MAY 2016 | VOL 174 | NO 5

ADVANCED MATERIALS & PROCESSES

AN ASM INTERNATIONAL PUBLICATION

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AEROSPACE MATERIALS & APPLICATIONS

FLYING HIGH WITH COLD SPRAY REPAIRS

P. 24

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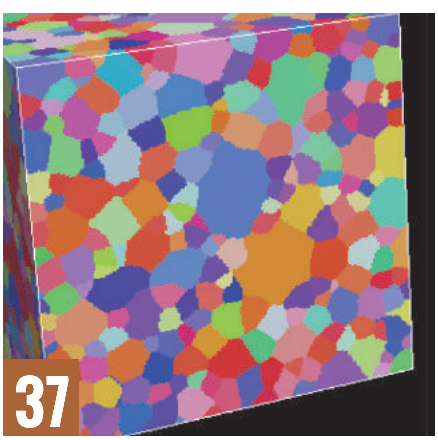
NEW TRENDS IN AEROSPACE: SAVING THE BOTTOM LINE WITH COLD SPRAY REPAIRS

Julio Villafuerte and Linh Tran

Cold spray is an effective method of depositing a variety of temperature-sensitive materials in specialized applications, such as high-value aerospace component repair.

On the Cover:

Boeing 787 Dreamliner. Cold spray is now being used as an effective method for high-value aerospace component repair. Courtesy of Boeing, www.boeing.com.



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CONFERENCE HIGHLIGHTS ADVANCEMENTS IN TITANIUM TECHNOLOGY

Vasisht Venkatesh and Rodney Boyer

Developments in titanium technology and opportunities for increased use in several markets were highlighted at the 13th World Conference on Titanium.

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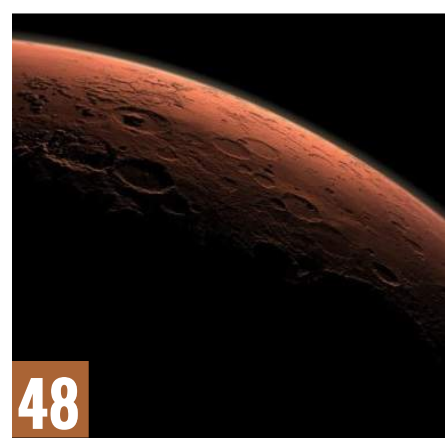
ASM NEWS

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



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3D PRINTSHOP

The NASA In-Situ Materials Challenge competition mandated that competitors use materials found on Mars.

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FEATURES

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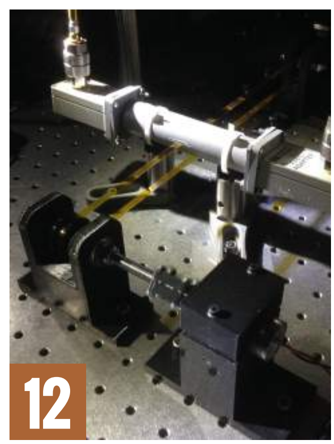

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TRENDS

INDUSTRY NEWS

DEPARTMENTS

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AI AND AM CHANGING THE INDUSTRIAL LANDSCAPE

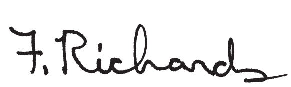
As I write this column, I am in the middle of a press visit to Germany built around the theme of Industry 4.0, the German name for what Americans call the Industrial Internet. These two terms essentially define the same idea—merging the physical world with the virtual world of the Internet and software. As part of this technological tour across Deutschland, the DFKI—German Research Center for Artificial Intelligence (AI)—demonstrated an Industry 4.0 system at Hannover Messe, the world's largest industrial fair. The modular SmartFactoryKL system showcases ideas such as plug and produce, predictive maintenance, zero-downtime maintenance, scalable automation, and mix-and-match machine modules collaborating in a production environment.

Detlef Zühlke, DFKI's scientific director, explained how the Industry 4.0 world will be covered in intelligent sensors, enabling highly dynamic, automated cyber-physical systems, in which much of the intelligence lives in the cloud rather than individual physical components. Central controllers will be relics of the past. Instead, modular production units (think of Lego bricks with specific tasks) will self-identify once they are plugged into the larger system, communicate what they can do, and then autonomously network with other machine units to accomplish different jobs. Zühlke believes this model is likely five years away from widespread industry adoption. One reason for the delay is that international standards still need to be developed so systems can work together seamlessly. In the U.S., we have a newer entity called the Digital Manufacturing and Design Innovation Institute (DMDII), Chicago, working on similar goals. DMDII is a federally funded R&D organization that "encourages factories across America to deploy digital manufacturing and design technologies, so those factories can become more efficient and cost-competitive."

In other advanced manufacturing news, GE's breathtaking and ambitious Center for Additive Technology Advancement (CATA) opened a few weeks ago near Pittsburgh. The $39 million, 125,000-sq-ft facility is designed as a regional innovation hub to support GE's eight business segments. Key additive manufacturing (AM) technologies showcased at the new center include direct metal laser melting, fused deposition modeling, laser hot wire, poly jet, and sand binder jetting. CATA will work with other organizations such as printer suppliers, universities including nearby Carnegie Mellon, and institutes like America Makes to develop AM technologies and best practices.

CEO Jeff Immelt was on hand to commemorate the opening. He says we are only in the "first 15 minutes of this industry" and leadership is still up for grabs. With more than 400 AM machines in service across GE, the company is planning to build on the stunning success of its 3D-printed jet engine fuel nozzles. Immelt added that the company hopes to make as much as 25% of its products using AM over the next few years—an ambitious goal.

It seems clear that a manufacturing revolution is now in full swing, with AI and AM as key technologies. From aerospace and automotive components to consumer goods and medical products, every industry will be transformed. We hope you will stay tuned to *AM&P* to keep informed about how these changes will impact the materials community.



frances.richards@asminternational.org

CORPORATE SPOTLIGHT

THERMO-CALC SOFTWARE

The use of modelling and simulation tools in materials R&D is growing rapidly as highlighted by the publication from the National Academies on Integrated Computational Materials Engineering (ICME) in 2008, and the announcement of the Materials Genome Initiative (MGI) in 2011.

As a leading developer of software and databases for calculations involving computational thermodynamics and diffusion controlled simulations, Thermo-Calc Software is a foundational component of any ICME/MGI framework. For more than 30 years, Thermo-Calc has been used within industry, government research labs and academia to gain insight into problems related to materials science and engineering and is now licensed by more than 1,000 of the world's top companies, research labs and universities in over 70 countries.

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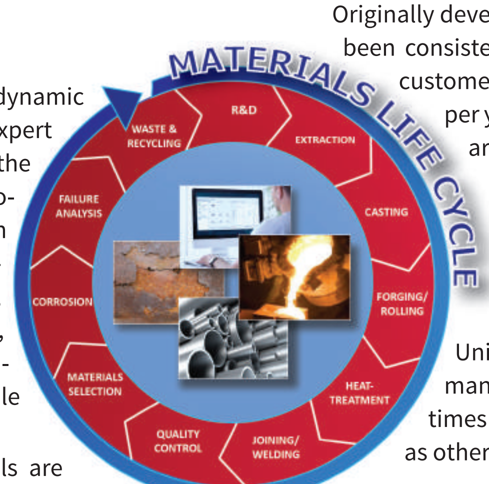

Our modelling and simulation tools are used for many different purposes within the lifecycle of a material, from R&D efforts in designing new materials to identifying optimal processing windows, all the way through addressing waste and re-cycling issues. Typical benefits expressed by our customers include:

- Reducing the number of costly, time-consuming experiments and testing by making better use of pre-screening/pre-test calculations
- Increasing the value of experiments through deeper understanding of the results
- Defining safe and optimal processing windows in terms of composition tolerances and temperatures
- Basing decisions on scientifically supported models, tools and data
- Shortening development times and bringing products to market faster
- Making predictions that are difficult or even impossible with an experimental approach

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Originally developed in the early 1980s, Thermo-Calc has been consistently updated to satisfy the needs of our customers. Our software are now on a two times per year release cycle, and our main databases are also updated regularly.

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Thermo-Calc Software
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MARKET SPOTLIGHT

U.S. MANUFACTURING COMPETITIVENESS RISING TO THE TOP

The United States is expected to be the most competitive manufacturing nation by 2020, moving China into the number two position, according to the *2016 Global Manufacturing Competitiveness Index* report from Deloitte Touche Tohmatsu Ltd. and the Council on Competitiveness. The prediction is based on an in-depth analysis of survey responses from more than 500 chief executive officers and senior leaders at manufacturing companies around the world. Report highlights include:

- The U.S. improved its ranking from fourth in 2010 to second in this year's study, and is expected to reach first place by 2020.
- Made up of the five Asia Pacific nations of Malaysia, India, Thailand, Indonesia, and Vietnam, the MITI-V could represent a "new China" and enter the top 15 rankings of global manufacturing competitiveness over the next five years. Low cost labor, agile manufacturing capabilities, favorable demographics, and market and economic growth are leading factors.
- Among the BRIC countries (Brazil, Russia, India, and China), only China is viewed as a top manufacturing nation in 2016. The other three have seen continuous declines in the study's rankings over the past six years. Brazil's political uncertainty, Russia's geopolitical activities plus impact from the slide in global crude oil prices, and India's economic and policy actions regarding infrastructure and investments have likely triggered the decline.
- The U.S. stands out as the anchor for North America with the highest level of manufacturing investments, a strong energy profile, and high quality talent, infrastructure, and innovation. Canada's low trade barriers, tariff-free zone, and investments in sectors key to its growing high-tech manufacturing future along with Mexico's 40 free trade agreements, low labor costs, and close proximity to the U.S. round out the region.
- European nations are lagging behind as they work through sluggish economic recovery efforts and look to their anchors, Germany and the United Kingdom, to pull them ahead.

For more information or to download the free report, visit deloitte.com/us/global-competitiveness.

Global CEO Survey: Drivers of Global Manufacturing Competitiveness

Source: Deloitte Touche Tohmatsu Ltd. and U.S. Council on Competitiveness

FEEDBACK

ASM SUPPORTS SCIENCE TEACHERS

I am a high school science teacher at the Academy for Enrichment and Advancement in Union City, N.J., and I attended the Materials Science Workshop this past summer at the New Jersey Institute of Technology. It was a great experience and I learned a lot, which led to some recent accomplishments I would like to share. First, I assembled a team of students from our school and entered the Materials Choice Award sponsored by ASM. Our team chose Nitinol as our material and "ThēORbēTalS" has moved to the second round of the competition. Second, I received a 2016 Urban Science Educator Award from the National Science Teaching Association and Shell at the National Science Conference held in Nashville, Tenn., in April. I was one of seven educators nationwide to receive this award. Both of these accomplishments were only possible with the support of the ASM and the local Chapter. My students and I are grateful for such opportunities.

Paul Orbe

PAYING HOMAGE TO METALS PIONEERS

I am just writing to tell you how much I enjoyed the *Pioneers* series ("Metallurgy Lane," September 2015-March 2016). I find that the level of difficulty is just right and the articles are very interesting. Keep up the good work.

Bob Rapp

[The ASM Technical Books Committee recently approved a proposal for a historical volume based on Charles Simcoe's popular "Metallurgy Lane" series. Publication is expected in late 2016. —*Eds.*]

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

CORPORATE SPOTLIGHT

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OMG!
OUTRAGEOUS MATERIALS GOODNESS

Image courtesy of arXiv:1602.07937 [physics.flu-dyn].

RING-FREE WHISKY INSPIRES NEW COATINGS

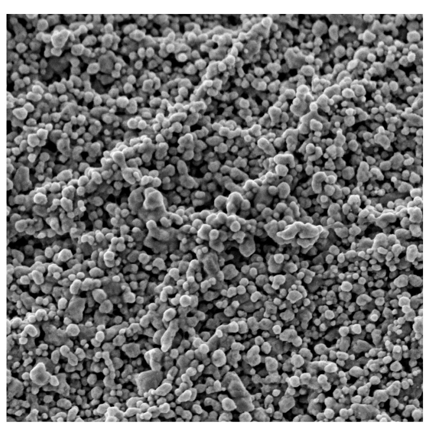
Researchers at Princeton University, N.J., with assistance from a photographer in Arizona, uncovered the secret behind why whisky does not leave behind "coffee rings" when it dries. The team believes their results could lead to a new type of industrial coating.

Ernie Button, a photographer in Arizona, noticed that the residue left behind when whisky dried in a clear drinking glass was starkly dramatic when lit from below with various colors. He teamed up with a group at Princeton to investigate the phenomenon.

Upon taking a closer look, the team found two important features in whiskies that did not leave behind a coffee ring-type pattern when evaporated. First, they found fat-like molecules that lowered surface tension—as the liquid evaporated, they collected on the edges of the drying surface, which in turn caused a tension gradient that pulled the liquid back inward. The second feature was plant-derived polymers that caused a sticking effect, which in turn help channel particles in the liquid to the base material (drinking glass) where they stay stuck. Researchers noted that because of its even coating distribution characteristics, whisky-type liquids could be suitable for industrial coatings or even as a type of ink for 3D printers. *princeton.edu.*

SITTING IN THE SUN COULD CLEAN YOUR CLOTHES

A spot of sunshine is all it could take to get your washing done, thanks to pioneering nanoresearch into self-cleaning textiles. Researchers at RMIT University, Australia, developed an inexpensive and efficient new way to grow special nanostructures—which can degrade organic matter when exposed to light—directly onto textiles. Rajesh Ramanathan says the process has a variety of applications for catalysis-based industries such as agrochemicals, pharmaceuticals, and natural products, and could be easily scaled up to industrial levels. "Textiles already have a 3D structure so they are great at absorbing light, which in turn speeds up the process of degrading organic matter," he notes. *For more information: Rajesh Ramanathan, rajesh.ramanathan@rmit.edu.au, www.rmit.edu.au.*



Close-up of the nanostructures grown on cotton textiles by RMIT University researchers. Magnified 150,000 times.

NEW MATERIAL SNIFFS OUT EXPLOSIVES

Scientists created a material that turns fluorescent when explosive molecules are in the vicinity. The discovery could improve airport security and also gives insight into a chaotic microworld where molecules and atoms are constantly responding to their surroundings.

Researchers from the University of Southern Denmark were inspired by dogs' noses, which unlike humans, are so sensitive that they can detect single molecules in the air, and are thus valuable helpers when it comes to detecting explosives. Many resources have been devoted to develop electronic or chemical *noses,* which similarly can detect explosive molecules.

Researchers created a new material that includes the molecules TTF-C[4]P and TNDCF. TNDCF becomes fluorescent when an explosives molecule is near. "This knowledge could lead to the development of a small device which airport security staff could use to test if explosive molecules are on or near a bag," explains Steffen Bähring. *For more information: Steffen Bähring, sbahring@ifk.sdu.dk, www.sdu.dk/en.*

Bähring by roadside bomb, Afghanistan 2005. Courtesy of Steffen Bähring/SDU.

Are you working with or have you discovered a material or its properties that exhibit OMG - Outrageous Materials Goodness?
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CORPORATE SPOTLIGHT

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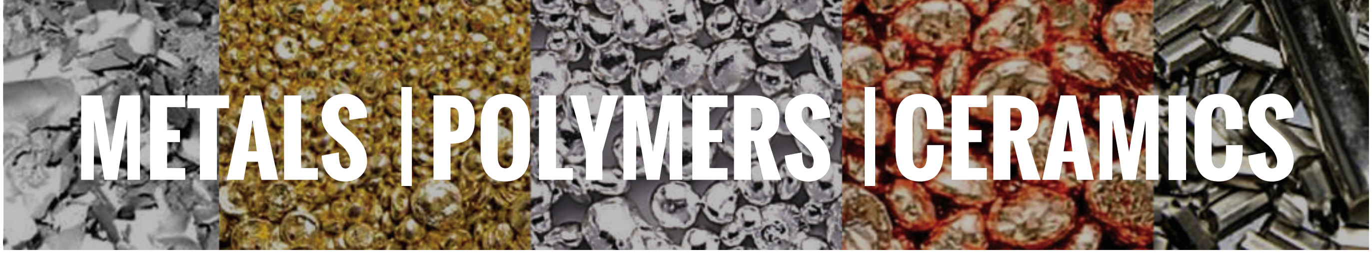
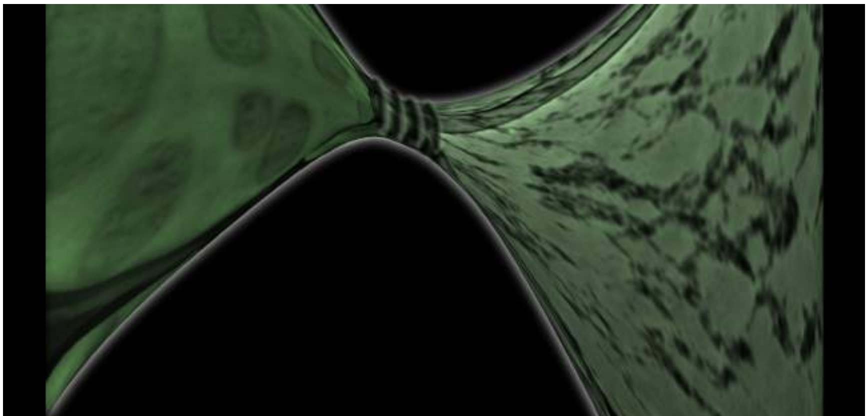


METALS | POLYMERS | CERAMICS



ORNL's tough new plastic is made with 50% renewable content from biomass. Courtesy of ORNL. Conceptual art by Mark Robbins.

