SEPTEMBER 2017 | VOL 175 | NO 6

ADVANCED MATERIALS & PROCESSES

AN ASM INTERNATIONAL PUBLICATION

AEROSPACE TRENDS

SPECIALIZED COATINGS PREVENT CORROSION

P.23

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On the Cover:

Silhouette of Eurofigher Typhoon jet aircraft. Hardide CVD coatings have been used by BAE Systems Co., UK, to prevent galling and wear on the Typhoon since 2005. Courtesy of eurofighter.com.

CHEMICAL VAPOR DEPOSITION COATINGS EXTEND AEROSPACE COMPONENT LIFE

Yuri Zhuk

Nanostructured tungsten-tungsten carbide chemical vapor deposition coatings provide a practical, technical, and commercially viable alternative to hard chrome plating for aircraft components.

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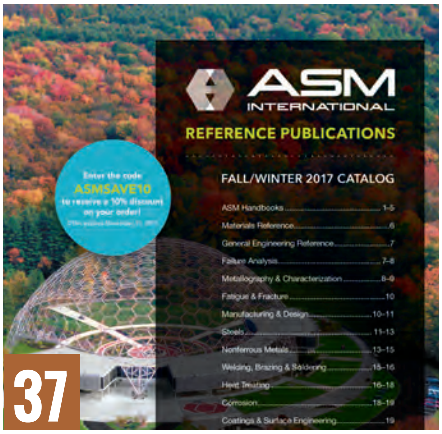
NEW ASM FALL EVENT

The ASM Board of Trustees and ASM International announce the launch of a new annual event, set to debut in September 2020.



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ASM REFERENCE PUBLICATIONS CATALOG

Our vast, authoritative reference library offers the most comprehensive and up-to-date information.

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ASM NEWS

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

ADVANCED MATERIALS & PROCESSES

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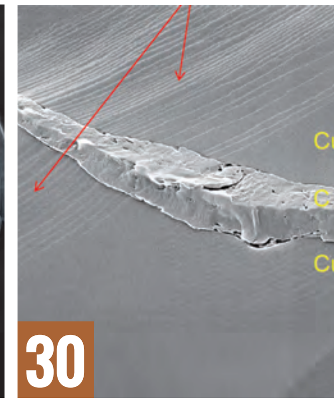
FEATURES



TRENDS

INDUSTRY NEWS

DEPARTMENTS

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FLEXIBILITY IS KEY TO SUCCESS

Welcome to our action-packed September issue! Starting with the elegant yet powerful Eurofighter Typhoons gracing the cover, we hope that you will discover many intriguing and inspiring news stories, interesting technical articles, and timely ASM happenings throughout the next hundred pages or so. You'll also notice that our comprehensive reference publications catalog is included, full of must-have technical information across many disciplines and topics that fall within the scope of materials science and engineering. Be sure to check it out!

Beyond our two aerospace-related technical articles, if there is a theme to this issue, it is *flexibility.* Consider this statement from the "Revolution" article featured in our *HTPro* newsletter: "Factors traditionally used by commercial heat treaters to evaluate induction equipment include technical capability, quality, price, delivery, and longevity. However, in light of recent industrial trends, an even more important factor is flexibility." The authors go on to make a case for flexibility in manufacturing due to ever-changing parts contracts and the need to be adaptable. Besides heat treating and parts contracts, it's fair to say that the need for flexibility applies to almost every business in existence. A common theme these days is that the most innovative and successful companies are those that can react quickly and nimbly to market trends and forces. No doubt, these are the ones that excel and prosper while others contemplate what to do and remain mired in a state of "analysis paralysis."

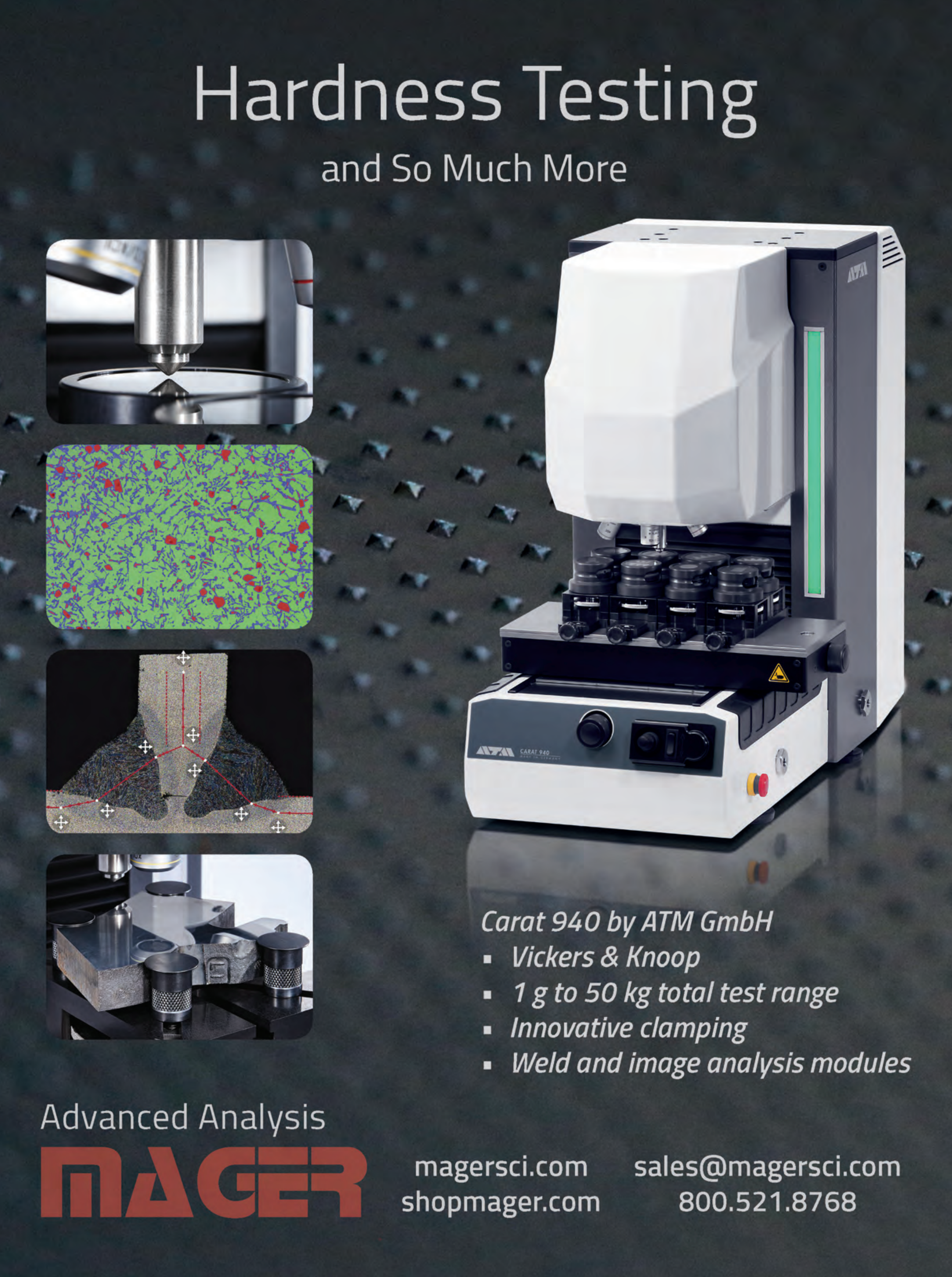
With this in mind, ASM is also flexing its flexibility muscle. As one example, our "digital transformation" initiative is moving full speed ahead. For an update, see the "MD Corner" column in ASM News. In addition, ASM President Bill Frazier answers some questions about another ASM initiative—the announcement of a new fall event set to debut in September 2020. To learn more about the inaugural conference, be sure to read his column on page 94 and take a look at the meeting announcement on page 27. Let us know what you think and if you have any questions.

In addition to being flexible, another winning attribute of successful companies—and individuals—is the pursuit of excellence. I like that this idea is captured in the theme of this year's ISTFA (testing and failure analysis) conference: "Striving for 100% Success Rate." Although this meeting is geared toward the microelectronics failure analysis community, the theme of reaching for perfection is a lofty and worthwhile goal for every industry. Don't forget to take a look at the ISTFA show preview included in this issue. We hope to see you there in November.

In the meantime, we look forward to seeing many of you at MS&T17 in Pittsburgh and our Heat Treat conference in Columbus, Ohio, with both events taking place in October.

F. Richards

frances.richards@asminternational.org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MARKET SPOTLIGHT

U.S. ALUMINUM DEMAND ON THE RISE

U.S. demand for aluminum is steadily increasing, according to “Aluminum: United States,” a new report by Freedonia Focus Reports, Cleveland. Sales to the transport market will outpace other sectors as automakers increasingly use aluminum parts to reduce vehicle weight. Domestic production is forecast to total 4.5 million metric tons in 2021, representing annual growth of 0.8% from 4.3 million metric tons in 2016. Further, production is expected to grow at a rate consistent with U.S. demand, as the vast majority of domestically produced aluminum is consumed in the U.S.

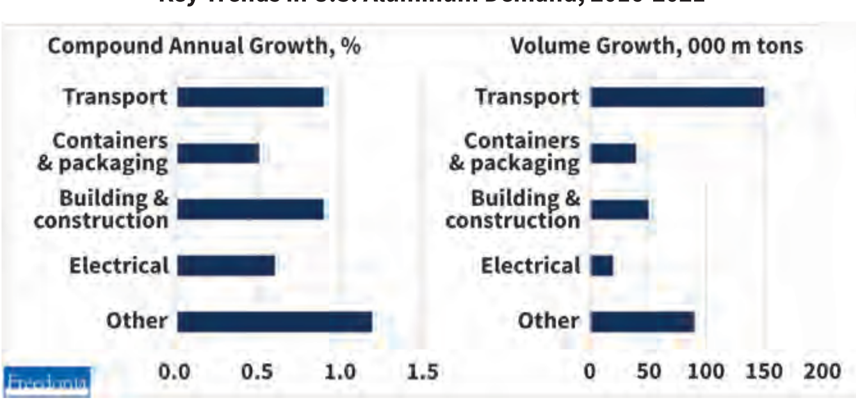
Demand stood at a decade high of 9.7 million metric tons in 2006. However, the 2007-2009 recession resulted in sharp declines—including an 18% plunge in 2009—as shipments of fabricated metal products contracted 22% in real (inflation adjusted) value terms. As manufacturing output began to recover in 2010, so did aluminum demand. Consumption expanded 12% in 2012, the fastest gains of the period, supported by surging demand in the transport and construction markets. Motor vehicle production rose more than 19% in unit terms that year, while construction activity began to rebound after several years of declines, say analysts. Further driving gains, aluminum demand benefited from increasing use in motor vehicles as manufacturers sought to expand fuel efficiency by decreasing vehicle weight.

To illustrate historical trends, total demand and production, various market segments, and trade are provided in annual series from 2006 to 2016. Following are highlights from the new report:

- U.S. demand for aluminum is forecast to total 8.7 million metric tons in 2021, representing average annual gains of 0.8% from 8.3 million metric tons in 2016. The rising use of aluminum in motor vehicles will drive growth.
- Demand for aluminum in the transport market is expected to reach 3.5 million metric tons in 2021, maintaining its position as the leading segment. In addition to a slight expansion in motor vehicle production, increased use of aluminum per vehicle will boost demand.
- In 2016, leading suppliers of aluminum to the U.S. market included Alcoa, Century Aluminum Co., and Rio Tinto.

For more information, visit *freedoniafocusreports.com/pub/10912486.html.*

Key Trends in U.S. Aluminum Demand, 2016-2021



Source: The Freedonia Group

FEEDBACK

U.S. STEEL DECLINE: WHY?

I found the two-part story on the decline of the U.S. steel industry very interesting (“Metallurgy Lane,” Nov/Dec 2016 and January 2017). Everything that was included in the articles happened. But someday, someone will look at what was written and ask, “Was it inevitable?”

There are still blast furnaces in the world. Thankfully no more open hearths, but the basic oxygen furnace (BOF) still exists. We cannot produce every ton of steel using only scrap in electric furnaces. I wonder if the author ever thought about digging deeper to discuss the “Whys” of the decline?

In 1962 I was working in the Bridgeport, Connecticut, mill of Carpenter Steel as a melting metallurgist. This was the year that the new contract between labor and management gave the top half of each seniority group a 15-week vacation every five years. Management and labor both thought that this would create jobs. What it created was additional overtime for the workers who were not on vacation. I wonder how many parts of the many bargaining agreements signed by labor and management bear responsibility for the decline. And if they were responsible, who has suffered? It sure as hell isn’t management. We all retired, and thanks to the Pension Benefit Guaranty Corp., we still get our pensions.

I worked in the Syracuse mill of Crucible from 1969 to 1980. There were many union workers making more than $50,000 per year. Today’s workers do not make that nor do they have the defined benefit pension plan. What is left of the industry today is very different. I’d love to hear more on this topic from others.

Bill Eisen

Send letters to frances.richards@asminternational.org.

