SEPTEMBER 2018 | VOL 176 | NO 6

ADVANCED MATERIALS & PROCESSES

AN ASM INTERNATIONAL PUBLICATION

AUTOMOTIVE MATERIALS

HOME ON THE RANGE WITH ALUMINUM

P. 14

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On the Cover:

This 1978 three-door Range Rover Classic sports aluminum skins for the front and rear fenders, leaf screen, door outers, roof, and upper rear quarter panels. Courtesy of Jaguar Land Rover/ Nick Dimbleby.

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FEATURES

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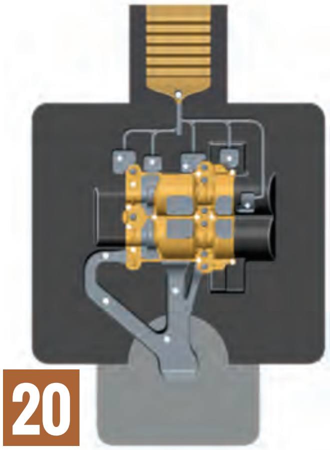

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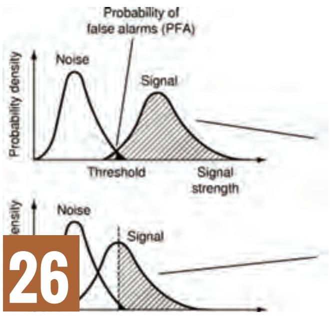

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Advanced Materials & Processes (ISSN 0882-7958, USPS 762080) publishes eight issues per year: January, February/March, April, May/June, July/August, September, October and November/December, by ASM International, 9639 Kinsman Road, Materials Park, OH 44073-0002; tel: 440.338.5151; fax: 440.338.4634. Periodicals postage paid at Novelty, Ohio, and additional mailing offices. Vol. 176, No. 6, SEPTEMBER 2018. Copyright © 2018 by ASM International®. All rights reserved. Distributed at no charge to ASM members in the United States, Canada, and Mexico. International members can pay a $30 per year surcharge to receive printed issues. Subscriptions: $475. Single copies: $51. POSTMASTER: Send 3579 forms to ASM International, Materials Park, OH 44073-0002.
Change of address: Request for change should include old address of the subscriber. Missing numbers due to “change of address” cannot be replaced. Claims for nondelivery must be made within 60 days of issue.
Canada Post Publications Mail Agreement No. 40732105. Return undeliverable Canadian addresses to: 700 Dowd Ave., Elizabeth, NJ 07201. Printed by Publishers Press Inc., Shepherdsville, Ky.

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ADVANCED MATERIALS & PROCESSES

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BACK TO SCHOOL WITH FALL EVENTS

Welcome to the September issue, which I consider our “back to school” edition. Fall is in the air and summer is swiftly drawing to a close. Students of all ages are getting back into their routines, along with the rest of us. Here at ASM, we have education courses in full swing in our renovated lab space and several exciting fall events to look forward to. Among these are Heat Treat Mexico later this month, MS&T in mid-October, ISTFA at the end of October, and our inaugural ASM Fellows Executive Summit in early December. What I enjoy most about these events is the wide variety of offerings. From diving into a half-day course and enjoying nonstop technical sessions to simply walking the exhibit floor and taking in a high-level keynote, it’s all up to you. No matter what, the opportunity to network is invaluable.

Getting together with industry peers and having small group discussions is something the best social media networks can never replace. The honest and spontaneous brainstorming that occurs when people communicate face-to-face is simply impossible to replicate in the digital world. I had this very experience at our Leadership Days event in Cleveland a few weeks ago. As part of this annual gathering of ASM Chapter representatives, the Emerging Technologies Awareness Committee (ETAC) held a focus group to gather feedback and learn what ASM can do to help our members better respond to technology advancements. Talk about opening a fire hose. We had roughly 40 people in attendance and we discussed ideas quickly in small groups. We then had a spokesperson from each table share a brief summary.

Some of the ideas included ASM facilitating dissemination of precompetitive research; compiling a directory of who is working in different areas of materials research and applications; creating a consultant/expert database; presenting more review articles that separate myths from facts; and adding a website area about emerging technologies that lists various international consortia and what they’re working on. It is truly amazing what a small group of motivated members can come up with in a few minutes of open dialogue.

Speaking of amazing, we hope you’re enjoying our new series on the evolution of automotive aluminum. Part III starts on page 14, hence the rugged Range Rover gracing our cover. Does that image scream “Road Trip!” or what? The article is packed with historical tidbits about the painstaking development of aluminum auto body sheet, including the continuous battle against springback. From alloy developers and diemakers to design engineers and manufacturers, the early automotive aluminum industry had its hands full. On a more modern note, be sure to check out the automotive heat treating article from Jack Titus in *HTPro.* Besides aluminum, he talks about the other automotive materials designers have to choose from these days, namely magnesium, carbon fiber reinforced polymer, gray cast iron, plain carbon and alloy steel, and ductile iron. Although the industry has come a long way over the past hundred years, there is so much unpaved road ahead. We hope you enjoy the journey.

F. Richards

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RESEARCH TRACKS

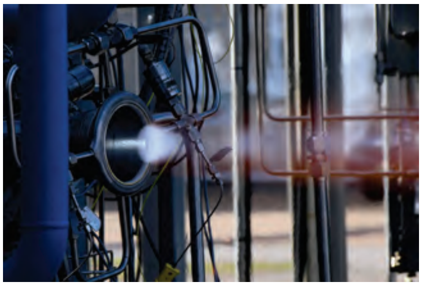
ACADEMIA-INDUSTRY PARTNERSHIP BLASTS OFF

The Advanced Materials Processing Laboratory (AMPL) at the University of Alabama in Huntsville (UAH) led by Professor Judy Schneider, FASM, continues to spearhead advanced materials research in metal additive manufacturing (AM) for NASA, the Defense Department, and industry. While most university groups involved in AM tend to purchase one type of machine and investigate a particular process, Schneider's group collaborates with several industrial partners developing AM processes with custom machines. This allows the AMPL to work with a variety of processes and materials. With the industry connections, the lab at UAH is provided samples from across the AM community to evaluate the effects AM processes have on the microstructure and mechanical properties of different metallic alloys.

One company UAH partners with is Keystone Synergistic Enterprises Inc. of Port St. Lucie, Fla. Keystone developed a process called direct energy deposition (DED) by employing a robotic arm to deposit metal wire feedstock layer-by-layer until a complete component is built. More recently, AMPL, Keystone, and NASA's Marshall Space Flight Center (MSFC) are working together with a new AM process called laser wire direct closeout (LWDC) that was codeveloped with Keystone and patented by NASA. The new process is designed to reduce the cost and time associated with manufacturing advanced liquid rocket engine nozzles.

Modern rocket nozzles are expensive and complex to manufacture due to tight tolerances and complex design geometries. Nozzles are designed with active coolant channels that extend nozzle length to keep the walls from melting during operation. The LWDC process enables manufacture of liquid rocket nozzles with active cooling in less time and more cost effectively than traditional methods such as brazing. Advancement of the new process was completed under a NASA Small Business Technology Transfer award to Keystone and UAH. Using the wire-fed DED process and the new LWDC process conducted with AMPL materials characterization, Keystone manufactured a rocket nozzle for NASA. After proof testing, the component was successfully hot fire tested for over 800 seconds at the MSFC facility.

Through the AM nozzle project and others, AMPL and Keystone have worked together for over 10 years. Within this partnership, Keystone fabricates AM parts and samples under various build and heat treatment parameters while the UAH lab conducts metallurgical evaluations. The relationship developed between these two entities illustrates the benefits of such industry-university collaborations. The partnership not only provides funding for general research, but also exposes students to a variety of cutting-edge AM processes and applications by technology leaders such as Keystone and NASA. *For more information, visit uah.edu.*



Hot fire testing of 3D-printed rocket nozzle at NASA.

FEEDBACK

TITANIUM HOLDS UNTOLD PROMISE

Bravo to Sam Froes for his fine articles on "Titanium: A Historic and Current Perspective" [February/March and April issues]. I have followed the industry for 60 years and could not find a single nit to pick. I would have mentioned the Army's howitzer frame and their hand grenade launcher tube, but it's not my paper. It is a bit ironic that he mentioned the Navy's use topside because they have been so slow in using titanium. Two examples: The USS Thresher crushed at less than 1000 ft while the Russians were building fleets of titanium subs. Also, the USS Cole had a 40-by-60-ft hole blasted in its side by a little outboard boat. I would guess a titanium hull might not have failed.

Fifty years ago at Reactive Metals, we were asked to write a short essay on where we expected the titanium industry to go. I said then and still believe we are much too dependent on the aerospace industry. At Reactive, we built two tanks for chemical tanker trucks to replace the rubber-lined stainless tanks. We could haul in two trips as much as the stainless tanks could in three trips. With automated welding, they would be much easier to build today. Commercial uses at commercial prices must be developed for the industry to move forward. We waste untold billions of dollars each year on rust and rust prevention. Titanium does not rust.

Chuck Dohogne

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

PROCESS TECHNOLOGY

Engineers test new laser-made aircraft parts on a fighter jet. Courtesy of RUAG Australia.

LASERS ENABLE 3D-PRINTED AEROSPACE PARTS

Researchers from RMIT University, Australia, are developing laser technology to build and repair steel and titanium parts in what they believe could be a breakthrough application for industry. The scientists are using laser metal deposition technology to build and repair defense aircraft parts during a two-year collaboration with RUAG Australia and the Innovative Manufacturing Cooperative Research Centre. The new technology feeds metal powder into a laser beam and adds new material in a precise, web-like formation when the beam is scanned across a surface. The resulting metallurgical bond has mechanical properties that either meet or exceed those of the original material.

Researchers say that by enabling onsite repair and production of parts, the technology could completely transform the concept of warehousing and transporting components for defense and other industries. Currently, replacement parts typically must be ordered from local or overseas storage and suppliers. Although the current project focuses on military aircraft, it is potentially transferable to the civil aircraft, marine, rail, mining, and oil and gas industries. *www.rmit.edu.au.*

SPIDER GLUE AND COMMERCIAL ADHESIVES

Overcoming the effects of interfacial water is one of the main challenges facing developers of commercial adhesives. Interfacial water forms a slippery, nonadhesive layer between the glue and the surface to which it is meant to stick, inhibiting formation of adhesive bonds. To find a solution, researchers at The University of Akron, Ohio, are looking to spider silk. The sticky glue that coats the silk threads of spider webs is a hydrogel. A subject of intensive research for years, spider glue is one of the most effective biological adhesives found in nature. The team set out to examine the secret behind the hygroscopic success of the common orb spider, *Larinioides cornutus*, and how it overcomes the primary obstacle of achieving good adhesion in humid conditions where water could be present between the glue and target surface.

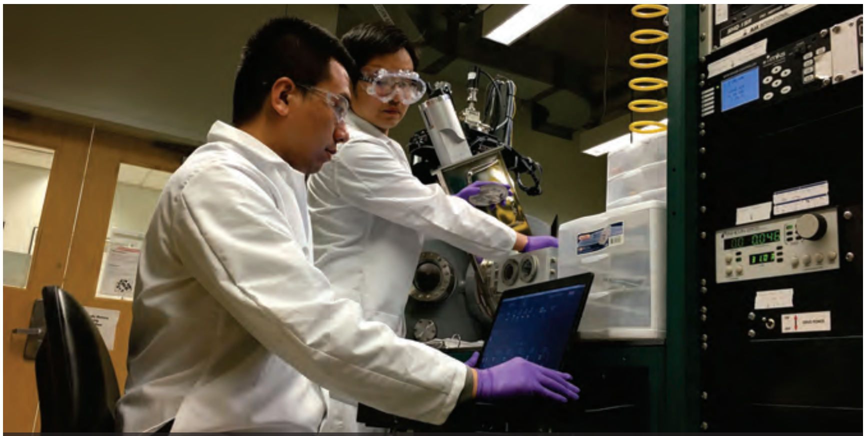
An orb spider makes glue as it works on a web.

Spider glue is made of three elements—two specialized glycoproteins, a collection of low molecular mass organic and inorganic compounds (LMMCs), and water. The team discovered that these glycoproteins act as primary binding agents to the surface. Glycoprotein-based glues have been identified in other biological sources such as fungi, algae, and English ivy. The LMMCs in spider glue perform a previously unknown function of sequestering interfacial water, preventing adhesive failure. The team then determined it is the interaction of glycoproteins and LMMCs that governs the adhesive quality of the glue produced. The ability of the spider glue to overcome the problem of interfacial water by effectively absorbing it is the key research finding that may enable commercial development of new adhesives. *uakron.edu.*

BRIEF

Steel Dynamics Inc., Fort Wayne, Ind., will invest $140 million in its Columbus Flat Roll Division, adding a third galvanizing line at the Columbus, Miss., facility. The new line will have an annual coating capability of 400,000 tons, producing gauges between 0.013 and 0.160 in. and widths between 36 and 72 in. Operations are expected to begin mid-year 2020. *steeldynamics.com.*

METALS | POLYMERS | CERAMICS



Qiang Li builds a deposition program on the computer as Yifan Zhang loads samples into a sputtering chamber to prepare high-strength Al alloy coatings.

NEW ALUMINUM ALLOY RIVALS STRENGTH OF STEEL

Researchers at Purdue University, West Lafayette, Ind., developed a new superstrong material—a high-strength aluminum alloy coating—that could change some manufacturing processes for the aerospace and automobile industries. The material is a durable, flexible, and lightweight aluminum alloy that is just as strong as stainless steel, if not stronger. Researchers say the new alloy could be used for making wear and corrosion-resistant automobile parts as well as coatings for optical lenses used in specialized telescopes for the aerospace industry.

The team creates the superstrong aluminum alloy by introducing stacking faults in the crystal structure. Such distortions can lead to nanotwins and complex stacking faults, including the 9R phase. Researchers introduce both twin boundaries and the 9R phase within nanograins to the lightweight Al alloys that are both strong and highly deformable under stress. Beyond coating applications, researchers are also looking into scale-up potential for bulk high-strength Al alloys. The team also created a way to develop the superstrong alloy coatings by introducing iron or Ti atoms into aluminum's crystal structure. The resulting nanotwinned aluminum-iron alloy coatings proved to be one of the strongest aluminum alloys ever created, comparable to high-strength steels. Purdue's Office of Technology Commercialization helped secure a patent for the technology, which is available for licensing. *purdue.edu.*

PRECISELY CONTROLLING POLYMER GRIDS

Although covalent organic frameworks (COFs) were first discovered in 2005, their quality has been poor and preparation methods uncontrolled. Now, a research team at Northwestern University, Evanston, Ill., is the first to produce high-quality versions of these materials, demonstrate their superior properties, and control their growth. The researchers developed a two-step growth process that produces organic polymers with crystalline, 2D structures. The precision of the material's structure and the empty space its hexagonal pores provide will allow scientists to design new materials with desirable properties.

Even low-quality COFs have shown preliminary promise for water purification, electricity storage, body armor, and other tough composite materials. Once developed further, higher quality samples of these materials will enable

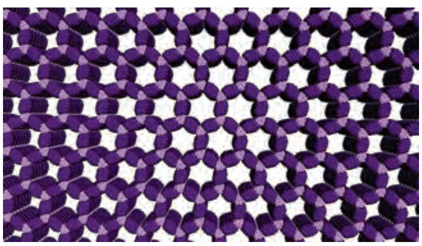
BRIEFS

Steel Dynamics Inc., Fort Wayne, Ind., acquired **Heartland Steel Processing LLC,** Terre Haute, Ind. Heartland produces various types of flat roll steel by further processing hot roll coils into pickle and oil, cold roll, and galvanized products. The acquisition will expand Steel Dynamics' annual flat roll steel shipping capacity to 8.4 million tons and total steel shipping capability to 12.4 million tons. *steeldynamics.com.*

Wieland Metals, Wheeling, Ill., announced plans for a $25 million expansion that will create an estimated 65 new jobs. The copper manufacturing company, headquartered in Germany, plans to build a 110,000-sq-ft industrial building at a location northwest of Chicago. The new building will be used to manufacture, warehouse, distribute, and sell metal tubes. *wielandmetals.com.*

JW Aluminum, Mount Holly, S.C., has started an expansion project at its flat-rolled aluminum plant in Goose Creek, S.C. The 220,000-sq-ft expansion will house new equipment focused on more environmentally friendly processes. The company predicts the project will increase production capacity by 175 million pounds on an annual basis. Completion is expected by early 2020, adding 50 new jobs to the site. *jwaluminum.com.*

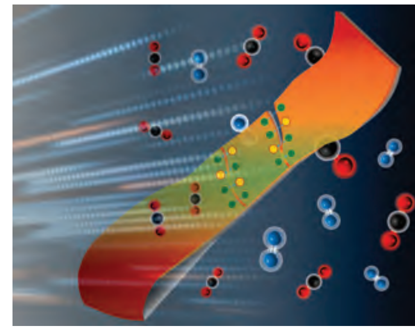
these applications to be explored more fully. In the two-step process, the scientists first grow small particle seeds to which they slowly add more of the building blocks under precisely controlled conditions. The slow addition causes the building blocks to add to the seeds instead of creating new seeds. The result is bigger, high quality particles made up of large, hexagonal sheets instead of many aggregated crystals. Particles are also perfectly uniform throughout the entire structure. The team's findings show that energy can move through these materials for much longer distances than the sizes available through older methods. *northwestern.edu.*



Covalent organic frameworks hold promise for water purification, energy storage, and electronic devices.

STRETCHY POLYMERS HEAL THEMSELVES

Researchers at Oak Ridge National Laboratory, Tenn., developed ultra-stretchy polymers with impressive self-healing abilities that could lead to more durable consumer products. The new polymers are among the world's most pliable and can elongate about 1000-5600% before breaking. After breaking, they can be healed with complete elastic restoration by merely touching adjacent pieces. By tailoring the properties of segments and how they link to the polymer, scientists tuned the tensile strength, toughness, and elastic recovery. In addition, they used stretchy polymeric strips to create a permeable membrane that selectively separated two gases. After that membrane broke, it self-healed to once again separate the gases. Tailoring the degree of hydrogen bonding is the key to self-healing and could be exploited to make other self-healing materials. These new polymers provide an advantageous platform for building coatings, functional films, membranes, and devices with longer lifetimes. *ornl.gov.*



Rubbery segments in a ribbon-shaped polymer membrane make it stretchy. Hydrogen-bonding molecules (yellow and green) allow the material to self-heal after a cut and recover its ability to separate gases such as CO_2 (red and black) from nitrogen (blue). Courtesy of Pengfei Cao and Bingrui Li/ORNL.

TESTING | CHARACTERIZATION

Sandia is using its solar tower to help assess the impact of extreme temperature changes on materials for the Air Force.

SOLAR TOWER TESTS THERMAL RESPONSES

Sandia National Laboratories, Albuquerque, N.M., is using its solar tower to help assess the impact of extreme temperature changes on materials. The tests, now in their second year, take advantage of Sandia's National Solar Thermal Test Facility's ability to simulate a rapid increase in temperature followed by an equally rapid decrease. Researchers place a 4×4-in. sample of composite material into a test chamber and then expose it to a burst of intense heat. The coupon is set flush to a test chamber wall facing a quartz window that accepts the heat produced by mirrors. Initially, sliding shutters in front of the window are closed. The team focuses reflected light from the heliostats onto a calibration panel and uses a heat flux gauge to measure the power that will hit the sample. Then they move that reflected light onto the shutters. When ready, the shutters slide open and then close very quickly to produce the heating curves needed. At the same time, a wind tunnel forces air across the sample, simulating convective cooling.

Researchers can subject a sample to heat multiple times to establish material response thresholds after exposure. Before and after a test, researchers examine samples with a 3D scanner, which determines various texture changes in the materials, while another team takes reflectivity measurements. A third team uses nondestructive methods to look inside the sample after a test, checking for changes below the surface. The project has led to improvements at the test facility, including a new tracking algorithm for the heliostats and advancing heat flux characterization techniques. *sandia.gov.*

MICROSCOPY AT EXTREME HEAT

Researchers report that stainless steel alloy 709 has potential for elevated temperature applications such as nuclear reactor structures. North Carolina State University, Raleigh, and the University of Birmingham, U.K., scientists say alloy 709 is exceptionally strong and resistant to damage when exposed to high temperatures for long durations, making it a promising material for use in next-generation nuclear plants. The team developed a new technique that allows them to perform scanning electron microscopy (SEM) in real time while applying extremely high heat and high loads to a material. The method allows scientists to observe

Afsaneh Rabiei and the device she developed to capture SEM images in real time at temperatures up to 1000°C.

BRIEFS

Micromeritics Instrument Corp., Norcross, Ga., a global manufacturer of products for advanced materials characterization, acquired **Freeman Technology,** Tewkesbury, U.K. The technology group specializes in providing instruments for the measurement of powder flow and other behavioral properties of powders. *micromeritics.com.*

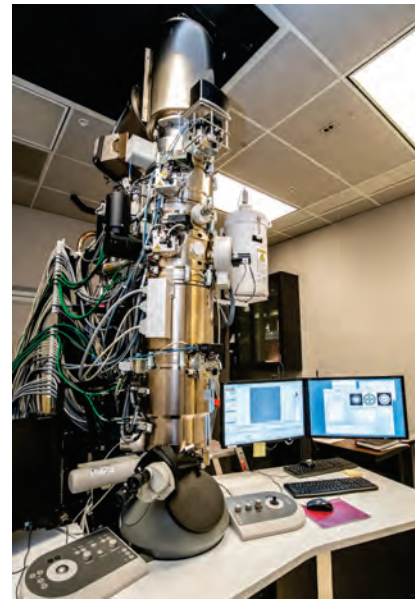
Materion Corp., Mayfield Heights, Ohio, received AS9100D certification from National Quality Assurance (NQA) for its facilities in Elmore and Lorain, Ohio; Elmhurst, Ill.; Reading, Pa.; and Warren, Mich. The AS9100D standard incorporates the ISO 9001 quality management system and adds additional requirements specific to the aviation, space, and defense industries. *materion.com.*

crack growth, damage nucleation, and microstructural changes in any material during thermomechanical testing. With this increased visibility, the team found that alloy 709 outperformed 316 stainless steel at all temperatures. The next step is to assess how alloy 709 will perform at high temperatures when exposed to cyclical loading. *ncsu.edu, www.birmingham.ac.uk.*

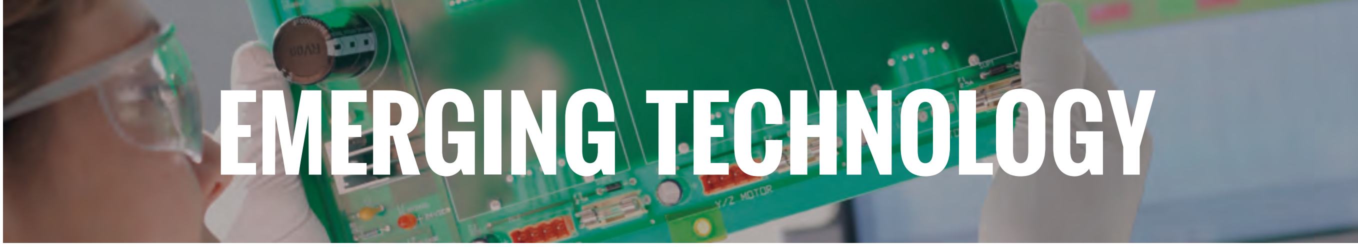
NEW ATOMIC-SCALE IMAGING TOOL

Researchers at the DOE's Lawrence Berkeley National Laboratory, Calif., now have access to a new microscope that combines atomic-scale imaging capabilities with the ability to observe real-world sample properties and behavior in real time. Housed at Berkeley Lab's Molecular Foundry, the instrument is a high-stability, high-resolution Thermo Fisher ThemIS transmission electron microscope (TEM). The *IS* in its name means it is customized for in situ experiments. The microscope will provide unprecedented insight into fundamental atomic-scale material transformations that occur at solid-liquid interfaces, essential for making advances in battery and desalination technologies, for example.