RENEWABLE MATERIALS MAKE STRONGER PLASTIC

Researchers at the Department of Energy's Oak Ridge National Laboratory, Tenn., made a better thermoplastic by replacing styrene with lignin, a brittle, rigid polymer that, with cellulose, forms the woody cell walls of plants. In doing so, they invented a solvent-free production process that interconnects equal parts of nanoscale lignin dispersed in a synthetic rubber matrix to produce a meltable, moldable, ductile material at least 10 times tougher than acrylonitrile, butadiene, and styrene (ABS). The resulting thermoplastic—called ABL for acrylonitrile, butadiene, lignin—is recyclable, as it can be melted three times and still perform well. *ornl.gov.*

BACTERIA HELPS PLATINUM FORM

Panning for platinum grains in Brazil: Frank Reith and Barbara Etschmann. Courtesy of University of Adelaide.

Scientists uncovered the important role of specialist bacteria in the formation and movement of platinum and related metals in surface environments. "These platinum group elements are strategically important metals, but finding new deposits is becoming increasingly difficult due to our limited understanding of the processes that affect the way they are cycled through surface environments," says Frank Reith, at the University of Adelaide's School of Biological Sciences and visiting researcher at CSIRO Land and Water, both in Australia. "This research reveals the key role of bacteria in these processes. This improved biogeochemical understanding is not only important from a scientific perspective, but we hope will also lead to new and better ways of exploring these metals."

"Traditionally it was thought that these platinum group metals only formed under high pressure and temperature systems deep underground, and that when they were brought to the surface through weathering and uplift, they just sat there and nothing further happened to them," says Reith. "We've shown that is far from the case. We've linked specialized bacterial

BRIEFS

Constellium N.V., Amsterdam, signed a contract with **Airbus,** France. Under the new agreement, Constellium will supply Airbus with a broad range of advanced aluminum rolled products for airframes including wing skin panels, aero-sheets for fuselage panels, as well as rectangular and pre-machined plates for structural components. *constellium.com, airbus.com.*

Dutch startup **Eurekite** developed a new kind of ceramic, one that is both flexible and easily made at varying degrees of thickness. The company, affiliated with the University of Twente in the Netherlands, is initially marketing the new product as a replacement for traditional printed circuit board materials. *eurekite.com.*

Alcoa Inc., Pittsburgh, received a five-year contract from the **U.S. Army** worth up to $50 million for R&D projects focused on developing lightweighting solutions for ground combat vehicles, such as the monolithic hull for combat vehicles shown here. *alcoa.com, tardec.army.mil.*

communities, found in biofilms on the grains of platinum group minerals at three separate locations around the world, with the dispersion and reconcentration of these elements in surface environments. We've shown that nuggets of platinum and related metals can be reformed at the surface through bacterial processes." *For more information: Frank Reith, 61.8.8303.8469, frank.reith@adelaide.edu.au, www.adelaide.edu.au.*

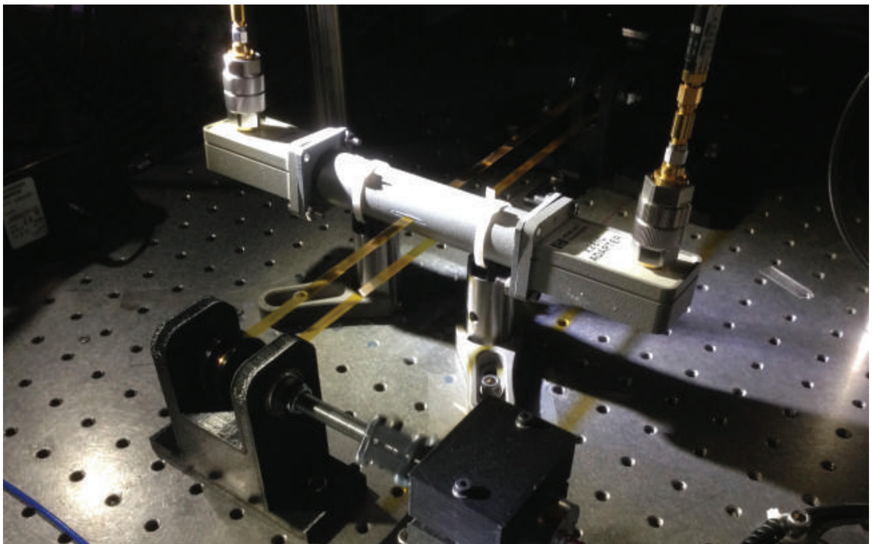
COAL COULD HOLD KEY TO DOMESTIC RARE MINERALS

Virginia Tech engineers developed a way to extract valuable rare earth minerals from coal and coal byproducts. Eventually they hope to construct a mobile pilot plant in Southwest Virginia.

With supplies growing scarce of essential materials needed to make products ranging from smart phones to windmills, researchers at Virginia Polytechnic Institute and State University (Virginia Tech), Blacksburg, are working with academic and industry partners on a $1 million pilot project to recover rare earth elements from coal. Funded in part by a U.S. Department of Energy National Energy Technology Laboratory grant, engineers will test HHS technology, a patented process that takes advantage of properties of water-friendly and water-repellent materials to extract rare earth elements from coal waste, according to Professor Roe-Hoan Yoon.

The best known source of the heavy rare earths is the clay from the Jiangxi Province, South China. But those resources are expected to be exhausted within 20 years, while recent studies show that coal may be an excellent source of higher value heavy rare earth elements. If the currently funded Phase I project is successful, researchers will seek $6 million in Phase II funding that will involve construction and testing of a mobile facility to be tested at different coal cleaning facilities in the central Appalachian coal field. *For more information: Roe-Hoan Yoon, 540.231.7056, ryoon@vt.edu, www.eng.vt.edu.*

TESTING | CHARACTERIZATION



Electrical property measurements of a plastic tape (yellow) were taken using a specially designed microwave cavity (white cylinder at center) and accompanying electrical circuit. Courtesy of N. Orloff/NIST.

BRIEFS

Thermo Fisher Scientific, Tewksbury, Mass., acquired **Inel Inc.,** France, a provider of real-time x-ray diffraction systems. The business will be integrated into Thermo Fisher's analytical instruments segment. *thermofisher.com.*

Ceralink Inc., Saint Clairsville, Ohio, expanded its materials testing lab and will serve the aerospace industry's metal testing programs, putting 16 new MTS Landmark Generation test frames to work on metals. *ceralink.com.*

Zwick/Roell AG, Germany, will supply 19 testing systems to **Sapa Extrusions North America,** Rosemont, Ill., an aluminum extrusion producer. Sapa recently conducted an internal audit of its North American tensile testing labs to enhance product quality and standardize testing procedures. *zwick.com, sapagroup.com.*

REAL-TIME RESONANCE TESTING ON A ROLL

Physicists at the National Institute of Standards and Technology (NIST), Gaithersburg, Md., developed a fast, nondestructive testing method for roll-to-roll manufacturing that can be used in real-world conditions. A roll-to-roll setup was used to run a strip of polyimide plastic tape through a microwave cavity. Electromagnetic waves build up inside the metal cavity at a specific resonance frequency determined by its dimensions, but when an object enters the cavity, the resonance frequency changes according to the object's size, electrical resistance, and dielectric constant. When researchers passed the polyimide tape through the cavity, the change in resonance frequency corresponded to the tape's thickness.

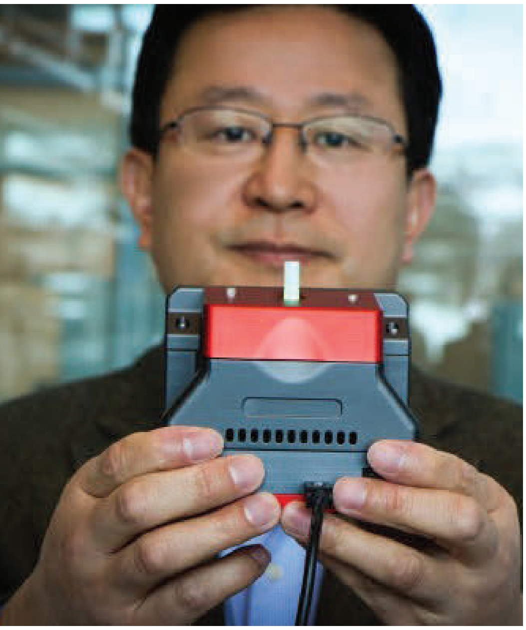
Because polyimide's electrical properties are well known, this method of cavity resonance could be used on production lines to monitor whether or not tape is being produced at a consistent thickness. Real-time testing could be used to tune the manufacturing process without shutting it down or to discard faulty product before it leaves the factory. The entire product—not just a sample—can be measured, and because the method is nondestructive, a batch that passes the test could be sold. *nist.gov.*

HANDHELD NANOFIBER SCANNER SEEKS LEAKS

Engineers at the University of Utah, Salt Lake City, developed a fiber composite material for a handheld scanner that can detect small traces of alkane fuel vapor, an odorless and colorless ingredient in combustible materials such as airplane fuel and oil. The composite contains two nanofibers that transfer electrons to each other. When alkane is present, it blocks the electron transfer, alerting the scanner. Until now, there has been no way to sniff out alkane in the field. Detection required an oven-sized instrument in a lab. Uses for the new device include early leak detection on oil pipelines and aircraft fuel tanks as well as security applications. Many homemade explosives, such as those used in the

The founders of **Jeol Ltd.,** Peabody, Mass., were honored at Pittcon 2016, held during March in Atlanta. The Pittcon Heritage Award was presented to Gon-emon Kurihara, Jeol president, "In recognition of their scientific vision and pioneering leadership, directing the post-World War II effort in Japan to build an electron microscope and founding one of the greatest Japanese instrumentation companies." *jeolusa.com.*

From left, Carsten Reinhardt, Gon-emon Kurihara, and William Sharpe. Courtesy of Roy Engelbrecht.

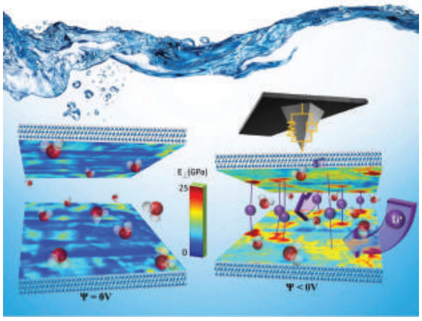


Professor Ling Zang displays a prototype handheld detector that can sense explosive materials and toxic gases. Courtesy of Dan Hixson/University of Utah.

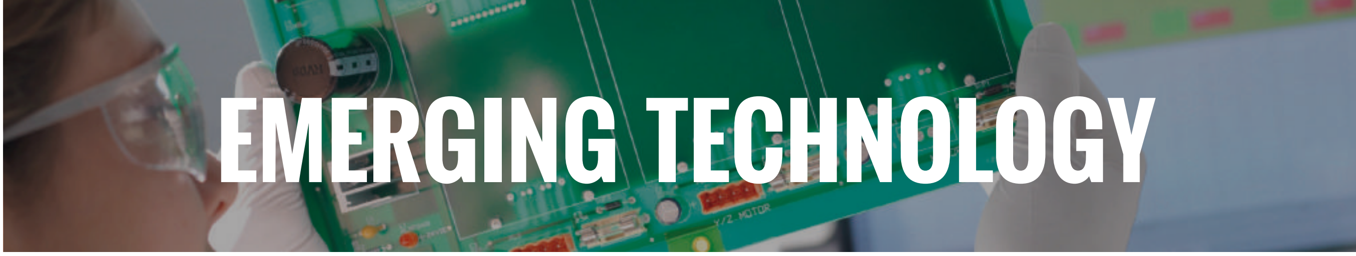
Oklahoma City Bombing, include alkane-containing fuel oils. *utah.edu.*

2D ELECTRODE ENERGY STORAGE MAKES HEADWAY

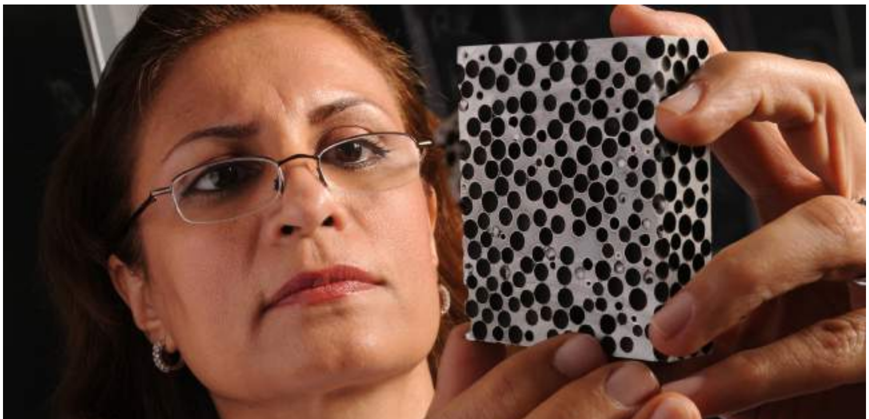
Researchers at Oak Ridge National Laboratory (ORNL), Tenn., observed for the first time at the nanoscale and in a liquid environment how ions move and diffuse between layers of a MXene electrode during electrochemical cycling. MXene—a 2D material composed of carbon or nitrogen sandwiched between transition metal layers—exhibits very high electrical capacitance and is being explored as a next-generation energy storage material for supercapacitors and batteries. Using scanning probe microscopy and theoretical calculations, the team explored how ions enter and migrate within the MXene and how they interact with the active material. Scientists observed that when positively charged cations are introduced into the negatively charged MXene material, it becomes stiffer. The team measured local changes in stiffness and found a direct correlation between the diffusion pattern of ions and stiffness. Working within a liquid environment allowed measurement of mechanical properties in-situ at different stages of charge storage, providing direct insight about where ions were stored. *ornl.gov.*



When a negative bias is applied to a 2D MXene electrode, Li+ ions from the electrolyte migrate in the material via specific channels to the reaction sites, where the electron transfer occurs. Courtesy of ORNL.



EMERGING TECHNOLOGY



Afsaneh Rabiei examines a sample of composite metal foam.

METAL FOAM CAN TAKE THE HEAT

Researchers at North Carolina State University, Raleigh, determined that lightweight composite metal foams (CMFs) are significantly more effective at insulating against heat than the conventional base metals and alloys that comprise them and also exhibit greater thermal stability. CMFs are hollow spheres made of materials such as carbon steel, stainless steel, or titanium embedded in a matrix of steel, aluminum, or metallic alloys.

In one test, researchers exposed samples of steel-steel CMF, measuring 2.5 × 2.5 in. and 0.75 in. thick, to a fire with an average temperature of 800°C for 30 minutes on one side. It took eight minutes for the steel-steel CMF to reach 800°C through the entire thickness of the sample, but it took only four minutes for a piece of bulk stainless steel with the same dimensions to reach the same temperature throughout. Researchers also found that the CMF made entirely of stainless steel expands 80% less than bulk stainless steel at 200°C, and the differential increases at higher temperatures. Additionally, the CMF expands at a fairly constant rate, whereas conventional bulk metals and alloys expand more rapidly as temperature increases. The findings demonstrate that CMF is promising for use in storing and transporting nuclear material, hazardous materials, explosives, and other heat-sensitive materials, as well as for space exploration. *ncsu.edu.*

FOLDABLE 3D MATERIAL CHANGES SHAPE AND SIZE

Researchers at Harvard University, Cambridge, Mass., designed a novel 3D material that is versatile, tunable, and self-actuated. Inspired by an origami technique called snapology, the structure is made from extruded cubes with 24 faces and 36 edges. By folding certain edges, which act like hinges, the material can be deformed into many different shapes. The team connected 64 of these individual cells to create a 4 × 4 × 4 cube that can grow and shrink, change its shape globally, change the orientation of its microstructure, and fold completely flat. As the system changes shape, it also changes stiffness. These actuated changes in material properties add a fourth dimension to the structure. While the Harvard team used pneumatic actuators that were programmed to bend specific hinges, the material can be embedded with any type of actuator—including thermal, dielectric, or even water—eliminating the need for external input.

"This research demonstrates a new class of foldable materials that is also completely scalable," explains graduate student Johannes T.B. Overvelde. "It works from the nanoscale to the meter-scale and could be used to make anything from surgical stents to portable pop-up domes for disaster relief." *harvard.edu.*

Harvard researchers designed a new type of foldable material that is versatile, tunable, and self-actuated. Courtesy of Johannes Overvelde/ Harvard SEAS.

