NOVEMBER/DECEMBER 2019 | VOL 177 | NO 8

ADVANCED MATERIALS & PROCESSES

AN ASM MATERIALS SOLUTIONS PUBLICATION

MATERIALS TESTING/CHARACTERIZATION

PATENT ANALYTICS DRIVE BETTER BUSINESS DECISIONS

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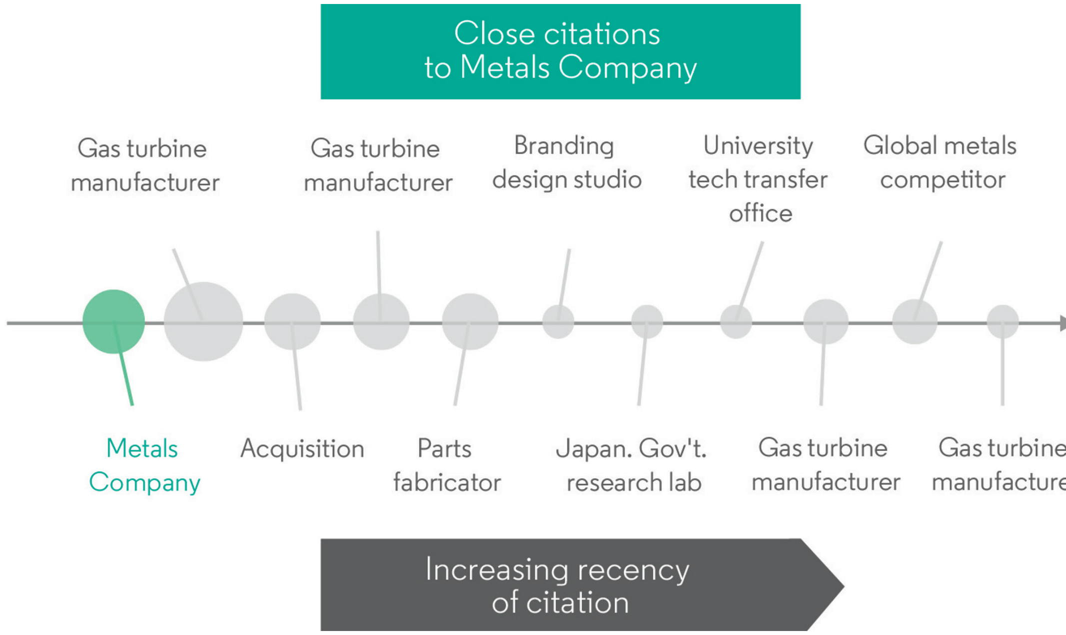
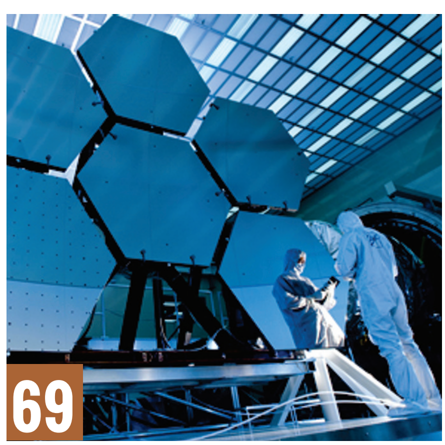


On the Cover:

Titled "Dawn to Dusk," this image received first place in Class 4 Artistic Microscopy (Color) of the 2019 International Metallographic Contest. The background is a 10,000x-magnification image of the fracture surface of ductility-tip cracking in a nickel-based filler metal 52M multipass weld. Courtesy of Sam Luther/ The Ohio State University.



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FEATURES

TRENDS

INDUSTRY NEWS

DEPARTMENTS

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FALL TRAVELOG

As a plenary speaker in Portland in October, Wolfgang Bleck of RWTH Aachen University ended his talk with a bulleted list of "souvenirs" from his presentation on the use of the TRIP effect to develop new materials such as manganese alloyed steels. I hope many of you were able to travel to one or more of ASM's fall conferences and came away with souvenirs of your own—gems of research insights, new contacts, and ideas to implement in your work life.

The stunning image gracing this issue is a souvenir from the IMS International Metallographic Contest held in Portland this past fall. In 2020, we will run an article featuring the 2019 Jacquet-Lucas grand prize winner of that contest.

Another type of souvenir was acquired by our own AM&P Editorial Committee vice chair, John Shingledecker of EPRI, who came away from the ASM Annual Meeting with a new designation—ASM Fellow, Class of 2019. Congratulations to John and all 2019 award winners. We brought back some postcards of our fall meeting awardees and activities to share with you. Check out the photo galleries from the ASM Annual Meeting (see pages 74-75) and from Heat Treat 2019 (see pages 56-57).

John P. Shingledecker, FASM

New this fall at both Heat Treat in Detroit and ISTFA in Portland were women in engineering events. The Heat Treat conference included a Women in Manufacturing Networking Breakfast with a featured speaker. At ISTFA, the newly formed Women in Electronics Failure Analysis (WEFA) organized a special symposium and lunch. Attended by women and supportive men, these gatherings help to highlight the contributions of women in the field and provide a forum for mentoring and networking. The groups also are supported by ASM's Board of Trustees task force on diversity, equity, and inclusion (DEI). Dr. Zi-Kui Liu elaborated on the DEI initiative in his presidential speech during the ASM Annual Business Meeting. An excerpt can be found on page 72. Liu will use his "From the President's Desk" column to communicate with the membership throughout his term.

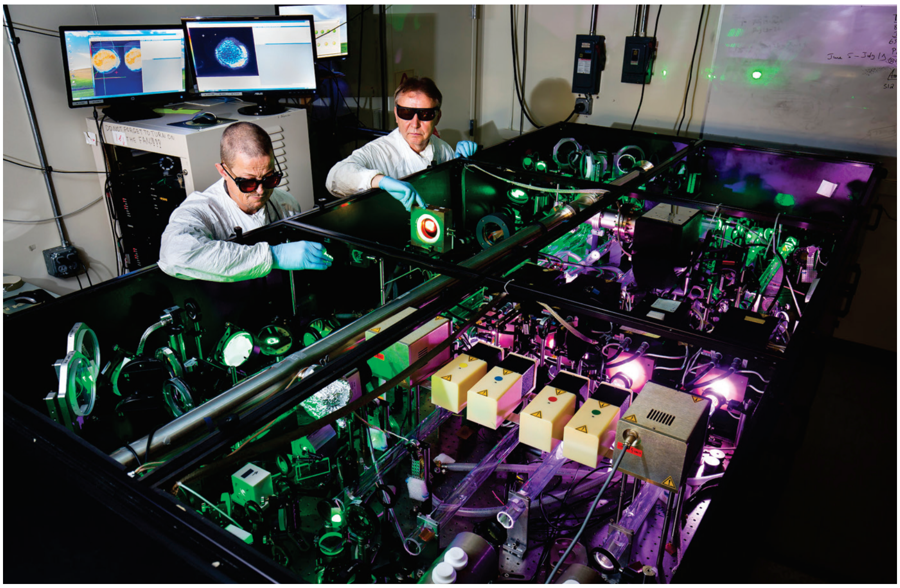
Now, as we turn the page on our fall travelog from 2019 events, we look forward with great anticipation to the debut of IMAT 2020—the International Materials Applications & Technologies Conference and Exhibition. ASM's new fall event will be held in Cleveland from September 14 through 17, 2020. With a theme of "Solving Global Materials Challenges," IMAT 2020 will be like no other event. The new conference will offer not only the best materials-related technical talks, but also will include a focus on the business and economic side of commercializing materials innovations to help companies calculate their return on investment.

As a precursor to IMAT, this issue of *AM&P* leads off with an article on "Improved Business Decisions through Patent Intelligence." The author shows how patent analysis can aid inventive companies through the R&D phase, business development, and IP security. Coincidentally, our *JTST* Highlights on page 44 showcases a journal abstract on a related topic, "A Review on Suspension Thermal Spray Patented Technology Evolution." So the interest in this field across multiple segments of our membership is growing.

As you read this final edition of *AM&P* for 2019, think about the souvenirs you have taken away from all of this year's issues. Let us know what specific content has made your reading journey more memorable. And be sure to make IMAT a key part of your 2020 travel itinerary!

joanne.miller@asminternational.org

RESEARCH TRACKS



From left, scientists Anatoly Maksimchuk and John Nees demonstrate use of the Hercules laser. Courtesy of Joseph Xu.

LASER AIMS AT MATERIALS SCIENCE RESEARCH

A new three-petawatt laser named Zeus will soon be built at the University of Michigan (U-M), Ann Arbor. Funded with $16 million from the National Science Foundation, the facility will enable basic and applied research, and will test a leading theory on how the universe operates at a subatomic level. The results could lead to advancements in materials science, medicine, and national security.

"This laser will have the highest peak power in the United States and will be among the world's most powerful laser systems for the next decade," says Karl Krushelnick, director of the Gérard Mourou Center for Ultrafast Optical Science at U-M, where the laser will be built.

The U.S. built the world's first petawatt laser in 1996, but has not kept pace with more ambitious systems under construction elsewhere. This includes two 10-petawatt systems in Europe and a 5.3-petawatt laser in China, which also has plans to build a 100-petawatt laser. Zeus will be an upgrade of an existing 0.5-petawatt laser known as Hercules.

The new laser will be a user facility, providing access to extreme laser intensities to scientists and engineers across the country. One of the planned experiments will shoot the laser at a high-energy electron beam going the opposite way in order to mimic a much more powerful zettawatt laser. With this capability, the U-M team is most excited about the possibility of probing quantum electrodynamics, the reigning theory of how the universe operates at the subatomic level. Regarding materials science activities, Zeus could help develop methods such as improving detection of nuclear weapons materials in shipping containers and exploring how materials change on very fast timescales. *umich.edu.*

PARTNERSHIP EXPLORES ADHESIVES FOR LIGHTWEIGHT VEHICLES

A new DOE partnership with PPG, Pittsburgh, will use supercomputing resources to accelerate development and testing of structural adhesives for vehicles made of lightweight materials. PPG will collaborate with DOE's Lawrence Livermore National Laboratory (LLNL) and Pacific Northwest National Laboratory (PNNL) to develop computer-based models of the aging characteristics of a variety of next-generation adhesives designed to join lightweight materials. Vehicle manufacturers are exploring the use of high-strength steel, aluminum, magnesium, carbon-fiber composites, and other lightweight materials to reduce vehicle mass and improve fuel economy. This approach requires new adhesive chemistries that will mitigate corrosion and thermal expansion issues associated with joining dissimilar materials.

"It is critical to understand how adhesive bonds evolve over the life of a vehicle," says Peter Votruba-Drzal, PPG global technical director, automotive OEM coatings. "This knowledge has traditionally come through iterative formulation and testing, including lengthy exposure tests. This project will enable us to reduce adhesives testing time by up to 75%, which in turn will help manufacturers accelerate development of increasingly energy-efficient vehicles."

The project will use supercomputing to achieve a fundamental understanding of the influence of water on the chemistry and adhesion properties of adhesives joined to lightweight substrates. Supercomputing resources are necessary due to the extremely large data sets involved in each simulation. PPG will provide $60,000 for the project in the form of technical activities at the company's Global Coatings Innovation Center in Allison Park, Pa. The DOE will provide $300,000 to LLNL and PNNL for modeling expertise and use of their supercomputing resources. *ppg.com.*

OMG!
OUTRAGEOUS MATERIALS GOODNESS

Five sea urchin tooth tips stacked on top of each other within the jaws. Courtesy of Horacio Espinosa.

SELF-SHARPENING SEA URCHINS

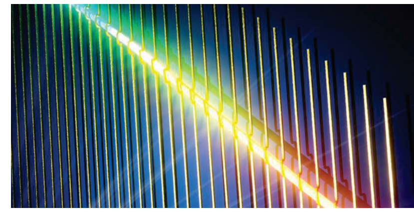
In the middle of their spiked bodies, pink sea urchins have five teeth—each one held by its own circular jaw. A team of researchers at Northwestern University, Evanston, Ill., has discovered how these fangs sharpen themselves. Instead of simply resisting wear, the teeth are built to chip in a way that helps them maintain a sharp edge. To make up for the loss of material, an urchin's teeth continue to grow throughout life. Scientists have long thought that sea urchins might have a sharpening mechanism, but it was not clear how they could selectively cleave portions of their teeth to stay sharp.

In the new study, researcher Horacio Espinosa and his colleagues combined sophisticated mechanical testing and electron microscopy to capture 3D movies showing how the urchin's dental structures wear. Their studies show that the teeth consist of ceramic composites arranged in a precise way. On the convex side of the tooth, calcite fibers provide structural integrity. This fibrous composite transitions to another composite made of inclined calcite plates. As the tooth wears, those calcite plates chip away to maintain sharpness. These results could help guide the design of both microstructure and materials for tools used in a wide range of cutting, grinding, and boring applications. *cell.com/matter.*

REACTIVE POLYMER AM SYSTEM

Magnum Venus Products (MVP), Knoxville, Tenn., recently collaborated with Polynt, Italy, and the DOE's Oak Ridge National Laboratory (ORNL) to deploy the first large-scale reactive polymer additive manufacturing (AM) system commercially available to industry. MVP's reactive additive manufacturing (RAM) machine, first announced in March, and Polynt's reactive additive deposition material (PRD 1520) are working together to enable fabrication of thermoset materials at a larger scale than previously possible. The thermoset advantage stems from the ability to cross-link polymers between printed layers resulting in stronger, more thermo-tolerant products. By collaborating with ORNL, MVP was able to scale up the technology from a benchtop solution to a commercially ready machine. PRD 1520 is a specially formulated reactive monomer material developed for use in the RAM machine. The material offers superior interlaminar adhesion, exceptional machinability, and a high heat distortion temperature compatible with aerospace grade tooling applications. *mvpind.com.*

RAM is the only large-scale thermoset AM machine enabling 3D printing of thermoset materials for prototype and production parts.



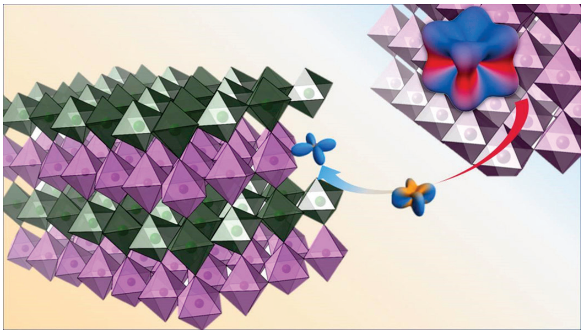
Artist's impression of a single-nanowire spectrometer. Courtesy of Ella Maru Studio.

SINGLE-NANOWIRE SPECTROMETER

Scientists at the University of Cambridge, U.K., designed an ultra-miniaturized device that could image single cells without the need for a microscope or make chemical fingerprint analysis possible with a smartphone camera. Made of a single nanowire, the new device is the smallest spectrometer ever created. Most modern spectrometers are bulky, and are based around principles similar to what Isaac Newton first demonstrated with his prism in the 1600s—the spatial separation of light into different spectral components.

Researchers have now produced a system up to 1000 times smaller than those previously reported. The Cambridge team, working with colleagues from the U.K., China, and Finland, used a nanowire whose material composition is varied along its length, enabling it to respond to different colors of light across the visible spectrum. Using techniques similar to those employed for making computer chips, they then created a series of light-responsive sections on the nanowire. The team hopes the tiny platform will lead to a new generation of ultra-compact spectrometers. *www.cam.ac.uk.*

METALS | POLYMERS | CERAMICS



Right: Electrons around an iridium ion. Left: Interfacing iridium with nickel alters its shape. Courtesy of Fangdi Wen.

IRIDIUM'S IDENTITY CRISIS

Scientists recently discovered a new kind of magnetic state when they created super-thin artificial structures containing iridium and nickel. Iridium loses its identifying properties and its electrons act oddly in an ultra-thin film when interfaced with nickel-based layers.

According to researchers at the National Science Foundation (NSF), Alexandria, Va., the nickel has an unexpectedly strong impact on iridium ions.

The discovery could lead to improved control of quantum materials and a deeper understanding of the quantum state for new electronics.

Scientists discovered that at the interface between a layer containing nickel and one with iridium, an unusual form of magnetism emerges that strongly affects the behavior of spin and orbital motion of electrons. The newly discovered behavior is important because quantum materials with very large spin-orbit interaction are popular candidates for new materials and exotic superconductivity.

The research was funded by two awards from NSF's Division of Materials Research. *nsf.gov.*

BRIEFS

Fortify, Boston, a composite 3D printing company, won the Awards for Composites Excellence (ACE) award in the Manufacturing category for Equipment and Tooling Innovation. The American Composites Manufacturers Association (ACMA) presented the ACE award to Fortify at the sixth annual Composites and Advanced Materials Expo for its Digital Composite Manufacturing platform. The technology improves performance by aligning fibers optimally throughout parts. *3dfortify.com.*

Fortify team accepts ACE award. Courtesy of CAMX.

MANIPULATING THE FUNDAMENTAL STRUCTURE OF POLYMERS

A research team at Florida State University (FSU), Tallahassee, has developed a method to manipulate polymers in a way that changes their fundamental structure, paving the way for potential applications in cargo delivery and release, recyclable materials, shape-shifting soft robots, antimicrobials, and more.

The FSU scientists are working to develop high-performance polymers with super-elastic and super-soft properties that could be used as joint or cartilage replacements. To accomplish this, their team is exploring the boundaries of how existing polymers respond to stimuli and can be reorganized for better performance.

Polymers that spontaneously "unzip" or deteriorate in response to an external stimulus have gained traction from scientists for their potential use in a variety of applications. However, this spontaneous deteriorating—called depolymerization—often makes them difficult to assemble in the first place.

The researchers refined a process to both create the polymer and cause it to break down, completely changing its structure.

They developed a thermodynamic strategy where they synthesize the macromolecules at a lower temperature and then stabilize the polymer before warming it up. At warmer temperatures, the materials could depolymerize with

Florida State University researchers authored a study on how to change the fundamental structure of a polymer. Courtesy of Bruce Palmer/FSU.

Parker Hannifin Corp., Cleveland, recently announced an agreement to acquire aerospace systems manufacturer **Exotic Metals Forming Co.,** Kent, Washington. Parker Hannifin will pay $1.725 billion in cash and plans to house Exotic Metals as a standalone operation within its aerospace unit. *parker.com, exoticmetals.com.*

a triggering event—the introduction of a catalytic amount of the element ruthenium—which causes an unzipping of the polymer.

"We've really invested in leveraging fundamental thermodynamic principles in polymer science, and we use this to transform the molecules into a variety of possible shapes and chemistries," the researchers say. "It's a way to recycle these materials, but it's also a way to get them to respond and change their architecture. There are a lot of fun possibilities with this." *fsu.edu.*

HARD AS CERAMIC, TOUGH AS STEEL

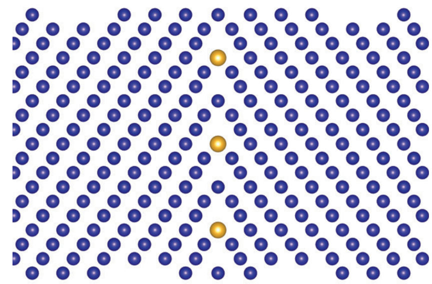
Engineers at the University of Michigan, Ann Arbor, found a new way to calculate the interaction between a metal and its alloying material, contributing to the search for a new material that combines the hardness of ceramic with the resilience of metal. The new method identifies two aspects of this interaction that can accurately predict how a particular alloy will behave—and with fewer demanding, from-scratch quantum mechanical calculations.

"Our findings may enable the use of machine learning algorithms for alloy design, potentially accelerating the search for better alloys that could be used in turbine engines and nuclear reactors," says lead researcher Liang Qi.

The search is on for a material that is very hard even at high temperatures but also resistant to cracking. Alloying elements combine with defects to create a network of disruptions in the lattice of the host metal, but it's hard to predict how that network will affect the metal's performance.

The team limited their study to metals with just one alloying element at defects—still a considerable design space with hundreds of material combinations and millions of defect structures. The researchers found they could predict how atoms of the alloying element concentrated at various kinds of defects.

However, they note that more descriptors must be discovered for predictions of how more complex alloys will behave, for instance those with two or more alloying elements at defects. And while these descriptors may feed into machine learning, humans will probably identify them. *umich.edu.*



Two iterations of a metal lattice meet at a grain boundary defect, with atoms of an alloying element (gold) fitting into the defect. Courtesy of Liang Qi.

TESTING | CHARACTERIZATION

The fibers of this UHMWPE test subject failed to break after numerous attempts at deformation. Courtesy of Simon Skovgård.

NEW SUPER MATERIAL TAKES ON BULLETS

In a partnership between Aarhus University, Denmark, and the University of Cambridge, U.K., researchers have established guidelines and failure maps for use of a lightweight, superplastic material in joints with steel bolts. Commercially known as Dyneema or Spectra, the ultra-high molecular weight polyethylene (UHMWPE) material is quickly superseding the para-aramid fibrous material, Kevlar, for use in bullet-proof jackets. Demand exists for this super material in several other applications.

The UHMWPE material consists of long chains of polyethylene, which strengthen the intermolecular interactions of the substance and enable the material to transfer stress loads effectively to the polymer skeleton.

This means that UHMWPE fibers have an incredibly high tensile strength compared to many other thermoplastics and also implies that the material is much stronger than steel in its fiber direction. The tensile strength of high-strength steel is approximately 900 MPa, but 3000 MPa would be required to break the fibers in UHMWPE.

The new research results are favorable for the commercial use of UHMWPE, which is being increasingly introduced in the shipping industry's containers, ropes, and nets, as well as armor for vehicles and personnel and in the textile industry. *www.international.au.dk, www.international.au.dk.*

AVOIDING CRITICAL FAILURES IN BIOMEDICAL DEVICES

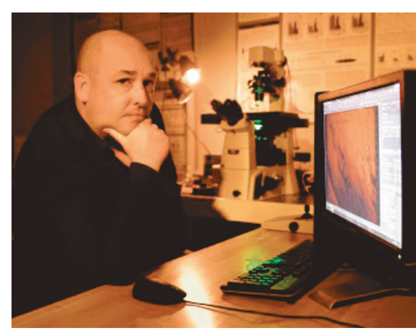
A research team from Binghamton University, N.Y., is using the topography of human skin as a model—not for preventing cracks but for directing them in the best way possible to avoid failures in critical components and make repairs easier.

The Binghamton research team engineered a series of single-layer and dual-layer membranes from silicone-based polydimethylsiloxane (PDMS), an inert and nontoxic material used in biomedical research. Embedded into the layers are minuscule channels meant to guide any cracks that form which, as part of a biomedical device, would give more control over how the cracks form. Potential damage could avoid critical areas of flexible electronics, for instance, increasing its functional lifespan.

What's particularly important, the researchers say, is having PDMS as the basis for the flexible membrane, since it is known for its wide variety of uses. The study also integrates other common materials.

Through ongoing research on human skin, the team realized that the outermost layer—known as the stratum corneum—exhibits a network of V-shaped topographical microchannels that appear to be capable of guiding fractures to the skin.

This study began with the idea of recreating this effect in nonbiological materials. Previous attempts to direct microcracks have utilized more solid means, such as copper films around



Associate professor of biomedical engineering, Guy German, aims to replicate the flexibility of human skin in nonbiological materials. Courtesy of Binghamton University, State University of New York.

BRIEFS

Verder Scientific, Newton, Pa., is looking for strategic investments, creating stable, highly competitive instrument business companies focusing on niche markets. **EZ-mat** is a distributor of materials testing equipment in China and currently represents two of the Verder Scientific product lines for metallographic preparation and hardness testing—ATM and Qness. *verder-scientific.com, ez-mat.com.*

AMETEK, Inc., Berwyn, Pa., will acquire **Gatan,** Pleasanton, Calif., a manufacturer of instrumentation and software used to enhance the operation and performance of electron microscopes, from **Roper Technologies, Inc.,** Lakewood Ranch, Fla., for approximately $925 million. Gatan is a pioneer in direct detection technology for electron microscopy. Its product portfolio includes electron microscopy cameras and instrumentation, electron energy filters, software, and accessories. *ametek.com, gatan.com, ropertech.com.*

the most sensitive parts of flexible electronics components. Applications in biomedical devices can help extend the life of critical components by allowing them to subtly stretch.

The researchers credit the increasing precision of additive manufacturing and its ability to print ever-smaller features with making the production of the membranes possible. *binghamton.edu.*

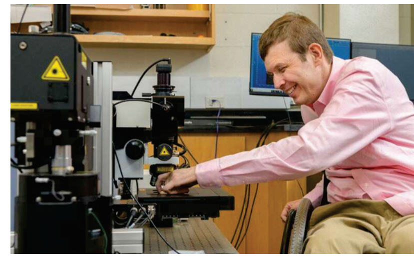
NEW MICROSCOPE OFFERS SCIENTIFIC TWOFER

Using an atomic force-Raman microscope, researchers at the University of Delaware (UD), Newark, can now examine at high resolution airborne toxic pollutants, single strands of DNA, and microscopic paint samples, among multiple other uses. The microscope, now housed at UD's Lammot du Pont Laboratory, affords scientists the capability to drive research forward in a wide array of fields. This new tool is a "scientific twofer," combining two microscopes in one, the features of a Raman instrument and an atomic force microscope.

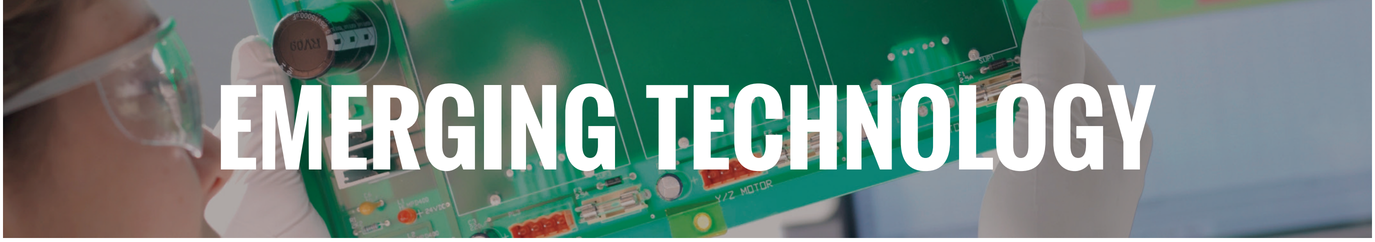
A Raman microscope can scan a sample with a laser, interacting with the vibrations of the molecule of interest, scattering the light; these light patterns serve as "fingerprints" for identifying the molecules and for studying their chemical bonds and degree of interactivity with other molecules.

An atomic force microscope scans a sample using a small probe that yields information about the surface, such as its topography, hardness, electrical, and thermal properties.

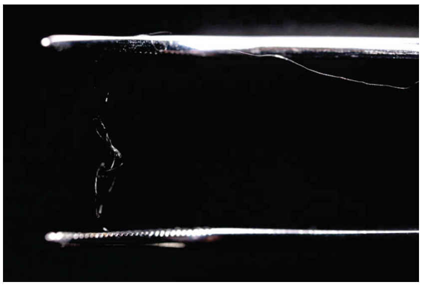
Combining both techniques within a single microscope delivers a trove of information simultaneously. This is important for a number of studies across the University and with industry collaborators. *udel.edu.*



Professor Karl Booksh helped UD acquire the new atomic force-Raman microscope. Courtesy of University of Delaware.



EMERGING TECHNOLOGY



Silk is a natural protein but can also be synthetically produced. Courtesy of Eeva Suorlahti.

NEW BIO-BASED MATERIAL MIMICS PLASTIC

Inspired by nature, researchers at Aalto University and the VTT Technical Research Center of Finland recently created a truly new bio-based material by gluing together wood cellulose fibers and the silk protein found in spider web threads. The result is a very firm and resilient material which could be used as a possible replacement for plastic, as part of bio-based composites, and in medical applications, surgical fibers, textile industry, and packaging.

The spider web silk used by Aalto University researchers is not actually taken from spider webs but is instead produced by the researchers using bacteria with synthetic DNA.

According to researchers, this work demonstrates new and versatile possibilities of protein engineering. They are currently developing new composite materials as implants, impact resistance objects, and other products. *www.aalto.fi/en, www.vttresearch.com.*

DIAMOND-LIKE SUPERHARD CARBON

Scientists use superhard materials to create scratch-resistant coatings and to slice, drill, and polish other objects. Now, researchers are using computational techniques to identify 43 previously unknown forms of carbon that are thought to be stable and superhard—including several predicted to be slightly harder than or nearly as hard as diamonds. Each new carbon variety consists of carbon atoms arranged in a distinct pattern in a crystal lattice.

Researchers at the University at Buffalo, N.Y., combined computational predictions of crystal structures with machine learning to hunt for novel materials in their theoretical work.

The hardest structures the scientists found tended to contain fragments of diamond and lonsdaleite—also called hexagonal diamond—in their crystal lattices.

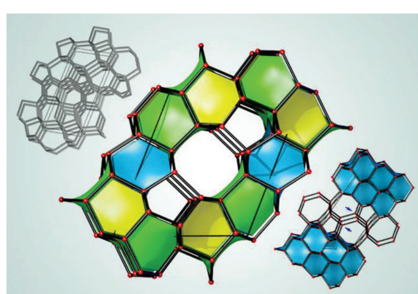


Illustration of three of the new superhard carbon structures. Blue indicates sections that are structurally related to diamond. Courtesy of Bob Wilder/University at Buffalo.

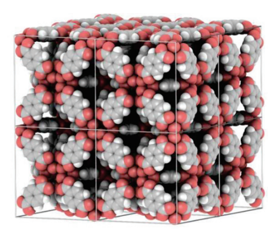
The techniques used in the research could be applied to identify other superhard materials, including ones that contain elements other than carbon. *buffalo.edu.*

METAL-ORGANIC FRAMEWORK DESIGN

Scientists from the University of Amsterdam are demonstrating design strategies for adjusting the thermal expansion behavior of microporous metal-organic frameworks (MOFs). The ability to realize negative thermal expansion coefficients is of great relevance to the potential MOF applications, e.g., at material interfaces where they could prevent cracking and peeling.