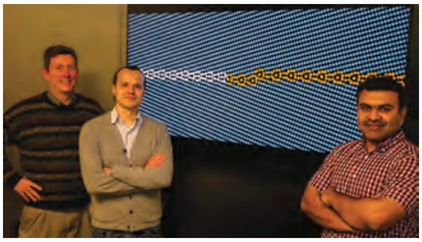
Previously, in situ transmission electron microscopy was limited by the speed and resolution of the microscope. With the advanced TEM and newly developed technologies, scientists are able to image chemical reactions and study materials dynamics in liquids with a resolution that was previously impossible. In situ TEMs use special sample holders that allow researchers to observe the physical behavior of materials in response to external stimuli such as temperature, environment, stress, and applied fields. By studying samples in liquids or gases using these holders, researchers can observe the atomic-scale details of nanoparticles and how they undergo changes in their reactive environments. This capability not only provides a deeper understanding of chemical reactions, but also allows for the study of a wider variety of nanoparticle systems where reaction pathways are still unknown. *foundry.lbl.gov.*



High stability, high resolution ThemIS TEM. Courtesy of Marilyn Chung/LBNL.



EMERGING TECHNOLOGY



From left, Robert Rudd, Timofey Frolov, and Amit Samanta pose with a simulation of material crystallites separated by grain boundaries.

MACHINE LEARNING PREDICTS MATERIAL PROPERTIES

Researchers at Lawrence Livermore National Laboratory (LLNL), the University of Nevada–Las Vegas, Stony Brook University, and UC Davis devised a method capable of combing through the vast space and potential arrangements of atoms in grain boundaries and predicting how they will interact under certain conditions. Scientists say the new technique, based on evolutionary algorithms and machine learning, finally provides a way to predict material properties and could lead to major breakthroughs in developing materials with greater strength, more heat resistance, or higher conductivity.

"What we developed is the first-of-its-kind computational tool that effectively samples possible structures of grain boundaries and finds low-energy structures as well as important metastable states," says principal investigator Timofey Frolov of LLNL. "What's surprising and shocking is that we thought we understood the structures of boundaries, but we don't. Basically, we start from scratch now because many boundaries we look at have a different structure from what we previously thought."

The work could have a significant impact on designing materials for a broad range of energy applications including solid state fuel cells, thermoelectrics, oxygen sensors, optical fibers, switches, laser amplifiers, and lenses, say scientists. Researchers created and characterized the new model using copper and successfully demonstrated and tested it with silicon, tungsten, and other materials. The method is already being implemented within LLNL's fusion energy program. *llnl.gov.*

NEW SUPERHARD MATERIAL DEBUTS

An international team of scientists at the Moscow Institute of Physics and Technology (MIPT) has predicted a new superhard material that can be used in drilling, machine building, and other applications. The team reports that the new tungsten boride they discovered outperforms the widely used *pobedit,* a hard tungsten carbide and cobalt composite material with artificial diamond interspersed. The researchers at MIPT, in collaboration with scientists from the Skolkovo Institute of Science and Technology (Skoltech), Moscow, used their USPEX evolutionary algorithm to predict the new material, WB5, which can be synthesized at normal pressure. They say that WB5 can successfully compete with pobedit in the two most essential parameters—hardness and fracture toughness—which are 50% higher and 20% lower, respectively. *www.mipt.ru.en.*

NEW NANOLASERS MIMIC CHAMELEONS

A research team at Northwestern University, Evanston, Ill., developed a novel nanolaser that changes colors using the same mechanism as chameleons. The work could enable advances in flexible optical displays in smartphones and televisions, wearable photonic devices, and ultrasensitive sensors that measure strain. In the same way a chameleon controls the spacing of nanocrystals on its skin, the new laser exploits periodic arrays of metal nanoparticles on a stretchable polymer matrix. As the matrix either stretches to pull the nanoparticles farther apart or contracts to push them closer together, the wavelength emitted from the laser changes, which also transforms its color. The resulting laser is robust, tunable, reversible, and has a high sensitivity to strain—critical properties for applications in responsive optical displays. *northwestern.edu.*

A new nanolaser employs the same color-changing mechanism that a chameleon uses to camouflage its skin.

BRIEF

In June, the DOE's **Oak Ridge National Laboratory,** Tenn., debuted Summit as the world's smartest and most powerful scientific supercomputer. With a peak performance of 200,000 trillion calculations per second (200 petaflops), Summit will be eight times more powerful than America's current top-ranked system, Titan, also housed at ORNL. *energy.gov.*

3D PRINTSHOP

Assistant professor Emre Gunduz uses ultrasonic vibrations to maintain a flow of material through the printer nozzle. Courtesy of Purdue University/Jared Pike.

ROCKET SCIENCE CALLS FOR COOKIE DOUGH

New research at Purdue University is making it possible to 3D print extremely viscous materials with the consistency of clay or cookie dough. By applying high-amplitude ultrasonic vibrations to the nozzle of the 3D printer, engineers were able to solve a problem that has plagued manufacturers for years. While other approaches involve changing the material composition, the Purdue team used a vastly different method. By vibrating the nozzle in a specific way, they reduced the friction on the nozzle walls, allowing the material to slide through. The team has printed items with 100-μm precision—better than most consumer-grade 3D printers—while maintaining high print rates. Solid rocket fuel is now being explored as the first practical application. *purdue.edu.*

MIT PRINTS MAGNETICALLY ACTIVATED STRUCTURES

Engineers at the Massachusetts Institute of Technology (MIT) recently designed and built soft, 3D-printed structures whose activities can be orchestrated with a magnet. The collection includes a smooth ring that wrinkles up, a long tube that squeezes shut, a sheet that folds itself, and a spider-like grabber that can crawl, roll, jump, and snap together fast enough to catch a ball.

MIT researchers built structures from a new type of 3D-printable ink infused with tiny magnetic particles.

Researchers fabricated each design from a new type of 3D-printable ink infused with tiny magnetic particles. They fitted an electromagnet around the nozzle of a 3D printer, causing magnetic particles to swing into a single orientation as ink is fed through. By controlling the magnetic orientation of individual sections in the structure, researchers can make devices that quickly shift into intricate shapes and move around. Professor Xuanhe Zhao says the technique could be used to fabricate magnetically controlled biomedical devices.

"For example, we could put a structure around a blood vessel to control the pumping of blood, or use a magnet to guide a device through the GI tract to take images, extract tissue samples, clear a blockage, or deliver drugs to a specific location," says Zhao. "You can design, simulate, and then just print to achieve various functions." *mit.edu.*

BACK TO SCHOOL WITH GE PRINTER PACKS

The GE Additive Education Program (AEP) recently awarded polymer 3D printing packages focused on science, technology, engineering, art, and mathematics (STEAM) to more than 600 schools. Tailored to students in grades K-12, the goal is to build an understanding of 3D printing by networking students, machines, and content via an online platform called the Polar Cloud. The AEP has also donated more than 1000 polymer 3D printers to schools in 30 countries over the past two years, impacting more than 400,000 students. Packages include a Polar Cloud account, Dremel Digilab 3D45 polymer printer, six rolls of replacement filament, and lesson plans. *ge.com.*

STEAM students benefit from GE's Additive Education Program. Courtesy of Syda Productions/Shutterstock.com.

Automotive Aluminum

—Part 3

European Developments Continue

In the early 1950s, European carmakers continued to face the necessity of **stringent fuel economy targets** that their American counterparts would only confront **20 years later.**

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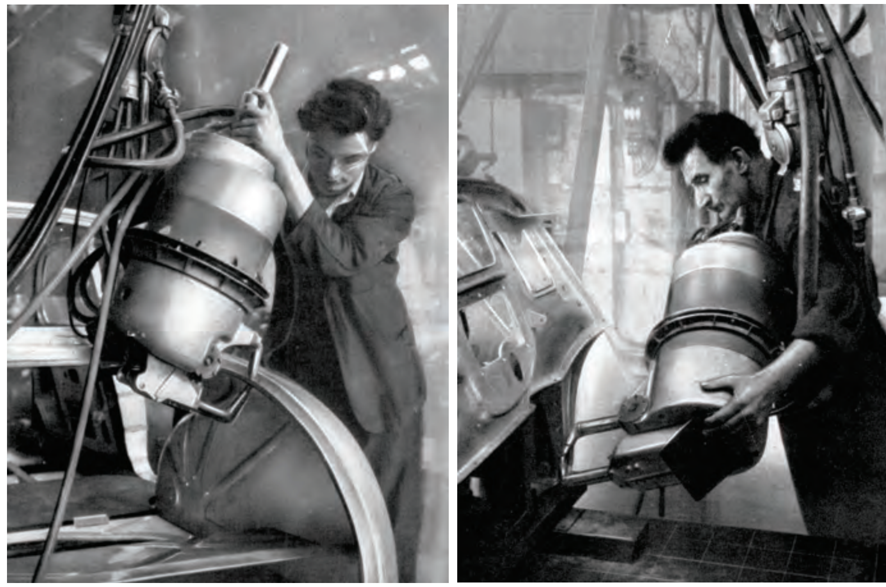
Not only was fuel expensive in Europe during the 1950s, it was imported from a Middle East seeking greater political independence from former colonial rulers. A decade after the end of WWII, the European economies had finally started growing and people were beginning to look beyond a mass market of small cars with small engines and sluggish performance. The question was how to satisfy a growing desire for larger and more comfortable cars without bigger engines and lower fuel efficiency.

Nowhere was this more apparent than France: By the end of 1950, Panhard's Dyna X was getting old in a market that was changing rapidly. It was viewed as a small and quirky little car, out of style and in need of a modern successor. The Dyna X was a mixed metal car with aluminum skins over a frame made of several large aluminum castings supported by a steel underbody. It did not have a decklid, so the trunk space was reached from the inside by pivoting the back of the rear bench. At a board meeting on December 29, 1950, Panhard decided on a thoroughly revolutionary concept for a new model that would feature all-aluminum stamped construction.

DYNA Z DEVELOPMENT

The Dyna Z was to be spacious and aerodynamically efficient, with engaging driving dynamics and excellent fuel efficiency. By keeping the car as light as possible, Panhard could carry over the proven air-cooled two-cylinder engine and running gear, thus holding the budget within their limited investment capabilities. The press introduction was slated for mid-June of 1953 with a launch date in October at the Paris Motor Show. The engineering and manufacturing teams had 30 months to design, prototype, test, tool, and launch a completely new body and related closures.

As for the Dyna X, a Tier 1 supplier would deliver the completed body in white (BIW) with doors-on to Panhard for paint and final assembly. But this time, Chausson was responsible not only for the stamping tools, but for the production of the stampings and the body assembly as well. The assembly was done using new resistance spot welding (RSW) equipment developed by Sciaky and Languepin capable of 100 welds per minute. Careful optimization reduced the number of spot welds to about 3000 per car.



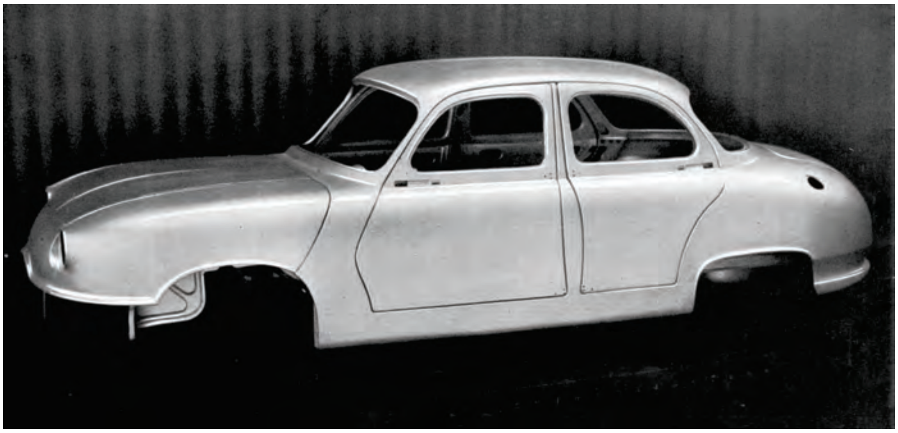
Single phase portable spot welders.

Péchiney, as L'Aluminium français was now called, provided A-G5, a new alloy with 5% magnesium. A-G5 was a stronger yet more formable alloy for the underbody and other inner parts that were difficult to form. The other parts, including the skins, used alloy A-G3 (3% magnesium). Once again, developing and launching the stamping tools proved to be the most difficult aspect of the project.

The experience gained with the previous model helped as did the new and improved formability alloys, but there was nothing the aluminum supplier could do to tame springback. In the early 1950s, there were no resources and little prior art or lessons learned to guide diemakers in their fight against springback. High-strength steels were still in the future, so the diemakers were truly blazing a new trail.

Higher strengths and more complex parts conspired against toolmakers accustomed to mild steel, resulting in multiple tool face recuts. Chausson would struggle for months to achieve acceptable fit and finish. Getting the newly developed high-speed portable spot weld guns to work took time. When the car finally appeared in public for the first time at the Paris Motor Show, Panhard had only completed nine cars. Two had been available for test drives by the motoring press, three were in use for final testing and development, and all four displayed at the show were not drivable.

The bright spot was the glowing reviews: The new car was an impossible combination of performance, efficiency, comfort, and roominess, with styling to boot. This was in part due to the incredible aluminum design, with a BIW and bumpers weighing less than 120 kg (265 lb). The six-passenger car had a wheelbase of 2570 mm (101.2 in.), an overall length of 4570 mm (180 in.), a width of 1668 mm (66 in.), and a height of 1430 mm (56.3 in.), similar to a 2005 Honda Civic. Its aerodynamic design provided stable behavior in crosswinds and enabled 130 km/h (81 mph) with an 850-cc engine developing 42 HP. The combination of advanced body engineering and aluminum resulted in a dry weight of only 710 kg (1565 lb), a weight savings of more than 25% compared to period competitors of the same size. Lower weight, superior aerodynamics, and an efficient powertrain combined to yield a fuel consumption equivalent to much smaller and slower cars.



1954 Dyna Z full aluminum body.

Panhard had a winner on its hands if they could only succeed in getting it into series production. However, by the end of 1954, one year into production, Chausson and Panhard were still struggling with unacceptable productivity. Ill-fitting parts and repeatedly fouling weld tips conspired against achieving reliable spot welds, causing repairs and low production yields.

Lüders bands on the deeply shaped outer skins showed through paints, so the bodies required significant surface finishing. To make matters worse, the planners at Panhard had made a crucial mistake: Aluminum buying assumptions were based on part weights, not blank weights, so the invoices from Chausson were double what the company had been expecting. It also meant that no one had taken into consideration the resale of stamping scrap as an offset for the material cost.

Panhard conducted a quick study comparing the weight and cost of the aluminum body to a steel version. The aluminum body weighed 117.5 kg (259 lb), at a cost of French francs (FF) 55,719 (about $159 in 1954 or $1500 today), while a steel equivalent would weigh 239.9 kg (528.9 lb), but cost only FF 15,578 (about $45 in 1954 or $420 today).

CITROËN BUYS PANHARD

1954 was also the year of Dien Bien Phu, the French military catastrophe in Indochina, and the company was struggling with its military vehicles division, where an expensive contract for the French Army had been slashed. Bankruptcy loomed. Panhard first sought an alliance with Ford, but no deal could be worked out. The government intervened and prodded Citroën, then owned by tire maker Michelin, to step in. On April 6, 1955, Panhard ceased to exist as an independent company, and its progressive absorption into Citroën started. By September 1955, after two years of production and 25,580 all-aluminum vehicles, the BIW was converted to steel; the closures would go by the next model year. The 1957 Dyna Z was all steel, lighter than its competitors by virtue of its advanced body engineering and powertrain, but no longer as quick or nimble as it had been.

Citroën had come to Panhard's rescue not out of kindness, but out of cold necessity. Its small model, the iconic 2CV, was France's best seller and sales were constrained by a lack of capacity. Citroën was simultaneously in the process of launching the radical replacement for its venerable Traction Avant, itself in production for more than 20 years. The DS is remembered for its many radical innovations and avant-garde styling, but few realize its significance for aluminum auto body sheet. Citroën had decided on an aluminum hood and decklid, as well as an aluminum or fiberglass roof depending on the trim option. The aluminum decklid remained in production through 1957 and was then replaced by steel. Several other bolt-on parts were also to be stamped in aluminum. They selected Péchiney as the supplier, who offered the same alloy used on the Dyna Z, A-G3.

A-G3, like all similar 5xxx alloys, had significant shortcomings. First, it was subject to Lüders bands after stamping, resulting in unacceptable surface quality and heavy metal finishing. Second, it had to be delivered in "O" temper to provide the necessary formability. As such, it offered only modest strength on the order of 90-100 MPa or roughly two-thirds the strength of mild steel, necessitating serious up-gauging to maintain denting performance.

Both problems had beset Panhard since the beginning, but they were a small carmaker and did not hold much sway with metal suppliers. Also, as a

Body in whites and closures delivered by Chausson.

former low volume luxury automaker, they were probably accustomed to heavy metal finishing. The low strength was a problem that Panhard had acknowledged and by keeping the outer panels to 1.2-mm thickness, they knowingly accepted inferior dent resistance in pursuit of maximum weight savings. In fact, Jean Panhard admitted years later that he could dent the outer panels with a finger and that customers complained about the problem. Citroën, on the other hand, was the leading French car producer at the time and they would accept neither situation. The lack of strength could be countered by increasing the panel thickness to 1.5 mm, but that added cost and weight. After a few acrimonious meetings, the automaker prevailed over its metal supplier who scrambled for a suitable alternative.

The pressure from Citroën precluded lengthy alloy development, thus Péchiney could only look into their existing portfolio. One could raise the magnesium content of a 5xxx alloy to increase strength, but this also increased the potential for Lüders bands, eliminating A-G5 as an option. Péchiney had unsuccessfully experimented with some 6xxx sheet alloys in the mid 1930s, so the only remaining avenue was a 2xxx alloy that had been used experimentally with Panhard at the time of the Dyna X. The alloy was A-U2G (2% Cu, 0.3% Mg, 0.1% Si).

ALLOY DEVELOPMENT CONTINUES

A-U2G was a derivative of 2117 (see Table 1), a common aircraft alloy, and had been used for cargo containers under the name of Avional 21. As an automotive alloy, it was still an experimental solution because 2xxx alloys had a history of corrosion susceptibility. Further, as an alloy capable of precipitation hardening, its natural aging response needed to be studied. Péchiney had started a development program with Panhard in 1949 with lab corrosion testing and aging characterization. They had also made a number of prototype parts that remained subject to static weather exposure on the Atlantic Coast. Despite lab characterizations that revealed no insurmountable difficulties, Panhard elected to continue with A-G3 for the Dyna Z. Thus, more than five years into testing without any significant issues and their backs to the wall, Péchiney offered A-U2G to Citroën, who promptly adopted it. A-U2G was almost twice as strong as A-G3, so Citroën was immediately able to downgauge to 1.2 mm. However, with a yield strength of 180 Mpa, A-U2G must have proven quite a challenge for the diemakers. Nonetheless, the parts made it into production and the hood would remain for the totality of the production run of over 1.5 million units.

These aluminum parts signaled the first departure from 5xxx alloys for a modern aluminum automotive skin. For Péchiney, they marked the beginning of an active market development program focused on the automotive sector, more than a decade earlier than its American counterparts. A-U2G ended up on the hood and other parts of the Citroën SM, the Rover 2000 and 2600, and all the closures at Rolls-Royce.

LAND ROVER SUCCESS

Across the Channel, the Land Rover had turned into a major commercial success. By 1954, the base model's wheelbase had increased to 86 in. (2184 mm) and a new 107 in. (2718 mm) wheelbase model was introduced. Sales were coming close to 30,000 units per year. No longer a stopgap measure, it had evolved into its own product line. Series II would enter production in 1958, retaining the 5xxx alloy sheets.

Citroën DS makes a splash at the 1955 Paris Motor Show, with 12,000 orders taken on the first day.

The Land Rover success prompted the company to look into a larger, more upscale model. The first attempt took place as early as 1951, but the project fizzled and the idea would lie dormant for 15 years. In 1966, the success of the Jeep Wagoneer in the U.S. rekindled interest in a more refined 4x4. By 1969, the Range Rover design was finalized and 26 development prototypes were built. To keep weight in check, it sported aluminum skins for the front and rear fenders, leaf screen, door outers, roof, and upper rear quarter panels. Rover had not experienced Lüders bands with the flat panels of the Land Rover and so it carried over the alloy selection. The Range Rover launched on June 17, 1970.

It would soon become another automotive icon, but the selection of a 5xxx alloy for stamped skins would now reveal its limitations, burdening the company with additional metal finishing for its 25-year production run. These challenges would also trigger the search for different suppliers and alloys

1978 Range Rover Classic.

TABLE 1 – GENEALOGY OF 2XXX SHEET ALLOYS

Alloy	Si	Fe	Cu	Mn	Mg	Year
Duralumin			3.5-4.5	0.25-1.0	~0.5	1911
2017	0.2-0.8	0.7	3.5-4.5	0.4-1.0	0.4-0.8	1916
2117	0.8	0.7	2.2-3.0	0.2	0.2-0.5	1921
A-U2G	0.1-0.2	0.4-0.5	2.2-2.5	0.2	0.3-0.4	1950s
2036	0.5	0.5	2.2-3.0	0.1-0.4	0.3-0.6	1970

for the company's next model, the Land Rover Discovery.

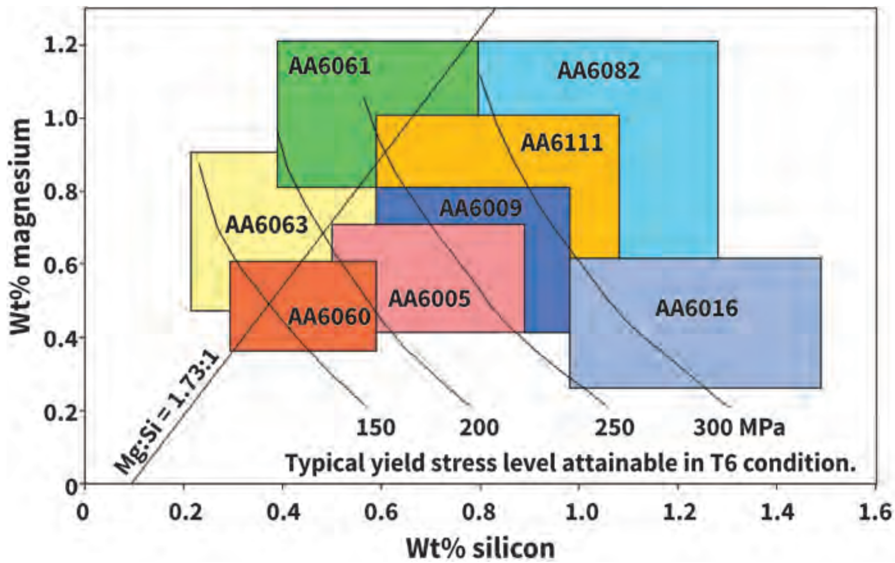
PORSCHE MAKES PROGRESS

It would be left to Porsche and Alusuisse to take the next step in auto body sheet alloy development. In the early 1970s, Porsche was looking to replace the 911 with a more sophisticated Grand Touring vehicle, the 928. It was wider, longer, and had a front engine/rear drive layout with a V8 engine. To keep weight down, the design specified aluminum for the hood, fenders, and doors; the parts would be produced by Läpple using aluminum sheet supplied by Alusingen, part of Alusuisse. Porsche and Läpple quickly realized that 5xxx alloy sheet would be unsuitable for the skins. The result of their development work with Alusingen was an alloy that would be later marketed as Ac-120 and registered as alloy 6016.