STRESS RELIEF

GETTING TO THE BOTTOM OF GRAPHENE HYPE

According to a recent story in the South China Morning Post, Nobel Prize-winning scientist Andre Geim has accused a Chinese underwear manufacturer of using his name and false comments to promote its products without his permission. Geim jointly won the Nobel Prize for physics in 2010 for his work on graphene. Jinan Shengquan Group says it uses graphene to produce underwear and claims that the graphene helps retain heat, eliminate odors, and kill bacteria, among other benefits. The firm has used pictures of Geim to promote its "graphene underwear" since 2015. Geim, a physicist at the University of Manchester, UK, told the newspaper that he had never tried the products, praised them, or given his permission to promote them.

"It's absolutely shameful for them to use my name in their marketing campaign without my permission and, more importantly, attributing such false statements to me," says Geim, who came across the company two years ago at a conference in Qingdao. "I was told that because the material is 'very black,' it retains heat better. I pointed out that this contradicted basic science because dark surfaces emit heat better, not retain it. The company gave me boxers and a pair of socks to try for myself to see how it works. I never put them on because their textile felt uncomfortable. The company then asked for a photo with me, and I obliged."

After he returned to Britain, Geim showed the underwear to fellow researchers. "Everyone agreed that the company hyped graphene, using it as a marketing tool…we could not find any evidence for any improvement provided by graphene in their products," he says. Geim said he would consider legal action to stop the firm from misusing his name. However, Chinese law does not protect foreigners' rights to their name in China, so mainland firms are generally free to use the names of foreign celebrities on their products without any penalty. *scmp.com.*

Andre Geim, left, agreed to pose for a picture with a Jinan Shengquan Group executive, not knowing the photo would be used in advertising materials to make false claims about graphene.

JARGON-FREE SCIENCE WRITING

A free program designed to help researchers improve and adapt vocabulary use when communicating with non-experts is now available. To help scientists recognize words that are considered jargon and should be avoided or explained when engaging with the public, a team at the Technion-Israel Institute of Technology and HIT–Holon Institute of Technology created a program that automatically identifies terms the average person may not know. The scientist-friendly "De-Jargonizer" hosted at scienceandpublic.com is simple to use: Once a text is uploaded or pasted, the algorithm color codes words in the text as either frequent or intermediate-level general vocabulary, or jargon. The tool will be updated periodically and can be expanded to include other sources and languages. *ats.org.*

Tiny houses, customized and 3D printed for hermit crabs.

3D-PRINTED TINY HOUSES

A recent advertisement for UK property website Zoopla was shot on a beach in Costa Rica and features a multitude of hermit crabs moving into 3D-printed shells topped with miniature houses. All shells and houses were printed using multi-color, multi-material 3D printing capabilities from Stratasys Ltd., Minneapolis. Designers at Artem Ltd., Israel, overcame numerous challenges to produce more than 20 realistic miniature houses and 10 shells for the "Crab World" TV spot. Each model—no bigger than a matchbox—mirrors an architectural style currently popular in the UK, from townhouses to country cottages. Check out the video at *http://bit.ly/2uMmFEe.*

METALS | POLYMERS | CERAMICS

Daryush Aidun uses HFIR beam line HB-2B to study a dissimilar weldment of low carbon steel and stainless steel, measuring where and how residual stresses are distributed. Courtesy of Genevieve Martin.

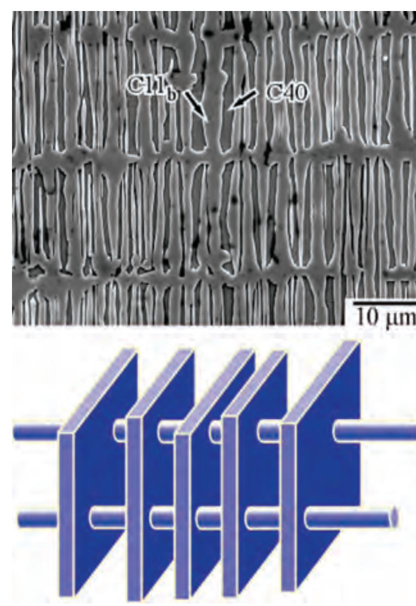
A DEEP LOOK AT DISSIMILAR WELDS

To analyze residual stresses in dissimilar welds, a researcher from Clarkson University, Potsdam, N.Y., is tapping the power of the High Flux Isotope Reactor (HFIR) at Oak Ridge National Laboratory, Tenn. Mechanical and aeronautical engineering professor Daryush Aidun is using HFIR beam line HB-2B at ORNL's Neutron Residual Stress Mapping Facility to study stress levels in stainless and low carbon steels before and after they are welded together in order to understand how and where residual stresses are distributed.

"When we say steel and stainless steel, we are really talking about two different metals," explains Aidun. "They have different thermo-physical properties. Particularly affected are their thermal conductivity and coefficient of thermal expansion with respect to residual stresses." While x-rays are sufficient for seeing a millimeter or two inside a material, neutrons can penetrate several millimeters further, providing a deeper look into a weld—and more data. Aidun ultimately aims to prevent failure by improving the structural integrity of dissimilar welds, which are increasingly used in the petrochemical and power industries due to economic incentives. *clarkson.edu, ornl.gov.*

STAYING STRONG WHEN THE HEAT IS ON

In their ongoing quest to develop ultrahigh-temperature alloys that can withstand harsh mechanical forces, scientists at Osaka University, Japan, created a new material with a unique microstructure that brings them one step closer to their goal. Their latest advance emerges from past work with transition-metal disilicides, lightweight alloys with impressive high-temperature resistance. The team previously



This unique cross-lamellar microstructure can be developed in the $NbSi_2/MoSi_2$ two-phase alloy by the addition of minute amounts of Cr and Ir.

BRIEFS

HEICO Corp., Hollywood, Fla., acquired 100% of **Carbon by Design,** Oceanside, Calif., a rapidly growing manufacturer of complex composite components for UAVs, rockets, and spacecraft. Carbon's staff is expected to remain in their existing roles when the company joins the Specialty Products Group at HEICO, a composites supplier for commercial aviation and defense applications. *heico.com.*

Bonnell Aluminum, Newnan, Ga., a subsidiary of **Tredegar Corp.,** Richmond, Va., launched a state-of-the-art aluminum extrusion line at its AACOA division facility in Niles, Mich. The $18 million expansion project, which includes a new 3600-ton (9-in. container) aluminum extrusion press and handling systems, will serve the automotive and specialty markets with custom finished extrusions. *bonlalum.com.*

Spirit AeroSystems, Wichita, Kan., and **Norsk Titanium AS,** Norway, entered into a contract to produce 3D-printed structural titanium components for the commercial aerospace industry. Spirit, one of the industry's largest suppliers of fabricated parts, expects that at least 30% of the parts they deliver could be candidates for Norsk's proprietary plasma arc rapid plasma deposition technology. *spiritaero.com, norsktitanium.com.*

3D-printed titanium part.

combined two of these disilicides into a new alloy consisting of alternating layers of crystals from each material. While this "lamellar" microstructure did improve the material's strength, the alloy did not meet room temperature toughness requirements and deformed at very high temperatures. Low strength in the direction parallel to the two-phase interface was the culprit.

To fix this, the team added two additional metals to the mix (Cr and Ir), which caused new crystals to grow through the layers, like staples piercing a stack of paper. This cross-lamellar microstructure prevents deformation parallel to the lamellar interface, improving high-temperature creep strength and fracture toughness. The material could increase efficiency in applications with extreme forces and high temperatures, such as aircraft engines and power turbines. *www.osaka-u.ac.jp.*

CERAMIC SPONGES FLEX UNDER FIRE

A group of researchers from Brown University, Providence, R.I., and Tsinghua University, China, devised an inexpensive, scalable method to fabricate ultralight "sponges" from nanoscale ceramic fibers, creating a porous, deformable material with ceramic's exceptional heat resistance. The team used a process called solution blow-spinning, in which a liquid solution containing ceramic material is forced through a tiny aperture. The solution quickly solidifies into filaments, which are tangled up in a spinning cage and heated to burn away the solvent, leaving a cluster of ceramic nanofibers.

While ceramics are typically too brittle to withstand deformation, they function differently at the nanoscale, where crack activation and propagation require more energy, and mechanisms such as creep are promoted. The new sponges can rebound after compressive strain up to 50% and maintain that resilience up to 800°C. They also have a remarkable capacity for high-temperature insulation. In one experiment, a 7-mm-thick titanium-dioxide sponge shielded a flower petal from a 400°C blast, while other types of porous ceramics let petals burn to a crisp. Potential applications include use as a flexible insulating material in firefighters' protective gear or in water purification systems as an alternative to powdered titanium dioxide that cannot be wrung out and reused. *brown.edu, www.singhua.edu.cn.*

Researchers from Brown and Tsinghua Universities have developed spongelike materials made of ceramic nanofibers. Courtesy of Gao/Li/Wu/Brown/Tsinghua.

TESTING | CHARACTERIZATION

Argonne Accelerator Systems Division engineer Matt Kasa checks instrumentation on the superconducting undulator. Courtesy of ANL.

PROTOTYPE POINTS TO BRIGHTER FUTURE FOR X-RAY LASERS

Researchers from the DOE's Lawrence Berkeley National Laboratory, Calif., and Argonne National Laboratory, Lemont, Ill., developed a prototype superconducting undulator (SCU) and demonstrated that it could be used in contemporary x-ray free-electron lasers (FELs) to increase their power, efficiency, versatility, and durability. The team built and tested a 1.5-m-long SCU magnet with coils containing niobium-titanium superconducting wire. Using in-house cryogenic systems and magnetic measurement techniques, researchers confirmed that the prototype meets all x-ray FEL technical requirements, including high-precision field quality and consistency along the entire magnet.

Current FELs produce x-ray light by wiggling high-energy clusters of electrons in the alternating magnetic fields produced by permanent magnetic undulators. An SCU the same length as one of these conventional undulators could produce light between two and 10 times more powerful, and could also access a wider array of x-ray wavelengths. This means that the same electron beam energy—the key factor in light facility construction costs—could produce increased x-ray energy ranges. Additionally, SCUs could prove more durable than permanent magnetic undulators. There are no macroscopic moving parts to maintain and superconductors are significantly less prone to damage by high-intensity radiation in high-power accelerators. *lbl.gov, anl.gov.*

NEW METHOD ENABLES MORE EFFICIENT MATERIALS DESIGN

Scientists at the University of North Carolina at Chapel Hill and Duke University, Durham, N.C., created the first general-purpose system that uses machine learning to predict the properties of new metals, ceramics, and other crystalline materials. The Properties Labeled Materials Fragments (PLMF) method was developed by analyzing data on approximately 60,000 samples from NIST's Inorganic Crystal Structure Database, then creating "fingerprints" from the crystal structures that comprise the smallest units of each material. Applying machine learning to the fingerprints resulted in a set of universal models that can accurately predict eight electronic and thermomechanical properties of virtually any inorganic crystalline material, including conductivity, stiffness, compressibility, heat transfer, and response to temperature change.

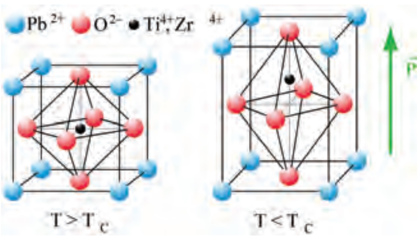
To test PLMF, the team sought a cathode material to replace nickel oxide in a certain type of solar cell. After 50,000 possibilities were screened, lead titanate emerged the as most promis-

BRIEFS

The industrial analysis division of **Oxford Instruments,** UK, joined **Hitachi High-Technologies,** Japan, to become **Hitachi High-Tech Analytical Science,** UK. The new company boasts a range of lab-based and in-field testing instruments, along with an in-house team of experts who have developed customized testing methodologies for hundreds of industrial applications. *hitachi-hightech.com/hha.*

Laboratory Testing Inc. (LTI), Hatfield, Pa., acquired **Fracture Technology Associates,** Bethlehem, Pa., an independent laboratory that provides fracture mechanics testing services and tailored software systems to commercial, government, and university labs. LTI offers materials testing, nondestructive testing, and metrology to the aerospace, power, medical, and military industries, among others. *labtesting.com.*

ing, which was surprising because its structure is unlike nickel oxide, and structural similarity would have traditionally been prioritized when seeking alternatives. Tests confirmed the model's prediction, however, showing that the devices using lead titanate exhibited the best performance in aqueous solution. The new model could allow materials designers to arrive at novel solutions while bypassing tedious trial and error. *unc.edu, duke.edu.*



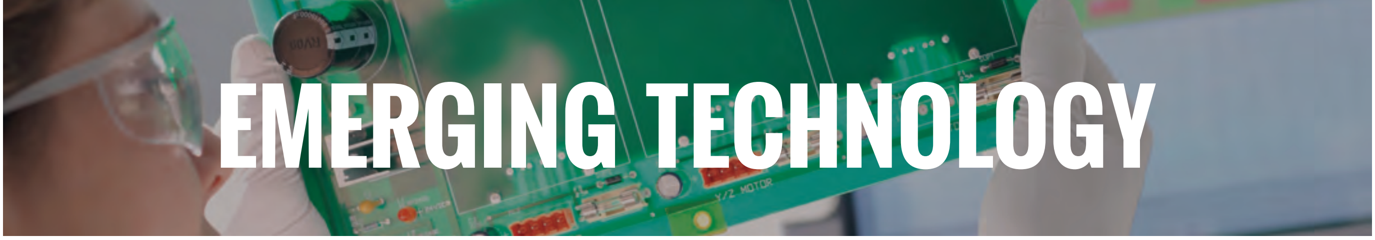
Tetragonal unit cell of lead titanate. Courtesy of Wikimedia Commons.

