solidifies into a thin sheet. This sheet can be hot rolled with fewer passes than a long stand of rolls, saving on energy, space, and time to produce a finished product. The Castrip concept was adopted at the Nucor plant to manufacture wide-flanged structural beams and railroad rails. The continuous casting machines were rebuilt to cast a beam or rail near finished size. This new shape, called *near-net shape,* could then be rolled to finished size without the long train of rolls. The entire minimill industry had to follow Nucor's lead in this new technology to be competitive, and the large integrated steel mills were faced with yet another problem in maintaining sales in their best markets.

By 1977, North Star Steel Co. had become the second largest minimill producer in the U.S. The company moved beyond St. Paul, Minn., buying a mill in Wilton, Iowa, that went onstream in 1974 with a capacity of 150,000 tons per year and building a minimill in 1977 in Duluth, Minn., to make parts for grinding mills at iron mines. In 1980, North Star built a minimill in Monroe, Mich., to manufacture higher quality steel bars for the automotive industry. The company purchased a mill in Beaumont, Texas, in 1983 with a 500,000 ton capacity to make rod and wire products, and bought a minimill from Hunt Steel Co. in Youngstown, Ohio, in 1985. North Star increased capacity of the original St. Paul plant to 650,000 tons in 1993. In 1996, the company built a minimill in Kingman, Ariz., with 500,000 tons of capacity to make rod and wire for the West Coast market. North Star entered the flat products market in 1996 by partnering with BHP Steel, an Australian company. This plant, located in Northwest Ohio, had capacity of 1.5 million tons per year. North Star now had an annual steel capacity of 5 million tons per year.



Twin roll casting uses two copper water-cooled, counter-rotating rolls. The Castrip process produces a thin strip that requires minimal rolling to achieve finished size. Courtesy of castrip.com.

Nucor's Castrip line in Arkansas. Courtesy of castrip.com.

In 1993, several executives at Nucor left the company to start their own minimill company, Steel Dynamics Inc. (SDI). Headquartered in Fort Wayne, Ind., the company built its first minimill in Butler, Ind., to produce flat products, coming onstream in 1996. SDI entered the wide flange and railroad rail markets with a minimill in Columbia City, Ind., at a cost of $315 million. Welding facilities were installed at this plant to join rail steel into lengths up to 1600 feet—a major advantage over the other rail mills.

MINIMILL CONSOLIDATION

After 2000, a few corporations began to grow by acquisitions. Many privately held mills could not compete for recycled steel and for markets where they were still producing only small bars and shapes. This trend was led by Nucor when they purchased Birmingham Steel in 2002, acquiring minimills in Alabama, Mississippi, Illinois, and Washington. Nucor then purchased the Kingman, Ariz., rod and wire mill from North Star in 2004. Later, the company acquired Harris Steel in Canada for $1 billion and David J. Joseph, a major recycler of feedstock for minimills, for $1.4 billion. It was now vital for bigger minimill companies to enter the recycling industry to ensure scrap supply. Nucor bought a cold rolling plant located in Sparrow's Point, Md., which was part of the now bankrupt Bethlehem Steel Co. The company's latest acquisition is the Gallatin Steel minimill located in Kentucky, bought for $770 million. Nucor's production capacity now reached 28 million tons per year, slightly exceeding that of U.S. Steel. They are not only the biggest minimill at 50% of the market, but the largest steel company with 25% of all steelmaking in the U.S.

In 1999, a new company came on the scene and began buying minimills—Gerdau, a name unfamiliar to the American public. Gerdau is from Brazil and has holdings of both minimills and integrated mills in South America, Central America, and Mexico. Its first purchase was Florida Steel, a minimill making concrete reinforcing rods with four plants in Florida, Tennessee, and North Carolina. Gerdau then bought four mills from North Star in 2004. Over the next decade, the company acquired 10 more minimills for a total of 18 in 12 states and Canada. Most of these were older ones that produce bars and shapes. Gerdau's most important acquisition was Chaparral Steel Co., the minimill built by Gerald Heffernan. Chaparral enabled Gerdau to enter the wide-flanged beam and rail markets. Without building a single facility, Gerdau became the third largest minimill producer in the U.S. In addition, with its global holdings, Gerdau now approaches Nucor in production capacity and sales.

The ability to make large flanged beams was a new market for the minimills. Courtesy of steeldynamics.com.

Steel Dynamics bought Roanoke Electric Steel Corp. in 2006, its first acquisition, which included Steel of West Virginia. The company also bought into the manufactured beam market, acquiring New Millennium Building Systems. SDI's strategy followed that of Nucor—having an in-house market for long products. SDI made its biggest acquisition in 2014 when it purchased all the assets of a large sheet product mill in Columbus, Miss., for $1.63 billion. This minimill was built in 2007 by Severstal, a Russian company, and featured the latest technology and capacity of 3.3 tons per year. SDI's production capacity in sheet, structural beams, rail, and long products is now 11 million ton per year, making it the second largest minimill company in the U.S. This was accomplished just 18 years since the opening of its first minimill.

North Star, the original leader with the first U.S. minimill, was still second in production in 1997 with capacity of 5 million tons per year. The company upgraded its mills, added new ones, and entered the flat steel product markets. During the early 2000s, Cargill (owner of North Star) decided to leave the steel industry except for the flat product mill in Ohio they owned jointly with Bluestone (formerly BHP) of Australia. North Star sold its newest mill in Kingman, Ariz., to Nucor and four of its other mills to Gerdau. North Star is now a minor player in the minimill industry.

NEW PROCESSES FOR MAKING IRON

Availability of recycled steel for the minimills was a critical problem due to rapid industry growth after 1995. The price for high-grade scrap had increased from $30 per ton in 1970 to $125 in 1995, reaching $150 by 2005. Big producers, especially Nucor and Steel Dynamics, responded by buying national recycling companies to ensure supply, but they had no control over price, which was set by the global market. Next, iron units were sought for electric arc furnaces, to use new processes that convert iron ore by direct reduction, i.e., removing oxygen without adding carbon. Other elements in the ore are then eliminated by using slags. Steel Dynamics installed a plant to make iron as a feedstock in its Butler, Ind., plant. The latest development is a direct reduction plant in Louisiana, built by Nucor. The company plans to build a second plant in the near future and eventually add a blast furnace, coke ovens, and a basic oxygen converter to make steel. If these plans materialize, Nucor will move closer to the integrated mills of its competitors.

REVOLUTION IN STEELMAKING

The introduction of flat products, flanged beams, and railroad rails along with consolidation of the industry into large corporations completed a revolution in steelmaking in the U.S., albeit a quiet one that occurred in small towns and rural areas out of sight of the general public. There is no Pittsburgh of minimills, and this revolution came at the expense of the large integrated steel mills—as most disappeared with their best assets bought by U.S. Steel or ArcelorMittal.

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

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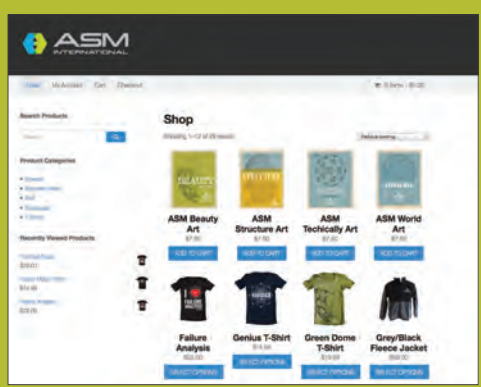

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iTSSe

INTERNATIONAL THERMAL SPRAY & SURFACE ENGINEERING

THE OFFICIAL NEWSLETTER OF THE ASM THERMAL SPRAY SOCIETY

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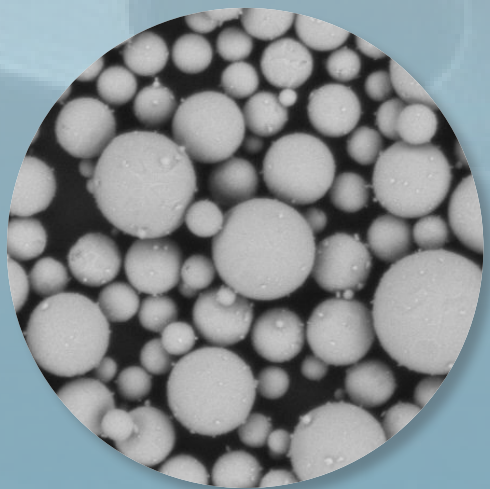

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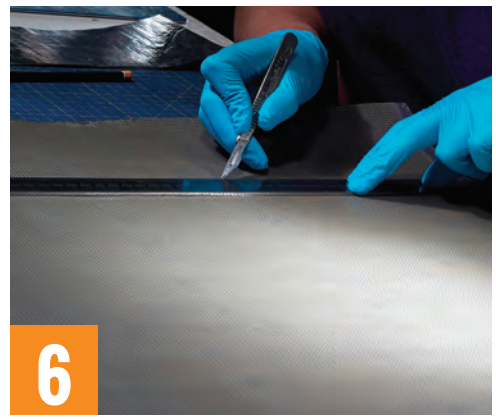

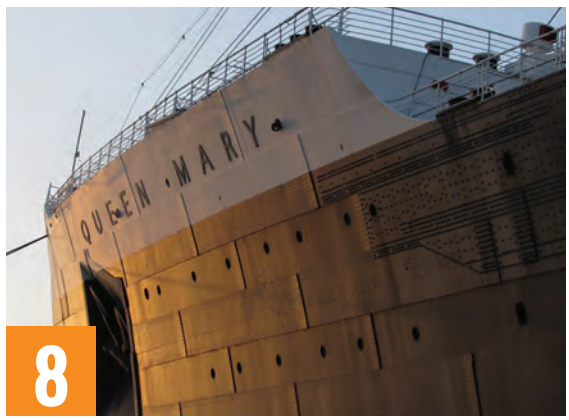

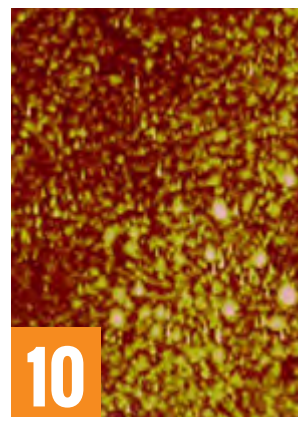

DEPARTMENTS

ABOUT THE COVER

JMW Motorsports uses the ZircoFlex heat shield on its Ferrari 458. The heat shield features ceramic platelets applied via plasma spray onto a metal substrate to add additional temperature resistance to standard pressed aluminum versions found on today's automobiles. *zircotec.com.*

EDITORIAL OPPORTUNITIES FOR *iTSSe* IN 2015

The editorial focus for *iTSSe* in 2015 reflects established applications of thermal spray technology such as power generation and transportation, as well as new applications representing the latest opportunities for coatings and surface engineering.

November Issue:
Emerging Technologies/Applications & Case Studies

To contribute an article, contact Julie Lucko at julie.lucko@asminternational.org.

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

THERMAL SPRAY HOLDS POTENTIAL FOR AUTOMOTIVE INDUSTRY

Bamola

Welcome to the summer edition of *iTSSe,* which focuses on automotive and industrial applications for thermal spray and surface engineering. For interest's sake, I have taken some liberties in extending the automotive industry to include vehicles used in construction and military operations.

Thermal spray is a mainstay in the traditional automotive industry, providing coatings to combat wear on piston rings, shifter forks, synchronizer rings, and more recently, integrally sprayed engine block piston bores. In addition, the racing arena has used titanium valves with plasma sprayed stems and HVOF-coated tips for many years and ceramic-coated piston domes have been used in both four and two-wheel racers as well as in speed boat racing. In the aftermarket, thermal spray continues to be used for repair of crankshafts and transmission parts. Military depots also use thermal spray to restore components in light armored vehicles, tanks, and Coast Guard vehicles as a cost-effective and time-saving alternative to obtaining OEM parts.

A growing offshoot of traditional automotive applications is chrome replacement in actuators and rams of earthmoving vehicles. Here, HVOF tungsten carbide has been shown to outperform hard chrome by a factor of four without incurring an environmental penalty as in chrome bath plating.