MOFs are predicted to exhibit wide-spread negative thermal expansion (NTE), due in part to their nano-porosity and flexible framework. They are particularly intriguing as NTE materials since they offer great design flexibility.

A fundamental understanding of MOF thermal expansion is crucial to advancing their use in a wide range of potential applications that include coated monoliths, microcantilever sensors, and electronic devices. *www.uva.nl/en.*

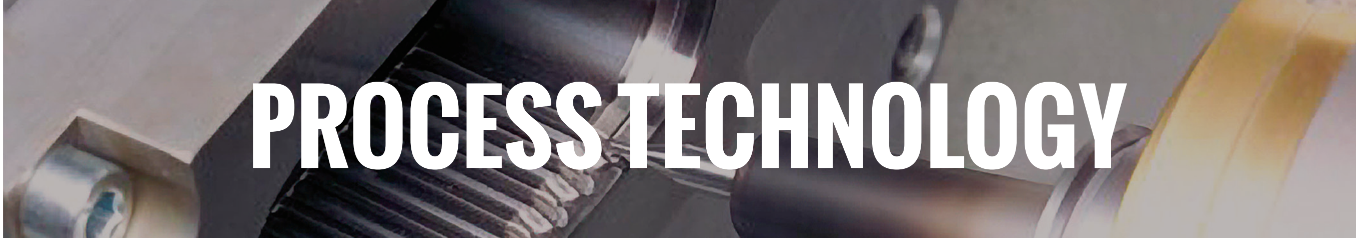


Metal-organic frameworks are the key to new design strategies. Courtesy of HIMS.

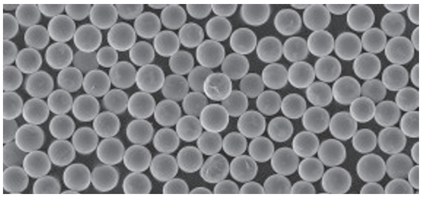
BRIEF

Scientists at the **University of Leeds, U.K.,** have created a new form of gold which is just two atoms thick—the thinnest unsupported gold ever created at just 0.47 nanometers. The material is regarded as 2D because it comprises just two layers of stacked atoms. *www.leeds.ac.uk.*

Artificially colored gold nanosheet.



PROCESS TECHNOLOGY



SEM image of Equispheres' aluminum alloy powder. Courtesy of Business Wire.

AM BREAKTHROUGH WITH ALUMINUM ALLOYS

Through extensive testing, scientists have found aluminum alloy powders that are suitable for sintering with binder jet technology. These findings have major implications for the automotive industry as aluminum alloys represent over 30% of the overall material demand in this space. The research was conducted by scientists at McGill University, Canada, in partnership with manufacturers at Equispheres.

Binder jet printers are 100 times faster than traditional laser based additive manufacturing (AM) printers and hold the promise of enabling AM to be used in mass production. However, until now, binder jet printer technology was unable to sinter aluminum alloys. The powder, developed by Equispheres, Canada, will enable one of the most efficient and scalable production methods—binder jet printing—to work with some of the most in-demand production materials, including aluminum alloys. This combination was previously unfeasible. Equispheres is presently working with key partners on the development of specialized binder agents required for aluminum and for specific automotive applications. *equispheres.com, mcgill.ca.*

NEW MATERIALS FOR FAST-NEUTRON REACTORS

Creating a new generation of fast-neutron reactors calls for the development of new structural materials. Now, scientists from NUST MISIS, Moscow, have developed a composite material that can be used in harsh temperature conditions, such as those in nuclear reactors.

To simultaneously achieve both the microhardness and the thermal stability of the composite material, the scientists used one of the severe plastic deformation methods—high-pressure torsion (HPT)—which enabled the creation of a specific multilayer structure with vanadium alloy.

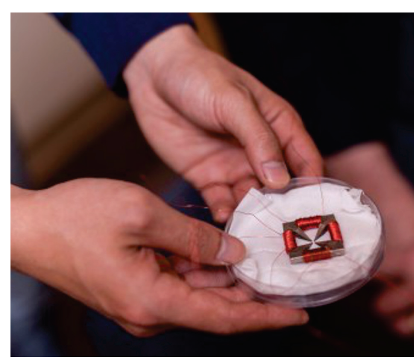
The resulting sample showed that, after HPT, the strength of the "sandwich" increased by three times compared to the strength of each of the individual components. In addition, the multilayer structure enabled the final material to withstand heating up to 700°C. Thus, for the first time, a composite nanostructured sandwich material with such high thermal stability was obtained. *en.misis.ru.*

NOVEL PRINTING CAPABILITY

A team of researchers from Oregon State University, Portland, and University of Oregon, Eugene, in collaboration with HP Labs, Palo Alto, Calif., is developing the capability to print electric and magnetic devices. In a project funded by the National Science Foundation, the first milestone will be the ability to print devices such as sensors or antennas.

In the same way a standard inkjet printer mixes color, the team's experimental printer uses inks composed of dielectric and magnetic nanoparticles to digitally print materials with tailored electromagnetic properties. If it proves successful, device designers will have the ability to print custom equipment for very specific applications.

This novel printing capability will also accelerate the development of new technologies by enabling rapid prototyping and optimization. *uoregon.edu.*

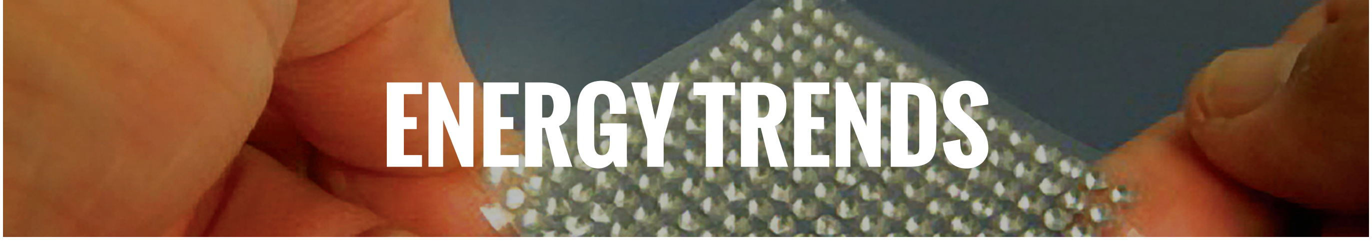


This digital inket printer head uses magnetic or dielectric particles.

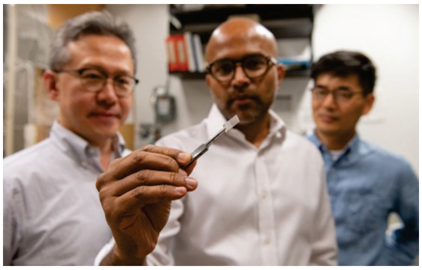
BRIEFS

Nanotronics, Brooklyn, N.Y., will open a high-tech manufacturing center at the Brooklyn Navy Yard, creating 190 new jobs and investing $11 million. *nanotronics.co.*

Hyperion Materials & Technologies Inc., Worthington, Ohio, a global materials science company focused on hard and superhard materials for high precision applications, will acquire **Arno Friedrichs Hartmetall GmbH & Co. KG,** Germany, a global solutions provider in premium cemented carbide blanks used in the manufacture of high precision rotary cutting tools for drilling and milling applications. *hyperionmt.com/en, afcarbide.de/en.*



ENERGY TRENDS



Researchers at Georgia Tech inspect a piece of platinum-graphene catalyst. Courtesy of Allison Carter.

USING ATOMICALLY THIN PLATINUM-GRAPHENE AS FUEL CELL CATALYSTS

Researchers at the Georgia Institute of Technology, Atlanta, are using ultrathin, graphene-supported platinum films to enable fuel cell catalysts with unprecedented catalytic activity and longevity.

Platinum is one of the most commonly used catalysts for fuel cells because of how effectively it enables the oxidation reduction reaction at the center of the technology. But its high cost has motivated research efforts to find ways to use smaller amounts of it while maintaining the same catalytic activity.

Most platinum-based catalytic systems use the metal's nanoparticles chemically bonded to a support surface, where surface atoms of the particles do most of the catalytic work, and the catalytic potential of the atoms beneath the surface is never utilized as fully as the surface atoms—if at all.

To prepare their atomically thin films, the Georgia Tech researchers used a process called electrochemical atomic layer deposition to grow platinum monolayers on a layer of graphene, creating samples that had one, two, or three atomic layers. They found that the bond between neighboring platinum atoms in the film essentially combines forces with the bond between the film and the graphene layer to provide reinforcement across the system. That was especially true in the platinum film that was two atoms thick.

Additionally, the new platinum films at that minimum thickness outperformed nanoparticle platinum in the dissociation energy, which is a measure of the energy cost of dislodging a surface platinum atom. The measurement suggests such films could make potentially longer-lasting catalytic systems. *gatech.edu.*

SOLAR LEADS GLOBAL INVESTMENTS IN RENEWABLE ENERGY

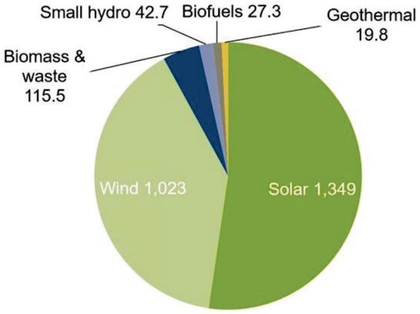
Worldwide investment in renewable energy capacity is on track to have roughly quadrupled in the past decade, according to the Global Trends in Renewable Energy Investment 2019 report, released ahead of the UN Global Climate Action Summit. Global investment in this sector from 2010 through 2019 is set to hit $2.6 trillion, with more gigawatts of solar power capaciity than any other generation technology.

Solar power will have drawn half of the $2.6 trillion in renewable energy investments made over the decade.

The global share of electricity generation accounted for by renewables reached 12.9% in 2018, up from 11.6% in 2017. This avoided an estimated two billion tons of carbon dioxide emissions last year alone—a substantial savings given global power sector emissions of 13.7 billion tons in 2018.

The cost-competitiveness of renewables has also risen dramatically. The levelized cost of electricity is down 81% for solar photovoltaics since 2009; for onshore wind, it's down 46%.

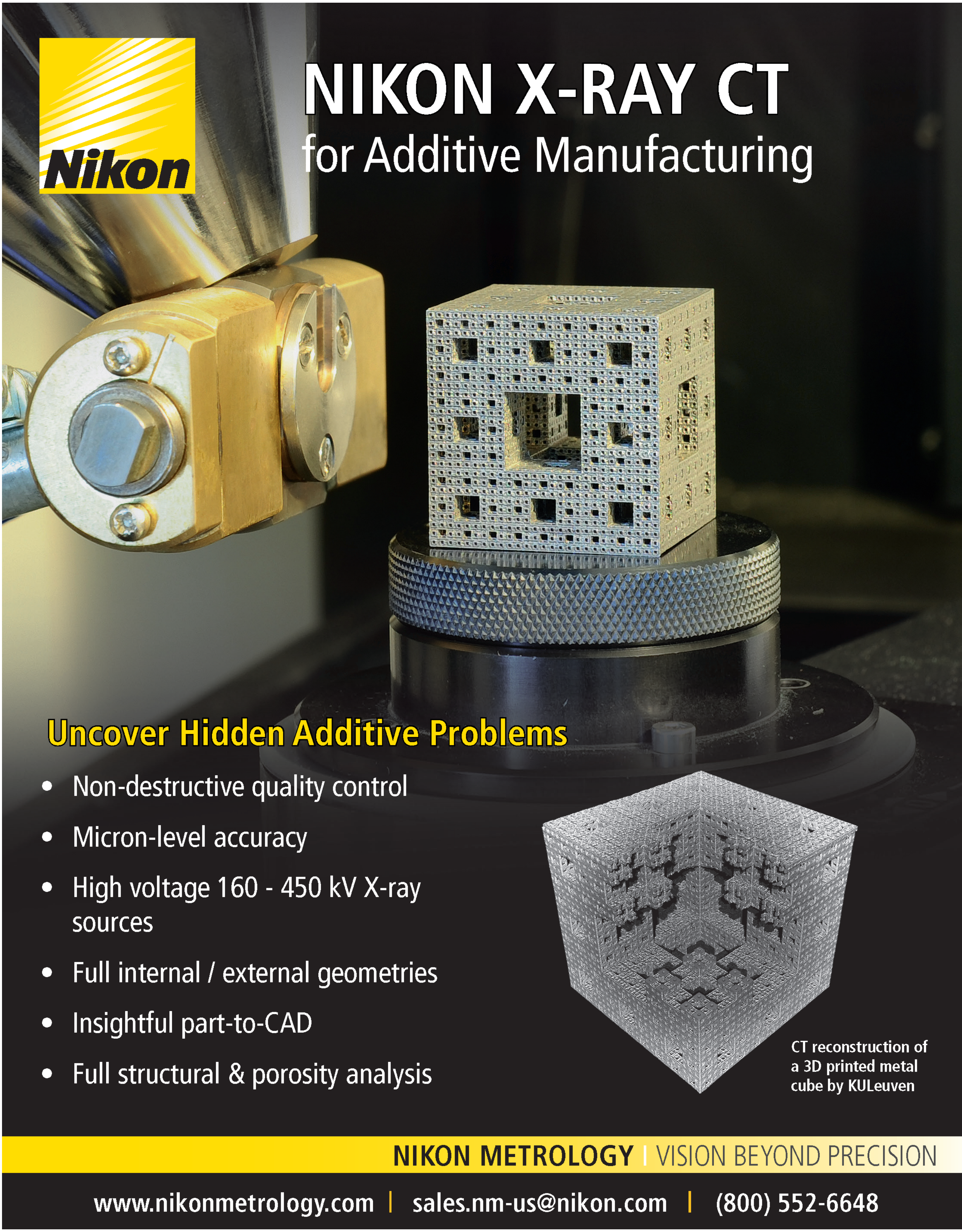
China has been the biggest investor in renewables capacity over this decade, having committed $758 billion between 2010 and the first half of 2019, with the U.S. second on $356 billion and Japan third on $202 billion. Europe invested $698 billion in renewables capacity over the same period, with Germany and the United Kingdom contributing the most. *unenvironment.org.*



Solar power represents more than half of the $2.6 trillon in renewable energy investments in the last decade. Courtesy of UN Environment/FS/BNEF.

BRIEF

Hyundai Motor Co., Fountain Valley, Calif., and **Cummins Inc.,** Columbus, Ind., have entered into a memorandum of understanding to jointly evaluate opportunities to develop and commercialize electric and fuel cell powertrains. The new powertrains are expected to combine Hyundai's fuel cell systems with Cummins' electric powertrain, battery, and control technologies. *hyundaiusa.com, cummins.com.*


Nikon
NIKON X-RAY CT
for Additive Manufacturing
Uncover Hidden Additive Problems
• Non-destructive quality control
• Micron-level accuracy
• High voltage 160 - 450 kV X-ray sources
• Full internal / external geometries
• Insightful part-to-CAD
• Full structural & porosity analysis
CT reconstruction of a 3D printed metal cube by KULeuven
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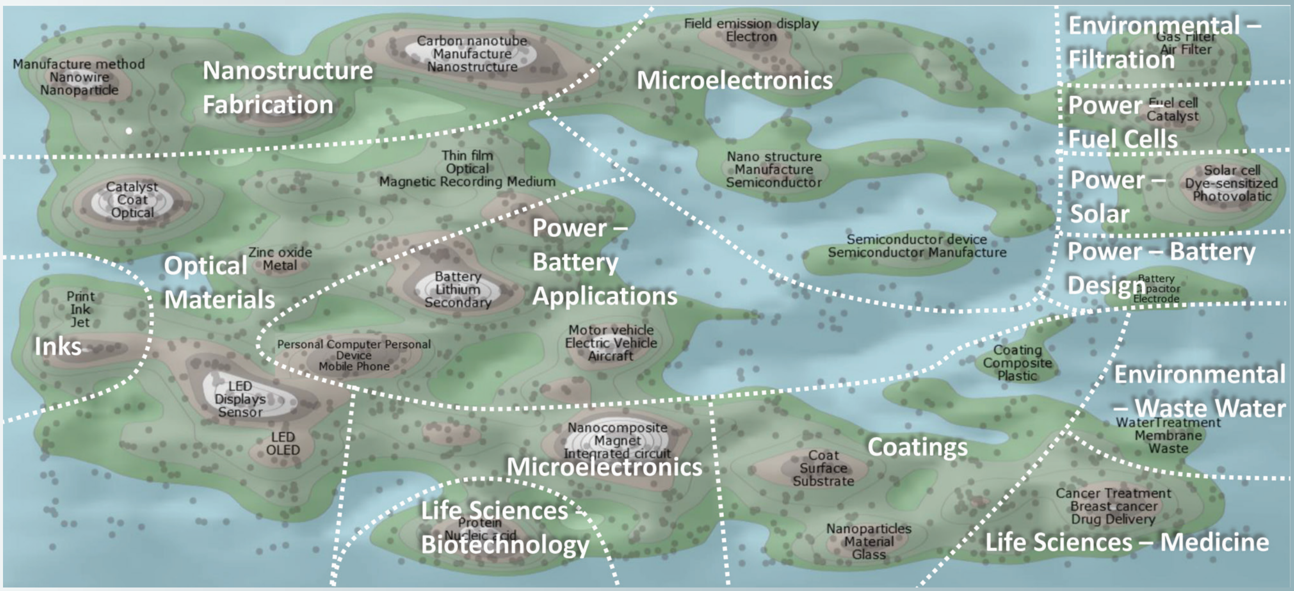
IMPROVED BUSINESS DECISIONS THROUGH PATENT INTELLIGENCE

Patent analytics enable analysis of hundreds or even thousands of patents, leading to insightful conclusions related to technologies and markets.



ThemeScape map of nanotechnology-related patents filed 2000-2015.

Jeffrey M. Davidson, Derwent, a Clarivate Analytics company, Philadelphia*

*Member of ASM International

For most materials professionals—whether working in a commercial business, university, or government research environment—exposure to patents is typically at the level of individual patent documents. This interest may be driven by a desire to understand the scope of in-force patents, as well as those that could limit an entity's ability to protect a specific invention or practice a certain technology. Many organizations also have formal or informal patent review processes that support technology scouting activities or help organizations generate new ideas for commercializable technologies.

Anyone who has done this type of work will note that patents are not easy reading; they are often complex documents that require time and focus in order to understand what is being "taught" by the patent, as well as the many elements of the invention that are described or claimed. For that reason, there are practical time and cost limits to the number of patents that can be read completely to support any of these objectives.

Less familiar to most materials professionals are the opportunities to analyze large numbers of patents—without thoroughly reading each one—to help inform a multitude of technical, business, or legal decisions. The core of this analysis is patent analytics, comprising lists, tables, charts, or other visualizations that summarize rankings, trends, and relationships in the patent data. While patent analytics may sacrifice a detailed understanding of any individual patent or invention, they enable the analysis of hundreds or even thousands of patents, as well as the development of insightful conclusions related to technologies and markets that can lead to faster and smarter decisions—the ultimate focus of patent intelligence.

FROM BUSINESS DRIVERS TO PATENT INTELLIGENCE

As with the analysis of any type of data, patent analytics by themselves are simply information that may be interesting, but not necessarily useful. While many patent studies make the mistake of starting and ending with patent analytics, what organizations actually need is patent intelligence developed in the context of specific organizational requirements and the environment around them. This intelligence provides insight and guidance that enable an organization to act.

As illustrated in Fig. 1, patent intelligence must be developed and analyzed in the context of organizational needs (i.e., business drivers) to be truly meaningful and actionable. The first step in the patent intelligence process is to understand these business drivers, which represent the underlying needs of the organization to make a more informed decision or develop an action plan. While many analyses can be developed for any patent dataset, only certain analytical frameworks can address the key driver at hand. An important skill of any patent analyst, therefore, is to identify or design analytics based on what is driving the analysis in the first place.

Business drivers might be related to issues of technology (e.g., new technology areas in which to invest the R&D budget or acquire externally), business development and strategy (e.g., expand a company's geographic scope for technology commercialization), or legal (e.g., optimize or monetize an organization's patent portfolio through pruning and/or licensing). These drivers might also vary depending on where an organization is with respect to the innovation lifecycle; burning issues are likely to be different if the organization is doing front-end exploratory research vs. leveraging a mature technology. Finally, business drivers may be dependent

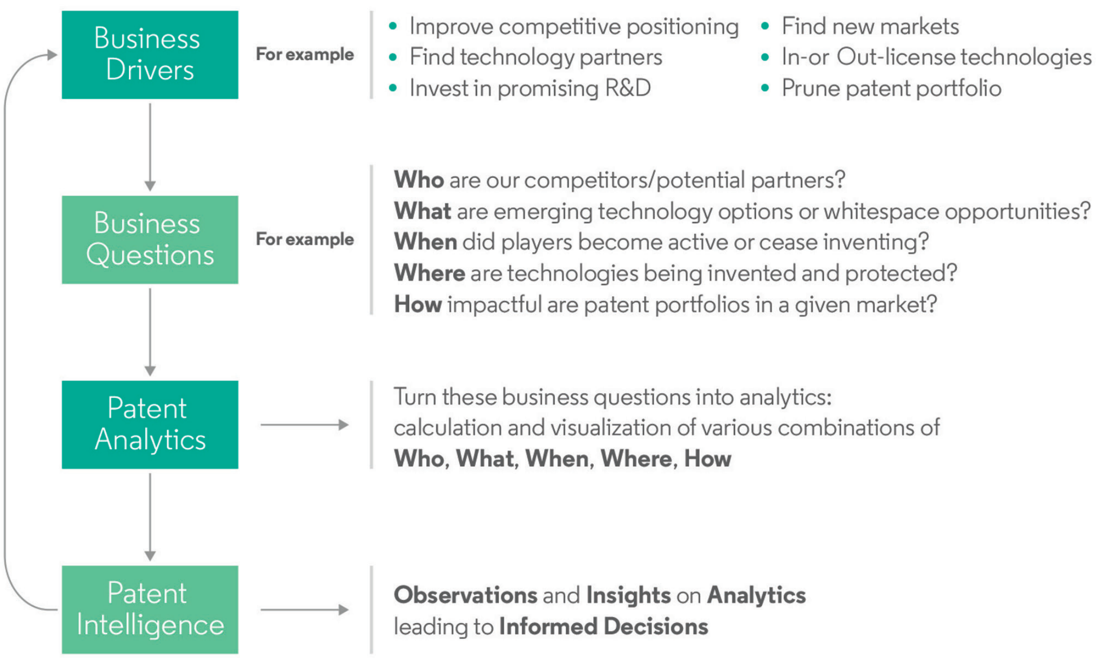


Fig. 1 — The patent intelligence process.

on the type of organization: small start-up, large corporation, university, government research lab, or even national government agency.

Despite differences in the specific business drivers, they can all be addressed by a finite group of simple business questions, which typically are based on who, what, where, when, and how, or any combinations of these, as illustrated in the Fig. 1 examples. It is only after the business drivers and relevant business questions have been defined that patent analytics are introduced. Typically, these analytics are visual representations of rankings, trends, or relationships that address the relevant questions. As highlighted in the sidebar, patent analytics might be provided within the software and/or service used to gather patent data, or they can be developed with the assistance of other popular data handling software packages or more powerful statistical and semantic analysis tools.

Analytics addressing these specific questions can be developed from typical patent data. For example, a pie chart may illustrate the top assignees (i.e., who) in any given technology area, or a line graph may show patenting time trends (i.e., when) for a given technology. These various information components might also be combined in a variety of ways to address more complex questions (e.g., a timeline of patenting activity of the most prolific inventing entities within a specific region to address who, when, and where in a single analytic).

Once the appropriate patent analytics are defined and developed, they need to be further interpreted in light of the technology/business/legal issues of concern to lead to patent intelligence—the combination of the analytics and the observations and insights derived from them. Only with this interpretation of the analytics can an organization define an action plan to address the original business drivers.

One can imagine a fairly extensive array of drivers and questions that might be addressed in any single patent study. However, after undertaking hundreds of patent intelligence studies, we often find a core set of drivers, questions, and analytics that address a broad range of organizational types, functions, and stages of business development.

R&D FUNCTION–EARLY STAGE

Driver: An advanced materials company's R&D has particular expertise in nano-sized materials fabrication and wants to explore opportunities for commercial exploitation of these technologies.

Questions: What end-use applications of nanomaterials that are potentially being commercialized, as evidenced through patent filings, might be considered for internal R&D investment? When have these patents been filed and, specifically, what end-use applications appear to be more recent and therefore possibly emerging?

Patent Analytics: A variety of patent analytics can be designed to visualize key technology themes and trends within the nanotechnology area. For example, the ThemeScape map shown on the first page highlights several end-use applications of nanotechnology described in patents filed globally between 2000 and 2015 based on semantic analysis and clustering of textual similarities of select patent fields (in this case, the Derwent World Patent Index "Use" field). In this map, each dot represents an invention, and the distances between inventions are determined by similarity in their textual content; the closer the location, the higher the similarity. Superimposed on these are key high-level themes that summarize this information, revealing particular focus in the areas of microelectronics, power applications, optical materials, environmental applications, and life sciences.

While this ThemeScape map provides information regarding what technologies are active in this area, additional actionable insights may be gained through "time slicing" the map. This would help to identify when the technologies have been developed to differentiate those that are emerging vs. those that are declining in activity.

The discovery of technology themes and time trends can be further refined with greater precision by first designing a "taxonomy" that predefines specific technology categories of interest and then categorizing each patent into one or more of these "buckets" through semantic and patent classifications analysis. Figure 2 is an example of this deep-dive categorization, showing

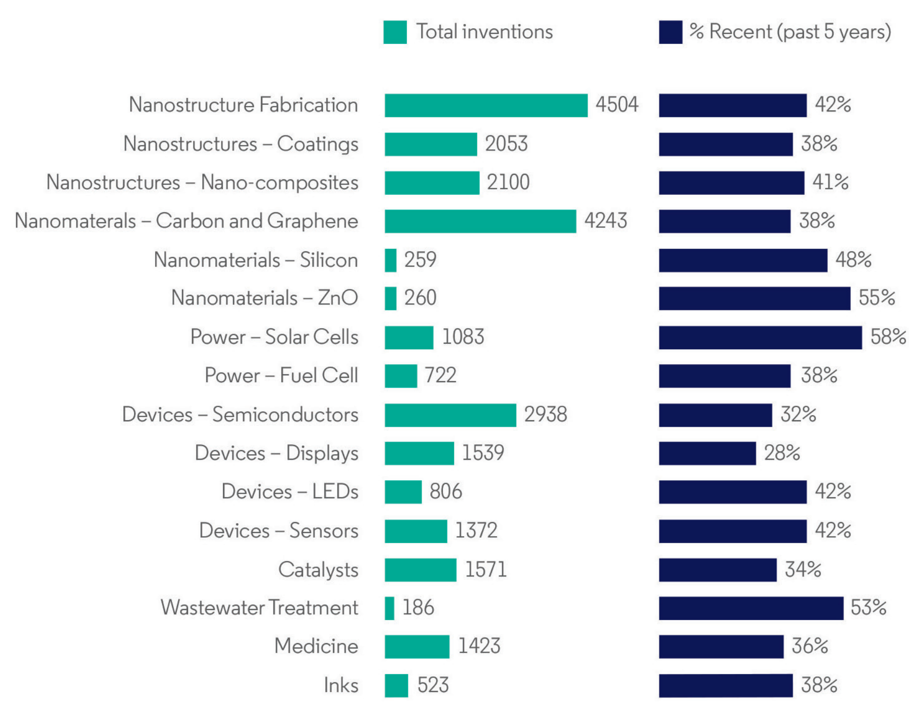


Fig. 2 — Detailed categorization of nanotechnology patents using pre-defined categories, 2000-2015.

the volume of patents in each category, as well as the "recency" (i.e., the percentage of patents in each category filed during the past five years). Based on this analysis, some topics of intense patenting over the 2000-2015 time period are evident, including technologies related to fabrication or carbon/graphene materials. Some areas of less overall but more recent patenting (indicating potentially emerging technologies poised for future growth) include ZnO nanomaterials, wastewater treatment, and solar cell applications.

Patent Intelligence: At a high level, the ThemeScape map summarizing hundreds or even thousands of patents can be easily shared and assessed across different divisions, functions, or levels of an organization. Comparison of the focal areas highlighted in the map vs. an organization's inventory of technologies can help identify opportunities for filling technology gaps through internal development, technology acquisition, or leveraging technology strengths in new markets. Even more quantitative information on potential opportunities is provided through detailed analysis of patent volumes and recency evaluations.

Ultimately, the materials company sponsoring this study may explore a number of other factors before committing to a new R&D program, including its business growth strategy, core expertise, strategic alliances, and more. However, the fact-based analysis of opportunities such as those shown here enhances the likelihood of success for the company's plan of action while providing identification and prioritization of those avenues of further research.

BUSINESS DEVELOPMENT FUNCTION–EXTERNAL TECHNOLOGY ACQUISITION

Driver: A large steel producer (Steel Co. A) has a relatively large patent portfolio focused on welding, with particular emphasis on arc-welding technologies (e.g., TIG, MIG), but with only a small number of patents focused on energy-beam (e.g., laser, electron beam) welding. Hoping to quickly expand its range of offerings in welding products and technologies, the company is looking to acquire patents related to energy-beam welding externally rather than developing the technology itself.

Questions: Who are the top commercial organizations with respect to welding technology development, and which of those are particularly focused on energy-beam welding? When have these entities been active in the field? Are they recently emerging, which might be attractive for early technology alliances? Or have they been recently inactive, perhaps exiting the market and seeking to sell their patents?

Patent Analytics: Figure 3 shows a listing of several large welding-related patent portfolio holders. Additional relevant data includes the welding patent portfolio size, the recency of the portfolio, and the relative intensity of patenting in specific welding technology types.

Patent Intelligence: The highest patent volume entities in this field appear to be commercially focused either on steel production or the automotive industry. Two steel company competitors (Steel Co. B and Steel Co. C) have a slightly greater number of energy-beam welding patents. Although these companies may not be desirable transaction partners due to their competitive nature, they nonetheless might be worth evaluating for possible shifts in business focus and consequent interest in patent out-licensing or sale.