Anticorodal 120 or Ac-120 (1.2% Si, 0.4% Mg) was originally developed as a food container sheet alloy to replace higher Mg 5xxx alloys considered hard to roll on their existing equipment. Anticorodal was the trade name given to Alusuisse 6xxx alloys due to their good corrosion resistance compared to existing 2xxx heat-treatable alloys. The original concept was to use a continuous heat treatment to increase strength prior to cold working to the required can stock temper. For automotive use, they decided to stamp the parts in the more formable T4 temper and take advantage of the new E-coat ovens as a no-cost-added heat treat process. Ac-120 was different from other 6xxx alloys of the time because it was lower in Mg and high in Si. The high Si/Mg ratio resulted in several advantages in mechanical properties and formability.

Compared to 2xxx alloys such as A-U2G and 2036, 6016 offered similar strength after paint, but with lower incoming strength and therefore much more manageable springback (Table 2).

The 6016 alloy also had a low degree of natural age hardening at room temperature but offered an increase in strength after forming and bake hardening comparable to other 6xxx alloys. Due to the introduction of E-coat,



Chemical composition of various 6xxx alloys.

TABLE 2 – MECHANICAL PROPERTIES OF EARLY ALUMINUM AUTO BODY SHEET ALLOYS

Alloy	Yield strength, MPa (as received)	Tensile strength, MPa	Work hardening exponent, n	Total elongation, %
A-U2G-T4	179	276	0.25	27
2036-T4	186	325	0.22	25
6009-T4	131	234	0.23	24
6010-T4	186	296	0.22	23
6016-T4	127	235	0.26	28

Porsche had a ready-made hardening oven in its paint system. This allowed an alloy like 6016 to be delivered as a relatively low strength alloy in T4 temper, offering good formability and manageable springback. After the E-coat bake and resultant hardening, the alloy achieved comparable strength levels to the mild steel sheet used at the time.

Another special feature of 6016 is its low Cu level. While Cu is known to increase post-paint bake strength, it is generally not beneficial for corrosion resistance. Structural alloys in Europe ranging from 6060 to 6082 had always been Cu-free, so there was no intentional addition to alloy 6016. The combination of good stretch formability and hemming capability combined with adequate strength after paint bake would make 6016 the favorite body skin alloy in Europe for the next 25 years and spawn numerous variants by multiple suppliers worldwide since then.

The use of Ac-120 was not the only first for sheet aluminum on the Porsche 928. The door inners were the first European automotive use of yet another food container alloy, 5182 (4.5% Mg, 0.3% Mn). This alloy was registered by

Ferry Porsche and the 928 at the 1977 Geneva Motor Show.

Alcoa in 1967 for use in beverage can lids. As an automotive alloy, it remains the highest formability alloy available and is used for difficult and complex inner closure parts such as door inners and liftgate inners. However, its high Mg content can make it susceptible to stress corrosion cracking under certain conditions, so it is not typically used for structural applications.

Looking at the narrow hood of the 928, one can only wonder if this is not one of those rare instances in which manufacturing considerations trumped engineering and design: Alusingen's line was narrow and there was a hulking V8 under that hood. Servicing the engine surely would have been easier with cut lines similar to the earlier 914.

The aftermath of the Yom Kippur War briefly delayed the program development, and it was only on March 17, 1977, that Ferry Porsche introduced the 928 at the Geneva Motor Show. Few would have predicted that it heralded the start of a new era in aluminum auto body sheet with the European launch of two alloys still in use today. Alusuisse applied for a patent for the production method behind Ac-120 on March 31 of the same year. Interestingly, it does not mention automotive applications, only cans. Its registration as alloy 6016 would have to wait until 1984. **~AM&P**

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USING PHYSICAL VAPOR DEPOSITION TO OPTIMIZE SURFACE PROPERTIES

Thin film cathodic arc PVD coatings offer an easy and economical way to optimize surface properties without changing bulk performance.

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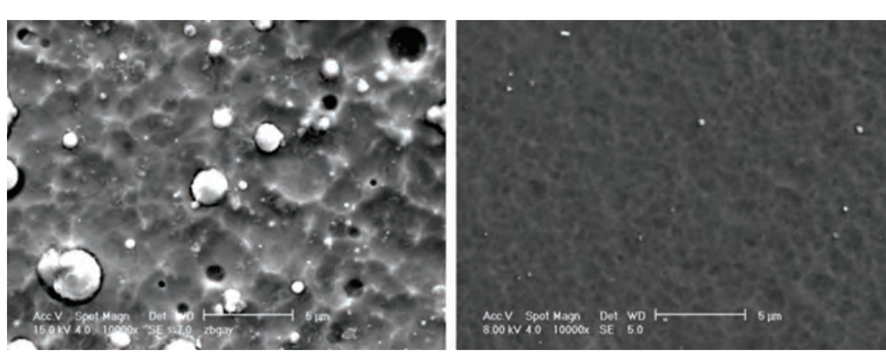
Many engineering components require surface properties that are significantly different than bulk material properties. For example, superior wear resistance might be required on the surface, while the bulk material might call for easy machinability. Often, both properties are not attainable in one material, necessitating a compromise of specifying a material with only moderate wear resistance and moderate machinability to make the component. Surface engineering technologies, however, allow the properties and performance of a component's surface to be modified and controlled independent of its bulk. There are a number of different surface engineering technologies available, including weld overlay, surface hardening, and hard coatings, but physical vapor deposition (PVD) offers a straightforward and inexpensive approach to optimize surface properties without changing bulk performance.

PVD SPECIFICS

Physical vapor deposition involves vaporizing atoms from a solid source and transporting and depositing them onto a substrate. PVD can produce different categories of coatings including single elements such as titanium and diamond-like carbon (DLC), alloys (e.g., Al-Cr), and compounds (e.g., CrN and TiC). The most commonly used PVD coatings are metal nitrides such as CrN, TiAlN, and AlCrN, which are produced by admitting low-pressure nitrogen gas into the PVD chamber. This enables vaporized metallic atoms to react with the nitrogen gas during deposition on the substrate. Typically, PVD coating processes are performed at temperatures below 600°C, which enables depositing the coating onto a fully hardened steel without compromising the hardness of the steel substrate through over-tempering. PVD coatings are typically 1 to 6 µm thick.

Cathodic arc evaporation (CAE), a commonly used PVD process, involves evaporation and ionization of atoms from the target (source) material through the use of a high current-density arc. CAE produces high density coatings with extremely high adhesion and cohesion. However, one drawback of CAE is ejection of relatively large macroparticles (about 2 to 10 µm diameter) from the target material, which can become incorporated into the coating (Fig. 1a). Macroparticles form when unwanted droplets of liquid metal splash from the arc source and land on the substrate during coating growth. As the size of these macroparticles is similar to the PVD coating thickness, and because they are poorly adhered to the substrate, they negatively impact the coating's integrity, performance, and overall life.

This article describes a modified cathodic arc process called arc plasma acceleration (APA), which enables production of high density, thin film coatings containing minimal macroparticles.



(a) (b)

Fig. 1 — (a) CrN coating produced using conventional cathodic arc evaporation (CAE) process contains detrimental metallic Cr macroparticle inclusions (white) and dark pores of various sizes; (b) CrN coating produced using the arc plasma acceleration process is essentially free of macroparticles.

ARC PLASMA ACCELERATION

The APA technique is a modified cathodic arc vapor deposition process patented by Phygen Coatings Inc.[1] The process uses a magnetic field generator to create a field with a distinctive cusp shape, which provides enhanced trapping of plasma particles generated from the cathodic source. The contoured field creates an electron trap with an aperture through which plasma ions are directed at the substrate; the plasma deposition rate is higher per unit of magnetic field strength than can be obtained with conventional designs. The APA process enables control over coating growth, both via the intensity of ion bombardment (through plasma density control) and the energy of arriving particles (through the substrate bias potential). It is necessary to ensure that a large number of ions bombard the surface with a velocity in a specific range, and by tuning that range, crystalline configurations with weaker bonding can be minimized while preserving the strongest bonds. This phenomenon results in growth of a dense, highly textured coating with an excellent metallurgical bond to the substrate (Fig. 2).

Another benefit of the APA approach for producing CAE coatings is that the volume fraction of macroparticles within the coating is significantly reduced (Fig. 1b), and both average macroparticle size and volume fraction are significantly reduced compared with conventional CAE techniques. Decreasing the volume fraction of macroparticle defects within a coating can improve performance and significantly extend coating life.

Typical properties of CrN and AlCrN coatings produced using the APA process are listed in Table 1. The APA process is also used to produce CrN-DLC and CrN-SiC bilayer coatings (Fig. 3). Properties of CrN-DLC and CrN-SiC bilayer coatings are listed in Table 1 as well.

COATING PERFORMANCE

PVD coatings are used in many applications where surface performance is crucial. As noted previously, one of the main benefits of thin film coatings is the ability to modify surface behavior independent of bulk performance. This is illustrated in several examples using both single-layer and bilayer coatings produced by the APA process.

Corrosion protection. For many applications, PVD coatings cannot provide

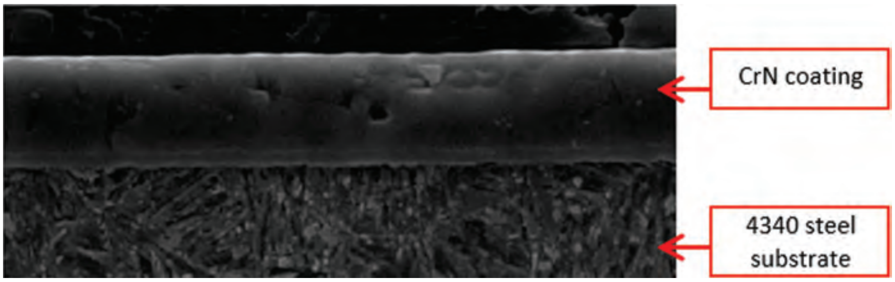


Fig. 2 — Coatings produced using the arc plasma acceleration method are dense and free of defects as illustrated in this cross section of a 3-μm thick CrN coating deposited on an AISI 4340 alloy steel substrate.

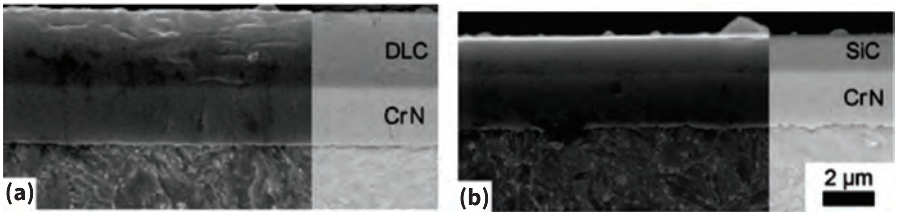


Fig. 3 — SEM micrographs showing cross sections through bilayer PVD coatings deposited onto AISI 4340 alloy steel substrates using the arc plasma-acceleration process. In (a), CrN-DLC coating; (b) CrN-SiC coating (in each image, the left-hand side is viewed using secondary electrons, while the right-hand side is viewed in electron-backscattered mode).

TABLE 1 – PROPERTIES OF ARC PLASMA ACCELERATION COATINGS

Coating compound (product name)	Typical coating thickness, μm	Nanoindentation hardness, GPa	Maximum operating temperature (based on oxidation resistance), °C	Adhesion strength (by scratch test) Critical load, N
CrN (FortiPhy)	3-6	22-26	800-850	110-120
CrN(a) (FortiPhy Plus)	3-6	23-27	825-875	112-135
AlCrN (CertiPhy)	3-6	31-35	~950	115-130
AlCrN(a) (CertiPhy Plus)	3-6	31-35	~950	115-130
CrN-DLC	~2 each layer	23	~350	80-105
CrN-SiC	~2 each layer	30	>600	89-90

(a) Duplex coating where substrate material is plasma ion nitride prior to coating for improved mechanical support.

adequate corrosion protection due to the presence of defects within the coatings, such as macroparticles, pits, and flakes. These defects originate during the deposition process along with a columnar growth structure that often is not entirely dense. However, the U.S. Army Armament Research, Development and Engineering Center at Benet Laboratories[2] recently evaluated the corrosion protection of steel substrates by several coatings produced using the APA process. Tests were performed in accordance with the GM9540P specification[3] involving 30 cycles of 16-hour exposure to chloride solutions at 50°C. Results show that a CrN coating and a CrN-SiC bilayer coating exhibit significantly better corrosion resistance than an electroplated chromium coating (12 and 40 μm thick), and equivalent corrosion resistance to a 40-μm thick electroless high-phosphorous nickel plate. Figure 4 shows the surface of the PVD CrN coating following accelerated corrosion testing, which exhibited a significantly smaller amount of corrosion than steel substrates with electroplated chromium coatings.

The excellent corrosion protection of APA CrN and CrN-SiC coatings is attributed to their lower concentration of defects[2] and dense structure. For example, APA coatings were found to contain a macroparticle density of 3.5 x 10^3/mm^3, which is four to eight times lower than values typically found in coatings produced using conventional cathodic arc processes[2]. In addition, the macroparticles were significantly smaller; average and maximum particle sizes were 0.67 and 4.2 μm, respectively, two to 16 times smaller than particles within coatings made using conventional cathodic arc processes[2].

Applications requiring solid lubricants. Coefficient of friction (CoF) measurements were performed at Benet Labs on several APA coatings by sliding coatings against 6-mm alumina balls at room temperature using a ball-on-disk tribometer[2]. Results shown in Table 2 reveal that two bilayer coatings (CrN-DLC and CrN-SiC) have lower CoF values than single-layer CrN PVD coatings, electroless Ni-P, and electroplated Cr coatings. The bilayer coatings are suitable in applications requiring solid lubricants[2].

Wear resistance. PVD coatings have excellent wear resistance due to their high as-deposited hardness. Table 3 shows wear rates from ball-on-disk tribometer tests of the three PVD coatings produced using the APA process, conventional Ni-P and Cr coatings, and bare AISI 4340 alloy steel substrate. The PVD coatings have significantly lower wear rates.

Metal forming and casting tools. PVD coatings are also commonly applied to metal forming and casting tools, such as stamping tools and core pins used in die casting. A driveshaft housing produced at Mercury Castings, Fond du Lac, Wis., provides an example of the benefits of using PVD coatings[4]. Casting production involves the use of several long cores, and when using uncoated H13 tool steel cores, the aluminum die casting alloy rapidly solders to the steel core (Fig. 5), creating high loads during casting ejection, which causes the entire housing to bend. Applying a 5-μm AlCrN coating using the APA process to the core eliminates soldering (Fig. 5), avoids bending the casting during core pull, and eliminates the need for 100% inspection of the castings.

Recent research has taken the concept of coatings on forming and casting tools even further, with the goal of eliminating the need to lubricate dies used to produce die castings. During die casting, a water based organic lubricant is applied to the hot faces of the steel casting die prior to each shot to prevent the aluminum castings from soldering (sticking) to the die. However, a number of undesirable outcomes can arise from applying these lubricants, including lower casting quality (higher residual porosity), shorter die life, and effluents that need to be disposed of.

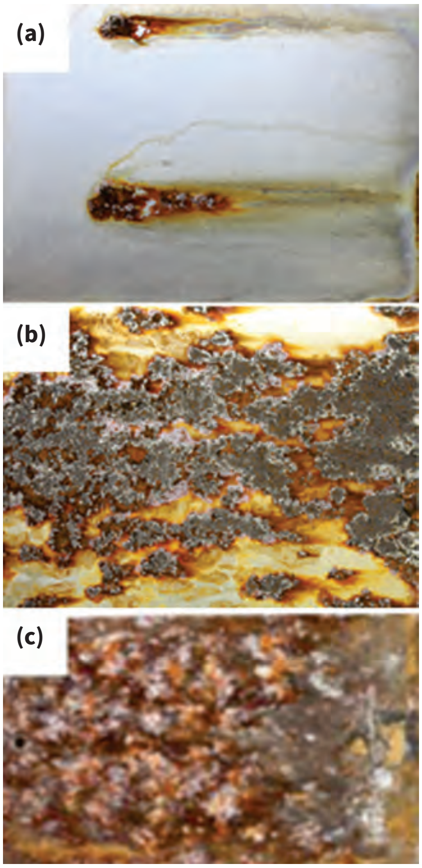


Fig. 4 — Surface of samples following accelerated corrosion tests consisting of 30 cycles of 16 h exposure to chloride solutions at 50°C in accordance with specification GM9540P[2]: (a) APA CrN coating, (b) 40-μm thick electroplated Cr coating, and (c) 12-μm thick electroplated Cr coating.

TABLE 2 – STEADY-STATE COEFFICIENT OF FRICTION FOR SELECT COATINGS[2]

Coating	Average steady-state coefficient of friction
CrN-DLC	0.07 ± 0.01
CrN-SiC	0.07 ± 0.01
CrN	0.28 ± 0.02
Ni-P	0.23 ± 0.02
Cr	0.55 ± 0.09

TABLE 3 – WEAR RATES OF SELECT COATINGS[2]

Coating	Wear rate, mm^3/N m
CrN	5.30×10^{-7}
CrN-DLC	7.32×10^{-7}
CrN-SiC	7.90×10^{-7}
Ni-P	25.5×10^{-7}
Cr	263×10^{-7}
Uncoated AISI 4340 alloy steel	556×10^{-7}

Fig. 5 — Steel slide inserts used in the production of a die cast driveshaft housing after 1256 shots[4]. The upper core with a 5-µm thick AlCrN coating shows no soldering, while the lower uncoated insert shows soldering.

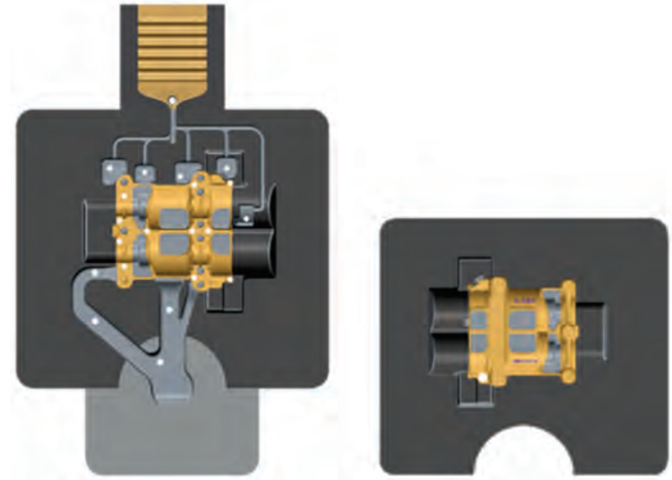


Fig. 6 — 3D models of die cast balance shaft housing die: (left) ejector side and (right) cover side. An AlCrN coating applied to the entire die reduced the need for lubricant and improved both production cycle time and die casting quality.

The research objective was to identify permanent PVD thin film coatings that could be applied to the hot faces of the die and eliminate the need for conventional lubrication. Following extensive laboratory testing at the Colorado School of Mines[5], an AlCrN coating was selected and applied to the entire die used to produce balance shaft housings. As illustrated in Fig. 6, all surfaces of the steel die contacted by the liquid aluminum were coated, including the shot block, runners, cavity insert and chill vent on the ejector side of the die, and the runners, cavity insert, and chill block (not shown) on the cover side of the die.

Plant trials demonstrate that the AlCrN coating enables a reduction of about 85% in the use of conventional organic lubricant, improves cycle time by about 12%, and improves the internal quality of the die castings. The coating is also expected to extend the life of the casting tool. To date, roughly 20,000 castings have been produced using the AlCrN coated tool, so details of extended die life are not yet available[5].

SUMMARY

Thin film cathodic arc PVD coatings have excellent commercial potential for a number of markets, as they enable surface properties to be modified and optimized independent of the material's bulk performance. However, many cathodic arc processes suffer from the presence of defects within the coating thickness, limiting commercial application. The arc plasma acceleration process reduces the size and number of macroparticles and other defects in the coating. This process should open up new applications and markets for PVD coatings, including corrosion protection, wear resistance, reduction of die lubrication, and life extension of forming tools. **~AM&P**

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ISTFA/2018

FAILURES WORTH ANALYZING

44TH INTERNATIONAL SYMPOSIUM FOR TESTING AND FAILURE ANALYSIS

OCTOBER 28 – NOVEMBER 1 2018

PHOENIX CONVENTION CENTER

The 44th International Symposium for Testing and Failure Analysis (ISTFA), the premier conference and exhibition for the microelectronics failure analysis community, will be held October 28 – November 1 in Phoenix. This year's theme—Failures Worth Analyzing—will be evident throughout the five-day event in user group meetings, technical presentations, and on the exhibitor floor amidst the largest display of failure analysis equipment in the industry with live demonstrations of the latest tools and technology. Throughout the conference, attendees will have ample opportunity to engage in networking events, receptions, and social activities each day, including the popular EDFAS video and photo contests.

ISTFA once again opens on a Saturday, offering early arrivers the opportunity to take an immersive half or full-day educational course. This year's all-day tutorial program on Sunday extends the learning process to a wider selection of topics. Technical sessions begin Monday, featuring over 125 presentations of original unpublished work in areas such as organic electronics, sample preparation and device deprocessing, fault isolation, scanning probe analysis, and emerging FA techniques and concepts. In keeping with the theme of failures worth analyzing, ISTFA's keynote session will focus on autonomous vehicle (AV) technology with presentations by two industry experts.

For the first time, ISTFA will co-locate with the International Test Conference (ITC), an IEEE conference dedicated to logic and memory testing of electronic devices, diagnosis, and yield analysis. Joint sessions with ISTFA and ITC highlighting topics such as diagnosis and yield will be offered. Attendees will also benefit from a joint expo floor that represents the largest ever at ISTFA with 30% more companies, technologies, and products to visit and explore.

Organized by: EDFAS Electronic Device Failure Analysis Society ASM INTERNATIONAL · ASM INTERNATIONAL

EDUCATION COURSES

SATURDAY, OCTOBER 27

- Fault Isolation Techniques for Failure Analysis
- EOS/ESD Failure Mechanisms and Design Solutions
- Failure Analysis of Electronic Devices
- Shining a Light on LED Technology: Construction, Reliability, Qualification, Failure Modes
- Beam-Based Defect Localization

For full course descriptions visit **asminternational.org/web/istfa-2018.**

TUTORIALS

SUNDAY, OCTOBER 28

An expanded tutorial program addresses 23 topics, including three new ones:

- EOS/ESD Failure Mechanisms and Design Solutions
- Early Life Failures in Automotive Electronics and Their Root Causes
- Reliability of FIFA Challenges of Medical Device Electronics

SPECIAL CONTESTS

See the winners of the EDFAS Video Contest, as well as the best of the EDFAS Photo Contest by attending the event.