SPRAY-ON SENSORS SET THE CURVE

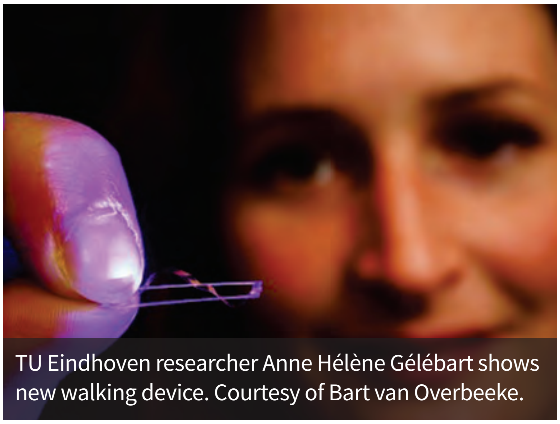
Hong Kong Polytechnic University researchers developed new nanocomposite sensing technology that can be sprayed directly onto flat or curved surfaces, delivering a lighter and lower cost alternative to traditional structural health monitoring systems. The new network is comprised of an ultrasound actuator and several nanocomposite sensors made of a carefully optimized hybrid of carbon black, 2D graphene, conductive nanoscale particles, and polyvinylidene fluoride. Each sensor is linked to the network via a printed wire.

Hong Kong Polytechnic University researchers recently developed a novel approach to spray-on sensing.

When the actuator emits guided ultrasonic waves, the network reads their scatter pattern, identifying changes in the nanocomposite's piezoresistivity that indicate structural defects and translating them into 3D images. The network can measure a wave with ultralow magnitude from static up to 900 kHz—more than 400 times the frequency discernable by other nanocomposite sensors—and detect cracks of 1-2 mm in most engineering materials. While a conventional ultrasound sensor costs more than $10 and weighs a few grams, a new nanocomposite sensor costs only 5 cents and weighs just 0.04 g, allowing a denser network to be installed for the same cost and weight. In fact, the new technology is so lightweight and the spray application so flexible, the sensors can be used on curved, moving structures like trains or aircraft. *www.polyu.edu.hk.*



EMERGING TECHNOLOGY



TU Eindhoven researcher Anne Hélène Gélébart shows new walking device. Courtesy of Bart van Overbeeke.

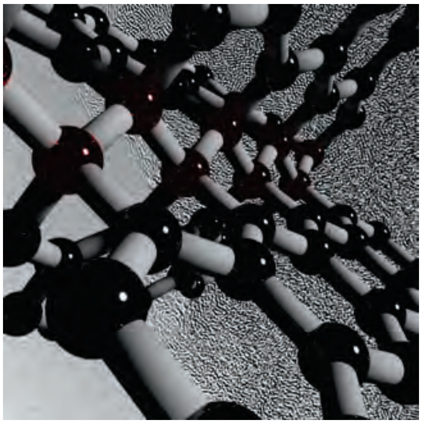
WALK TOWARD THE LIGHT

Using a novel polymer that undulates when illuminated, researchers at Kent State University, Ohio, and Eindhoven University of Technology, the Netherlands, developed the first machine ever to convert light directly into locomotion. To create the new material, the team incorporated a light-sensitive variant in a liquid crystalline polymer network. One side of the polymer contracts when exposed to light, while the other side expands, creating a bulge. When the light is extinguished, the deformation instantly disappears.

To assemble their tiny machine, researchers bowed a small strip of the polymer into an arc and fixed it in a rectangular frame about the size of a paperclip. When they shined a concentrated LED light onto the front of the curved strip, the portion of the strip that was illuminated bulged downward, exposing the next portion of the strip—which had been in shadow—to the light. This segment of the strip was deformed in turn, exposing the following segment of the strip to the light, and so on, establishing a continual undulation that propelled the device away from the light. When the device was turned upside down, the wave reversed direction, causing the machine to walk back toward the light. The miniature machine could be used to transport small items into hard-to-reach places or to keep the surface of solar cells clean. While it moves at caterpillar speed—only about 0.5 cm/s—the little locomotive is so powerful that it can transport an object much bigger and heavier than itself up an incline. *kent.edu, www.tue.nl/en.*

NEW LIGHTWEIGHT CARBON OFFERS STRENGTH AND STRETCH

Researchers from the Carnegie Institution for Science, Washington, and Yanshan University, China, developed a new form of ultrastrong lightweight carbon that is both elastic and electrically conductive. To create the material, the team began with a structurally disordered form of carbon called *glassy carbon,* then subjected it to 250,000 times normal atmospheric pressure and a temperature of approximately 1800°F. Under the high-pressure synthesis conditions, disordered layers within the glassy carbon buckled and merged, creating a structure that lacks a long-range spatial order, but features short-range spatial organization on the nanometer scale.



Ultrastrong and elastic compressed glassy carbon. The illustrated structure is overlaid on an electron microscope image of the material. Courtesy of Timothy Strobel.

The combination of graphite-like and diamond-like bonding motifs in the new carbon results in its unique array of properties. Scientists had previously tried subjecting glassy carbon to cold compression—but the material could not maintain its structure at ambient pressure—and to extremely high temperatures, but nanocrystalline diamonds were formed. The new material could be especially useful where weight savings are paramount, such as aerospace engineering or military armor applications. *carnegiescience.edu, english.ysu.edu.cn.*

BRIEF

The **University of California, Riverside** and the **Korea Institute of Materials Science (KIMS)** are launching the **UC-KIMS Center for Innovative Materials for Energy and Environment** to enable collaborative research and development of high performance, environmentally friendly materials. KIMS—a government-funded research institute specializing in development of metals, semiconductors, polymers, and ceramics—is supporting the initiative through a $350,000 commitment over three years. *ucr.edu, www.kims.re.kr/eng.*

KIMS President Hai-Doo Kim and Riverside Mayor Rusty Bailey.

PROCESS TECHNOLOGY

HIGH-ENTROPY ALLOYS CHANGE UNDER PRESSURE

In a crucial step toward customizing the properties of advanced metal mixtures, researchers at Stanford University, Calif., used extreme pressures to change the atomic structure of a high-entropy alloy. Using a diamond-anvil cell, the team subjected tiny samples of the alloy to pressures as high as 55 GPa—roughly equivalent to a profound meteorite impact—which shifted the alloy to a hexagonal close-packed (hcp) structure. These alloys typically exhibit a body-centered or face-centered cubic structure. Scientists speculate that the magnetic forces between atoms are what prevent an hcp structure from naturally occurring, but it looks like these magnetic forces can be dialed down with high pressure.

"That's what appears to be happening here," explains postdoctoral researcher Cameron Tracy. "Compressing the high-entropy alloy makes it non-magnetic or close to non-magnetic, and an hcp phase is suddenly possible." In fact, even after the pressure is removed, the alloy retains an hcp structure, which is unusual. The researchers also discovered that by slowly increasing the pressure, they could increase the amount of hcp structure in their alloy, suggesting the possibility of tailoring the material's mechanical properties to a specific application.

Alloys comprised of five or more metals are stronger, lighter, and more resistant to heat, corrosion, and radiation than conventional alloys. Despite significant interest from materials scientists, these high-entropy alloys have yet to make the leap from the lab to actual products, in large part because scientists hadn't figured out how to precisely control their atomic packing structure. While a few high-entropy alloys with an hcp structure were created in the past, they contained exotic elements, unlike the alloy used in the Stanford research, which is composed of manganese, cobalt, iron, nickel, and chromium—common metals typically used in engineering applications. *stanford.edu.*

Simple alloys like the molten steel in this factory are usually composed of just one or two dominant metals. But a new Stanford study shows that high pressure could be used to control the final properties of advanced, high-entropy alloys that have five or more mixed metals. Courtesy of Stanford/Shutterstock.

BRITTLE PHASE BREAKTHROUGH

Scientists at the University of Warwick, UK, developed a method to strengthen lightweight steel-base alloys without robbing them of their durability and flexibility, an advancement in the control of brittle phases that will finally allow these materials to be processed on an industrial scale. The Warwick team tested two lightweight steels—Fe-15Mn-10Al-0.8C-5Ni and Fe-15Mn-10Al-0.8C—that can experience two brittle phases during production, kappa-carbide (k-carbide) and B2 intermetallic.

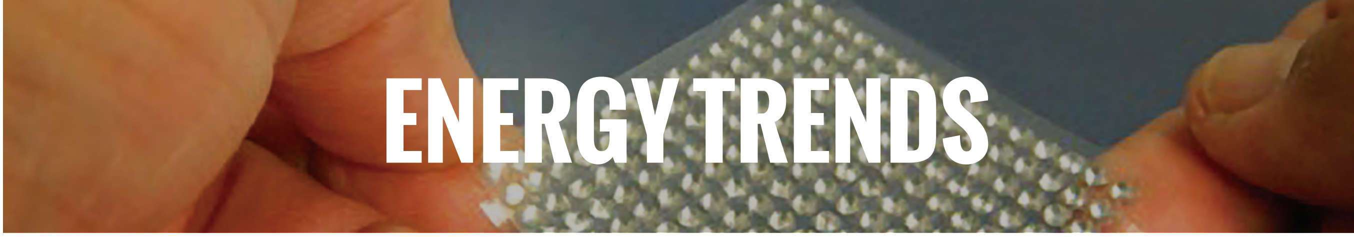
The team used simulation, then experimentation, to determine that these brittle phases can become much more controllable at high annealing temperatures. Between 900° and 1200°C, the k-carbide phase can be removed from production, and the B2 intermetallic brittle phase can become manageable, forming in a disc-like, nanosized morphology, as opposed to the coarser product that forms at lower temperatures.

The new process, which allows for large-scale rolling of high-strength lightweight steels, could ultimately lead to safer, more fuel-efficient cars and more graceful automotive designs, as more malleable steels can conform to increasingly streamlined shapes. *www2.warwick.ac.uk.*

International Manufacturing Centre at WMG, University of Warwick.

BRIEF

Nucor Corp., Charlotte, N.C., will invest $176 million to build a hot band galvanizing and pickling line at its sheet mill in Ghent, Ky. The new line will expand Nucor Steel Gallatin's product capabilities and have annual capacity of 500,000 tons. At 72 inches, it will be the widest hot-rolled galvanizing line in North America. *nucor.com.*



ENERGY TRENDS

Graduate student Sunyeol Jun calibrates the molecular beam epitaxy apparatus used to characterize various semiconductors. Courtesy of Joseph Xu.

NEXT GEN SOLAR CELLS SEE RED

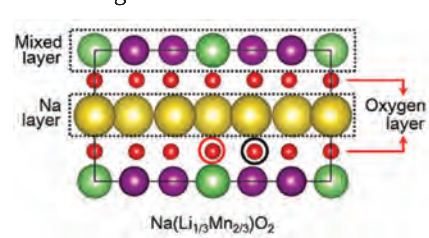
Scientists at the University of Michigan, Ann Arbor, developed a new semiconductor alloy that can capture near-infrared light on the edge of the visible spectrum. The alloy is compatible with next generation solar cells called concentrator photovoltaics (CPVs), which boast efficiency rates upwards of 50%—about twice that of conventional, flat-panel silicon solar cells. Current CPVs gather and focus sunlight onto a layered wafer consisting of three different superconductor alloys. Each layer is only a few microns thick and captures a different segment of the solar spectrum, but near-infrared light escapes them all. To trap these elusive wavelengths, researchers have long sought a "fourth layer" that is not only cost effective, stable, and durable, but compatible with all the other layers. Using a combination of methods such as x-ray diffraction and ion beam analysis along with customized computer modeling, the Michigan team created the new alloy, which not only meets these criteria, but is easier to manufacture and at least 25% less costly than previous formulations.

The advance comes on the heels of another innovation from the lab that replaces pricey, toxic beryllium with cheaper, safer silicon in the semiconductor doping process. Together, these innovations could make the semiconductors used in CPVs as much as 30% cheaper to produce, a big step toward making the high efficiency cells practical for large-scale electricity generation. *umich.edu.*

NEW BATTERY MATERIAL COULD OUST LITHIUM

Researchers at The University of Texas at Dallas, in collaboration with Seoul National University, South Korea, developed a novel manganese and sodium-ion-base material that could supplant lithium-ion technology in next generation devices and electric cars. As demand for these devices and vehicles surges, the production of lithium—a limited resource mined from just a few regions on the globe—may not be able to keep up. The new technology replaces most of the lithium in the cathode with sodium, while manganese serves in place of the more expensive and rarer elements cobalt and nickel.