BRIEF

The University of British Columbia, Canada, received $11 million from Vancouver-based diamond pioneer and philanthropist Stewart Blusson and his wife, Marilyn, to support quantum materials research. In recognition, the UBC Quantum Matter Institute has been renamed the **Stewart Blusson Quantum Matter Institute.** The Institute will move to a new facility later this year and will include 20 professors by 2019. *www.ubc.ca.*

From left, UBC President Martha Piper, Stewart and Marilyn Blusson, and Andrea Damascelli. Courtesy of Don Erhardt.

CORPORATE SPOTLIGHT

INSTRON

ABOUT INSTRON

Instron is a leading global manufacturer of testing equipment for the material and structural testing markets used to evaluate materials ranging from native tissue to advanced high-strength alloys. Instron systems perform a variety of tests such as tension, compression, cyclic, fatigue, impact, melt flow, multi-axis, rheology, and torsion. Providing single-source convenience through a comprehensive range of solutions and localized service & support, Instron's broad range of service capabilities include assistance with performance verification & calibration, standards compliance, testing system relocation, staff training, and preventative maintenance.

The Instron Centers of Excellence around the world ensure that behind every Instron system is an unprecedented commitment and dedication to quality and customer satisfaction. Instron remains involved with multiple ASTM and ISO committees, gaining firsthand knowledge of recent and upcoming changes to standards that affect our customers.

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PROCESS TECHNOLOGY

ORNL researchers demonstrated a production method that dramatically reduces the cost and energy required to produce carbon fiber.

CARPET FIBER TO CARBON FIBER

Researchers at the DOE's Oak Ridge National Laboratory (ORNL), Tenn., demonstrated a production method for carbon fiber that uses the low cost, acrylic fiber commonly found in carpets and clothing as a precursor material. This process could reduce the cost of carbon fiber by as much as 50% and reduce the energy consumed in its production by more than 60%.

To make carbon fiber, a carbon-containing polymer fiber precursor—typically polyacrylonitrile (PAN) that has been chemically optimized—is subjected to an energy-intensive process of controlled heating and stretching. It was suspected that textile-grade PAN, which is chemically similar to specialty PAN but costs roughly half as much, could be used instead, but laboratory-scale experiments weren't sufficient to demonstrate this. Using ORNL's Carbon Fiber Technology Facility, researchers were able to define a production method that not only uses the more affordable precursor, but also is significantly more efficient. Because more than 90% of the energy needed to manufacture advanced composites is consumed in manufacturing the carbon fiber itself, the new method will enable an earlier net energy payback. Mechanical property analysis and automotive industry prototyping are promising, and ORNL is accepting license applications for the process. *ornl.gov.*

SINGLE-CRYSTAL SOLIDS

Scientists at Lehigh University, Bethlehem, Pa., demonstrated a new process to make solid materials in single-crystal form, giving them the properties required in high-tech applications such as lasers and semiconductors. Because many solids decompose when melted, the group devised a novel heating strategy to convert glass into a single crystal without having it pass through a gaseous or liquid phase. The researchers first use a laser to heat antimony-sulfide (Sb_2S_3) chalcogenide glass from the ambient temperature to a crystallization temperature well below its melting point. Next, they use electron diffraction and microscopy color mapping to detect the orientation of atomic configurations and prove single crystallinity at different places on the sample. "Once we make the single-crystal line, we backtrack to get additional parallel single-crystal lines and eventually a single-crystal-layer surface on top of the glass. We can stitch these lines to convert the entire glass surface into a single crystal," says Himanshu Jain, professor of materials science and engineering. *lehigh.edu.*

Scanning electron micrograph (a) and image quality map (b) of the micrograph demonstrate the ability to fabricate patterned single-crystal architecture on a glass surface. Courtesy of Dmytro Savytskii.

BRIEFS

New websites were launched by **The Metal Powder Industries Federation** (MPIF), **APMI International,** and the **Center for Powder Metallurgy Technology** (CPMT), all in Princeton, N.J. The MPIF site includes a directory of powder metallurgy (PM) fabricators and suppliers, a PM publications section hosted by Thomson Reuters Techstreet, and educational video content. The APMI International site provides industry employment postings and information on the Powder Metallurgy Technology Certification program, along with members-only access to an archive of the *International Journal of Powder Metallurgy,* the *Who's Who in Powder Metallurgy Membership Directory,* and a series of free e-learning courses. On its website, CPMT offers information on current and completed technology programs, student scholarships, and the CPMT/Axel Madsen Conference Grants program. *mpif.org, mpif.org/apmi, cpmtweb.org.*

CORPORATE SPOTLIGHT

SCIENTIFIC ALLOYS INC.

ABOUT SCIENTIFIC ALLOYS

Scientific Alloys, Inc. is a steel mill in miniature for manufacturing small quantity orders of specialty metals. When small quantities are not in stock…We make it! Our products include hot forged bar, hot rolled plate and sheet, cold finished bar and rod, drawn wire, and many other custom orders. Materials readily supplied: Hiperco 50A®, Pure Nickel 270®, Hi Mu 80®, Mu Metal®, Kovar®, Invar 36®, Permendur®, Invar FM, Super Invar, Ni Alloy 39, Ni Alloy 42, Ni Alloy 46, Ni Alloy 49, Ni Alloy 52, Constantan, and many more. Scientific Alloys, Inc. is the only company in the USA that stocks and sells Nickel 270 forgings, hot rolled plate, and cold finished bar that is produced on premises. We produce this material ourselves from high purity nickel powder to very strict and stringent quality standards. We have billet material on hand, ready to process into the forms our customers' need, when they need it. You can buy specialty metals from a broker, or you can come directly to the source. Serving the Scientific, Defense, Electronics, Magnetics, Optical, and Aerospace industries for over 30 years.

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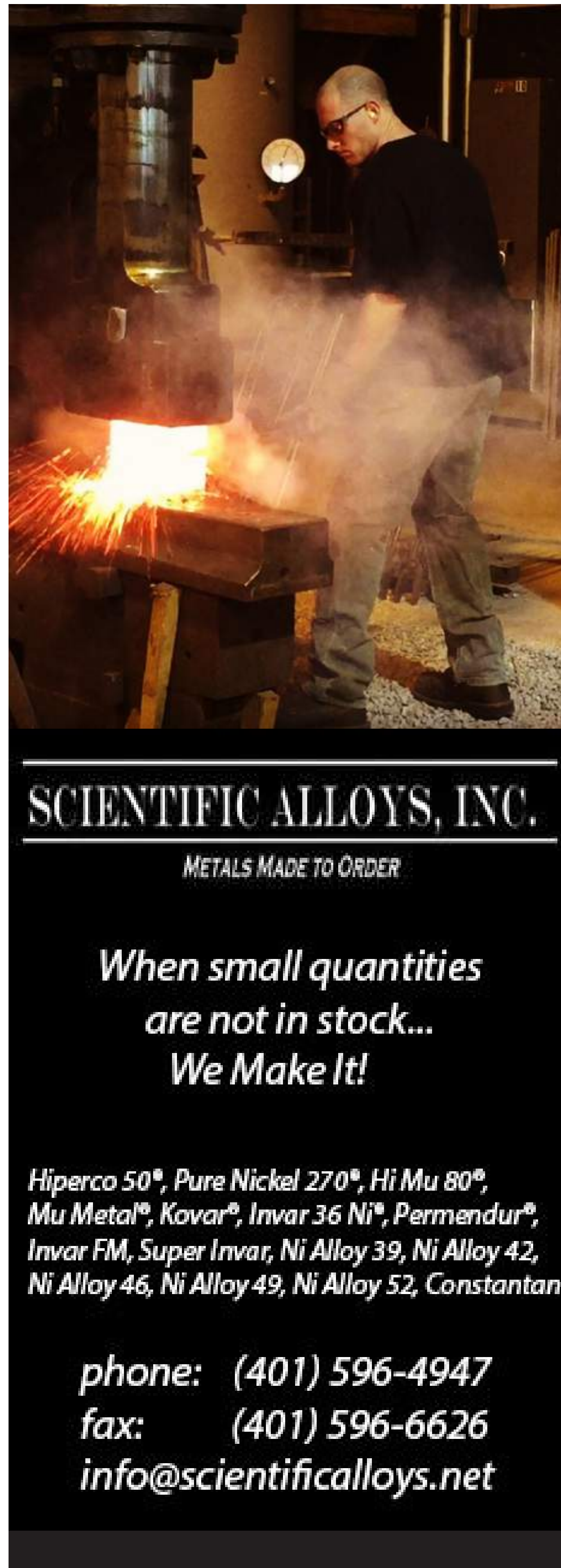
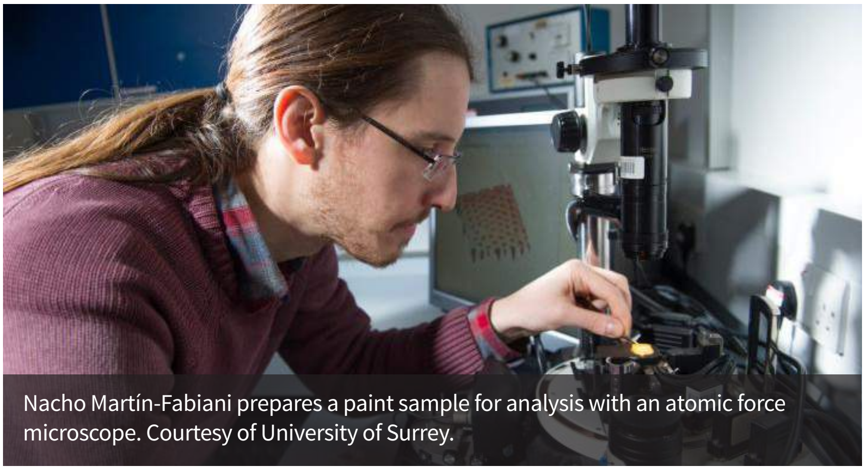


SURFACE ENGINEERING



Nacho Martín-Fabiani prepares a paint sample for analysis with an atomic force microscope. Courtesy of University of Surrey.

NANOTECH RESEARCH COULD IMPROVE EVERYDAY ESSENTIALS

Researchers from the University of Surrey, UK, in collaboration with the Université Claude Bernard, France, used computer simulation and materials experiments to show how coatings with different sized particles, such as paints, spontaneously form two layers as they dry. This mechanism can be used to independently control properties at the top and bottom of coatings, which could help increase performance across industries as diverse as beauty and pharmaceuticals.

"When coatings such as paint, ink, or even outer layers on tablets are made, they work by spreading a liquid containing solid particles onto a surface, and allowing the liquid to evaporate. This is nothing new, but what is exciting is that we've shown that during evaporation, the small particles push away the larger ones, remaining at the top surface whilst the larger ones are pushed to bottom," says Andrea Fortini of the University of Surrey.

The team is continuing research to understand how to control the width of the layer by changing the type and amount of small particles in the coating and explore their use in industrial products such as paints, inks, and adhesives. *For more information: Andrea Fortini, 01483 68 6856, a.fortini@surrey.ac.uk, www.surrey.ac.uk.*

DIAMOND COATINGS ENHANCE IRON AND STEEL TOOLS

Due to their hardness, diamond coatings are widely used in the manufacture of cutting tools. They are used to treat some metal alloys, ceramics, and carbon composites, but are ineffective for iron and steel because at high temperatures, carbon interacts with these metals and gradually collapses. To resolve this problem, scientists at Tomsk Polytechnic University, Russia, developed a composite coating based on diamond and cubic boron nitride, the hardest known material.

Coatings were obtained from gas by means of plasma. Researchers have already developed a diamond sputtering technology from a mixture of methane and hydrogen. Cubic boron nitride can also be obtained from gas, enabling the scientists to cover a carbide tool with thin films, increasing its strength. *tpu.ru/en.*

TPU scientists created coverings for next-generation cutting tools that are not only durable, but also suitable for the treatment of most materials. The technology produces diamond and cubic boron nitride thin films from a gas mixture.

BRIEFS

PPG Industries completed a $7.8 million investment at its **Coatings Innovation Center** in Allison Park, Pa., just 20 minutes from its global headquarters in Pittsburgh. Upgrades to the facility include increased laboratory and testing space and upgraded equipment that improves the technical capabilities of the company's primary research and development facility for paint and coatings. *ppg.com.*

The **National Science Foundation,** Arlington, Va., awarded a $746,366 grant to **WattGlass LLC** to further develop the **University of Arkansas'** (Fayetteville) patent-pending coating technology that makes glass anti-reflective, self-cleaning, and highly transparent. The nanoparticle-based coating will increase the efficiency of solar panels and reduce cleaning and maintenance costs, according to company sources. *nsf.gov, wattglass.com.*

NSL ANALYTICAL SERVICES, INC.

TEST, ANALYZE, CHARACTERIZE

ADDITIVE MANUFACTURING: A NEW FRONTIER IN TESTING

NSL Analytical Services, Inc. (NSL), a materials testing company, has long focused on the raw materials (metal powders) used to grow finished parts, and its analytical results have helped support the rise of Additive Manufacturing (AM) for over 25 years. “As an analytical laboratory, we have been testing metal powders for more than 40 years. Testing the chemical composition is a natural thing for us and we’re bringing that expertise to AM in a new way,” shares Larry Somrack, President of NSL. “New clients are now more interested in how the powders behave after multiple runs in a powder bed application. The properties of metal powder reuse are a hot topic right now and companies are hungry for scientific data.”

NSL offers complete Chemical Composition, Powder Characterization and Metallurgical Evaluation for AM applications. Our technical specialists work with clients to verify feed stock, identify mechanical and chemical properties, and improve the properties of their products.

NSL’s Metallurgists and Chemists help the client to understand the chemistry and physical properties of powder metal and how the powder responds to Direct Metal Laser Sintering (DMLS) over multiple runs. Our Metallurgical Engineers apply their industrial experience to the process, assisting customers at identifying and preventing problems.

NSL’s team is actively involved in organizations such as ASM, SAE and the ASTM F42 Committee on Additive Manufacturing Technologies, assisting the industry in establishing guidelines, test methods and standards.

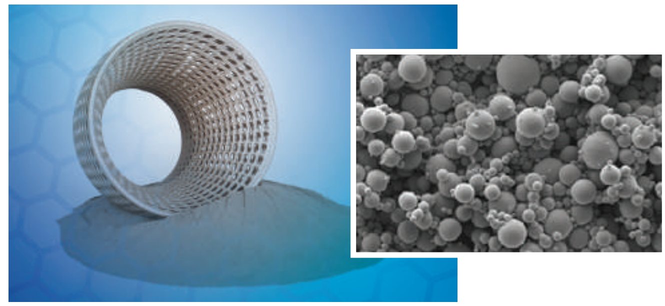
CUSTOMERS ASK AND NSL RESPONDS

More than just providing numbers, NSL listens to help customers reach the highest standards of product quality from design to product launch. Customers rely on NSL to meet their production needs by providing rush results, detailed failure analysis and consulting services.

When you require material characterization, quality control checks, process evaluation, failure analysis, or specialized testing, you can trust the staff of NSL to provide accurate, reliable and repeatable testing results.

Our testing capabilities include:

- Bulk Chemistries for Alloys
- Inorganic Trace Element Analysis
- Thermal Analysis
- Mechanical Testing



- Microscopy Evaluations
- Metallurgical Evaluations

QUALITY AND SAFETY COME FIRST

Through the dedication of NSL employees, their determination for excellence and the integrity of their work, NSL has achieved great success in the laboratory testing industry. NSL continues to dedicate itself to a culture of safety, continuous improvement, employee training, and a robust quality system. NSL maintains major industry accreditations and approvals such as:

- ISO/IEC 17025
- Nadcap
- GE-S-400
- Boeing
- SNECMA
- Rolls-Royce
- Pratt & Whitney
- ASME NQA-1 compliant
- 10 CFR Part 21
- 10 CFR 50 Appendix B

TRUST - TECHNOLOGY - TURNAROUND

NSL is dedicated to being one of most reliable test labs in the world. Customers can trust us with their most critical materials testing needs.