EDFAS GENERAL MEMBERSHIP MEETING AND BREAKFAST

MONDAY, OCTOBER 29
8:00 - 10:00 A.M.

This year, the EDFAS General Membership Meeting moves to Monday morning. Enjoy breakfast while hearing news of the Society and seeing your colleagues honored with awards.

TOOLS OF THE TRADE TOUR

MONDAY, OCTOBER 29

ISTFA attendees will see the latest equipment and tools in action and obtain useful information in a guided tour. Participating organizations include BSET EQ, DC - Digit Concept, Hitachi High Technologies, JIACO Instruments, Keyence Corporation, Mentor, A Siemens Business, Nordson Dage, ULTRA TEC, and ZEISS.

Preregistration required. Limit of 125 attendees.

KEYNOTE SESSION

TUESDAY, OCTOBER 30

Mark Tehranipoor, Intel Charles E. Young Preeminence Endowed Chair Professor in Cybersecurity, University of Florida, will present "Hardware Root-of-Trust for Cyber Security: Uncovering the Role of Test and Failure Analysis in Enabling Cyber Defense."

Mark-Tami Hotta, president of Integrity First Consulting Services LLC, will talk on "Transformation to Automated Driving" including the potential significance, what some of the challenges are likely to be, what the transition period may look like, and how technologies and vehicles may be tested and validated.

ISTFA.ORG

EXHIBIT HOURS

TUESDAY, OCTOBER 30 | 9:30 A.M. – 7:00 P.M.
WEDNESDAY, OCTOBER 31 | 9:30 A.M. – 4:30 P.M.

TECHNICAL PROGRAM TOPICS

- Emerging FA Techniques and Concepts
- Future Challenges of FA
- Fault Isolation
- 3D Devices Failure Analysis
- Organic Electronics
- Wireless, Self-Powered, Sensors, MEMS Failure Analysis
- Detecting Counterfeit Microelectronics
- Alternative Energy
- Packaging and Assembly Level FA
- Diagnostic Testing, Scanning and Debug
- Board and System Level FA
- Metrology and In-Line Device Characterization
- Circuit Edit
- Sample Preparation and Device Processing
- Scanning Probe Analysis
- Yield and Reliability Enhancement
- Nanoprobing, Electrical Characterization
- Competitive Analysis and Reverse Engineering
- FA Use Cases

EXHIBITOR LIST

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JEOL USA
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Keyence Corporation
Kleindiek Nanotechnik
LatticeGear
Leica Microsystems
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Materials Analysis Technology
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MSSCORPS Co., Ltd.
Nanoscience Instruments
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Neocera LLC
Nikon Metrology
Nippon Scientific Co, Ltd.
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OKOS
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Quantum Focus Instruments
Quartz Imaging
Raith America, Inc.
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Thermo Fisher Scientific
TMC Ametek
Trion Technology
ULTRA TEC
Varioscale Inc.
XEI Scientific
Yxlon FeinFocus
ZEISS
Zurich Instruments AG

Exhibitor list current as of August 14.

A NONCOMPREHENSIVE GUIDE TO NONDESTRUCTIVE EVALUATION

This article is an excerpt from the completely revised *ASM Handbook,* Volume 17, *Nondestructive Evaluation of Materials,* just published this month.

Samuel W. Glass III
Pacific Northwest National Laboratory, Richland, Wash.

The most common application of nondestructive evaluation (NDE) is detection of flaws caused by manufacturing anomalies, service or environmental stresses, or natural material aging. More generally, applications may include estimation of mechanical and material properties, stress/strain, and dynamic response behavior. NDE comprises a large family of specific test disciplines including visual inspection, dimensional metrology, ultrasound, radiography, penetrant tests, magnetic particle tests, leak tests, eddy current tests, potential drop tests, flash and vibrothermography, shearography, acoustic emissions, and many other methods. This article offers an overview of NDE science and discusses some key considerations for choosing specific techniques.

FLAW DETECTION AND EVALUATION

Before an NDE method is chosen, the inspection objective should be clearly defined. Considerations include:

- Reasons for performing the NDE (failure prevention, performance enhancement, end-of-life prediction, quality control)
- Types of flaws or material characteristics of interest (fatigue cracks, stress corrosion cracks, creep, pitting, erosion, embrittlement, wear, planar cracks/voids, transverse/axial cracks, color variation, density, resonant frequency)
- Size and orientation of rejectable/reportable flaws
- Anticipated locations of flaws of interest (surface, volumetric, welds, heat affected zones, high stress points, areas subject to wear)
- Material characteristics (hardness, toughness, density, strength)
- Size and environmental, temporal, and spatial accessibility of test component

Typical inspection techniques examine a particular metric or signal against a threshold level. Whether the signal is a simple indicator level or a complex multidimensional image, the basic concept of flaw detection is that the signal exceeds a detection threshold. Quantification of this aspect of NDE is known as the *probability of detection* (POD)[1]. The detection threshold must be set sufficiently low to ensure detection of significant flaws, yet not so low that noise or normal variations in the signal frequently exceed the threshold and increase the *probability of false alarms* (PFA) (Fig. 1). Realistic expectations for any NDE technique appreciate that there is some threshold of flaw size below which it is unlikely for the inspection to detect degradation. Conversely, there is a signal level at which the chance of flaw detection is very high. NDE methods are designed to allow detection thresholds to be set to maximize POD while minimizing PFA.

Factors affecting POD include signal sensitivity to degradations of

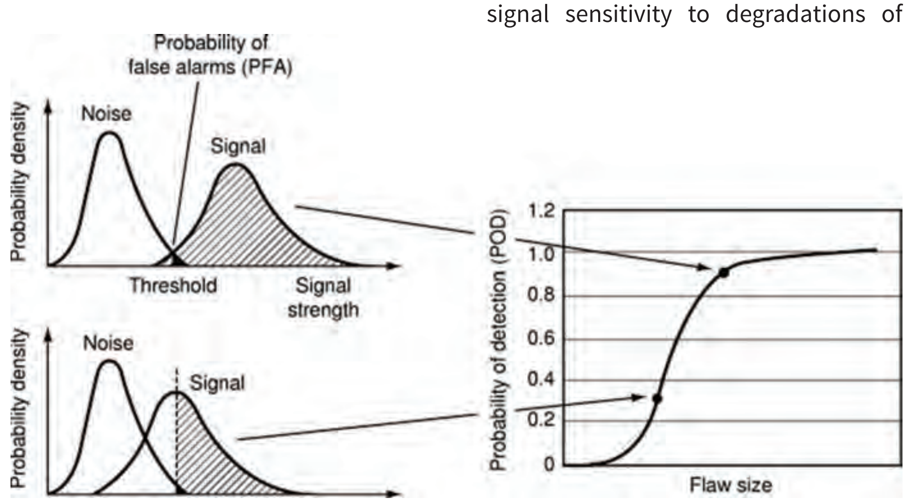

Fig. 1 — Probability of detection (POD) and probability of false alarm (PFA) are determined by fractions of signal and noise distributions above a threshold. Signal distribution generally shifts to higher levels as flaw size increases, leading to the sigmoidal POD curve.

interest, size or severity of degradation that constitutes a critical flaw, instrument and material noise, and human factors. Quantification of these factors is possible in cases where a significant number of inspections have been performed and where the population of actual flaws is known and may be compared to the NDE detection record. For some critical examinations, the influence of human factors can be minimized by independent analysis where the data is subjected to multiple independent reviews. Any indication of disposition discrepancy is subject to an additional review. This type of analysis is common in critical nuclear NDE programs such as steam generator tube inspection[2].

CODES AND STANDARDS

Numerous codes and standards for inspection are widely available and range from being quite specific to rather general in nature. Table 1 includes a few examples. Information may include details on calibration standards, inspection frequency, guidance on how to perform inspections, applicability, mandatory and nonmandatory practices, tips on where to focus inspections to detect damage or degradation, and other aspects of inspection. NDE personnel should be familiar with codes and standards related to their industry and consider the code and standard guidance when applicable. As a practical matter, if an inspection is performed in accordance with some standard, it may be more efficient to cite the standard for details of how the inspection was performed. Such a standard reference may also add credibility to the examination. Keep in mind that codes and standards do not address all aspects of NDE and cannot replace education, experience, and the use of engineering judgment.

EMERGING NDE METHODS

New methods are continually being introduced to improve NDE accuracy or reduce the cost and time associated with traditional methods. Examples of techniques emerging in the industry include:

- *Wave field analysis* where an ultrasound emitter generates an acoustic wave and the behavior of the wave is mapped over the part surface using scanning contact transducers, water or air immersion transducers, or laser velocimetry sensors.
- *Guided wave ultrasound* using piezoelectric, electromagnetic acoustic transducer (EMAT), or magnetostrictive sensors. This is a growing inspection approach due to advancement of techniques for focusing, steering, temperature, and dispersion curve compensation, and other developments leading to increased confidence in this technology.
- *Nonlinear ultrasound* exploits nonlinear waveform distortion of the primary excitation frequency that typically manifests in a first harmonic or 2× the primary frequency. Filtering for this harmonic response can enhance sensitivity to some conditions of interest including some types of medical imaging, nuclear reactor hydrogen embrittlement, and titanium diffusion bonds.
- *Various thermographic techniques* taking advantage of higher resolution temperature discrimination and new ways to induce thermal gradients including sonic, flash heating lamps, inductively coupled eddy currents, and lasers.
- *Visual image processing algorithms* designed to detect subtle differences between a reference part image and an inspection object or between images of a part taken after a time interval looking for indications of change.

STEPS TO SUCCESSFUL NDE

The guiding principle of any inspection is that the NDE-specific procedure must be demonstrated to be able to detect and, if required, determine the size of any defects of interest. Demonstration of the efficacy of any NDE method typically follows a rigorous logical process whose steps include the following:

1. Define the minimum target size and overall range of flaw, defect, material characteristic anomalies, or measurement property of interest. Typically, this is performed in conjunction with responsible component designers who understand the component's design stresses and fracture mechanics experts who can help assess likely failure mechanisms, stress concentration factors, expected flaw growth rates,

TABLE 1 – EXAMPLES OF NDE CODES, STANDARDS AND INDUSTRY GUIDELINES

Codes, standards, and guidelines	Reference
ASME Boiler and Pressure Vessel Code, Section XI: Rules for Inservice Inspection of Nuclear Power Plant Components	3
ASME Boiler and Pressure Vessel Code, Section V: Nondestructive Examination	4
ASME Boiler and Pressure Vessel Code, Section III: Subsection NB Class 1 Components – Rules for Construction of Nuclear Facility Components	5
API 1104, Welding of Pipelines and Related Facilities	6
ACI 349.3-02, Evaluation of Existing Nuclear Safety Related Concrete Structures	7
ACI 228, Nondestructive Test Methods for Evaluation of Concrete in Structures	8
International Atomic Energy Agency Guidebook on Nondestructive Testing of Concrete Structures	9
AC 43.13-1B, Acceptable Methods, Techniques, and Practices – Aircraft Inspection and Repair	10
MIL-HDBK-6870B, Nondestructive Inspection Program Requirements for Aircraft and Missile Materials and Parts, 2012	11

strength design margins, and frequency of inspection.

2. Identify the material to be inspected plus the geometry of interest and any preferential flaw location if applicable.
3. Produce an actual and/or analytical representation of the component to be inspected with a range of flaws, defects, or anomalies, preferably including examples near the minimum target size.
4. Examine the produced sample(s) and either justify the detectability to a referee who is competent in NDE to corroborate claims of detectability or demonstrate successful detection of flaws of interest through blind test samples.
5. If flaw sizing is also of interest (e.g., wall thickness, crack length, crack width, or flaw volume), measurement accuracy is usually determined by a regression analysis of estimated or measured versus true flaw sizes. Errors are typically characterized as the root mean square error of the NDE flaw size estimate.

NDE is a mature engineering science where inspection methods have been developed based on a number of well understood physics principles. A noncomprehensive overview of these methods and their applications, limitations, and advantages is presented in Table 2. **~AM&P**

TABLE 2 – EXAMPLES OF NDE METHODS AND TEST CATEGORIES

Method	Principle of operation	Application	Limitations	Advantages	Materials
Visual test — direct viewing, borescopes, video, magnifying glass, speckle metrology	Visual observation of test object surface to evaluate dimensions, color, and presence of surface discontinuities indicative of defects	Postmanufacturing inspections, in-service inspections for dimensional anomalies, color variation, cracks, and pits	Only sensitive to surface flaws	Low cost, intuitive; may be enhanced with other methods, laser reference lines, video, and magnifying lenses	All
Liquid penetrant test	Liquid penetrant fluid preferentially collects in crevices and attracts dyes that accentuate flaw visibility	Locating fabrication discontinuities, stress cracks	Will not find subsurface defects	Ease of application; improvement over simple visual inspection	Most metals and composites with nonporous surfaces
Magnetic particle test	Magnetic particles are attracted to breaks in magnetic lines of force	Near-surface flaws are sensitive to magnetization; includes blow holes, laps, and cracks	Not applicable to nonmagnetic metals or materials	Can detect flaws up to 0.25 in. below surface under good conditions	Iron and steel, nickel, cobalt
Barkhausen noise test	Changes in magnetic flux from stress applied to magnetic material	Online monitoring of magnetic material	Not suitable for nonmagnetic material	Online monitoring; can sense stress without cracking	Magnetic metals, steel, nickel, iron, chrome
Penetrating radiation test (RT), computed tomography (CT), digital x-ray, neutron RT, x-ray diffraction	Penetrating rays (x-ray, gamma, or neutron) passing through or reflecting from test object cast shadows or patterns on film or digital imaging plates	Manufacturing, weld inspection, finding objects in closed containments, metrology of enclosed objects, thickness	Hazardous radiation operation, not sensitive to defects less than 1–2% thickness of total metal; complex shapes difficult to analyze	Permits visual analysis of buried defects or components in assembly; also possible to measure near-surface strain	Metals, foods, films, nonmetals, composites, assemblies
Acoustic emission (AE) test	Multiple distributed sensors detect and triangulate AE stress wave source in response to mechanical or thermal stress	Corrosion, stress corrosion cracking, weld cracking, creep and fatigue cracking	Sensitive to noise and vibration; identifies location of defect rather than type	Allows entire volume of structure to be inspected nonintrusively in a single loading operation	Aircraft, bridges, welds, metal forming, composite and metal pressure vessels, piping

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EDITOR SPOTLIGHT

Ahmad

Aquil Ahmad, FASM, and **Leonard Bond** offered their expertise as volume editors of the revised *ASM Handbook*, Volume 17, *Nondestructive Evaluation of Materials.* The 2018 edition of Volume 17 is a completely revised and updated work written and reviewed by the leading experts in the field. Last published in 1989, the new Volume 17 provides detailed technical information that will enable readers to select, use, and interpret methods used to nondestructively test and analyze engineered products and assemblies.

As chief metallurgist for Eaton Corp. before he retired, Ahmad used NDT techniques and technologies for projects including ultrasonic testing for steel cleanliness, eddy current for flaws, the Barkhausen effect for residual stress, hardness, and austenite levels in steels, and others during his 40-year career.

Bond

Bond served as director of the Center for Nondestructive Evaluation at Iowa State University from July 2012 to May 2018. He was previously a laboratory Fellow at Pacific Northwest National Laboratory, Richland, Wash., and has held positions as an academic, in industry, and at national laboratories in both the U.S. and U.K. His technical work has focused on ultrasonics and its applications, with more recent applications in advanced diagnostics and prognostics.

Volume 17 includes more than 40 articles written by industry experts and is a valuable resource for engineers involved in NDE and those who want to learn more about the techniques.

HTS
Heat Treating Society
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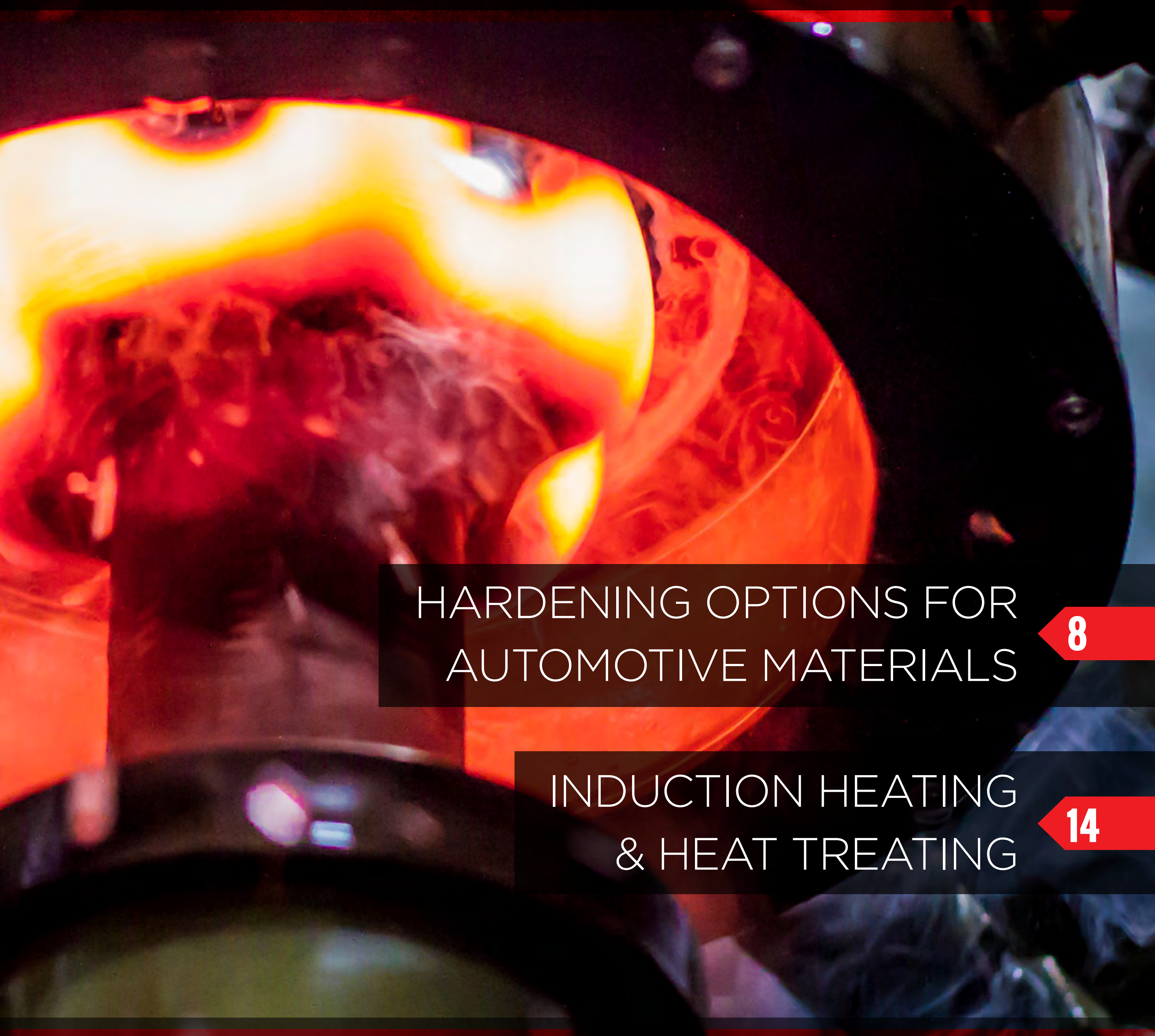
SEPTEMBER 2018 | VOLUME 6 | ISSUE 3

HTPRO

BUSINESS AND TECHNOLOGY FOR THE HEAT TREATING PROFESSIONAL



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EDITORIAL OPPORTUNITIES FOR HTPro IN 2018

The editorial focus for *HTPro* in 2018 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.

November/December Atmosphere & Vacuum Heat Treating

To contribute an article to one of the upcoming issues, contact Frances Richards at frances.richards@asminternational.org.

To advertise, contact Erik Klingerman at erik.klingerman@asminternational.org.

DEPARTMENTS

ABOUT THE COVER

Static induction hardening of a complex geometry component. Courtesy of Inductoheat Inc.

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RESOURCES AT NATIONAL LABS ENABLE HEAT TREATMENT ADVANCEMENTS

Heat treatment is an active area of research and development due to its economic impact and scientific challenges. Advancing heat treatment (HT) processes requires expertise from several areas of science and engineering: materials science (e.g., phase transformations, precipitation of secondary phases), physics (e.g., mass and energy transport), and mechanical engineering (e.g., thermal distortion and residual stresses). The Department of Energy's (DOE) National Laboratory system addresses complex research and development challenges with multidisciplinary approaches.

The heat treatment industry has engaged with several DOE labs, including Oak Ridge National Laboratory (ORNL). Over the past two decades, ORNL pioneered infrared (IR) heating, IR heat treatment, magnetic processing, and residual stress measurement for HT applications. IR installations for heat treatment are smaller than corresponding hot air ovens due to the higher heat fluxes and energy efficiency (radiant) from the IR radiator to the product. Beyond IR tungsten-halogen lamps, which offer incident heat fluxes up to 50 kW/m^2, ORNL employs a plasma-arc lamp (PAL) of a type that was initially developed in the semiconductor industry for the flash-anneal of semiconductors using ultra-short pulses of 200 ms.

The water-wall PAL consists of a confined plasma arc in a quartz tube with a line-focus reflector, which redirects the radial radiant energy output to the specimen surface. At ORNL, the PAL is used for processing or testing new materials when high heating rates, high temperatures, and/or high heat fluxes are required. In 2017, a new line-focus reflector for ORNL's PAL was designed, fabricated, and installed to attain an incident heat flux of 12,000 kW/m^2. The new reflector features two observation ports, which enable monitoring of specimen condition and temperature.

In addition to the processing, metallurgical expertise, and facilities, unique user facilities are also available within the National Laboratory system. These resources serve to complement research centers at universities that provide research opportunities for the HT industry, such as the Center for Heat Treating Excellence (CHTE) at Worcester Polytechnic Institute. At ORNL, the Center for Nanophase Materials Sciences (CNMS) provides national and international users with community access to expertise and equipment for a broad range of nanoscience research including imaging, electron and atom probe microscopy, and nanoscale characterization.

ORNL operates two powerful neutron scattering facilities for DOE's Office of Science—the High Flux Isotope Reactor (HFIR) and the Spallation Neutron Source (SNS). The HB-2B NRSF beam line at the HFIR was optimized to use the high penetration power of neutrons to generate maps of the strain resulting from residual or applied stresses in engineering materials. The VULCAN instrument at SNS is designed with in situ loading and deformation capabilities for phase transformation, residual stress, and texture studies from ambient to 1873 K. VULCAN provides rapid volumetric mapping and a measurement time of minutes. In conclusion, the HT industry has the opportunity to harness the multidisciplinary expertise and facilities available within the National Laboratory system to further advance HT applications and understanding.