Patent acquisition from one of the automotive companies may have fewer competitive constraints and present different sourcing options. Automotive Co. X has the overall largest welding technology patent portfolio, along with a moderately sized patent portfolio related to energy-beam welding. The fact that Co. X also has the most recent portfolio (70% filed in past five years) might suggest, on the positive side, technologies that leverage the latest developments in the field. On the other hand, because Co. X appears to be actively building a portfolio in the energy-beam welding area, it might be less inclined to pursue out-license or sale of patents in that area.

In contrast, although the energy-beam welding patents owned by Automotive Co. Y and Co. Z might be more mature and therefore less "cutting edge," their less recent patent portfolios might also suggest that they are no longer focused in this area and might be open to out-licensing or sale negotiations.

As illustrated in this example, additional options become available for

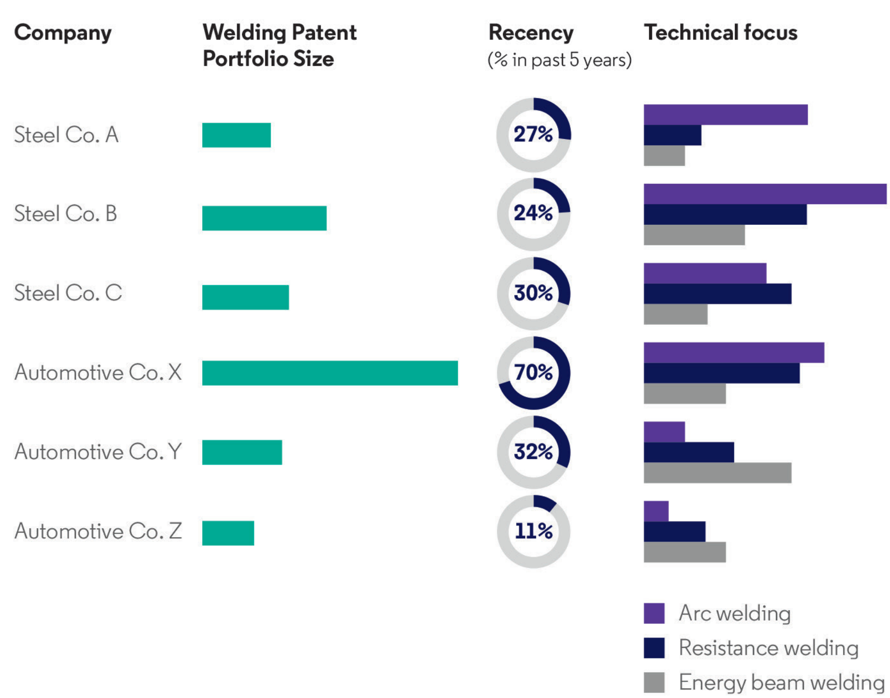


Fig. 3 — Company commercial focus, patent portfolio size, recency, and technical focus.

consideration by analyzing not only how many patents the key players in a field have, but also in what technology sub-areas they are focused and when they have been inventing in this area. While the patent analytics shown here do not by themselves single out the best strategy moving forward, they do use facts to narrow down the options to consider for further exploration.

LEGAL/IP FUNCTION–PATENT PORTFOLIO OPTIMIZATION

Driver: A global metals company has developed and patented technologies related to additive manufacturing (AM) of parts used in the aerospace industry. Due to the company's shift in strategic direction, as well as its desire to lower its patent portfolio maintenance costs, the company may consider "monetizing" (i.e., licensing or selling) AM IP assets that are no longer vital to its business operations and growth objectives.

Questions: How valuable are the company's patents related to AM for aerospace applications? Who might recognize that value and be interested in in-licensing or purchasing these patents?

Patent Analytics: The pricing of individual patents for license or sale is typically based on relatively complex tools and methods for non-tangible goods valuation using market-, cost-, or income-based approaches. While such valuations are important for establishing patent licensing royalty rates or patent sale pricing, these approaches are expensive and time consuming, involving more than what would generally be required for assessing whether patents should receive further maintenance, to what extent they should be filed in multiple jurisdictions, and if they should be exploited for further development.

However, a relatively quick assessment of the perceived importance of specific patents in a portfolio can be achieved through metrics that reflect the collective views of entities connected to the patent: those citing the patent, the examiners who ultimately allow or deny the granting of the patent, and the patenting entity itself. At Clarivate Analytics, a Derwent patent strength index (DSI) has been developed that ranks the level of interest of these three groups for all patents in a collection and uses this parameter as a proxy for commercial value. While such assessments do not necessarily identify which patents will eventually yield the greatest financial return, they do provide a consensus view (somewhat similar to crowd sourcing) regarding which patents are deserving of priority attention.

Figure 4 details the DSI ranking of the metals company's AM-aerospace patents relative to a peer group of several hundred patents filed globally since 1996 in this field. As noted, about 70% of the metals company's patents in this area can be considered either "very strong" or "somewhat strong," with the remaining 30% of the patents rated as only "somewhat weak" or "very weak." The higher strength patents (i.e., those of higher perceived value) appear to have higher rankings based on forward citations to those patents, patent grant rates, and global geographic coverage.

Once the portfolio is segmented according to strength ranking, the next task would be to identify what entities might be interested in licensing or buying these patents. One likely indicator

ENABLERS OF PATENT ANALYTICS

The creation and use of patent analytics are enabled by three key factors:

Structured Data: Patents are highly structured documents that can be organized into searchable databases. A patent's format is defined by patent authorities such as the U.S. Patents & Trademarks Organization (USPTO). Each U.S. patent has a number of specifically required fields[1] that can be represented as patent "metadata" (e.g., a publication number, a publication date, or patent assignee(s)), as well as a variety of text fields such as the patent title, abstract, and claims. In addition, a patent typically includes technology classifications related to its subject matter assigned by patent authorities such as the USPTO or the World Intellectual Property Organization (WIPO). Additional "value-added" classifications and summaries might be provided by companies such as the Derwent division of Clarivate Analytics.

The advent of digitization and machine translation enables patents to be organized into large databases that are relatively easily searchable online by any one or combination of several patent fields. Several databases with limited search capabilities are available free online, including websites of various country, regional, or global patent authorities[2,3,4], as well as other open sources such as Google Patents[5] and PatentLens[6]. Other commercially available, fee-based databases such as Derwent Innovation[7], Questel-Orbit[8], or GridLogics-PatSeer[9] enable more complex searches, along with more powerful data download capabilities.

Analytics Software: The fielded data for large numbers of patents, once downloaded, can subsequently be imported into other software packages for additional data mining (to reveal statistical patterns and relationships in the data) or text mining (to reveal concepts expressed in the text fields as well as similarity between text fields or documents). Such capabilities can be provided in "shrink wrapped" software applications, such as Microsoft Excel, or in more sophisticated software packages specifically designed for document analytics, such as Derwent Data Analyzer[10].

Visualization Tools: The third enabler of patent landscaping is the now nearly ubiquitous presence and availability of visualization tools[11]. Such visualization capabilities have been rapidly embraced by the patent analytics community. By converting vast quantities of patent data into easily understood graphs and charts, key trends and factors that impact those trends can be more easily grasped by the non-expert and communicated broadly across an organization.

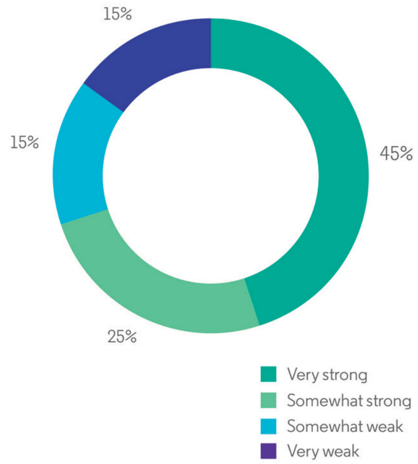


Fig. 4 — The metals company's DSI patent portfolio profile.

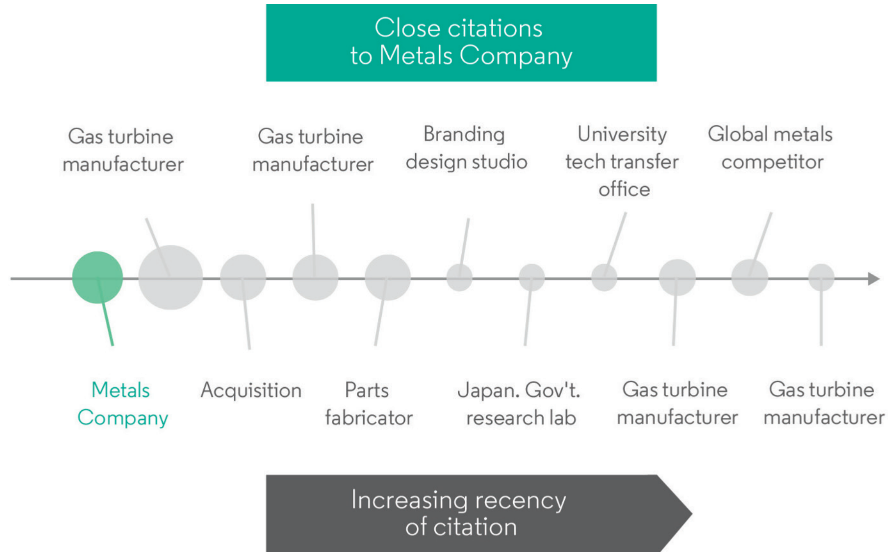


Fig. 5 — Patents citing the metals company's patent portfolio related to AM for aerospace applications (circle size represents volume of citing patents).

of interest might be entities that have cited patents within the metals company portfolio and are therefore developing closely related technologies.

Figure 5 shows various entities with patents that cite the metals company's portfolio. Ordered by their recency (from least to most recent) are citations classified as "highly relevant."

Patent Intelligence: The process of monetizing patents is driven by the significant costs for both filing and maintaining a patent portfolio, especially if the patents are filed in multiple global jurisdictions. As illustrated in this scenario, the first step in this process is to identify patents in the portfolio that might attract the greatest amount of interest externally—and presumably the highest license or sale price.

The second step of identifying potentially interested parties from citation analysis yields a list of possible target entities to contact for licensing or sales negotiations. Several business and strategic factors need to be considered in addition to the interest of these entities, including the degree to which they compete with the metals company or, alternatively, the likelihood that they have the resources to successfully complete the license/sales transaction. Based on these criteria, the four gas turbine manufacturers might be obvious entities to target, whereas the global metals competitor would not. Although the Japanese government research lab and the university tech transfer office may not be good candidates for a license/sales transaction, they may still be worth contacting to explore options for connecting with their partners or university-industry consortia.

PUTTING PATENT INTELLIGENCE TO WORK

In all the examples shown here, the underlying needs of an organization are addressed through the examination of large patent collection data to uncover meaningful patterns, trends, and relationships, and then the interpretation of these to address those that are most pressing. Because business needs vary across organizations, technologies, and timeframes, the specific analytics developed for any single study will likewise vary.

For any study, however, the overall framework of business drivers, questions, patent analytics, and patent intelligence remains the same. The desired end result is always a higher quality, data-informed decision-making process for big-bet investments in technology development and commercialization. Whether this study is performed in-house using patent search and analytics tools or through services provided by external vendors, the costs in terms of money, resources, and time should be far outweighed by the value of increased investment success rates. **~AM&P**

For more information: Jeffrey M. Davidson, consultant – Patent Analytics, Derwent, 1500 Spring Garden, Philadelphia, PA 19130, 215.386.0100, jeff.davidson@clarivate.com, https://clarivate.com/derwent.

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TECHNICAL SPOTLIGHT

FIVE TRENDS IN MATERIALS TESTING EQUIPMENT

Automation, ease of use, safety, and data integrity are driving changes in the mechanical testing industry.

In addition to the evolution in technology used to evaluate mechanical properties of materials, components, and structures, the people using the equipment and the processes surrounding the equipment have also evolved. Over the past few years, requirements from operators and lab managers across diverse industries have merged to reveal new trends and expectations in the field of mechanical testing. These trends broadly include adding automation to reduce operator errors, locking down system permissions to ensure data integrity, superior usability to reduce the demand for operator training, and safety. A closer look at these trends reveals that they heavily rely on the software platform used to control the testing system. From Instron's perspective, the most common trends in the industry are:

1. Barcoding
2. Integration with laboratory information management systems/databases
3. Data integrity
4. Usability of the system and software
5. Safety

BARCODING

Barcoding specimens or batches of specimens aims to reduce operator error caused by typing incorrect information into the test system. Many software packages offer barcode scanning that directly inputs fields such as lot number and batch number into the software program. This is the most basic sort of barcode functionality where the barcode acts as a keyboard emulator. However, many users want to take barcoding a step further by linking the barcoded information to test recipes or test methods. In these instances, most labs prefer to use QR codes because of the additional information that can be stored in the QR code format. The desired trend is to allow a technician to scan a barcode or QR code on a batch of specimens that would then open the correct software test method and populate all necessary fields. This allows the operator to scan a single field and immediately conduct a test, without the concern of making a simple human error that could invalidate the test results.

LIMS INTEGRATION

While barcoding automates the entering of data into the software, many users also want to automate the process of extracting test results and raw data from the system. Most labs use a network drive or company database to store or back up the results and/or raw data from their materials testing system. Laboratory Information Management Systems (LIMS) are designed to store large datasets from multiple pieces of testing equipment in one place. However, many LIMS are password protected and come in a variety of shapes and sizes, making it difficult for a third-party equipment supplier to directly interface

Users can avoid typing errors by using a barcode to emulate a keyboard. Barcodes and QR codes can store information to automate many manual processes.

Instron's Bluehill Universal software is displayed on a large format touch monitor and utilizes a flat intuitive user interface.

with them. For this reason, the current trend is to automate the process of extracting data from testing equipment in completely customizable formatting. By offering a flexible export format, IT departments who manage the LIMS can easily pull the exported data into their LIMS as part of a weekly, daily, or hourly process. Many software programs can also run an executable file to trigger a data pull after every export, further automating and simplifying the process of backing up the results of the test system. Some equipment suppliers may also have a separate tool that allows users to export results to a database that lets them view those results over time. These types of data trend tracking tools can be used in combination with an export of results and raw data to a larger LIMS.

DATA INTEGRITY

Whether a materials testing professional is in the medical device, aerospace, food testing, automotive, or pharmaceutical industry, data integrity and results validation is constantly under a microscope. FDA 21 CFR Part 11, ISO/IEC 17025, and NADCAP accredited labs have always focused on ensuring data integrity and traceability so that labs know who tested what, when, and why any modifications to testing recipes or protocols were made. However, the desire to track changes to test methods and require sign-offs on changes has become a trend in the industry for many quality control and production laboratories. Having an electronic audit trail from the testing system not only makes audits easier to pass, it also helps the lab manager troubleshoot issues and provides peace of mind that testing is being done correctly. Many software packages have the option to track test recipe history, provide an audit trail that tracks all uses of the system, and configure signatures to ensure people in the lab are not making unauthorized changes to methods. The trend toward focusing on data integrity is present across many different industries, not just medical and aerospace, and stems from recent data integrity issues in the news where labs were falsifying results. For many companies, it is best to put measures into place to prevent problems before they come to the surface in an audit or quality complaint. Many labs performing coupon testing have shifted away from operator-based testing and implemented the use of robotic systems to run tests in hopes of increasing throughput and avoiding accidental or malicious falsification of results. However, not all mechanical tests are appropriate for robotic automation, especially in cases where the throughput is not high enough to justify the financial investment. Furthermore, in cases where structures or components need to be tested, operator intervention to set up the unique product configuration is needed.

USABILITY

With the global popularization of smart phones, users have come to expect all technology to be similarly intuitive with flat, simple interfaces. Most users can agree that having to “right click” on a screen to see more detail is not necessarily intuitive. Over the past few years, there has been a growing shift towards “touch friendly” software. However, there is a difference between touch friendly and touchable. With a touch monitor or computer with a touch screen, any software can become touchable. However, users must think about the experience of opening their browser and navigating to a webpage on their smart phone verses opening an app on their smart phone. When software is not designed for touch, the icons are smaller, press points are difficult to interact with, and the intuitive advantages of touch, such as the elimination of the right click, tend to disappear. The trend in software programs is not necessarily to make software touchable, it is about making the software touch friendly, with all the intuitive gestures and functionality expected by users. Having a flat, intuitive software program reduces the amount of training required for operators and provides a more enjoyable user experience.

Materials testing systems with inherent safety functionality helps protect sensitive transducers like load cells. Even the simplest safety reminders to set mechanical travel limits on the system can prevent an accident.

SAFETY

Test equipment safety is not a new trend. Over the decades, companies have always sought to make testing equipment safer, especially in the field of materials testing where the systems are, in fact, designed to break things. However, in recent years, companies have started to look more closely at the sources of injuries and accidents. They have discovered that systems with simple, smart, built-in safety features are always superior.

Systems with safety functions such as software reminders, software guidance, enhanced sensing, and hardware limits are becoming more popular. Not only do these features and functions help protect the operator from accidents, but they also protect the equipment. In the materials testing world, force transducers can be very accurate and sensitive, and can be easily damaged by overloading or excessive force. A correctly set up system with hardware and software limits not only protects the operator, it also protects the hardware, ultimately saving the company money by avoiding unnecessary costs associated with repair.

Overall, barcoding, better integration with laboratory information management systems, data integrity, software usability, and safety are the top five current trends in testing equipment. These trends broadly encompass the higher-level trends of adding automation to reduce operator error, locking down system permissions to ensure data integrity, superior usability to reduce the demand for operator training, and safety to reduce OSHA recordable incidents while simultaneously protecting sensitive hardware from damage. Adapting these features allows labs to increase safety and throughput while ensuring that test results are accurate and repeatable. **~AM&P**

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AUTOMOTIVE ALUMINUM—PART IX OBSTACLES ON THE ROAD TO ALUMINUM VEHICLE PRODUCTION

Industry consolidation, lubricant concerns, and springback issues continued to test automakers as they worked toward aluminum-intensive vehicles.

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Industrial consolidation via mergers, acquisitions, and takeovers defined the 1990s, restructuring both the metal and automotive industries, among many others. In 1997, Reynolds Metals Company (RMC) decided to concentrate on four core businesses, selling its McCook operation on November 4 to a private equity group under the name McCook Metals. With the new owners primarily focusing on aircraft products, auto body sheet (ABS) production ended. As chronicled in Part V of this series, McCook's outdated, inefficient heat treatment line was never going to be competitive in the evolving ABS market. That left Alcan-Kingston, Alcoa-Davenport, and the newly opened Alcoa-Danville plant as the only ABS suppliers in North America. In early 1999, RMC sold both its recycling business and remaining hot rolling asset in Muscle Shoals, Alabama, to a private rolled products company, Wise Metals. The plant focused on can sheet production under RMC and Wise management.

Alcoa's takeover of the leftover assets of RMC and Alcan's proposal to merge with Alusuisse and Pechiney were followed by British Steel's takeover of the Dutch steel and aluminum producer Koninklijke Hoogovens. The resulting mixed-metal conglomerate was renamed Corus Group and included the aluminum mill in Duffel, Belgium. At the time, Alusuisse enjoyed a near monopoly on ABS production in Europe, due in part to the patent on its Cu-free Ac120 alloy. German automakers had an aversion to copper-containing alloys because they were blamed for corrosion issues in the early days of cast aluminum wheels. Pechiney's AU2G (>2% Cu) and Alcan's 6111 (0.7% Cu) had always been nonstarters in Germany, leaving alloy 6016 as the clear choice for German automakers. Pechiney had started work on a new alloy, but it was so close to 6016 that it prompted a dispute with Alusuisse. They eventually registered 6016A in 1995, just two years before the Ac120 patent expired.

Consolidations and mergers among automakers and within the metals industry defined the 1990s.

Merger activity was not limited to the sheet metal industry. Germany's Daimler and U.S.-based Chrysler merged in May 1998. Ford Motor Company bought Volvo Car in February 1999. In March, Renault announced it was forming an alliance with Nissan. However, as 1999 progressed, most if not all of this merger activity was lost on the Ford and Jaguar teams working to bring aluminum-intensive vehicles (AIVs) to market. For the Ford team, part of the D219 project included a study of the evolving ABS supply footprint. The D219 program would require about 25,000 mt/yr of 6111 and 120,000 mt of 5xxx ABS. In 1999, Alcan and Alcoa still had enough heat treat capacity and there were several other potential suppliers for 5xxx ABS. Further, aluminum prices had stabilized around $1500/mt following the dissolution of the Soviet Union in late 1991. From a supply point, D219 was in a historical sweet spot, a period of relatively low prices and sufficient open capacity.

JAGUAR X350 DEVELOPMENT

The low production volume of the X350 meant that Jaguar faced no supply concerns other than Alcan's ability to deliver outer quality 6111. Development continued steadily, and despite another two-month delay, Ford's board of directors approved the program in late June 1999 with Alcan as the sole sheet metal supplier. The focus now turned to finalizing the design and starting the long march toward production. The design followed the AIV, with 6111 skins, 5754 for the body structure, and 5182 for hood and trunk lid inners. The door inners were multi-piece assemblies that included castings and extrusions. The

**Member of ASM International*

body included seven high-pressure die castings for the suspension mounting points and center driveline mount. Extrusions were used for the bolt-on front bumper system and bumper beams.

X350 attracted a great deal of interest from Dearborn, which was not always helpful. As the clay model was being finalized, Ford CEO Jacques Nasser dropped by the studio in Whitley. Over the objections of the design and manufacturing teams, he decreed that the roof be made flatter. This required additional structure to compensate for the lost panel stiffness. Despite all such "help," the clay was finally approved in October and engineering continued in earnest.

Twenty years ago, stamping feasibility was still almost entirely based on experience. Although Jaguar had a rich history with aluminum sheet, it had been for low volume, specialty models. For X350, the Ford/Jaguar stamping team was keen to minimize uncertainty and decided to mandate 3D forming simulations of all the major stampings. Alcan supported a team of analysts in Whitley, while Ford had its own team in Dearborn. Both teams used Optris, an early commercial 3D finite element analysis (FEA) stamping simulation program. Ford provided the standard simulation setups and evaluation criteria.

Meanwhile, the aluminum technology team led by Ford's Bruno Barthelemy concluded that aluminum resistance spot welding (RSW) technology was not mature enough to support a full body shop, opting instead for self-piercing rivets (SPRs), which had entered production with the Audi A8. Choosing SPRs simplified the body shop power distribution and mostly eliminated the need for destructive testing. Through careful optimization and the use of 120 meters of structural adhesive, Jaguar was able to keep the number of SPRs below 3200, compared to 5000 RSWs in a typical steel body. The new body was larger and offered better crash performance than its predecessor, yet it was 60% stiffer and 40% lighter weight than the steel model.

As a low volume luxury carmaker, Jaguar relied on full-service tooling suppliers. In 1999, securing suppliers with aluminum expertise meant using toolmakers who had worked for Audi on the A8 and A2 models. Sourcing for the 119 sets of stamping tools was divided among Läpple, Allgaier, Nothelfer, Fagro, and Ford's own tool shops in Cologne, Germany, Dagenham in the U.K., and Dearborn.

The biggest surprise for the tooling suppliers was the requirement that they could not start machining until a successful simulation had been completed. As the simulation runs accumulated and the weeks ticked by, the pressure to start the physical tryout mounted, but the stamping team stood firm. Finally, one by one, the simulations turned "green" and the physical tool tryouts could begin. In the end, the effort paid off: 86% of the draw dies successfully made a part during the first phase of the die tryout. Unfortunately, the technology did not include any springback compensation nor did it include the secondary operations, leaving the stamping team to face many uncertainties as the months went by.

LUBRICANT ISSUES

Toolmakers reported an unexpected issue with the AL070 lubricant in the first physical tool tryouts: AL070 accumulated in the tools to the point of preventing them from closing, even damaging some. The problem was traced back to abnormally high coating levels. The design of AL070 had focused on delivering unparalleled lubricity with a robust compatibility with the chosen epoxy structural adhesive, but little thought had been given to an industry-friendly application method. It could only be roller-coated at high temperature as a liquid, and Alcan's Nachterstedt plant found the process difficult to control using the equipment at their disposal. The result was that some blanks had more than four times the expected amount.

There was no time to develop an alternative lubricant before the launch, so the only solution was to find a better application method. After months of trials and equipment upgrades, the process improved to an acceptable level. Even so, scheduled lubricant cleanups from the tools remained a fixture of X350 production. Finding a lubricant solution suitable for larger production volumes became a high priority of the aluminum technology team.

FORD PRODIGY, X350, D219 PROGRESS

Neil Ressler, Ford's VP of research and vehicle technology, introduced the Ford Prodigy concept car at the North American Auto Show in Detroit in January 2000. The culmination of Ford's Partnership for a New Generation of Vehicles (PNGV) work, the Prodigy was an all-aluminum, hybrid electric vehicle based on the P2000 platform, delivering 78 mpg. But the buzzword in early 2000 was not fuel economy, but industry consolidation. That same week, GM exercised its option to complete the acquisition of Saab Automobiles. On March 14, Alcan announced it was withdrawing its bid to acquire Pechiney in the face of stiff opposition from the European Antitrust Commission, but it had received the green light to acquire Alusuisse. The same day, GM revealed it was buying a 20% stake in Fiat, while

Ford Prodigy, an all-aluminum, hybrid electric vehicle introduced in January 2000.

Ford bought Land Rover from BMW three days later. Alcan completed its acquisition of Alusuisse in early June.

At that point, X350 was about 32 months from Job1. Presses and equipment for a new shop on the Castle Bromwich site had been ordered. The new plant's layout included provisions to segregate 5xxx and 6xxx series alloys prior to recycling the stamping offal. Because that would be Jaguar's first stamping plant, the Dutch company Polynorm was hired to staff and launch the facility. Plant management returned to Jaguar after the launch. Construction of the new body shop was underway and the program was steadily progressing toward production.

Meanwhile, back in the U.S., the future of the D219 program as an AIV was in serious trouble: The purchase of Volvo 18 months earlier had provided Ford with a modern D-size platform. The idea of using a Volvo platform appealed to Rick Borsos, the D219 body engineering manager, who had never liked the AIV concept. The lack of an optimized powertrain was the final straw: The weight savings of an AIV by itself could not deliver enough fuel economy improvement to justify the added cost or development time. Compounding the problem, the word "optimization" really meant switching to engines with fewer cylinders, from a V8 to a V6 or from a V6 to an I-4. In the 1990s and early 2000s, the American public clearly associated powertrain quality with the number of cylinders. Consider that both the Audi A8 and the Jaguar X350 launched with V8s in North America—rather than the fuel efficient, 3L V6 available in Europe.

By late 2000, low gas prices and the absence of a proper powertrain left D219 without significant Corporate Average Fuel Economy (CAFE) benefits, and the program reverted to steel, becoming the first North American vehicle to ride on a Volvo platform. The only aluminum ABS content was found in the hood.

Jaguar was now officially the AIV implementation leader within Ford and it played a growing role in the company's aluminum technology projects. The focus began to switch to lessons learned and gap assessments, resulting in several new R&D projects. For example, X350 had been forced to accept an old-fashioned two-piece body side with two cosmetic joints to the roof. Formability dictated 5754 for the door aperture itself, but the skin of the rear fender had to be 6111 for surface appearance reasons. Worse yet, the team had counted on minimal Lüders bands on the 5754 part to allow a small, visible portion of the door aperture at the front pillar. Unfortunately, that proved impossible and they had to add a 6111 cover piece, creating a three-piece design (Fig. 1).

Multi-piece designs had long been replaced by one-piece designs in steel, improving fit-and-finish and eliminating costly and tricky cosmetic joints. Therefore, one of the major projects aimed to define the design and stamping guidelines that would enable a one-piece 6xxx door opening panel, similar to a steel construction.

Other projects included better springback management and improving craftsmanship for aluminum sheet metal parts. But the development of a new generation of stamping lubricants to replace AL070 remained a top priority. The choice of laser blanking in lieu of traditional blanking dies was one of the more controversial decisions of the X350 program. In the end, it turned out to be very cost-effective: It lowered the tooling bill and fit nicely in Nachterstedt's process plan along with the new surface pre-treatment line and the AL070 application system.

TOOLING TRYOUTS

By early 2001, pressure was mounting for the stamping team to deliver the tooling. The highly complex rear rails had been sourced to Ford's Dearborn Tool and Die. The equivalent high-strength steel parts for the DEW98 were produced by an outside supplier using a nine-die process. For X350, the original process plan called for a much condensed five-die lineup that would fit within Jaguar's new stamping plant. The tool tryout quickly demonstrated the foolishness of the concept, requiring months of old-fashioned trial and error development that eventually concluded with a seven-die process. The early builds used the resultant patched-up tools while a new set of production tools were being built for series production. As anticipated, overcoming springback in the complex structural parts turned into a lengthy series of manual iterations, each requiring several weeks. At that stage, not much had changed for the toolmakers since the pioneering days of the Panhard Dyna Z 40 years earlier: More experience, some better measuring and analysis tools, but success still entailed more art than engineering.

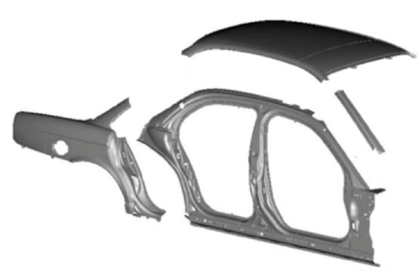

Fig. 1 — Three-piece body side panel with two cosmetic joints to the roof.

All of these developments were taking place in the shadows of great upheavals at Ford. The Explorer/Firestone debacle that began as a trickle in 1999 had blossomed into a major crisis by May 2001, prompting Ford to voluntarily recall the affected tires and sever a nearly 100-year-old business relationship with Firestone. Finding an additional 13 million replacement tires became a logistical feat that spanned many months, keeping the story alive with it. Explorer sales went into a downward spiral that even a completely new model could not overcome. The economic shock that accompanied the terrorist attacks of September 11, 2001, further underscored Ford's strategic vulnerability to fuel prices. Ford entered an austerity period that contrasted with Jac Nasser's buying spree, leading to his departure at the end of October 2001.