This issue features articles from Zircotec, a provider of custom ceramic coatings for heat retention in motorsport and other applications, and a summary of the International Thermal Spray Conference and Exhibition, which took place in May in Long Beach, Calif.

Don't forget that the call for papers for ITSC 2016 is now open until September 25. Submit your abstract soon to be part of this outstanding thermal spray event taking place next year in Shanghai. Visit www.dvs-ev.de/itsc2016 for submission details.

Rajan Bamola
iTSSe co-editor
Surface Modification Systems Inc.

SEEKING NOMINATIONS FOR THERMAL SPRAY HALL OF FAME

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

JOURNAL OF THERMAL SPRAY TECHNOLOGY VOLUME 23 BEST PAPER AWARDS

The *Journal of Thermal Spray Technology* (*JTST*) presented the *JTST* Volume 23 Best Paper Awards, chosen by an international committee of expert judges, at the International Thermal Spray Conference & Exposition 2015, in Long Beach, Calif.

Journal of Thermal Spray Technology Editor-in-Chief Christian Moreau (right) presents the JTST Volume 23 Best Paper Award to (from left) Chen Jiang and Eric H. Jordan.

Each paper is reviewed and evaluated on its merits for scientific and engineering content, originality, and presentation style. The JTST Editorial Board and the ASM Thermal Spray Society Executive Board of Directors extend their congratulations to the winning authors listed below.

***The Journal of Thermal Spray Technology* Volume 23 Best Paper Award:**

"Low Thermal Conductivity Yttria-Stabilized Zirconia Thermal Barrier Coatings Using the Solution Precursor Plasma Spray Process" by Eric H. Jordan, Chen Jiang, Jeffrey Roth, and Maurice Gell.

***The Journal of Thermal Spray Technology* Volume 23 Best Paper Honorable Mention (tie):**

"Improved Thermal Cycling Durability of Thermal Barrier Coatings Manufactured by PS-PVD" by Stefan Rezanka, Georg Mauer, and Robert Vassen.

"Formation Mechanisms, Structure, and Properties of HVOF-Sprayed WC-CoCr Coatings: An Approach Toward Process Maps" by Tommi Varis, Tomi Suhonen, Arash Ghabchi, Alfredo Valarezo, Sanjay Sampath, Xuwen Liu, and Simo-Pekka Hannula.

TSS SAFETY SURVEY

The Safety Committee's mission is to make thermal spray environmental, health, and safety (EH&S) information available to the thermal spray community to both collaborate with other professional organizations in the development and deployment of thermal spray EH&S information, and to establish guidelines for the safe installation, operation, and maintenance of thermal spray equipment.

This committee strives to meet the needs of the Society and would like to expand its offering of current information related to matters of EH&S interests within the industry. Please help by taking a short survey at surveymonkey.com/s/TSSSafety.

The *JTST* Volume 23 Best Paper Award Honorable Mention was presented by Christian Moreau to (from left) Robert Vassen and Georg Mauer.

The *JTST* Volume 23 Best Paper Award Honorable Mention was presented by Christian Moreau to (from left) Sanjay Sampath, Arash Ghabchi, Tomi Suhonen, and Alfredo Valarezo.

ITSC 2016

May 10-12 • Shanghai

The International Thermal Spray Conference and Exhibition is an opportunity for the global thermal spray community to meet, exchange information, and conduct business. This annual event is jointly organized by the German Welding Society, ASM International's Thermal Spray Society, and the International Institute of Welding.

Call for Papers

Interested authors must submit abstracts by September 25. Topics include applications, properties, equipment/consumables, thermal spray processes, economic and other business issues, and a special track for young professionals. To view the full list of topics and submit an abstract, visit www.dvs-ev.de/call4papers/index.cfm?vid=81&id=4.

Exhibit

Exhibitors at ITSC have a chance to meet a global audience and display solutions and cost-saving opportunities. Visit asminternational.org/web/itsc-2016-expo to learn more. To reserve exhibit space, contact Kelly Thomas at 440.338.1733 or kelly.thomas@asminternational.org.

THERMAL SPRAY OF SUSPENSIONS & SOLUTIONS SYMPOSIUM (TS4)

December 2-3 • Montreal

TS4 gives scientists and engineers interested in emerging S&S thermal spray technologies a chance to address both research challenges and development of industrial applications. The conference features a balanced group of speakers from industry, academia, and national laboratories. The show is geared towards participants looking for innovative solutions to improve coating performance in the aerospace, energy generation (gas turbine and fuel cells), and transportation industries. For more information, visit asminternational.org/suspension-2015.

INTRODUCTION TO THERMAL SPRAY

September 21-22 • Materials Park, Ohio
Instructor: Richard A. Sayman

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

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 also are covered. A greatly expanded selection of applications includes examples and figures from various industries, including electronics and semiconductors, automotive, energy, and biomedical. Emergent 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 also are reviewed. Visit asminternational.org to learn more.

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PLASMA-SPRAYED HEAT SHIELDS OFFER THERMAL MANAGEMENT OPTIONS

Heat shields help protect vehicle-critical components that could delaminate and fail if exposed to high temperatures for any length of time.

Thermal management problems in vehicles are often difficult to address, leading to a wide array of problem-solving products, from muffler wraps to composite coatings. One strategy is to use heat shields. Their purpose is simple—to shield sensitive components from heat emitted from engines and manifolds. This can be achieved either by insulating hot components to prevent heat from spreading under the hood or by reflecting it away from vulnerable areas.

Heat shields range from thermal wraps to purpose-built shields molded to suit specific components. Many heat shields are constructed from steel or aluminum. Some feature fiberglass between two metal layers, while others are constructed of lightweight materials such as carbon composites.

Regardless of composition, heat shielding can be used in a variety of thermal management applications. Critical components such as batteries can be protected from damaging heat that may be radiated from a high-performance engine. Heat shields can also be used to protect bodywork that may contain materials such as carbon fiber, which could delaminate and fail if exposed to excessive temperatures for any length of time.

HEAT SHIELDS PROTECT DRIVERS AND RACE CAR COMPONENTS

In one approach, Zircotec, UK, is developing a range of heat shields under the ZircoFlex name (Fig. 1). All products in this range feature ceramic platelets applied via plasma spray onto a metal substrate to create a heat shield that adds additional temperature resistance to standard pressed aluminum versions found on today's automobiles.

Ranging from an ultrathin single layer to triple layers—yet still very thin—this range of heat shields offers users many options to suit diverse applications. For example, ZircoFlex I can reduce surface temperatures by 64%, with reductions of 77% and 85% possible with the new double and triple-layered options.

To date, these heat shields are used in a host of automotive applications. Just glance at any F1 starting grid and cars sporting ZircoFlex will be well represented. The heat shield can be fitted quickly and easily, so plenty of F1 and motorsport teams have been known to keep a spare supply to solve thermal management issues that may arise at the track.

OTHER APPLICATIONS FOR HEAT SHIELDS

ZircoFlex heat shields are also popular in the restoration and maintenance of classic automobiles. As modern fuels and engine modifications result in higher combustion temperatures, under-bonnet heat in classic autos tends to be higher than the levels they were originally built to tolerate. Without sufficient thermal protection, radiant heat can cause fuel to evaporate inside the carburetor, as well as damage other sensitive components. According to Zircotec engineers, its heat shields offer a simple solution to reflect heat away from such components so that classic vehicles can remain on the road (Fig. 2).

Further, the ceramic surface can be painted without affecting the insulation properties of the embedded platelets, so heat shields can be used in classic car restoration projects without the need to deviate from period-correct color palettes.

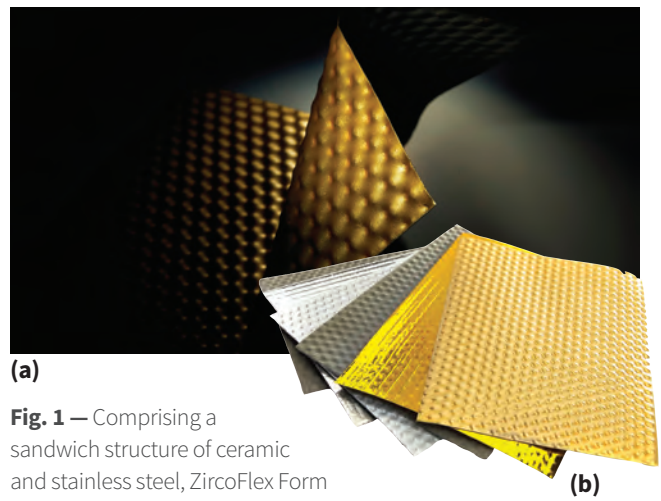


Fig. 1 — Comprising a sandwich structure of ceramic and stainless steel, ZircoFlex Form means engineers can benefit from ceramic coating protection together with the strength and ability to form structures (a). The blend of materials enables Form to protect drivers and componentry from both conductive and reflective heat (b).

Fig. 2 — ZircoFlex can be cut to shape.

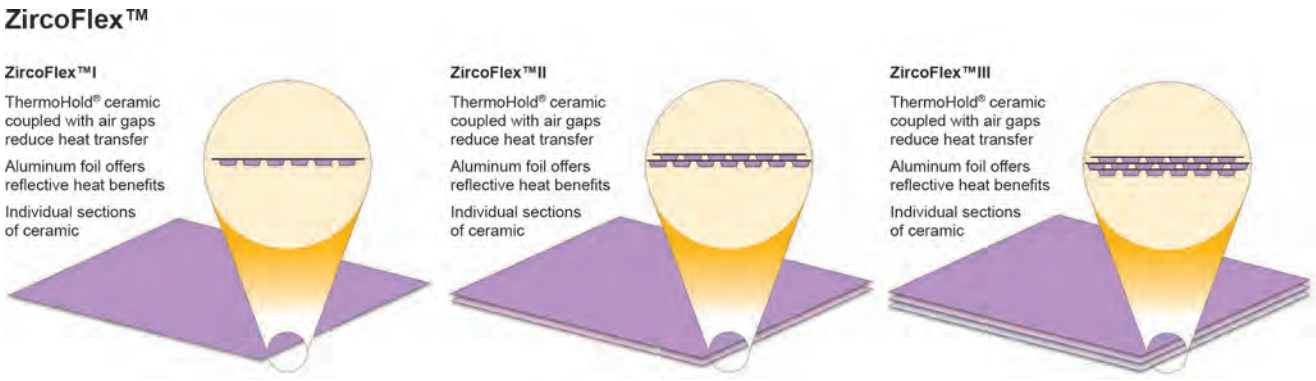


Fig. 3 — A range of ZircoFlex sheets is available with different performance levels.

With the automotive industry downsizing engines and incorporating tighter packaging, comprehensive heat management is becoming a pressing concern for manufacturers and car enthusiasts alike. Flexible heat shields offer another thermal management tool (Fig. 3). **iTSSe**

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

CASE STUDY

ZircoFlex heat shields improve transmission and gear shift reliability along with lowering cockpit temperatures in long distance races. Ferrari race team JMW Motorsport is using these heat shields on the gearbox and bulkhead of the team's Ferrari 458 (Fig. 4) to reflect heat away from the transmission's regulator and control cockpit temperatures (Fig. 5). Situated in a high-temperature environment, the gearbox is often considered the Achilles heel of sports car racing, as it endures under-bonnet heat and strain from drivers making rapid shifts during long stints at race pace. Regulating the transmission's air pressure is crucial to ensuring that optimal gear shifts are sustained throughout long races.

"Maintaining the transmission's air pressure at 10 bar is important," says JMW Motorsport race engineer Davey Nicholas. "If the unit heats up, it can cause the pressure to rise, risking damage to the seals that can affect shifting. With engines and transmissions being the most costly items to service, we want to do all we can to control this."

Driver concentration is also critical to success in endurance racing. Heat can sap energy and erode levels of alertness resulting in miss-shifts or engine damage. To solve such issues, ZircoFlex can be used on bodywork and bulkheads to shield the cabin from engine bay heat. Such thermal management can also bypass the need to use performance-draining air conditioning systems.

Further, the lightweight and easy-to-fit application of the shield combined with the ability to reduce temperatures by 85% enables engineers to delete bulkier heat shields, reducing a car's overall weight.