"Our sodium-ion material is more stable, but it still maintains the high energy capacity of lithium," explains Kyeongjae Cho, professor of materials science and engineering, "and we believe this is scalable. We want to make the material in such a way that the process is compatible with commercial mass production." To develop the new technology, researchers used rational materials design, running computer simulations to determine the configuration of atoms that showed the most promise before making and testing the material in the lab. Although sodium tends to deliver 20% lower energy density than lithium, it is abundant and easily extracted from seawater, making the new material a more ecofriendly and potentially more affordable option in the long run. *utdallas.edu.*



This sodium-ion design replaces most of the lithium atoms (green) with sodium (yellow). The layered structure of the new material also incorporates manganese (purple) and oxygen (red).

BRIEF

Scientists at **Cornell University,** Ithaca, N.Y., received $1 million from the **W.M. Keck Foundation** to create a specific topological superconducting material. The team's interdisciplinary project, "A Materials-by-Design Approach to an Odd-Parity Topological Superconductor," builds on a foundation of extensive theoretical calculations and could lead to a stable and scalable quantum computing technology. *cornell.edu.*

SURFACE ENGINEERING


A team of British and Chinese researchers say their new carbide coating could revolutionize hypersonic travel.

COATING KEEPS IT TOGETHER WHEN TEMPERATURES SOAR

A team of scientists from The University of Manchester, UK, and Central South University, China, designed and fabricated a new carbide coating that could revolutionize hypersonic travel. Temperatures on the exterior of an object traveling at or above Mach five—five times the speed of sound—can spike to 2000° to 3000°C, leading to destructive oxidation and ablation on its surface. Currently, conventional ultra-high temperature ceramics (UHTCs) cannot meet ablation requirements when subjected to this extreme heat.

"Future hypersonic aerospace vehicles offer the potential of a steep jump in transit speeds," explains Manchester professor Philip Withers, "but at present, one of the biggest challenges is how to protect critical components such as leading edges, combustors, and nose tips so that they survive the severe oxidation and extreme scouring of heat fluxes at such temperatures." The new coating performs 12 times better than the conventional UHTC, zirconium carbide, at temperatures to 3000°C. Fabricated using a process called reactive melt infiltration, which dramatically reduces production time, the coating is reinforced with carbon-carbon composite, making it not only strong but extremely resistant to surface degradation, bringing hypersonic travel for air, space, and defense a few degrees closer to realization. *www.manchester.ac.uk, en.csu.edu.cn.*

UNEARTHING ANTI-CORROSION TECHNOLOGY

A researcher at Swansea University, UK, used soil bacteria to develop a corrosion resistant coating for steel, providing a more environmentally-friendly alternative to current anti-corrosion coatings without any reduction in performance. The project's innovator, Alex Harold, aimed to create a coating that wasn't just inspired by nature, but actually used biological components to solve an industrial problem. Her team began with the common soil bacteria, *Streptomyces sp.* Not only is the cell surface of this bacteria hydrophobic, but it protects the organism from desiccation by preventing the movement of water across the cell barrier. After extracting this biomaterial, the researchers dissolved it, creating a protein solution that self-assembles along hydrophobic/hydrophilic interfaces. The resulting protein-base coating for steel products reduces the potential for corrosion and can withstand boiling and freezing—all at less than 10 nm thick.

The bio-based coating does not just beat corrosion—it beats the competition. Harold's project, "Superhydrophobic Coatings from Bacterial Proteins," bested over 5000 applications to win the "Dare to Try" award in an international contest sponsored by the Tata Group, India, that recognizes innovation in research and development. *www.swansea.ac.uk.*


Water droplets on an agar plate with *Streptomyces* bacteria.

BRIEFS

Argonne National Laboratory, Lemont, Ill., entered into an exclusive license agreement with **Forge Nano,** Louisville, Colo., to commercialize Argonne's continuous atomic layer deposition method. Forge Nano scaled a proprietary coating technology that increases lithium-ion cathode material lifetimes more than 250% while enabling higher capacity nickel-rich battery chemistries. The company's technology similarly improves conventional and emerging anode materials. *anl.gov, forgenano.com.*

AZZ Inc., Fort Worth, Texas, a global provider of galvanizing and welding solutions, specialty equipment, and highly engineered services to the industrial and power markets, acquired **Enhanced Powder Coating Ltd.** (EPC), Gainesville, Texas. EPC is a privately held, high specification, Nadcap certified provider of powder coating, plating, and anodizing services to industries such as transportation and aerospace. *azz.com.*

ADDITIVE MANUFACTURING FOR AEROSPACE APPLICATIONS —PART II

Fabrication of aerospace components using additive manufacturing has matured to the point where part microstructures and mechanical properties compare well with those of conventionally produced material.

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Aerospace materials are required to provide exceptional performance, with mechanical properties such as high strength and resistance to fatigue and heat of utmost importance. Manufacturing costs can be very high due to the fabrication cost, which includes conventional machining. Additive manufacturing (AM) offers economic advantages compared with conventionally processed material, reducing energy use by up to 50% and slashing material costs by up to 90%. The first part of this article (July/August 2017, *AM&P*) discussed the basics of AM, part design considerations, CAD models, and build and powder removal considerations. This article looks at characteristics of AM methods, post-processing of AM parts, and AM part properties.

THERMAL PROCESSING

Thermal processing for metal AM parts often includes hot isostatic pressing (HIP) to reduce voids and porosity within the material, with some materials requiring heat treating to obtain the desired microstructure. In most cases, thermal processing does not define or change the design, unless there is significant distortion during the thermal process due to drastically varying thicknesses compared with part length or height. This requires choosing the correct additive manufacturing technology. Large parts can be difficult to produce by laser systems due to the "cool" process, which can result in insufficient thermal exposure to anneal out residual stresses. Stress relief is required on most laser builds, but even more so on parts that span the build area. Generally, electron beam melting (EBM) is a better choice for large parts in both horizontal and vertical orientations, because it eliminates the need for a stress relief step. If distortion is still an issue for a part, a few options are available to help parts hold their shape through thermal processing. For example, adding a sacrificial gusset or frame around thin-walled components that is subsequently removed by machining provides stability during thermal processing steps. The thermal cycle that is used can also have a significant effect on mechanical properties.

SURFACE FINISH

The surface finish of metal parts produced by laser powder bed fusion (LPBF) technologies is rougher than that of a conventional casting. Finish also depends on surface orientation. Top surfaces can be fairly smooth, while vertical surfaces typically have a consistent rough finish, and surfaces oriented at angles less than 90° from the build plate are the roughest. Generally, laser parameters and powder are optimized for a smoother surface finish in LPBF systems. The focus of using EBM is to optimize cost through build speed, and therefore parts are rougher. It is desirable to keep the as-built surface finish to optimize cost, but sometimes flow requirements, part structure, and aesthetics make it necessary to use various methods to reduce surface roughness.

The selected method influences design changes and it is necessary to know the material removal rate and compensate for the removal in the as-built model. For example, if a tumbling process removes 0.005 in. from the surface, then that extra amount of material is added to the as-built CAD file so part features conform to specified dimensions after post processing. Designers must consider the physics of the post-process surface-finishing method when compensating to achieve the desired surface finish. For example, part corners undergo a more aggressive material removal rate in a vibratory bowl than does a flat surface, so profile tolerances may have to be relaxed. Part locations with critical features and tolerances can be machined, or they can be masked to maintain the as-built surface during the surface finishing process. Internal cavities also require surface finishing methods to smooth out channels to meet flow requirements.

MACHINING

Most parts produced by conventional (subtractive) manufacturing methods require some level of machining to achieve the final product (Fig. 1), with approximately half the cost of the final part associated with machining cost. Critical features and tight tolerances that cannot be achieved

Fig. 1 — Examples of AM parts that may require final machining.

with the AM process often must be brought into conformance using conventional CNC machining. There are a few upfront design considerations that make CNC machining more effective. Design and manufacturing engineers should collaborate to determine how the part will be held in the fixture during CNC machining setup. Employing the advantages of the AM process, datum features can be added to the as-built model to reduce custom tooling, or at a minimum provide consistent tooling across a part family of similar geometries. Tabs, pins, holes, slots, and even a temporary handle can all be added to the printed part to help align fixtures and tooling, and subsequently cutoff. Having these discussions early in the design process reduces development iterations and speeds up both the setup and development time.

Another design consideration with regard to machining is wrap stock. Just as with surface finishing methods, some material must be removed to bring critical tolerances into conformance. Adding wrap stock to those features ensures there is sufficient material to remove in the machining step. Determining the correct amount of wrap stock is important to prevent adding too much time and cost to CNC machining. This will vary depending on material, part geometry, and the technology used. Designing for AM requires an understanding of the full manufacturing value stream, cost analysis, and even structural and materials engineering. A better scenario is to have experts in all disciplines available to collaborate and provide insight into the design process as it unfolds. All parts of this process are interconnected and include cause and effect correlations between them. Material properties and post processing are important upfront considerations in the design process, as many steps later in the process depend on material selection, manufacturing technology, and required operations.

PART BUILDING TECHNOLOGY

Additive manufacturing technologies for metals can be broadly classified into two categories[1-5]: directed energy deposition, or DED (Fig. 2), and powder bed fusion, or PBF (Fig. 3). There are several technologies in each category developed by different manufacturers. While PBF technologies enable building of complex features, hollow cooling passages, and high-precision parts, they are limited by build envelope, single material per build, and horizontal layer building. By comparison, DED technologies offer a larger build envelope and higher deposition rates, but are limited in their capability to build hollow cooling passages and fine geometry.

Direct metal deposition (DMD) and laser energy net shaping (LENS) technologies also offer the ability to deposit multiple materials in a single build and to add metal to existing parts. Three types of heat sources used with commercially available AM technologies include laser, electron beam, and plasma transferred arc (PTA), which are used to melt the feedstock (powder and wire). Laser-based systems operate under inert atmosphere (for titanium processing), while electron beam systems operate in a vacuum environment. Vacuum systems are more expensive, but they offer the advantage of low residual stresses in the part compared with laser-based systems, and electron beam-processed parts can be used without any stress relieving operation.

From a supply chain perspective, AM can have a significant impact and differs substantially from conventional (subtractive) manufacturing. While conventional manufacturing typically relies on a three-tier organization system, AM offers the opportunity of a one-tier system, eliminating the second tier of tooling suppliers. AM also eliminates the need for large part warehouse inventories, thus removing a third tier in the supply chain. This is possible due to the flexibility of AM technology to quickly switch from production of one part to another. In addition, AM is highly effective for new product launches, as it allows quick design changes and does not require tooling. This reduces the lead time for a new part and allows customers to bring a new product to the market very quickly—from concept to engineering to manufacturing. These advantages make AM a great tool for lean manufacturing.

The advantages of AM discussed here are based on producing titanium parts[1-5]. However, they also apply to other metals, polymers, and composite materials. Due to higher material and machining costs, the advantages of AM are greater for titanium and Ni-base alloys than for other metals, such as aluminum and steel.

OTHER CONSIDERATIONS

In an ideal scenario, the mechanical properties of AM parts would match or exceed those of various wrought product forms, which would enable the use of AM technology for Ti-6Al-4V parts[1-5], for example. However, this is not the case because some parts meet requirements and others do not. There are situations where part properties in the build direction are lower than those in other directions. In these cases, stress analysis must be conducted to determine if the "shortfall" will affect the part's function. These analyses can be time consuming and expensive, and they limit the number of parts that can be manufactured via AM. This epitaxial growth can result in a microtexture, which could also have an effect on fatigue and damage tolerances. Heat treatment (including HIP) can minimize this effect.

Directionality is also a concern. As the AM process builds the part layer by layer, grains formed in the previous layer are remelted, and the orientation of the previous layer serves as a seed for the layer being deposited, resulting in epitaxial growth and long columnar grains in the part in the growth direction (Fig. 4). This generally results in slightly lower strength in the growth dimension. Heat treatment (including HIP) can reduce the difference in strength (Table 1). Results of fatigue tests under high cycle loading conditions show that fatigue properties of AM fabricated and machined Ti-6Al-4V compare well with conventionally manufactured material[1-5].

It is anticipated that different processes could result in different design

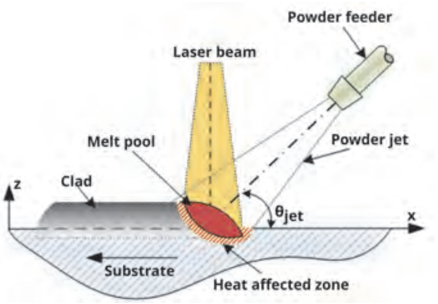

Fig. 2 — Schematic of direct energy deposition (DED) process.