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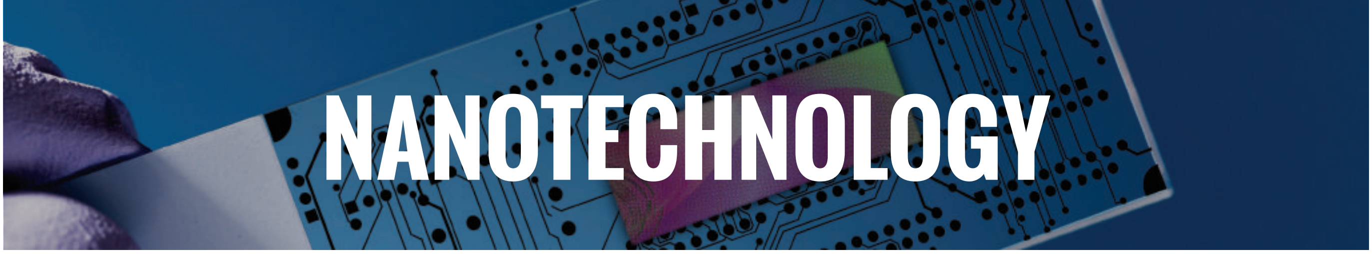
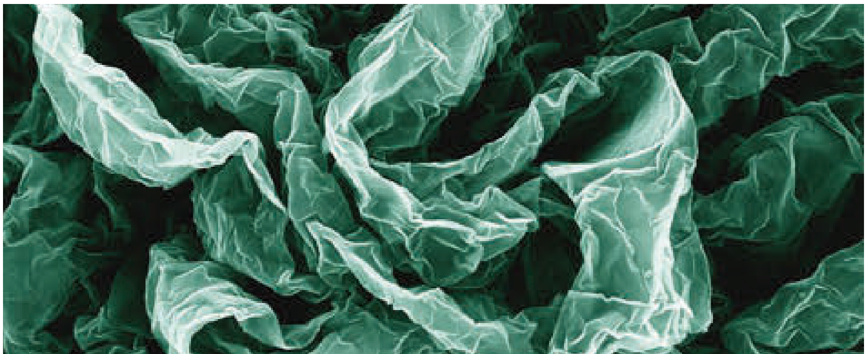
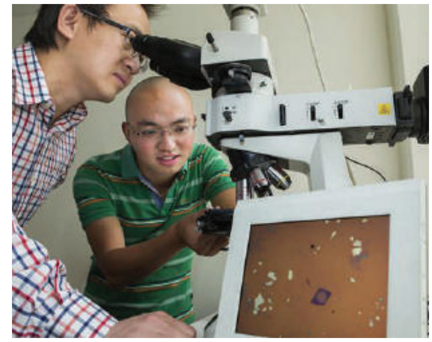


NANOTECHNOLOGY



Wrinkles and crumples, introduced by placing graphene on shrinky polymers, can enhance graphene's properties. Courtesy of Hurt and Wong Labs/Brown University.



Larry Lu (left) and Jiong Yang with lens shown on screen. Courtesy of Stuart Hay/ANU.

ENHANCING GRAPHENE WITH WRINKLES

Engineers at Brown University, Providence, R.I., show that graphene, wrinkled and crumpled in a multistep process, becomes significantly better at repelling water. Researchers deposited graphene oxide in layers onto shrink films. As the films shrink, the graphene on top is compressed, causing it to wrinkle. Researchers experimented with different configurations in the successive generations of shrinking. For example, sometimes they clamped opposite ends of the films, which caused them to shrink only along one axis. Clamped films yielded graphene sheets with periodic, nearly parallel wrinkles across its surface. Unclamped films shrank in two dimensions, both length- and widthwise, creating a graphene surface that was crumpled in random shapes.

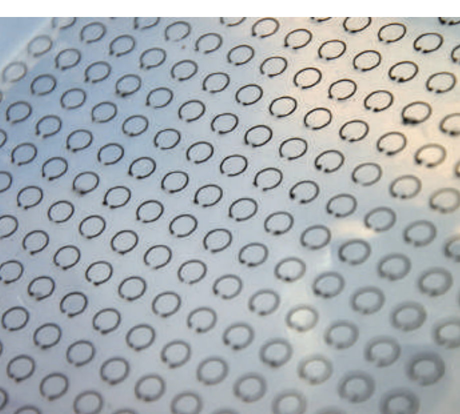
A highly crumpled graphene surface becomes superhydrophobic with three unclamped shrinks. Crumpling also enhances graphene's electrochemical behaviors, which could be useful in next-generation energy storage and generation. Crumpled graphene used as a battery electrode has as much as a 400% increase in electrochemical current density over flat graphene sheets, significantly boosting efficiency. *brown.edu.*

THIN LENS SEES FUTURE IN MINIATURE CAMERAS

Scientists created the world's thinnest lens, one two-thousandth the thickness of a human hair, opening the door to flexible computer displays and a revolution in miniature cameras. "This type of material is the perfect candidate for future flexible displays," says Yuerui Lu of the Australian National University Research School of Engineering. "We will also be able to use arrays of micro lenses to mimic the compound eyes of insects."

The 6.3-nm lens outshines previous ultrathin flat lenses, made from 50-nm thick gold nanobar arrays, known as a metamaterial. Molybdenum disulphide is in a class of materials known as chalcogenide glasses that have flexible electronic characteristics, which have made them popular for high-tech components. The team created their lens from a crystal 6.3-nm thick, which they peeled off a larger piece of molybdenum disulphide with sticky tape. They then created a 10-μm radius lens, using a focused ion beam to shave off layers atom by atom, until they had the dome shape of the lens.

The team discovered that single layers of molybdenum disulphide, 0.7 nm thick, have remarkable optical properties, appearing to a light beam to be 50 times thicker, at 38 nm. This property, known as optical path length, determines the phase of the light and governs interference and diffraction of light as it propagates. *For more information: Yuerui (Larry) Lu, 61.2.612.59582, yuerui.lu@anu.edu.au, www.anu.edu.au.*



BRIEF

Engineers at **Iowa State University,** Ames, developed a flexible, stretchable, and tunable *meta-skin* that uses rows of small, liquid-metal devices to cloak an object from the sharp eyes of radar. By stretching and flexing the polymer skin, it can be tuned to reduce the reflection of a wide range of radar frequencies. *iastate.edu.*

Meta-skin developed at Iowa State University. Courtesy of Liang Dong.

Powerful but Simple Diagnostics

Ipsen's PdMetrics™ software platform for predictive maintenance securely connects to a network of integrated sensors on your furnace to gather data, analyze it and provide real-time diagnostics that improve the health and integrity of your equipment. After analyzing the data in our secure Diagnostic Support Center – where we look for anomalies and trends that may indicate the need for further actions – we contact you directly with suggested next steps when needed. If the Platinum Protection Plan was selected, Ipsen will also send a qualified technician and any needed parts to help resolve the issue. Other key features include:

- Monitor the health and integrity of critical systems on the PdMetrics dashboard, including the hot zone, pumping system, cooling system and vacuum integrity
- Experience real-time furnace visibility for faster, better decision making – from monitoring dashboards at the furnace, office PC, smartphone or tablet to sending urgent alerts by text or email
- Achieve smart factory integration with furnace fleet analytics, allowing you to see the health of all furnaces at all of your facilities

Overall, the PdMetrics software platform integrates with critical systems to provide you with sophisticated monitoring and diagnostics, as well as help you achieve insights never before seen in the thermal processing industry.

Boeing 787 Dreamliner. Courtesy of Boeing.

NEW TRENDS IN AEROSPACE:

SAVING THE BOTTOM LINE WITH COLD SPRAY REPAIRS

Julio Villafuerte, CenterLine (Windsor) Ltd., Windsor, Ontario*
Linh Tran, L.J. Walch Co. (FAA-DMIR), Livermore, Calif.

Cold spray is an effective method of depositing a variety of temperature-sensitive materials in specialized applications, such as high-value aerospace component repair.

**Member of ASM International*

Cold spray is a solid-state coating process that uses a high-speed gas jet to accelerate powder particles toward a substrate where metal particles plastically deform and consolidate upon impact. The technique got its name from the relatively low temperature involved in the process, which is typically much lower than the melting point of both the spray material and substrate. The concept of "cold spraying" metallic materials onto substrates dates to the early 1900s. However, it was not until the 1980s that the applicability of this technology was demonstrated and patented by the Institute of Theoretical and Applied Mechanics of the Academy of Sciences in Novosibirsk[1] (high pressure cold spray) and then by the Obninsk Center for Powder Spraying[2] (low pressure cold spray) in the former Soviet Union.

In cold spray equipment, air, nitrogen, or helium at prescribed pressures and temperatures is injected into converging-diverging (de Laval) nozzles to accelerate the gas jet to supersonic speeds. The spray material, in powder form, can be introduced upstream in the nozzle (high pressure cold spray) or downstream into the diverging section of the nozzle (low pressure cold spray) and is then propelled by the gas jet against a substrate at high velocities (Fig. 1). At a given impact temperature, each type of spray material requires a minimum level of kinetic energy, above which acceptable bonding to the substrate may occur. The type of gas, gas pressure, and gas temperature determine the amount of kinetic energy available to accelerate the particulate. Many common engineering materials can be successfully cold sprayed at relatively low pressures (less than 300 psi) and gas temperatures (below 600°C), by using nitrogen or air.

Metal powder adheres to the substrate and the deposited material is achieved in the solid state. Therefore, cold spray deposit characteristics are unique, making this technique suitable for depositing well bonded, low porosity, oxide-free coatings using a range of traditional and advanced materials on many types of substrates, especially in nontraditional, temperature-sensitive applications, such as high-value aerospace component repair.

COLD SPRAY IN THE AEROSPACE INDUSTRY

For many years, aluminum and magnesium alloys have been the materials of choice for use on both structural and nonstructural aircraft components including castings for housings of many aircraft components. Well-known performance characteristics, established fabrication methods, and recent technological advances are just a few reasons these alloys are still preferred. An aircraft lifespan often surpasses the commercial availability of standard replacement components. One challenge for the industry is that this obsolescence makes replacement components increasingly expensive or even impossible to obtain. Therefore, the ability to economically and reliably restore damaged components is an important necessity of aircraft maintenance.

Thermal spray processes, such as plasma or arc wire spraying, have traditionally been used to perform limited repairs on damaged aircraft components. However, excessive heat, porosity, distortion, oxide inclusions, and other issues associated with conventional thermal spray have prevented their widespread use in a vast number of aircraft repairs. In addition, the thermal spray plume is usually very wide and requires labor-intensive masking procedures to protect areas around the repair from overspray. Masking often represents a sizeable portion of repair costs.

Over the past decade, pioneering thermal spray shops serving the aerospace industry have developed numerous cold spray repair procedures to bring back to service hundreds of high-value aircraft components. This requires the ability to restore these components to the same quality standards as original OEM components while saving the industry millions of dollars.

REPAIR OF INTEGRATED DRIVE GENERATOR (IDG) HOUSINGS

One excellent attribute of cold spray technology is its ability to create well bonded, low porosity, oxide-free coatings in the solid state and at low temperatures. This is paramount when restoring tight tolerance aircraft castings made of magnesium and/or aluminum, which do not tolerate distortion. Over the past few years, the use of cold spray has seen a significant increase in the repair and restoration of housings for integrated drive generators (IDG), which are used in commercial aircraft such as the Boeing 737NG, 747, 777, and Airbus A320, A330, and A340 (Fig. 2).

An IDG is an in-flight power generation device that converts the variable input rotational speed of an aircraft engine into constant speed, which is used to drive an AC generator unit contained within the device. Ultimately, the IDG supplies constant frequency AC electrical power to the aircraft, greatly simplifying the design of the aircraft's electrical system.

Fig. 1 — Commercial downstream injection cold spray system. Courtesy of CenterLine Windsor Ltd.

Fig. 2 — Boeing 747 integrated drive generator (IDG). Courtesy of L.J. Walch.

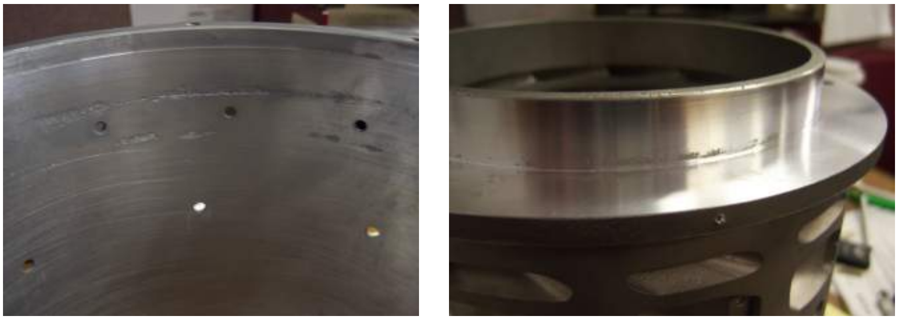


Fig. 3 — Pitting corrosion damage in a Boeing 747 APU generator housing. Courtesy of L.J. Walch.

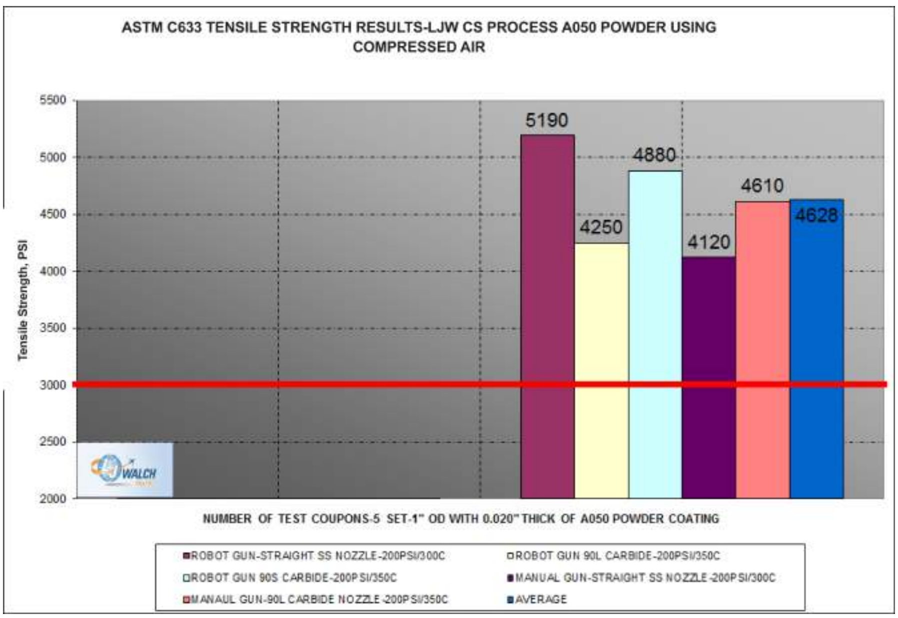


Fig. 4 — ASTM C633 qualification test results. Courtesy of L.J. Walch.

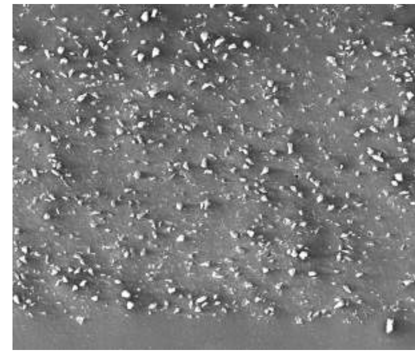


Fig. 5 — Microstructure of SST A050 cold spray composite deposit showing well-dispersed aluminum oxide particles in an aluminum matrix. No lack of bonding with porosity less than 2%. Substrate is aluminum 6061. Courtesy of CenterLine Windsor Ltd.

The device's complex casing is often made of magnesium or aluminum alloys. After years of service, the housing becomes worn or damaged beyond normal repair. Many failures are located at tight tolerance, heat-sensitive areas such as stator bores, exciter bores, pilots, mounting pads, and mating faces (Fig. 3). These areas are difficult to dimensionally restore using conventional thermal methods such as plasma flame spray. With the cold spray approach, these repairs are both feasible and economically viable.

PROCESS QUALIFICATION

With regard to IDG repairs, process qualification included selecting optimum cold spray grade powders (in this case, CenterLine SST A050) and process parameters to produce coatings within the required specifications. Validation was successfully obtained by ASTM C633 bond strength tests, metallographic examination, and 90° bend tests per the OEM's repair validation specifications (Hamilton Sundstrand SPR52). Bond strength results indicate that all test samples failed at stress levels well above the minimum level required (Fig. 4). Metallographic examination reveals a microstructure with porosity levels of less than 2%, no cracking, and no lack of bonding. A typical microstructure is shown in Fig. 5. Further, 90° bend tests with the coating in tension bent around a 0.25-in. radius exhibit no spalling or chipping.

REPAIR PROCEDURE AND QUALITY ASSURANCE

The following steps were taken to ensure proper surface preparation, repair, and inspection:

(a) Existing corroded and/or damaged surfaces were removed.

(b) Spray deposition was facilitated by pre-machining as necessary.

(c) Grit blasting or other methods were used to prepare surfaces and increase surface roughness.

(d) Robotic gun or manual cold spray took place (Fig. 6a).

(e) Repairs were post-machined per OEM engineering specifications (Fig. 6b).

(f) Visual and dimensional inspection occurred.

(g) Nondestructive examination took place.

(h) Painting and/or anodizing was performed as required to improve corrosion performance (Fig. 7).

The main justification for using cold spray in the restoration of these types of components is its ability to extend component lifespan at a fraction of their OEM replacement cost, assuming that the part is commercially available. In many instances, components are no longer available, thus making even stronger economic sense for cold spray restoration. Figure 8 shows examples of the relative cost of replacement of IDGs versus the cost of cold spray restoration to meet required OEM specifications.