Adrian S. Sabau
Senior Research Staff Member
Oak Ridge National Laboratory

HTS NAMES NEW BOARD MEMBERS FOR 2018

The Heat Treating Society (HTS) board, at the recommendation of the HTS Awards and Nominations Committee, named new board members including **Benjamin Bernard, Fred Hamizadeh,** and **Deidra Minerd** to serve on the HTS Board for the 2018-2021 term; **Joseph Fignar** was reappointed to serve as emerging professional board member for the 2018-2019 term; and **Noah Tietsort** to serve as student board member for 2018-2019. Terms begin October 1. Continuing on the board are **Jim Oakes** (president), **Eric Hutton** (vice president), **Steve Kowalski** (past president and treasurer), **Robert Cryderman** (secretary), **Chuck Faulkner** (member), **Marc Glasser** (member), **Joseph Powell** (member), **Olga Rowan** (member), and **Thomas Wingens** (member). Leaving the board are **Nathan Chupka** (member), **Michael Pershing** (member), **Craig Zimmerman** (member), and **Jonah Klemm-Toole** (student board member).


Bernard

Benjamin Bernard is VP of business development, R&D, and sales at Surface Combustion Inc. in Maumee, Ohio. He has a B.S. in materials science and engineering, as well as an international business certificate, both from Michigan Technological University. He gained international experience as an engineering intern for Alcoa in Brazil and Chugai Ro Co. Ltd. in Japan. He currently serves as HTS Exposition Committee co-chair and previously was Young Professional Board Member (2012-2013). He received the Governor's Award for Export Excellence in 2013.


Hamizadeh

Fred Hamizadeh is director of manufacturing services at American Axle & Manufacturing, having worked at the company since 2007. He received his B.S.M.E. from the University of Toledo and started his career in the heat treat industry at Williams Industrial Service in 1988 as a designer and later as an engineer. He then worked at Surface Combustion Inc. for over 13 years in various engineering roles. Hamizadeh has established or expanded heat treating facilities in eight countries.


Minerd

Deidra Minerd is operations manager at Euclid Heat Treating, Ohio, where she has worked for over 20 years. Prior to Euclid, she was a sales engineer at Therm-O-Disc in Mansfield, Ohio. Minerd received a B.S. in metallurgical engineering from The Ohio State University in 1997 and is a graduate of the management training program through the Metal Treating Institute (MTI). She has served on the MTI Education Committee and is a career day speaker at various area high schools.


Fignar

Joseph Fignar earned his B.Sc. in materials science and engineering from Penn State University in 2015. He was active in the Material Advantage program and served as student metallurgist on the SAE Formula Student Penn State Racing Team. He interned at ArcelorMittal and with the Penn State Applied Research Laboratory, completing a research project that culminated in a peer-reviewed article. Fignar is a process engineer at Honda Transmission Manufacturing in Russells Point, Ohio, where he is responsible for Fe/Ni-base heat treatment of transmission gears and components.


Tietsort

Noah Tietsort is an undergraduate student studying materials science and engineering at Case Western Reserve University in Cleveland. He is also a metallurgical engineer intern at Arconic Forgings and Extrusions and an undergraduate research assistance at Case's Solar Durability and Lifetime Extension Center. For the past two years, he has served as the committee lead in planning and hosting events for the Case Engineers Council during National Engineers Week. Tietsort's interests in materials science include metallurgy, pyrometry, and materials characterization.

WHITLEY WINS 2018 ASM HTS/BODYCOTE BEST PAPER IN HEAT TREATING AWARD


Whitley

The winner of the 2018 HTS/Bodycote Best Paper in Heat Treating Award is entitled, "Understanding Microstructural Evolution During Rapid Heat Treatment of Microalloyed Steels Through Computational Modeling, Advanced Physical Simulation and Multiscale Characterization Techniques" by **Blake Whitley,** senior engineer I, R&D at ATI Specialty Materials in Monroe, N.C. Whitley wrote the paper while he was a Ph.D. student in metallurgical engineering at the Colorado School of Mines.

The award will be presented at the ASM Leadership Awards Lunch on Monday, October 15, at MS&T18 in Columbus, Ohio. The award includes a plaque and $2500 cash prize endowed by Bodycote Thermal Process-North America.

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 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, 2019.** Submissions should be sent to Mary Anne Jerson, ASM Heat Treating Society, 9639 Kinsman Rd., Materials Park, OH 44073 or maryanne.jerson@asminternational.org.

HTS AWARD DEADLINES

Nominations Sought for George H. Bodeen Heat Treating Achievement Award

ASM's Heat Treating Society (HTS) is currently seeking nominations for the George H. Bodeen Heat Treating Achievement Award, which recognizes distinguished and significant contributions to the field of heat treating through leadership, management, or engineering development of substantial commercial impact. **Deadline for nominations is February 1, 2019**.

Nominations Needed for ASM HTS/ Surface Combustion Emerging Leader Award

The ASM HTS/Surface Combustion Emerging Leader Award recognizes an outstanding early-to-midcareer heat treating professional whose accomplishments exhibit exceptional achievements in the heat treating industry. The award was created in recognition of Surface Combustion's 100-Year Anniversary in 2015. The winning young professional will best exemplify the ethics, education, ingenuity, and future leadership of our industry. **Deadline for nominations is February 1, 2019**.

For nomination rules and forms for both awards, visit the Heat Treating Society website at hts.asminternational.org and click on Membership & Networking and Society Awards. For additional information, or to submit a nomination, contact Mary Anne Jerson at maryanne.jerson@asminternational.org.

HTS MEMBERS NAMED ASM FELLOWS

Three HTS members have joined the newest Class of ASM Fellows. Awards will be presented at ASM's annual Awards Dinner, October 16, in Columbus, Ohio, during MS&T18. Congratulations to all.


Jarosinski

Mr. William J. Jarosinski, FASM, associate director, Materials, Praxair Surface Technologies Inc., Indianapolis. His citation reads, "For recognition of continuous development of advanced powder processing technologies and coating solutions for enhanced wear and corrosion resistance throughout numerous industries."


Jones

Mr. Roger A. Jones, FASM, CEO, Solar Atmospheres Group, Souderton, Pa. His citation reads, "For advancing production vacuum thermal processes and procedures for large and heavy assemblies utilizing state-of-the-art vacuum furnaces, for the enhancement of the overall heat treating industry."


Pathak

Mr. Udayan Pathak, FASM, deputy general manager**,** Engineering Research Centre, Tata Motors Limited, Pune, India. His citation reads, "For developing innovative solutions that achieve significant cost and energy savings in materials and processes for automotive applications and for attracting and mentoring young minds to pursue careers in materials engineering."


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PROS AND CONS OF VARIOUS AUTOMOTIVE MATERIALS AND HARDENING PROCESSES

Automotive designers and heat treaters have many choices when it comes to the materials and processes that will meet their overall needs.

Wallace (Jack) Titus
AFC-Holcroft LLC, Wixom, Mich.

Typical automotive parts made of austempered ductile iron. From left, turbo charger housing, exhaust manifold, and ring and pinion set. Courtesy of Wikimedia Commons/Panoha and zircotec.com.

Automotive heat treating has benefited from significant developments in recent years due to the need for high production and predictive process automation (PPA) to improve efficiency. Four major goals of automotive component heat treating include:

- Reduce distortion in low mass transmission gears.
- Choose materials that reduce vehicle weight to improve fossil fuel economy.
- Reduce fossil fuel emissions like CO_2, CO, and particulate matter.
- Improve the range of hybrid and electric vehicles.

Each heat treating and/or quenching process provides unique solutions for automobile designers and plant engineers. However, it is likely there is no single process or material that provides all the answers. There are advantages and disadvantages of quenching media options such as oil and press quenching and high pressure gas quenching (HPGQ), austempering (salt) for steel, austempering ductile iron (ADI), and the use of aluminum alloys versus other materials. This article discusses how OEMs and heat treaters can take advantage of particular hardening processes.

Challenges facing auto designers include reducing emissions produced during acceleration to cruising speed and decreasing overall vehicle weight. Two methods for reducing weight include shrinking the overall unit size and adopting lighter (less dense) materials. Auto manufacturers in Europe and the U.S. each face their own unique challenges because consumers desire different car models, which affects the size and utility of product offerings. Thus, it is necessary to not only manufacture vehicles that meet government standards, but also produce vehicles that consumers will purchase.

CONSUMER PURCHASING STATISTICS

Per the Car Sales Statistics report on January 29, 2018, by Henk Bekker, in Europe the VW Golf was again the leading vehicle sold in 2017 with 445,206 units. In the U.S., SUVs and crossovers were segment leaders, with 3.53 million sold in 2017. Light trucks or pickups totaled 2,988,856 units. Overall, 17,134,700 vehicles of all kinds were sold the in the U.S. in 2017. For clarification, crossover SUVs are sport utility vehicles based on an automobile platform, while SUVs are truck-based. Considering that SUVs and light trucks on average weigh more than passenger cars, they require on average a higher proportion of weight reduction to meet their respective efficiency criteria.

Meeting the 2025 CAFE standards in the U.S. will be a challenge due to the weight of the vehicles: Americans love their trucks. With the deadline just around the corner, improving mileage by weight reduction alone seems impossible. Therefore, a new generation of engines, transmissions, and hybrid technology will likely need to play a major role. However, electric and hybrid vehicles have not impressed the American consumer to date.

2016 VEHICLE SALES IN U.S. AND EUROPE

Best-selling cars in Europe, 2016:

- VW Golf 491,681
- Renault (Clio) 310,944
- VW Polo 307,462
- Ford Fiesta 298,999

Best-selling vehicles in the U.S., 2016:

- Ford F-Series 820,799 (half-ton pickup truck)
- Chevrolet Silverado 574,876 (half-ton pickup truck)
- Dodge RAM Trucks 489,418 (half-ton pickup truck)
- Toyota Camry 388,616
- Honda Civic 366,927
- Toyota Corolla 360,483
- Honda CR-V 357,335 (crossover SUV)
- Toyota RAV4 352,139 (crossover SUV)

COUNTRIES ADOPT AUTOMOBILE FUEL STANDARDS

A decade ago, the EU entered into a series of voluntary agreements known as the European Union Automotive Fuel Economy Policy with associations of automobile manufacturers that sell vehicles in the European market to reduce CO_2 tailpipe emissions. These agreements applied to each manufacturer's new vehicle fleet and set an industrywide target of 140 g CO_2/km (100 km per 6 L or 39 mpg). The original agreement with the European Automobile Manufacturers Association (ACEA) had an initial compliance date of 2008, while the Asian manufacturers (represented by South Korean and Japanese associations KAMA and JAMA) had to comply by 2009.

However, automakers did not meet the voluntary target and the European Commission (EC) has now set mandatory targets. In June 2007, the Council of Environment Ministers formally adopted a resolution to approve the shift to mandatory standards and an integrated approach to achieve 120 g CO_2/km (100 km per 5.2 L or 45.6 mpg), with automakers achieving 130 g CO_2/km (100 km per 5.6 L or 42 mpg) through technical improvements and the remaining 10 g CO_2/km coming from complementary measures. The full EC strategy to reduce CO_2 emissions from cars and vans is available online, as is the regulation[1].

In the U.S., the CAFE (corporate average fuel economy) standard was adopted in 1975, and was primarily targeted to improve fuel mileage for automobiles in the wake of the Middle East oil crisis of 1970. As time passed, political pressures also mandated the reduction of greenhouse gases (GHGs) such as CO_2 and NOx (nitrogen oxides).

EXISTING MODIFICATIONS

Attempts to reduce fuel consumption were adopted over the decades, including decreasing the number of cylinders to reduce engine block mass. Probably the most significant and successful solution to date (and perhaps the most cost effective) has been the integration of turbochargers to four and six-cylinder gasoline and diesel engines combined with six, seven, eight, and even nine and 10-speed transmissions. This approach also has limits, especially as fuel economy standards are applied to larger passenger vehicles and half-ton pickup trucks.

Where light trucks are concerned, one OEM substituted aluminum for steel body panels with a reported weight savings of 500 to 700 lb (227 to 318 kg). However, body panels are just one of many components that are candidates for potential weight reduction, including suspension parts, transmission and transfer cases, and structural and space frame components, some of which will be fabrications, castings, and forgings. In every case, the tradeoff between mass and strength must be considered, as well as the potential for reducing post-heat treat processing.

MATERIALS AND PROCESSING

Six materials with suitable strength-to-weight ratios used in automotive construction today include magnesium, carbon composites, cast gray and ductile irons, aluminum, and steel. Each material is used for a specific performance characteristic:

Magnesium has been slowly gaining acceptance for use in automotive applications. Its low density and machinability makes it an ideal candidate for transmission, differential, and transfer cases. However, it lacks aluminum's overall strength, making it unsuitable for engine blocks and similarly stressed applications. It also requires a protective coating to reduce corrosion, whereas aluminum has very good oxidation resistance. Probably the biggest advantage of magnesium is its availability, although it is not inexpensive to refine. It is not found in the pure state, but can be refined from several materials including dolomite and magnesite ore, sea water, and salt brines, which contain about 10% magnesium chloride. Ocean water contains about 0.13% magnesium[2].

Carbon fiber reinforced polymer (CFRP) has one of the most advantageous strength-to-weight ratios of any engineered material. However, it is not as easily recycled as aluminum and wrought and cast ferrous alloys, and there has been much research to make recycling more cost effective. Most virgin woven poly fiber is produced in Japan and is used for aerospace applications and expensive automobiles. The aerospace industry produces about 35% CFRP scrap, which is used in many under-hood automotive applications, because the chopped recycled fiber material does not have the structural strength offered by virgin long-fiber polymers for chassis and body panel applications[3]. Although heat is used to manufacture raw carbon fiber, it does not play a significant role in making the final product.

One of the major obstacles facing CFRP is the end-of-life (EOP) products stated in ELV Directive 2000/53/EC. This directive issued a 2015 target applicable to Europe and Japan that 95% of an automobile ready for the scrap yard must be recoverable and recyclable. Today, it is accepted that approximately 75% of an automobile is made of ferrous and nonferrous metals and the remaining 25% is made of toxic materials.

Gray cast iron has been the material of choice for automobile engine blocks for decades, primarily due to its low cost and adequate strength for gasoline, but not diesel, engines. Due to its lack of as-cast strength and the fact that it is not typically hardened by heat treatment, it has limited application for stressed components. As for heat treatment, gray iron is rarely heat treated to increase hardness, but it does receive treatments such as annealing and normalizing to enhance machinability. Stress relieving after welding is also common. Gray cast iron automotive components include engine blocks, brake rotors, constant-velocity joint housings, exhaust manifolds, transmission cases, and cylinder heads.

Aluminum is more expensive to manufacture than steel, but it has an attractive strength-to-weight ratio and therefore has continued to see more application in automobiles and trucks. Much of it is recycled and it also requires different forming and coating techniques. The 2*xxx*, 6*xxx*, and 7*xxx* series grades are hardenable by solution treating, rapid water quench, and natural and artificial (heat) aging. As such, the 6*xxx* series is finding application in vehicle structural and body panels. A less tangible effect of material selection is sound conduction. For example, a material can have ideal properties but transmit undesirable sound and vibration to the passenger cabin.

Plain-carbon and alloy steels have the highest percentage of application in cars and trucks simply due to their wide range of strength-to-weight relationships through diverse heat treating options. High-strength low-alloy (HSLA) grades have been used for years in the substructures of U.S. cars and trucks. The more recent use of higher hardenability alloy steel has been directed to drivetrain components, such as transmission and differential gears, where the goal is to reduce gear mass. This has resulted in the growth of using high pressure gas quenching (HPGQ) and improved distortion control. The growth of HPGQ is primarily due to increased distortion control required for more precise, less massive gearing in multispeed transmissions. In addition, OEMs realize that improving the hardenability, even at increased cost, can reduce or eliminate post-heat treating machining, grinding, and straightening. One of the original growth drivers for HPGQ was the use and recovery of helium. However, as the capital cost and maintenance of compressors has increased, nitrogen is making a comeback. Nitrogen forces users to improve the hardenability of steels, because the horsepower for the fan motors required to equal the quench capacity of helium would have to be increased to impractical levels.

Ductile iron (DI), specifically austempered ductile iron (ADI), has been around for decades, but it never gained mainstream acceptance compared with steel and aluminum. One reason, in this author's opinion, is the negative perception of heat treating in salt. However, today's salts are much more EPA-friendly than those used in the past for carburizing and cyaniding. Austempering salts consist of a 50-50 mixture of sodium nitrite and sodium nitrate compounds. A significant quantity is recycled by recovering salts from post-wash solutions. Similar to steel, alloying elements play a significant role in ADI to produce properties that increase hot strength and improve tensile strength and hardness.

A fundamental misunderstanding still exists regarding the microstructure formed when DI is quenched in hot salt compared with austempered steel and ferrous alloys. Years ago, investigators were credited with identifying the ferrite/Fe_3C/austenite microstructure as *ausferrite* or *upper bainite,* as some have called it, when DI is isothermally held above the martensite start (M_s) temperature, but not long enough to form bainite. Further, they reportedly discovered that the carbon-enriched stable austenite formed is different from what some called retained, or metastable, austenite. Lawrynowicz[4] indicated that ausferrite is a mixture of ferrite and high-carbon austenite, and forms at austempering salt temperatures (Fig. 1). He further noted that bainite will not form unless the DI is held at temperature for very long times, much longer than is perhaps practical for normal production.

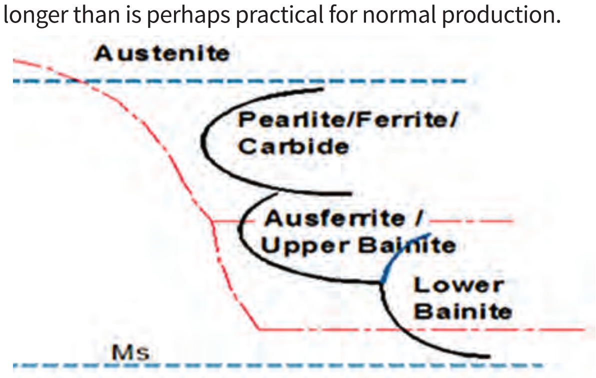

Fig. 1 — Ausferrite is a mixture of ferrite and high carbon austenite formed at austempering salt temperatures. Bainite will not form unless the ductile iron is held at temperature for a very long time[4].


1916 AFC-HOLCROFT 2016
INNOVATION THAT ENDURES

Fig. 2 — Universal batch quench austemper furnace (914 × 1829 × 1422 mm) used at Zanardi Fonderie S.p.A. to study heat treated properties of cast iron and austempered ductile iron. Three chambers enable transferring product to a salt-quench tank under a protective atmosphere.

Austenite is not retained as some have indicated, because the parts would never have cooled below the M_s temperature. Carbon in the austenite is high enough to lower the M_s temperature well below room temperature. Some proposed that this microstructure contributes to the hardening effect when the part is subjected to strain or stress, producing the shear or deformation required to change from face centered cubic (fcc) austenitic lattice to body centered tetragonal (bct) martensitic lattice.

Zanardi Fonderie S.p.A.[5] compared the properties of cast iron and ADI parts treated in a universal batch quench austemper (UBQA) furnace (Fig. 2). Fig. 3 shows a suspension arm made of austempered ductile iron compared to a pearlitic-ferritic cast iron version. Both weight savings and strength are gained by using austempered ductile iron versus pearlitic-ferritic cast iron. In addition to strength, DI is inherently quieter than steel alternatives due to the presence of graphite. Fig. 4 shows the relative damping of ductile iron and steel[6].

CONCLUSION

Several weight reduction options exist when it comes to the materials and processes available to designers and heat treaters for automotive applications. However, remaining challenges include whether the choice for weight reduction can be cost effective in vehicle pricing, and whether the selected process can be integrated cost effectively into the predictive process automation methodology of the manufacturer.

From a heat treating perspective, controlling distortion is a primary goal in reducing manufacturing cost. Because steel and ductile iron offer the greatest potential for achieving an appropriate strength and wear resistance parameter, austempering with its predictable, uniform growth seems

(a) (b)

Fig. 3 — (a) Austempered ductile iron (ISO 17804/JS/900-S) suspension arm provides weight savings (5.9 kg machined weight versus 8 kg) and strength (600 MPa yield, 900 MPa tensile, 8% elong. versus 370 MPa, 590 tensile, and 10% elong.) over the (b) GH 60-38-10 pearlitic-ferritic cast iron version.

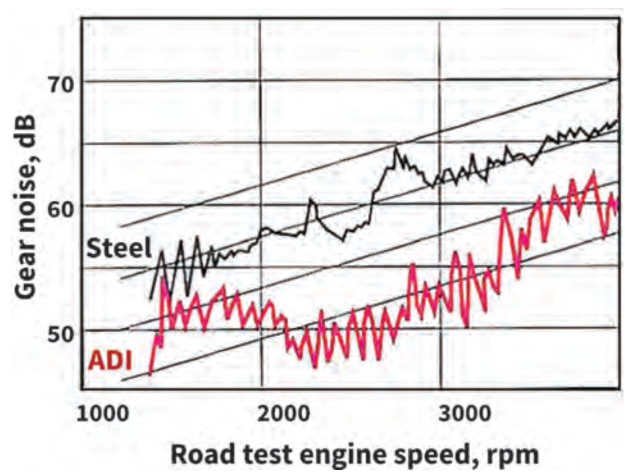

Fig. 4 — Relative damping of ductile iron and steel.

poised to satisfy weight-related obstacles. The one remaining issue with austempering—the "Holy Grail of bainite"—is hardness. Additional research in microalloying ADI and steel would solve that major hurdle. **~HTPro**

For more information: Jack Titus, AFC-Holcroft LLC,49630 Pontiac Trail, Wixom, MI 48393, 248.231.3950, jtitus@afc-holcroft.com, www.afc-holcroft.com.

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INDUCTION HEATING: EVERYTHING YOU WANTED TO KNOW, BUT WERE AFRAID TO ASK

As a regular contributor to the *HTPro* eNewsletter, Professor Induction answers a wide variety of questions regarding induction heating and heat treating. Included here are three recent challenges and solutions.

Valery Rudnev, FASM,* IFHTSE Fellow
Inductoheat Inc., Madison Heights, Mich.

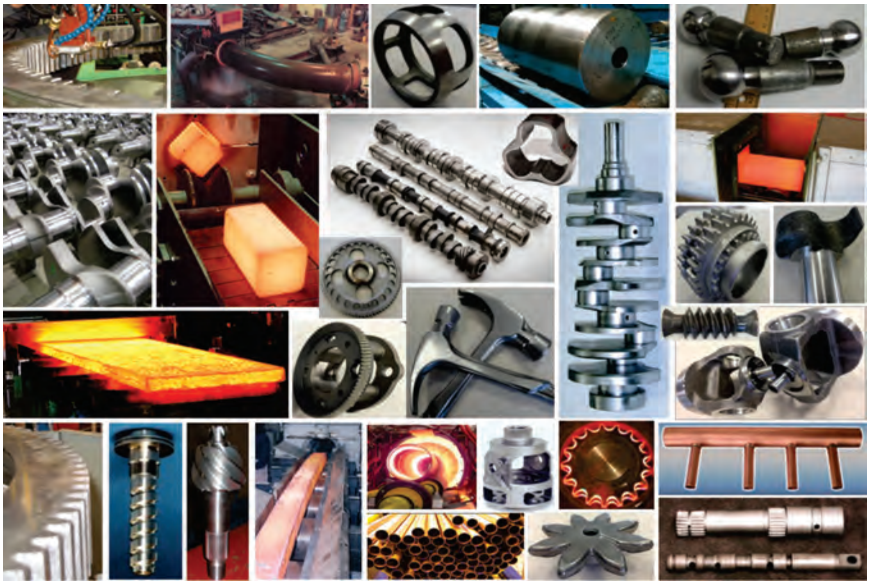

Fig. 1 — Induction heating applications across a variety of industries.