Nicholas is keen to achieve such weight savings with JMW's 458. "We hope that the effectiveness of ZircoFlex will enable us to remove the bulky glass fiber shield previously fitted—that would reduce weight and improve under-bonnet airflow," he says.

As tight packaging becomes more prevalent in motorsport and automotive manufacturing, ZircoFlex offers engineers the option to place temperature-sensitive components close to heat sources without impinging on performance and reliability. The ability to install the heat shield with high-temperature adhesive or metal fasteners presents both race teams and OEMs with a material that can be applied during manufacturing or at later retrofitting and aftermarket modification stages.

Fig. 4 — JMW Motorsports continues its technical partnership with Zircotec, using the ZircoFlex heat shield on its Ferrari 458.

Fig. 5 — JMW Motorsport is using ZircoFlex heat shields to reflect heat away from the transmission's regulator.

ITSC 2015 HITS A HOME RUN

The 2015 International Thermal Spray Conference joined AeroMat and IMS for the first-ever combined mega-event in Long Beach, Calif. Held May 11-14, the event attracted over 2000 aerospace and thermal spray technologists, researchers, manufacturers, and suppliers from 34 countries. It featured 180 booths on the combined show floor from a mix of 130 companies. The technical program had more than 450 oral and poster presentations, and featured speakers from over 30 countries around the globe.

While each show had separate programming, attendees were free to explore any session as well as the shared show floor, making it a truly unique and cross-functional experience. Robert Vassen presented the ITSC plenary talk on recent advances with thermally sprayed barrier coatings, including the rise in popularity of suspension plasma spray and physical vapor deposition, as well as an intensive study of advanced materials. Below are photos highlighting the event. (The *JTST* Volume 23 Best Paper Awards photos can be found on page 3.)

TSS President Christian Moreau (left) presents the TSS Hall of Fame award to Christian Coddett, of the University of Technology of Belfort-Montbeliard, France. He was recognized for developing innovative thermal spray techniques and applications as well as international collaboration programs dedicated to thermal spray research in developing countries.

Sanjay Sampath (left), TSS Hall of Fame Inductee, is presented his award by President Christian Moreau. Sampath, distinguished professor at Stony Brook University of New York, was recognized for innovative, interdisciplinary thermal spray research bridging the gap between fundamental science and industrial practice through better understanding of coating properties and development of advanced diagnostic tools.

Steve Ort (left), Oerlikon Metco, was on hand for a special event celebrating his company's recent designation as an ASM Historical Landmark. TSS Board members Ann Bolcavage and Doug Puerta unveiled the plaque.

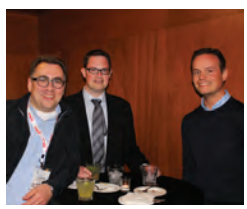
Lech Pawlowski, TSS Hall of Fame Inductee, who could not be there, provided a video of his acceptance speech. Professor at the University of Limoges in France, Pawlowski was cited for sustained and innovative thermal spray research and development and significant contributions to the fundamental and technical advancement of thermal spraying.

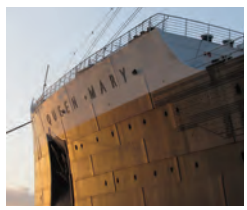
Robert Vassen, professor of mechanical engineering at the Ruhr-University Bochum, Germany, gave the ITSC plenary talk on May 12.

Jens Jerzembeck of the DVS German Welding Society gives opening remarks at the Tuesday plenary and awards ceremony.

Christian Moreau (right), announces Mitchell Dorfman, Metco Fellow at Oerlikon Metco, as the 2015 recipient of the TSS President's Award. The award will be presented to Dorfman in person later this year.

ITSC Best Paper winner, Jocelyn Veilleux, is congratulated by Julio Villafuerte, chair of the ITSC Best Paper competition, for his paper "Lithium Iron Phosphate Coatings Deposited by Means of Inductively-Coupled Thermal Plasma."





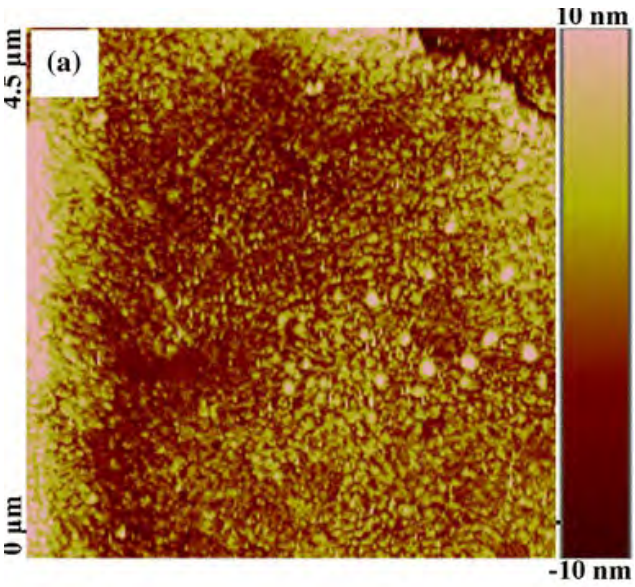
Attendees enjoyed a festive dinner and networking event aboard the historic Queen Mary.

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 June and August issues, as selected by *JTST* Editor-in-Chief Christian Moreau, are highlighted here. In addition to the print publication, *JTST* is available online through springerlink.com. For more information, visit asminternational.org/tss.

"MORPHOLOGY AND SIZE EVOLUTION OF INTERLAMELLAR TWO-DIMENSIONAL PORES IN PLASMA-SPRAYED $LA_2ZR_2O_7$ COATINGS DURING THERMAL EXPOSURE AT 1300°C"

Tao Liu, Xiao-Tao Luo, Xu Chen, Guan-Jun Yang, Cheng-Xin Li, and Chang-Jiu Li

$La_2Zr_2O_7$ (LZO) is expected to be one of the promising thermal barrier coating materials for application in high-temperature conditions (1200°C). However, high-temperature exposure causes sintering, which heals interlamellar 2D pores and intrasplat pores. This sintering increases stiffness and thermal conductivity of thermal barrier coatings, consequently reducing durability. In this study, LZO coating and splat were deposited by atmospheric plasma spraying and were exposed to 1300°C for different durations to find a possible critical opening of 2D pores above which they are free from sintering. The evolution of the parameters of residual 2D pores in the coating and the surface morphology of LZO splat were characterized. There is a critical opening width for 2D pores above which grain bridging does not occur across the gaps. Accordingly, pores with an opening larger than this critical width are free from sintering across the 2D pores despite surface roughening of splats, whereas pores with an opening less than the critical width sinter rapidly at the early stage of thermal exposure through the formation of grain bridges.

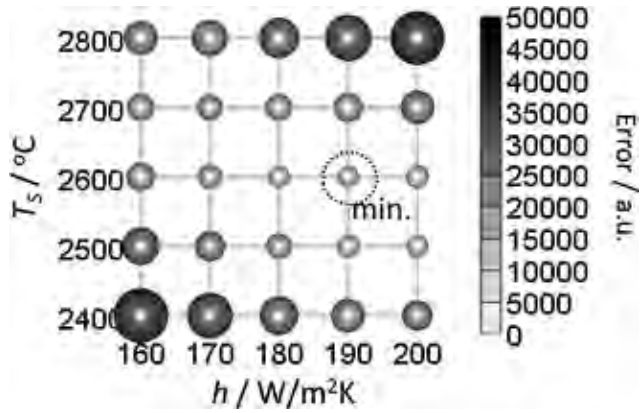


AFM surface morphology of LZO splat as-sprayed.

"A NUMERICAL STUDY ON GENERATION MECHANISM OF VERTICAL CRACKS IN TOP COAT OF TBCs DURING APS DEPOSITION"

K. Ito, H. Kuriki, and M. Enoki

Clarification of crack generation mechanisms in the top coat of the thermal barrier coatings (TBCs) during atmospheric plasma spray is important to improve TBC reliability. Finite element analyses of stress and strain during deposition were conducted with a layer-by-layer method to understand the cracking behaviors. Stress relaxation by generation of vertical cracks was expressed as an elasto-plastic behavior of the coating. The effects of preheating temperature of the substrate and plasma power on crack development were analyzed by changing the initial and atmospheric temperatures in simulation, respectively. Simulation results of radial strain explain experimental results of crack monitoring by non-contact laser acoustic emission.



Temperature error between the experiment and analysis substrate's center.

"DETERMINATION OF THE MECHANICAL PROPERTIES OF PLASMA-SPRAYED HYDROXYAPATITE COATINGS USING THE KNOOP INDENTATION TECHNIQUE"

Md. Fahad Hasan, James Wang, and Christopher Berndt

The microhardness and elastic modulus of plasma-sprayed hydroxyapatite coatings were evaluated using Knoop indentation on the cross-section and top surface.

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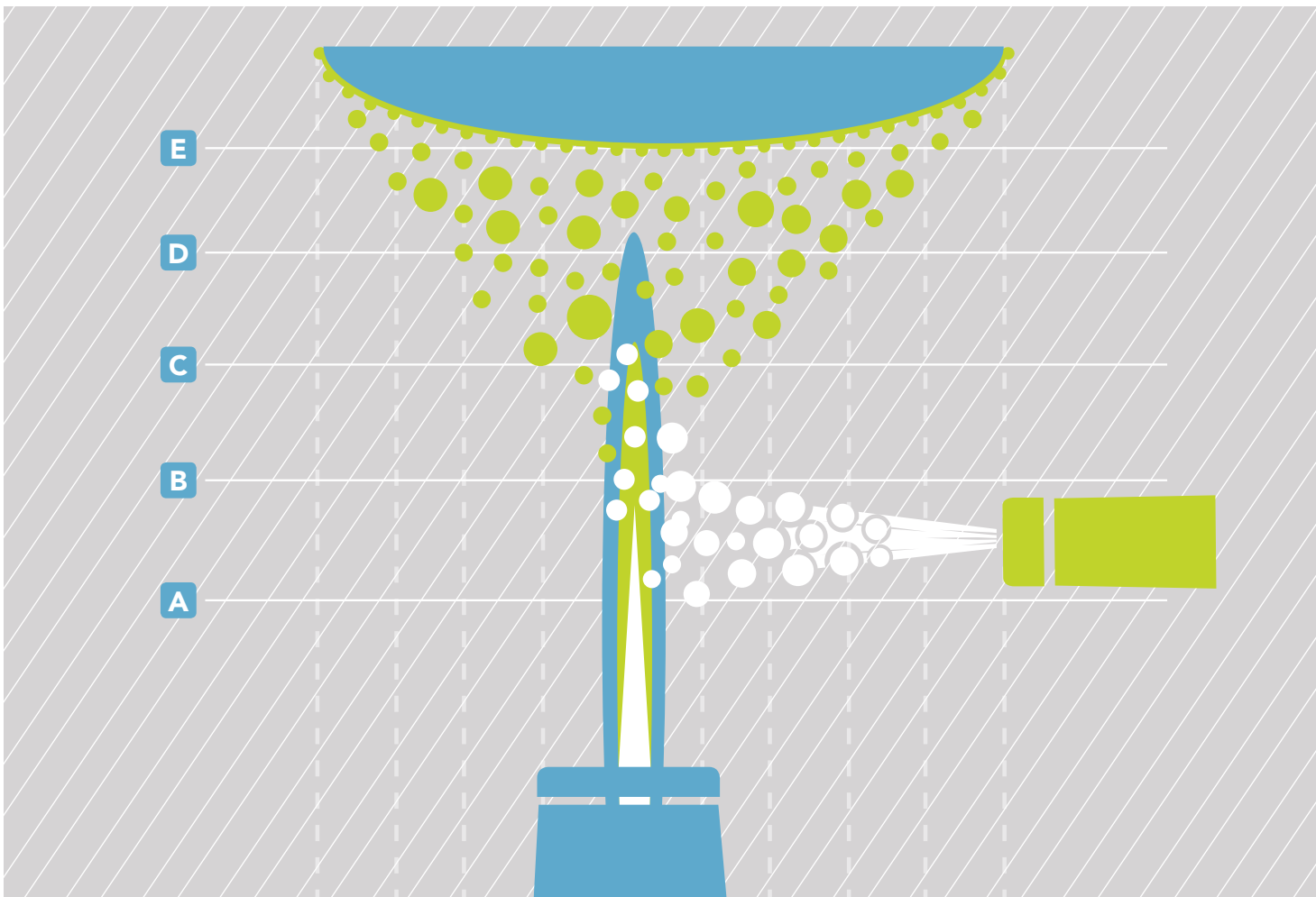

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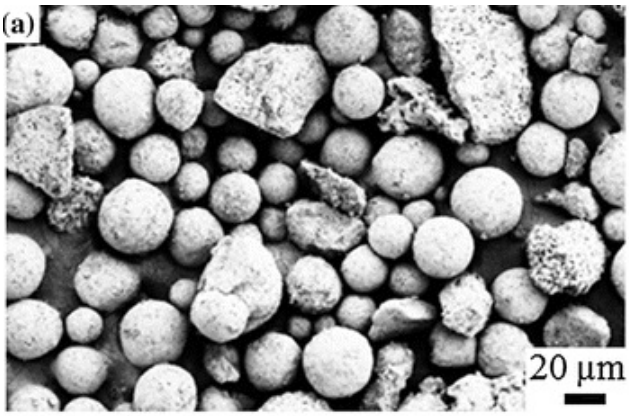
Christian Moreau, Concordia University, Canada
Filofteia-Laura Toma, Fraunhofer Institute for Material and Beam Technology IWS, Germany



Hydroxyapatite powders: Particles image.