CONCLUSION

Cold spray has become an essential tool that complements traditional thermal spray methods for repair and restoration of IDG housings used

(a)

(b)

Fig. 6 — Robotic cold spraying (a) and post-machining (b) operations.

in commercial aircraft. The process enables the aerospace industry to recover high-value and irreplaceable components that otherwise would be scrapped—at a fraction of their replacement cost—thus maximizing profitability. **~AM&P**

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Acknowledgments

The authors acknowledge valuable contributions made by CenterLine (Windsor) Ltd. and L.J. Walch.

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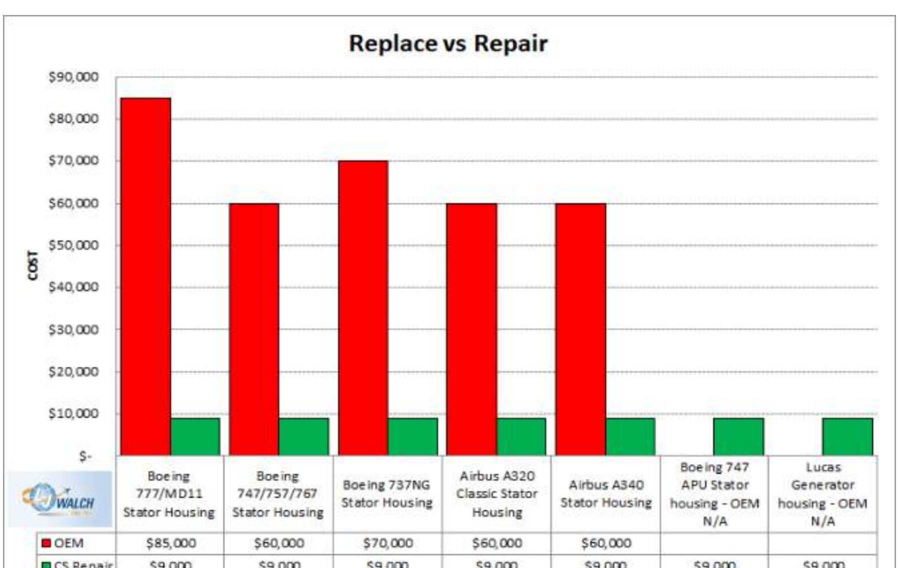


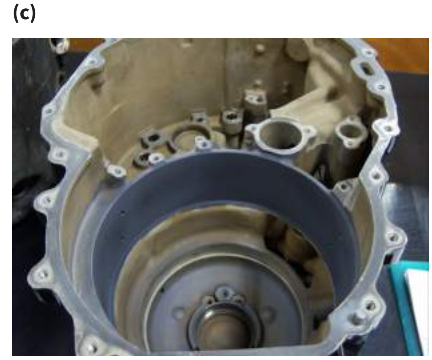
	Boeing 777/MD11 Stator Housing	Boeing 747/757/767 Stator Housing	Boeing 737NG Stator Housing	Airbus A320 Classic Stator Housing	Airbus A340 Stator Housing	Boeing 747 APU Stator housing - OEM N/A	Lucas Generator housing - OEM N/A
OEM	$85,000	$60,000	$70,000	$60,000	$60,000		
CS Repair	$9,000	$9,000	$9,000	$9,000	$9,000	$9,000	$9,000

Fig. 8 — Relative cost of cold spray repair versus replacement for IDGs. Courtesy of L.J. Walch.

(a)

(b)

(c)



(d)

Fig. 7 — Repaired and finished components: (a) Pilot OD, (b) stator bore ID, (c) housing mating surface, and (d) housing bore. Courtesy of L.J. Walch.

DESIGNING SPACE MATERIALS TO WITHSTAND COSMIC DUST

Materials used to construct spacecraft and protective gear—including the International Space Station and space suits for astronauts—must be lightweight yet strong enough to guard against cosmic dust that travels at hypervelocity.

Graham Rideal, Whitehouse Scientific Ltd., Waverton, UK

Hypervelocity is defined as speeds in excess of 2-3 km/sec (7000 mph). While such speeds do not occur naturally on Earth, they are common in space. Hypervelocity impact between objects can generate pressures of up to 1 TPa (150 million psi) and temperatures high enough to vaporize the colliding bodies.

While collisions of large objects are comparatively rare, notable exceptions include craters on the surface of the moon and the giant asteroid believed to have killed off the dinosaurs. The 150-km crater on the Yucatan Peninsula in Mexico (Fig. 1) is widely assumed to have been caused by a 100-km-wide asteroid travelling at 30 km/sec (70,000 mph). Smaller meteors have also been known to knock out satellites (Fig. 2).

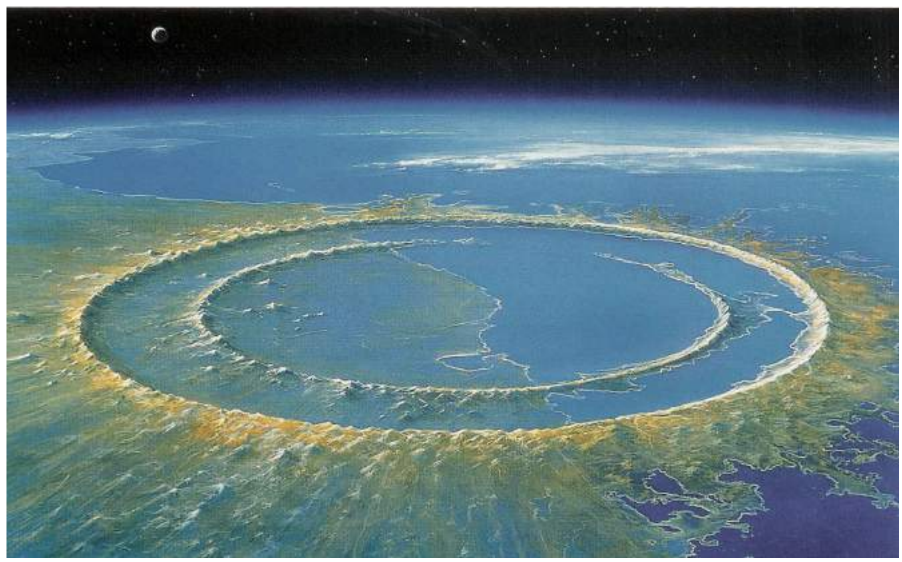


Fig. 1 — Simulation of an asteroid impact in Mexico. Courtesy of National Geographic.

The most frequent collisions in space, however, occur from cosmic dust whose size varies from roughly 1 mm to below 1 μm. Evidence of these collisions was first seen on spacecraft returning to Earth whose surfaces were peppered with microindentations.

Fig. 2 — Meteor damage to a satellite. Courtesy of University of Kent.

CAPTURE AND ANALYSIS

Several methods of collecting cosmic dust for analysis exist, but one technique, which also allows their speed to be calculated, uses aerogel foam (Fig. 3). This ultra-lightweight ceramic foam is approximately 1000 times lighter than glass. When the specialized foam is mounted outside spacecraft, cosmic dust penetrates its structure. It can then be subsequently recovered and analyzed and its penetration depth recorded (Fig. 4). Individual particles are collected and microscopically measured, enabling accurate density calculations.

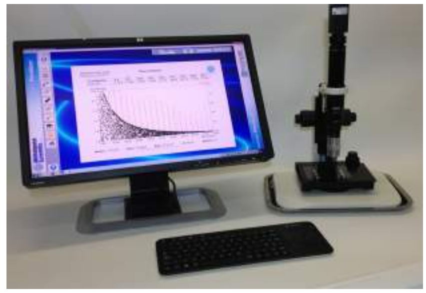
Fig. 3 — Aerogel foam for capturing cosmic dust.

Fig. 4 — Cosmic dust penetrating aerogel foam.

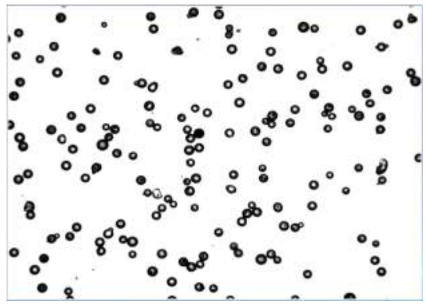
COSMIC DUST SIMULATION

Although cosmic dust is comprised of a range of different types of mineral materials, it is mostly glassy in nature, making glass microspheres a useful experimentation model. In order to determine the appropriate speed to mimic conditions in space, microspheres closest in size to the particles recovered from space were used. These microspheres were then fired into aerogel foam using a hypervelocity gas gun developed at the University of Kent (Fig. 4). The muzzle velocity was varied until it matched the penetration depth observed from the particles collected in space.

During the initial work conducted at the University of Kent, individual glass beads of similar size were collected from broader sized glass beads using tweezers—a time-consuming procedure that made exact size matching difficult. This, in turn, resulted in questionable reproducibility. Use of monodisperse (single size) glass beads enabled a much larger number of beads to be used at a size distribution significantly narrower than could ever be produced manually. Further, the extensive size range made it possible to replicate almost any cosmic dust particle.



(a)



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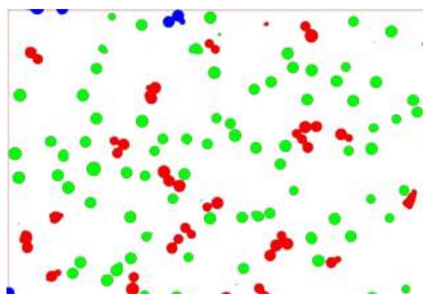

(c)

Fig. 5 — ShapeSizer microscope (a), live image (b), and digitized image (c); touching and edge particles not counted.

These monodisperse microspheres are prepared using a number of different methods including sieving and sedimentation. However, because glass microspheres are manufactured from an industrial melt process, the possibility exists for some irregular particles (cullet) not to be spherulized in the heating column. Therefore, they must be removed from the bulk of the product.

Fig. 6 — Hypervelocity gas gun.

The principle analytical tool, the ShapeSizer Optical Image Analyzer (Fig. 5), is essentially a computer controlled, high power microscope with magnifications up to 80 nm pixel, which was specifically designed to measure and quantify particle size and shape.

All measurements are traceable to the National Institute of Standards and Technology (NIST), Gaithersburg, Md., and have a unique validation procedure that guarantees repeatability. It is therefore possible to monitor the progress of the classification and shape sorting in the manufacturing process. The microspheres used in this experiment were 177±3.7 μm, with 90% of the distribution falling between 171 and 184 μm.

The hypervelocity gun features a muzzle velocity up to 14,000 mph and can fire simulated cosmic dust particles of sizes up to ~1 mm (Fig. 6). The gun is a two-stage device comprising a high pressure chamber followed by an evacuated chamber to simulate the space environment. In between the two chambers sits a microcartridge, measuring 4.3 mm diameter by 4.5 mm long, which contains microspheres that

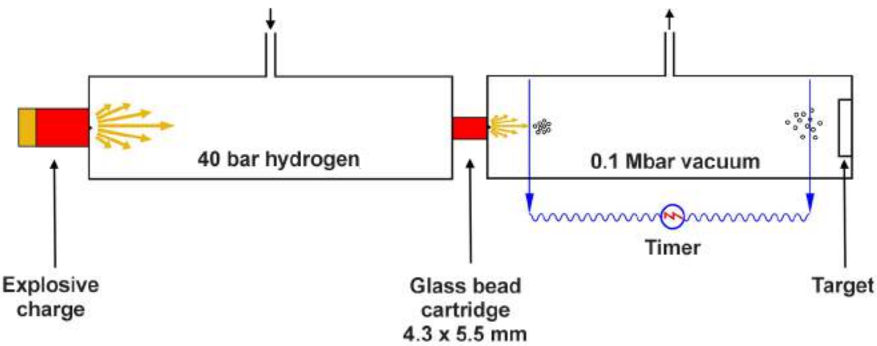

Fig. 7 — Simplified schematic of hypervelocity gas gun.

are held in position by a bursting disc (Fig. 7).

In the first chamber, hydrogen gas is compressed to 40 bar, while the second chamber is evacuated to 0.1 Mbar. The target is mounted at the end of the second chamber. Once the pressure difference between the two chambers is maximized, a shock wave is sent into the compressed chamber via a piston using a standard 12 bore shotgun cartridge. This exceeds the pressure specification of the bursting disc and contents are fired through two laser timing points into the target. In this study, muzzle velocities reached 11,000 mph and a range of metal foils were used as targets.

IMPACT RESULTS

Three different metal foils targets were used, each featuring a 203 μm thickness:

(a) Half hard 302 austenitic stainless steel
(b) Annealed beryllium-copper alloy 25
(c) 2024T3 aluminum alloy

Figure 8 shows impact results for the three materials using 177-μm glass microspheres travelling at 11,000 mph. The dark microcraters show incomplete penetration, while those with white centers show that the beads have partially penetrated the metal. The large hole in the stainless steel foil was caused by a 1-mm ball bearing. Note that the hole is perfectly round because the speed was so high that the metal did not have time to distort.

With regard to the stainless steel (a), some *blind* microcraters are evident where microspheres failed to penetrate, while other microcraters punctured the foil. This could be due to very small differences in the particle size of the microspheres or an inhomogeneous structure in the stainless steel. The annealed beryllium-copper (b) showed similar results. In the case of the aluminum alloy (c), however, all the microspheres passed, showing less resilience in the material to cosmic dust impact.

CONCLUSION

By using glass microspheres to model cosmic dust, it is possible to simulate conditions found in space. This enables aerospace engineers to be more precise in specifying which materials should be used on the outside of space vehicles, such as the International Space Station, in order to provide a safe work environment for the astronauts.

Similarly, astronauts' protective suits, helmets, and visors were optimized for safety by using the glass microspheres and hypervelocity light gas gun. The enhanced space apparel now offers greater protection for astronauts—even when they venture outside the spacecraft to repair damage caused by cosmic dust. **~AM&P**

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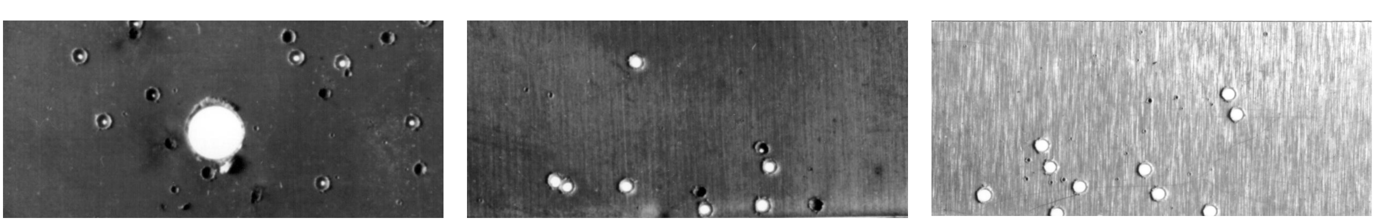


(a) (b) (c)

Fig. 8 — Impact results for 177-μm glass microspheres travelling at 11,000 mph. Half hard 302 austenitic stainless steel (a), annealed beryllium-copper alloy 25 (b); 2024T3 aluminum alloy (c). Courtesy of M. Baron, University of Kent.

UNDERSTANDING THE AIR FORCE OFFICE OF SCIENTIFIC RESEARCH GRANT PROCESS

This article facilitates the research grant application process by explaining funding considerations and providing application advice. In particular, proposals must target research that meets a scientific U.S. Air Force need.

Jaimie Tiley, FASM, and Thomas Rice*
Wright Patterson Air Force Base, Dayton, Ohio

The Air Force Office of Scientific Research (AFOSR), Arlington, Va., is dedicated to discovery and development of the basic science that shapes the U.S. Air Force. Specifically, opportunities for significant scientific advancements and breakthrough research being conducted internationally are identified through the AFOSR[1]. Founded in 1951, the organization has successfully developed many critical science technologies that continue to impact research today. It awards hundreds of industry-based contracts and a number of research projects within its parent unit, the Air Force Research Laboratory.

AFOSR typically awards more than 1600 grants per year totaling approximately $330-$470 million to leading academic institutions. These grants usually range from $200-$400K per year and typically last from one to five years. Over 90% of these resources are spent within the U.S.[2]. While obtaining a research grant might seem straightforward, many find navigating the red tape associated with new awards difficult. This article attempts to facilitate the grant application process by explaining funding considerations and providing application advice. In particular, proposals must target research that meets a scientific need of the US Air Force.

The AFOSR strives to develop and transition groundbreaking technology to improve operational warfighting capabilities. Research portfolios focus on critical basic science issues related to current and planned technology needs. Needs are often identified by senior Department of Defense (DoD) personnel and specified in strategic planning documents. For example, Defense Deputy Secretary Robert Work recently required that the U.S. build a strong deterrent posture, including an increased focus on learning machines, human-machine collaborations, assisted human operations, human-machine combat teaming, and autonomous weapons[3]. Additional needs were recently published in the *AF Future Operating Concept,* a 2015 document that referenced the need to integrate manned and uninhabited systems in air, space, and cyberspace.