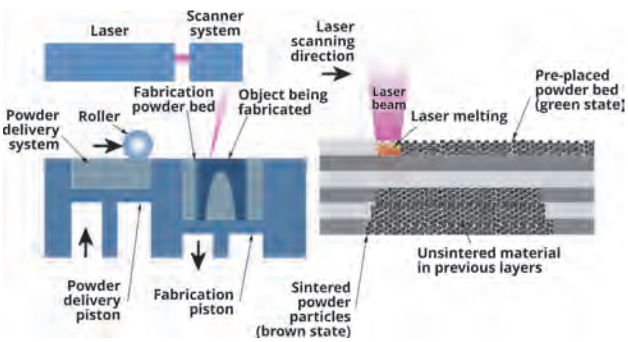

Fig. 3 — Schematic of laser powder bed fusion (LPBF) process.

TABLE 1 - MECHANICAL PROPERTIES OF AM Ti-6Al-4V AFTER HIP

Test direction	Yield strength, MPa	UTS, MPa	Elongation, %
Along *x-y* build plane	881	971	15.7
Along *z* direction (normal to *x-y* plane)	864	950	14.4

Fig. 4 — Epitaxial growth and long columnar grains in the growth direction in an AM part, which generally results in slightly lower strength in the growth dimension.

properties. This creates an issue of how to handle a unique set of "allowables" for each process. If the scatter is minimal, the lowest properties could potentially drive the design numbers. If the scatter is more prominent, different allowables for different processes must be addressed.

Inspection of AM parts is another area of concern for OEMs, especially for components designed for fatigue resistance. Except in special circumstances, the smallest defect that can be detected via ultrasonic inspection is around 0.8 mm (0.32 in.). It is anticipated that defects smaller than this could easily be generated via AM, and if close to the surface, these small stress risers can have a significant impact on fatigue performance. This is probably not a problem for parts designed for static use, based on ample blended-elemental data indicating that static properties can be met with part densities of ≥98% of theoretical density.

LOOKING TO THE FUTURE

According to McKinsey & Co., a global consulting firm, 3D printing could have a meaningful impact on certain consumer product categories, including toys, accessories, jewelry, footwear, ceramics, and simple apparel[6]. It has been predicted that global sales of products in these categories could grow to $4 trillion a year by 2025. Manufacturers can choose from a wide range of different materials when making products using conventional or AM practices. Within the polymer family alone, there are thousands of choices, from thermoplastics like nylon and polycarbonate, to thermosets like polyurethane and silicone, and engineering grade polymers like ABS to polymer fibers like polyester, rayon, acrylic, and Kevlar. There are also myriad other materials such as ceramics, glass, and metals that can be fabricated by AM.

Production of aerospace components using AM techniques has matured to the point where standards covering different aspects of the technology have been issued or are in progress

Fig. 5 — BALD bracket for USAF joint strike fighter built using AM electron beam melting technology. Courtesy of Oak Ridge National Laboratory, Tenn.

Fig. 6 — 24-in. diameter Inconel housing for turbine engine built using DM3D Technology's TransFormAM.

(see Part 1 of this article). Further, in ideal scenarios, AM microstructures and mechanical properties will meet or exceed those typical of conventionally produced material. Thus, several AM components are being used in aerospace applications and it is projected that many more AM parts will see real-world use in the near future. Examples of aerospace parts fabricated by additive manufacturing are shown in Figs. 5 and 6. **~AM&P**

For more information: Professor Sam Froes is a consultant to the additive manufacturing and titanium industries. He may be reached at 253.517.3034 or ssfroes@comcast.net.

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CHEMICAL VAPOR DEPOSITION COATINGS EXTEND AEROSPACE COMPONENT LIFE

Nanostructured tungsten-tungsten carbide chemical vapor deposition (CVD) coatings provide a practical, technical, and commercially viable alternative to hard chrome plating for aircraft components.

Eurofighter Typhoons use Hardide CVD coatings to protect parts from galling and wear. Courtesy of Eurofighter/Niccoli Grosseto.

Yuri Zhuk, Hardide Coatings Inc., Martinsville, Va., and Oxfordshire, UK*

Extreme operating conditions for aircraft push materials and components to the edge of their design capabilities. Addressing corrosion and wear is of particular importance to meet the challenge of maintaining high performance while ensuring economic viability. For example, the leak tightness of aircraft hydraulic actuators and rotating shafts depends on seals, and metal seal track and piston rod surface finish degradation in abrasive and corrosive environments can accelerate seal wear rate by an order of magnitude.

In addition, tighter legislative restrictions on commonly used protective hard chrome plating (HCP) together with the limitations posed by alternatives, such as high velocity oxygen fuel (HVOF) coatings, compel the industry to change its approach to surface protection. There is growing demand for comparably hard, wear resistant coatings that can increase component life and improve dimensional stability and component quality, while reducing downtime costs and improving competitiveness.

HARD CHROME AND CADMIUM PLATING

Hard chrome plating is widely used on thousands of different aircraft parts to protect steel components against wear, corrosion, and galling. However, because it uses carcinogenic hexavalent chromium salts in its production process, its use is now banned without special authorization in the European Union under REACH environmental and health and safety regulations. In the U.S., the Occupational Safety and Health Administration (OSHA) is imposing increasingly tighter restrictions.

Hexavalent chromium, or Cr(VI), is also used in the aerospace industry as a pretreatment for sacrificial corrosion-resistant coatings such as cadmium plating. Chromates provide corrosion resistance in coating stackups. For example, the stackup on an aircraft fuselage might consist of a thin chromate conversion coating that provides some corrosion resistance while enhancing the adhesion of subsequent coating layers.

ANALYZING HCP ALTERNATIVES

HCP alternatives include thermal spray (in particular HVOF) as well as emerging processes such as electroless nickel composite plating, explosive

**Member of ASM International*

bonding, electrodeposited nanocrystalline cobalt-phosphorus alloys, and physical vapor deposition (PVD) coatings. To date, HVOF and other spray coatings are considered the best available alternative to HCP. Although successful in some applications, each coating has limitations. Thermal spray can build a thick, durable coating layer, but coatings cannot be applied to internal surfaces, and their rough, porous structure often requires post-coat grinding, which is not possible on intricate shapes.

PVD coatings produce an extremely hard layer with accurately controlled thickness, but are very thin (typically less than 4 μm) and have limited load-bearing capacity. Various wet electroplating and electroless coatings are more suitable for internal surfaces and parts with complex shapes, but have lower hardness than HCP, and thus inferior wear resistance. Metal plating also has limitations, including insufficient corrosion protection due to plating porosity and insufficient adhesion to steel substrates.

ENGINEERING A SOLUTION

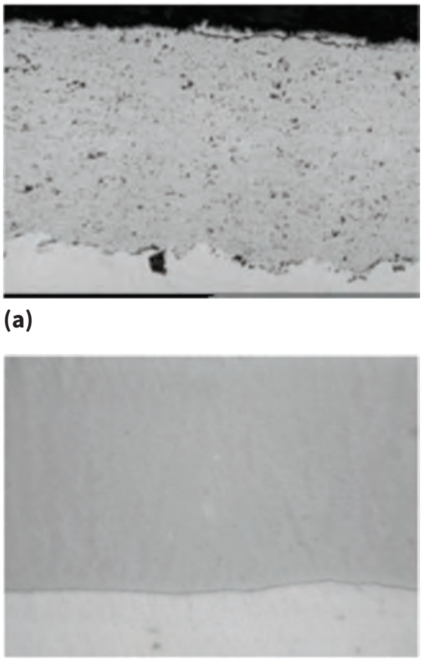
Until now, researchers investigating HCP and HVOF alternatives mostly disregarded chemical vapor deposition (CVD) coatings. They are considered to be brittle and are deposited using high process temperatures that are prohibitively expensive and, in some cases, unsuitable for mass production. By comparison, test results of Hardide CVD coatings show that low temperature CVD coatings are tough, provide a practical solution that is both technically and commercially viable, and can dramatically increase aircraft component life. Hardide CVD coatings belong to a family of nanostructured tungsten-tungsten carbide coatings. This formulation is crystallized atom-by-atom from low-pressure gas media, enabling uniform, pore-free coating of internal surfaces and complex shapes.

The Hardide-A variant was developed as a replacement for HCP, especially for designs and geometries where spray coatings cannot be used. The CVD coating matches HCP in thickness (50 to 100 μm) and hardness (800 to 1200 HV), with the upper limit exceeding the maximum hardness of HCP. Hardide-A features a low friction, smooth, as-coated surface, and can be diamond ground, honed, and superfinished for tighter dimensional accuracy. This nanostructured CVD coating combines high hardness with enhanced toughness and ductility, increasing wear and erosion resistance and withstanding impact and part deformation. CVD outperforms HCP and HVOF in terms of fatigue resistance and as a barrier against corrosion. Unlike traditional line-of-sight technologies, the Hardide coating process builds a dense W-WC layer bonded together at the atomic level, enabling full, uniform coating of complex geometric shapes and internal surfaces. This capability is increasingly attractive as technological developments such as 3D printing enable manufacturers to seamlessly join parts together to make one larger, more complex component.

COATING PERFORMANCE

Components with complex shapes and parts that operate under high loads at risk of corrosion and galling are the types of applications most suitable for CVD WC coatings. Traditional coatings such as HCP, thermal spray, and electroplating contain micropores and microcracks that grow when the substrate deforms under load, allowing media to attack the substrate. Sealing improves corrosion protection, but the use of organic sealants limits maximum operating temperature to 400°F. In addition, coating wear eventually exposes deeper, previously concealed pores that are not sealed. By comparison, the deposition mechanism of CVD WC coatings results in exceptionally low porosity, eliminating the need for sealing (Fig. 1). In crystallizing from the gas

Hardide coated aerospace bushes.



(a)

(b)

Fig. 1 – Porosity in cross sections. (a) HVOF WC/Co has 2.55% porosity and (b) CVD tungsten carbide coating has 0% porosity.

phase, highly mobile reaction products fill micropores and defects in the coating as it grows.

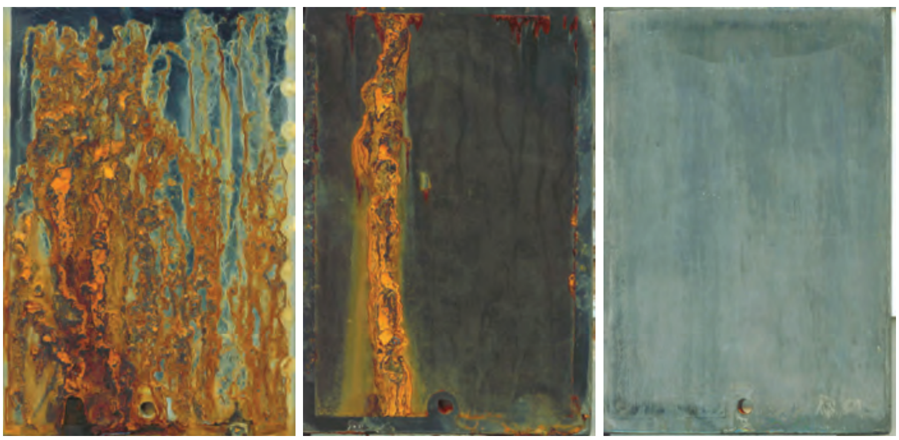
Tungsten and tungsten carbide have high chemical resistance. Therefore, the pore-free CVD WC coating is resistant to many aggressive chemicals and can be used as a highly effective anticorrosion barrier coating for critical parts. CVD coatings also offer enhanced wear and erosion resistance at temperatures to 750°F, beyond the capabilities of organic coatings and sealants (Fig. 2).

Galling prevention is one of the main functions of HCP. High-frequency reciprocating wear test results show that the CVD WC coating outperforms HCP with no galling, even under the maximum load (800 N), equivalent to 810 MPa contact pressure of a coated pin on a coated flat plate (Fig. 3).

The hardness of the CVD coating has a large effect on its wear resistance. Test results in accordance with ASTM G65 "Standard Test Method for Measuring Abrasion Using the Dry Sand/Rubber Wheel Apparatus" show that Hardide-A outperforms HCP by a factor of 13, and various grades of HVOF coatings by up to three times. In addition, the coatings wear uniformly and retain their surface finish in operation—even in abrasive or corrosive environments, important in applications on hydraulic actuators, rotating shafts, and bearings.

Toughness and resistance to impact and deformations without spalling or cracking are of significant practical importance for applications involving shock loads and impact, such as aircraft landing gear and wing flap actuators. HCP has suitable toughness, but is brittle and has poor impact resistance. HVOF coatings can crack and spall under high load and high cycle fatigue conditions. In contrast, the structure and composition of CVD coatings are optimized to maximize toughness. During micro and nanoscale testing, the CVD coating did not fracture after 100 nano-impacts, and a diamond cube corner indentation failed to induce cracks (Fig. 4). Its fracture toughness exceeded the level that can be measured by methods commonly used on hard coatings.