Effects of indentation angle, testing direction, measurement location, and applied load on the microhardness and elastic modulus were investigated. The variability and distribution of the microhardness and elastic modulus data were statistically analyzed using the Weibull modulus distribution. Results indicate that the dependence of microhardness and elastic modulus on the indentation angle exhibits a parabolic shape. Dependence of microhardness values on the indentation angle follows Pythagoras's theorem. Microhardness, Weibull modulus of microhardness, and Weibull modulus of elastic modulus reach their maximum at the central position (175 µm) on the coatings' cross-section. The Weibull modulus of microhardness reveals similar values throughout the thickness, and the Weibull modulus of elastic modulus shows higher values on the top surface compared to the cross-section.

"PREPARATION AND ABLATION PROPERTIES OF Y_2SiO_5 COATING FOR SiC COATED C/C COMPOSITES BY SUPERSONIC PLASMA SPRAYING"

Jia-Ping Zhang, Qian-Gang Fu, Lei Zhuang, He-Jun Li, and Can Sun

Y_2SiO_5 coating was prepared on the surface of SiC coated C/C composites by supersonic plasma spray at powers of 35, 40, 45, and 50 kW. The microstructures and phase compositions were characterized by scanning electron microscopy and x-ray diffraction, respectively. Coating roughness was measured by a confocal laser scanning microscope. Bonding force between the Y_2SiO_5 outer coating and SiC inner coating was measured by a scratch tester. Results show that the Y_2SiO_5 coating prepared at spray power of 45 kW possesses the biggest deposition rate, minimum surface roughness (Ra=11.12 µm), and maximum bonding force (up to 28 N). The linear and mass ablation rates of the Y_2SiO_5 coating prepared

Call for Papers

Abstract Deadline: September 25, 2015

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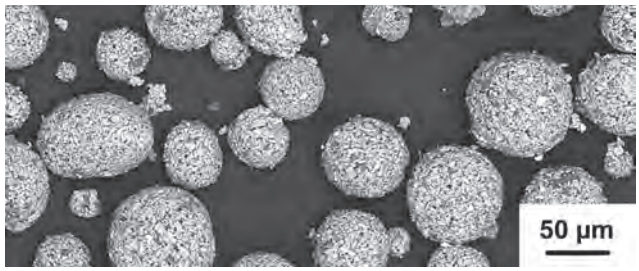


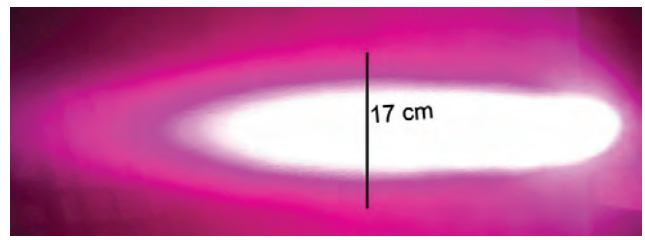
Surface morphology of Y_2SiO_5 powders.

at 45 kW are 2.6 µm/s and 0.031 mg•cm^{-2}•s^{-1} in the heat flux of 2.38 MW/m^2 under oxyacetylene torch. During ablation, a glassy layer of SiO_2+Y_2O_3 was formed, acting as a barrier to high-speed gas flow of oxyacetylene flame.

"CHARACTERIZATION OF PLASMA JET IN PLASMA SPRAY-PHYSICAL VAPOR DEPOSITION OF YSZ USING A <80 KW SHROUDED TORCH BASED ON OPTICAL EMISSION SPECTROSCOPY"

Qing-Yu Chen, Xiao-Zhuang Peng, Guan-Jun Yang, Cheng-Xin Li, Chang-Jiu Li

During plasma spray-physical vapor deposition (PS-PVD) of YSZ coatings, the evaporation of YSZ powder is essential, although difficult to achieve using a commercial <80 kW plasma torch. In this study, a shrouded plasma torch was examined to improve YSZ evaporation. Plasma characteristics were diagnosed using optical emission spectroscopy. Results show that electron number density in the plasma jet was maintained at an order of magnitude of 1014 cm^{-3}, which indicate local thermal equilibrium of the plasma jet. Compared to a conventional torch, the shrouded torch results in a much higher plasma temperature and much lower electron number density. With the shrouded torch, more plasma energy was transferred to YSZ material leading to increased evaporation of YSZ powder and thereby a much higher deposition rate. Results show that using a shrouded torch is a simple and effective approach to improve the evaporation of feedstock material during PS-PVD.



Diameter of plasma jet without powder and shroud. 66 x 31 mm (300 x 300 dpi).

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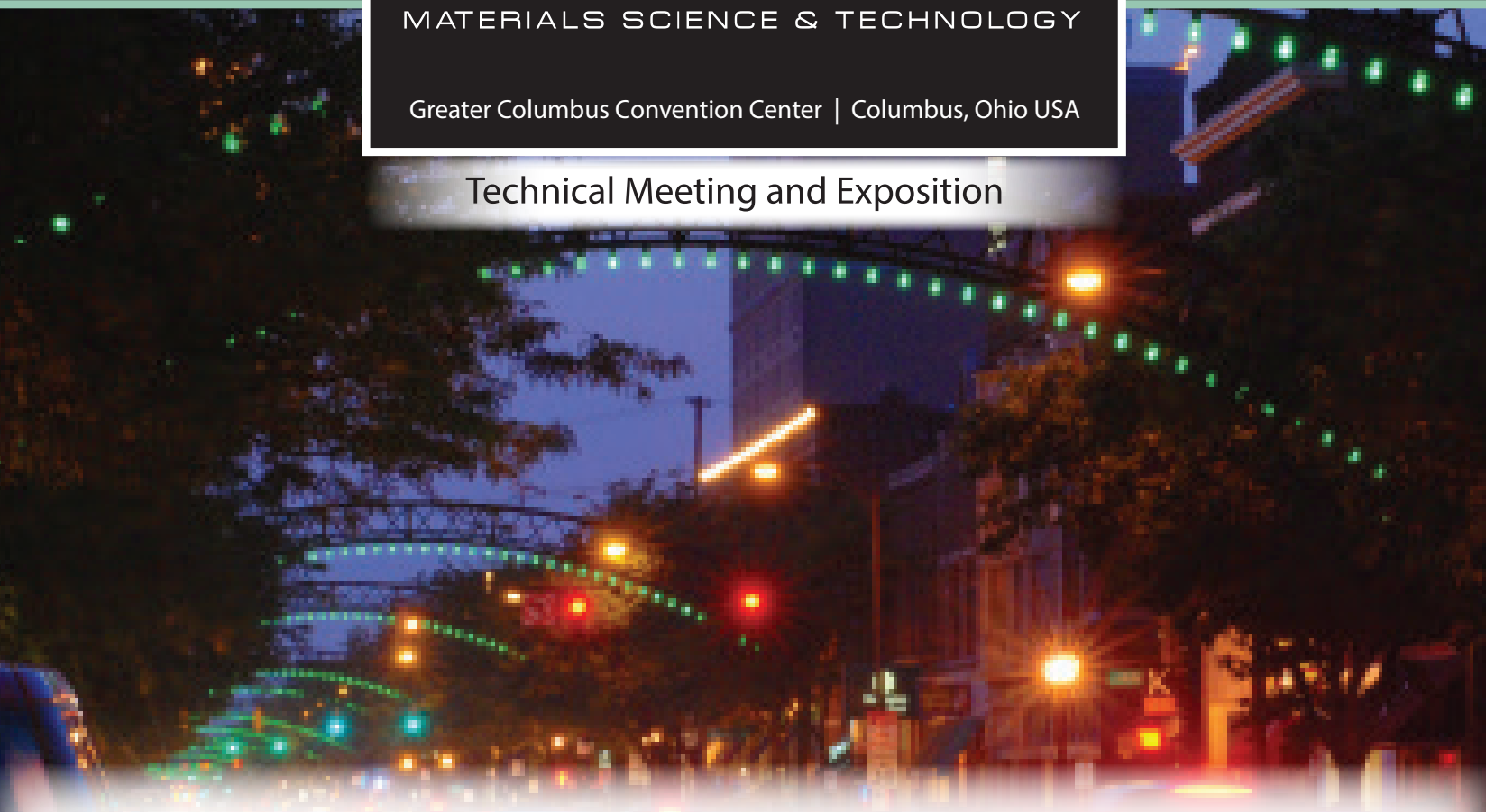

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AIST Association for Iron & Steel Technology

ASM International

TMS The Minerals, Metals & Materials Society

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NACE International The Corrosion Society

ASMNEWS

ASM Names 2015 Award Recipients

The ASM International Board of Trustees has named award recipients for 2015. The awards program recognizes achievements of members of the materials science and engineering community. Awards will be presented at ASM's Awards Dinner, October 6 in Columbus, Ohio, during MS&T15. Tickets for the dinner cost $90 each and can be ordered by using the MS&T registration form. Those interested in purchasing a table may contact Christine Hoover, ASM International, Materials Park, Ohio 44073-0002; 440.338.5151 ext. 5509; fax 440.338.6614; christine.hoover@asminternational.org.

Honorary Membership

Dr. Siegfried Hecker, FASM, research professor, department of management science and engineering, and senior fellow, Center for International Security and Cooperation, Stanford University, will receive this year's award "for scientific enlightenment of plutonium technology, for leadership of Los Alamos National Laboratory, and for leadership in international control of nuclear arms." Honorary Membership in the Society was established in 1919 to recognize distinguished service to the materials science and engineering profession, ASM strategic plan and initiatives, and the progress of mankind.

Distinguished Life Membership

Mr. Robert E. Rumcik, retired, president, Ellwood Quality Steels Co., New Castle, Pa., will receive this year's award "for visionary leadership in pioneering the successful development and commercialization of ladle refining technology in steelmaking and building two companies, Ellwood Quality Steels and Ellwood National Steel, into recognized market leaders."

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

Gold Medal

Dr. James C. M. Li, FASM, A. A. Hopeman Professor of Engineering, University of Rochester, will receive this year's award "for his elucidation of the mechanical properties of materials through the application of thermodynamics and kinetics to the understanding of microstructural phenomena and for his mentoring of students and colleagues." The medal was established in 1943 to recognize outstanding knowledge and great versatility in the application of science to the field of materials science and engineering, as well as exceptional ability in the diagnosis and solution of diversified materials problems.