**Member of ASM International*

Experimental blast test.

United States Air Force F-15 Aircraft.

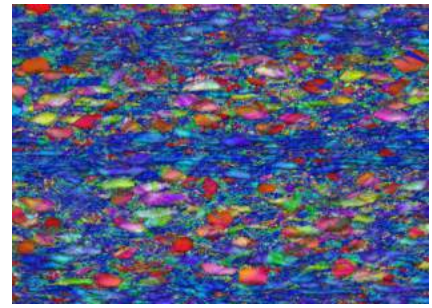
The document explained that the need for each of these systems requires varying degrees of automation to improve decision-making and performance[4].

DOMESTIC RESEARCH ACTIVITIES

The AFOSR science and engineering division (RT) is organized into 36 major research portfolios divided among four research divisions: Engineering and Complex Systems; Information and Networks; Physical Sciences; and Biological Sciences[2]. The Engineering and Complex Systems team strives to shape the future of aerospace sciences through the discovery and application of critical fundamental science, including the integration and convergence of multiple scientific disciplines. These disciplines include but are not limited to electronics, fluid dynamics, materials, propulsion, and structural mechanics, with an overall aim to enhance the operational capabilities of AF aerospace systems.

The information and networks team supports basic science development and application in several AF high priority areas including cyber security, big data, and autonomy. Research programs within this division are organized into information, decision-making, and network focus areas, which address critical issues in mathematics, information, and network oriented sciences.

The physical sciences team focuses on advancing AF capabilities in sensing, characterizing, managing the operational environment, and developing devices for new capabilities. The main research areas involve quantum matter devices, plasma and high-energy density physics, optics and electromagnetics, and aerospace materials.



High resolution electron back scattered diffraction image of high strength alloy.

The chemistry and biological sciences team manages research on advancing understanding of fundamental chemistry, biology, mechanics, and biophysics sciences. Research focuses on the hierarchical design of mechanical and functional properties from the nanoscale through the mesoscale to provide chemistry/biochemistry, and material or structural behavior capable of enhancing mission versatility. Select research emphasis areas and relevant program officers can be found in Tables 1-4. The emphasis areas are only a small subset of potential research topics. Additional information on needs and interests are provided on the AFOSR website under the “Research Opportunities” tab.

The program officer (PO) is the key contact person for both international and domestic divisions. POs have autonomous control over their funding portfolios and complete decision authority over program execution decisions within their areas of expertise. Knowing each PO’s research area of interest is critical to successful grant writing. Normally awarded to single researchers for a one- to four-year period, these grants are funded by particular portfolios to address relevant technical needs.

Because new grants are awarded each year, based on fiscal availability and current needs, grant writers must contact the PO as early as possible in order to refine potential proposal ideas. Grant writers should provide the

TABLE 1—PHYSICAL SCIENCES

Research area	Emphasis areas (not inclusive)	Program officer
Aerospace materials for extreme environments	Predictive materials science, materials response far from equilibrium, and combined external fields.	Ali Sayir 703.696.7236 extreme.environment@afosr.af.mil
Atomic and molecular physics	Quantum degenerate atomic and molecular gases, strongly interacting quantum gases, new quantum phases of matter, nonequilibrium dynamics of cold quantum gases, cold/ultracold plasmas, precision spectroscopy, and high-precision navigation, guidance, and sensing.	Tatjana Curcic 703.696.6204 amphysics@afosr.af.mil
Electromagnetics	Electromagnetic properties of novel materials/composites, parity-time symmetry media, inverse scattering theory, wideband radar waveforms, and nonlinear EM phenomena.	Arje Nachman 703.696.8427 electromagnetics@afosr.af.mil
Laser and optical physics	High average power lasers, novel lasing processes, methods for enhancing power, energy, and waveform stability of lasers across the wavelength spectrum.	John W. Luginsland 703.588.1775 laser.optics@afosr.af.mil
Optoelectronics and photonics	Nanophotonics, light at the nanoscale, plasmonics and excitonics, sub-wavelength components, photonic crystal and negative index materials, optical logic, optical signal processing, and chip scale optical networks.	Gernot S. Pomrenke 703.696.842 opto.elec@afosr.af.mil
Plasma and electro-energetic physics	High power microwaves (HPM) and/or vacuum electronics, phonon transport, contribution of phonon dispersion modes to thermal transport, extreme thermal conductivity, and thermal conductivity in hybrid materials.	Jason A. Marshall 703.696.7721 eephysics@afosr.af.mil
Quantum electronic solids	Materials that improve efficiency and selectivity of and reduce the size of communications system components including antennas, filters, and lenses, and thin-film, oxide-based materials with strong electronic application.	Harold Weinstock 703.696.8572 quantum.solids@afosr.af.mil
Remote sensing and imaging physics	Remote sensing and imaging; propagation of electromagnetic radiation; remote target location, characterization, and tracking; space object identification; and spectral and polarimetric signatures.	Julie Moses 703.696.9586 remote.sensing@afosr.af.mil
Space science	Structure and dynamics of the solar interior, mechanism(s) heating the solar corona, triggers of coronal mass ejections, magnetospheric plasma, geomagnetic storms, electron density structures, and neutral atmosphere densities.	Julie Moses 703.696.9586 space@afosr.af.mil
Ultrashort pulse laser-matter interactions	High-field laser physics, optical frequency combs, and attosecond science.	Enrique Parra 703.696.8571 short.laser@afosr.af.mil

relevant PO(s) with a short descriptive summary that includes their research objectives, test requirements, collaborative partners, and resource estimates.

Constructive iteration of the summary document helps refine proposal quality and greatly increases funding potential. The appropriate PO then evaluates the proposal, and this process usually involves a peer review where subject matter experts provide assessments. This often involves technical personnel working with one of the nine AFRL Technical Directorates. If a grant is approved for funding, the PO will work to award the grant of contract action. Due to the AF fiscal schedule, this process may involve funding availability issues that each of the proposing agencies should consider. For example, grant funding availability may not align with the academic schedule of the universities or academic facilities involved, which may create problems with hiring student researchers or recruiting technical personnel. Therefore, these issues should be considered when scheduling tasks.

After a research award is granted, program officers work with researchers to review progress and help transition results. Status reports are provided, and patents and other technological discoveries are identified. Researchers also present their research status at an annual program review sponsored by the program manager. POs use this review to highlight their respective research portfolios and provide networking and collaboration opportunities for researchers and interested colleagues, including fellow POs within AFOSR and AFRL.

TABLE 2—INFORMATION AND NETWORKS

Research area	Emphasis areas (not inclusive)	Program officer
Complex network systems	Methods of consideration in network modeling, characterization of network behavior, and design and management of advanced networks.	James H. Lawton 703.696.5999 complex.networks@afosr.af.mil
Computational cognition and machine intelligence	Innovative basic research on the fundamental principles and methodologies needed to enable intelligent machine behavior in support of autonomous and mixed-initiative systems.	James H. Lawton 703.696.5999 machine.itel@afosr.af.mil
Computational mathematics	Multiscale and multiphysics algorithms, high-order spatial and temporal algorithms, mesh-free and particle methods, high-order moving interface algorithms, rigorous model reduction techniques, and uncertainty quantification.	Jean-Luc Cambier 703.696.1141 comp.math@afosr.af.mil
Dynamics and control	Adaptive control/decision-making for coordinated autonomous/semi-autonomous aerospace vehicles; methods for understanding and mitigating the effects of uncertainties in dynamical processes; and control of large complex, multiscale, hybrid, and highly uncertain nonlinear systems.	Frederick A. Leve 703.696.7305 dycontrol@afosr.af.mil
Dynamic data driven applications systems	Cyber infrastructure software frameworks, applications modeling, advances in mathematical and statistical algorithms, and application measurement systems and methods.	Frederica Darema 703.588.1926 dddas@afosr.af.mil
Information operations and cybersecurity	Composition of security properties and protocols, abstract formulations, information flow security and noninterference in dynamic and distributed settings, and rigorous formulation and construction of obfuscation techniques.	Tristan Nguyen 703.696.7796 info.security@afosr.af.mil
Optimization and discrete mathematics	New nonlinear, integer, and combinatorial optimization algorithms, including those with stochastic components; and techniques designed to handle uncertain, evolving, incomplete, conflicting, or overlapping data sets.	Jean-Luc Cambier 703.696.1141 odmath@us.af.mil
Science of information, computation, and fusion	New techniques that address disparate and complex data types, expressive data structures for reasoning and computation, local-to-global data-fusion problems, mechanized reasoning, and computing, high-dimensional, and massive datasets.	Doug Riecken 703.696.9736 icf@afosr.af.mil
Sensing, surveillance, and navigation	Develop resilient algorithms for data representation in fewer bits (compression), image reconstruction-enhancement, and spectral/frequency estimation in the presence of external corrupting factors.	Arje Nachman 703.696.8427 ssnav@afosr.af.mil
Systems and software	New technology research, legacy system research concerning existing AF platform operating systems and software.	Kathleen M. Kaplan 703.696.7312 software@afosr.af.mil
Trust and influence	Empirical studies to examine drivers of trust; impact of socially-designed cues; trust metrics and other relevant constructs; modeling of human-machine teaming; antecedents of trust in cross-cultural interactions; sources of influence and persuasion; social, cognitive, and neural mechanisms; influence in the cyber domain; and behavioral effects of influence tactics.	Benjamin A Knott 703.696.1142 ti@afosr.af.mil

The AFOSR also manages several university research initiatives that provide resource opportunities for funding and equipment. The multidisciplinary research program of the university research initiative (MURI) are DoD sponsored programs that support basic research involving multiple engineering or science disciplines.

Awards typically cover three years for up to $1.5M per year, depending on available funds. The proposal submission includes review of short program descriptions and full project proposals. The current list of MURI topics is available at grants.gov. Contact Chakila Tillie at 703.588.1773 or muri@afosr.af for more information.

TABLE 3—ENGINEERING AND COMPLEX SYSTEMS

Research area	Emphasis areas (not inclusive)	Program officer
Aerothermodynamics	Shock/boundary layer interactions, flow-structure interactions at hypervelocity conditions, physics-based models for aero-vibrational-dissociation processes, and modeling of nonequilibrium flows and ablative surfaces.	Ivett A Leyva, 703.696.8478 aerothermodynamics@us.af.mil
Dynamic materials and interactions	Mesoscale experiments and associated models to understand initiation in energetic materials, detonation physics, high strain rate and shock response, high-energy density materials, and shock loading and mechanical response.	Jennifer L. Jordan 703.588.8436 dynamicmaterials@afosr.af.mil
Flow interactions and control	Time-dependent flow interactions; theoretical-analytical, numerical, and experimental approaches; and physically-based predictive flow models.	Ivett A Leyva, 703.696.8478 flow.control@afosr.af.mil
GHz-THz electronics	Particles/quasiparticles interactions with host lattices, boundaries, and defects; carrier velocities; dielectric properties and electric field distributions within the dielectrics; and new methods of device operation.	Kenneth C. Goretta 703.696.7349 GHz.THz@afosr.af.mil
Energy conversion and combustion sciences	Turbulent combustion, combustion chemistry, game-changing energy conversion processes, and energy storage concepts.	Chiping Li 703.696.8574 energy@afosr.af.mil
Low density materials	Hierarchical or hybrid materials; design, model, and fabrication processes for multimaterial, multiscale, and multifunctional material systems.	Joycelyn Harrison 703.696.6225 ldmaterials@afosr.af.mil
Multiscale structural mechanics and prognosis	Physics-based models, analytical tools, numerical codes, and predictive methodologies validated by carefully conducted experiments.	James Fillerup 703.588.1777 structural.mech@afosr.af.mil
Space power and propulsion	Fundamental aspects of a coupled plasma/material system in nonequilibrium states; smart, functional nanoenergetics for propulsion; increasingly extreme pressures; and multiphase liquid electrospray that can be used for nanoenergetic materials.	Mitat A. Birkan 703.696.7234 space.power@afosr.af.mil
Test science for test and evaluation (T&E)	Novel measurement techniques, materials, and instruments; advanced algorithms and computational techniques; increased bandwidth use; and advanced mathematical techniques and processes that improve test reliability and efficiency.	Michael Kendra 703.588.0671 tande@afosr.af.mil
Turbulence and transition	Turbulence studies, receptivity, multimode transition, and flow field analysis and diagnostics.	Ivett A. Leyva 703.696.9558 turbulence@afosr.af.mil

The Defense University Research Instrumentation Program (DURIP) helps U.S. academic organizations acquire major research equipment. This program is managed by AFOSR, the Army Research Center, and the Office of Naval Research. Awards are usually one year in length, valued between $50K and $1.5M. Proposals are greatly strengthened by collaborative research with AFRL and other DoD organizations, and by leveraging cost match resources and support. For more information, contact Katie Wisecarver at 703.696.9544 or durip@afosr.af.mil, and the AFOSR.

INTERNATIONAL RESEARCH ACTIVITIES

The AFOSR international division (IO) also has four branches: The European Office of Aerospace Research and Development (EOARD), London, which provides coverage of Europe, Eurasia, the Middle East, and Africa; the Asian Office of Aerospace Research and Development (AOARD), Tokyo, which provides coverage of Asia, India, and Pacific Rim countries, including Australia and New Zealand; the Southern Office of Aerospace Research and Development (SOARD), Santiago, Chile, which covers the Latin American region; and the International Office North (AFOSR/ION), as part of AFOSR, Arlington, Va., serving as the Washington liaison for AFOSR's international activities.

Although the international offices primarily deal with research in foreign countries, they heavily leverage expertise within other directorates of the AFRL, as well as U.S. academic institutions. Funding for international grants is usually more modest than domestic grants. However, the international offices provide a critical collaborative

TABLE 4—CHEMISTRY AND BIOLOGICAL SCIENCES

Research area	Emphasis areas (not inclusive)	Program officer
Biophysics	Bio-molecular imaging below the diffraction limit, bioelectricity, electromagnetic stimulation, quantum biology, and mechanisms of sensory systems.	Hugh De Long 703.696.7722 biophysics@us.af.mil
Human performance and biosystems	Advanced understanding of cortical and sub-cortical, noise interference and reverberation, psychoacoustic basis of informational masking, automatic speech detection, 3D spatial segregation, and sensory and sensorimotor processes.	Patrick Bradshaw 703.588.8492 sensory.info@afosr.af.mil biosystems@afosr.af.mil
Mechanics of multifunctional materials and microsystems	Autonomic and adaptive structures and structural integration of power harvesting, storage, and transmission capabilities for self-sustaining systems.	Byung-Lip "Les" Lee 703.696.8483 mmmm@afosr.af.mil
Molecular dynamics and theoretical chemistry	Chemical reactivity, bonding, and energy transfer processes; molecular clusters and nanoscale systems in catalysis; dynamics at gas-surface interfaces; reaction dynamics; ion-molecule reactions; and electron-ion dissociative recombinations.	Michael R. Berman 703.696.7781 mdtc@afosr.af.mil
Natural materials, systems, and extremophiles	Natural chromophores and photoluminescent materials found in microbial and protein-based systems; synthesis of novel materials and nanostructures using organisms as materials; biomimetics research; biomaterials; and biointerfacial sciences.	Hugh C. De Long 703.696.7722 nature@afosr.af.mil
Organic materials chemistry	Photonic polymers and liquid crystals, polymers with interesting electronic properties, and novel properties polymers modified with nanostructures.	Charles Y-C Lee 703.696.7779 organic@afosr.af.mil

United States Air Force F-35 Aircraft.

resource for initiating communication between AFRL and non-domestic researchers.

The international programs officers (IPOs) divisions also provide traveling assistance for visiting researchers and sponsor attendance at international conferences. Domestic academic researchers may find these offices helpful in contacting and leveraging international research programs. Specific contacts for these divisions are located on the AFOSR website[2]. Arranging meetings with IPOs and potential researchers during international workshops to capitalize on the close proximity of participants has proven beneficial given their busy schedules.

Additional opportunities are available within AFOSR, including the young investigator program, summer faculty fellowship program, the AFRL research associateship program, as well as the small business research (SBIT and STTR) programs. Information on these is readily available from the AFRL and AFOSR websites, including instructions on how to compete for contracting actions. Researchers are encouraged to visit the websites and relevant POs for additional information. **~AM&P**

For more information: Jaimie Tiley is materials engineer, U.S. Air Force Research Lab, 2230 10th St., Dayton, OH, 45433, 937.255.5347, jaimie.tiley@us.af.mil, www.wpafb.af.mil/afrl.

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CONFERENCE HIGHLIGHTS ADVANCEMENTS IN TITANIUM TECHNOLOGY

Developments in titanium technology and opportunities for increased use in several markets were highlighted at the 13th World Conference on Titanium (Ti-2015).

Vasisht Venkatesh, Pratt & Whitney, East Hartford, Conn.