After 18 months of development, a new lubricant had passed all lab tests and by summer of 2001 was cleared for a production trial at Ford in the U.S. The developer, Quaker Chemicals, installed a temporary application system at Alcan-Kingston. The first production application trial was supported by a team of manufacturing engineers from Ford, Alcan, and Quaker Chemicals. Earlier that day, at the Frankfurt Motor Show, Jaguar announced that the next-generation XJ sedan would feature an aluminum body and that the company was building a new stamping plant to support it. The date was September 11, 2001. The events in New York quickly overshadowed the announcement, and the lubricant team had to remain in Canada until the border reopened three days later.

The first tools started arriving at Jaguar's Castle Bromwich plant in 2002, and by early summer, the aluminum manufacturing implementation team disbanded with the focus shifting to support the launch. At that stage, several Ford engineers were serving foreign service assignments with Jaguar. Coordination builds soon began and manufacturing started to tune its processes to achieve productivity and fit-and-finish targets.

JAGUAR X350 DEBUT

Jaguar officially introduced X350 as the 2004 Jaguar XJ on September 26, 2002, at the Paris Motor Show, with the U.K. introduction following a month later at the Birmingham Show. Sales began in the U.K. in April 2003 and within months the car was shipping to worldwide markets. As expected, the Jaguar XJ was the lightest vehicle in its class, achieving superb driving dynamics without sacrificing comfort or fuel efficiency. As X350 entered production, work was already underway on X150, the next generation XK. Jaguar was now part of Ford's Premium Auto Group, which included Land Rover and Volvo, and work soon started on a new shared lightweight rear-wheel drive platform. It had taken 24 long years, but David Kewley's vision for a lightweight body structure was finally in series production. Most importantly to Ford Motor Company, it heralded a scalable technology, which could now be studied and perfected within a real production framework.

About three months after Job1, the entire aluminum technology team

Jaguar XJ, introduced in September 2002 at the Paris Motor Show.

met in Castle Bromwich to review their accomplishment. The self-congratulation lasted all of one afternoon, after which they devoted the rest of the week to defining lessons learned and gap analysis. The first AIV was in production, but serious developments were still needed to scale it to high-volume series production. For the next several years, X350, X150, and Castle Bromwich would become an important stop for "up and coming" Ford manufacturing and product development managers. Importantly, its very existence reminded the entire corporation that an AIV was not only possible, but desirable.

CONSOLIDATION CONTINUES

The aluminum industry's consolidation continued: In 2002, Hydro had acquired VAW Aluminium AG, which included the other half of Alunorf's output and Grevenbroich, a capable rolling facility that would later enter ABS production. Alcan finally acquired Pechiney in November 2003, but at a cost: To satisfy the regulators, it had to spin off the rolled products entity that became Novelis on January 1, 2005. This included Alusuisse's Sierre plant and Alcan's historical rolling locations in the U.S., Canada, and Germany. Novelis' half of Alunorf, the largest aluminum rolling mill in the world, and the cold rolling/finishing capabilities at Nachterstedt, would be strategically important to Novelis' ABS production. This left Novelis in an enviable ABS production position with rolling capacity and heat treatment lines in Switzerland, Germany, and North America. Alcan had kept its primary metal operations, extrusions, and Pechiney's rolling facility at Neuf-Brisach, a demonstrated producer of ABS. But its primary aluminum production was too much for the Australian mining giant Rio Tinto to resist and they gobbled up Alcan at a huge cost to obtain the smelting assets. The rolling mill and extrusion business became Alcan Engineered Products.

Aleris was born in 2004 through the merger of Commonwealth Aluminum and IMCO Recycling, creating a North American company with a capable rolling mill in Lewisport, Kentucky, that had belonged to Kaiser. Aleris became an international company when it acquired the aluminum assets of the Corus group in 2006, thus securing a position in the European ABS market. Corus installed a new dedicated ABS heat treat line in Duffel during 2004-2006 and began production of a whole line of 6016-based ABS products.

FORD AFTER X350

When series production started in 2003, the U.K. and U.S. administrations were preparing for the second Iraq War. The fall of Saddam Hussein and the allied occupation resulted in a new era of political uncertainty in the Middle East, triggering a rapid increase in oil prices. By 2005, U.S. gas prices exceeded $2/gallon on a continuing upward trajectory. A year later, the price surpassed $2.50/gallon and was still rising. Jac Nasser had envisioned a golden goose powered by trucks and SUVs, but as people deserted them, Ford had no ready answer and the company started bleeding red ink (Fig. 2).

Despite the turmoil, AIV work continued in the form of individual projects, some sponsored by Jaguar, some supported by an unofficial network of like-minded AIV supporters. Bruno Barthelemy, former manager of the aluminum technology department, provided the seed idea for one such project. The failure of the D219 program made him realize that an AIV was a step change in technology that did not fit within the existing CAFE target evaluation methodology. It was not simply a cost/mpg calculation, but an enabler for a cascade of other options, some of which offered cost offsets as well as improvements in fuel efficiency. He envisioned an optimization at the vehicle level. Embedded in a formal software program and supported by an integrated cost/benefit evaluation system, such an approach would allow product planners to evaluate multiple scenarios and seek the most robust solution for both their vehicle program and the larger corporation. Ford Research accepted the project and soon two engineers were working on it. By 2006, they had extended the methodology to enable planners to manage the entire Ford fleet.

On September 5, 2006, Bill Ford surprised the automotive world by resigning and appointing Alan Mulally as CEO. Within three months, he had mortgaged all the company's assets and announced that the company would focus on Ford. Aston Martin was sold within six months, Jaguar Land Rover followed within a year, and finally Volvo was divested in 2010. But Mulally was not just cutting costs and closing plants. He had liberated the engineering organization, challenging them to forget "following with pride" and instead discover the joys of being technology leaders.

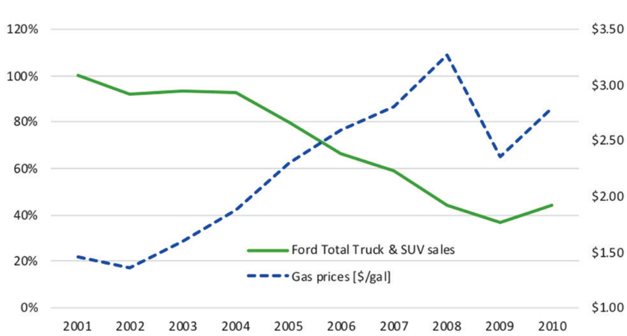

Fig. 2 — Ford's truck and SUV sales versus gas prices.

The quiet transformation of stamping engineering in Ford's North American operations would soon prove to be a key development. As the previous generation of diemakers-turned-managers retired, they were replaced by graduate engineers keen to formalize practical know-how into engineering methods. The transformation was accelerated in 2005 when Jim Morgan was named director of both body engineering and stamping engineering and the two formerly separate organizations were comingled on a single floor of Ford's sprawling Product Engineering Center. Stamping engineering's transformation was supported by the emergence of powerful computer applications that included 3D solid models, surface morphing, shop floor computer-assisted NC programing, and a quantum leap in forming simulation capabilities.

Between 2003 and 2008, Dearborn Tool and Die evolved from a traditional tool shop relying on practical floor experience into a model-driven machining and assembly powerhouse. Working in concert with stamping engineering, the plant reorganized and improved tool development costs and schedules by leaps and bounds. The transformation took place during workforce reductions so severe that, by 2008, stamping engineering had lost one out of every two employees. And yet astounding progress was taking place, with tryout-to-first-panel going from several weeks to hours, regardless of the material. By 2009, engineers had gained the upper hand on springback: Tool development for aluminum ABS had been conquered at last.

Ford's transformation extended to the powertrain as well: On May 19, 2009, the first 3.5L Ecoboost engine left Cleveland Engine Plant No. 1. A modified version of the same V6 became the premium engine for the F-150 for the 2011 model year. It immediately exceeded all sales expectations, demonstrating that even truck buyers were ready to embrace technologically advanced smaller engines.

MORE INDUSTRY CHANGES

The year 2009 was also the lowest point of the Great Recession that began in December 2007. As Ford was surviving on loans it secured in 2006, GM and Chrysler cycled through accelerated bankruptcies, emerging with government loans and Fiat purchasing part of Chrysler. Transformation of the aluminum industry continued as well: Alcan Engineered Products was sold to private investors in 2011 by Rio Tinto and reconstituted as Constellium. While centered in Europe, Constellium acquired Wise Metals in 2014 and bought access to Logan Aluminum's hot mill production in North America. Constellium would soon invest $750 million to position the Muscle Shoals, Alabama, plant for ABS production.

See what happened next in Part X of this article series, to be published in a future issue of *AM&P*. **~AM&P**

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Selected References

Alcan: Mike Kelly (retired)

Jaguar: Mark White, chief technical specialist, lightweight structures (retired)

Carl Dixon, lead, body structures engineering (retired)

Jim Harper, former lead tooling engineer, now press tooling technical manager, Jaguar Land Rover

Duncan Whipps, former senior manufacturing engineer, Jaguar Cars, now design engineering supervisor, Ford Motor Company

Ford: Joe Porcari, retired

In memoriam: Henry "Hank" Cornille (January 14, 1937 – October 27, 2019), body structure technical specialist who designed the aluminum body structures for the AIV and P2000 projects at Ford Motor Company.

TECHNICAL SPOTLIGHT

ADVANCED EDS DETECTORS DRIVE NANOPARTICLE RESEARCH

The rapid ability of next-generation EDS detectors to characterize beam-sensitive materials is leading to breakthroughs in nanoparticle research.

Energy-dispersive x-ray spectroscopy (EDS, or EDX) is an important electron microscopy tool for materials characterization and is commonly used in a wide range of applications and industries from manufacturing to energy and resource management to consumer-packaged goods. Despite the wide use of EDS, the technique has limitations in certain applications, such as difficulty in obtaining high-quality images of polymers, catalysts, and other nanoparticles sensitive to damage from the electron beam. Next-generation EDS detectors such as Thermo Fisher Scientific's Dual-X have helped to meet these challenges. Today's advanced EDS detectors are overcoming the barriers to EDS analysis by making it quick and easy to obtain quality results without requiring expertise and making it possible to obtain high-resolution images of beam-sensitive materials, which were previously unobtainable.

The ability to apply EDS acquisition and automated processing to a broader range of samples will enable taking nanoparticle research to new levels, paving the way toward new applications in industries ranging from food to medicine to textiles and energy research.

USING X-RAYS TO PRODUCE CHEMICAL INFORMATION

EDS is used to characterize the chemical composition of samples by taking advantage of the fact that every atom has a unique number of electrons that reside in specific positions, or shells, around the nucleus of the atom. Under normal conditions, the electrons in a specific shell have discrete energies. As an electron beam strikes the inner shell of an atom, it knocks an electron from the shell, leaving a hole. When the electron is displaced, it attracts another electron from an outer shell to fill the void. As the electron moves from the outer to the inner shell of the atom, it loses some energy and the energy difference generates an x-ray with an energy and wavelength unique to the specific element (Fig. 1).

X-rays emitted during the process are collected by silicon drift detectors, which separate the x-rays of different elements into an energy spectrum. Software is then used to analyze the spectrum and determine specific elements contained within the sample.

TAKING EDS DETECTORS TO THE NEXT LEVEL

To obtain a high-quality image, it is necessary to maximize the number of x-rays captured from different angles. Historically, round-shaped EDS detectors have been used with active areas as small as 10 mm^2, limiting the signals that could be obtained. In contrast, Dual-X detectors have an oval shape, and each detector has a large active area of 100 mm^2 (or a total of 200 mm^2). The large racetrack-shaped 100 mm^2 detectors in Fig. 2 are positioned at exactly 180 degrees with respect to each other, and both are located at exactly 90 degrees with respect to the holder. The analytical large-gap X-twin pole pieces and detector distance and height have been optimized to place the detector as close as possible to the specimen for the highest throughput of x-rays, enabling low-dose analytics. The shadowing of the holder is also visible in the

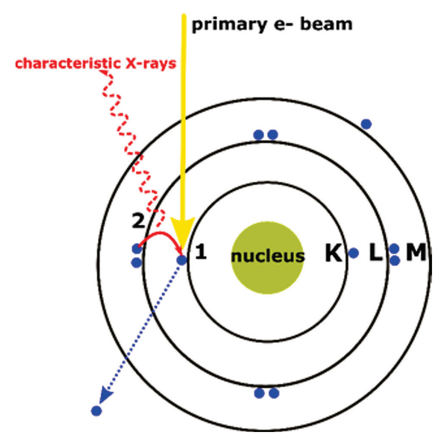

Fig. 1 — X-rays are generated using EDS in a two-step process: Energy transferred to the atomic electron knocks it out of its shell leaving behind a hole, which is then filled by another electron from a higher energy shell, releasing the characteristic x-ray.

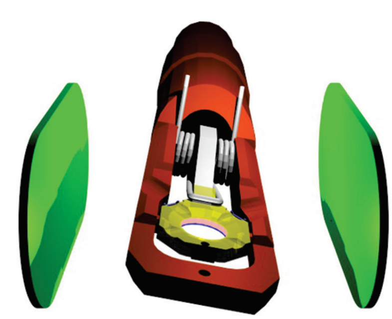

Fig. 2 — Dual-X detectors are symmetrically positioned at 180-degree angles in relation to the specimen, maximizing the number of x-rays that can be captured regardless of the sample tilt or orientation.

figure; correcting for this and the detector geometry is essential for accurate EDS quantification. This placement of detectors maximizes the number of x-rays that can be captured in a short period of time, regardless of sample tilt/orientation.

The detectors make it possible to perform EDS analyses more quickly than with previous EDS detectors. For example, for a single large-area EDS map, results can be generated in less than 60 seconds. By comparison, producing the same map a decade ago would have taken an hour or longer.

Not only does the speed of acquisition enhance productivity, it broadens the types of samples that can be imaged. With a short time-to-acquisition, high-quality compositional information can be obtained from beam-sensitive materials before they are damaged by the electron beam. When combined with a high-brightness X-FEG (extreme field emission gun) electron gun, the high-speed EDS detectors can dramatically improve imaging and spectroscopy performance, detecting hidden features that until now could not be observed in beam-sensitive samples.

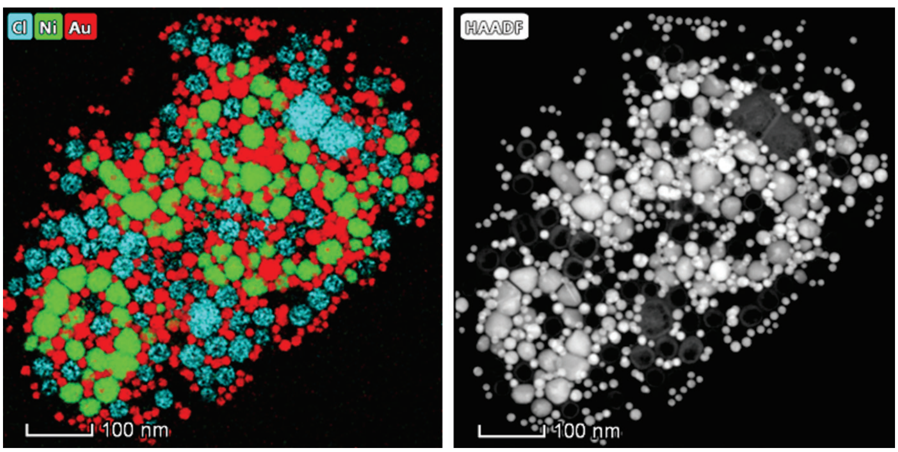

Fig. 3 — Large-area, high-resolution EDS maps of gold-nickel nanoparticles produced in less than one minute using Dual-X detectors. Courtesy of J. Bursik, Institute of Physics of Materials, Brno, Czech Republic.

EXTENDING THE USE OF EDS

As the use of EDS expands to include beam-sensitive materials, automation breakthroughs are simplifying the technology, extending its applications. Fully embedded Dual-X EDS detectors enable:

- Automated EDS tomography for fast access to 3D chemical information. The microscope can be set up to automatically acquire 3D chemical information overnight unattended.
- STEM and EDS Maps software for automated acquisition of statistically relevant data on large area images at high resolution. Data from different imaging and analysis modalities are easily correlated including on-the-fly processing and statistics using Thermo Fisher's visualization and analysis software Avizo.
- An automatic correction for absorption, which adjusts for holder geometry and detector dimensions. The absorption correction is embedded into the company's Velox software, making it possible to obtain accurate elemental quantification information.

These features make EDS far easier to use, extending the technique to

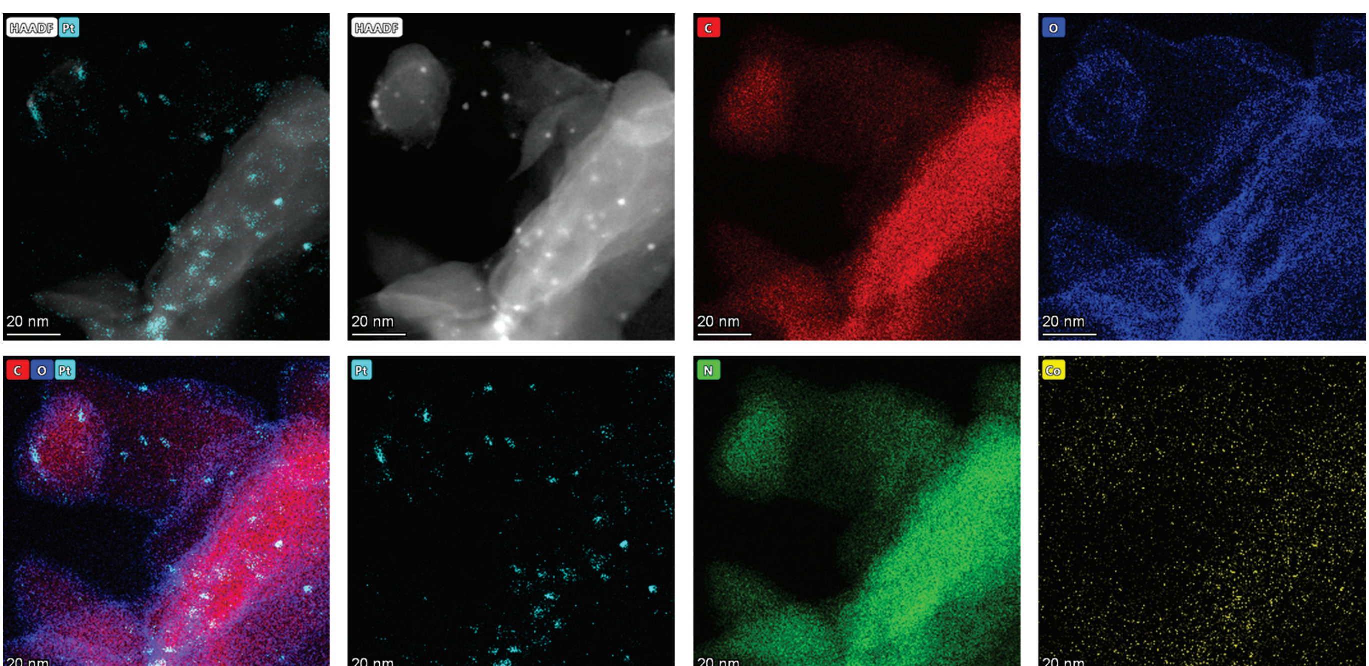

Fig. 4 — High-resolution EDS maps of beam-sensitive material used for photocatalytic hydrogen evolution. Courtesy of Prof. ShengChun Yang, Xi'an Jiaotong University, China.

more users, while increasing research productivity.

After EDS maps are created, they are stored together with other microscopy information, making it easy to combine and correlate data captured from different microscopy techniques. This enables researchers to completely characterize samples using a single tool.

ADVANCING NANOPARTICLE RESEARCH

Next-generation EDS detectors are advancing nanoparticle research at institutions around the world. For example, researchers at University of Physics of Materials in Brno, Czech Republic used the detectors to investigate a sample where a large-area, high-resolution EDS map of gold-nickel nanoparticles was acquired in less than one minute (Fig. 3). The nontoxic gold nanoparticle combined with the magnetic properties of nickel atoms are promising carriers of surface-anchored agents, which can attach to therapeutic drugs and precisely target them to specific cells in the human body using a controlled release.

Researchers at Xi'an Jiaotong University, China, are using the detectors to map the effectiveness of nanoparticles such as platinum and cobalt as catalysts in the production of hydrogen fuel (Fig. 4). Hydrogen is the mostly widely proposed fuel for use in fuel cell-powered cars, promising a new generation of vehicles that combine the sustainability of electric cars with the large driving range of conventional fossil fuels. Catalyst nanoparticles are needed to optimize the production of hydrogen fuel via photocatalysis. The catalyst uses the synergistic effects of platinum and cobalt nanoparticles to improve hydrogen productivity.

These are just two examples where next-generation EDS detectors, with their rapid ability to characterize beam-sensitive materials, are leading to breakthroughs in nanoparticle research. In the future, we can expect to see high-resolution EDS imaging of a wider range of nanoparticles, which, in turn, will deepen our understanding of nanoparticles and their applications across a diverse range of industries. **~AM&P**

For more information: Yuri Rikers, Product Manager Talos at Thermo Fisher Scientific, Zwaanstraat 31 G/H, 5651 CA Eindhoven, The Netherlands, +31 40.2356000, yuri.rikers@thermofisher.com, www.thermofisher.com.

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iTSSe

INTERNATIONAL THERMAL SPRAY & SURFACE ENGINEERING

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AEROSPACE COATINGS RESEARCH EXTENDS ITS REACH

AN ASM MATERIALS SOLUTIONS PUBLICATION

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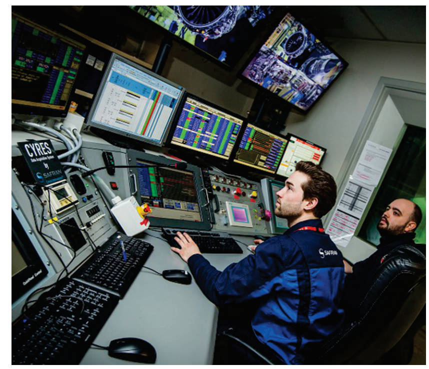
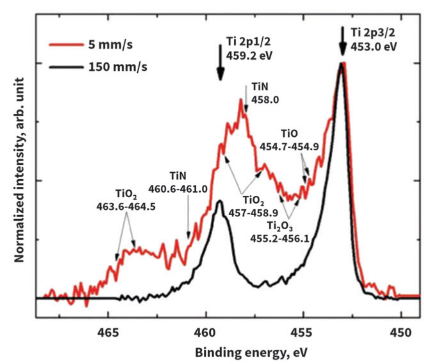




EDITORIAL OPPORTUNITIES FOR *iTSSe* IN 2020

The editorial focus for *iTSSe* in 2020 reflects established applications of thermal spray technology such as power generation and transportation, as well as new applications representing the latest opportunities for coatings and surface engineering.

February/March: Aerospace and Defense Applications

July/August: Energy and Power Generation

November/December: Emerging Technologies/Applications & Case Studies

To contribute an article, contact Joanne Miller at joanne.miller@asminternational.org.

To advertise, contact Kelly Johanns at kelly.johanns@asminternational.org.

DEPARTMENTS

ABOUT THE COVER

Protheis and SAFIR will benefit from this state-of-the-art equipment platform for materials characterization. Courtesy of IRCER.

TSS TOPICALS: FROM EXPERIMENT TO ONGOING SUCCESS

When writing this editorial, I had recently returned from TSS's latest topical event, TS4E in Boucherville, Quebec. This conference brought together many of the leading researchers of suspension and solution thermal spray technology. The meeting was highly successful, with record attendance of 127 attendees for TSS topical events. This positive outcome made me think back to the origin of these topical conferences and how the idea has become a great success for TSS and ASM.

Most of our readers are aware that the flagship TSS conference, ITSC, is held every three years in North America. The other two years the event is held in Europe or the Pacific Rim. When the meeting is held in Europe, the German Welding Society (DVS) is responsible for organizing the majority of the conference. In the Pacific Rim, the organizing of the conference and trade show is shared between local thermal spray organizations such as the Japan Thermal Spray Society and China Thermal Spray Society. Back in 2007, TSS made the decision to rotate ITSC throughout the world instead of holding it each year in North America. This decision had great foresight in helping to grow the community and technology of thermal spray by further exposing the technologies and enhancing the collaboration for many more users, researchers, and suppliers.

However, this unselfish decision by the TSS leadership had a cost, as the revenues from ITSC were now shared with other organizations, and this occurred at a time when the financial stability of TSS was not as strong as it is today. Fortunately, the void this decision created sparked the beginning of the TSS topicals, with the first event being TSS Cold Spray 2007. This experiment was a great success, and it showed TSS how to become more financially stable in years when ITSC is not held in North America. It also enabled further scientific collaboration for the thermal spray community.


Lenling

There were many TSS members who helped craft the idea of the first topical, but TSS Hall of Famers Mark Smith, Chris Berndt, Bob Tucker, Al Kay, and Richard Knight deserve most of the credit. Their visionary idea has helped strengthen TSS through 10 subsequent topicals since the first in 2007. Many volunteers have followed in the footsteps of the original topical founders by organizing the numerous other TSS topical conferences.

Most recently, the society thanks the TS4E 2019 organizers Rogerio Lima and Christian Moreau for showing the society that topical conferences can be taken to a new level of success. Already well into the planning stages, the next topical conference, North America Cold Spray 2020, is being organized by Charlie Kay and Peter Richter. This event already has the added excitement of being co-located with ASM's inaugural IMAT 2020 conference next September 15-16, in Cleveland. Let the success continue!

Bill Lenling, FASM, TSS-HoF
ASM Thermal Spray Society Vice President
Founder/CTO, Thermal Spray Technologies Inc.

TSS ANNOUNCES NEW BOARD MEMBERS

TSS President **André McDonald,** University of Alberta, recently announced new appointments to the TSS Board. **Komal Laul,** senior principal engineer, Delta Airlines, and **James Ruud,** repair process engineering – Ops Support Lab, General Electric, were reappointed to the board for a second three-year term.

Andrew Ang, research engineer, Swinburne University of Technology, Australia, and **Luc Bianchi,** Safran, SA, France, were appointed to the board for a three-year term.

Milad Rezvani Rad, University of Alberta, was reappointed as student board member, and **Edward Gildersleeve,** Stoney Brook University, was also appointed student board member. Both appointments are for one year.


McDonald

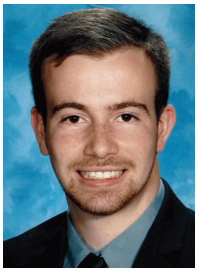

Laul


Ruud


Ang


Bianchi


Rad


Gildersleeve

ASM THERMAL SPRAY SOCIETY BOARD SEEKS NOMINATIONS

The ASM TSS Nominating Committee is currently seeking nominations to fill one vice president, one secretary/treasurer, and two board member positions. Candidates for these director positions can be from any segment of the thermal spray community. Nominees must be a member of the ASM Thermal Spray Society and must be endorsed by five TSS members. Board members whose terms are expiring may be eligible for nomination and possible reelection on an equal basis with any other nominee. **Nominations must be received no later than March 1, 2020.** Forms can be found at tss.asminternational.org. For more information, contact Doug Puerta, ASM TSS Awards & Nominations Committee chair, at dpuerta@stackmet.com.

SOLICITING STUDENT MEMBERS FOR TSS BOARD

The ASM Thermal Spray Society is seeking applicants for the two student board member positions. **Nominations are due by April 1, 2020.** Students must be a registered undergraduate or graduate during the 2020-2021 academic year and must be studying or involved in research in an area closely related to the field of thermal spray technology. For more information on eligibility and benefits, visit tss.asminternational.org.

DEVELOPING LIGHTER, LONGER-LASTING AEROSPACE PRODUCTS COMPLIANT WITH THE EU REACH REGULATION

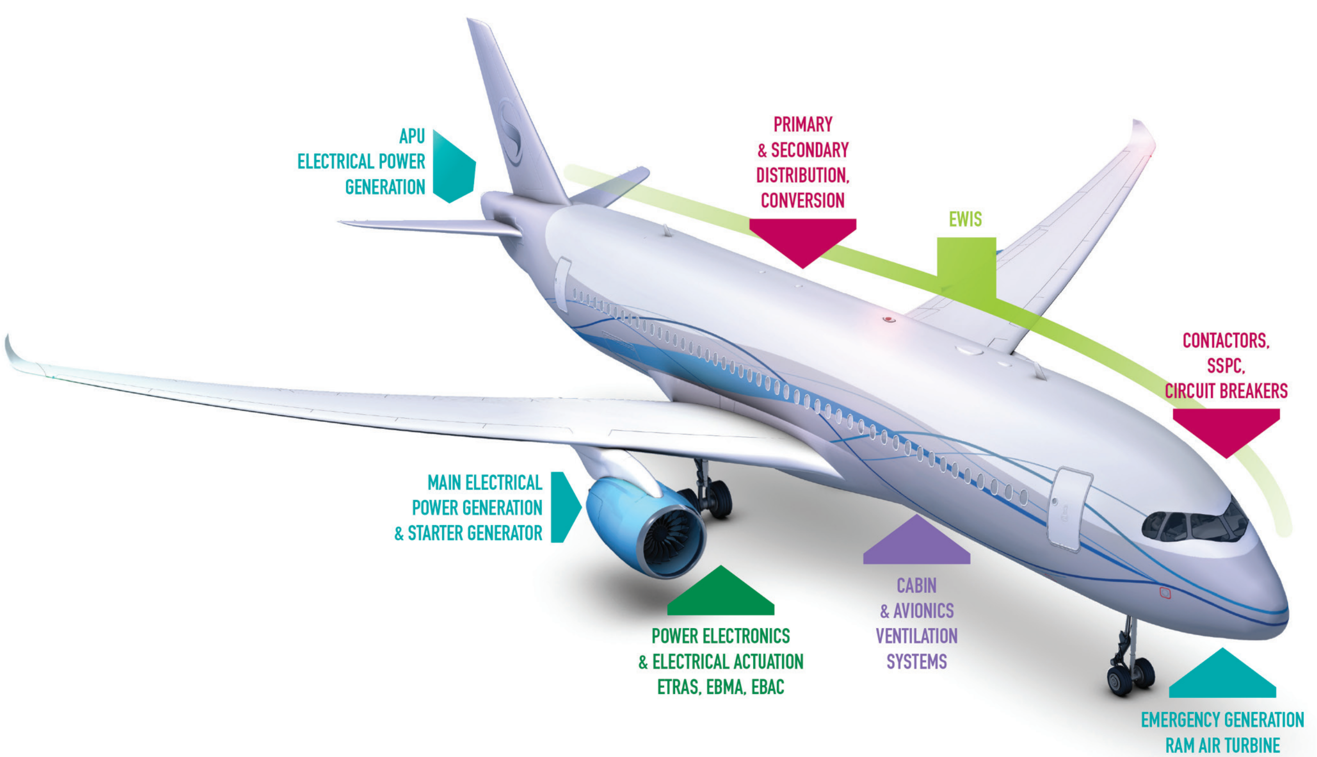
A joint research project will develop surface treatments that comply with the REACH regulation, which addresses the production and use of chemical substances and their impact on human health and the environment.