Medal for the Advancement of Research

Dr. Raymond F. Decker, FASM, chief technical officer and VP of new business development, Thixomat Inc. nano/MAG LLC, Livonia, Mich., is the recipient of this year's

In This Issue

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

Decker

award. He is cited "for executive leadership in industrial, university, government, and technical society advancement of research and for research, invention, and leadership in commercialization of metallurgical technologies for advanced materials and processing." The award was established in 1943 to honor an executive in an organization that produces, fabricates, or uses metals and other materials. The recipient, over a period of years, will have consistently sponsored research or development, and by foresight and actions, will have helped substantially advance the arts and sciences related to materials science and engineering.

Engineering Materials Achievement Award (EMAA)

Paul Jablonski, metallurgist, National Energy Technology Laboratory (NETL); **Paul Turner,** supervisory metallurgist, NETL; and **Jeffrey S. Hansen,** retired, metallurgist, Albany Research Center (NETL), will receive this year's award "for the development, transfer, and successful commercialization of a novel platinum-chromium alloy for use in manufacturing the next generation of coronary stents." Established In 1969, this award recognizes an outstanding achievement in materials or materials systems related to the application of knowledge of materials to an engineering structure or to the design and manufacture of a product.

Albert Sauveur Achievement Award

Prof. Harshad Bhadeshia, Tata Steel professor of metallurgy, department of materials science and engineering, University of Cambridge, UK, will receive this year's award "for seminal contributions to the theory of solid-state phase transformations and computational materials design of high performance steels and high temperature alloys." Established in 1934 in honor of a distinguished teacher, metallographer, and metallurgist, the award recognizes pioneering materials science and engineering achievements that stimulated organized work along similar lines to such an extent that a marked basic advance was made in the knowledge of materials science and engineering.

William Hunt Eisenman Award

Dr. Frederick E. Schmidt, FASM, senior managing consultant and director, materials technology, Engineering Systems Inc., Aurora, Ill., will receive this year's award "for pioneering industrial developments in electronics, polymer, and chemical processing, wear and corrosion problems, and especially the reduction of scrap in small caliber ammunition production." The award was established in 1960, in memory of a founding member of ASM, and its first and only secretary for 40 years. It recognizes unusual achievements in industry in the practical application of materials science and engineering through production or engineering use.

J. Willard Gibbs Phase Equilibria Award

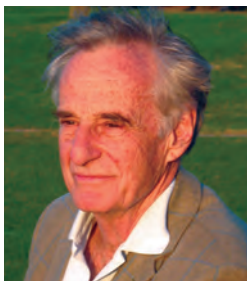
Prof. John G. Speer, FASM, professor, George S. Ansel department of metallurgical and materials engineering, Colorado School of Mines, Golden, will receive this year's award "for innovative applications of fundamental phase transformation principles in ferrous systems, development of the quenching and partitioning process, and contributions to phase equilibria education." The award was established in 2007 to recognize outstanding contributions to the field of phase equilibria. The award honors J. Willard Gibbs, one of America's greatest theoretical scientists. In addition to many other contributions, Gibbs laid the thermodynamic foundations of phase equilibria theory with his brilliant essay "On the Equilibrium of Heterogeneous Substances," published in 1876 and 1878 in the *Transactions of the Connecticut Academy.*

Allan Ray Putnam Service Award

Mr. Thomas K. Glasgow, FASM, manager, microgravity materials science branch, retired, NASA Glenn Research Center, Cleveland, will receive this year's award "for lifelong commitment and continued service to materials education for students, teachers, and materials professionals through the K-12 teacher grant program, Materials Camp, and development and instruction of ASM education courses." Established in 1988, the award recognizes the exemplary efforts of various outstanding members of ASM International on behalf of the Society to further its objectives

and goals. The purpose of this award is to recognize those individuals whose contributions have been especially noteworthy and to whom the Society owes a particularly great debt of appreciation.

Albert Easton White Distinguished Teacher Award



Prof. Marc Andre Meyers, FASM, professor, University of California, San Diego, is recognized "for inspired teaching for 45 years, and for leadership in the field of materials science and engineering through research, organization of conferences and symposia, and writing textbooks used globally." The award was established in 1960 in memory of an outstanding teacher and research engineer, who was a founding member and president of ASM in 1921. It recognizes unusually long and devoted service in teaching as well as significant accomplishments in materials science and engineering and an unusual ability to inspire and impart enthusiasm to students.

Silver Medal Award

Dr. Ryan Deacon, DuPont materials engineering consultant, physical metallurgy and failure analysis, DuPont Engineering Research and Technology, Wilmington, Del., will receive this year's award "for his leadership in the fields of materials characterization, metallography, and microstructural analysis as well as exemplary volunteer service to ASM International and the profession of materials science and engineering." Established in 2010, the honor of Silver Medal of the Society recognizes members who are in mid-career positions (typically 5 to 15 years of experience), for distinguished contributions in the field of materials science and engineering, and to the Society. The purpose of this award is to recognize leadership at an early stage and encourage individuals to grow, nurture, and further contribute to the growth of the profession as well as the Society.

Bronze Medal Award

Ms. Emily R. Kinser, patent engineer, IP licensing and development, IBM Corp., Hopewell Junction, N.Y., will receive the inaugural Bronze Medal Award "for her seminal technological achievements in semiconductor 3D integration along with 15 years of local and national service to ASM International." Established in 2014, the honor recognizes ASM members who are in early-career positions, typically 0 to 10 years of experience, for significant contributions in the field of materials science and engineering through technical content and service to ASM and the materials science profession.

Bradley Stoughton Award for Young Teachers

Prof. Steven May, assistant professor, department of materials science and engineering, Drexel University, Philadelphia, will receive this year's award "for dedication and enthusiasm in teaching and mentoring undergraduate and graduate students and for broadening awareness of materials science among high school students." This award, accompanied by $3000, was established in 1952 in memory of an outstanding teacher in metallurgy and dean of engineering who was president of ASM in 1942. The award recognizes young teachers of materials science, materials engineering, and design and processing, by rewarding them for their ability to impart knowledge and enthusiasm to students. The recipient must be 35 years of age or younger by May 15 of the year in which the award is made.

Henry Marion Howe Medal

Thomas K. Bieler, Leyun Wang, Armand J. Beaudoin, Peter Kenesei, and Ulrich Lienert, will receive this year's award for their paper entitled "In Situ Characterization of Twin Nucleation in Pure Ti Using 3D-XRD," *MetTrans* Vol. 45A, 2014. The award was established in 1923 in memory of a distinguished teacher, metallurgist, and consultant, to honor the author(s) whose paper was selected as the best of those published in a specific volume of *Metallurgical and Materials Transactions.*

Bieler

Wang

Beaudoin

Kenesei

Lienert

HIGHLIGHTS ASM HISTORICAL LANDMARKS

Khalia

Rhamdhani

Brooks

Marcus A. Grossmann Young Author Award

Grandfield

Abdul Khalia, Muhammad Akbar Rhamdhani, Geoffrey A. Brooks, and John Grandfield will receive this year's award for their paper entitled "Removal of Vanadium from Molten Aluminum—Part III. Analysis of Industrial Boron Treatment Practice," *MetTrans* Vol. 45B, 2014. The award was established in 1960 in recognition of Dr. Grossmann's accomplishments, especially his abiding interest in and encouragement of younger metallurgists and materials engineers whose paper was selected as the best of those published in a specific volume of *Metallurgical and Materials Transactions* for authors under 40 years of age on January 1 of the year in which the paper was published.

ASM Student Paper Contest

Anthony Lombardi is recognized for his paper entitled "Determining the Mechanism of In-Service Cylinder Distortion in Aluminum Engine Blocks with Cast-in Gray Iron Liners." The contest was established in 1985 as a mechanism for student participation in Society affairs. The award 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.

Emerging Professional Achievement Award

Dr. Dharma R. Maddala, Alcoa Technical Center, is the 2015 recipient of this award. Established in 2010, the award recognizes extraordinary ASM volunteers with 0-5 years of post-graduation experience who have made a significant impact on ASM International through devoted service and dedication to the future of the Society.

ASM Historical Landmark Designations

Park Metallurgical/Heatbath Corp., Detroit, has been selected for a 2015 Historical Landmark Award. The citation reads, "At the forefront of expanding the business and science of metalworking, Park Chemical's contributions to metallurgical advancements began here in Detroit by visionary ASM Founder and President, William Park Woodside."

Scranton Iron Furnaces, Scranton, Pa., was also selected for a 2015 Historical Landmark Award. The citation reads, "The Scranton Iron Furnaces spurred the nation's Industrial Revolution in iron and coal through the use of anthracite. Locally produced rails contributed to the growth of America's 19th century railroads."

In 1969, the ASM Historical Landmarks Designation was established to permanently identify the many sites and events that have played a prominent part in the discovery, development, and growth of metals and metalworking. In 1987, the scope of this award broadened to include all engineered materials.

Official ASM Annual Business Meeting Notice

The Annual Business Meeting of members of ASM International will be held in conjunction with MS&T15 on:

Monday, October 5

4:00 - 5:00 p.m.

Greater Columbus Convention Center, Columbus, Ohio

The purpose of the ASM Annual Business Meeting is the election of officers for the 2015-16 term and transaction of other Society business.

MS&T 2015 Lecturers Announced

Continuing the grand tradition of ASM International events, three distinguished lecturers will speak at the 2015 Material Science & Technology Conference and Exhibition (MS&T15) to be held October 4-8 at the Greater Columbus Convention Center in Columbus, Ohio. MS&T brings together the strengths of four major materials organizations: ASM International, The American Ceramic Society (ACerS), The Association for Iron & Steel Technology (AIST), and The Minerals, Metals & Materials Society (TMS).

2015 Alpha Sigma Mu

Monday, October 5

Dr. Siegfried Hecker, FASM

Research Professor, Department of Management Science & Engineering

Senior Fellow, Center for International Security and Cooperation, Stanford University

"Metallurgy and Nuclear Diplomacy"

When I began my metallurgy career 50 years ago at Case Institute of Technology focused on steels, I never imagined that I would wind up studying the metallurgy of exotic elements such as plutonium. As it turned out, steel metallurgy and the iron-carbon phase diagram were good training grounds for my research on plutonium, which is unquestionably the most complex element in the periodic table. Plutonium also has profound international security implications because it is the heart of nuclear bombs. During the past 25 years, I have been involved in international security assessments and diplomacy in which plutonium metallurgy played a central role. I will describe some of my adventures at the intersection of plutonium metallurgy and nuclear diplomacy in Russia, China, North Korea, India, Pakistan, Iran, Kazakhstan, the UK, and France.

2015 ASM/TMS Distinguished Lectureship in Materials and Society

Tuesday, October 6

Dr. Vincent J. Russo, FASM

Executive Director, Aeronautical Systems Center, Wright-Patterson AFB (retired)

"What is a Splendid Leader?"

The desirability for leaders of major organizations to possess an engineering education seems to be growing daily. But unfortunately, the vast majority of engineers are seldom trained to be effective leaders. This talk is structured to help engineers understand a leadership framework that can be applied to every level of an organization. The framework is identified in the following four pillars: Behavior Realities; Leadership Tenets; Essence of Leaders; and Life Balance. The talk will explain the four pillars and offer tools for use by potential and current leaders. Leadership can be learned. It just takes dedication, study, and hard work. A full treatment of leading technical organizations can be found in the book, *The Splendid Leader*.

Russo

2015 Edward DeMille Campbell Memorial Lecture

Tuesday, October 5

Prof. David N. Seidman, FASM

Walter P. Murphy Professor, Department of Materials Science and Engineering, Northwestern University

"A Correlative Five Dimensional Study of Phase Separation at the Subnano to Nanoscale of Nickel Aluminum Alloys"

Prof. Seidman will discuss the temporal evolution of ordered gamma-prime ($L1_2$)-precipitates in a disordered gamma (fcc)-matrix studied for Ni-12.5 Al and Ni-13.4 Al at% alloys aged at 773, 798, 823, or 873 K for times ranging from 0.08 to 10,287 h, in a comprehensive study utilizing 3D atom-probe tomography (3D APT), transmission electron microscopy (TEM), and monovacancy-mediated lattice-kinetic Monte Carlo ($LKMC_1$) simulations. The 3D APT results are compared in detail to $LKMC_1$ simulations, which include monovacancy-solute binding energies through fourth-nearest-neighbor distances, for the same mean compositions and aging temperatures. The temporal evolution of the measured values of the mean radius, number density, aluminum supersaturation, and volume fraction of the gamma-prime-precipitates are compared to the predictions of a modified version of the Lifshitz-Slyozov-Wagner coarsening model due to Calderon, et al., which takes into account the thermodynamics of the gamma-matrix. The resulting experimental rate constants are used to calculate the Gibbs interfacial free-energies between the gamma- and gamma-prime-phases using data from two thermodynamic databases. The diffusion coefficient for coarsening is then calculated from the same rate constants and is compared to all extant archival diffusivities and is demonstrated to be the interdiffusivity of Ni and Al at the four aging temperatures. The monovacancy-mediated $LKMC_1$ simulation results are found to be in good agreement with 3D APT data for all the quantities determined by 3D APT.