Rodney Boyer (retired), Boeing, and RBTi Consulting, Bellevue, Wash.

The aerospace sector consumes more than 70% of all titanium produced in the U.S., but major opportunities exist for increased use in the automotive and biomedical sectors, as well as other industrial sectors. This is being driven by factors such as new process development to lower manufacturing costs, enhancing performance of existing and new titanium alloys to meet new application requirements, and development of computational models to both reduce new alloy development cycle times and accelerate new process qualification times at reduced cost.

The aerospace industry is continually looking for titanium products for next-generation airframes and engines to meet stringent fuel efficiency standards and cost pressures associated with large orders for new aircraft such as the B787, B777X, B737MAX, A320NEO, A350XWB, and A380 (Fig. 1). Thus, some of the latest developments focus on growing titanium use through innovation in key capabilities and reduced final component costs. Examples include development and qualification of a third-generation forgeable γ-TiAl for low-pressure turbine blades in the Pratt & Whitney PW1000G engine and evaluation of new α+β alloys for superplastically formed nacelle components in next-generation airframes and engines.

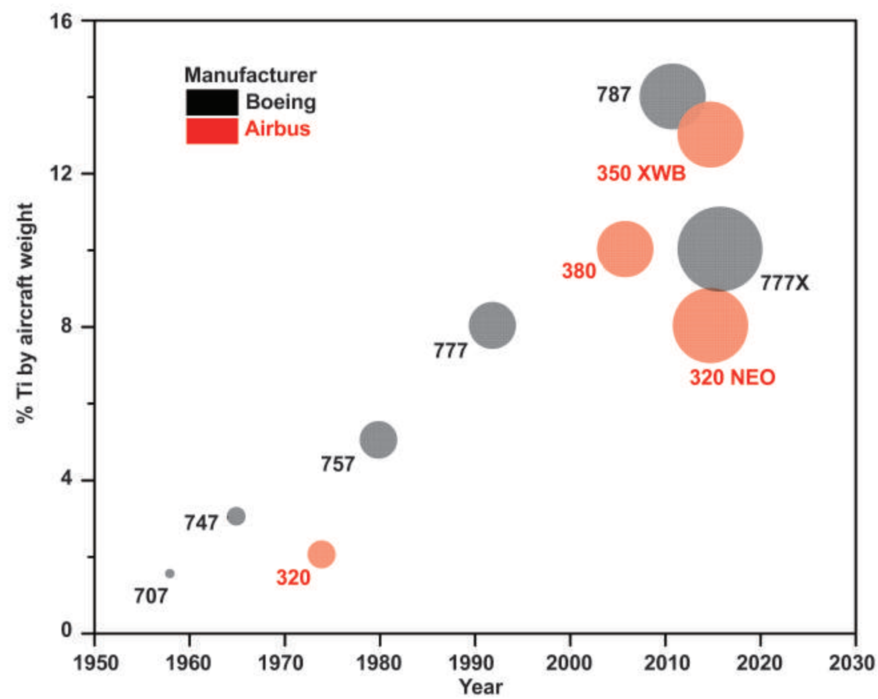

Fig. 1 — Increased titanium use in aircraft over the past several decades. Bubble size indicates aircraft passenger capacity[1].

Many of these developments were discussed at the 13th World Conference on Titanium, held during August 2015 in San Diego, Calif. This article highlights some of the major advancements presented at the conference.

NEW ALLOY DEVELOPMENT

Conventional titanium alloys are typically limited to a maximum temperature of roughly 500°-550°C due to poor oxidation resistance. In addition, severe grain growth in single-phase titanium alloys at elevated temperatures degrades its mechanical properties. During a few of the conference sessions, recent titanium developments were presented to provide an overview of the industry. For example, Kobe Steel Ltd., Japan, developed several titanium alloys over the past two decades including:

- Ti-0.4Ni-0.015Pd-0.025Ru-0.14Cr (AKOT), a corrosion-resistant alloy containing a small amount of chromium to enrich palladium and ruthenium on the corroded surface resulting from selective dissolution of titanium.

- Ti-0.5Al-0.35Si (Ti-0.9SA) and Ti-0.5Al-0.45Si-0.2Nb (Ti-1.2ASN), which achieve high-temperature oxidation resistance to 750°C via a combination of aluminum, silicon, and niobium additions. Also, the formation of silicides in the matrix inhibit grain growth.
- Ti-4.5Al-2Mo-1.6V-0.5Fe-0.3Si-0.03C (Ti-9), a cold-rolled alloy, and Ti-4.5Al-4Cr-0.5Fe-0.2C (EL-F), a forgeable alloy with carbon for improved high temperature strength.
- Ti-2Al-1Sn-1Fe-1Cu-0.5Cr-0.3Si (Ti-2111S), a near-alpha alloy containing low-cost alloying elements designed for sheet products, which exhibits lower levels of anisotropic properties and improved superplastic properties.

Allegheny Technologies Inc. (ATI), Pittsburgh, and Timet Metals Corp., Exton, Pa., developed new $\alpha+\beta$ alloys with improved superplastic forming (SPF) capability. TIMETAL 54M, or Ti-54M (Ti-5Al-4V-0.75Mo-0.5Fe), demonstrates SPF capability at temperatures as low as 775°C, providing a significant cost benefit during SPF processing. ATI 425 (Ti-4Al-2.5V-1.5Fe-0.25O) exhibits excellent cold and hot workability, and can be produced in various forms from coil to forged products with SPF properties similar to Ti-54M.

RTI International Metals Inc., Pittsburgh, developed a heat treatable $\alpha+\beta$ alloy, RTI-XPT (5.5Al-4.3 Zr-5.7V-1.3 Mo-0.10O2-0.06Pd), to compete with Grade 29 titanium for use in highly stressed tubular applications used in high-pressure and high-temperature corrosive environments. Its corrosion resistance makes it suitable for sour and sweet aerated and de-aerated chloride media at temperatures up to 290°C. RTI-XPT is approved for sour service under the ANSI/NACE MR01750/ISO 15156 Standard.

Timet also developed a new titanium alloy for the chemical process industry targeted for use in aggressive environments severe enough to require palladium or rhenium alloys or high-end industrial nickel alloys. Corrosion resistance of the new carbon-bearing alloy is similar to, or better than, that of the alloys previously mentioned. Material costs are dramatically reduced by not using expensive alloying elements.

Dynamet Techology Inc., Burlington, Mass., developed CermeTi-10, a titanium carbide particle-reinforced titanium alloy for die-cast shot sleeve liners. The alloy reportedly increases sleeve life up to 20 times longer, enables three times longer plunger tip life, reduces maintenance costs, and results in fewer defects and decreased lubrication requirements. These lower cost, lightweight Al components further enable their use by the auto industry to meet the federal government's increasingly strict standards for improved fuel economy. In a cooperative effort with Medtronic Inc., Dynamet used another CermeTi alloy containing particulates to fabricate the Prestige LP Disc, an artificial cervical disc. These components have been used in Europe since 2004 and are now approved for use in the U.S. They have a lower wear rate and produce less scatter on post-operative MRI scans than stainless steel.

Next-generation aeroengine architectures challenge the properties of traditional materials with higher engine core temperatures and turbine speeds, which led to development of a third-generation γ-phase containing Ti-aluminide alloy (Fig. 2). Alloy TNM combines good processability with required mechanical properties, resulting in the first application of forged γ-TiAl turbine blades jointly developed by Pratt & Whitney and MTU Aero Engines, Munich.

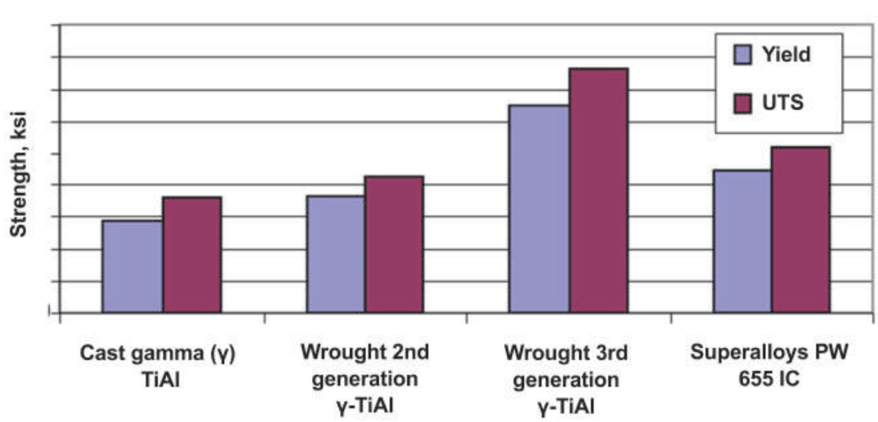

Fig. 2 — Comparison of room-temperature strength of third-generation forged γ-TiAl alloy with other materials used as low-pressure turbine blades in the PW1000G engine.

NEW CHARACTERIZATION METHODS

Advanced characterization methods such as atomic-force spectroscopy (AFS), high resolution digital image correlation (DIC), and scanning transmission electron microscopy (STEM) provide the means to understand phase transformations and deformation mechanisms under a variety of external conditions. These techniques were discussed during several conference sessions.

For example, researchers at University of Manchester, UK, are combining electron backscatter diffraction (EBSD) orientation maps and high resolution DIC to observe nanoscale strain behavior in Ti-6Al-4V with varying degrees of microtexture. Two extreme microstructures show noticeable differences in strain heterogeneity, with the strong microtexture sample exhibiting a higher density of slip traces with increased maximum shear strains. Nanoscale deformation studies provide more detailed insight into the actual extent of the strain heterogeneity, with maximum shear strain intensities of approximately 10 times the applied strain.

Spatially resolved acoustic spectroscopy (SRAS), a laser-based ultrasonic method that resolves crystal orientation in titanium, was developed at University of Nottingham, UK. The technique is based on local surface acoustic wave velocity in different directions to image

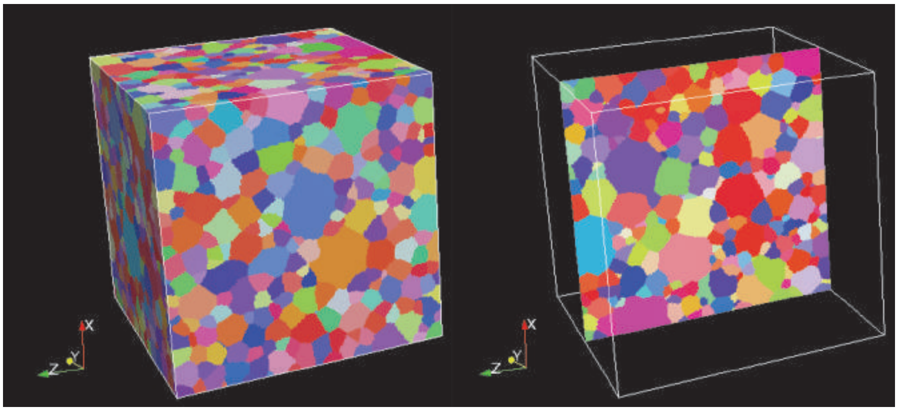

Fig. 3 — Synthetic volume element created in DREAM-3D.

the microstructure with orientation information. The method has been used on Ti, Ni, Zr, and Al alloys.

Researchers at The Ohio State University, Columbus, are using STEM to characterize the α/β interface in three different types of α precipitates in Ti-5Al-5V-5Mo-3Cr. High-angle annular dark-field (HAADF) imaging identifies and quantifies the terrace and ledge structure along the α/β interface. This provides valuable insight into the influence of the α/β interface on mechanical properties, which can be used to develop predictive models to optimize processing. Microtextured regions (MTRs) have a deleterious effect on dwell fatigue response for various near α and $\alpha+\beta$ titanium alloys. Robust microtexture characterization methods that include size, hard/soft grain orientations, and misorientations were developed.

One method uses DREAM-3D (Hampshire, UK) open-source software to extract critical MTR metrics from representative samples. Data is used to create statistically equivalent synthetic microstructures to assess the probability of certain microtexture combinations that could manifest a given volume of material (Fig. 3). After identifying critical microstructure and texture combinations, synthetic volume elements created in DREAM-3D are analyzed in a finite element analysis package with a linked crystal-plasticity code to assess damage accumulation.

Overall, the conference was well received with technical discussions in just about every technology area including extraction, melting, thermomechanical processing, machining, welding, additive manufacturing, and more. All countries active in the titanium industry were well represented.

Note: TIMETAL54M and ATI 425 are registered trademarks of Timet and Allegheny Technologies Inc., respectively. RTI-XPT is a trademark of RTI International Metals Inc. CermeTi-10 is a registered trademark of Dynamet Technology Inc. **~AM&P**

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ASMNEWS

NOMINATIONS SOUGHT FOR 2017 ASM/TMS DISTINGUISHED LECTURESHIP IN MATERIALS & SOCIETY

Nominations are now being accepted for the ASM/TMS Distinguished Lectureship in Materials & Society. The lecture was established in 1971 and is jointly sponsored by The Minerals, Metals & Materials Society (TMS) and ASM International. The topic of the lecture shall fall within these objectives:

- To clarify the role of materials science and engineering in technology and in society in its broadest sense.
- To present an evaluation of progress made in developing new technology for the ever changing needs of technology and society.
- To define new frontiers for materials science and engineering.

Qualifications of the lecturer include:

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

Nominations may be proposed by any member of either Society. Submit nominations by September 1 for consideration. Recommendations should be submitted to the headquarters of either Society. For a complete listing of the rules and nomination form, visit asminternational.org/membership/awards/nominate or contact Christine Hoover at 440.338.5151 ext. 5509, christine.hoover@asminternational.org., or Deb Price of TMS at awards@tms.org.

FAS
Failure Analysis Society
ASM INTERNATIONAL

President of New ASM Failure Analysis Society Shares Insights


Akyuz

In April, ASM International announced its latest affiliate society, the Failure Analysis Society. We recently spoke with Burak Akyuz, the society's first president, about his hopes and dreams for the new organization.

ASM: *What were some of the reasons for establishing ASM's new Failure Analysis Society (FAS)?*

Akyuz: The FAS emerged from an existing ASM committee that has offered failure analysis programming and content for more than 15 years. Committee members decided that a society dedicated to advancing the important role of failure analysis and prevention in the materials science industry would provide more opportunities to its members.

ASM: *Please describe the main goals of the new society.*

Akyuz: The society aims to promote safer, more reliable products and prevention of failures by studying the many ways in which failures occur and to educate the larger engineering, manufacturing, and user communities regarding their findings. Our founding members have extensive experience and knowledge of failure analysis and prevention and they would love to share this with the industry, including our emerging professionals.

ASM: *As the first president, what do you hope to accomplish?*

In This Issue

ASM INTERNATIONAL

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

Akyuz: I would like to create a strong foundation for this new organization so we can continue to serve our members and the community for many years to come. We also would like to start "internationalization" of the FAS immediately so we can become the leading organization in this field within the first few years.

ASM: *Can you tell us a little about your background?*

Akyuz: I received my Bachelor of Science in metallurgical engineering from Istanbul Technical University. After graduating, I moved to Atlanta and received my master's degree in information technology from Southern Polytechnic State University. I have been working at Applied Technical Services Inc. in Marietta, Georgia, for 12 years. I am very lucky to work with a company and management team that supports my involvement with the FAS and ASM. My current title is team lead of metallurgy and failure analysis and my main focus is metallurgical failure analysis using metallography, fractography, mechanical testing, materials characterization, and corrosion analysis supporting a broad range of industries. I am actively involved in ASM International. I served as the Atlanta Chapter chair for two terms and I am currently Chapter Council for District V. I also served on ASM's Web Committee and Failure Analysis Committee.

ASM: *With regard to membership, what types of people would get the most out of joining the new society?*

Akyuz: Anybody who is involved in or has an interest in failure analysis will receive great benefits by joining the society. We need contributions from experienced failure analysts and materials scientists, but I strongly urge emerging professionals and students to join this society as well, especially for the opportunities in training, networking with the best in the field, and to have access to great knowledge.

ASM: *Anything else we should know about the society and its first-year initiatives?*

Akyuz: We will continue to have our own technical programming at the annual Materials Science & Technology (MS&T) conference. We will have our first annual meeting and a launch party during MS&T16 in Salt Lake City. The FAS will continue to publish its own journal, the *Journal of Failure Analysis and Prevention.* Our Committees have already started working on failure analysis courses and the publications.

FROM THE PRESIDENT'S DESK

Tirpak

Exploring ASM's Core Values

In my last column, we explored ASM's beliefs statement. I will now focus on core values. Values are worth a detailed look because they guide both staff and volunteers on all matters. Following are six proposed key values embraced by ASM's members and staff as part of our updated Strategic Plan:

Integrity—The international materials community depends on the content ASM delivers. This content must be true, like the staff and volunteers developing and delivering this information. All functions of ASM International are supported by members and staff who can be trusted.