Fatigue resistance is critical for aircraft components, and hard coatings reduce fatigue life by fatigue "debit." As the CVD coating cools from its application temperature of 840°F to room temperature, the mismatch in thermal expansion coefficient between coating and substrate results in a compressive stress, which is beneficial for wear



(a) **(b)** **(c)**

Fig. 2 – Samples of three different coatings after salt spray corrosion tests. (a) Hard chrome after 288 hours, (b) HVOF after 480 hours, and (c) CVD tungsten carbide coating after 480 hours.

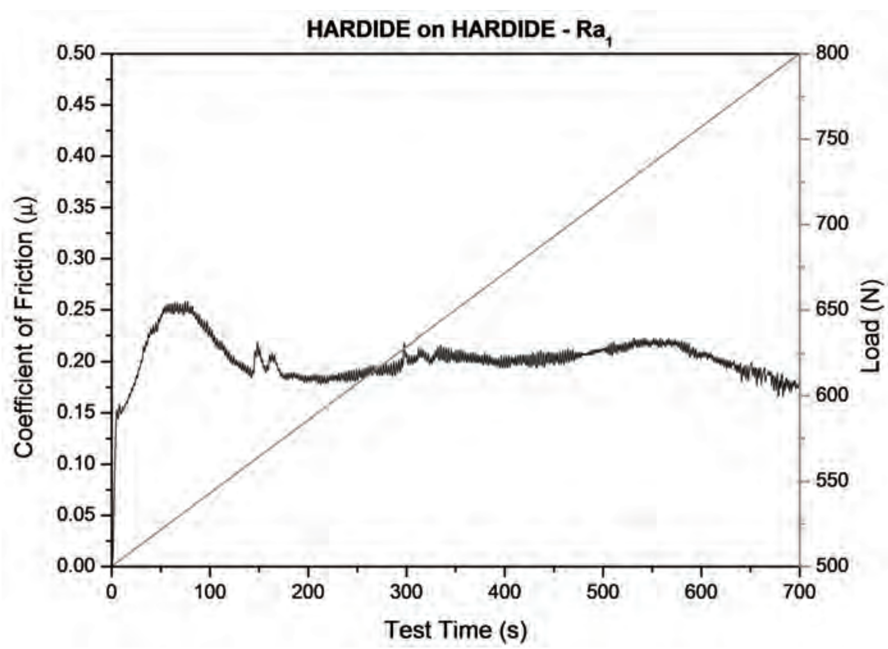


Fig. 3 – Coefficient of friction measured in a CV tungsten carbide-coated pin/CVD tungsten carbide-coated plate combination in a TE77 standard galling test under load gradually increasing to 800 N (810.2 MPa) contact pressure.

Fig. 4 – Diamond cube corner indenter with sharp edges used to measure fracture toughness; no cracks were produced, which in brittle coatings would extend from indentation corners.

resistance and fatigue properties. The combination of toughness and ductility, a uniform and pore-free microstructure, and compressive residual stresses enhance fatigue performance. CVD coatings have a minimum fatigue debit ranging from +10% to –10%, compared with –20% for HCP, and a higher debit for HVOF coatings.

REAL-WORLD CAPABILITY

The Hardide CVD coating has been used by BAE Systems Co., UK, to prevent galling and wear on parts for its Eurofighter Typhoon jet aircraft since 2005. The manufacturer recently certified additional parts for the aircraft. The helicopter division of Leonardo S.p.A., Italy, is planning to test CVD coatings on safety-critical main rotor components as well as transmission components.

Airbus Group, the Netherlands, approved the CVD coating in March. Further, as well as having Nadcap accreditation, Hardide Coatings is now on the global list of approved suppliers, which opens opportunities for coating components on a number of parts and aircraft platforms, including wing structure and landing gear for the A320, A330, A380, and A400M. Typical aerospace applications include pins, bushes, bearings, hooks, catches, landing gear, flap tracks and slats, sleeves, rods, valves, pistons, reverse thrust actuator rods, hydraulic and pneumatic pistons and cylinders, compressors, and shafts. **~AM&P**

For more information: Yuri Zhuk is technical director, Hardide Coatings Inc., with its international headquarters at 11 Wedgwood Rd., Bicester, Oxfordshire OX26 4UL, UK, yzhuk@hardide.com, www.hardide.com.

Selected Reference

1. M. Klingenberg, Electroplated Hard Chromium Replacements for Landing Gear Applications, Proc. of AeroMat, 2011.

Zhuk

ASM ANNOUNCES NEW MATERIALS CONFERENCE TO DEBUT IN 2020

#ASMROCKSCLE2020 will highlight advanced materials, processes and applications

The ASM Board of Trustees and ASM International proudly announce the launch of a completely new annual event, with the inaugural meeting to be held in Cleveland in early September 2020. The conference will include a comprehensive technical program and exposition along with the ASM awards banquet, Leadership Days, ASM annual business meeting, Women in Materials Engineering Program, Materials Girl Program, committee meetings, ASM leadership awards luncheon, Materials Camp, and a host of networking opportunities. In even years, the annual fall meeting will be presented as a standalone ASM event, while in odd years the event will be co-located with both the Heat Treating and American Gear Manufacturers Association (AGMA) conference and exposition.

Planning is already underway with the ASM Programming Committees, AeroMat Committee, and all six of ASM's Affiliate Societies heavily involved in building the technical symposiums, which will have a strong focus on application-oriented, real-world technologies that can be put to use today. Participating affiliates include the Electronic Device Failure Analysis Society, Failure Analysis Society, Heat Treating Society, International Metallographic Society, Shape Memory and Superelastic Technologies, and Thermal Spray Society. The new ASM fall meeting will also have broad appeal to a wider demographic than ever—with activities and programming specifically designed for pre-college STEM students, graduate and undergraduate students, and both emerging and seasoned professionals.

ASM's fall 2020 event promises an industry-focused conference and exposition targeted at advanced materials, processes, and applications—all addressing a spectrum of emerging technologies in key growth markets. The exposition will encompass major OEMs, materials suppliers, producers, and corporate partners to deliver cutting edge technology with hands-on educational workshops and demonstrations to further professional development and offer practical materials solutions. ASM is looking forward to its volunteers and members driving the technical information that will define ASM as the premier technical society leading the materials industry.

With the 2020 event slated for Cleveland, the event will kick off Sunday evening with Dinner Under the Dome. Attendees will have the opportunity to visit the famous geodesic dome—ASM International's headquarters—a National Historic Landmark designed by Buckminster Fuller and built in 1959. During this dinner event and throughout the conference, attendees will be able to network and tour the iconic building and also visit ASM's state-of-the-art teaching laboratories, completely renovated in 2016.

One question remains: What should the annual fall event be called? ASM invites all members to participate in naming the new event. If your conference title is chosen, you will receive complimentary registration to the 2020 event, a five-night hotel stay at the headquarters hotel, and a lifetime ASM membership. If multiple people select the same title, a drawing will be held to determine the winner.

For more information or to submit an event name, email asm2020@asminternational.org.

ASM ANNUAL EVENTS

TAKING PLACE IN PITTSBURGH, OCTOBER 8-12, 2017

Mark your calendars for these special events, lectures and networking opportunities.

Planning to travel to Pittsburgh to take part in the ASM annual event this October? ASM's annual fall gathering of the materials community will be held October 8-12 at the David L. Lawrence Convention Center.

Following are a few highlights you won't want to miss:

SUNDAY, OCTOBER 8

EDUCATION COURSES

8:30 a.m. – Noon

- Additive Manufacturing of Metals
- Failure Mechanisms and Analysis

8:30 a.m. – 4:30 p.m.

- A Design Mindset for Additive Manufacturing
- Essential Microstructure Interpretation
- Testing and Qualification in Additive Manufacturing

MONDAY, OCTOBER 9

7:00 – 9:00 a.m.

ASM WOMEN IN MATERIALS ENGINEERING BREAKFAST

Join your colleagues and listen to a lively discussion of relevant topics with featured speakers. This breakfast sold out last year and is expected to sell out again in 2017.

11:30 a.m. – 1:00 p.m.

ASM LEADERSHIP AWARDS LUNCHEON

ASM's organizational unit awards as well as awards and scholarships of the ASM Materials Education Foundation will be presented. ASM's incoming Committee/Council chairs will also be recognized for their leadership.

4:00 – 5:00 p.m.

ASM 104TH ANNUAL BUSINESS MEETING

Attend our annual business meeting where officers will be elected for the 2017-18 term and other ASM business will be transacted. ASM members and guests are welcome.

9:00 p.m. – midnight

CANADA COUNCIL SUITE AND IMS 50TH ANNIVERSARY CELEBRATION

Join ASM's Canada Council and IMS in celebrating their milestone anniversaries during the ASM Annual Meeting. Festivities will be held at the Canada Council Suite.

WORKSHOP: **METALLOGRAPHY INSIGHTS**

Monday, 2:00 – 4:00 p.m.
Tuesday, 11:30 a.m. – 1:30 p.m.
Instructor: John Peppler, ASM International

Insights and perspectives on sample preparation procedures and consumable choices that reveal true microstructures will be presented. Advances in optical and electron microscopy capabilities and software to enhance metallographic laboratory capabilities will be discussed. Attendees will have the opportunity to experience hands-on training in the Struers Mobile Showroom (located on the MS&T Expo Show Floor), a fully functional materials testing lab. Sponsored by Struers.

There is no charge to attend this workshop, but pre-registration is required.

Space is limited to 25 people.

TUESDAY, OCTOBER 10

9:00 a.m. – 2:00 p.m.

ASM MINI-MATERIALS CAMP

Students interested in STEM topics will enjoy hands-on materials demonstrations in this special mini-camp organized by the ASM Materials Education Foundation.

10:15 a.m. – 1:30 p.m.

ASM "DOMESDAY" COMPETITION

Can these student-designed domes handle the weight? Visit the exhibit hall for the display, judging, and selection of winners at the fourth ASM Geodesic Dome Design Competition. For more information, visit asminternational.org/domesday.

12:45 – 1:45 p.m.

ASM EDWARD DEMILLE CAMPBELL MEMORIAL LECTURE

Magnetic Transformations and Phase Diagrams

Presentation by David E. Laughlin of Carnegie Mellon University.

2:00 – 4:40 p.m.

SPECIAL IMS SYMPOSIUM

In celebration of the 50th anniversary of the ASM International Metallographic Society (IMS), a special symposium will be held on Tuesday and Wednesday. The 2017 Sorby Award winner, Professor Sir Colin Humphreys of Cambridge University, will open the Tuesday session with his lecture "How Microscopy Can Help to Save Energy, Save Lives, Create Jobs, and Improve Our Health."

7:00 – 9:00 p.m.

ASM AWARDS DINNER

Join us in celebrating the accomplishments of this year's award recipients and the 2017 Class of Fellows. Tickets include the President's Reception following dinner and can be purchased via the registration form.

9:00 – 11:00 p.m.

PRESIDENT'S RECEPTION

Get ready to kick off 2020 early at this event! Come find out what the buzz is all about. #ASMROCKSCLE2020

WEDNESDAY, OCTOBER 11

8:00 a.m. – 4:40 p.m.

SPECIAL IMS SYMPOSIUM

This special symposium beginning on Tuesday celebrates the 50th anniversary of the ASM International Metallographic Society.

9:30 a.m. – 2:00 p.m.

ASM MINI-MATERIALS CAMP

Students interested in STEM topics will enjoy hands-on materials demonstrations in this special mini-camp organized by the ASM Materials Education Foundation.

4:40 – 5:30 p.m.

IMS GENERAL MEMBERSHIP MEETING

Attend the IMS annual business meeting where officers will be elected for the 2017-18 term and other IMS business will be transacted. IMS members and guests are welcome.

6:30 – 7:30 p.m.

FAS GENERAL MEMBERSHIP MEETING

Attend the Failure Analysis Society's annual business meeting where officers will be elected for the 2017-18 term and other FAS business will be transacted. FAS members and guests are welcome.

WORKSHOP:
HANDS ON TECHNIQUES:

Preparation, Characterization and Analysis of Powder Metals for Additive Manufacturing

Tuesday, 11:30 a.m. – 1:30 p.m. or 2:00 – 4:00 p.m.
Wednesday, 9:30 – 11:30 a.m. or noon – 2:00 p.m.

Presented by Verder Scientific instructors: Kyle James, business unit manager; Michael Hager, business unit manager; Nico Masciantonio, applications specialist; and Gert Beckmann, product manager.

This workshop will provide hands-on experience with live operating test systems for:

- Feedstock, particle size analysis, and morphology
- Heat treatment for annealing, debinding, and sintering
- C, S, N, O, H a nalysis of powder metals and finished products
- Recovery/recycling of nonconforming products for reuse of feedstock materials
- Cutting, polishing, and mechanical testing of finished products

There is no charge to attend this workshop, but pre-registration is required.

Space is limited to 25 people.

CARBON COVETIC NANO-MATERIALS SHOW PROMISE

A recently discovered nanocarbon phase, first imaged to atomic resolution in 2012, is being exploited to increase the electrical and thermal conductivity of metals and alloys.