Seeking Nominations for 2016 ASM/TMS Distinguished Lectureship in Materials & Society

Qualifications of the lecturer include:

- An eminent individual who has an overall understanding of technology and society, and how both are affected by developments in materials science and engineering.
- Experienced in national or industrial policy-making in the field of materials science and engineering.
- Associated with government, industry, research, or education.

Nominations may be proposed by any member of either Society. Submit nominations by **September 1.** For complete details, visit asminternational.org/membership/awards.

ASM CHAPTER HONOR ROLL

The ASM Volunteerism Committee proudly announces the 2015 Chapter Volunteer Honor Roll recognizing chapter volunteers whose performance is exemplary and essential for ASM's success. All chapters were invited to nominate one person. Chapter Executive Committees were encouraged to select a member who serves as a volunteer in an ongoing capacity. Submissions for the 2016 Honor Roll will open in March 2016. Join us in recognizing the following 2015 Chapter Honor Roll volunteers who will receive an ASM MVP tie or scarf.

Alamo Chapter—James Callahan

Since joining the Chapter in the last two years, James Callahan has taken on the responsibility of membership chairman. He keeps in contact with members, tracks lapsed ones, and welcomes new people. He also set up a new website and Facebook account to keep members informed. Callahan has maintained his dedication even following a company downsizing. While looking for work, he kept his commitment to the Chapter and tasks he agreed to perform.

Brandywine Valley Chapter—Jeanette Vass

Jeanette Vass' volunteer work has helped to enable many Chapter accomplishments. In addition to serving as an active member of the executive committee for the past three years, she organized the popular "Family and Friends" event for a number of years. Last summer, the Chapter and the University of Delaware sponsored a new ASM Teachers Camp on campus. Vass played a key role by providing daily assistance to ensure that all went smoothly. She was also involved in organizing and presenting "Metallurgy for the Non-Metallurgist" to a 30+ member class arranged by the Chapter.

Central Massachusetts Chapter—Francis Blanchard

Francis Blanchard has served on the executive committee for over 20 years as treasurer. Digital records for the Chapter go back to 1995 and he is listed as treasurer every year since. In addition, for roughly 10 years, he has headed the Chapter's fundraiser that brings in most of the operating budget for the year.

Cleveland Chapter—Alex Derkaschenko

Alex Derkaschenko has been manning the registration table at events, collecting money, and providing typed name tags, drink tickets, and meal choices for over 21 years. He has earned this award for his tireless dedication to the Cleveland Chapter.

Lehigh Valley Chapter—Darwin Evangelista

Darwin Evangelista manages all Chapter arrangements, including technical and social meetings, executive committee meetings, and the Eastern Pennsylvania Materials Expo. In recent years, he has negotiated meeting pricing, enabling the Chapter to maintain strong financial standing. He is an excellent point of contact for guest speakers and effectively communicates with the executive team to ensure deadlines are met and turnout is good. He also serves as a mentor for the Chapter's Materials Camps.

Ontario Chapter—Nathan Bamsey

Nathan Bamsey oversees the arrangements and accommodations for monthly meetings including events for students, university meetings, and tours. He is always the first face people see and he is there to welcome everyone equally, regardless of whether they are fresh or senior members. His organizational skills assist tremendously with hospitality, registration, and travel arrangements for students, making everything run seamlessly.

Orange Coast Chapter—Merna Salama

Merna Salama has taken the initiative on the Chapter's outreach to schools. The most recent activity was a visit and

demo at Currie Middle School in Tustin, Calif. She is also very active at UC Irvine in outreach to Eastwood Elementary School and an aviation exposition held at Compton's Aeronautical Museum.

Pittsburgh Golden Triangle Chapter—Parag Bedekar

Parag Bedekar performed outstanding volunteer work for the Chapter at an ASM Materials MiniCamp where he ran a materials display station for two days. He also ran an ASM station at Engineering Week, as well as National Chemistry Week. In addition, he has volunteered many hours of reading through student resumes and was part of the committee to select an Owen Katz award winner.

South Central PA Chapter—Dan Elliott

Dan Elliott has served as Chapter Chair for many terms and after ceding this responsibility to others, he continues to ensure that the Chapter operates properly. He was instrumental in handling all aspects of the Chapter's first Teachers Camp, and did almost all of the volunteer work himself. He is also active in promoting many ASM Historical Landmarks and is very active in encouraging young members via science fairs.

Student Board Members for 2015-2016 Announced

The ASM Board of Trustees values the insights, ideas, and participation of Material Advantage students. The Student Board Member program provides the opportunity to attend four board meetings where the students will meet and work with leading technical professionals and gain leadership skills that will benefit them throughout their career. The next deadline for submissions is April 15, 2016. Details can be found on the ASM website.

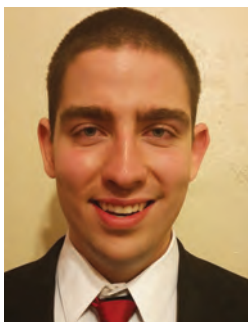
Aaron Birt

Worcester Polytechnic Institute

Aaron Birt is a Ph.D. candidate at Worcester Polytechnic Institute studying materials science and engineering. His current research project is on a process called Laser Assisted Cold Spray (LACS), which takes fine metallic particles and accelerates them through a miniature rocket nozzle to supersonic speeds. A laser is used as a heat source to soften, anneal, and ablate the deposited material in situ to processing. In order to expedite development of applications for LACS, Birt is working on a machine learning model to help understand how the vast array of inputs can be used to ultimately predict the bulk properties of these materials. Outside of research, he stays busy working with local entrepreneurial groups, ASM, and Material Advantage. At the end of a long week though, he says nothing is better than getting outside and going on a hiking, camping, or snowboarding trip with friends.

Joseph DeGenova

Case Western Reserve University



Joseph DeGenova is a rising senior at Case Western Reserve University (CWRU) studying materials science and engineering. He is on the advanced materials track, taking graduate-level electives for in-depth study in the field. At CWRU, DeGenova served as president of the local Materials Advantage society for the past year and a half. During his presidency, he sat on the executive board of ASM's Cleveland Chapter and serves on the undergraduate advisory committee to CWRU's dean of engineering. DeGenova has work experience in metallurgy through two internships. During summer 2014, he worked at The Timken Co. in Canton, Ohio, and is currently working at Alcoa Forgings and Extrusions, part-time during the school year and full-time during summer. He plans to pursue a career in materials engineering upon graduation in May 2016.

Sarah Straub

Rensselaer Polytechnic Institute

Sarah Straub is currently pursuing a Bachelor of Science in materials engineering with a minor in management and technology at Rensselaer Polytechnic Institute (RPI). Her concentration is in electrochemistry and corrosion with research projects including an electrochemical study of pit initiation in aluminum and an XPS study of copper oxidation. Outside of academics and research, she is also a member of Material Advantage, the Society of Women Engineers, Tau Beta Pi, and the ASM Women in Materials Engineering committee. Straub's free time is spent working as an educational outreach volunteer, playing tennis, and studying classical voice with an emphasis on Italian and German opera.

Theobald Retires from ASM

At the end of May, Stanley C. Theobald officially retired from ASM International. He spent more than 30 years with ASM and served as managing director for just over 10. Many great things were accomplished under his leadership. In the past few years, Theobald made major strides in developing ASM's government relations and secured several grants for future business development. He will now spend the majority of his time in Hilton Head, S.C., with his wife Kate. ASM extends sincere thanks to Theobald for his tireless contributions and we wish him good luck, health, and happiness for the future.

Han Named National Merit Scholar

The ASM Materials Education Foundation selected Nicholas Han as the 2015 ASM Materials Education Foundation National Merit Scholar. Han will graduate from Westview High School, Portland, Ore., this year. He was selected based on his outstanding academic achievements, diversity of activities, and interest in pursuing a career in materials engineering. The ASM Materials Education Foundation has been participating in the National Merit Scholarship Program for over 50 years. The National Merit Scholarship Corp. is a not-for-profit organization with a portion of its scholarship activities underwritten by corporate, college, and foundation sponsors like the ASM Foundation. For more information, contact Jeane Deatherage at 440.338.5151 ext. 5533 or jeane.deatherage@asminternational.org.

FROM THE PRESIDENT'S DESK

Collins

On Diversity and Inclusion

In April, I had the privilege of representing ASM International at the 2015 Convocation of the Professional Engineering Societies at the National Academy of Engineering, held in Washington. Nearly 100 representatives of 44 engineering societies gathered for presentations and discussions on Big Data insights into complex socioeconomic systems, and supporting reentry and alternative career paths into the engineering workforce. On the second day, we visited Capitol Hill for a review of the engineering policy priorities for the Administration and Congress, which include Big Data, energy policy, and manufacturing policy.

One of my key takeaways from the meeting was that the cohort of engineering societies are facing the same challenges—an aging membership base, recruitment and retention of new members, and a general concern that engineering is perceived as too old, too male, and too white. On the other hand, opportunities on the horizon are truly compelling. Some of these include solving problems of energy capture, storage, and delivery, reenergizing manufacturing and developing a technical workforce, and wisely using the power of Big Data to identify and solve societal issues. These are all arenas where ASM members play significant roles and contribute to the future. Further, these opportunities will set the context for many rewarding careers, which should be open and available to anyone willing to develop themselves and contribute.

In its 2012 report, the President's Council of Advisors on Science and Technology identified a need for up to one million additional STEM professionals over the next decade than are projected to graduate at current rates. Presentations from some of the other engineering societies and the Office of Science and Technology Policy focused on efforts around diversity and inclusion to broaden participation in STEM education and strengthen the STEM workforce. Attraction and retention are keys to bridging this gap. By identifying and addressing barriers to entry and reentry, as well as enabling nontraditional paths to STEM careers, we can shape the future with a more diverse and inclusive workforce. ASM has always been open to anyone with an interest in materials, and our volunteer leadership is committed to strengthening our long tradition of diversity and inclusion for the benefit of society.

Sunniva R. Collins
sunniva.collins@case.edu

AUTHOR SPOTLIGHT

George Krauss

George Krauss, FASM, published his second edition of *STEELS*: *Processing, Structure, and Performance* with ASM in March. The volume is an up-to-date description of state-of-the-art physical metallurgy of steel. Krauss explains, "Text comes from a half century in understanding steel, learning from others in industry and universities, step-by-step discoveries with my students and colleagues, and participation in the international materials community specializing in steel. The key with *STEELS*, *Second Edition* is understanding microstructure as influenced by chemistry and processing, including steelmaking, mechanical and thermal processing, and surface heat treatment, and relating that structure to performance. These considerations have been updated in almost every chapter of the second edition and help to provide the basis for new discoveries and applications."

Krauss is currently University Emeritus Professor at the Colorado School of Mines and a metallurgical consultant specializing in steel microstructural systems. In addition to *STEELS*, he coauthored the book *Tool Steels, Fifth Edition* with ASM and has published over 300 papers and lectured widely in technical conferences, universities, corporations, and ASM chapters, including a number of keynote, invited, and honorary lectures.

Krauss also served as president of the International Federation of Heat Treatment and Surface Engineering (IFHTSE) and is a past president of ASM. He is a Fellow of ASM, TMS, and IFHTSE. Krauss has been awarded medals from numerous organizations including the Adolf Martens Medal of the German Society for Heat Treatment and Materials and has received several other professional and teaching awards, including the ASM Albert Easton White Distinguished Teacher Award. He dedicates the new edition to the "men and women that make, use, and study steel."