Passion—Linking to our first belief statement, "We believe that materials enable Society," we are driven to understand, develop, and apply materials for the benefit of humanity. Every day we rise to the challenge of innovating with materials, and rest every night knowing that we served the world well.

Service—With respect to serving others, we are servant leaders. We welcome the opportunity to lead efforts in materials science, engineering, and education while offering our expertise to others as they exploit materials in domains such as energy, transportation, and medicine.

Teamwork—Together, like the elements of ASM's iconic Dome at Materials Park, we can make great things happen. Many hands make light work.

Diversity—We welcome all to the grand enterprise of ASM International. Just as there are many different types of materials and processes, there are many people with different backgrounds and experiences. ASM welcomes the varied views of others from around the world.

Technology—ASM International clearly values materials and process technology, and just as important, we value information technology to connect our members, develop and deliver content, and be the world class materials information society that serves all.

As we move the Society forward, we will continue to refine these values. As your Chief Volunteer, I welcome your comments. Feel free to contact me via email to discuss these values in depth as we deliver the best value in materials science, technology, and engineering to our members around the world.

Jon D. Tirpak, PE, FASM
Chief Volunteer of ASM International
jon.tirpak@scra.org

VOLUNTEERISM COMMITTEE

Profile of a Volunteer

James Boileau, Technical Expert, Ford Motor Co.

Boileau

Stories matter. James Boileau was new to materials when he entered Detroit's Wayne State University and took an *Introduction to Metallurgy* course. "I had an excellent teacher with a great collection of stories, each with a lesson built in. He made a complex subject easy to understand," recalls Boileau. "I changed my major within a month."

With his bachelor's degree, he was hired by Ford Motor Co. and given the opportunity to complete a master's and Ph.D. while working. After 28 years, he is now in Ford's Research and Innovation Center, conducting research on lightweight automotive components, managing the optical and electrical microscopy labs, and conducting materials analyses to improve vehicle durability.

After joining ASM as a student in 1984, Boileau received several scholarships, made industrial contacts, toured facilities, and learned about potential jobs for his future. After graduation, he attended Chapter meetings until life got busy with four daughters—and coaching lots of soccer. In 2008, Boileau answered the call to join the Detroit Chapter and has served on the executive board ever since.

Now his focus is on supporting students and teachers in the field of materials science. He modernized his Chapter's college scholarship applications by creating online forms, which boosted the number of applicants from two to 32 in one year. He also serves on a national committee that will be extending scholarships to community college students in 2016. And he has led a creative twist on the Chapter's ASM scholarships—overseeing the creation and distribution of six grants to provide much needed classroom materials for teachers who attend the local ASM Teachers Camp. In addition, Boileau is teaching materials science at Wayne State and University of Michigan-Dearborn. "To all those who have helped me, I am paying it forward and telling good stories with lessons built in," he says.

EMERGING PROFESSIONALS

Understanding the Power of Networking

Shane Kennett, Ph.D., P.E., CWI

Kennett

During graduate school, Ph.D. candidates are tasked with developing new theories and proving new results that push the scientific envelope in their respective fields of study. When students finish their dissertation and decide to transition away from academia, their next major task is to learn how to assimilate into the "real world" which, in some cases, can be a relatively easy task. In the field of engineering consulting, this transition can be challenging due to the diverse nature of problems that are encountered for a wide array of industries. For consulting engineers to grow and be successful, they must be able to build trust with diverse clients who may come from a range of scientific and non-scientific fields. This may come easier for a confident and competent engineer—once they start working on projects.

However, a significant hurdle in the career of a young consultant lies in obtaining new clients that trust him or her with their most important issues. Young engineers are challenged not only by the projects, and at times, rapid turnaround times, but also by having to communicate findings with professionals who work in a variety of industries and/or those who may have vastly different educational or professional backgrounds. Each field tends to have its own terminologies or ways of approaching problems. These are hurdles every engineer will encounter. Effectively working through them will lead to becoming a well-rounded engineer. Professional networking is a key tool to overcoming these hurdles, but effective networking is not taught in graduate schools. Further, it can be lost when an engineer does not engage with professional societies. Because of this, it becomes increasingly important for engineers to become—and remain—active in professional communities while seeking to work across many disciplines. By maintaining relationships made during networking and obtaining a general knowledge of some of the difficulties or successes that colleagues are experiencing, one will continue to grow as an engineer and build a desirable set of experiences and skills. Networking can truly put the young engineer on a path to success.

CHAPTERS IN THE NEWS

Pittsburgh Chapter Hosts Young Members' Night

In February, the Pittsburgh Chapter held its 30th annual Young Members' Night at the University of Pittsburgh's (Pitt) University Club. The event included a poster competition, presentation by student speaker Whitney Schoenthal of Carnegie Mellon University (CMU), and guest lecture by ASM President Jon Tirpak, FASM. Undergraduate poster winners included Rekha Shnepf, CMU, first place; Shannon Biery, Pitt, second place; and Eamonn Hughes, Pitt, third place. Graduate poster contest winners were Luke Klosterman, CMU, first place; Erica Stevens, Pitt, second place; and Jenifer Hajzus, CMU, third place. Sponsors included Alcoa, American Stress Technologies, CBMM North America, Elliot Co., Ellwood Group, U.S. Steel, ATI Powder Metals, Westmoreland Testing and Research Inc., Product Evaluation Systems, Solar Atmospheres of Western PA, Perryman, Latrobe Specialty Steel, and Webb Law Firm. The event was attended by 120 people representing local industries in Pittsburgh, sponsors, students, and researchers and faculty from CMU and Pitt.

Back row, from left: David Sapiro, Corinne Charlton, Ian Dickey, Sean Kane, and Tim Hosch. Front row, from left: Heather Bowman, Natasha Gorski, Betsy Clark.

ASM President Jon Tirpak receives a token of appreciation from Dharma Maddala, Pittsburgh Chapter chairman.

Peoria Joins 2016 Engineering Day Festivities

As part of engaging middle and high school students in materials science and engineering, the Peoria Chapter participated in Engineering Day 2016, held at the Peoria Riverfront Museum on February 21. Over 2700 people attended this free event, in which the Peoria Chapter participated by presenting live demonstrations of casting, forging, memory shape alloys, and magnetic properties. After the demonstrations, many students indicated that they wanted to pursue a STEM-related career.

Peoria Chapter volunteers give live demonstrations during Engineering Day 2016.

Northwestern Pennsylvania Tours Corry Forge

In March, the Northwestern Pennsylvania Chapter coordinated a plant tour of Corry Forge Co., Corry, Pa. The group enjoyed a company presentation and tours of the destructive test lab, open die forge press, and machine shop, in addition to the company's advanced heat treat facility, machining centers (including new Phoenix X-Large Engine Lathe), and automatic ultrasonic system.

Corry Forge tour group from the Northwestern Pennsylvania Chapter.

Ravindran Visits Warangal

ASM Past President Ravi Ravindran, India Council chair Prem Aurora, and India Chapter executive director Suhas Sabnis were invited speakers representing ASM International at the Golden Jubilee (50th) Celebrations and Alumni Meeting of the National Institute of Technology-Warangal, India, on Feburay 12.

From left, T. Srinivasa Rao, Ravi Keshav, Ravi Ravindran, Prem Aurora, and Suhas Sabnis.

From left, Suhas Sabnis, Prem Aurora, and Ravi Ravindran met in Hyderabad in February to discuss new Indian chapters and plans for MET+HTS 2016 (Material, Engineering and Technology Conference + Heat Treat Show), Mumbai. These events are co-sponsored by ASM International along with the ASM India Chapter and ASM India Council.

MEMBERS IN THE NEWS

Kuehmann Joins Tesla and SpaceX

Kuehmann

In December, Charles Kuehmann became the vice president of materials engineering at both Tesla Motors, Palo Alto, Calif., and SpaceX, Hawthorne, Calif., working on electric cars and space travel, respectively. He is the only employee who shares his time between the two companies, besides CEO Elon Musk. Before joining Musk's ventures, Kuehmann was head of a product design team at Apple, Cupertino, Calif.

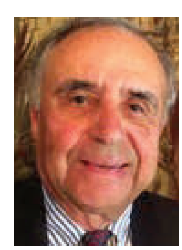
Sangid Wins Early Career Award

Sangid

Michael D. Sangid, an assistant professor in Purdue University's School of Aeronautics and Astronautics, received the Minerals, Metals and Materials Society's Early Career Faculty Fellow Award. His research focuses on integrated computational materials engineering with models that can simulate material behavior at the crystal level. Sangid, who joined Purdue as an assistant professor in 2012, leads the Advanced Computational Materials and Experimental Evaluation (ACME) Laboratory. The ACME group combines computational modeling and in situ experiments to solve complex applied problems in aerospace materials.

Beaman, Kalpakjian Honored by SME

Beaman



Kalpakjian

SME recognized seven professionals from industry and academia with its 2016 International Honor Awards, including **Joseph Beaman Jr.** and **Serope Kalpakjian, FASM.** Beaman, a professor in the mechanical engineering department at The University of Texas, Austin, is receiving the 2016 SME Albert M. Sargent Progress Award "for pioneering, developing, commercializing, and making his research widely available in laser sintering, and for advancing the field of additive manufacturing through leadership, research, and organization." Kalpakjian, Professor Emeritus of mechanical and materials engineering at Illinois Institute of Technology, Chicago, is recognized with the 2016 SME Gold Medal "for his sustained commitment, leadership, and numerous education and research contributions."

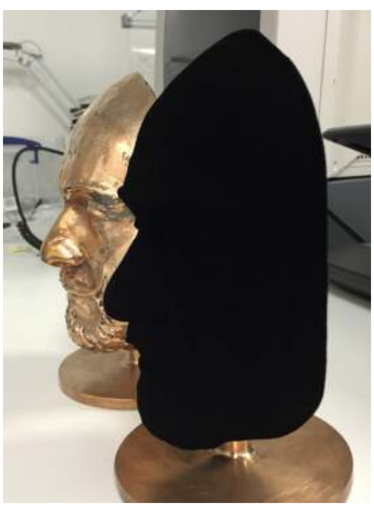
STRESS RELIEF

RURAL BIRDS ARE COUNTRY BUMPKINS

Birds living in urban environments are smarter than rural birds because they adapt to their city dwellings, enabling them to exploit new resources more favorably than their rural counterparts, according to researchers at McGill University, Canada. In a first-ever study to find clear cognitive differences in birds from urbanized compared to rural areas, researchers report key differences in problem-solving abilities such as opening drawers to access food, and temperament (bolder) among city birds versus country. The team tested the two groups of birds using not only associative learning tasks, but also innovative problem-solving tasks.

Bullfinches in Barbados. Courtesy of Louis Lefebvre.

"We found that not only were birds from urbanized areas better at innovative problem-solving tasks than bullfinches from rural environments, but that surprisingly, urban birds also had better immunity than rural birds," says Jean-Nicolas Audet, a Ph.D. student. *mcgill.ca.*



VANTA IS BACK IN BLACK

Development of a new spray version of the world's blackest coating material, Vantablack, enables a whole new range of products to take advantage of its astonishing characteristics. The new substance, Vantablack S-VIS, is easily applied at large scale to virtually any surface, while delivering the same performance as the original Vantablack.

Vantablack's nanostructure absorbs virtually all incident light, optimizing the performance of precision optical systems. The material's developer, Surrey NanoSystems, UK, has mimicked the performance of its original Vantablack formula, which requires application via a chemical vapor deposition (CVD) process. Even though the new version is applied using a simple spraying process, it traps a massive 99.8% of incident light. This property gives Vantablack S-VIS its ability to make objects appear to be 2D black holes, as it becomes impossible to see surface topography. *surreynanosystems.com.*

Two 3D masks of the face of BBC science presenter Marty Jopson, one covered in Vantablack S-VIS.

VIOLIN VARNISH PROTECTS AND TONES

Varnish does more than provide a protective sheen to a violin. It influences the vibrations and impulses that the wood absorbs and therefore the quality of sound the instrument produces, says Marjan Gilani of the Swiss Federal Laboratories for Material Science and Technology (EMPA), Switzerland. Gilani and her colleagues demonstrate the importance of the vibro-mechanical properties of varnish, its chemical composition, thickness, and penetration into wood.

Often, a violin's sound board is made of spruce tonewood. Varnish is applied to protect the wood from the long-term effects of humidity and wear. Violin makers normally have their own particular method for applying varnish to finished instruments. It is applied in liquid form, and then dries to a solid transparent film. All varnishes were found to increase damping throughout the wood surface. A moderate increase of damping can, in general, benefit the sound of violins. When high notes are dampened, instruments sound warmer and mellower. In unvarnished wood, the sound is faster along the grain and slower perpendicular to it. The sound is also damped more strongly perpendicular to the grain than along the grain. With all applied varnishes, these differences are reduced, leading to a more isotropic sound radiation. *empa.ch/web/empa.*

The Caspar Hauser violin by Giuseppe Guarneri 'del Gesu. Courtesy of Walter Fischli - Stiftung/Martin Spiess.

ADVANCED MATERIALS & PROCESSES

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3D PRINTSHOP

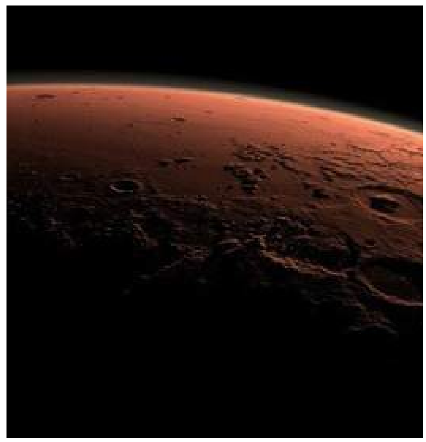
ALCOA TO SUPPLY 3D-PRINTED PARTS TO AIRBUS

Alcoa, Pittsburgh, will supply 3D-printed titanium fuselage and engine pylon components for Airbus commercial aircraft, delivering the first additively manufactured (AM) parts to Airbus in mid-2016. According to company sources, the agreement will draw on Alcoa's aerospace experience as well as new technologies gained through the recent acquisition of RTI International Metals Inc. and organic expansion in Whitehall, Mich. Last year, Alcoa acquired RTI, now known as Alcoa Titanium & Engineered Products (ATEP), which grew Alcoa's AM capabilities to include 3D-printed titanium and specialty metals parts produced at ATEP's Austin, Texas, facility. The Airbus agreement will use these capabilities as well as ATEP's titanium ingot melting and billetizing, machining, finishing, and inspection technologies. Alcoa will also use advanced CT scan and hot isostatic pressing (HIP) capabilities at its aerospace facility in Michigan. Additionally, Alcoa is bolstering its AM capabilities through a $60 million expansion in advanced 3D-printing materials and processes, including metallic powders. The expansion is located at the Alcoa Technical Center near Pittsburgh. *alcoa.com.*

ALCOA

SELECTIVE SEPARATION SINTERING WINS NASA CHALLENGE

A new 3D-printing process called selective separation sintering (SSS), developed by Behrokh Khoshnevis of the University of Southern California (USC), won first place in the NASA In-Situ Materials Challenge due to its breakthrough application in the construction of physical structures in space. Khoshnevis is director of the Center for Rapid Automated Fabrication Technologies at the USC Viterbi School of Engineering. His team used a synthetic material similar to those found on Mars to formulate a robotic fabrication process, which employs high melting-point ceramics, such as magnesium oxide, to create tiles capable of withstanding the pressure and heat of exhaust plumes of landing spacecraft. The SSS process uses Khoshnevis' existing contour crafting, a large-scale 3D printing method that won the 2014 NASA competition grand prize. However, the contour crafting is an extrusion-based 3D printing method and is mainly suited for large-scale monolithic structure construction, while the SSS is a powder-based technique that is suitable for constructing smaller-scale objects such as bricks, interlocking tiles, and a number of functional objects such as metallic components. Khoshnevis' team will test the SSS process in a vacuum chamber of USC's Astronautics Rocket Lab and NASA's Kennedy Space Center facilities. *nasa.gov, usc.edu.*



The NASA In-Situ Materials Challenge competition mandated that competitors use materials found on Mars. Courtesy of NASA.

NAVY GRANTS MISSILE SYSTEM CONTRACT TO MTI

The U.S. Navy recently granted Metal Technology (MTI), Albany, Ore., a contract to develop advanced aerospace additive manufacturing techniques for low-cost manufacturing of refractory metal components for missile propulsion systems used on the Trident D5 missile system. While the Trident system is expected to remain in service until 2042, current manufacturing techniques for refractory metal components of the propulsion system are complex and labor intensive. MTI will work with the Navy to reduce cost using advanced additive manufacturing to fabricate refractory metal parts with significant reductions in complexity. "Phase one of this project is to develop processes and demonstrate the fabrication of simplified, sub-scale articles using C103 Niobium alloy and provide approaches for fabrication of additional refractory metals and alloys including molybdenum and tantalum," says CEO Gary Cosmer. *mtialbany.com.*

Metal Technology is moving forward with advanced technology to support the Trident II missile program.