David R. Forrest, FASM, Advanced Manufacturing Office, Department of Energy, Washington*

U. (Balu) Balachandran, Argonne National Laboratory, Lemont, Ill.

These unique materials, known as carbon covetic nanomaterials or *covetics* for short, represent an opportunity to improve energy efficiency over a wide range of applications using low-cost raw materials and scalable processes. Volume production of these materials has not been straightforward, requiring fundamental and applied research efforts at the National Laboratories and at universities in order to understand: the physics of the process, the effect of processing on microstructure, and how nuances in processing conditions can be tuned to consistently produce material with exceptional properties.

The authors are acutely aware of the need for caution in making claims about the potential cost and performance of these materials, and of the perils surrounding hyperbole that has accompanied this technological advance. The claims for covetics are indeed remarkable:

- Permanent infusion of carbon in metals to levels wildly beyond thermodynamic equilibrium (for example, more than 4 wt% carbon in copper, aluminum, gold, silver, and other metals).
- Increases of up to 50% in thermal conductivity.
- Increases of up to 30% in electrical conductivity.
- The nanocarbon phase is completely novel, has not been previously identified in metallurgical systems, and is so tenaciously bound to the metal structure that it does not float out or oxidize to CO_2—even when covetics are remelted.
- The nanocarbon phase can survive e-beam sputtering and covetics can be deposited as a metallic thin film.
- The nanocarbon has very little effect on density; covetics have approximately the same densities as the base metals.

The covetic conversion process was first discovered by inventor Roger Scherer in 1998 and has been the target of ongoing development since then. The ability to remelt, cast, hot work, and cold work covetics using conventional metallurgical processing represents an important potential for volume production using industry's existing manufacturing infrastructure.

More recent U.S. government investment by the Dept. of Energy, NASA, Navy, Air Force, Army, and DARPA has been used to characterize the structure and properties, and to verify and replicate the synthesis process. The authors have verified each of the above claims, employing advanced scientific instruments such as the aberration corrected TEM at NIST, the helium ion microscope at Oak Ridge's Center for Nanoscale Materials Science, EXAFS and XANES at Brookhaven's National Synchrotron Light Source, and HAADF-STEM and x-ray nanotomography at Argonne's Electron Microscopy Center and Advanced Photon Source. In addition, researchers have used more traditional analytical tools including XRD, SEM-EDS, STEM, XPS, Raman, EELS, and AFM. Apart from industrial laboratory scale production at GDC Industries in Dayton, Ohio, covetics have been synthesized at Argonne National Laboratory and the National Energy Technology Laboratory, Albany, Ore.

STRUCTURE

Covetics can best be described as metal matrix composites with an integral nanocarbon phase. The nanocarbon seems to occur in two distinct morphologies—either flat thin discs measuring about 5 to 200 nm in diameter or nanoribbons measuring a few nanometers wide. The nanoribbons seem to be arranged as an intragranular network, anchored by the discs. The metal matrix itself is otherwise nothing extraordinary, and can consist of a pure metal or an alloy. Figure 1 shows a high resolution image of nanoribbons in a copper sample.

We know that the nanocarbon phase is tightly bound to the metal matrix, but we do not fully understand the nature of the bonding. The metal-carbon bonds do not express themselves as carbide peaks in XPS spectra or XRD. The carbon-carbon bonds are sp^2 and the phase is structurally comparable to graphene and single wall carbon nanotubes in EELS and Raman spectra. Microscopy has shown that rows of carbon atoms appear to be interlaced with rows of metal atoms in the metal matrix, which qualitatively explains

*Member of ASM International

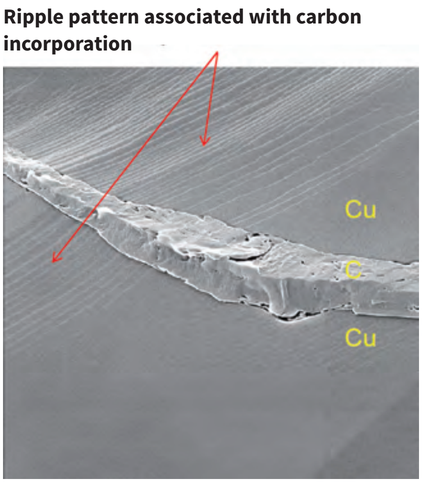


Fig. 1 – Helium ion microscope image of ribbons of the carbon nanophase, attached to a larger particle of carbon in copper.

the negligible effect of the nanocarbon phase on overall density. So, the answer is the nanophase is not a carbide and, while similar to graphene, it must be something more complex than that—and certainly more interesting.

PROPERTIES

While a rational characterization of the microstructure has evolved through these extensive investigations, it has been more of a challenge to obtain consistent physical properties. This is likely due to a range of process variables that are not fully understood and are the subject of ongoing investigation. Thermal conductivity increases of up to 50% and electrical conductivity increases up to 30% in copper have been confirmed. Figure 2 shows data from a thin film resistivity measurement that corresponds to an electrical conductivity of 136% IACS (International Annealed Copper Standard).

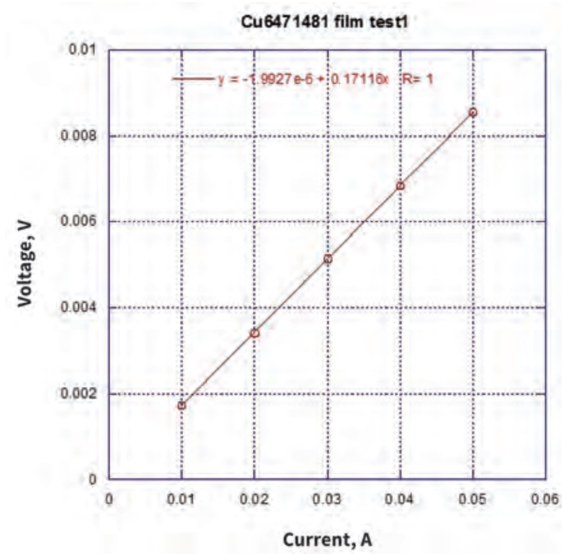


Fig. 2 – Voltage and current data measured on a 45-nm-thick film of e-beam sputtered copper covetic. The measured sheet resistance translates to a bulk conductivity of 79.22 MS/m, or 136.6% IACS.

APPLICATIONS

Thousands of energy applications exist for covetic nanomaterials. For example, automobiles and aircraft could be lightweighted with more efficient electrical power cables and motor windings; the electrical grid could transmit power with significant reductions in losses; heat exchangers could be more thermally efficient; and microelectronics could dissipate heat more efficiently and microcircuits could be less resistive. **~AM&P**

For more information: David R. Forrest is a technology manager, Dept. of Energy, Advanced Manufacturing Office, Room 5F-065, 1000 Independence Ave. SW, Washington, DC 20585, 202.586.5725, david.forrest@ee.doe.gov.

LEARN MORE

Special Session on Emerging Technologies to Develop and Commercially Adopt Innovative Materials

MS&T17, Oct. 10, 2:00-4:30 p.m., DLL Convention Center, Room 329

- **2:10 p.m.** – Advanced Manufacturing Research Activities in the Commercial Scaling of Additive, Battery, Carbon Fiber, and Composites Fabrication, by William Peter, Oak Ridge National Laboratory
- **2:30 p.m.** – Accelerated Design and Deployment of New Materials Using ICME Strategies, by Aziz Asphahani, QuesTek Innovations LLC
- **2:50 p.m.** – Emerging Applications for Rare Earths, by Josh Collins, Intelligent Material Solutions Inc.
- **3:20 p.m.** – Covetic Nanomaterials for Energy Applications, by David Forrest, Dept. of Energy

Development of Nanocarbon-Infused High-Performance Conductors

MS&T17, Oct. 11, 8:40 a.m., DLL Convention Center, Room 319

Presentation by Balu Balachandran.

Also, watch for a dedicated symposium next year at MS&T18 in Columbus, Ohio, October 14-18.

ISTFA/2017

STRIVING FOR 100% SUCCESS RATE

43RD INTERNATIONAL SYMPOSIUM FOR TESTING AND FAILURE ANALYSIS

CONFERENCE & EXPOSITION

PASADENA, CA | NOVEMBER 5-9, 2017

PASADENA CONVENTION CENTER

The 43rd International Symposium for Testing and Failure Analysis (ISTFA), the premier conference and exhibition for the microelectronics failure analysis community, will be held November 5-9 in Pasadena, Calif. This year's theme—Striving for 100% Success Rate—will echo 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 many networking events, receptions, and social activities scheduled each day, including the popular EDFAS video and photo contests.

ISTFA again opens on a Saturday, offering early arrivers the opportunity to take an intense half or full-day educational course. An all-day tutorial program on Sunday extends the learning process to a wider selection of topics, including novel atomic force microscopy, failure analysis in aerospace electronics, and how to read and interpret voltage contrast. Technical sessions begin Monday, featuring 120 presentations of original unpublished work in areas such as nanoprobing, sample preparation and deprocessing, ion beam analysis, reverse engineering, and challenges and opportunities in space. In keeping with the theme of success, ISTFA's keynote address—presented by Adam Steltzner, Team Leader and Chief Engineer EDL, NASA Mars Rover, Curiosity—will focus on the power of curiosity and collaborative innovation.

ATTEND ISTFA 2017

EDUCATION COURSES

Saturday, November 4

Fault Isolation Techniques for Failure Analysis

This all-day course taught by David Vallett, FASM, examines fault isolation techniques for ICs and 2D/3D packages, including TDR/eOTPR, SQUID/GMR, lock-in thermography, OBIRCH/TIVA, TRE/RCI, TLS/PLS, LADA, PEM, LVP/LVI, PICA, EBIC/EBAC/EBIRCH, and AFP & SEM nanoprobing. Vallett covers the pros and cons of each method, providing physics-based comparisons, case histories, and future outlook.

Yield Analysis for Systematic Defect Failure Analysis: Theory and Applications

Instructors Rao Desineni and Manish Sharma introduce the latest analytical techniques, including volume diagnosis-driven yield analysis and transistor-level diagnostic and data-mining tools, along with best practices for high-volume yield data analysis and fast systematic defect screening.

Beam-Based Defect Localization

Edward Cole, Jr., covers a broad range of test methods and tools for IC failure analysis, including standard approaches (secondary electron imaging, backscattered electron imaging, x-ray analysis, and e-beam induced current imaging); specialized SEM approaches (novel voltage contrast, resistive contrast, and charge-induced voltage alteration); and SOM techniques (light-induced voltage alteration, Seebeck effect imaging, and others).

TUTORIALS

Sunday, November 5

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

- How to See Voltage Contrast
- Yield Analysis for Systematic Defect Failure Analysis: Theory and Applications
- Optical and Infrared Microscopy
- Novel AFM Techniques and Applications in Semiconductor Failure Analysis and Characterization
- Reliability and FIFA challenges of Aerospace Electronics
- 3D Device/Package Fault Isolation and Failure Analysis

TOOLS OF THE TRADE DEMOS

Monday, November 6

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, Mentor Graphics, Nordson Dage, SELA USA, ULTRA TEC, Varioscale Inc. and Zurich Instruments.

KEYNOTE SESSION

Tuesday, November 7

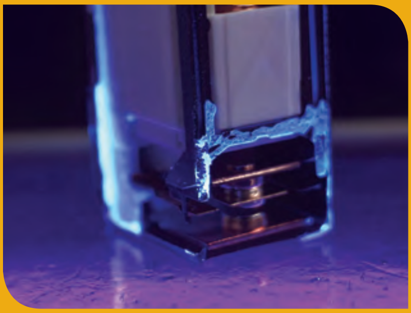
Adam Steltzner, Jet Propulsion Laboratory, NASA, discusses the power of curiosity, the importance of fostering a culture of collaborative innovation, and how we can achieve the impossible with the “right kind of crazy.”

TECHNICAL PROGRAM TOPICS

- Emerging FA Techniques
- Nanoprobing and Electrical Characterization
- Sample Preparation and Device Deprocessing
- Low Power Devices: Case Studies
- Mixed Mode & High Power Devices: Case Studies
- FA Processes: Case Studies
- Reverse Engineering
- Detecting and Preventing Counterfeit Microelectronics
- Board and System Level FA
- FIB Circuit Analysis and Edit
- 3D Device Failure Analysis
- Packaging & Assembly
- Scanning Probe Analysis
- Microscopy
- Fault Isolation
- FIB Sample Preparation
- Product Yield, Test & Diagnostics
- Space Application FA

SPECIAL CONTESTS

See the winners of the EDFAS Video Contest, featuring three-minute videos on failure analysis, as well as the best of the EDFAS Photo Contest, with categories in optical microscopy, x-ray/UV micrographs, and photon emissions.



EDFAS Photo Contest winner. Courtesy of Jordan Hendricks, Hi-Rel Semiconductor.

EDFAS Photo Contest winner. Courtesy of Lori Samecki, Fairchild Semiconductor.

EXHIBITION HOURS

Tuesday, November 7
9:00 a.m. – 6:30 p.m.

Wednesday, November 8
9:30 a.m. – 3:30 p.m.