VOLUNTEERISM COMMITTEE

Profile of a Volunteer

Steve Brubaker

A young materials engineering graduate left the University of Cincinnati for Brazil in 1969 with the Peace Corps—and brought back a lifelong lesson in developing communities. Steve Brubaker now shares that with ASM, as education outreach volunteer in Delaware's Brandywine Valley Chapter. Brubaker joined ASM in 1974, but during his 29-year career as a materials consultant with DuPont he focused on raising a family and growing his skills. It wasn't until he was in his 60s that he became an active member on the executive board. He was invited by Art Graham, a retired DuPont Ph.D. with expertise in surface engineering. "Art was a real inspiration. It was important to him to rescue a near-dormant chapter," says Brubaker. "He demonstrated that a chapter is totally dependent on volunteers. He was in his 70s and retired, and when he had to back off, I stepped up along with the rest of the executive committee."

Brubaker

Brubaker's retirement years have been "healthy and invigorated" by working with ASM. He worked to build a stronger affiliation with the University of Delaware's department of materials engineering, including sponsorship of graduate student poster sessions and a successful Teachers Camp. Looking back, he reflects, "I became Chair in 2010 and thought it would be too much stress when I retired, but a strong and motivated executive committee practically runs itself." The chapter has grown from a base of 130 members to more than 180 and now includes a Materials Advantage chapter at the University, graduates of the Teachers Camp, and a *Metallurgy for the Non-Metallurgist* course.

Brubaker's advice for a vital chapter:

1. Invite older members and retirees to get involved.
2. Strive for excellent programming with fun planning meetings.
3. Provide valuable professional development to attract volunteers.

"Everything is an opportunity," he says. "But it only happens when people get together and motivate each other!"

Materials Genome Toolkit Competition Winners Announced

ASM's Computational Materials Data Network (CMD Network) is pleased to announce the winners of the 2015 ASM Materials Genome Toolkit competition. Six engineering schools—University of Maryland, Michigan Tech, Cal-Poly Pomona, Carnegie Mellon, Virginia Tech, and Alfred University—were selected by a review committee to receive state-of-the-art materials modeling software for use in undergraduate education and enrichment. The winning schools will be recognized at MS&T15, taking place October 4-8 in Columbus, Ohio.

Schools were required to submit a proposal stating how they planned to integrate the software into their undergraduate curriculum and how they would use it in the context of the ASM Undergraduate Design Competition. Winners were chosen based on how well their proposal balanced the use of the software between theory and application. Each

HIGHLIGHTS ASM UPDATES HEAT TREATER'S APP

school will receive the 2015 ASM Materials Genome Toolkit consisting of a three-year, multi-user license to a package of tools from Thermo-Calc Software. An equivalent package was also awarded to the Colorado School of Mines under the auspices of the Lightweight Innovations for Tomorrow (LIFT) consortium.

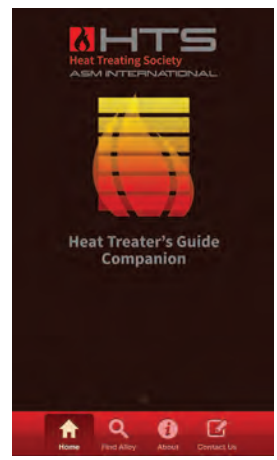
The concept of the toolkit program was introduced in 2009 by ASM Foundation's Action in Education Committee (AEC) and its subcommittee, Computational Materials Engineering. The committee established requirements for participation and negotiated with Thermo-Calc Software, which offered an 85% discount on a set of tools worth $1.6 million. After a three-year pilot program at Michigan Technological University, the balance of the funding was secured through the NIST-sponsored Center for Hierarchical Materials Design (CHiMaD), a five-year MGI development initiative led by Northwestern University. The Toolkit competition is the first of three made possible by CHiMaD. Over the next two years, six more winners will be selected by members of the ASM Foundation's AEC subcommittee.

Coming Soon: ASM Handbook on Protective Organic Coatings

ASM International will release *ASM Handbook*, Volume 5B, *Protective Organic Coatings* on August 31. A new entry in the esteemed ASM Handbook series, Volume 5B grew out of an article from 2003, "Organic Coatings and Linings" by Kenneth B. Tator, P.E., of KTA-Tator Inc., published in *ASM Handbook*, Volume 13A, *Corrosion: Fundamentals, Testing, and Protection*. Tator, editor and author of numerous articles in the new 5B, along with ASM content developers identified the need for an entire book dedicated to industrial protective coatings, based on the engineering and economic significance of the industry. Volume 5B—like every ASM Handbook—was written by recognized industry experts, reviewed by their peers, and edited by professionals dedicated to developing reference publications of the highest technical and editorial quality.

The new volume is comprised of 480 pages and divided into five divisions, which offer introductory material, an in-depth presentation of specific coating materials, practical information on surface preparation and application techniques, coating use by various industries, and a detailed discussion of coating analysis and evaluation methods. The latest information on industry standards that must be adhered to in the preparation, application, and testing of protective coatings is also included. Notably, Volume 5B is the first ASM Handbook to be printed in full color—a special feature made possible by Tator as well as KTA-Tator Inc., a corrosion, coatings consulting, and inspection firm.

Heat Treater's Guide Companion App 3.0 Just Released



Recently updated, more than 100 wrought and cast aluminum and magnesium alloys have been added to the mobile app. Created by ASM International and the ASM Heat Treating Society, the Heat Treater's Guide Companion now provides ready reference data and practical heat treating information on nearly 440 steel, aluminum, and magnesium alloys.

Content includes chemical composition, similar U.S. and foreign alloys, characteristics, and recommended heat treating procedures. The app can be used by itself or as a companion to the ASM Heat Treater's Guide print and online database products, which provide additional heat treating data such as representative micrographs, isothermal transformation diagrams, cooling transformation diagrams, tempering curves, and data on dimensional change. Available for iPhone, iPad, and Android devices, the free app can be downloaded from the Apple and Google App stores.

Hartford Chapter Enjoys Joining Presentation

From left, Tom Jain, Arnie Grot, Stan David, Hal Brody.

The May 12 meeting of the Hartford Chapter brought together a former student with his Ph.D. advisor. In the photo, past chair Arnie Grot (second from left) presents Stan David (third from left), corporate fellow and group leader emeritus from Oak Ridge National Laboratory, with a speaker mug after his presentation, "Science Base for the Joining Technologies of the Future." David was a graduate student studying solidification under Hal Brody (right) at the University of Pittsburgh in 1967. He applied what he learned in a very successful career in solidification and welding metallurgy. On the left is Tom Jain who worked with David at ORNL for five years.

Los Angeles Chapter Celebrates Student Night

Cal Poly Pomona students with Prof. Vilupanur Ravi.

The Los Angeles Chapter held its annual Student Night in April, which featured poster presentations by area students from Cal Poly Pomona, Loyola Marymount University, and University of California, Riverside.

New Egyptian Chapter Debuts

Material Advantage Students from Suez University (Egypt) celebrate their founding as a new ASM chapter.

Ottawa Valley Chapter Hosts Trustee Dinner

The ASM Ottawa Valley Chapter held its annual ASM Trustee dinner meeting on May 19. Prof. Ravi Ravindran, FASM, and past president, gave a talk on "Light Alloys Processing Revolutionizing the Automotive Industry." Pictured are Prof. Ravindran (sixth from left), Chapter executives, and active members.

Lehigh Valley Chapter Announces Materials Expo

ASM's Lehigh Valley Chapter is pleased to announce its fifth Materials Exposition, taking place at the Holiday Inn and Conference Center on Thursday, November 12, in Breinigsville, Pa. The Expo will bring together materials-related manufacturers, service providers, and educational institutions from Eastern Pennsylvania and provide an opportunity to learn about the local materials community, network with industry professionals, exhibit the latest materials solutions and testing methodologies, and collaborate on technical challenges. This year's keynote speaker is Bob Hill, president, Solar Atmospheres of Western Pa. The company specializes in vacuum heat treating, vacuum brazing, vacuum carburizing, vacuum nitriding services, and thermal processing research and development. For more information, visit lvasm.org.

Rhode Island Chapter Hosts President Collins

From left, Sunniva Collins, Greg Dexter, Gary Haupt, Paul Ford, and David Shaner.

The Rhode Island Chapter held its May dinner meeting with ASM President Sunniva Collins, FASM, speaking on "Orbital Welding for Critical Applications." Collins discussed how orbital welding is a precise, automated method for welding process tubing systems in high-tech industries from semiconductor equipment manufacturing to aerospace. She also spoke with the Chapter board and discussed ways to enhance member participation.

Central Massachusetts Chapter Holds Awards Program

From left, Alex Feng, Tasos Gavras, Virendra Warke, Baillie McNally, Aaron Birt, Prof. Ravi Ravindran, Inigo Anza, Carl Soderhjelm, Diana Galinda, Carlos Exiga, and Prof. Diana Lados.

The Central Massachusetts Chapter held its annual awards night on March 25 at the O'Connors Restaurant in Worcester. In memory of Chester M. Inman, who helped found the Worcester Chapter (now Central Mass.), a scholarship is presented annually by the Chapter to a regional student in the field of metallurgy or materials science. This year's award was presented to Baillie McNally, a graduate student in materials science and engineering at Worcester Polytechnic Institute.

HIGHLIGHTS MEMBERS IN THE NEWS

Singh Recognized by National Academy of Inventors

On March 20, **Raj Singh, FASM,** Williams Distinguished Chair Professor and Head of the School of Materials Science and Engineering at Oklahoma State University, was inducted as a Fellow of the National Academy of Inventors by the Deputy U.S. Commissioner for Patent Operations from the U.S. Patent and Trademark Office. Singh's inventions have been used in the development of many products such as ceramic matrix composites for more efficient aircraft engines, more powerful sodium-sulfur batteries utilized for energy storage systems, and novel electrolyte retainers and self-repairing glasses for molten carbonate and solid oxide fuel cells.

Sridharan Inducted into Institute of Materials, Minerals, and Mining

Kumar Sridharan, FASM, distinguished research professor in the departments of engineering physics and materials science and engineering, University of Wisconsin-Madison, was inducted as a Fellow of the Institute of Materials, Minerals, and Mining, UK, in recognition of his contributions to materials science and applications, and education.

Vander Voort Teaches in Spain and Russia

George Vander Voort, FASM, presented a two-day seminar on the metallographic characterization of steels at the Arcelor-Mittal steel plant in Aviles, Spain. He also

IN MEMORIAM

George Harwood Bodeen, FASM, ASM past president, passed away on May 21 at age 91. Born in Chicago on March 31, 1924, Bodeen graduated from Amundsen High School in June 1941 and was accepted to Northwestern University's engineering school. After his father's sudden passing, he became the primary provider for his family at age 17. He withdrew from school and took a position with Teletype Corp., enlisting in the U.S. Army Air Corps in 1943. He served as a navigator/bombardier as well as a radar operator on B-17s and B-24s. Following the war, he was again accepted to Northwestern on the G.I. Bill, graduating with a B.S. in 1949. He began his career with Neenah Foundry and then went to Lindberg Steel Treating Co. Bodeen attended night school at Northwestern to earn his master's degree in materials science (1970). He later became president, chairman, and CEO of Lindberg, shepherding the company's growth from a regional heat treating company to the largest commercial heat treater in North America. One of Bodeen's major achievements was the successful processing of solid rocket fuel motor cases for the Minuteman and other missile programs. Bodeen was the founding president of the ASM Heat Treating Society, and the George H. Bodeen Heat Treating Achievement Award was established in his honor in 1997. He was a humble, compassionate, and energetic man who made everyone smile when they saw him.