Alain Denoirjean and Armelle Vardelle, FASM, TSS-HoF, IRCER, University of Limoges-CNRS, France
Aurélien Joulia and Martine Monin, Pôle M&P, SafranTech, Châteaufort, France
Francis Monerie-Moulin, Safran Landing System, Oloron Saint Marie Cedex, France
Gilles Widawski, Oerlikon France, Ferrières-en-Brie

Safran S.A. (Paris), Oerlikon (Pfäffikon, Switzerland), the French National Center for Scientific Research (CNRS), and the University of Limoges (France) have formed a joint research laboratory (Protheis) and a technology platform (Safir) specializing in surface treatments for use in aerospace applications. The initiative will comply with the European regulation REACH (registration, evaluation, authorization, and restriction of chemicals). The laboratory will be located at the Institute of Research for Ceramics (IRCER), the joint research laboratory of the University of Limoges and CNRS.

Protheis and Safir make it possible to unite the skills of the three entities. The aerospace company Safran operates in the aircraft propulsion and equipment, space, and defense markets. The Swiss technology group Oerlikon will contribute its expertise in the manufacture of powders, equipment, and coatings. IRCER is a leading research institute on surface coating technologies focusing on understanding, characterizing, and modeling coating processes. The laboratory's roadmap will include the numerical simulation of processes, in line with Safran's Factory of the Future initiative, by capturing, analyzing, and exploiting production data, to ensure control over product quality.

Protheis will benefit from the existing IRCER platform "Charactérisations des Matériaux de Limoges (CARMALIM),"



Schematic of a "more electric" airplane, to be developed with lighter components, more fuel-efficiency, and reduced greenhouse gas emissions. Courtesy of Safran.

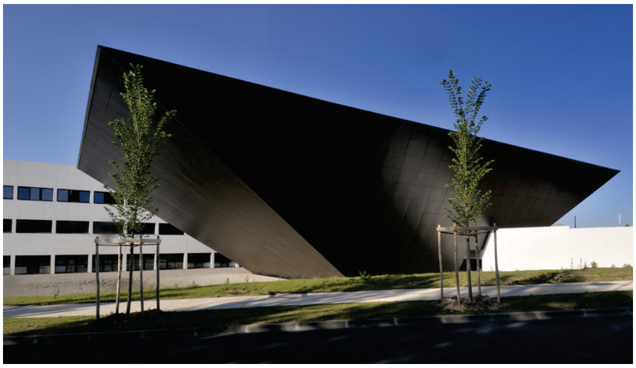
which is dedicated to the physical and chemical characterization of materials and is unique in Europe in this area. The SAFIR platform will cover technology readiness levels (TRL) from TRL1 (describing basic principles) to TRL6 (demonstrating a prototype in a representative environment). It will manage the entire maturation process, while ensuring requisite safety conditions. With an investment of over €8M, the platform will translate the laboratory's scientific work into thin-film and thick-coating technologies, and will assist R&D of other transport, energy, and electronics companies.

Protheis and Safir will offer two full-time positions within the IRCER thermal spray team for young professionals to work on roadmap objectives; one faculty-researcher on thermal spray techniques and a CNRS researcher on modeling innovative thermal spray processes (contact Dr. Philippe Thomas at IRCER for more details).

Safran will manage greenhouse gas emissions linked to their production and reduce the environmental impact of its products to meet the International Civil Aviation Organization objective of bringing greenhouse gas emissions in 2050 down to 50% of their 2005 levels. In this context, in addition to the development of "more electric" aircraft and alternative fuels, the company will design more fuel-efficient engines and lighter aircraft equipment to reduce greenhouse gas emissions.

FILMS AND COATINGS: A PATH TO GREENER PRODUCTS

Film and coating technologies can help reduce plane consumption and emission through improved engine management and higher operating temperature, helping to meet environmental requirements set by the air transport industry. A standardized methodology used to identify and improve environmental impacts associated with a product or a process is the life cycle assessment (LCA) method (ISO 14040 and 14044). This requires quantifying resources used and emissions at all stages of the products/processes supply chain and life cycle and converting data to impact scores along different environmental dimensions. LCA helps to design more sustainable products with decreased emissions during their production. It also helps to choose the best coating technology for the environment and for the producer and user, as conservation of natural resources contributes to making the technology and products not only more environmentally friendly, but also more economically efficient.



The entrance of the Institute of Research for Ceramics (IRCER). Courtesy of IRCER.

MORE EFFICIENT, SUSTAINABLE PRODUCTS IN THE CONTEXT OF INDUSTRY 4.0

Digitization of manufacturing is changing the way the products are produced; a large volume of data collected from connected machines provide information about performance, maintenance, and corrective actions. Data analysis enables identifying patterns and insight impossible for a human to do in a reasonable timeframe.

Safran, Oerlikon, and IRCER will apply Industry 4.0 principles to films and coatings manufacturing to help define an implementation scenario. The scenario will encompass collection and analysis of all coating process data including process data (e.g., operating parameters), material data (e.g., characteristics of the solid, liquid, or gaseous feedstock and of the material during processing), and product data (e.g., coating thickness, temperature, and uniformity).

TRAINING NEXT-GENERATION MATERIALS AND SURFACE ENGINEERS

Protheis and Safir will benefit not only Safran and Oerlikon, but also graduate and post-graduate students at University of Limoges and Safran's 20+ partner schools and universities (e.g., Mines-ParisTech, ENSAM, ESTACA, ENSMA, UTC). Students preparing for advanced degrees in materials and surface engineering and data science and digitalization will be able to conduct research in line with the laboratory's roadmap. Subjects for M.S. and Ph.D. degrees will be proposed at an international level and supported by the lab partners Region Nouvelle Aquitaine and the Department of Education of France.

Students can follow continuing training at CampusFab (Bondoufle, France), the training center of the industry of the future launched by several French companies including Safran. The center is entirely dedicated to the digital transformation of the industrial world; it provides students with the industrial and digital means typical of a factory of the future, including digital room, additive manufacturing hub, assembly line using robots, cobots and automated carts, assembly and erection hubs, and maintenance and production means hub.

Engineers at Safran control and monitor the test environment of aircraft engines. Courtesy of Safran.

Protheis partners are setting up a new program of engineering apprenticeship in materials and surface engineering, which will provide students the opportunity to simultaneously gain an engineering degree and professional autonomy while putting theory into practice. Safran and Oerlikon are helping University of Limoges to fine-tune this new curriculum around the new skills that their companies and the industry of the future will need. **~iTSSe**

For more information: Armelle Vardelle, professor, IRCER, University of Limoges-CNRS, 12 rue Atlantis, 87068 Limoges, France, + 33 (0) 555 423 684, armelle.vardelle@unilim.fr.

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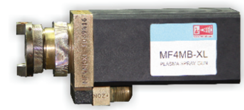

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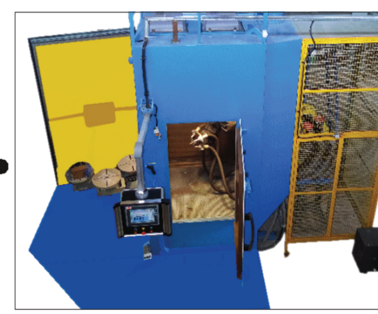

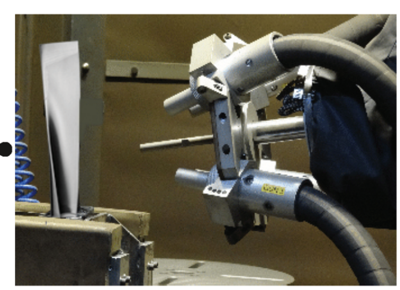

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COLD SPRAY: ADVANCED CHARACTERIZATION METHODS—X-RAY PHOTOELECTRON SPECTROSCOPY, X-RAY FLUORESCENCE, AND AUGER ELECTRON SPECTROSCOPY

This article series explores the indispensable role of characterization in the development of cold spray coatings and illustrates some of the common processes used during coating development.

Dheepa Srinivasan

X-ray photoelectron spectroscopy (XPS) is a technique used to determine the elemental and chemical state on the surface of the coating. In XPS, soft x-rays bombard a sample material, causing electrons to be ejected. Based on the kinetic energy of the ejected photoelectrons, the chemical state of the sample can be determined, and the relative concentration of the elements can be discerned from the relative photoelectron intensities. XPS typically probes to a depth of two to 20 atomic layers and, depending on the material, can be used to probe depths of 5 to 50 Å. This technique serves as a valuable tool in cold spray characterization to determine the oxidation or nitridation state of the coatings.

In general, a higher inlet gas temperature and therefore a higher substrate temperature is found to be beneficial for cold-sprayed coatings. However, when trying to achieve these conditions in practice, excessive oxidation and nitridation of the resultant coatings can occur. XPS is used to accurately determine the temperature effect on the coatings. Figure 1 illustrates this application for a commercially pure titanium coating, showing the effect of substrate temperature. The influence of particle temperature can also be determined by XPS when an external gas heater is used to heat the particles. XPS is also a useful technique for determining the surface contamination in cold-sprayed coatings.

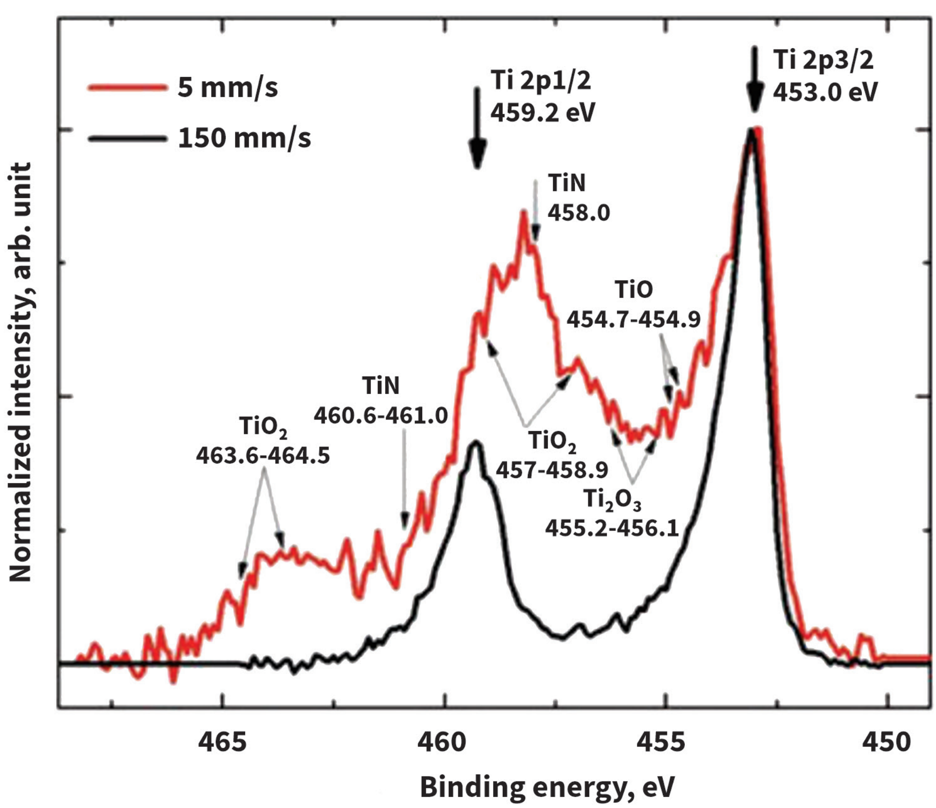

Fig. 1 — Comparison of surface characteristics of helium-sprayed versus nitrogen-sprayed titanium coatings for oxidation and nitridation characteristics.

X-ray fluorescence (XRF) is a nondestructive method used for elemental analysis of materials. This technique is used for cold-sprayed feedstock powders to provide accurate estimates of the chemistry, especially the oxygen and nitrogen levels, because coating chemistry is known to affect mechanical properties. With this method, an x-ray source is used to irradiate the specimen and cause the elements in the coating powders to emit or fluoresce their characteristic x-rays. A detector is used to detect the emitted x-ray peaks for quantitative estimation of the elements present. All elements except hydrogen, helium, and lithium can be detected using XRF. It is possible to determine accurate values of elemental information using this method.

The impurity levels and the moisture/oxygen content in the powders can lead to significant-

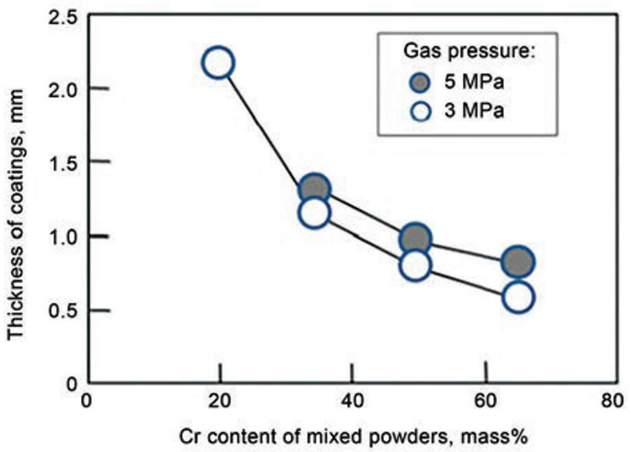

Fig. 2 — Relationship between the chromium content of mixed powders and coating thickness, as evaluated by x-ray fluorescence spectroscopy.

ly poorer coatings, despite optimized parameters, especially because adsorbed moisture can lead to significant powder-feeding issues and thus premature degradation of the formed coating. In this application, XRF can provide precise information about the starting powder chemistry. Figure 2 is an example of using XRF to characterize the amount of copper in a mixture of copper-chromium powders taken at different ratios, as a function of the coating thickness.

Auger electron spectroscopy (AES) is a surface characterization technique that enables determination of the elemental composition and chemistry of sample surfaces. It uses a focused electron beam to create secondary electrons near the surface of a solid sample. Some of these have energies characteristic of the elements and, in many cases, of the chemical bonding of the atoms from which they are released. Typically used in combination with ion sputtering to gradually remove the surface, AES can be used to characterize sample through-thickness and therefore the chemistry and bonding through the sample depth.

The high spatial resolution of the process allows microanalysis of high lateral resolution (300 Å), semiquantitative elemental analysis, and accurate chemical bonding information, including standardless semiquantitative analysis. It is useful

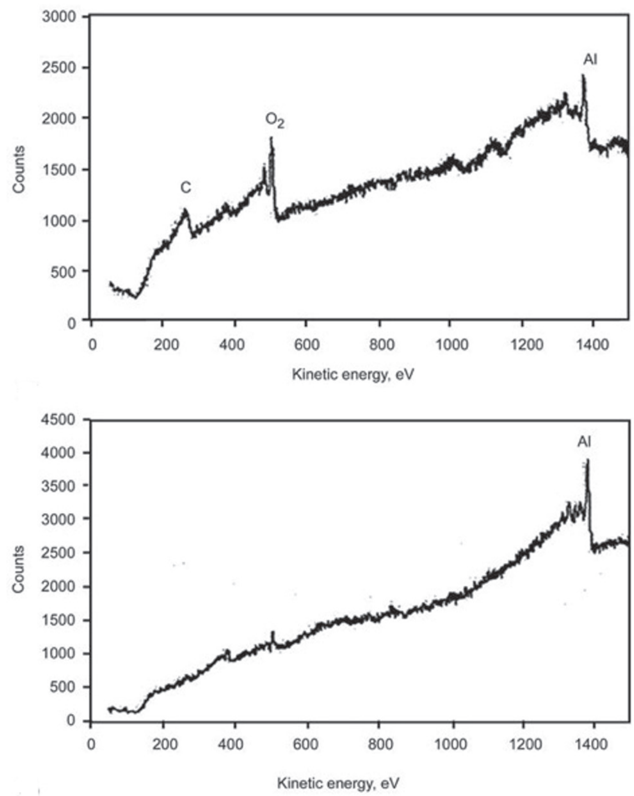

Fig. 3 — Auger electron spectroscopy of the fracture surface of an aluminum cold-sprayed coating (a) in the as-sprayed condition and (b) after ion beam milling, revealing the surface layer chemistry.

in analyzing fractured cold-sprayed samples to evaluate the oxygen levels across the coating fracture surface, as shown in Fig. 3a, which indicates peaks of aluminum, carbon, and O_2. After removal of a surface layer using ion beam milling, the Auger spectrum was devoid of oxygen and carbon, as shown in Fig. 3b, which confirms the presence of an oxide layer of 31-nm thickness in the as-deposited condition. **~iTSSe**

For more information: This article series is adapted from *Chapter 5, Cold Spray—Advanced Characterization* authored by Dheepa Srinivasan in High Pressure Cold Spray—Principles and Applications, edited by Charles M. Kay and J. Karthikeyan (ASM, 2016). Complete references are included in this volume. The author may be reached at dheepasrinivasan6@gmail.com.

JTST HIGHLIGHTS

The *Journal of Thermal Spray Technology (JTST),* the official journal of the ASM Thermal Spray Society, publishes contributions on all aspects—fundamental and practical—of thermal spray science, including processes, feedstock manufacture, testing, and characterization. As the primary vehicle for thermal spray information transfer, its mission is to synergize the rapidly advancing thermal spray industry and related industries by presenting research and development efforts leading to advancements in implementable engineering applications of the technology. Articles from the June, August, and October issues, as selected by *JTST* Editor-in-Chief Armelle Vardelle, are highlighted here. In addition to the print publication, *JTST* is available online through springerlink.com. For more information, visit asminternational.org/tss.

FATIGUE BENDING BEHAVIOR OF COLD-SPRAYED NICKEL-BASED SUPERALLOY COATINGS

A. Silvello, P. Cavaliere, A. Rizzo, D. Valerini, S. Dosta Parras, and I. Garcia Cano

Cold-sprayed Ni-based superalloy coatings offer new possibilities for manufacturing and repairing damaged components, such as gas turbine blades or other parts of aircraft engines. This development shines a new light on the conventional additive manufacturing technologies and significantly broadens application fields of cold spray. The idea is that cold spray can contribute to improving the fatigue properties of manufacturing and repaired components. This study deals with the analysis of the microstructural and mechanical properties of IN625 cold-sprayed coatings on V-notched carbon steel substrate. Process conditions of 1000°C and 50 bar were employed to produce coatings in V-notched (60° and 90°) samples in order to evaluate the fatigue crack behavior of the sprayed material. The results achieved demonstrate that cold spray deposition and repair can contribute to resistance and to the increase in the global fatigue life of cracked structures (Fig. 1).

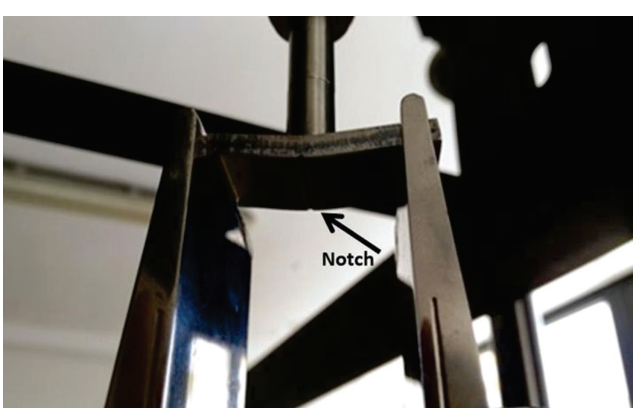

Fig. 1 — Three-point bending setup.

A REVIEW ON SUSPENSION THERMAL SPRAY PATENTED TECHNOLOGY EVOLUTION

Maniya Aghasibeig, Fariba Tarasi, Rogerio S. Lima, Ali Dolatabadi, and Christian Moreau

Suspension thermal spray (STS) includes any thermal spray process that is based on injection of a suspension of solid particles in a liquid carrier into the gas jet, such as suspension plasma spray, suspension high-velocity oxy-fuel, and high-velocity suspension flame spray. This review is on the state of the art of the STS technology and includes an overview of the current patent situation including the number of patents published in English, patenting institutions, and invention domains. Apparatus and methods, feedstock, and new material systems and applications were identified as the three main domains of focus for the STS inventions. The presented patents show a general perspective of the current situation and present the technology advancements in each domain. It also shows the potential of implementing this technology in new applications based on the needs of the thermal spray market through further technology development. (Fig. 2).

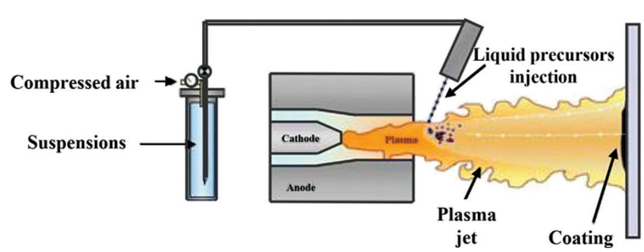

Fig. 2 — Schematic view of a suspension plasma spray system with radial injection.

RESIDUAL STRESS IN HVOF THERMALLY SPRAYED WC 10Co-4Cr COATING IN LANDING GEAR APPLICATION

M. Gui, R. Eybel, S. Radhakrishnan, F. Monerie-Moulin, R. Raininger, and P. Taylor

Type “N” Almen strips were HVOF thermally sprayed WC-10%Co-4Cr coating with spraying parameters used for landing gear coating production. The Almen strips were coated at variable passes and different cooling conditions. Deflections of Almen strip specimens were measured, and the coating residual stresses were calculated. With the same facility and spraying parameters, an in situ coating property sensor was also used to continuously monitor the curvature of beam specimens being coated during and after coating deposition to evaluate coating deposition stress and final residual stress. The experiments, together with a microhardness test, reveal that peening action occurring in the current HVOF spraying is limited, and the residual stress in the coating is dominated by quenching stress and cooling stress. In this study, the substrate temperature of specimens was adjusted by cooling air flow and torch recess time in between spraying passes. The coating residual stress apparently impacts the substrate temperature because it significantly affects the cooling stress. Since the spraying parameters are frozen in industrial coating production, the cooling condition is a feasible approach for tailoring the coating residual stress (Fig. 3).

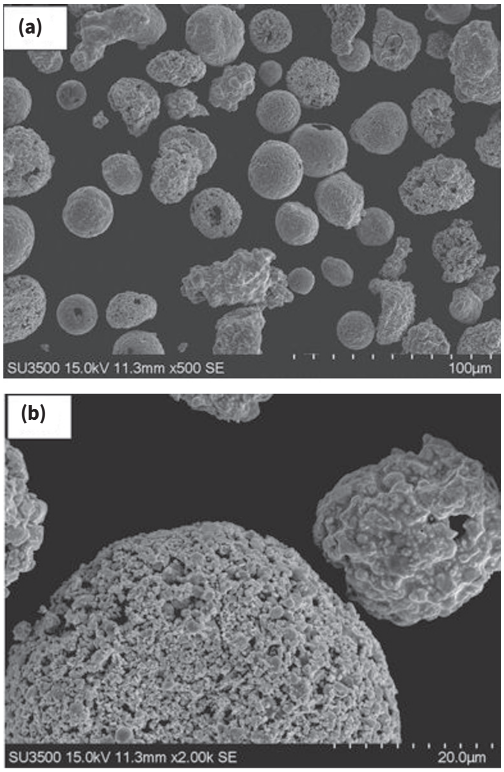

Fig. 3 — SEM micrographs showing morphology of WC-10Co-4Cr powder (a) at low magnification and (b) at high magnification.

DEPOSITING Al-BASED METALLIC COATINGS ONTO POLYMER SUBSTRATES BY COLD SPRAY

M.R. Rokni, P. Feng, C.A. Widener, and S.R. Nutt

The feasibility of depositing aluminum onto thermoplastic substrates via cold spray (CS) was investigated. Dense coatings of 7075 Al and CP Al (commercial purity) were achieved on three substrates—polyetheretherketone (PEEK), polyetherimide (PEI), and acrylonitrile butadiene styrene (ABS) using an iterative optimization process. 7075 Al deposition yielded low deposition efficiencies (DEs) and low thicknesses but high adhesive strengths, while CP Al deposition led to high DEs and thicknesses but relatively low adhesive strengths. PEEK and PEI were more suitable substrates for cold spray than ABS, which suffered from surface erosion and substrate distortion. Two key factors were identified that influenced the DE and adhesive strength of the coating. The first factor was the bond layer, the initial few particle layers that fused with the substrate to allow subsequent buildup. The bond layer was influenced by the substrate hardness, yield strength, glass transition temperature, and impact strength, as well as the differences in thermal expansion coefficients of Al and the polymer substrates. The second factor was the CS process parameters selected, as the bond layer and the build-up layers may require different process conditions in order to optimize both bonding strength and coating strength, respectively (Fig. 4).

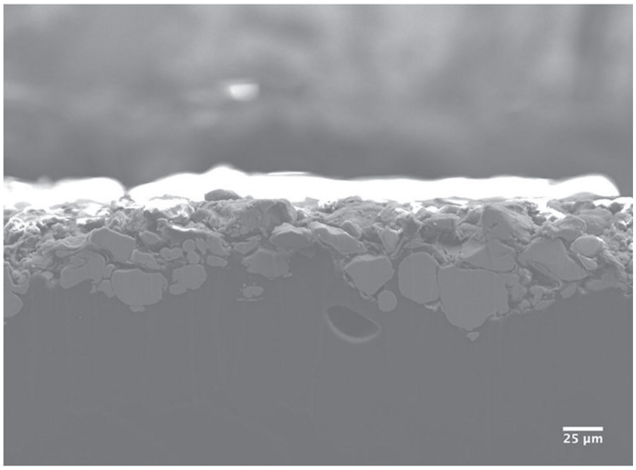

Fig. 4 — Cross-sectional image of CP Al deposited on ABS with four passes.

INFLUENCE OF HEAT TREATMENT AND SEALING ON HOT CORROSION BEHAVIOR OF 80Ni-20Cr COATINGS

Harkulvinder Singh, Sukhpal Singh Chatha, and Hazoor Singh Sidhu

The present work aims to examine the influence of heat treatment and sealing on high-temperature hot corrosion performance of HVOF-deposited 80Ni-20Cr coating on T347H austenite steel. The high-temperature corrosion performance of T347H, 80Ni-20Cr, 80Ni-20Cr heat-treated and 80Ni-20Cr sealed coatings has been investigated in Na_2SO_4-$60V_2O_5$ atmosphere at 750°C for 50 cycles. Corrosion kinetics were measured by weight change calculations after each cycle. Bare T347H steel experienced severe spallation of the oxide scale indicating weak resistance toward high-temperature hot corrosion. 80Ni-20Cr coatings have given a significant protection to austenite steel due to the development of oxides and spinels of Ni and Cr. Further, the post-treatment by way of heat treatment and sealing improved the corrosion resistance of 80Ni-20Cr coating. Both the post-treatments lead to choking the interconnected porosity of the 80Ni-20Cr coating, which resulted in better performance of post-treated coatings (Fig. 5).

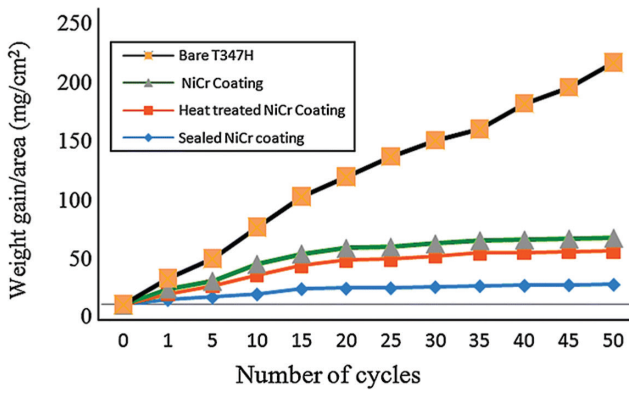

Fig. 5 — Weight gain/area vs. number of cycles plots for the bare T347H , as deposited, heat-treated and sealed coating on T347H steel subjected to cyclic corrosion for 50 cycles in molten (Na_2So_4-60%V_2O_5) salt environment at 750°C.