Induction heating is a multifaceted phenomenon composed of complex interactions involving electromagnetics, heat transfer, materials science, metallurgy, and circuit analysis—with applications across multiple industries. Figure 1 shows a small portion of a virtually endless variety of workpieces where electromagnetic induction heating is used to develop an attractive blend of microstructures and properties at a competitive cost.

We use an induction process where we need to include physical barriers and/or a safety warning for people with medical devices such as metallic implants and cardiac pacemakers to stay a certain distance away. What is the required distance for people with such devices to stay away from induction heating coils? Thank you for any help you can provide on stand-off distances.

Answer: Many studies have been conducted to evaluate the direct and indirect effects of electromagnetic field (EMF) exposure on health, passive and active medical implants, and hypersensitivity. Several national and international organizations including the Institute of Electrical and Electronic Engineers (IEEE), International Radio Protection Association (IRPA), World Health Organization (WHO), Occupational Safety & Health Administration (OSHA), and others have developed awareness programs regarding non-ionizing radiation and evaluation of the health risks associated with external field exposure when using any electromagnetic device (such as cell phones, household electrical appliances, computer monitors, transmitting antennas, microwave ovens, induction coils, and others). A large body of scientific research exists and a number of international standards, guidelines, and regulations have been put into effect. For example, in the U.S. these include the following standards:

- IEEE: C95.6 Safety levels with respect to human exposure to electromagnetic fields, 0 to 3 kHz.
- IEEE: C95.1 Safety levels with respect to human exposure to electromagnetic fields, 3 kHz to 300 GHz.

All manufacturers of electromagnetic devices (including induction heating manufacturers) are supposed to comply with international/national standards and regulations related to controlling external exposure to EMF in the workplace.

*Member of ASM International


Fig. 2 — Holaday 3-axis VLF Magnetic Field Meter HI-3637.

There is no universal guideline for so-called "safe stand-off distances" for employees with medical devices or people without them, because such distances are application-specific and greatly depend on coil design details, applied power and frequency, presence of other electromagnetic devices in coil surroundings, and other factors. The magnitude of an external magnetic field can be either computer modeled or measured. For example, at Inductoheat we use both techniques.

In some cases, the induction coil is not the main source of EMF exposure and other electromagnetic sources (e.g., transformers, bus bar networking, electromagnetic lifting devices) might contribute to an even greater degree to the magnitude of EMF at the workplace.

A number of devices are available to measure EMF exposure in the workplace, ranging in applied frequencies and designs. Based on our experience, three-axis measuring devices provide acceptable accuracy if properly used and calibrated. For example, for a number of years Inductoheat has been using the Holaday 3-axis VLF Magnetic Field Meter HI-3637 (Fig. 2). This device is capable of providing isotropic measurements of a magnetic field's magnitude. The instrument is designed to conform to the requirements issued in the IEEE protocols and guidelines for suitable frequencies

Following are some general guidelines for monitoring and supervision of EMF exposure:

- *Running conditions of the induction system:* The machine should be running with the maximum running parameters for output KW or the maximum allowable running current/voltage to the coil.
- *Measurement specifics:* The induction machine envelope should be drawn and measurements should be taken at the operator station (or where other people may be present) and at a number of points around the perimeter of the machine at distances from the machine of 0.25, 0.5, 1, 1.5 meters, and more (whatever is most appropriate) and different heights from the floor. Data should be reviewed and a report issued to indicate whether the measured values comply with safety requirements. All readings should be taken and properly documented including setup parameters for capacitor and output transformer settings. If necessary, measurements should be made to calculate the coil running current for the specified meter readings.

Over the years, manufacturers of induction machinery have developed a number of ways to minimize external magnetic field exposure in cases where it exceeds maximum permissible levels. This includes a number of patented designs and proprietary techniques including passive and active magnetic shields, magnetic shunts, and Faraday rings, to name a few.

For a few years, we scan hardened relatively straight shafts using a 30 kHz machine. Our new component has a 4.8-mm radial step (sharp shoulder) that overheated when we tried to scan harden. We heard that a single-shot inductor could reduce shoulder overheating and still provide sufficient hardening in the internal corners of the diameter transition, so we asked a local coil builder to make one for us. Corner overheating is reduced, but now we have a 4-6 HRC surface hardness variation around the circumference of the as-quenched component. We didn't have this with scan hardening. How can we fix it?

Answer: An appropriate inductor/quench design and suitable process recipe should not produce such a wide hardness variation along the shaft circumference while using a single-shot inductor. A number of possible causes exist, with two of the most common discussed here:

Heat-related factor. With scan coils, induced eddy current flow is circumferential, producing uniform temperature distribution at any instant of the heat time. Only minor heat variation occurs in a flux fringing region of coil terminals. Part rotation makes this impact negligible, normally providing very uniform temperature distribution (assuming an absence of slots, keyways, holes, and similar geometrical discontinuities). Unlike scanning inductors, the majority of single-shot inductors produce predominately an axial eddy current flow rather than circumferential. Therefore, if the heating time is relatively short (e.g., 2-3 sec), the coil copper heating face is narrow, and rotation speed is insufficient, there might be a noticeable, nonuniform circumferential temperature pattern at the time quenching is applied (Fig. 3). Increasing rotation speed during single-shot heating might solve this problem. The use of a serpentine-type inductor is another option.

Quench-related factor. MIQ coils are often used with scan hardening, normally providing sufficiently uniform circumferential quenching. Quench rings/barrels/followers used in scan hardening also produce reasonably uniform quenching. With a single-shot inductor, there might be ob-

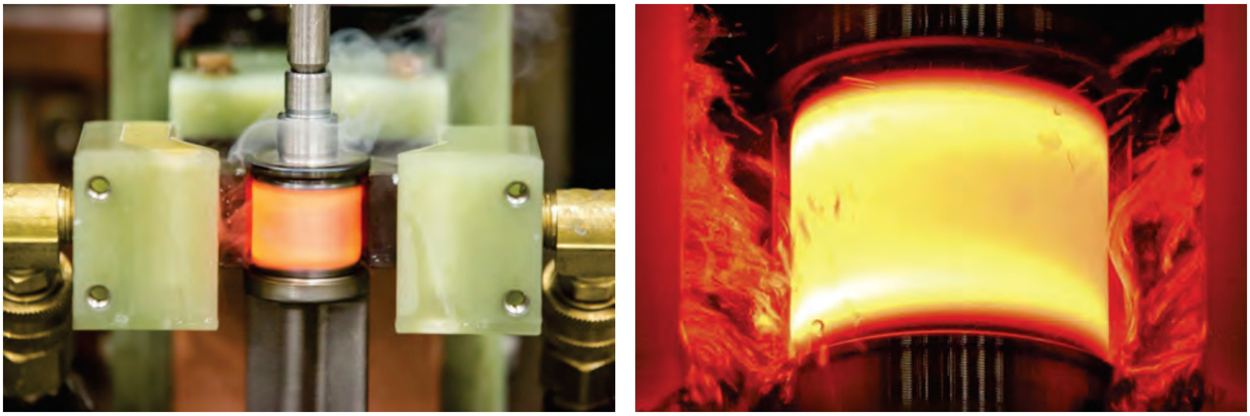

Fig. 3 — A nonuniform circumferential temperature pattern occurring at the time of quenching.

structions for providing 360° access for spray quenching. In some cases, quenching is done from one side, covering only 90°-120° of the austenized surface. This could result in appreciable circumferential spray-quench nonuniformity and correspondent hardness deviation. Solution: Redesign the quenching device, making an attempt to cover as much of the workpiece surface as possible. In addition, try to change the rotation speed during spray quenching (for example, a 25% increase and then a 25% decrease) and compare results. Both insufficient rotation and excessive rotation could result in circumferential quench nonuniformity[1].

We are planning to use induction to heat composite metallic materials prior to diffusion bonding. Is there any concern with respect to excessive noise? Have you found that certain frequencies are noisier than others? If so, do you have a solution for containing the noise level?

Answer: In the vast majority of induction applications, noise does not reach an appreciable level. Therefore, there is no reason to be concerned about excessive noise, although there are a few exceptions. Lower frequencies typically result in higher coil current thus increasing electromagnetic forces and coil turn vibration. So, it is reasonable to expect that a system applying line frequency would be associated with a greater magnitude of industrial noise compared to 30 kHz. In addition, systems with a greater amount of kW most likely would also be associated with more noise. Therefore, assuming all other factors are identical, 500 kW can produce greater noise than 100 kW.

When discussing audible noise, we must bear in mind the two main factors that impact how humans are affected by industrial noise—magnitude and unpleasantness/discomfort level. For example, low frequency audible noise (e.g., 60 Hz) could have a higher magnitude, but it might not be as unpleasant to the human ear compared to a lower magnitude noise at an elevated frequency (e.g., 1 kHz).

Following are the four main sources of noise generation during induction heating:

- *Noise generated by the power supply*. Numerous power supplies are available on the market. For induction heating, power and frequency combinations that use single-module inverters vary from line frequency to several hundred kHz and power levels exceeding 1000 kW even for a frequency in the 800 kHz range. Design features of modern power sources based on semi-conductor technology result in nearly silent operation. Therefore, noise stemming from the power supply is not usually a concern.
- *Noise generated from vibration of copper coil turns*. The two main approaches to building induction coils for hot working can be categorized as either open-wound or refractory-encased [Ref. 1]. The open-wound method provides more convenient repair in the event of failure, but coil turns must be secured using studs and proper fixtures to eliminate or minimize vibration and noise. An encased coil using a castable refractory (for example, special grades of cement) offers durability and longer life, eliminating or dramatically reducing the vibration of coil copper turns. Properly designed coils do not exhibit problematic noise levels.
- *Noise generated by workpiece vibration or resonant sound waves (amplifying effect)*. If a workpiece consists of some loose parts, then they may vibrate and produce noise. To assess this possibility, the specific workpiece geometry would need to be reviewed. Pressure can be applied in certain diffusion bonding applications to minimize the possibility of individual component vibrations. When induction heating hollow workpieces (e.g., relatively thin-walled pipes or tubes positioned inside other tubes), certain frequencies in combination with sufficiently high power densities could emit resonant sound waves of an appreciable magnitude, exceeding the audible limit. In cases like this, audible noise can also be a dominant factor that greatly affects the selection of frequency. Each tube has its own structural resonant frequency (SRF), which

depends on the diameter, wall thickness, material, and other factors. When the electrical frequency of the induction coil is sufficiently close to the tube's own resonant frequency, then high amplitude vibration and excessive audible noise may occur. In other words, as a radio receiver transforms electromagnetic waves into an audible sound, somewhat similar mechanisms can occur that cause a tube or pipe to act as an amplifier when dealing with certain frequencies.

- A decision as to whether noise could be reduced by choosing a different (higher or lower) frequency depends on a combination of the structural self-resonant frequency (SRF) of a particular tubular workpiece and the applied electrical frequency. Therefore, in cases like this it is beneficial to measure the workpiece SRF by simply hitting it with a hammer and measuring the resonant audible noise with some kind of audible receiver with the ability to detect the frequency and amplitude of the measured signal. As a result, more intelligent decisions can be made in determining whether a certain frequency would improve the noise level or not compared to a frequency that produces unacceptable noise. For example, if the SRF of a certain workpiece is 300 Hz, then the further away the selected frequency is, the lower the noise that will be produced. In this case, 6 kHz would produce a noticeably lower noise compared to 1 kHz. In contrast, if the SRF is 5 kHz, then the use of 6 kHz will make it worse compared to 500 Hz. Many times, a protective or reducing atmosphere is used while heating metallic materials. Therefore, if your induction system will be located inside a gas-tight chamber/enclosure, this will substantially reduce the noise level.
- *Noise generated by vibration of power cables, buses, and fixtures*. There is a very small probability of using the wrong design of fixtures, power cables, and bus bars. However, any concerns may be addressed by an induction heating expert. **~HTPro**

Note: More answers to commonly raised questions can be found in Ref. 1.

For more information: All are welcome to send questions to Dr. Rudnev at rudnev@inductoheat.com. Selected questions will be answered in his column without identifying the writer unless specific permission is granted.

Reference

1. V. Rudnev, D. Loveless, and R. Cook, Handbook of Induction Heating, 2nd Edition, CRC Press, 2017.


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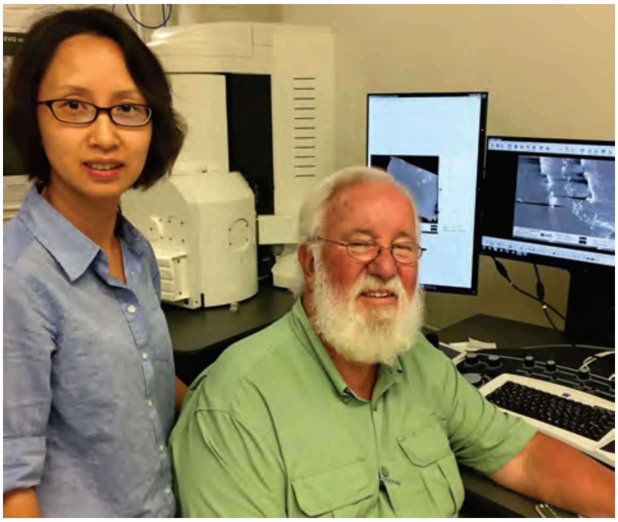
RESEARCHERS EXPLORE HEAT TREATMENT OF ADDITIVELY MANUFACTURED STEEL PARTS

Researchers at the Center for Heat Treating Excellence (CHTE) at Worcester Polytechnic Institute (WPI) are working with CHTE members to develop post-processing parameters to enhance the mechanical properties of additively manufactured (AM) steels.

CHTE's three-year project is focused on gaining a better understanding of how AM steel alloys respond during post-processing heat treatment such as normalizing, carburizing, and hardening. In their study, selective laser melting (SLM) is used to fabricate the AM parts. SLM, also known as direct metal laser melting, uses a laser as the power source to melt metallic powder successively, based on predesigned computer-aided specifications. This technique binds the material to create a solid structure.

Richard Sisson, CHTE's technical director and George F. Fuller professor of mechanical engineering, explains, "We are doing this research because we need to determine how to heat treat additively manufactured parts to achieve mechanical properties that are comparable or even better than heat treated, conventionally manufactured (wrought) parts."

This becomes incredibly important during critical operations like those being performed by the military, but it also applies to manufacturers everywhere. According to Mei Yang, assistant research professor on the project and associate technical director of CHTE, "Companies all over the world are interested in what impact additive manufacturing will have on their business. For some of our members, this research is an introduction to additive manufacturing and how it might help their business. For others who have already done major work in this field, it's an opportunity to learn more."



Mei Yang and Richard Sisson are working on groundbreaking research that will help heat treaters figure out how to additively manufacture steel parts to better specify post-processing parameters for superior performance.

TABLE 1 – SELECTED ALLOYS AND MATERIAL PROVIDERS

Alloy	Material provider		
	Powder	As-fabricated	Wrought
AISI 8620	Company A	Company A	Company A
20MnCr5	Company A	Company A	Company A
	Company B	Company B	Company B
AISI M2	Company B	Company B	Company A

RESEARCH OBJECTIVES

It is believed that the response of AM steel parts to heat treatment may be different from that of conventionally manufactured steel parts. As a result, CHTE researchers are working towards understanding the heat treatment process of AM steel parts so they can better determine the heat treatment process parameters. CHTE members and researchers selected three steel alloys to test. Alloys were selected based on their broad industry applications and mechanical properties. AISI 8620 and 20MnCr5 will be carburized, while AISI M2 will be quenched and tempered.

METHODOLOGY AND CURRENT RESEARCH

Selective laser melting is used to fabricate the additively manufactured AISI 8620 parts. The AM parts are carburized and compared to the properties of carburized wrought parts. Different defects may affect the properties after carburizing. Composition is measured by Optical Emission Spectroscopy (OES) and results are shown in Table 2.

The powder chemistry shown in Table 2 is from the powder certificate and the part chemistry is the average of five SLM parts. Carbon shows a decreases of 20% percent in the part compared with the carbon concentration in the powder. To verify decarburization of parts during SLM, the powder was sent to an independent testing laboratory for chemical analysis. Testing showed 0.244 wt% carbon concentration, which is in agreement with the carbon concentration from the powder certificate. Conclusion: Decarburization occurred during SLM.

TABLE 2 – CHEMISTRY COMPARISON BETWEEN POWDER AND PART FOR AISI 8620, WT%

	C	Cr	Mn	Mo	Ni	Si	P	S	Fe
Powder	0.24	0.6	0.9	0.21	0.6	0.3	0.009	0.005	Bal.
Part	0.192	0.59	0.86	0.21	0.66	0.276	0.0068	0.0032	Bal.

TABLE 3 – CHEMISTRY COMPARISON BETWEEN POWDER AND PART FOR 20MnCr5, WT%

	C	Cr	Mn	Si	P	S	Fe
Powder	0.17	1.2	1.2	0.31	0.0015	0.007	Bal.
Part	0.134	1.24	1.05	0.146	0.0036	0.0024	Bal.

Table 3 shows that decarburization also occurred during SLM for the 20MnCr5 component. In the part, carbon concentration is 0.134 wt%, which is out of specification. Therefore, the carbon concentration in the powder should be higher to compensate for the decarburization that occurs during the SLM process.

PRELIMINARY FINDINGS

The following results are based on characterization of AISI 8620 and 20MnCr5 powder, SLM parts, and wrought parts. Decarburization was observed during the SLM process. The carbon concentration in the powder should be higher to ensure the carbon concentration in the SLM parts. Both SLM and wrought parts show microhardness variations that may be related to residual stress, microstructure, or compositional variation. The average microhardness of the wrought part (HV 231 for AISI 8620, HV 186 for 20MnCr5) is much lower than that of the SLM part (HV 328 for AISI 8620, HV 331 for 20MnCr5). The microstructure of the SLM part is tempered martensite and retained austenite, while the microstructure of the wrought part is ferrite and pearlite.

Based on these preliminary findings, normalizing must be conducted before the carburizing process for both SLM and wrought parts. Normalizing will help to reduce the effects of the precarburizing condition. Different defects were found in the SLM and wrought parts. In SLM, part pores are the main defects, while in wrought parts inclusions are the main defects. Effects of different defects on the properties after carburizing need to be investigated.

NEXT STEPS

In the coming months, CHTE researchers will work to normalize and carburize AISI 8620 and 20MnCr5 SLM and wrought parts. The mechanical properties of carburized AISI 8620 and 20MnCr5 SLM parts will be compared with the carburized wrought parts separately. Expected completion of this three-year project is scheduled for late 2020. **~HTPro**

For more information: Visit www.wpi.edu/+chte or email Rick Sisson at sisson@wpi.edu.

ABOUT CHTE

The CHTE collaborative is an alliance between the industrial sector and university researchers to address short-term and long-term needs of the heat treating industry. Membership in CHTE is unique because members have a voice in selecting quality research projects that help them solve today's business challenges.

Research projects are member driven. Each project has a focus group comprising members who provide an industrial perspective. Members submit and vote on proposed ideas and three to four projects are funded each year. Companies also have the option of funding a sole-sponsored project. In addition, members own royalty-free intellectual property rights to precompetitive research and are trained on all research technology and software updates.

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

2017 Annual Report & Path Forward

LETTER FROM THE CHAIR

Dear Friends,

For the ASM Foundation, 2017 and 2018 have been about looking forward. As the board and staff have embarked on and worked through our strategic planning process, we have been energized by the possibilities before us to continue expanding our reach to K-12 students and teachers while continuing to provide scholarships and other opportunities for undergraduate students.

Because forward thinking has been such a big part of our past year, we are providing you with a slightly different annual report. In addition to the traditional retrospective of 2017, we are including a short prospective section on our plans for 2018 and beyond through a summary of our strategic plan.

Last year in this space, I pledged to ensure we had a sustainable business model for our programs and create a fundraising plan to support the programs now and into the future. Our strategic plan addresses both of those issues and provides promise for the Foundation's future. This is why I am so excited to share our plan with you. This is our blueprint for the next few years, which we will execute with your support and the volunteer leaders of our Foundation.

Sincerely,

Diran Apelian
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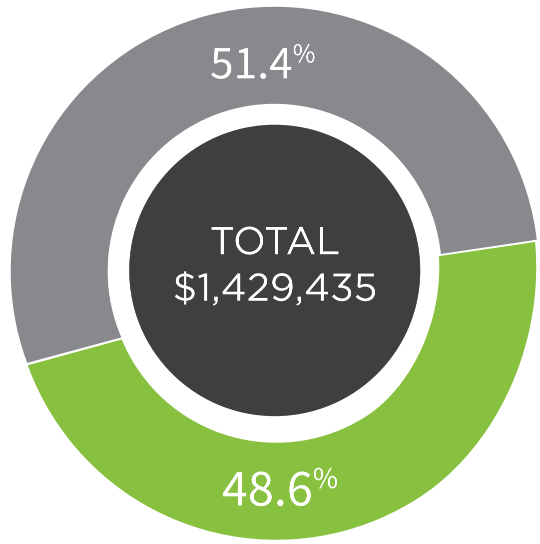
Mr. and Mrs. William A. Reich +
George A. Roberts +
Alton D. and Julie Romig
Karen Sabo
Dr. Frederick E. Schmidt
Lyle H. Schwartz and Celesta S. Jurkovich
Dr. William W. Scott, Jr. +
Roch J. Shipley
Jack and Ene + Simon
Edward E. Slowter +
Robert Sparks
Tom and Jan Stoebe
Dr. and Mrs. Carl E. Swartz +
R. C. Tucker, Jr., PhD, FASM
Julius L. Turk +
Mr. and Mrs. Kent R. Van Horn +
Dr. Christopher Viney and Dr. Lisa Gilliland-Viney
Dr. and Mrs. Charles A. Wert +

+ *Legacy Donors (Deceased)*

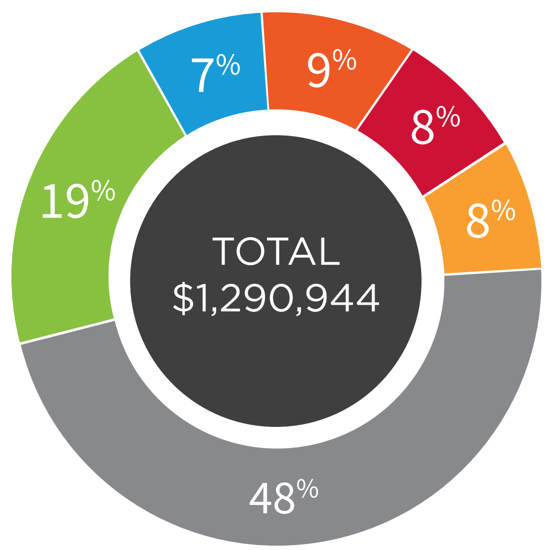
REVENUE

Contributions	($734,658)
Investment Income	($694,777)



EXPENSES

Materials Camps	($617,214)
Other Programs	($96,061)
Scholarships	($104,506)
Fundraising	($119,560)
Administrative	($248,184)
Governance	($105,419)



I truly loved this camp! I feel ***so inspired to teach*** this year because of it and feel like I have tools in my pocket to generate ***meaningful discussions*** and perform a spontaneous demo or lab anytime there are spare moments in class.