Edward Epremian, FASM, died on November 11, 2014, at age 93. Graduating from MIT in 1943 with a degree in metallurgy, he soon went to work for General Electric in his home town of Schenectady, N.Y. While at GE he was awarded patents for alloys he developed for the turbosuperchargers that enabled U.S. bombers to fly at higher altitudes, and for the first military jet engines. After receiving his doctorate from Carnegie Institute of Technology in 1951, he joined the Office of Naval Research as a scientific liaison in England and Western Europe. Returning to the U.S. in 1954, he served for four years as chief of the metals and materials branch of the Atomic Energy Commission. Moving to private industry, he worked for Union Carbide Corp. in a variety of research and management positions. In the 1960s, Epremian headed the division that developed and introduced the first carbon fibers for use in composite materials. In the 1970s, he returned to public service, joining the National Research Council of the National Academy of Sciences, followed by two years with the United Nations Industrial Development Organization as special assistant to the Director General.

George Vander Voort at the Arcelor-Mittal facility in Aviles, Spain.

gave the opening and closing keynote lectures at the Spain Minergy conference in Gijón, an international congress organized by the Foundation and Graduate Mining Engineers of Mines and Energy of Spain and the Association of Engineers of Mines and Energy of Asturias province. Vander Voort then traveled to Russia to teach his annual course at the St. Petersburg State Polytechnical University.

Lindemann Receives NSF Scholarship

Former Ames Laboratory Science Undergraduate Laboratory Internship student **William Robin Lindemann** received a prestigious scholarship from the National Science Foundation Graduate Research Fellowship Program (GFRP). The GRFP provides three years of financial support within a five-year fellowship period for graduate study that leads to a research-based master's or doctoral degree in science or engineering. Lindemann, who majored in materials science at Iowa State University, plans to pursue a Ph.D. in materials science and engineering at the Massachusetts Institute of Technology in the fall.

STRESS RELIEF

CUDDLY TOY SERVES AS COMPANION AND TEACHER

The Trobo Storytelling Robot is a toy that not only makes a great companion, but also tries to encourage curiosity in STEM topics. Trobos are interactive robots that read to children and have the potential for a virtually endless story library. Compatible with iPads and iPhones and incorporating their own app, the robots allow children to build their own avatar, include their name in the stories, and participate in interactive puzzles. The toy and app were developed by two Orlando-area engineering dads who left game and theme park development, Jeremy Scheinberg, a University of Pennsylvania engineering graduate, and Chris Harden, a former development director with EA Sports.

Part plush toy, part iPad app, Trobo blends cuddliness and science to answer the types of questions little kids ask.

Trobo aims to introduce 2 to 7-year-olds to STEM topics through stories and create an early love of learning through fun and personalized technology. Using stories, games, and quizzes, the toy attempts to tap into kids' natural curiosity about the world around them to teach them about science, 3D printing, the Internet, rockets, engineering, mechanics, math, and more. *herecomestrobo.com.*

Life-sized K'nex model of the Bloodhound Supersonic Car.

BLOODHOUND REPLICA IS LARGEST STRUCTURE BUILT WITH K'NEX

Based on measurements taken by the National Physical Laboratory (NPL), UK, Guinness World Records confirmed that a life-sized K'nex model of the Bloodhound Supersonic Car (SSC) was the largest structure ever constructed using the construction toy system. The Bloodhound SSC replica was built using 383,422 toy pieces and took a Royal British Legion Industries team consisting of ex-services personnel and enthusiasts 1287 hours to construct. At 13.382 m long, 2.44 m wide, and a height of 3.874 m, the stats of the K'nex model mirror those of the real supersonic vehicle and exceed those of the current record for the World's Largest K'nex Structure—a T. rex, located in the U.S. Space & Rocket Center in Huntsville, Ala.

Former World Land Speed Record holder, Bloodhound project director Richard Noble, revealed the completed Bloodhound K'nex model. "Bloodhound aims to inspire the next generation of scientists and engineers," he says. "If 164 people can build an amazing model like this in a matter of weeks, imagine what a generation can achieve in their lifetimes!" *www.npl.co.uk, bloodhoundssc.com, guinnessworldrecords.com.*

CAN RUBY SNEAKERS LEAD YOU HOME?

An Indian high-tech start-up is promising to lead you in the right direction with its GPS-enabled smart sports shoe that vibrates to give the wearer directions. The fiery red sneakers, which also count the number of steps taken, distance traveled, and calories burned, are sold under the name LeChal, which means "take me along" in Hindi. The shoes come with a detachable Bluetooth transceiver that links to a smartphone app to direct the wearer using Google maps, sending a vibrating signal to indicate a left or right turn. They are the brainchild of 30-year-old Krispian Lawrence and Anirudh Sharma, 28, two engineering graduates who founded Ducere Technologies in a small apartment in 2011 with backing from angel investors. The company now employs 50 people. *lechal.com.*

Krispian Lawrence, CEO of Ducere Technologies, tries on a pair of GPS-enabled smart sports shoes.

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SEPTEMBER 2015

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Advertising closes August 4

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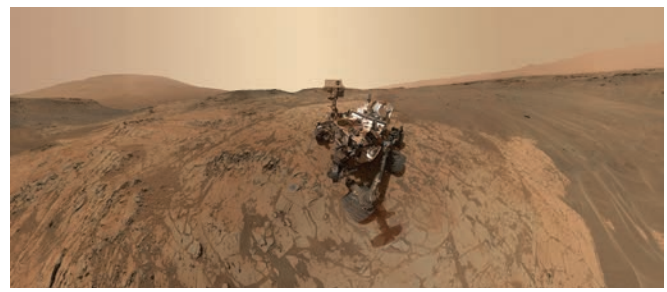
EXPLORERS IN ENGINEERING

Average length of a Martian solar day (sol): 24 hours, 39 minutes, 35.24409 seconds. Earth's equivalent day: 24 hours, 0 minutes, 00.002 seconds. As time went on, keeping a "normal" schedule became increasingly challenging for the Curiosity team.

SOL MAN

John Grotzinger, chief scientist and head of strategic science planning for NASA's $2.5 billion Curiosity Rover Mission to Mars, shares some details about his career and the future of Mars exploration. A veteran geologist with more than 30 years of experience exploring Earth and Mars, he has led expeditions to the far reaches of the globe. Grotzinger recently served as the keynote speaker at AeroMat, part of ASM's triple tradeshow event held in May, in Long Beach, Calif.

Grotzinger



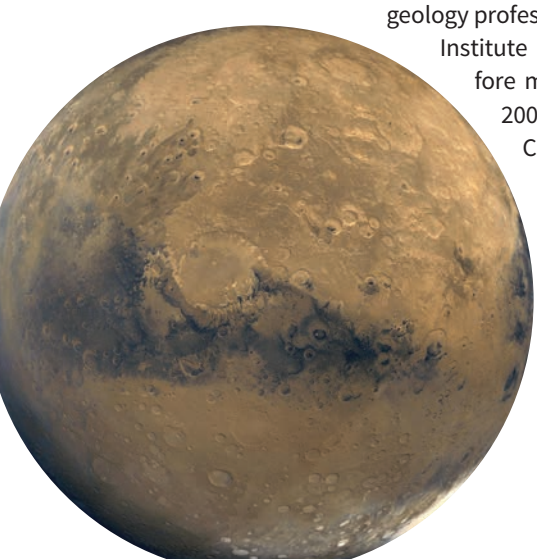
NASA's Curiosity Mars rover at the Mojave site.

WHAT DID YOU WANT TO BE WHEN YOU GREW UP?

I was pretty sure I wanted to be a scientist of some kind. I grew up in Pennsylvania and always enjoyed the outdoors, especially exploring the forests and wetlands near my home.

CAN YOU DESCRIBE YOUR EDUCATIONAL AND CAREER PATH SO FAR?

In elementary and middle school, I attended the local public school system in Pennsylvania, and then went to a private high school. They didn't offer Advanced Placement classes at the time, but I took some special biology classes that I found extremely interesting. I liked it so much that I started college as a biology major, but then switched to chemistry. That was at Hobart College in New York. In my senior year, I happened to sign up for one geology class and I was instantly hooked because geology combines all the sciences into one discipline. I earned my master's degree in geology at the University of Montana and then my Ph.D. at Virginia Tech. I spent 18 years as a geology professor at Massachusetts Institute of Technology before moving to Caltech. In 2006, after 18 months at Caltech, I was asked to lead the Curiosity Mission.



Lesson learned: If Grotzinger and the Curiosity team would have known how many conical, pointy rocks were on the Martian surface, they would have specified thicker wheels.

WHAT DO YOU CONSIDER YOUR GREATEST PROFESSIONAL ACCOMPLISHMENT SO FAR? YOUR BIGGEST SETBACK?

Leading the Curiosity team and achieving a successful landing, and then heading up the exploration of Gale Crater and Mount Sharp was—and is—incredibly rewarding. Our entire team was challenged in news ways and I learned a lot about the social dynamics of hundreds of scientists and engineers working together. As far as setbacks, 2009 was a very dark year. We discovered some major lubrication issues with the motors aboard Curiosity and we knew we had to fix them. However, this meant missing our launch window. We had to ice the entire mission for a year, and then put our best and brightest minds on solving the motor issue, which we eventually did.

DO YOU BELIEVE HUMAN EXPLORATION OF MARS IS POSSIBLE? HOW ABOUT COLONIZATION?

Yes, I believe humans will eventually get to Mars, but we must first overcome many technological hurdles before that day arrives. I don't see colonization happening any time soon.

ANY ADVICE FOR YOUNG SCIENTISTS AND ENGINEERS?

Same thing I tell my kids: Do what you love and love what you do. And don't promise more than you can deliver.

WORDS TO LIVE BY?

"Far and away the best prize that life has to offer is the chance to work hard at work worth doing."

—Theodore Roosevelt



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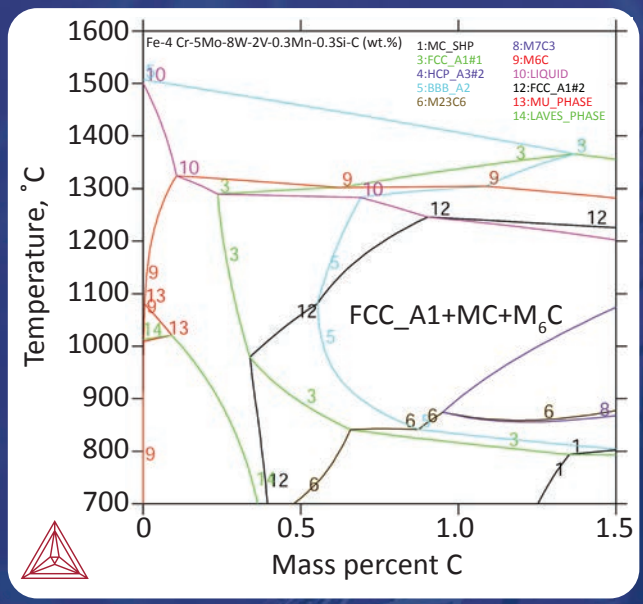

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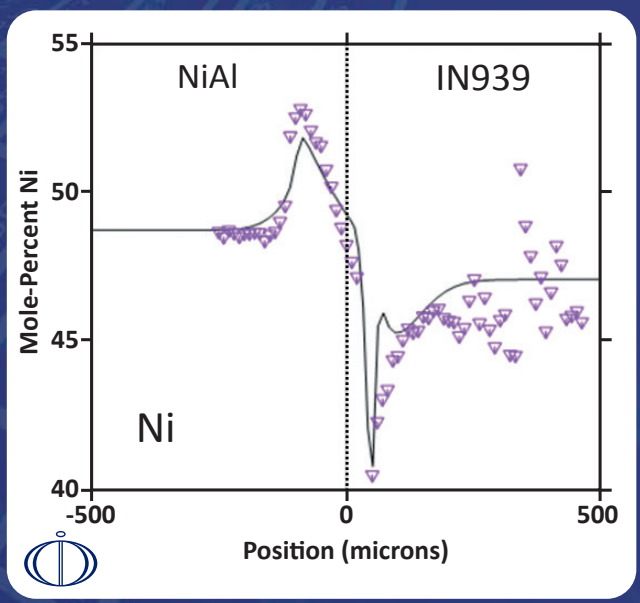

Diffusion in ordered phases

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Thermo-Calc Software AB
Email: info@thermocalc.com
Phone: +46-8-545 959 30

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Email: paul@thermocalc.com
Phone: (724) 731 0074