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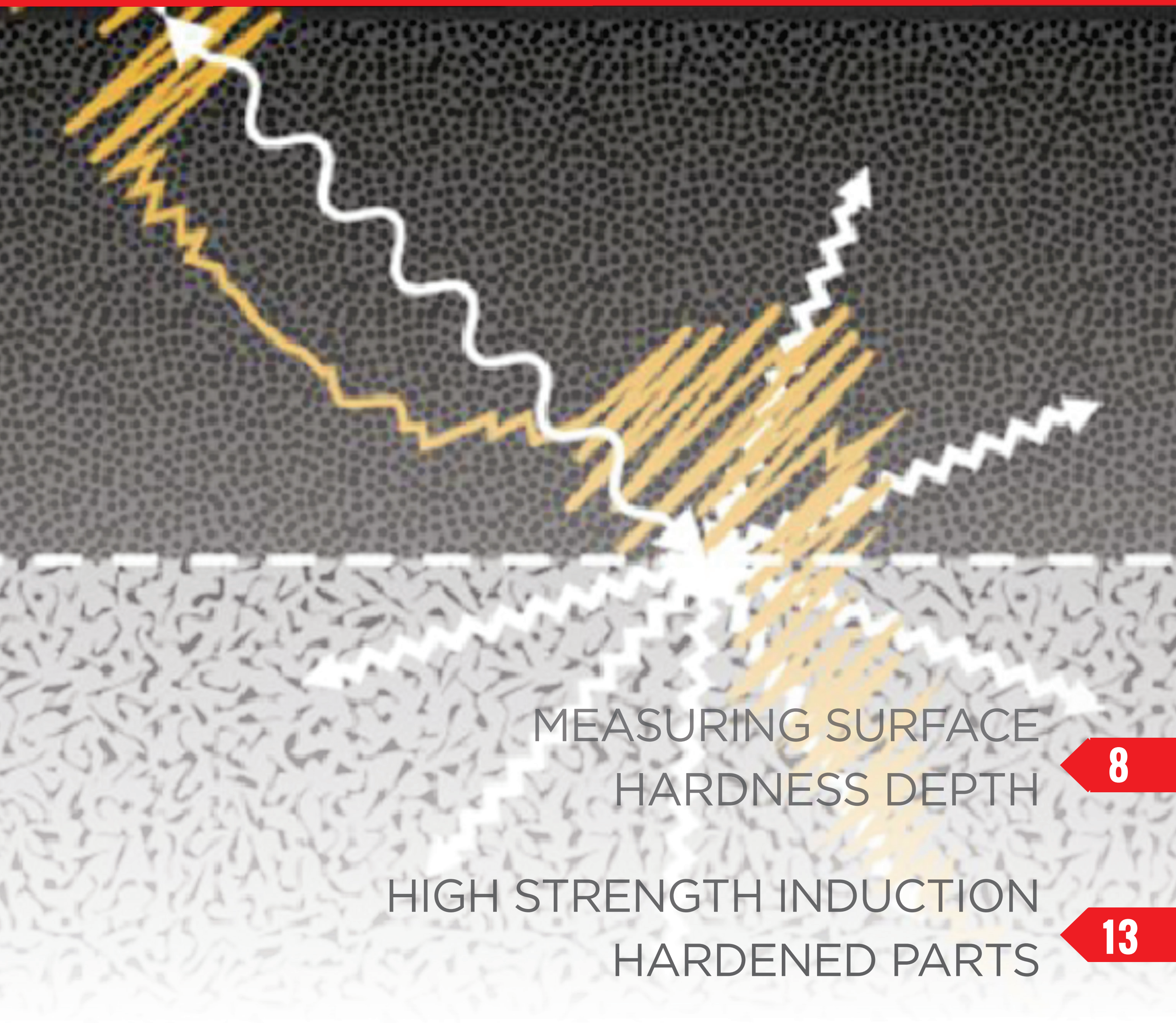

MEASURING SURFACE HARDNESS DEPTH 8

HIGH STRENGTH INDUCTION HARDENED PARTS 13

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EDITORIAL OPPORTUNITIES FOR *HTPro* IN 2020

The editorial focus for *HTPro* in 2020 reflects some key technology areas wherein opportunities exist to lower manufacturing and processing costs, reduce energy consumption, and improve performance of heat treated components through continual research and development.

February/March Thermal Processing in Aerospace

May/June Testing & Process Control

September Thermal Processing in On/Off Highway Applications

November/December Atmosphere & Vacuum Heat Treating

To contribute an article to one of the upcoming issues, contact Joanne Miller at joanne.miller@asminternational.org.

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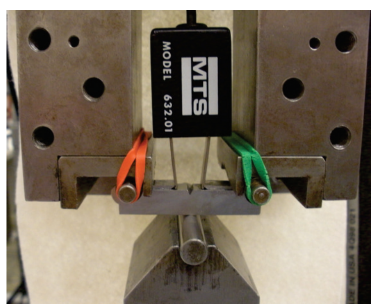

DEPARTMENTS

ABOUT THE COVER

Scanning for surface hardness depth control using ultrasonic backscattering. Courtesy of CNH Industrial.

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HEAT TREAT 2019: HTS EXCELS IN TECHNOLOGY, DIVERSITY AND STUDENT ENGAGEMENT

This is an amazing time to be in the engineering field and the Heat Treating Society (HTS) is here to help. As manufacturing becomes more global, diversity is changing the way we look at solving problems. Sustainable solutions and eco-sensitivity are pushing today's engineer to get more from materials; engineering is being driven for efficiencies, environmental awareness, and collaboration in problem solving. Additive technology is allowing us to engineer new solutions with materials, complex shapes, and structures not previously available. HTS is in the middle of these challenges and thriving.

The programming lineup for our Heat Treat Show that was held in Detroit, October 15-17, looked at several traditional areas of interest including metallography, failure analysis, additive manufacturing, and heat treat and coating technology. A new emphasis was placed on sustainable materials and processes and materials for energy and utilities. Materials for clean and renewable energy, fuel cells and materials for batteries, and lightweight and transportation materials were also in focus.

HTS membership diversity is important. The Women in Manufacturing Breakfast was successful as a first-time event. Held in conjunction with our show partners AGMA, the event was titled "Don't Stop — Five Lessons I Have Learned, So You Don't Have To" presented by Stacey M. DelVecchio, F. SWE, additive manufacturing product manager, innovation and technology development division, Caterpillar. We are excited that Lesley Frame, Ph.D., is our incoming HTS vice president, the first woman in an HTS officer role.

This past year, nearly 2000 new members joined ASM, of which 70% are below 40 years of age. We are excited to help ASM deliver meaningful information and services to the next generation of engineers and business owners. To this end, a major focus of the society is student recruitment.

In early fall, I visited the Colorado School of Mines (CSM) in Golden. It was thrilling to see many students experiencing hands-on involvement in metallurgy. The metallurgist is the backbone of our heat treating industry and the science is alive and well. At the ASM Rocky Mountain Chapter meeting, I was pleased to present the Bodycote Best Paper Award to a well deserving and energetic Ph.D. student from CSM, Virginia Judge. There are additional opportunities for students to win recognition, awards, and scholarship funds to assist with their academic costs. This year, we introduced the Fluxtrol Student Research Competition award.

In addition to scholarships and awards, student engagement also occurs at several points during our events. At the Heat Treat show in Detroit, our "THIS IS HEAT TREAT" student program allowed students to attend for free. There were travel grants available and the Materials Camp for STEM education for high school students added to the excitement on the expo floor. We hosted a networking event—the Young Professionals Reception—in conjunction with AGMA. And the recruitment program offered resume and job postings online, onsite interviews, and connected employers with potential employees during the networking student reception.

As an HTS past president noted, "Consider joining HTS for the educational and networking opportunities and stay for the fun!" HTS is a great place to be. We are taking on new challenges, delivering value, and expanding our membership. We may have just returned from Detroit, but I'm already looking forward to seeing you at the next Heat Treat event in 2021 in St. Louis as we continue to celebrate all things heat treat.

Eric Hutton

ASM Heat Treating Society President

Vice President Operations – ADE North America East, Bodycote

HTS NAMES NEW OFFICERS AND BOARD MEMBERS

Eric L. Hutton, vice president operations, ADE North America East, Bodycote, succeeds as president of the Heat Treating Society (HTS), while **James P. Oakes,** vice president business development, Super Systems Inc., remains on the board as immediate past president and treasurer. **Lesley Frame,** assistant professor, University of Connecticut, is elected to vice president. Officers serve a two-year term.

In addition, the following members were elected to the HTS board for a three-year term: **Robert Madeira,** vice president, Inductoheat Inc., and **Douglas Puerta,** CEO, Stack Metallurgical Group. **Michael Brant,** metallurgical engineer, Contour Hardening Inc., was appointed emerging professional board member for a one-year term. **Noah Tietsort,** undergraduate student, Case Western Reserve University was reappointed for a second, one-year term as student board member.

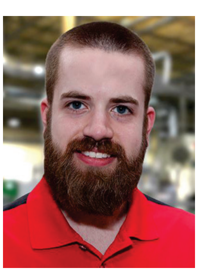

Hutton


Oakes


Frame


Madeira


Puerta


Brant


Tietsort

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

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

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

To view rules for eligibility and paper submission, visit hts.asminternational.org, Membership & Networking and Society Awards. **Paper submission deadline is March 1, 2020.** Submissions should be sent to Mary Anne Jerson, ASM Heat Treating Society, 9639 Kinsman Rd., Materials Park, OH 44073, 440.338.5446, maryanne.jerson@asminternational.org.

HEAT TREATING SOCIETY SEEKS BOARD NOMINATIONS

The HTS Awards and Nominations Committee is seeking nominations for three directors, a student board member, and an emerging professional board member. Candidates must be an HTS member in good standing. Nominations should be made on the formal nomination form and can be submitted by a chapter, council, committee, HTS member, or an affiliate society. The HTS Awards and Nominations Committee may consider any HTS member, even those who have served on the HTS Board previously. **Nominations for board members are due March 1, 2020.**

For more information and the nomination form, visit the HTS website at http://hts.asminternational.org and click on Membership and Networking and Board Nominations; or contact Mary Anne Jerson at 440.338.5446, maryanne.jerson@asminternational.org.

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The ASM Heat Treating Society (HTS) focuses on thermal processing of metals and materials. HTS members leverage this network of professionals to share technical information, industry knowledge, and best practices, and to recognize outstanding achievements and distinguished performance of fellow members. **For more information:** memberservicecenter@asminternational.org or 440.338.5151 ext. 0. JOIN ONLINE: asminternational.org/HTS

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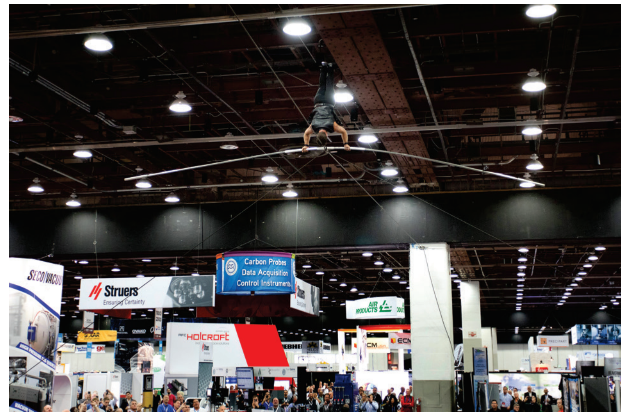
HEAT TREAT 2019: PHOTO GALLERY OF EVENT HIGHLIGHTS

Every two years, the ASM Heat Treating Society Conference & Exposition team puts on a must-attend event for the industry. The 2019 meeting held in Detroit, on October 15-17 was no exception. With nearly 5200 attendees, more than 100 oral and poster presentations, and over 330 booths to visit, the opportunities to learn and network were in abundance. The event included Fluxtrol-sponsored competition-based award and recognition programs for young innovative scientists and also for post-doctoral professors. Another highlight was a first-time Women in Manufacturing Networking Breakfast that is sure to become a tradition. Planning is already underway for the next top-notch Heat Treat event in St. Louis, to be held September 15-17, 2021. Heat Treat 2021 will be co-located with IMAT 2021.



Professional acrobat Blake Wallenda performed a headstand during his high-wire act that wowed the crowd at Tuesday's welcome reception with exhibitors.

Keeping with a recent torch-passing tradition, incoming HTS President Eric Hutton, left, accepts an HTS hat and pin from outgoing HTS President Jim Oakes.

Rob Madeira, left, receives a service award from HTS President Jim Oakes for his leadership as Expo co-chair for Heat Treat 2019. Ben Bernard also served as co-chair.

Daniel W. McCurdy gives his acceptance speech after receiving the 2019 HTS George H. Bodeen Heat Treating Achievement Award. McCurdy is president, Automotive & General Industrial HT – North America & Asia, Bodycote.

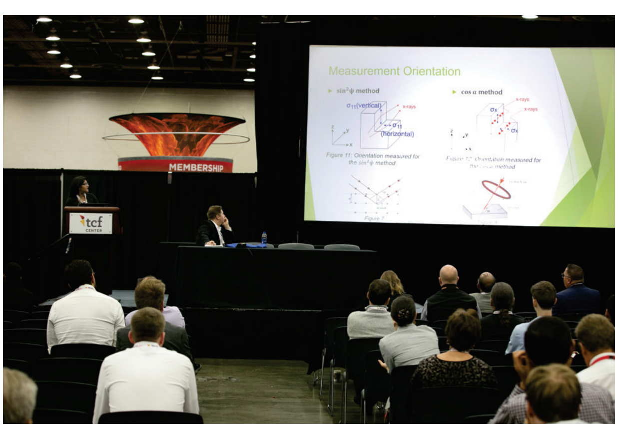
Olga Rowan and Rob Goldstein are recognized during the HTS general membership meeting for their service on the Heat Treat 2019 Organizing Committee as vice-chair and co-chair, respectively.

Trevor Jones, CEO, Solar Manufacturing Inc., left, accepts the 2019 ASM HTS/Surface Combustion Emerging Leader Award from Ben Bernard, vice president of international sales at Surface Combustion Inc.

The Wednesday evening networking event, sponsored by Surface Combustion, was a hit complete with fireworks, a back-by-popular-demand band, strolling actors and acrobats, and cigar rolling.

During Heat Treat's first Women in Manufacturing Networking Breakfast, featured speaker Stacey M. DelVecchio, F. SWE, from Caterpillar, took time to chat with an attendee.

Jim Oakes thanks the HTS officers, Steve Kowalski, Eric Hutton, and Lesley Frame, during his HTS President's Review at the general membership meeting on Wednesday.



Students participating in the Fluxtrol Student Competition were evaluated on both their poster and oral presentations.

The exhibit hall is a natural place to get reacquainted with colleagues and meet new customers.

SURFACE HARDNESS DEPTH MEASUREMENT USING ULTRASOUND BACKSCATTERING

Ultrasound backscattering enables direct determination of the interface between two materials with different microstructures.

Mike Bogaerts, CNH Industrial, Antwerp, Belgium
Michael Kroening, TPU, Tomsk, Russia
Paul Kroening and Tobias Mueller, Q NET Engineering, Saarbruecken, Germany

Surface hardening is commonly used to manufacture parts with high tensile properties and fatigue strength to resist surface cracking and abrasion. In addition, surface hardening depth (SHD) must be controlled in accordance with various international specifications[1]. Although evaluation of SHD can be done by cutting samples, this approach is time consuming, expensive, and does not lend itself to integration into a production line. These concerns led to the demand for a fast, nondestructive method to test hardened parts and to enable quick optimization of the induction hardening process when treating different parts and/or changing process parameters. Methods developed to accomplish this include eddy current testing, magnetic methods[2], and ultrasound. Electromagnetic methods take advantage of material characteristics that correlate to physical values like conductivity and permeability. However, various part specifics interfere with the correlation, which requires a set of calibration samples. Further, electromagnetic methods have limited penetration depth. By comparison, ultrasound backscattering offers a direct determination of the interface between two materials with different microstructures, including grain size, which is discussed here. This type of measurement is simple and does not require correlation of any kind nor calibration samples.

PRINCIPLES OF ULTRASOUND BACKSCATTERING

The ultrasonic method uses the physical phenomenon of Rayleigh scattering. Scattering in the Rayleigh regime occurs when randomly distributed scattering objects are much smaller than the wavelength. Backscattered power increases with the fourth power of the incident wave frequency. In ultrasonic testing, it is applied for microstructure characterization and effective grain size assessment, for example[3]. In the Rayleigh regime, backscattering power depends on the effective size of the scattering object by the third power. In solid materials, shear waves can be used with the advantage of a higher scattering coefficient due to the acoustic crystal anisotropy of iron, but with the practical disadvantage of angle beam scanning.

*Member of ASM International

Grains in polycrystalline metals are densely packed. The fundamental equation is simplified assuming an effective average grain size, the absence of a multiscattering contribution, averaged interference, and averaged refraction indices at the grain boundaries[4]. The Rayleigh scattering coefficient σ_λ is estimated as:

$$\sigma_\lambda \sim f^4 \cdot A_e^3 \cdot R_M$$

This simplified relation shows the role of material factors in backscattering intensity. Frequency, f, is a scaling factor; an increase in frequency increases the resolution of material characteristics by a power of four. Effective grain size, A_e^3, implies the contribution of various scattering sources and the effect of multiscattering, and R_M indicates the averaged impedance contrast at the interface of scattering objects.

Assuming an interface between the fine-grained martensitic case and the coarse-grained core material, an increase of measured backscattering intensity provides information about the depth of the interface by time-of-flight evaluation, knowing the angle of incidence and the sound velocity. The method senses the transition to the unaffected core material, thus indicating the thickness of the total hardening depth (THD). However, it is not possible to measure case hardening depth (CHD) or nitriding hardness depth (NHD) because there is no well-defined interface between case and core by means of effective grain size.

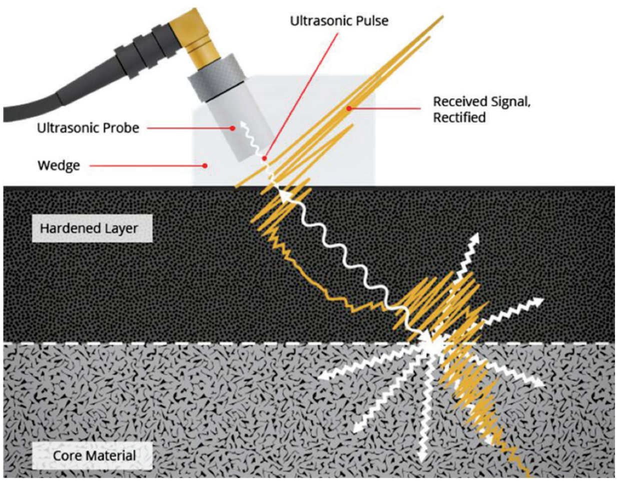
TECHNICAL CAPABILITY

Measured A-scans provide information about the part surface position by specular reflection of the sound pulse at the interface probe system to the part surface. The width of the surface peak is due to beam spread and from the roughness at both the wedge and part surface. At a frequency of 20 MHz, the fine, needle-shaped martensitic case should not scatter, but most of the coarse-grained core material does (Fig. 1). The wedge of the probe system is made of plastic material with low attenuation at high ultrasonic frequencies and does not scatter. The angle of incidence is above the first critical angle, but as low as reasonable for a steep increase of the backscattered signal when passing the interface. Backscattered intensity decreases exponentially according to the exponential attenuation law.

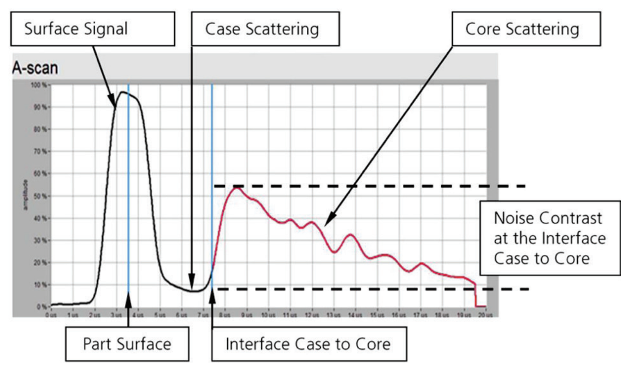
A huge number of scattered signals from the coherent pulse volume comprise the backscattered signal by interference. The signal has a typical "peaky" shape that jitters when the probe is moved and it is difficult to read for an accurate assessment of time of flight (Δ*t* in Fig. 1b). Signal smoothing is accomplished by algorithmic smoothing and local averaging (Fig. 2).

Signal quality is key to reliable SHD evaluation. Based on the required signal shape, the operator knows whether there is a wrong or poor coupling. Other crucial parameters include sound velocity and wedge angle to determine the SHD computation. These parameters are preset and part of the documentation.

The measurable SHD range is limited by the width of the surface signal for small SHD and by wave attenuation for large SHD. For most parts, the SHD range is 1.2 to 40 mm. For special applications, SHD can be measured from 0.5 mm on appropriately smooth surfaces using special wedge design. Control for very large SHD depends on part microstructural details requiring the appropriate choice of both frequency and the probe system itself.

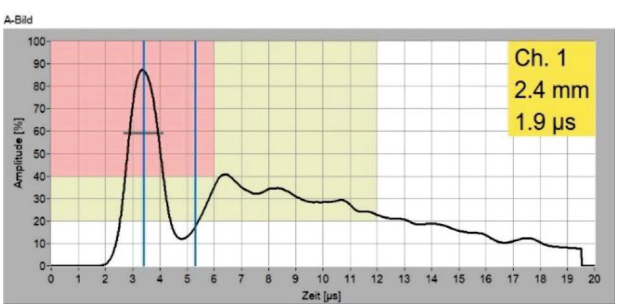


a) Scanning

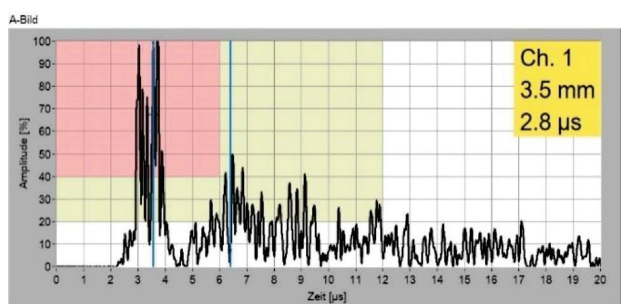


b) Signal processing

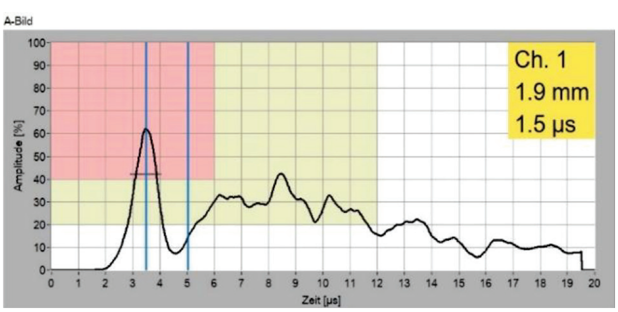
Fig. 1 — Scanning and signal processing for SHD control.



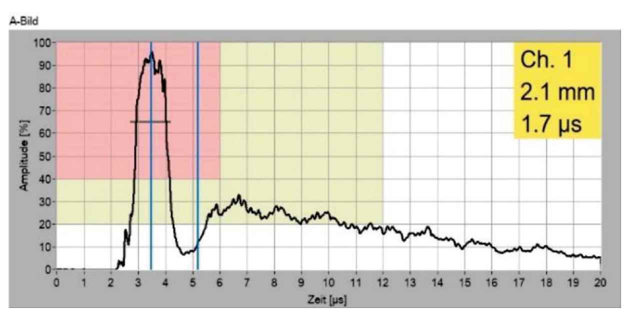
Algorithmic smoothing: 40; averaging: 256; gain: 58 dB.



Algorithmic smoothing: 0; averaging: 1; gain: 52 dB.



Algorithmic smoothing: 40; averaging: 1; gain: 56 dB.



Algorithmic smoothing: 0; averaging: 256; gain: 56 dB.

Fig. 2 — Signal smoothing and averaging.

MEASUREMENT ACCURACY

The main source of measurement error is evaluation of surface position: The shape of the surface signal depends on accurate coupling and operator skill. Another error source is setting the marker that provides the time of flight when the pulse reaches the interface. The steeper the signal rises, the lower the error. Thus, a shear wave angle as low as reasonable is used and scanning into the direction of decreasing SHD is recommended. Achievable accuracy of better than ±0.1 mm is possible for standard parts with high quality surfaces. However, the operator must control the "good" shape of the A-scan during data acquisition. Accuracy based on microindentation hardness profiles compared with the backscatter method is slightly lower, estimated as ±0.2 mm on average, depending on the material microstructure.

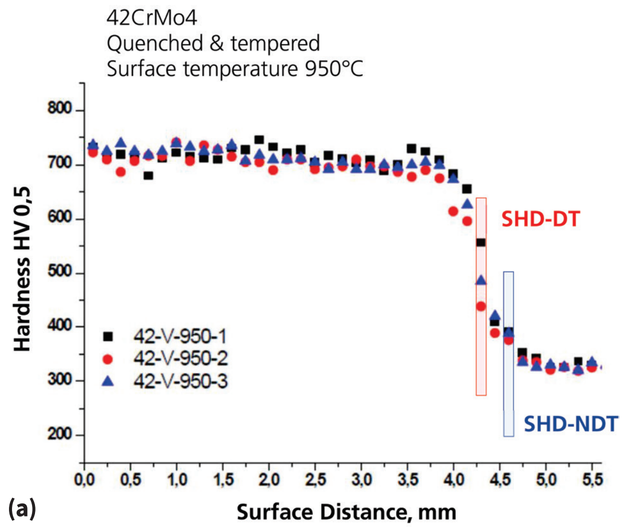
CORRELATION OF SHD TO THD

SHD is the point where the hardness depth profile reaches the limiting hardness. ISO 18203[1] defines the limiting hardness as 80% of the specified minimum surface hardness. In many cases, the hardness depth gradient shows a sudden decrease when reaching the core material (Fig. 3a). The hardened case is characterized by martensitic microstructure above a short transition zone of mixed phases, followed by the core microstructure unaffected by the hardening process. Total hardening depth (THD) is the point where the scattering core material begins a well-defined interface (Fig. 3a)[1]. For this type of interface, a straightforward correlation can be established between the SHD and the THD by taking off a small offset as shown in Fig. 3a.

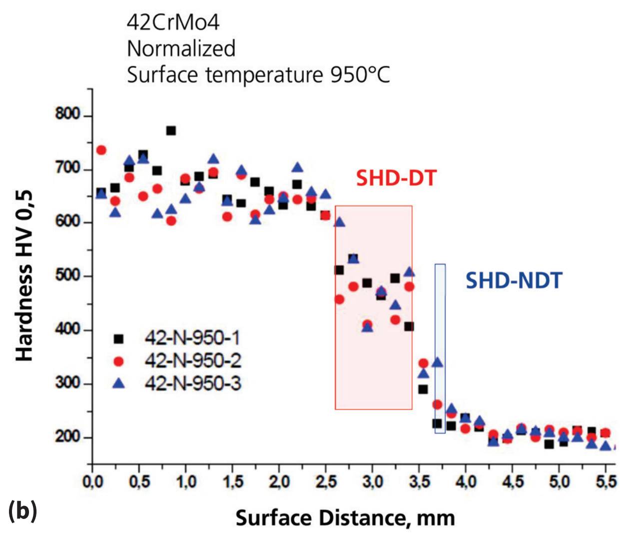
The correlation is less clear when material hardness values are scattered as shown in Fig. 3b for a normalized steel. The interface at the unaffected core is still well defined and measurement of THD is accurate. However, scattered hardness data makes the transition from SHD to THD less defined. A straightforward correlation can be established by taking off a constant offset value, which is usually slightly larger than for the case-hardened part and should be determined by cutting representative samples.

Parts with sections of different geometries pose problems for optimizing the heating and cooling regime during the hardening process. The transition from the martensitic case to the unaffected core is extended and changes locally. The microstructure of the transition zone could contain fine grains and coarse grains that increase with depth. Heating and cooling could cause grain refinement of the complete core material[6].

The SHD can still be measured accurately when the transition zone does not contain scattering structures. The offset value required for a good correlation could depend on the measured SHD and on part geometry, circumstances



(a)



(b)

Fig. 3 — (a) Hardness depth profile of quenched and tempered steel 42CrMo4, and (b) hardness depth profile of a normalized steel 42CrMo4[5].

that require a full calibration procedure. SHD and THD are measured on a representative sample for each position of interest. Calibration can be performed and supported by the instrument in the expert mode. THD measurement becomes increasingly uncertain when the transition zone contains scattering structures. The authors recommend a procedure that helps to explain the results of hardening. Usually, there are positions (often close to the runout) where good results can always be achieved. By scanning toward critical areas, an experienced engineer can gain reliable insight into material microstructure. When the core is refined completely, SHD is no longer assessable except through the material microstructure.

The difference in THD and SHD can be reasoned based on the microstructure. The extended seam of mixed phases depends on local heating and cooling conditions and might

(continued on page 12)

(continued from page 10)

be different at other positions. After appropriate calibration using a representative sample, it is possible to assess correct SHD by correlation.

This illustrates the influence of impedance contrast and grain shape on backscattering intensity. Core grain size is nearly the same average size as the grain size of the martensitic case. However, while the case does not scatter, the core does.

APPLICATIONS

Manual, semiautomatic, and automated multichannel systems are available. The manual device consists of a four-channel ultrasonic board controlled by a software package for program settings, signal processing, reporting, and general quality assurance (QA) requirements. The components are assembled into an industrial notebook designed for use in rough industrial environments. For example, Q Net Engineering's probe systems enable testing of complex shaped components. The wedge of the probe system is adapted to the geometry of the required test position. For SHD values larger than 1.5 mm, rough technical surfaces are available that enable control before machining. **~HTPro**

Note: The authors acknowledge the cooperation of Fraunhofer Institute for Nondestructive Testing, Saarbruecken, Germany.

For more information: Mike Bogaerts, CNH Industrial, Wilmardonksteenweg 32, 2030 Antwerp, Belgium, mike.bogaerts@cnhind.com, www.cnhindustrial.com.

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INVESTIGATING AN ANOMALY IN AN INDUCTION HARDENED WHEEL SHAFT

Situation

During induction hardening, an unexpected red discoloration was observed in the face area next to the R8 radius of a flanged wheel shaft used in a tractor rear axle (Fig. A). Typically, this coloration occurs further away from this radius (toward the flange). The materials lab was asked to check the case depth in this critical area using a P3123 NDT tester (Fig. B) to determine whether the case depth was in spec.

Results and Remedy

Testing showed that the case depth was too low (4.2 to 4.3 mm) versus the minimum specified case depth of 6 mm. This required that all induction hardened parts processed prior to the discovery (140 parts) be put on hold while conducting a complete check of the case depth. All shafts hardened since the discovery were checked, starting with the last parts hardened. For all incorrect shafts, the case depth in the radius was only 4.2 to 4.3 mm, and all were induction hardened on the left-hand spindle in a two-spindle IH machine. Case depth was also measured by generating a microindentation hardness profile in the hardened flange area, showing a case depth of 4.55 mm. This corresponds with the expected difference (between 0 and 10%) between ultrasound measurements with the P3123 and hardness measurements. Corrective action was taken including additional operator training.