– Sarah Regli, St. John's Kilmarnock, Ontario, Canada

ASM MATERIALS EDUCATION FOUNDATION
STATEMENT OF FINANCIAL POSITION (PRE-AUDIT)
December 31, 2017

ASSETS

CURRENT ASSETS		
Cash and short-term investments	$	27,128
Accounts Receivable		
Receivables		89,241
Prepaids		39
TOTAL CURRENT ASSETS		**116,408**
Investments at market value		
CAMP 1 Funds (fixed interest)		96,143
CAMP 2 Funds (anchored to portfolio)		8,188
Balance of Funds		12,311,650
Total Portfolio At Market Value		**12,415,981**
Debt Owed by ASMI		140,774
Life Ins Cash Surrender Value		5,812
Fixed Assets – Fundraising Software		5,950
Accumulated Depreciation – Fundraising Software		(3,735)
		12,564,781
TOTAL ASSETS	**$**	**12,681,190**

LIABILITIES AND NET ASSETS

CURRENT LIABILITIES		
Accounts payable and accrued expenses	$	9,711
Borrowing under the line of credit		752,159
Debt Owed to ASMI		0
TOTAL CURRENT LIABILITIES		**761,870**
Long-Term Liabilities		
Restricted Foundation Funds		0
Deferred interest income		6,049
Net Assets		
Unrestricted Net Assets		895,824
Operating		138,491
Unrealized gain (loss) on investments		2,069,130
Total unrestricted net assets		3,103,446
Restricted New Assets		
Temporarily Restricted		1,207,630
Permanently Restricted (Adjusted)		1,055,079
Board Designated Restricted		6,547,117
Total Restricted Net Assets		8,809,825
Total Net Assets		11,913,270
TOTAL LIABILITIES & NET ASSETS	**$**	**12,681,190**

PROGRAMS

ASM Materials Education Foundation provides materials science educational methods and resources to excite future generations about STEM learning and careers.

K-12

Materials Camps® for Students

Through hands-on learning principles, the camps offer a unique, team-based, problem-solving experience that explores materials science and engineering principles for high school juniors and seniors.

Materials Discovery®

Middle school students explore physical science concepts while learning to draw conclusions and apply basic engineering principles, focusing on common materials such as metals, ceramics, polymers, and composites found in everyday life.

UNDERGRADUATE

Materials Genome Toolkit

US undergraduate engineering programs compete for one of four free three-year licenses for a cutting-edge materials design software and database package.

Undergraduate Design Competition

This competition recognizes materials and related engineering department design curricula by teams of undergraduate students submitting design-focused projects from capstone courses or team projects.

Undergraduate Scholarships

ASM Materials Education Foundation has awarded more than $1 million in scholarships since 1953, annually awarding over 20 scholarships to undergraduate and community college students.

> I cannot describe how grateful I am for this ***eye-opening*** *and* ***educational experience***. This camp was not only fun, but also ***helpful in deciding my future*** down the road. Thanks to you, I was able to attend.
>
> *– David Hale, Detroit, MI*

TEACHERS

Materials Camps® for Teachers

Professional development workshops for middle and high school teachers held throughout the US, Canada, and Brazil utilizing hands-on, minds-on activities to provide NGSS-Aligned content knowledge.

Living In A Material World: K-12 Teacher Grants

Grants awarded annually to help K-12 teachers bring the real world of materials science into their classrooms.

2018 - 2021 STRATEGIC PLAN

OUR FUTURE

The ASM Materials Education Foundation (the Foundation) is embarking on a new strategic plan through 2021. This plan lays the groundwork for expansion and enhancement of programming and products by putting the Foundation on solid footing through funding and staffing capacity. The Foundation will be expanding its ways of providing content to students and teachers in order to truly excite and inspire students. And, as always, the Foundation will continue to work together with ASM International to be sure our work is aligned and complementary.

The Foundation began in 1952, initiated by ASM International to distribute scholarships to students pursuing materials science majors and careers. The Foundation has been operating programming beyond scholarships since 2000, seeking to reach the greatest number of individuals possible. New ideas have sparked new programming throughout the past two decades, all using materials science to provide STEM education.

ASM Materials Education Foundation wants to see students get excited about all STEM subjects and see where their creativity can take them. Materials provide a theme for STEM education by tying together concepts from chemistry, physics, mathematics, life sciences, and engineering, as well as bridging the gap between abstract concepts and real-world experiences. The science and engineering of materials lends itself to hands-on learning with many engaging and low-cost demonstrations and experiments to bring active learning into the classroom.

All ASM programming can be seen as points on a continuum in sharing materials science with individuals along an age spectrum. While the Foundation provides information to students and their teachers in grades K-12, and sometimes 16, its parent organization, ASM International, provides information to college students and professionals in their materials science, engineering, and related careers. In this age of technology and information sharing, this strategic plan addresses the need for increased fundraising at the same time as exploring new ways to share the Foundation's incredible content, all with the goal to reach as many students as possible with the excitement of materials science as the gateway to STEM fields.

A wide variety of organizations now provide STEM programming in the K-12 space. One of the Foundation's strengths is the hands-on nature of the materials science curriculum for both students and their teachers. Throughout the duration of this strategic plan, the Foundation will further define our programming, its strengths and unique qualities, and how it impacts students.

One piece we are always looking to add to our work is YOU. We are happy to talk with YOU about how YOU can be a part of our progress. Open the door for the Foundation to potential funders. Provide funding yourself. Mentor teachers or students. Connect the Foundation to new ways of reaching students or teachers.

Thank YOU for all that you do for ASM International and the Foundation. We are excited to forge ahead in our new direction, with your support.

Carrie Wilson
Executive Director

2018 - 2021 STRATEGIC PLAN *(continued)*

VISION STATEMENT

A leading provider of inspirational materials science educational resources to excite future generations about STEM learning and careers.

MISSION STATEMENT

Develop and deploy materials science content and hands-on, minds-on instructional strategies to inspire, engage, and empower future generations to create STEM solutions for 21st century challenges.

Initiative I

Improve fundraising methods and results

Goal A Develop and utilize board participation structure to make contact with individual and corporate prospects and donors

Goal B Increase the number of personal contacts with donors and prospects made by both board and staff

Goal C Develop improved materials and mailings

Initiative II

Create staffing plan through 2022

Goal A Determine full scope of needs for Foundation and how to best serve those needs

Goal B Create plan for transitioning away from current staff retiring and develop new position(s) to support current and anticipated future needs

Initiative III

Become a premier source of Materials Science education through a comprehensive continuum of resources across K-16, consisting of in-school and out-of-school resources

Goal A Strong Data Collection and Evaluation processes in place across all programs

Goal B All curriculum for camps and training, as well as classroom resources is copyrighted/owned by ASM MEF

Goal C Develop teacher camps and Materials Discovery program models into a more cohesive program of training education providers through different venues and at different grade bands

Goal D Ensure that all program models are able to serve underrepresented groups and expand focus to ensure those students are being reached

Goal E Seek opportunities for programming to produce revenue to help offset program costs

Goal F Explore possible partnerships with organizations serving complementary missions

Initiative IV

Improve cooperation and connection with ASMI board, HQ staff, and ASM chapter members

- **Goal A** Develop ways for ASM chapter members to connect with ASM MEF programs (mentoring teachers and students through new Materials Camp model)
- **Goal B** Continue to improve communication with ASM chapter members through a variety of methods
- **Goal C** Continue to work with ASMI staff on joint projects
- **Goal D** Expand communications with ASMI and affiliate boards to increase awareness of ASM MEF programs to benefit programs and fundraising through increased participation
- **Goal E** Assist ASMI in crafting ASMI – ASM MEF master service agreement

www.asmfoundation.org

440.338.5151

ASM Materials Education Foundation
9639 Kinsman Road
Materials Park, OH 44073-0002

ASM MATERIALS EDUCATION FOUNDATION

ASMNEWS

ASM Announces 2018 Class of Fellows

In 1969, ASM established the Fellow of the Society honor to provide recognition to members for their distinguished contributions to materials science and engineering and to develop a broadly based forum of technical and professional leaders to serve as advisors to the society. Following are the members recognized by their colleagues for 2018. Additional Fellows may be elected to this distinguished body in subsequent years. The solicited guidance, which the Fellows will provide, will enhance the capability of ASM as a technical community of materials science and engineering in the years ahead. Awards will be presented at ASM's annual Awards Dinner, Tuesday, October 16, in Columbus, Ohio, during Materials Science & Technology 2018.

Mr. Daniel J. Benac, FASM
Senior Principal Engineer
BakerRisk Engineering and Risk Consultants, San Antonio

In recognition of a distinguished career dedicated to investigating failures of components and understanding materials issues for diverse industries worldwide, including the aerospace, nuclear, refining and chemical industries, and for educating and mentoring students and professionals to prevent failures.

Dr. James M. Boileau, FASM
Technical Expert and Group Leader
Ford Motor Co., Novi, Mich.

For the research and implementation of lightweight metals for automotive applications, including innovations in aluminum casting technology and life prediction. His technical contributions spanned applications in engines, drivetrains, and brakes where his innovative approach resulted in the implementation of improved processes and products.

Prof. Susmita Bose, FASM
Herman and Brita Lindholm Endowed Chair Professor
Washington State University, Pullman

For significant contribution in materials science and engineering involving interdisciplinary research towards biomaterials, additive manufacturing, advanced ceramic materials, and mentoring of graduate and undergraduate students.

Mr. Michael K. Budinski, FASM
Chief, Materials Laboratory
National Transportation Safety Board, Washington

For contributions in making materials science and related technologies a fundamental part of the failure analysis processes in manufacturing, infrastructure, and transportation.

Prof. Amy J. Clarke, FASM
Associate Professor
Metallurgical and Materials Engineering
Colorado School of Mines, Golden

For broad, transformational contributions to metallurgical and materials engineering in steels, non-ferrous alloys, and in situ imaging of metals processing.

Dr. Dale A. Gerard, FASM
Senior Manager, Materials Engineering
General Motors, Pontiac, Mich.

For leadership and mentoring of global teams, impacting numerous materials technologies across the automotive community through the institutionalization of ICME and lean engineering principles to create customer-optimized solutions.

In This Issue

ASM INTERNATIONAL

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

HIGHLIGHTS 2018 CLASS OF FELLOWS

Mr. Michael C. Halbig, FASM
Materials Research Engineer
NASA Glenn Research Center, Cleveland

For sustained contributions and leadership in advancing the field of non-oxide ceramics, composites, and additively manufactured materials and related systems for high temperature aerospace and energy applications.

Prof. Robert W. Hyers, FASM
Professor
Mechanical and Industrial Engineering
University of Massachusetts, Amherst

For distinguished contributions in the field of high-temperature materials processing and properties, with proven applications of these technologies in aerospace and extractive industries.

Mr. William J. Jarosinski, FASM
Associate Director, Materials
Praxair Surface Technologies Inc., Indianapolis

For recognition of continuous development of advanced powder processing technologies and coating solutions for enhanced wear and corrosion resistance throughout numerous industries.

Mr. Roger A. Jones, FASM
CEO
Solar Atmospheres Group, Souderton, Pa.

For advancing production of vacuum thermal processes and procedures for large and heavy assemblies utilizing state-of-the-art vacuum furnaces, for the enhancement of the overall heat treating industry.

Dr. M. Kamaraj, FASM
Professor
Metallurgical and Materials Engineering
Indian Institute of Technology Madras

For significant contributions to the understanding of tribological behavior of surface coatings and development of wear resistant coatings for hydropower turbine blades, bio-implants, and dissimilar joints for automobiles.

Prof. Ibrahim Karaman, FASM
Chevron Professor and Head
Department of Materials Science and Engineering
Texas A&M University, College Station

For contributions to the understanding of structure-property-processing relationships in ferromagnetic shape memory alloys and ultrafine-grained materials, shape memory alloy materials for extreme environment applications, and microstructure engineering through severe plastic deformation.

Prof. Changhee Lee, FASM
Professor
Division of Materials Science and Engineering
Hanyang University, Seoul, South Korea

For remarkable contributions to scholarly development of welding and spray technology through his innovative research, published papers, and academic activities in ASM International.

Dr. Michael R. Mitchell, FASM
President
Mechanics & Materials Consulting LLC, Flagstaff, Ariz.

In recognition as an international leader in the areas of research, development, and education in the fatigue and fracture behavior of materials for ground vehicles, aerospace systems, and medical devices.

Prof. Frank Mücklich, FASM
Director, Materials Engineering Center
Saarland University, Germany

For his expertise in the theory of 3D microstructure research and technology contributions to the field.

Prof. G. Robert Odette, FASM
Distinguished Professor
Mechanical Engineering
University of California, Santa Barbara

For excellence and sustained seminal contributions to measuring, modeling, and managing irradiation effects in structural materials for nuclear energy applications and related areas of materials science.

Prof. Eugene A. Olevsky, FASM
Dean and Distinguished Professor
College of Engineering
San Diego State University

For outstanding contributions to materials engineering education and sintering research including the development of the continuum theory of sintering and fundamental studies of field-assisted powder consolidation technologies.

Mr. Udayan Pathak, FASM
Deputy General Manager
Engineering Research Centre
Tata Motors Limited, India

For developing innovative solutions that achieve significant cost savings and sustainability in materials and processes for automotive applications and for attracting and mentoring young minds to pursue careers in materials engineering.

Prof. Mark E. Schlesinger, FASM
Professor of Metallurgical Engineering
Missouri University of Science and Technology, Rolla

For contributions in metallurgical engineering education, analysis of phase equilibria, and promotion of recycling and professional registration of materials engineers.

Mrs. Beth Matlock Snipes, FASM
Senior Materials Engineer
TEC Materials Testing, Knoxville, Tenn.

For developing x-ray diffraction systems with improved resolution and portability for residual stress and retained austenite measurements.

Prof. Katsuyo Thornton, FASM
L.H. and F.E. Van Vlack Professor
University of Michigan, Ann Arbor

For groundbreaking contributions to the science of phase transformations, significant impact on the K-12 community by training educators in materials science and engineering curricula, and leadership in broadening participation in ICME.

Prof. Sammy Tin, FASM
Professor of Materials Engineering
Illinois Institute of Technology, Chicago

For distinguished contributions to the physical metallurgy of advanced single crystal and polycrystalline Ni-base superalloys.

Dr. Mark Tschopp, FASM
Regional Lead, ARL Central
U.S. Army Research Laboratory, Chicago

For distinguished and sustained contributions in computational materials science, solid mechanics, processing-structure-property relationships, and materials design for ICME leading to accelerated discovery and practical application.

Dr. Erhan Ulvan, FASM
Manager - Engineering, Field Engineering Services and Laboratories
Acuren Group, Ontario, Canada

For outstanding expertise and impact in failure analysis, forensic engineering, nondestructive testing, and materials engineering services, along with education of students and the materials community in these fields.

Prof. Christopher M. Wolverton, FASM
Jerome B. Cohen Professor of Materials Science and Engineering
Northwestern University, Evanston, Ill.

For innovative development and use of first principle atomistic and multiscale computational techniques that led to the use of density functional theory and statistical mechanics approaches, including predicting the stability of phases and evolution of microstructure in metals and the design of materials for energy applications.

HIGHLIGHTS NOMINATION DEADLINES

Dr. Dehua Yang, FASM
President
Ebatco, Eden Prairie, Minn.

For distinct and significant impacts on cutting edge nanotechnology applications, including nanoscale materials testing and characterization.

Dr. Linruo Zhao, FASM
Principal Research Officer
National Research Council of Canada, Ontario

For outstanding contributions to aerospace materials research and development in Canada and for providing leadership in championing the objectives and programs of ASM International.

ASM Nominating Committee Nominations Due

ASM International is seeking members to serve on the 2019 ASM Nominating Committee. The committee will select a nominee for 2019-2020 vice president (who will serve as president in 2020-2021) 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 440.338.5151 or leslie.taylor@asminternational.org, or visit asminternational.org/about/governance/nominating-committee.

Official ASM Annual Business Meeting Notice

The Annual Business Meeting of members of ASM International will be held in conjunction with MS&T18 on:

Monday, October 15

4:00 - 5:00 p.m.

Hyatt Regency Columbus

The purpose of the ASM Annual Business Meeting is the election of officers for the 2018-19 term and transaction of other Society business.

Nomination Deadline for the 2019 Class of Fellows is Fast Approaching

The honor of Fellow of the Society was established to provide recognition to ASM members for distinguished contributions in the field of materials science and engineering, and to develop a broadly based forum for technical and professional leaders to serve as advisors to the Society.

Criteria for the Fellow award include:

- Outstanding accomplishments in materials science or engineering
- Broad and productive achievement in production, manufacturing, management, design, development, research, or education
- Five years of current, continuous membership

Deadline for nominations for the class of 2019 is **November 30, 2018.** To nominate someone, visit the ASM website to request a unique nomination form link. Rules and past recipients are available at asminternational.org/membership/awards/asm-fellows or by contacting Christine Hoover, 440.338.5151 or christine.hoover@asminternational.org.

NOMINATIONS NEEDED FOR 2019 ASM/TMS DISTINGUISHED LECTURESHIP IN MATERIALS & SOCIETY

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

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

Nominations may be proposed by any member of either Society. Submit your nominations by September 15 for consideration. Recommendations should be submitted to the headquarters of either Society.

View sample forms, rules, and past recipients at http://www.asminternational.org/membership/awards/nominate. To nominate someone for this award, contact christine.hoover@asminternational.org for a unique nomination link. You may also contact Deborah Hixon at TMS Headquarters, hixon@tms.org.

ASM Indian Institute of Metals Announces Recipients of 2018 ASM/IIM Visiting Lectureship

The cooperative Visiting Lecturer program of ASM International and the Indian Institute of Metals (IIM) is pleased to announce the individuals named to participate in the 2018 Visiting Lecturer program: Prof. Pierpaolo Carlone, University of Salerno, Italy, and Dr. Veronique Vitry, UMONS, Belgium. The award includes an $800 honorarium to be used for travel expenses within India during the lecturer's visit. ASM is also pleased to announce the distinguished individuals who have been named to participate in the 2018 ASM/IIM Visiting Lecturer North American Program: Prof. Kantesh Balani, Indian Institute of Technology, Howrah, and Dr. Chiradeep Ghosh, Indian Institute of Engineering, Science, and Technology, Howrah. The award includes a $2000 honorarium to be used for travel expenses within the U.S. and Canada during the lecturer's visit. All recipients will receive a certificate of recognition to be presented at the ASM Leadership Awards Luncheon scheduled for October 15 in Columbus during MS&T18.

Carlone

Vitry

Balani

Ghosh

CEO CORNER

Impact Factors on the Rise for ASM Journals

Mahoney

Over the past few months, this column has focused on new developments taking place at ASM, including our Digital Transformation initiative, content reengineering work, and our Materials Solutions Network, all under the ASM Renewal. Along with the focus on these new endeavors, I am pleased to inform you that many of our traditional offerings are also growing, both in terms of revenue and market impact. One of these business lines is our journal program.

Taken as a group, ASM journals continue to be a reliable, multimillion dollar annual business. Our download numbers are steadily rising from month-to-month and year-over-year, thereby growing revenues. Perhaps more importantly, the impact factors for ASM journals and the journals we cooperatively produce with other societies are increasing. The chart shows impact factors for the respective journals from 2015 through 2017 (the latest year on record).

The business and market impact record for ASM journals is an important dataset for our members to consider when seeking publication of research results and technical communications. ASM journals remain a key resource for members, particularly from the academic and government segments of our Society. By publishing in ASM journals, you can be assured of both widespread exposure and excellent technical quality. These continuous improvements in journals are emblematic of the entire ASM Renewal.

ASM JOURNALS: IMPACT FACTORS

Journal Title	2015	2016	2017
International Materials Reviews*	7.914	8.605	12.703
Journal of Materials Engineering and Performance	1.094	1.331	1.340
Journal of Phase Equilibria and Diffusion	0.784	0.938	1.315
Journal of Thermal Spray Technology	1.568	1.488	1.949
Metallurgical and Materials Transactions A**	1.749	1.874	1.887
Metallurgical and Materials Transactions B**	1.474	1.642	1.834

*Co-owned with Institute of Materials, Minerals and Mining (IOM3)
**Co-owned with The Minerals, Metals & Materials Society (TMS)

In that vein, please let me know how I may be of improved service to you.

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

SMST Founders' Grant Open for Applications

The International Organization on Shape Memory and Superelastic Technologies (SMST), an affiliate society of ASM International, is seeking applications for the 2019 SMST Founders' Grant. The intent of the grant is to provide funding for early, exploratory research related to shape memory and superelasticity. It is expected that the funds will be used as a seed grant, to test a concept and lay a foundation for obtaining further funding from industry or government agencies. The award, which is financially funded in 2019 by Dr. T.W. Duerig, includes a stipend up to $50,000. Deadline to apply is **January 11, 2019.** For more information, visit asminternational.org/web/smst/smst-fellowship or contact carrie.wilson@asminternational.org.

Thermal Spray Hall of Fame Seeks Nominations

The Thermal Spray Hall of Fame, established in 1993 by the Thermal Spray Society of ASM International, recognizes and honors outstanding leaders who have made significant contributions to the science, technology, practice, education, management, and advancement of thermal spray.

For a copy of the rules, nomination form, and list of previous recipients, visit tss.asminternational.org or contact maryanne.jerson@asminternational.org. Nominations are due **September 30, 2018,** for recognition in 2019.

FAS & IMS Programming at MS&T18

Two of ASM's affiliate societies have taken their technical programming to MS&T. Both the International Metallographic Society (IMS) and the Failure Analysis Society (FAS) have chosen the October event in Columbus as the place to network with colleagues and learn about the latest developments in their fields.

The IMS Programming Committee, chaired by Dan Dennies, FASM, planned a symposium that spans four days: The IMS Symposium on Metallography and Microstructural Characterization of Materials and the Correlation of Microstructure to Mechanical Properties. The Tuesday afternoon session kicks off with the Henry Clifton Sorby Lecture on "Summary of Analysis of Human and Methodological Factors Affecting the Accuracy and Precision of Quantitative Descriptions of the Microstructure of Materials."

The FAS Programming Committee, chaired by Andrew Havics, organized three symposia: Characterization & Methods in Failure Analysis, Manufacturing-Related Failures, and User-Related Failures.

In addition, the two societies organized a joint session on Thursday morning, October 17, called FAS-IMS Failure Analysis Applications of Microanalysis, Microscopy, Metallography & Fractography.

Visit matscitech.org to learn more.

Cwajna Named 2018 Sorby Lecturer

Cwajna

Professor Jan Ludwick Cwajna has been named the 2018 IMS Henry Clifton Sorby Lecturer. Cwajna is from the Silesian University of Technology, Poland. He is currently on the faculty in the materials engineering and metallurgy department, having previously served as chief of the division of stereology and modeling. He was also head of the division of materials characterization for over 30 years. Cwajna cofounded the Polish Society for Stereology and served as its president and as a board member. In addition, he has been a member of the International Advisory Board of the IMS journal *Materials Characterization.* He is currently secretary of the Committee of Materials Science of the Polish Academia of Sciences and a member of the International Society for Stereology. Cwajna has published over 200 papers and received numerous awards in his country, including the Silver Badge of Honor for Development of Katowice Province (1976) and the Gold Order of Merit in 2004.