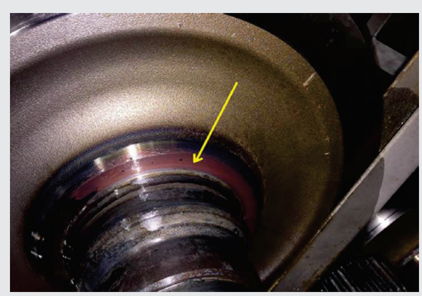


Fig. A — Unusual red discoloration in the radius/face area of flanged wheel shaft, indicating a possible problem with the induction hardening process.

Fig. B — NDT measurement of the case depth in the radius area.

METALLURGICAL STRATEGIES FOR HIGHER STRENGTH INDUCTION HARDENED PARTS

Induction hardening parts with small grain size achieves higher fracture strengths, but close control of thermal cycles is required to prevent grain growth.

Robert Cryderman,* Advanced Steel Processing and Products Research Center, Colorado School of Mines, Golden

Several tools and advanced techniques are available at the Advanced Steel Processing and Products Research Center (ASPPRC), Colorado School of Mines, to investigate microstructures and mechanical property limitations with the goal of increasing performance in steel components. One such limitation is that hardness greater than 53 HRC (565 HV) achieved using conventional furnace quench and temper heat treatment leads to brittle intergranular fracture and limits maximum tensile strength[1]. The change from ductile to brittle behavior is illustrated in Fig. 1 where peak strength is about 2000 MPa, then decreases with increasing hardness. Similar behavior has been reported for torsional fatigue properties of induction-hardened polished specimens, where low-cycle fatigue strength increases with increasing hardness up to about 58 HRC (650 HV), but fracture becomes intergranular at higher hardness, and there is

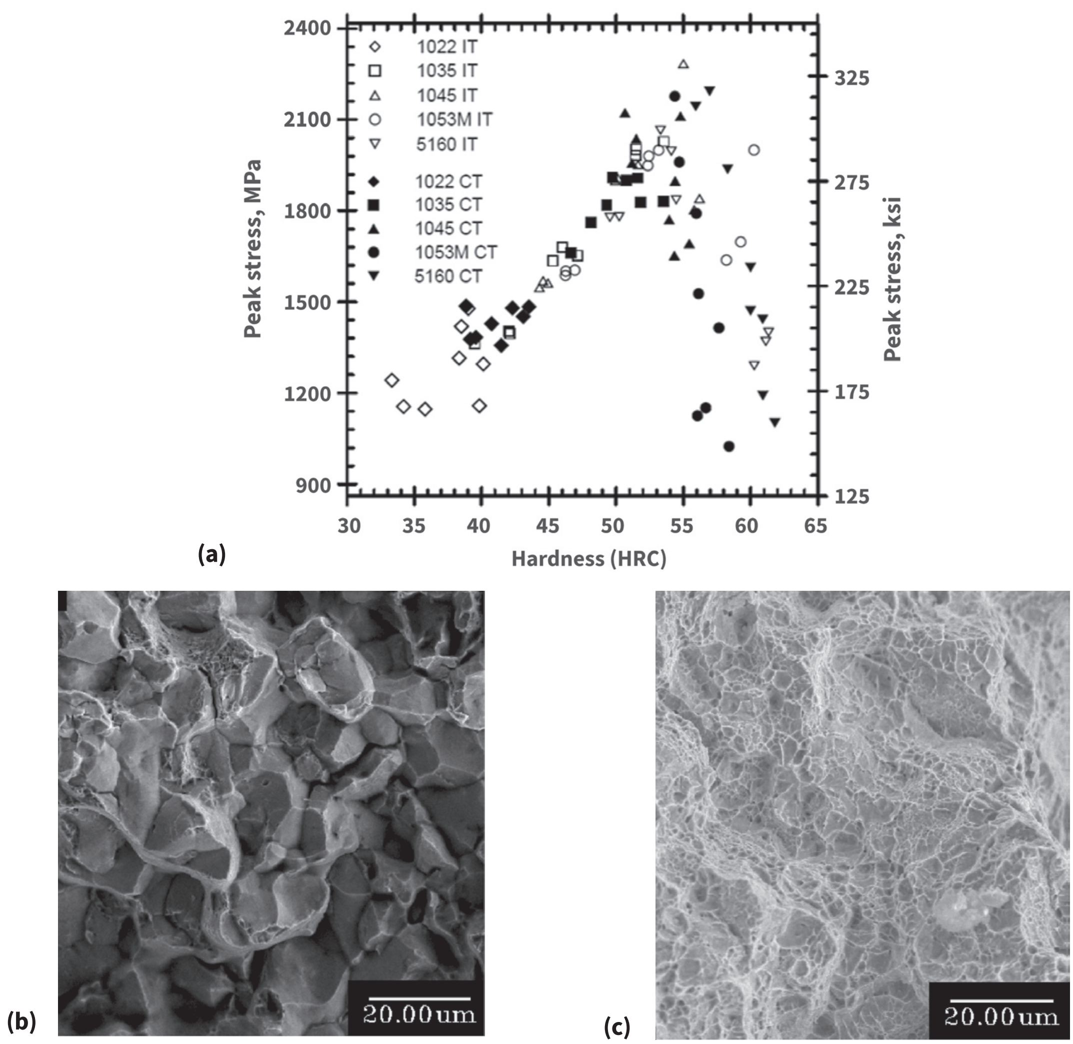


Fig. 1 — (a) Maximum tensile strength of furnace austenitized, quenched, and tempered steel is limited by brittle fracture in tensile specimens at hardness levels >53 HRC, (b) dimpled ductile fracture in specimen at 51 HRC hardness, and (c) brittle intergranular fracture in specimen at 55 HRC hardness.

*Member of ASM International

no further increase in fatigue strength[2]. The change in fracture mode to brittle failure limits the load carrying capability of quenched and tempered components, leading ASPPRC to identify microstructural improvements that could overcome this limitation.

The initial investigation looked for ways to reduce austenite grain size and modify element segregation at austenite grain boundaries where the brittle fracture occurs. Previous work shows that refining the austenite grain size through multiple heat treatments on carburized steel parts can lead to an increase in bending fatigue strength[3]. However, the multiple heat treatment process is not practical due to distortion and high cost. Induction heating offers the potential to reduce austenite grain size and limit segregation of substitutional elements to austenite grain boundaries due to the very short heating times.

During induction hardening, heating times are reduced to seconds rather than the hours required for conventional carburizing. An example of an induction hardening cycle using a two-turn scanning coil for a 2-mm case depth on a 38-mm diameter shaft is shown as the solid line in Fig. 2.

LABORATORY SIMULATIONS

ASPPRC used Gleeble 3500 test equipment to duplicate thermal cycles shown by the dashed line in Fig. 2 on test specimens large enough to enable characterization of material properties. Induction hardening of a series of alloys (11-mm^2 specimens) was simulated using a range of thermal heating cycles involving heating at 50°C/s to austenitizing temperatures between 850° and 1050°C for times of two to 1000 seconds.

Specimens for one group of tests contained nominally 0.56% carbon to ensure achieving hardness levels well above the normal range where brittle fracture is common. The steels contained additions of Mn, Mo, Ni, and W as shown in Table 1, and were previously heat treated by quenching from 900°C and tempering at 200°C. The steels also contain 0.011-0.015% P, 0.009-0.013% S, 0.23-0.25% Si, 0.002-0.009% Al, and 0.0063-0.0074% N. No grain refiners such as Nb or V were added to the steels.

After simulated induction hardening, a sharp notch was cut in the center of the test specimen using electro-discharge machining (EDM), and notched specimens were loaded to failure using three-point bending on a servo-hydraulic test frame as shown in Fig. 3(a). Areas evaluated on the fractured test specimens are shown in Fig. 3(b).

EXPERIMENTAL RESULTS AND DISCUSSION

Figure 4 shows measured austenite grain sizes for test-steel Mo. Austenitizing times at two and 10 seconds are consistent with induction hardening cycles, whereas the 1000-second austenitizing time is consistent with conventional furnace heating. Note that austenite grain sizes for the simulated induction cycles are much smaller than those for simulated furnace heating cycles. It is also important to note that restricting the simulated induction austenitizing temperature to below 900°C makes it possible to achieve austenite grain sizes smaller than 10 µm (ASTM 10).

Figure 5 shows the relationship of peak bending loads to the austenite grain size during the fracture tests for test-steel W. For grain sizes larger than about ASTM 7 (32 µm), peak breaking loads were less than 7000 N and

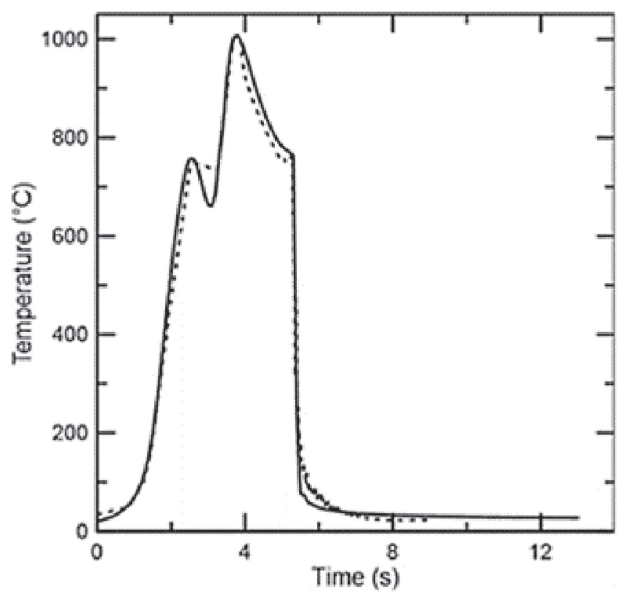


Fig. 2 — Example of induction hardening thermal cycle (solid line) for surface hardening[4].

TABLE 1 – CHEMICAL COMPOSITION OF TEST STEELS

Test-steel ID	Element(a), wt%					
	C	Mn	Ni	Mo	W	DI, mm
Base	0.57	0.80	0.01	0.00	0.001	28
Mn	0.55	1.44	0.00	0.00	0.003	46
Ni	0.55	0.79	2.12	0.00	0.008	50
Mo	0.58	0.80	0.01	0.25	0.001	49
W	0.56	0.77	0.00	0.01	0.560	–

a) Values in red indicate targeted element content to evaluate induction hardening response.

gradually decreased with increasing grain size. For a grain size of ASTM 12.5 (5 µm), achieved by simulated induction heating at 850°C for two seconds, peak bending load was 20,000 N, or almost three times the load for grain sizes larger than ASTM 7.

Fracture surfaces for test-steel W from specimens austenitized at 850°C for two and 1000 seconds are compared in Fig. 6. For the 1000-second austenitizing time, the austenite grain size was 53 µm (ASTM 6.2) and the hardness was 61 HRC (711 HV). After austenitizing for two seconds, the grain size was 4.4 µm (ASTM 12.8) and hardness was 59 HRC (666 HV). Fracture was intergranular for the 1000-second time compared with transgranular for the two-second austenitizing time.

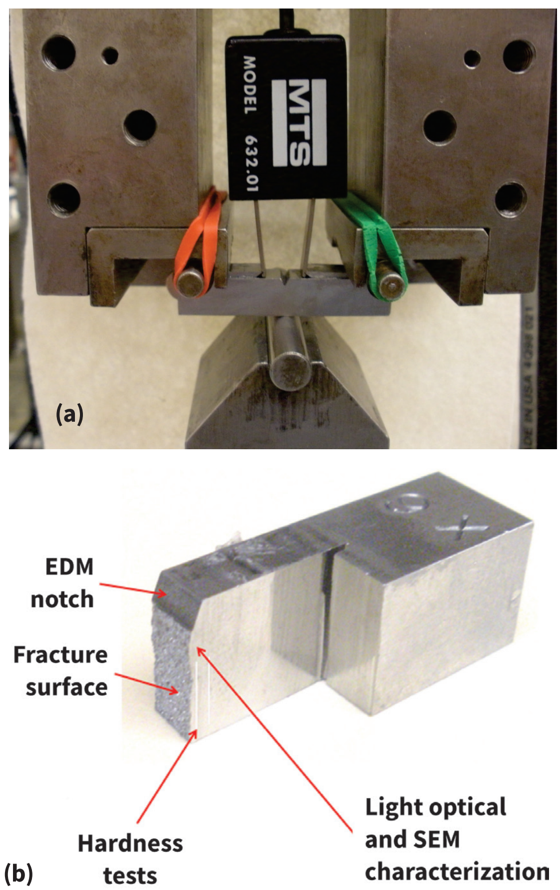


Fig. 3 — (a) Notched bend test (three point bending) of simulated induction-hardened specimen, and (b) areas evaluated on the fractured specimen.

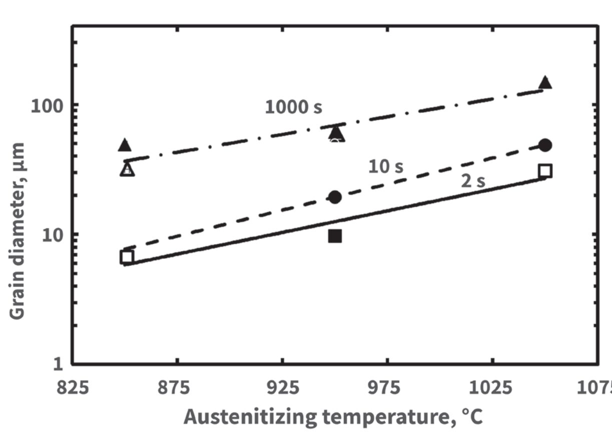


Fig. 4 — Effect of austenitizing temperature and time on austenite grain size for test-steel Mo[5].

Achieving the benefits of grain refinement for induction hardened parts requires careful design of the starting microstructure and the induction hardening cycle. Figure 4 shows that the peak induction-heating surface temperatures must be held below about 900°C to achieve small austenite grain size.

Many components such as axles and half shafts are produced from as hot-rolled AISI 1045 steel with a ferrite-pearlite microstructure (Fig. 7a and c). During induction heating of a ferrite-pearlite microstructure, transformation to austenite begins in the pearlite areas. As heating continues, ferrite transforms to austenite, and carbon must diffuse from previous higher carbon pearlite regions to previous low-carbon ferrite regions. If the temperature is not high enough, the carbon distribution remains non-homogenous, and on subsequent quenching the lower carbon regions can transform to lower strength bainite rather than martensite. Fig. 7(c) shows that the size of the ferrite requires carbon to diffuse over a distance up to about 10 µm. Non-martensitic transformation products that form during quenching are easily observed in the microstructure, so the tendency in induction hardening operations is to increase peak heating temperatures up to 1050°C or higher, resulting in larger austenite grain sizes.

In contrast, with the pre-quenched and tempered microstructures (Fig. 7b), small cementite particles are present uniformly throughout the microstructure (Fig. 7d), the distance required for carbon diffusion is on the order of only 0.5 µm, and lower induction heating temperatures are

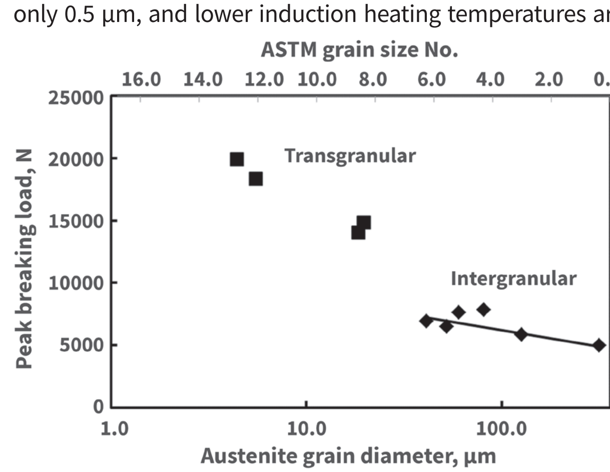
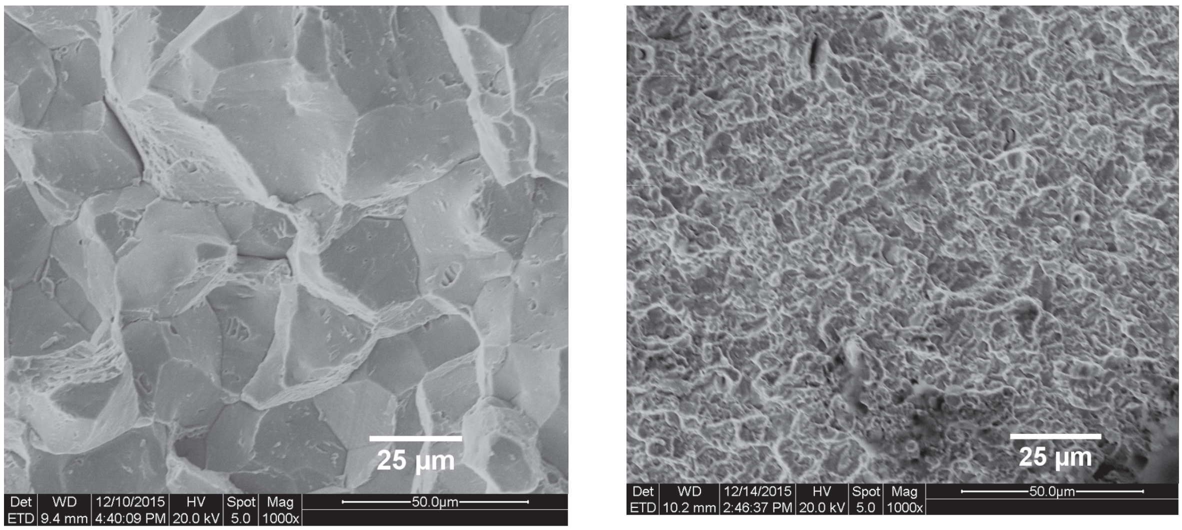
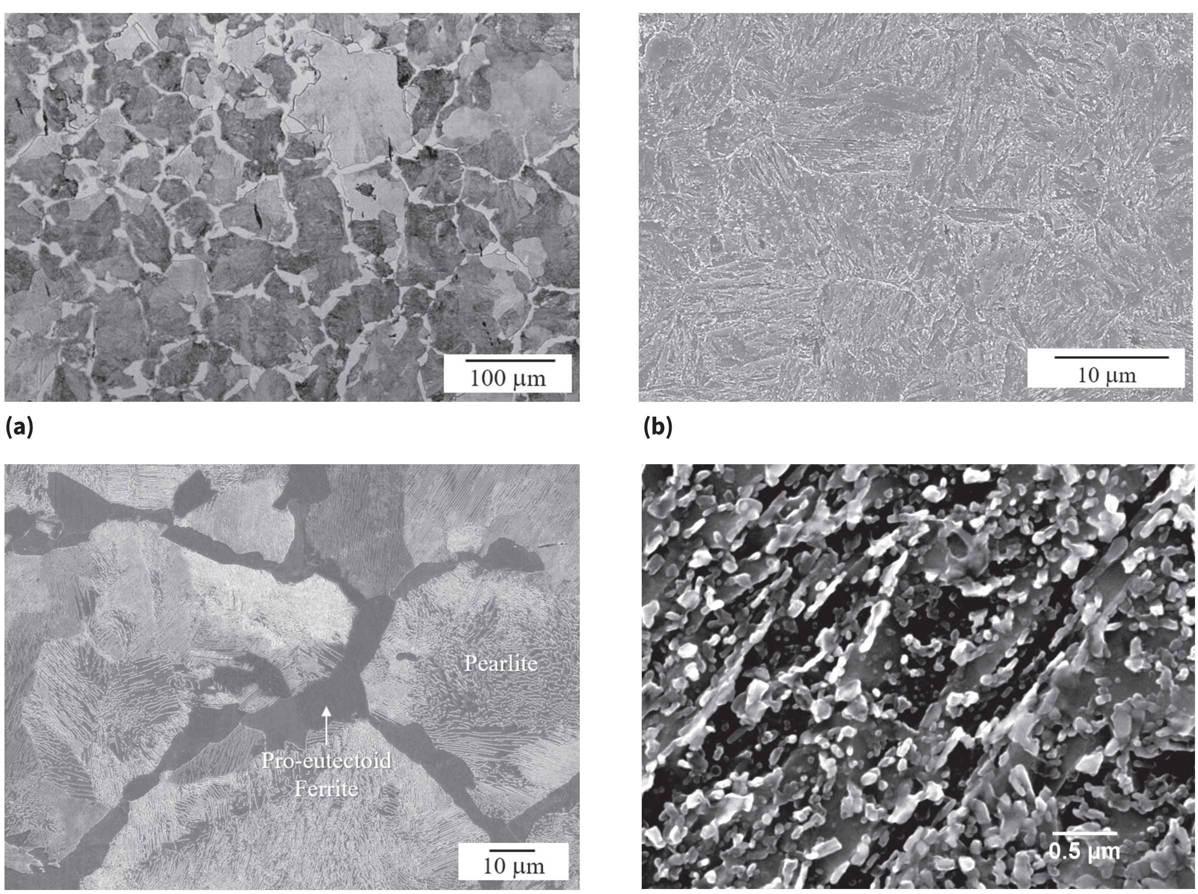


Fig. 5 — Relationship of peak bending load to austenite grain size for test-steel W; austenite grain sizes smaller than 25 µm result in higher fracture strength and transgranular fractures[6].



(a) (b)

Fig. 6 — SEM images of fracture surfaces for test-steel W austenitized at 850°C show that fracture changed from (a) intergranular for an austenitizing time of 1000 s with a peak breaking load of 6920 N to (b) transgranular for an austenitizing time of 2 s with a peak breaking load of 19,921 N[6].



(c) (d)

Fig. 7 —Microstructures of an AISI 1045 medium carbon steel show: (a) light optical image of ferrite and pearlite after hot rolling, (b) light optical image of tempered martensite after quenching and tempering, (c) SEM image of large ferrite grains formed during cooling after hot rolling, and (d) SEM image of uniform small carbides formed during induction heating martensite at 200°C/s to 700°C. Uniformly spaced small carbides are required to achieve full austenitization at low austenitizing temperatures during induction hardening.

peratures are adequate to achieve a fully martensitic microstructure during quenching.

SUMMARY

Attaining higher fracture strengths by means of induction hardening material with much smaller grain sizes like ASTM 12 requires careful discipline on the part of induction hardening-equipment operators. It is necessary to start with steels having a uniform microstructure, and then closely control induction-hardening thermal cycles to prevent grain growth. However, the improved resistance to fracture can be well worth the effort.

Note: Gleeble is a registered trademark of Dynamic Systems Inc., Poestenkill, N.Y.

Acknowledgment: The author acknowledges the support of corporate sponsors of the Advanced Steel Processing and Products Research Center, and thanks TimkenSteel Corp. for providing the test steels. ~**HTPro**

For more information: Robert Cryderman, research associate professor, Advanced Steel Processing and Products Research Center, George S. Ansell Department of Metallurgical and Materials Engineering, Colorado School of Mines, 1500 Illinois St., Golden, CO 80401, 734.735.3093, rcryderm@mines.edu.

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ASMNEWS

ASM Affiliate Societies Announce New Officers and Board Members

In accordance with their Rules of Governance, the ASM Affiliate Societies have completed their elections for officers and board members for 2019. Please join us in welcoming the following appointments.

ASM Electronic Device Failure Analysis Society

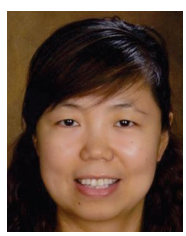
EDFAS president **Lee Knauss, FASM,** director, engineering and science, Booz Allen Hamilton, and vice president, **James Demarest,** International Business Machine, welcomes the following new members to the EDFAS board for three year terms: **Yan Li,** senior staff package engineer, Intel, and **Chris Richardson,** Allied High Tech Products. **Zhiyong Wang,** managing director, Maxim Integrated, remains on the board as immediate past president, **Martin Keim,** engineering director, Mentor Graphics, remains on the board as finance officer, and **Ryan Ross,** NASA Jet Propulsion Laboratory, remains on the board as secretary. Officers serve a two-year term. **Felix Beaudoin,** GlobalFoundries, remains on the board as general chair of ISTFA. **Attari Vahid,** Texas A&M University, is appointed student board member for one year.

ASM Failure Analysis Society

James Lane, principal consultant, Rimkus Consulting Group Inc., succeeds as president of FAS, while **Pierre Dupont,** key account manager, Industry, Schaeffler Belgium Sprl/bvba, remains on the board as immediate past president. **Daniel Dennies, FASM,** principal and CEO, DMS Inc., is appointed vice president and **Mark Hood,** consulting materials engineer, Hood Engineering LLC, is appointed secretary. Officers serve a two-year term.


Knauss


Demarest


Li


Richardson


Wang


Keim

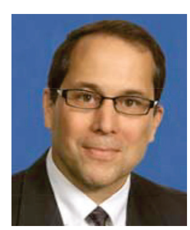

Ross


Beaudoin


Vahid


Lane


Dupont


Dennies


Hood

In This Issue

HIGHLIGHTS OFFICERS AND BOARD MEMBERS

Dale Alexander, principal and director of materials, Engineering Systems Inc., and **Christina Powell,** staff engineer, MPE failure analysis, Pratt & Whitney, are appointed to the FAS board for a three-year term. **David Riegner,** materials analyst, SEA Ltd., is appointed emerging professional board member, and **Casey Gilliams,** Colorado School of Mines, is appointed student board member. Both appointments are for one year.

ASM Heat Treating Society

The Heat Treating Society appointed a vice president and two members to the board, reappointed a student board member, and appointed an emerging professional board member. See page 4 of *HTPro* in this issue for the full story.

ASM International Metallographic Society

Daniel Dennies, FASM, principal and CEO, DMS Inc., succeeds as president of IMS, while **James E. Martinez,** materials scientist, NASA, remains on the board as immediate past president. **Michael Keeble,** U.S. labs & technology manager, Buehler, a Division of ITW, is appointed vice president, **George Abraham,** manager, technical services, Allied High Tech Products, is reappointed as secretary, and **David Rollings,** vice president, sales and marketing, Ted Pella Inc., is reappointed as finance officer. Officers serve a two-year term.

Burak Akyuz, team leader, metallurgy and failure analysis, Applied Technical Services Inc., and **Dominik Britz,** deputy director, Material Engineering Center Saarland, Saarbruecken, Germany, were appointed to the IMS board for a three-year term. **Johnathon Brehm,** University of Wisconsin-Madison, is named a student board member for one year.

ASM International Organization on Shape Memory and Superelastic Technologies

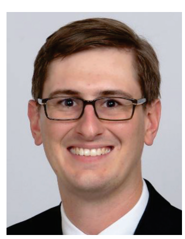
SMST president **Othmane Benafan,** materials research engineer, NASA Glenn Research Center, and vice president, **Jochen Ulmer,** director semi-finished product division, Euroflex GmbH, welcome the following new members for three-year terms: **Tom Duerig,** board member and scientist, Confluent Medical Technologies, and **Martin Wagner,** full professor, TU Chemnitz, Germany. **Jeremy Schaffer,** senior engineer, Fort Wayne Metals, remains on the board as immediate past president. **Kevin Eschen,** University of Minnesota, is named a student board member for one year.

ASM Thermal Spray Society

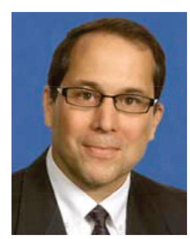
The TSS board reappointed two members and appointed two new members to the board. They also reappointed one student board member and appointed one new student board member to the board. See page 3 of *iTSSe* in this issue for the full story.


Alexander


Powell


Riegner


Gilliams


Dennies


Martinez


Keeble

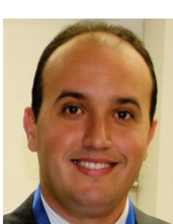

Abraham


Rollings


Akyuz


Britz


Brehm


Benafan


Ulmer


Duerig


Wagner


Schaffer


Eschen

FROM THE PRESIDENT'S DESK


Liu

The following is an excerpt from ASM President Zi-Kui Liu's speech at the ASM Annual Business Meeting in Portland on September 29.

Our 2016 strategic plan identified three critical areas in which ASM International must excel to ensure our success and growth: technical excellence, increased membership, and strategic partnerships/collaborations. ASM was fortunate to recruit Bill Mahoney in 2016 to lead the realization of the strategic plan. Bill and his team developed a three-year Renewal program and have demonstrated significant progress.

As we are coming to the end of the three-year Renewal program and the third year of the 2016 strategic plan, we ponder "How is ASM doing?" and "What's next?" At our annual strategic planning meeting this past August, an external facilitator evaluated the progress during the last three years in comparison with the strategic plan. The facilitator concluded that "Overall, ASM's operating efforts have met the goals and objectives in the 2016 Strategic Plan. Membership and revenue have been enhanced. The technical capabilities of ASM have improved markedly thereby starting to position ASM as a world leader for materials information. ASM has measurably expanded the number and quality of its strategic partnerships and collaborations, which will hopefully have a meaningful impact on ASM."

While our new strategic plan for the next five to 10 years is still being formulated, it is evident that the three areas remain critical to ASM. ASM has grown significantly in terms of its digital content and e-commerce capabilities. For example, all ASM legacy Handbooks, Failure Analysis guides, and Alloy Center databases are now in digital form and available via online subscription. The balance of ASM's legacy content will cross the digital divide in 2020.

New third-party digital capabilities, such as the NIST materials data curation platform, and the Materials Properties for Data Science database, are also available. All of these legacy and new capabilities are discoverable, searchable, and accessible via the internet. This access is facilitated by a new e-commerce and membership management systems backbone, utilizing cloud-based applications such as Member Nation, Salesforce, and the Silverchair digital library, all of which were implemented between 2017 and 2018. Under Dave Furrer's leadership, ASM has marched deeply into the field of ICME and is working on the development of a data ecosystem that integrates experimental and computational datasets with computational tools, enabling software as a service (SaaS) to all stakeholders.