Szczotok

The Sorby Lecture will be presented by Prof. Agnieszka Szczotok on his behalf during MS&T in Columbus, Ohio, on Tuesday, October 16, 2:00 to 3:00 p.m. at the Greater Columbus Convention Center. The title of Cwajna's talk is "Summary of Analysis of Human and Methodological Factors Affecting the Accuracy and Precision of Quantitative Descriptions of the Microstructure of Materials."

The Sorby Award is presented annually in recognition of lifetime achievement in the field of metallurgy. Recipients are acknowledged for 25 years or more of dedication to research, teaching, and/or laboratory sales and service.

International Metallographic Contest at MS&T

Deadline: October 2

The International Metallographic Contest (IMC), an annual contest cosponsored by the International Metallographic Society (IMS) and ASM International to advance the science of microstructural analysis, will again be held at MS&T in Columbus, Ohio, October 14-18. Five different classes of competition cover all fields of optical and electron microscopy. Best-In-Show receives the most prestigious award available in the field of metallography, the Jacquet-Lucas Award, which includes a cash prize of $3000. For a complete description of the rules, tips for creating a winning entry, and judging guidelines, visit ims.asminternational.org.

Emerging Professionals: Prepare for MS&T18

Hello emerging professionals! It is almost time for the annual MS&T Conference, which will be held in beautiful Columbus, Ohio, from October 14-18. The Emerging Professionals Committee (EPC) has curated a broad range of abstracts for the annual Perspectives for Emerging Materials Professionals symposium on Monday. The morning session will focus on introductions to a variety of career paths in the academic, industrial, and government sectors, including a presentation from ASM's incoming president, David Furrer, FASM, followed by a panel discussion. The afternoon session will focus on other topics of interest to emerging professionals such as international experiences, leadership development, and mentoring.

Along with the EPC symposium, MS&T18 will be full of excellent content across the entire spectrum of materials science and engineering. Register before September 12 for the early bird rate and check the website for hotel information. I look forward to seeing you in Columbus.

Andrew Frerichs
Emerging Professionals Committee Symposium Chair

MeTeDa Plenary/CEN Workshop: Digital Infrastructure Project Explores Advanced Structural Materials

An international group of organizations—including Oak Ridge National Laboratory, the Electric Power Research Institute, the European Commission Joint Research Center for Energy and Transport, and ASM International—is working together on a project to build a digital infrastructure for mechanical testing data (MeTeDa). The project consists of developing standard data formats for uniaxial creep, fatigue, creep crack growth, and creep-fatigue crack growth test data. The team is now working with data generated by the nuclear energy industry, but would like to broaden the scope of its efforts to include data from other industries. MeTeDa is an outgrowth of the DOE International Nuclear Energy Research Initiative (I-NERI). Test data is of particular interest and has been the focus of several European Committee for Standardization (CEN) workshops, which have produced data formats for ambient temperature uniaxial tensile testing, materials pedigree, and fatigue testing (FaTeDa). The organizations involved in the MeTeDa project intend to extend this work and would like to reach the manufacturing, standards, and testing communities. The final plenary session of this workshop will take place at MS&T18 in Columbus, Ohio, on October 17, 8:00 a.m.-1:00 p.m. at the Hyatt Regency, Marion room. For more information visit cen.eu/work/areas/ICT/eBusiness/Pages/WS-METEDA.aspx or contact Afina Lupulescu, afina.lupulescu@asminternational.org.

ASM Launches New Digital Course: Materials Characterization and the Selection Process

Learn materials science in a new way—on your computer, tablet, or smartphone—within a completely digital environment, on your own schedule. ASM just launched a new, highly interactive digital course format that makes it easier to comprehend, retain, and apply new concepts. The newest digital course module, "Materials Characterization and the Selection Process," is now available.

Selecting a material is one of the most critical design decisions an engineer can make. Compromises and tradeoffs among various design variables are routinely made and factors that are important in one system may be insignificant in another. In this self-guided digital course, students will learn—with the help of rich visuals, narrated animations, demonstration videos, and interactive quizzes—how to evaluate the various factors that impact material selection for component design. The course includes real-world case studies in materials selection for different products, based on their design specifications. For more information on course registration and other details, visit bit.ly/2L4HIKg or contact John Cerne at john.cerne@asminternational.org.

Screenshot from "Materials Characterization and the Selection Process" module.

ASM CHAPTER HONOR ROLL

The ASM Volunteerism Committee proudly announces the 2018 Chapter Volunteer Honor Roll recognizing individuals whose performance is exemplary and essential for ASM's success. All Chapters were invited to nominate members who serve as volunteers in an ongoing capacity. Submissions for the 2019 Honor Roll will open in March. Join us in recognizing the following 2018 Chapter Honor Roll volunteers.

Akron Chapter

Robert Shemenski, FASM, an integral part of the Akron Chapter, has served on the ASM executive committee as education chair. A 68-year member of ASM, Shemenski has procured funding for Teacher Camps for 11 years. He raised additional funds by teaching an ASM-based course in "Practical Metallurgy" locally. He also has been a speaker at chapter meetings and a judge at the Western Reserve Regional Science Fair.

Albuquerque Chapter

Deidre Hirschfeld worked diligently to sort out the abandoned account for a regional conference, which was historically managed by a group of professional societies. This required working with various banks, understanding IRS regulations, and gathering information from those previously involved. Going above and beyond her normal duties as ASM treasurer, this work helps ensure that the conference can continue in future years with its finances in order.

Boston Chapter

The team of **Patrick Hogan, Jon Trenkle, Robb Westby, Chris Craven,** and **Jim Ritchey** is recognized for tirelessly managing the Boston Chapter's Materials Experience for high school students for many years. They organize the planning meetings, flyers, online application process, learning modules, commemorative T-shirts, food and beverage, and make sure the participants learn and have fun. Everything works seamlessly because of this team's efforts.

Santosh Jha is affectionately known as the Chapter's treasurer-for-life since he is unanimously nominated each year for the position. The Chapter's financial picture is strong due to his active management of investments and steady management of registrations and funds for monthly events. Jha served as Chapter chair in 2007-2008 and is keeper of Chapter traditions. He also makes sure Chapter meetings run properly and adhere to the bylaws.

Central Florida

Steve Florczyk is recognized for his contributions to rejuvenating the Central Florida Chapter. He was the Chapter chair from 2015-2017 and guided the Chapter through the rejuvenation process. He also conducted several Chapter meetings with a variety of speakers and developed the virtual poster contest competition for the Chapter. Florczyk also serves as the Chapter's web administrator.

Chennai Chapter

V.P. Parthasarathy is known for his knowledge of industrial metallurgy and best practices. He conducts Chapter workshops, seminars, and student outreach programs. As chair of the technical program, he drafted the curriculum and organized metallurgy and materials science training programs for academics, industry professionals, and students. He also mentors the core committee and inspires young team members with his professional and energetic volunteering style.

Chicago Regional Chapter

Guiru Nash Liu is known for her support of the ASM Materials Camp programs in the Chicago area. With her leadership and perserverance, the Chicago Chapter has been a stellar supporter of the ASM Foundation's STEM outreach activities (over $80K in contributions for Teacher and Student Camps in 2017). Liu has been an officer of the Chapter for many years in various roles.

Tom Kozmel has been a long-time volunteer for the Chicago Regional Chapter, starting as a university liaison in 2012 and becoming Chapter chair in 2015. He continues to volunteer as an officer, currently serving as Education chair. His support for education-focused events is longstanding, as he is a fixture of the ASM Student Camps in the Chicagoland area, having served as coordinator for several years.

Cleveland Chapter

Roseanne Brunello-McCay hosted the golf tournament for the Cleveland Chapter and organized the formation of a Material Advantage Chapter at Cleveland State University. Brunello-McCay also was the recipient of the 2018 President's Award issued by the ASM Cleveland Chapter.

Detroit Chapter

Dave Masha is a regular at Detroit Chapter meetings going back to 2008. He is the unofficial Chapter photographer, where he does a great job of documenting the people, speakers, and awardees at all of the meetings. At Chapter events, Masha helps with registration and check-in, and greets each attendee with a smile and cheerful comment. He is an outstanding point of contact for the Detroit Chapter.

Eastern Virginia Chapter

Donald Geisler has been an active member of ASM since 1962. He is currently treasurer for the Eastern VA Chapter, serving in that capacity for more than five years.

He completes monthly reports and submits annual reports to ASM headquarters. Geisler has held all of the executive positions over the years. His 56 years of service has benefitted the Society immensely.

Fort Wayne Chapter

Leigh Chen is nominated for his strong leadership in motivating Chapter members, initiating various activities, and expanding outreach to other chapters. **Mort Schaffer** is recognized for devoting his time and effort to high school Teachers Materials Camps for several years. **David Snice** is nominated for his constant service to the Fort Wayne Chapter for more than seven years, previously as treasurer and currently as vice chair.

Houston Chapter

Ken Heil is the treasurer for the Houston Chapter and has accomplished the job with discipline and effectiveness. In addition to maintaining financial details for all Chapter events, he initiates new executive committee members and trains subcommittees to be accountable to their budgets. He also volunteered to serve as webmaster, helping the Chapter realize significant savings. Heil brings energy and a sense of responsibility to his role.

North Texas Chapter

Arun Kumar has served as the North Texas Chapter chair since 2012. He organizes most of the monthly technical meetings and tours including the yearly North Texas ASM Chapter Inter-University Materials Science and Engineering Symposium. During this meeting, college students present research papers and the Chapter awards scholarship money to the first, second, and third place winners.

Ontario Chapter (GTA)

Casey Julich-Trojan is a passionate and dedicated volunteer for the ASM Ontario Chapter. The executive team downsized this year, but she stepped up to help provide members with a successful event season. This is her second year as vice chair and she has done a fantastic job organizing local and international speakers, as well as coming up with ideas for less conventional events such as glassblowing.

Danielle DeRango is in her first year on the Ontario Chapter's executive team, serving as communications officer. She creates engaging emails and write-ups for the Chapter's monthly events. She also serves as the ASM Ontario graduate school representative for McMaster University to help attract more teachers and fellow students. DeRango does an excellent job of increasing ASM awareness at the school and bringing new faces to Chapter events.

Orange Coast Chapter

Janin Kardokus championed the first ever Student Materials Camp for the Orange Coast Chapter.

Ottawa Valley Chapter

Qi Yang has been serving the Ottawa Valley Chapter in various capacities for many years. He is enthusiastic, energetic, and effective in organizing chapter technical meetings, fundraising, and interactions with university/college students. His contributions have made a significant impact on the continuing success of the Chapter.

Philadelphia Chapter

Tim Steber has held several committee chair positions for the ASM Philadelphia Chapter through the years, including director and all other executive chair positions leading up to becoming the 2008-2009 Chapter chair. He has attended and supported ASM Leadership Days for years and is currently the region's Chapter Council. In addition, Steber has accepted the responsibility of becoming the chair of Chapter Council for ASM nationally.

Puget Sound Chapter

Mary Davis has been a stalwart member of the Puget Sound Chapter for more than 20 years. She joined the Chapter board in 1999, quickly moved to secretary, and progressed through to vice chair and chair. For the past 12 years, Davis has been the Chapter treasurer and main events coordinator. She does an outstanding job and excels at ensuring the Chapter's financial viability.

San Diego Chapter

Robert Klug is a constant source of energy and enthusiasm. Past positions he has held in the San Diego Chapter include chair and vice chair. In his current role as Chapter secretary, Klug sends out newsletters and event reminders to Chapter members. In addition, he is involved in organizing and planning monthly meetings, community outreach initiatives, and educational events. Klug's commitment is unwavering and inspiring.

Warren Chapter

Richard James Polenick has held the official title of Chapter secretary for 25-plus years, but he is also Mr. Everything ASM. If not for him, the Chapter likely would have folded years ago. He negotiates meeting locations, finds speakers, emcees the meetings, organizes supporting functions, completes Chapter reports, and frequently attends Leadership Days. The executive committee hopes Polenick will continue his volunteering tradition for many years.

West Michigan Chapter

Debbie Aliya is much more than an integral part of the Chapter. She works hard to make sure the meeting venue is ready, speaker biography is submitted, flyer is created and ready for distribution, social sponsor is secured, and many more tasks too numerous to count. The Chapter chair relies on her a great deal. Without Aliya's efforts, the Chapter would not be in its current healthy position.

WOMEN IN ENGINEERING

This profile series introduces leading materials scientists from around the world who happen to be females. Here we speak with ***Karly Chester Etzel,*** *quality assurance coordinator at PiSA BioPharm Inc.*

Etzel

What part of your job do you like most?

The part of my job I like the most is the same thing I love about materials engineering. I love stepping into a puzzle in the middle and figuring out what's happening and how to solve it. I like researching the different aspects or characteristics of the problem and fitting them all together to help find a solution. I always feel like I am stepping into the middle of a problem with materials because you never start with nothing.

What attracted you to engineering?

I am fortunate to have grown up with engineering as the family profession, as my mother, grandfather, and great-grandfather were all civil engineers. However, I wasn't interested in building structures or exposed to other types of engineering. After pursuing different options in community college, I returned to engineering because I missed the challenge math and science gave me in high school. My community college advisor was a female mechanical engineer. She introduced me to other engineering disciplines, which reopened that door for me. I eventually chose materials engineering because of its role in the forefront of technology. You can only redesign something so many times until you must make a better material for the job.

Did you ever consider doing something else with your life besides engineering?

Yes, I wanted to be an international business lawyer. I was able to take a few law courses while studying for my master's and it was great. I really enjoy law and the problem-solving that goes into it, but I don't enjoy legal writing. It was incredibly difficult for me to thoroughly explain the assumptions made when arguing a legal position. I understand the need and usefulness of it as it pertains to law, but coming from engineering where you get to list the assumptions as givens, it was incredibly tedious.

What are you working on now?

I'm currently working on implementing a quality management system (QMS) for a company in an FDA regulated industry. Working for a start-up means I have the wonderful opportunity to have a real, tangible impact on how the business operates and ensuring the product we're creating is safe for our end users. Creating a QMS is a giant puzzle. I use the same strategies I learned studying materials as I do solving a QMS puzzle.

If a young person approached you for career advice about pursuing engineering, what would you tell them?

I would tell them that engineering is a great field with a lot of opportunities. I would encourage them to attend engineering camps and interview engineers in various disciplines to obtain a better understanding of all of the different types of engineering. Having grown up with civil engineers, I didn't think it was the right path for me until I started exploring other engineering disciplines than the big three. I would also encourage them to get an internship as soon as possible. I think having hands-on, real-world learning is invaluable for determining if engineering is the right choice.

Hobbies?

Traveling, board games, and knitting.

Last book read?

"The Truth" by Terry Pratchett.

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

ASM Women in Materials Engineering Breakfast
Monday, October 15, 7:00 - 9:00 a.m.
MS&T18 • Hyatt Regency Columbus

Learn how to develop and share your success story in this interactive workshop. A group of expert panelists will describe how to develop your unique story, promote your successes, and apply these skills to further your career. This is a ticketed event so please be sure to register at matscitech.org.

For more information on the Women in Materials Engineering committee invitation, please visit our website, asminternational.org/committee/women-in-engineering-committee.

CHAPTERS IN THE NEWS

Ravindran Visits ASM Chapters in India

ASM Past President Ravi Ravindran, FASM, recently visited the ASM New Delhi Chapter, ASM Chennai Chapter, and the ASM India Chapter for interactive town hall meetings and dynamic discussions of the India Task Force Report. These meetings are part of an ongoing dialogue with the stakeholders of the ASM plan for improving membership, chapters, and student engagement, and also enhancing overall service to the materials community in India.

Ravindran met with the executives of the newest ASM Chapter in India, the New Delhi Chapter, on June 7. From left: Ajay Tiwari, P.K. Pankaj, Anil Kumar, N. Poojari, Ravi Ravindran, Sanjay Jain, K.K. Dixit, Arun Kapoor, and Jaisimha Pai.

Visiting the Chennai Chapter at the Hotel JP on June 16, Ravindran met with several participants. From left: Srinivasa Rao Bakshi, V.P. Parthasarathi, Prof. Kamaraj, V.L. Sridharan, Ravi Ravindran, Sankar Subbarathinam, T. Sundararajan, N. Sampathkumar, and R.J. Venkatesh.

The third leg of Ravindran's trip was a meeting at the office of the ASM India Chapter on June 25. Chapter leaders, from left: Jayesh Mukadam, A.K. Tiwari, V.R. Altekar, R.K. Mujumdar, H.M. Mehta, Ravi Ravindran, S.S. Sabnis, Sudhakar Bonde, Prem Aurora, and Yatin Shah.

Minnesota Holds 12th Student Camp

Mentors along with the 2018 graduating class of the Minnesota Student Camp capture the excitement of the Chapter's 12th annual high school materials camp in June. Nitinol samples used in hands-on experiments were supplied by Fort Wayne Metals.

Coming Soon: Virtual Career Fair

ASM is co-sponsoring an online career fair, ideal for both job seekers and employers. The event will be held on September 20. The Engineering & Science Career Network Online Career Fair offers job seekers and employers the chance to connect—with zero travel involved. View registration details and employer pricing options by visiting http://bit.ly/2CFioK0. The event is free for job seekers.

MEMBERS IN THE NEWS

Berndt Leads Australian Training Facility

Christopher C. Berndt, FASM, TSS-HoF, has been selected to lead the new Australian Research Council (ARC) Training Centre in Surface Engineering for Advanced Materials (SEAM). The center was awarded funding by the ARC and matching partners totaling more than $8.39 million. The core Australian university partners are Swinburne University, where Berndt is a distinguished professor, along with the University of South Australia, and RMIT University. Berndt is an ASM past president, TSS past president, and former editor of the *Journal of Thermal Spray Technology.*

Ryan Named Board Chair at Michigan Tech

Brenda Ryan was selected by the Michigan Technological University's Board of Trustees to serve as their new chair. Ryan is president and owner of Ryan Industries Inc. in Wixom, Mich., and Alliance Industries LLC in Springfield, Miss. She earned a bachelor's degree in metallurgical engineering from Michigan Tech and a master's in materials science and engineering from the University of Virginia. She joined the board in 2015, serving two years as vice chair.

Governor Selects Schafrik for Grant Award

Schafrik

Robert Schafrik, FASM, was selected as a recipient of the Governor's University Research Initiative (GURI) grant awards. The GURI program is one of Governor Greg Abbott's priorities in recent legislation to bring the best and brightest researchers to Texas. Schafrik joined the University of Texas at Arlington in February. His expertise is being used to support the university's technology commercialization efforts with corporate partners and start-ups to bring new technologies directly to consumers through the development of the Arlington Innovation Center. The university was awarded a matching GURI grant totaling $2 million.

SME Honors Beaman

Beaman

Joseph J. Beaman was recognized in June for contributions to manufacturing research at the annual North American Manufacturing Research Institution of the Society of Manufacturing Engineers (NAMR/SME) in Texas. Beaman received the 2018 NAMR/SME S.M. Wu Research Implementation Award. He is a professor at the University of Texas at Austin and a fellow of SME and ASME. Beaman's specific interest is in solid freeform fabrication, and one of its approaches, selective laser sintering, was developed in his laboratory.

Sherman: The Titanium Man

Sherman

Russell Gordon Sherman, FASM, aka The Titanium Man, was featured this summer in the Santa Monica Daily Press. His claim to fame, according to the article, is his R&D around alloys and heat treating protocols for the titanium industry. At age 92, he recently earned a lifetime achievement award from the International Titanium Association. Sherman's research helped pioneer high volume production of titanium aerospace fasteners during the Cold War. He was hired at Howard Hughes' aerospace company to work on the Surveyor, the first vehicle to land on the moon. Later he worked for Boeing on titanium fasteners. He still consults in the titanium industry, lending a helping hand in automotive parts for colleagues in the southern U.S.

Henthorne Receives NACE Award

Henthorne

Michael Henthorne, a 50-year member of ASM, came out of retirement managing U.S. forging companies to write a paper, "The Slow Strain Rate Stress Corrosion Cracking Test - A 50 Year Retrospective," which appeared in the NACE *Corrosion* journal and subsequently was awarded their Best Paper of the Year. He created the SSRT during his Ph.D. research at the University of Newcastle, U.K. For the past 40 years, it has remained the most widely used test for studying stress corrosion cracking worldwide. Henthorne received his award at the NACE annual meeting in Phoenix in April.

Newkirk Lectures Inspire Forward Thinking

Newkirk

Joseph Newkirk, FASM, is on the road delivering a series of talks to fellow materials scientists and engineers in hopes of spurring them to imagine new classes of metals, ceramics, and other materials that will help create future materials needed to transport people to Mars or make robots stronger. He delivered a talk titled "Creating the Materials of Tomorrow" during the 15th annual Congress on Materials Research and Technology in Paris in February. He spoke on a similar topic at MS&T in October 2017, and will do the same this November in Rio de Janeiro. Newkirk is a professor of materials science and engineering at Missouri University of Science and Technology and president of Alpha Sigma Mu, the international professional honor society for materials science and engineering.

Myers Recognized by Marquis Who's Who

Myers

Ronald E. Myers, Strongsville, Ohio, was presented with the Albert Nelson Marquis Lifetime Achievement Award by Marquis Who's Who. The principal and owner of Myers Consulting Services, Myers is a chemist and consultant with over 40 years of industry experience in problem solving for materials science-related industries. He has consulted for several Forbes Global 2000 companies and served as a researcher for Cabot Microelectronics Corp., Thermagon Inc., Sermatech International Inc., and B.F. Goodrich Co. The recipient of a 2005 Gettysburg College Distinguished Alumni Award for his achievements, one of his inventions was named among the Top 10 Best New Products of 1998 by SAE's *Aerospace Engineering magazine.*

REMEMBER TO UPDATE YOUR MEMBER PROFILE

Have you changed positions or employers lately? Do you have a new email address or new materials interests? Keep ASM in the loop by reviewing and updating your member profile at asminternational.org.

IN MEMORIAM

Bhat

Gopal Krishna Bhat, FASM, an ASM Life Member, passed away on May 27 at age 92. He completed his B.S. degree in metallurgical engineering at Banaras University, India. He received a master's degree in metallurgical engineering practice and industrial management in 1951 and a Ph.D. in metallurgical engineering in 1955, both from Lehigh University. From 1955 to 1958, he was staff metallurgist at Crucible Steel in Pittsburgh. He was then employed by Mellon Institute of Research, first as fellow but later rising to director of metallurgical and materials technology. From 1982 until retirement in 1998, Bhat was self-employed and engaged in metallurgical and materials process consulting and new technology transfer for commercialization. He authored three U.S. patents and was editor/coeditor for eight Proceedings of International Symposia on Special Melting Technology and served as their primary meeting organizer. He was chairman of the ASM Pittsburgh Chapter, 1968 to 1970. He was nationally and internationally recognized for his research on high-strength steels, electroslag and plasma melting, casting, welding, fracture mechanics, and stress analysis of pressure vessels.

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- Innovative Processing of Ti Alloys
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