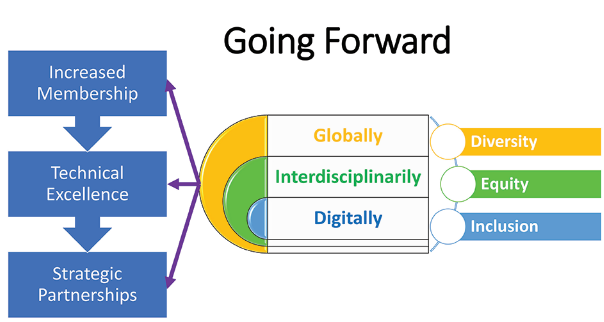
To grow interdisciplinarily, we need to extend both vertically and horizontally. Vertically, we will start a new task force on chapters and volunteerism with an enhanced new digital platform, to support chapters to build stronger interactions among individual and sustaining members and with universities and student organizations. Horizontally, we want to extend our services and collaborations to other professional societies and engineering disciplines. ASM has signed MOU's with a number of professional societies including MRS and NACE, and has formed collaborative agreements with corporations such as IMS, Nikon, Parker Hannifin, and Lincoln Electric with many of them to be present at our IMAT2020 conference.

ASM International is lagging behind in terms of global reach in comparison with other professional societies. For example, IEEE, MRS, and TMS all have half of their memberships outside of the U.S., while ASM's reach is shy of 20%. If we could achieve the same demographics as other societies, we will have the potential to significantly enhance ASM's impact through the global network of people and digital content.

The most significant event in the last year was the acquisition of Granta by ANSYS. Our visionary leaders led by ASM President Ashok Khare approved the investment of $1.6M in Granta in 2000, a spinoff from Cambridge University led by Prof. Mike Ashby, an ASM Distinguished Life Member. We received an amazing eight-figure return, of which $1M was donated to the ASM Materials Education Foundation, and paid off an eight-figure indebtedness, and still have eight figures left. Should we put the remainder into our regular investment portfolio like most professional societies do? Or can we develop approaches to systemize the Granta-type of investment to differentiate ASM from other societies. This is an important question that ASM leadership is working to answer. Your suggestions and ideas are highly appreciated.

Together, let us do better than our best to grow ASM digitally, interdisciplinarily, and globally with a solid diversity/equity/inclusion plan, and advance materials technologies for humanity.

ASM President Zi-Kui Liu, FASM
zi-kui.liu@asminternational.org



ASM Nominating Committee Nominations Due

ASM International is seeking members to serve on the 2020 ASM Nominating Committee. The committee will select a nominee for 2020-2021 vice president (who will serve as president in 2021-2022) and three nominees for trustee. Candidates for this committee can only be proposed by a Chapter through its executive committee, an ASM committee or council, or an affiliate society board. **Nominations are due December 15.** For more information, contact Leslie Taylor at 440.338.5472 or leslie.taylor@asminternational.org, or visit asminternational.org/about/governance/nominating-committee.

Annual ASM Award Nominations due Feb. 1, 2020

The deadline for the majority of ASM's awards is **February 1, 2020,** and we are actively seeking nominations for all of these awards, a few of which are listed below:

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

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

VISIT THE CAREER HUB

Matching job seekers to employers just got easier with ASM International's new CareerHub. After logging on to the ASM website, job seekers can upload a resume and do searches on hiring companies for free. Advanced searching allows filtering based on various aspects of materials science, e.g., R&D, failure analysis, lab environment, and manufacturing. Employers and suppliers can easily post jobs and set up pre-screen criteria to gain access to highly qualified, professional job seekers around the globe. For more information, visit the CareerHub site. http://careercenter.asminternational.org/.

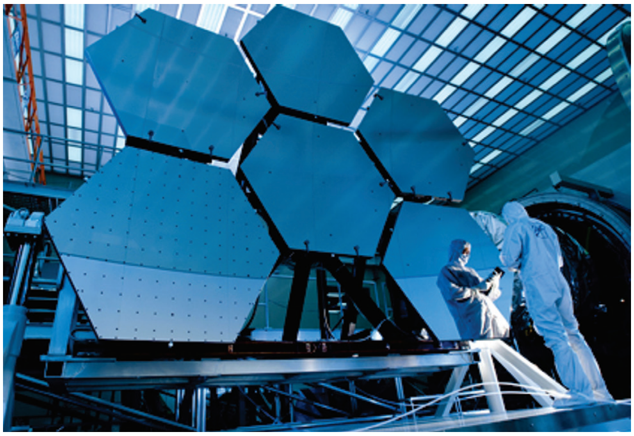
Materion's Historical Landmark Dedication

Dignitaries, employees, and guests gathered on September 12 at Materion Corp.'s Elmore, Ohio, plant for a dedication ceremony celebrating the location's status as a 2018 ASM International Historical Landmark. Keith J. Smith, vice president of Nuclear, Science and Government Affairs, was the master of ceremony. ASM President Zi-Kui Liu, FASM, assisted with the festivities. Also on hand were State of Ohio Representative D.J. Swearingen, Jr., and State of Ohio Senator Theresa Gavarone. The plaque was showcased in a unique setting, mounted on rhyolite excavated from a mine near Materion's Delta, Utah, plant.

Dr. Liu's travels brought him in touch with Materion again when he recently visited the James Webb Space Telescope at Northrop Grumman in Los Angeles, which features mirrors made with Materion beryllium. In fact, Materion developed a new grade of beryllium especially for the unique mirrors. The new telescope, set to launch in 2021, will have 100 times more power than the Hubble.

Materion Elmore plant manager Randall Willis (left) and ASM President Zi-Kui Liu prepare to unveil the plaque.

State of Ohio Senator Theresa Gavarone and Materion's Don Hashiguchi, FASM, alongside the unique plaque setting in Elmore.



Materion provided 18 hexagonal beryllium mirrors for the James Webb Space Telescope. Courtesy of NASA.

PHOTO GALLERY: HIGHLIGHTS FROM PORTLAND

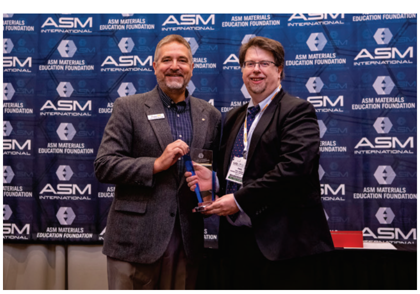
Conference attendees find opportunities to network during MS&T19, September 29-October 3, in Portland, Oregon.

2019-2020 ASM Board of Trustees.

Zi-Kui Liu, FASM, ASM President, 2019-2020, addresses the membership at the Annual Business Meeting on Monday.

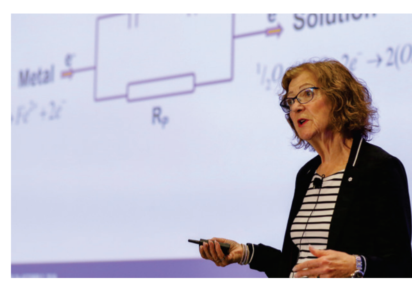
ASM Vice President Diana Essock, FASM, shares the Society's data management plans with the ASM past presidents.

J.P. Singh receives a tie from Zi-Kui Liu, FASM, for his leadership role as Chair of the Chapter Council.



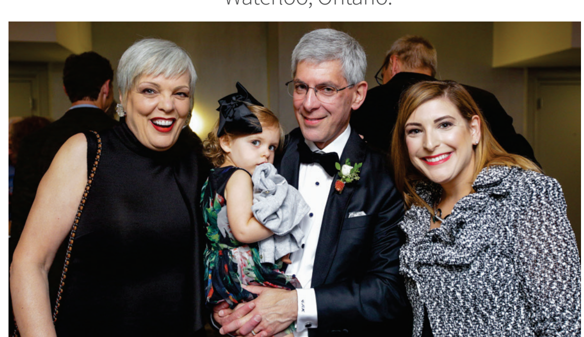
Chip Keough, FASM, (left) presents the ASM Foundation Pacesetter Award to Paul Mason, Thermo-Calc Software.

Margaret Showalter receives the Kishor M. Kulkarni Distinguished High School Teacher Award from Chip Keough, FASM.



The ASM/TMS Distinguished Lectureship in Materials and Society was presented by Carolyn M. Hansson, University of Waterloo, Ontario.

Panelists field questions during the ASM Women in Materials Engineering breakfast.



Charlie Kay, 2019 Class of Fellows, enjoys the ASM Awards Dinner festivities with his family.

Elizabeth Hoffman is welcomed to the 2019 Class of Fellows by ASM President David Furrer, FASM.

Awardees get to know each other at the head table during the awards dinner.

Susan Gentry gives an acceptance speech after receiving the Bradley Stoughton Award for Young Teachers.

Jeremy Schaffer is one of the recipients of the 2019 Silver Medal Award.

Danielle Cote and Dharma Maddala both receive the Bronze Medal Award from David Furrer, FASM.

Amy Roberts-Ebeling and Andrew Roberts present the 2019 George A. Roberts Award to Andy Nydam.

Prof. André McDonald, a new ASM Fellow, receives his certificate from David Furrer, FASM.

The 2019 recipient of Honorary Membership is Greg Olson, FASM.

ASM's booth highlighted new digital data resources and computational tools.

A DomesDay contestant makes remarks before her submission is put to the test during the sixth annual ASM Geodesic Dome Design Competition.

CEO CORNER

ASM and Partners at the World Manufacturing Forum

Mahoney

Last spring, ASM formed an MOU with Intelligent Manufacturing System International (IMSI). IMSI is a 30-year-old non-profit whose mission is to proliferate manufacturing technologies (Industry 4.0/Manufacturing 4.0) among small and medium-sized enterprises. IMSI is also the parent company of the World Manufacturing Forum, which has become, over time, the "Davos" of manufacturing. ASM has rightly predicted that partnering with IMSI will give ASM a leg up on leading "Materials 4.0" market segments, as the process triad between materials, design, and manufacturing becomes an ever more closed-loop triad.

Our IMSI partnership presented the opportunity for ASM to organize a half-day Technical Symposium at the WMF on September 25, which was scheduled as a "Technical Day" in advance of the main conference. I invited Anders Engstrom, Thermo-Calc Software CEO; Aziz Asphahani, QuesTek CEO and Chairman; Ajei Gopal, ANSYS CEO; Dave Cebon, ANSYS CTO (Granta co-founder); and Ray Fryan, TimkenSteel VP of Quality and Technology, to work with me to develop a program that would reflect the latest technologies and applications in the Materials 4.0 space.

The team worked during the summer to develop our program, which explored in sequence thermodynamic modeling (Thermo-Calc); how thermodynamic modeling is used to design new materials (QuesTek); the engineering simulation marketspace (ANSYS); and why it needs concurrent materials information, and how that information can be delivered (ANSYS Granta); how materials information and simulation is used to alter/improve materials-based products (TimkenSteel); and what ASM is doing to make sure our materials information can be delivered to all these processes readily and in the right form(s).

Audience members from the National Science Foundation, Lockheed Martin, and the National Research Council of Canada all shared with me their enthusiasm for our collective presentations, and the suggestion was made that we update and repeat the symposium at later venues, such as AeroMat this coming spring and certainly at IMAT.

Some important factoids were mined from the symposium:

- If anyone desires to deploy additive manufacturing at any scale, they must start with the (most likely custom-designed) material, and that need will drive demand for materials analytics and information.
- The additive manufacturing marketplace is estimated by reliable surveys to reach $11B in annual revenues, reflecting a 22% growth rate (CAGR) since 2016.
- The engineering simulation marketplace is a $7B annual market, of which ANSYS, as the biggest player, holds $1.4B, and that market is reliably forecast to grow to between $15-20B annually by 2026. ANSYS articulated that this market growth reflects "pervasive simulation" requirements, which prompted them to acquire Granta, to add a materials information layer supporting all the different physics models behind their simulation tools.

We are conducting active follow-up meetings with ANSYS on October 25 and in November to plan how ASM's (and possibly third party) materials information can best be deployed directly into the ANSYS simulation base. We will also be examining other collaboration opportunities such as data consortia and start-up co-investment. ANSYS is also following up with TimkenSteel this month based on opportunities identified between those organizations during the forum.

William T. Mahoney, CEO, ASM International
bill.mahoney@asminternational.org

Annual meeting session during the World Manufacturing Forum, Lake Como, Italy, September 25-27.

FROM THE FOUNDATION

Daehn Shares Goals for 2020

Daehn

Through my work, I witness the critical need for people who both understand materials, science, and engineering and can DO hands-on things, like tinkering, designing and making their own creations. I am confident you observe similar needs in your industries. The ASM Materials Education Foundation (MEF) is addressing workforce challenges by improving K-12 education and challenging the status quo. We put students on track for careers that are meaningful, fulfilling, and much needed; changing lives in a profoundly positive way—with a model that can scale.

ASM MEF educates teachers authentically, efficiently, and at great scale. Over 700 teachers per summer enroll in our weeklong Materials Camps for Teachers—at no cost to them. These programs, which allow for immeasurable student reach, are extremely popular with teachers as they fill gaps that many have in their education. This inspiring, tested, and vetted content provides insight to talk about materials and manufacturing in their classrooms, demonstrations that become part of chemistry classes, or a full high school course in materials science. Materials Camps for Teachers have immense leverage, reaching over 11,000 teachers to date who each educate thousands of students during their career. ASM MEF sees the great value in this work, despite Materials Camps being expensive to maintain, execute, and improve.

As a result of ASM MEF's work, and our constellation of incredible teachers, about 300 high schools now offer full materials science courses. Students from these programs enter the STEM workforce in careers ranging from hands-on makers to materials theorists. We have a successful program foundation, but we know there is a pressing need to reach more students and teachers.

Master Teacher Bob Wesolowski runs a summer camp for middle school students each year with assistance from students in his high school materials science course.

Our goals for ASM MEF's future include:

- Grow to reach over 50,000 students per year in both middle and high schools
- Continually improve, codify, and digitize our first-rate curriculum
- Hold Materials Camps in all 50 U.S. states
- Grow to meet these goals in a sustainable way

We need your support to maintain and grow this valuable program. Please help the Foundation by reaching out to your company or others that share our passion to bring more students into the STEM workforce. Contact Carrie Wilson, the Foundation's executive director, at carrie.wilson@asminterntional.org, or me at daehn.1@osu.edu. To make a donation, visit asmfoundation.org/asm-donate/.

As always, our sincerest gratitude for your support and commitment!

Glenn S. Daehn, FASM
Chair, ASM Materials Education Foundation

EMERGING PROFESSIONALS

The Importance of Continuous Learning

Joel Davis

Learning and developing new skills and competencies is one of the most important aspects of an emerging professional's career journey. This period of learning is often described as an S-curve in which the first six months are spent acquiring basic knowledge, the next two to three years are spent in a phase of accelerated growth in competency and confidence, and the final phase is a slower climb toward mastery. For emerging professionals who have many skills to learn, it is essential to be mindful of this framework.

There are many different avenues to learning and no one way is right. The key is to constantly strive to learn throughout your career. Many employers offer training courses or temporary cross-training assignments to broaden the skills of their employees. Some skills can be learned outside of work through volunteerism or training and then translated into your professional career. Other skills can be learned by undertaking optional projects not directly related to your job. Getting to know what different opportunities are available around you and being willing to jump on a sudden opportunity that comes up, are both keys to success.

One trap that is easy to fall into is becoming complacent after achieving mastery in a skill. To avoid this, emerging professionals should always be on the lookout for new learning opportunities as they reach the final phase of the S-curve. Another trap to avoid is passing up learning opportunities because of feeling unready. While some level of unreadiness is expected, feedback from peers and mentors can help determine if you could be ready for a new challenge.

Learning and acquiring new skills, while necessary for the successful emerging professional, follows you throughout your career. Even experienced specialists will tell you how continuing to acquire new skills and incorporating them into your knowledge base continues to be as important later in your career as it is right now.

Errata: The October issue's Emerging Professionals column was incorrectly credited to Jonathan Healy. The author was Ellen E. Wright. We apologize for the confusion. The digital edition has been corrected.

WOMEN IN ENGINEERING

This profile series introduces leading materials scientists from around the world who happen to be females. Here we speak with **Cindy Waters,** *senior science technology manager for Advanced Manufacturing and Materials, Naval Surface Warfare Center Carderock in West Bethesda, Md.*

Waters

What is your engineering background?

I earned bachelor's and master's degrees in material science and engineering from Virginia Tech and a Ph.D. in mechanical engineering from North Carolina A&T State University. My M.S. project, funded by the DOE's Savannah River Labs, focused on impact behavior degradation by hydrogen embrittlement of stainless steels. I began my engineering career in research labs at the University of South Carolina mechanical engineering department where I led fracture mechanics projects. My Ph.D. was completed in 2004. I was a tenured professor of mechanical engineering studying metal based additive manufacturing before joining my current organization.

What part of your job do you like most?

Working with other motivated and educated people who want to make a difference through engineering. I recently transitioned from being a tenured faculty member into my naval research position, and sharing knowledge is still gratifying. I think less now about fundamental research and more about transitioning research into the fleet. I continue to think materials engineering is amazing and love opportunities to teach other engineers and non-technical people how materials science affects the products in their lives.

What attracted you to engineering?

I grew up on a farm, was active in the 4-H Club, and was raised to believe I could do anything, whether it was baling hay, assisting in birthing a lamb, or helping Dad on the roof. I grew up problem solving and doing! I have since learned that engineers are the ones who make the dream a reality. Engineers are "doers." In high school, I enjoyed my science and math classes and was good at it. Before college, a friend's father offered me a summer job working in metallurgy labs and I was hooked.

What are you working on now?

I am working to develop, promote, coordinate, and oversee materials and manufacturing-related research and development planning and execution across the Navy enterprise. We are bringing additive manufacturing to sailors, Marines, and onto ships and submarines, from design to printing replacement parts.

Finish this sentence: Women in materials engineering are…

…diverse, creative, intelligent, indispensable, and too few!

Favorite motto or quote?

One of my children informed me that most other families they know do not get very involved with societal issues or problems in the community but that "our family are doers, not just complainers." As a family, we modeled the mantra "Think globally, act locally" and this ties in with a favorite quote from Coach John Wooden, "Being a role model is the most powerful form of educating."

Last book read?

Ken Follett's "Century Trilogy" series.

Do you know someone who should be featured in an upcoming Women in Engineering profile? Contact Vicki Burt at vicki.burt@asminternational.org

CHAPTERS IN THE NEWS

Philadelphia Honors Jones with William Hunt Eisenman Award

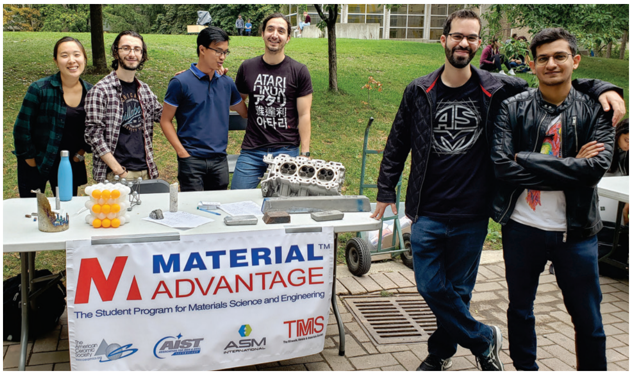
If there is such a thing as a "three-peat" in heat treating awards, the Jones family of Solar Atmospheres has achieved it. On Thursday, October 17, the ASM Philadelphia Liberty Bell Chapter held its annual William Hunt Eisenman Award night, honoring Jamie Jones with the prestigious prize. This makes him the third generation Jones to receive the award, a first in the Philadelphia Chapter's history.

Approximately 25 people attended the event, where the honoree gave a presentation on "Thermal Processing of Medical and Other Sensitive Materials in Vacuum." Jones is currently vice chair of the Chapter.

The William Hunt Eisenman Award was established in 1960 by ASM International. It recognizes unusual achievements in industry in the practical application of materials science and engineering through production and engineering usage. The Philadelphia Chapter's history with the award predates headquarters, as in 1957, Eisenman himself was the first recipient of the Chapter's award. Eisenman was a founding member of the Society and its secretary for nearly 40 years.

The Jones' left to right: Bill, Trevor, awardee Jamie, and Roger.

Frosh Week at Ryerson



Ryerson University Material Advantage members promoted their Chapter at the school's Frosh Week this past fall, complete with hands-on opportunities to entice new students' curiosity.

Sebastian Visits Bluegrass Chapter

As part of an ASM Trustee Visit, Jason Sebastian presented a talk on "New High Performance Alloys Designed Specifically for Additive Manufacturing Processes" at an ASM Bluegrass Chapter meeting on October 15. In addition to great attendance by Chapter members, the University of Kentucky Material Advantage Chapter was also well represented. Sebastian is the president of QuesTek Innovations LLC, Evanston, Ill.

Left to right: ASM Trustee Jason Sebastian, ASM Bluegrass treasurer Michael Raulinaitis, vice chair Mujan Seif, student affairs chair Kerry Baker, chair Phillip Swartzentruber, and online membership chair/web administrator Alexandra Allamon.

Houston Hosts Oktoberfest

The ASM Houston Chapter hosted its annual Oktoberfest meeting, the most popular event of the year, at St. Arnolds Brewery. Attendees not only enjoyed the technical presentation and networking opportunities but were able to get a first-hand look at the beer making process while feasting on traditional German food. Michael Pendley (pictured), general manager of National Heat Treat, gave a presentation entitled "Secrets of the Heat Treating Industry." Pendley covered a number of interesting topics including things your heat treater wants you to know, heat treating hacks for manufacturing mistakes, and how to choose a heat treater. The presentation was enthusiastically received by more than 100 attendees.

Ottawa Teachers Camp Graduation

Graduation day at the ASM Materials Camp for Teachers in Ashbury College, Ottawa—a year two camp—was commemorated on July 12 with this photo of teachers, featuring master teachers Briana Richardson (front row, seated on rock, far right) and Scott Spohler (middle row, seated on rock, far right); sponsors Taylor Robertson, chair, ASM Ottawa Valley Chapter (front row, seated on rock, second from right) and Glenn McRae, Carleton University Faculty of Engineering and Design (back row, far right, standing beside tree); and Materials Camp chair Winston Revie, ASM Ottawa Valley Chapter (front row, far right, standing). Photo courtesy of Chris Miedema, camp host and chemistry teacher, Ashbury College.

Chapters of Excellence Awards

MATERIAL™ ADVANTAGE
The Student Program for Materials Science and Engineering

Each year, ASM administers the Chapters of Excellence (COE) Awards Program on behalf of the Material Advantage Student Program. This competition judges the student chapters across programming, career development, service, social activities, chapter management, and overall report quality. Congratulations to this year's winning schools!

Most Outstanding Chapter (certificate and $750 prize):

- Suez University in Egypt

Chapter of Excellence Awards (certificate and $450 prize):

- Colorado School of Mines
- Michigan Tech
- University of Michigan
- University of Puerto Rico at Mayaguez
- Wuhan University of Technology

Runner-Up (certificate of achievement):

- Cal Poly Pomona
- Univ. of Illinois at Urbana-Champaign

Congratulations to these ASM Chapters celebrating milestones of serving local members!

Northeastern Iowa — 75 Years

Ottawa Valley — 75 Years

Thank you for your commitment!
We look forward to celebrating your future success!

IN MEMORIAM

Gerald Cole, FASM, of Southfield, Mich., passed away on September 11 at age 83. He was an ASM Life Member, member of the ASM Detroit Chapter, and director of lightweight operations at Automotive Insights LLC. He earned his Ph.D. in materials science and metallurgical engineering at the University of Toronto. Cole spent 37 years at the Ford Motor Co. as a senior staff technical specialist where he worked to weight-reduce the Ford fleet using magnesium. In his later career, Cole was president of LightWeightStrategies LLC, where he developed an R&D program for producing sustainable bamboo wood. He also served as an adjunct professor and lecturer at the University of Michigan and various universities worldwide. Cole presented over 350 invited lectures and courses in nine countries.

Robert Mayer, Jr., passed away in Dallas on March 30, 2018. Business owner, petroleum engineer, physicist, inventor, and protégé of Former Speaker of the U.S. House of Representatives Sam Rayburn, Mayer was born June 17, 1922, in Dallas. He graduated early from Harvard University in 1942 (Class of 1943). In 1941, he taught radar to Army and Naval personnel. Three years later, he enlisted in the military and was commissioned as a lieutenant in the U.S. Army, serving in the Army Corps of Engineers. In 1952, he founded Well Reconnaissance Inc., which was acquired in 1979 by Gearhart Owen Industries. He continued working from his Addison office, until two days before his passing. Mayer was a member of the Society of Petroleum Engineers, the Society of Exploration Physicists, and the ASM North Texas (Dallas) Chapter.

Triplicane Asuri Parthasarathy, FASM, aka TAP, 64, of Beavercreek, Ohio, died unexpectedly on May 31. A member of the ASM Dayton Chapter, Parthasarathy was born in Chennai, India. He received his bachelor's degree in metallurgical engineering from the Indian Institute of Technology, Chennai in 1976 and a Ph.D. in materials science and engineering from The Ohio State University in 1983. Parthasarathy spent the past 33 years employed as a director/senior scientist at UES Inc. in Dayton, engaged in R&D at the Materials and Manufacturing Directorate of the Air Force Research Laboratory, Wright-Patterson AFB. He was considered one of the world's leading scientists in the field of high temperature materials, receiving many prestigious honors and recognitions, including being named a Fellow of both the American Ceramic Society and ASM International.

Wilfredo V. "Fred" Venal, 77, of Warren, Pa., died on July 23 at his residence surrounded by his family. Venal resided in Warren for the past 20 years and was formerly of Pampa, Texas, Kokomo, Ind., and Chicago. He earned his bachelor's degree in engineering from University of the Philippines in Manila, his master's from Aachen University in Germany, and his Ph.D. from the University of Illinois. Venal was employed with the former National Forge Co. and the present Ellwood National Forge Co. as a metallurgist for over 20 years and was still working at the time of his death. He was a member of the ASM Northwest Pennsylvania Chapter.

ADVANCED MATERIALS & PROCESSES EDITORIAL PREVIEW

JANUARY 2020

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- Neutron Scattering
- Next-Generation Color Technology

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- Emerging Topics in Metallography
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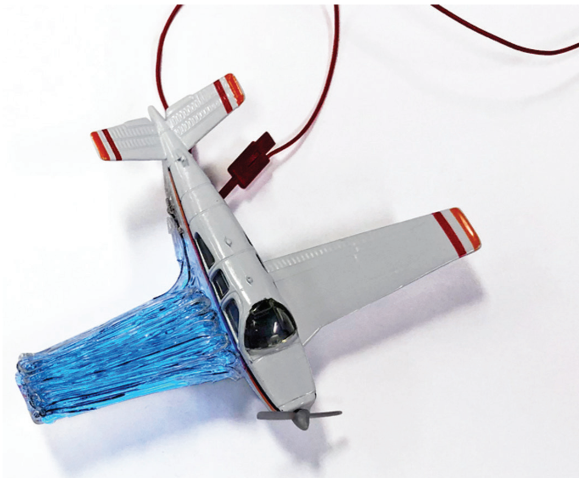
3D PRINTSHOP



Using a new 3D-printing method, this model airplane wing could have light emitters and detectors embedded in the material to detect micro-cracks. Courtesy of Felice Frankel.

MULTIMATERIAL INK SUITS 3D-PRINTED DEVICES

A novel technique developed by researchers at MIT, Cambridge, Mass., uses standard 3D printers to produce functioning devices with the electronics embedded inside. The devices are made of fibers containing multiple interconnected materials, which can light up, sense their surroundings, store energy, and perform other functions.

The system uses conventional 3D printers outfitted with a special nozzle and a new kind of filament to replace the usual single-material polymer filament, which is typically fully melted before extrusion from the printer's nozzle. The new filament has a complex internal structure made of materials arranged in a precise manner and surrounded by an exterior polymer cladding.

In the new printer, the nozzle operates at a lower temperature and pulls the filament through faster than conventional printers do, so that only the outer layer becomes partially molten. The interior stays cool and solid, with its embedded electronic functions unaffected. In this way, the surface is melted just enough to make it adhere solidly to adjacent filaments during the printing process, to produce a sturdy 3D structure.

The internal components in the filament include metal wires that serve as conductors, semiconductors that control active functions, and polymer insulators that prevent wires from contacting each other. As a demonstration, the team printed a wing for a model airplane using filaments that contain both light-emitting and detecting electronics. These components could potentially be used to reveal the formation of any microscopic cracks that might develop. *mit.edu.*

UNIQUE BRIDGE ENTERS TESTING PHASE

The Netherlands will soon test the first metal 3D-printed bridge ever constructed. Plans are to insert this bridge into its permanent location in Amsterdam in early 2020. The Dutch company MX3D built the bridge from a design by Joris Laarman Lab using groundbreaking robotic technology to complete the printing. University of Twente (UT) and Imperial College London will carry out the final construction tests, with initial testing to focus on total load-carrying capacity to safeguard safety and functionality. The bridge will remain at the UT campus for two months after the initial month planned for construction testing. The university will work closely with MX3D, Autodesk, and lead engineering firm Arup during this period on design, development, and testing of the permanent sensor network to be installed on the bridge. *www.utwente.nl.*

Additively manufactured bridge to arrive in Amsterdam, early 2020. Courtesy of UT.

3D-PRINTED ROCKET TO PLACE SATELLITES

Relativity Space, Los Angeles, signed a launch services agreement with Momentus, Santa Clara, Calif., to launch Momentus' small- and medium-sized customer satellites on Relativity's Terran 1 rocket, the world's first completely 3D-printed rocket. Momentus will then deliver the satellites to geosynchronous orbit using the Momentus Vigoride Extended in-space shuttle service. The agreement includes Momentus' purchase of a first launch scheduled for 2021, with options for five additional launches with Relativity Space. The agreement opens access to a more diverse range of orbits for Terran 1 including geostationary transfer orbit, lunar and deep space orbits, lower inclinations, and phasing of multiple spacecraft in low Earth orbit and medium Earth orbit. Relativity Space is developing the first and only aerospace factory to integrate machine learning, software, and robotics with metal 3D-printing technology to build and launch rockets in days instead of years, according to company sources. *relativityspace.com.*