EXHIBITOR LIST

BOOTH	COMPANY
620	Advanced Circuit Engineers
522	Advantest Corp.
507	Allied High Tech Products
110	Anasys Instruments
409	Angstrom Scientific
817	Applied Beams
504	Attolight AG
206	Balazs Nanoanalysis
402	Bruker
805	BSET EQ
626	Buehler
725	Carl Zeiss Microscopy
806	Checkpoint Technologies
302	Contech Solutions
822	Control Laser
209	Digit Concept
816	EAG Laboratories
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705	EDAX Inc.
406	Ephemeron Labs
823	FLIR Systems Inc.
815	Gatan
303	Hamamatsu Corp.
826	HDI Solutions - Hitachi
824	Herzan LLC
207	Hi-Rel Laboratories
415	Hitachi High Technologies
502	ibss Group
622	Imina Technologies
205	IR Labs
605	IXRF Systems
503	JEOL USA
405	Jiaco Instruments
309	Keyence Corp.
407	Kleindiek Nanotechnik
523	Leica Microsystems
603	Mager Scientific Inc.
414	Materials Analysis Technology
607	Mentor Graphics
317	Mesoscope Technology
506	Micro Support
114	Micromanipulator
420	Microsanj LLC
423	MSSCORPS Co. Ltd.
731	Nanotronics
717	Neocera LLC
203	Nikon Metrology
109	Nippon Scientific Co. Ltd.
702	Nisene Technology Group
115	Nordson Dage
825	Olympus America Inc.
521	Oxford Instruments
321	Park Systems
829	Primenan Inc.
112	PVA TePla America Inc.
814	Quantum Focus Instruments
721	Quartz Imaging
730	Raith America
304	Raytheon
621	RKD / Left Coast Instruments
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315	Samco Inc.
706	SELA USA Inc.
221	SEMICAPS
631	SmarAct Inc.
421	Sonoscan
508	SPI Supplies
408	Synopsys
307	TeraView LTD
707	TESCAN USA Inc.
615	Thermo Fisher Scientific (Formerly FEI)
723	TMC Ametek
807	Trion Technology
703	ULTRA TEC
306	Varioscale
715	XEI Scientific
403	Yxlon FeinFocus
804	Zurich Instruments AG

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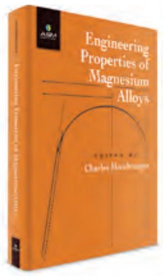
PRE-PUB

ASM Handbook Volume 18: Friction, Lubrication, and Wear Technology

Prepublication pricing through December 31!

See page 4 for details

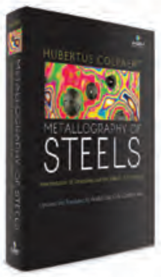
Turn the page for the latest releases



Engineering Properties of Magnesium Alloys

Prepublication pricing through November 30!

See page 14



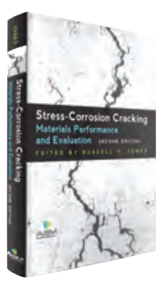
Metallography of Steels: Interpretation of Structure and the Effects of Processing

Prepublication pricing through January 31!

See page 9

ASM Handbook, Volume 1A: Cast Iron Science and Technology

See page 1



Stress-Corrosion Cracking: Materials Performance and Evaluation, Second Edition

See page 18

ASM Handbook, Volume 4E: Heat Treating of Nonferrous Alloys

See page 2

ASM Handbook, Volume 18: Friction, Lubrication, and Wear Technology

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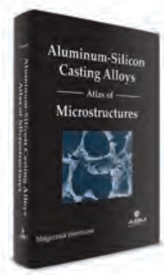
See page 4

Transformations: Selected Works of G.B. Olson on Materials, Microstructure, and Design

Prepublication pricing through September 30!

See page 7



Aluminum-Silicon Casting Alloys: Atlas of Microstructures

See page 13

Advances in Materials Technology for Fossil Power Plants, Proceedings from the Eighth International Conference

See page 6

ISTFA™ 2017 Proceedings from the 43nd International Symposium for Testing and Failure Analysis

See page 20

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ASM Handbook Complete Set, see page 5

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Volume 1A: Cast Iron Science and Technology

Edited by Doru M. Stefanescu

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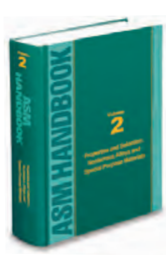

Volume 2: Properties and Selection: Nonferrous Alloys and Special Purpose Materials

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Your best single-volume source on compositions, properties, selection, and applications of nonferrous metals and alloys. Extensive coverage on aluminum, titanium, and copper. 1800 illustrations, hundreds of tables and data sheets.

Volume 3: Alloy Phase Diagrams

Edited by Hiroaki Okamoto, Mark E. Schlesinger, and Erik M. Mueller

2016 • 778 pages

ISBN: 978-1-62708-070-5

Product Code: 05442G

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40% of this volume has been updated and now includes 1083 binary systems, 1095 binary diagrams, 115 ternary systems, and 406 ternary diagrams. New material on solid solutions and phase transformations; thermodynamics; isomorphous, eutectic, peritectic, and monotectic alloy systems; solid-state transformations; and intermediate phases has been added.

Volume 4A: Steel Heat Treating Fundamentals and Processes

Edited by Jon L. Dossett and George E. Totten

2013 • 784 pages

IBSN: 978-1-62708-011-8

Product Code: 05344G

Price: $297 / ASM Member: $225

This volume addresses the basics of steel heat treating and thoroughly covers the many steel heat treating processes. Major topics include: the physical metallurgy of steel heat treatment, fundamentals and practical aspects of steel hardness and hardenability, quenching, annealing, tempering, austempering, and martempering. The volume provides greatly expanded treatment of surface hardening by applied energy, carburizing, carbonitriding, nitriding, and diffusion coatings.

Volume 4B: Steel Heat Treating Technologies

Edited by Jon L. Dossett and George E. Totten

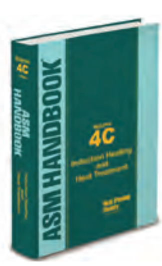
2014 • 582 Pages

ISBN: 978-1-62708-025-5

Product Code: 05434G

Price: $297 / ASM Member: $225

Volume 4B expands coverage on equipment, control, troubleshooting, and problems associated with steel heat treating. New articles extensively address distortion and the prevention of cracking – including the modeling and simulation of distortion. General process and procedure factors also are introduced—including temperature uniformity of furnaces, calculation of heat treating costs, and decarburization.



Volume 4C: Induction Heating and Heat Treatment

Edited by Valery Rudnev and George E. Totten

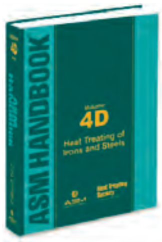
2014 • 820 pages

IBSN: 978-1-62708-012-5

Product Code: 05345G

Price: $297 / ASM Member: $225

This *all new* ASM Handbook gives design, manufacturing, and materials engineers an important new reference. Written by internationally recognized experts, Volume 4C provides in-depth and comprehensive coverage on one of the most significant technologies in the metals processing industries. Covering the breadth and significance of induction heating and heat treatment technologies and applications, this new ASM Handbook is a must-have addition to the bookshelf of any materials and manufacturing professional.



Volume 4D: Heat Treating of Irons and Steels

Edited by Jon L. Dossett and George E. Totten

2014 • 730 pages

ISBN: 978-1-62708-066-8
Product Code: 05352G

Price: $297 / ASM Member: $225

Packed with information and knowledge for anyone who uses or works with heat treated steels or cast irons. Written and reviewed by recognized authorities, this new handbook gives you in-depth articles with details on the processing and properties for all significant applications and types of heat treated ferrous alloys. New content includes not only updates on new alloys, but also expanded coverage on the effects of heat treating on the properties for more carbon and low-alloy steels, tool steels, stainless steels, and other high-alloy grades.

Volume 4E: Heat Treating of Nonferrous Alloys

Edited by George E. Totten

2016 • 712 pages

978-1-62708-112-2
Product Code: 05444G

Price: $297 / ASM Member: $225

This new volume completes the series of five volumes on the major technological subject of heat treating. This singular work gives engineers, analysts, and technicians a one-stop source on the wide variety of nonferrous alloys. With expanded coverage on both the industrial practice and the science of heat treating, this new handbook provides more practical information to guide processing requirements and the necessary background information for those without extensive prior knowledge.

Volume 5: Surface Engineering

1994 • 1056 pages

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Detailed information on surface cleaning, finishing and coating provided through published articles on testing of coatings and thin films, environmental concerns, and surface engineering of nonmetallic structural materials. Expanded analysis of advanced processes such as chemical and physical vapor deposition and diffusion coatings. Continuous coatings, electroplating and finishing methods.

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2013 • 412 pages

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Co-published by the Thermal Spray Society and ASM International. Replaces the *Handbook of Thermal Spray Technology,* edited by J.R. Davis (2004). Covers principles, processes, types of coatings, applications, performance, and testing/analysis. An excellent introduction and guidebook for those new to thermal spray.

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Edited by Kenneth B. Tator

2015 • 545 pages

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This completely new volume addresses a need for comprehensive information on organic coatings, including coating materials, surface preparation, application processes, industrial uses, and coating evaluation and analysis methods. This volume is essential for industrial coating users, specifiers, and contractors. The content in this volume has been written and reviewed by leading industry experts, making this latest ASM Handbook the definitive resource on this important topic. Plus, Volume 5B is the first volume in the ASM Handbook series to be printed in full color.

Volume 6: Welding, Brazing and Soldering

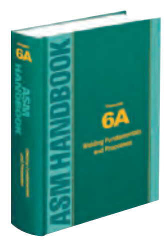
Edited by D.L. Olson, T.A. Siewert, S. Liu, and G.R. Edwards

1993 • 1299 pages

ISBN: 978-0-87170-382-8
Product Code: 06480G

Price: $297 / ASM Member: $225

Practical advice on consumable selection and procedure development, as well as joining fundamentals, processes, assemblies and selection. More than 500 illustrations and 400 tables.



Volume 6A: Welding Fundamentals and Processes

Edited by T. Lienert, T. Siewert, S. Babu, and V. Acoff

2011 • 936 pages

ISBN: 978-1-61503-133-7
Product Code: 05264G

Price: $297 / ASM Member: $225

A focused revision of the welding process information in Volume 6: *Welding, Brazing and Soldering* (1993). Updated and expanded articles on the fundamental principles of welding, including heat transfer, solidification, residual stress, and distortion. Workhorse methods of arc and resistance welding, friction stir welding, laser beam welding, explosive welding, and ultrasonic welding.

Brazing Handbook Fifth Edition

American Welding Society

2007 • 704 pages

ISBN: 0-87171-046-8
Product Code: 05336G

Price: $144 / ASM Member: $115

By agreement between the American Welding Society C3 Committee on Brazing and Soldering and the ASM Handbook Committee, the AWS Brazing Handbook has been formally adopted as part of the ASM Handbook series, and is significantly updated and expanded.

A comprehensive, organized survey of the basics of brazing, processes, and applications. Fundamentals of brazing, brazement design, brazing filler metals and fluxes, safety, and health. New chapters on induction and diamond brazing.

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2015 • 907 pages

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Product Code: 05438G

Price: $297 / ASM Member: $225

The updated and revised volume covers all aspects of powder metallurgy – including powder production and characterization, powder compaction, sintering, and compaction methods – and features new coverage of metal injection molding. Extensive coverage is provided of ferrous and nonferrous powder metallurgy materials. The new handbook format simplifies understanding of process and property relationships by treating each metal/alloy family in individual divisions.

Volume 8: Mechanical Testing and Evaluation

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Edited by G.F. Vander Voort

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1986 • 761 pages

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2002 • 1164 pages

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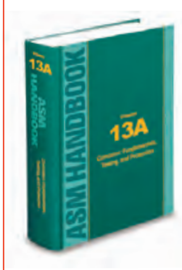

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Every article from the 1987 edition has been reviewed, revised, expanded, and updated. Six major sections: Fundamentals of Corrosion, Forms of Corrosion, Corrosion Testing and Evaluation, Methods of Corrosion Protection, Designing for Corrosion Control, and Prevention Tools for the Corrosionist.

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Volume 13C: Corrosion: Environments and Industries

Edited by Stephen D. Cramer and Bernard S. Covino, Jr.

2006 • 1168 pages

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Product Code: 05145G

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How corrosion impacts segments of the world economy – by environment and by industry sector. Provides answers to corrosion problems affecting your industry and ways to address corrosion issues in the environments that your equipment experiences. Over 250 leading authorities have written or reviewed articles in this volume.

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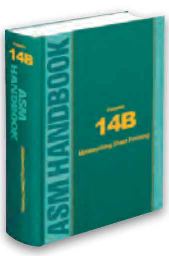
For manufacturing, materials, and design engineers. Covers the process-design relationships needed to select and control metalworking operations that produce shapes from forging, extrusion, drawing, and rolling methods.



Volume 14B: Metalworking Sheet Forming

Edited by S.L. Semiatin

2006 • 940 pages

ISBN: 978-0-87170-710-9
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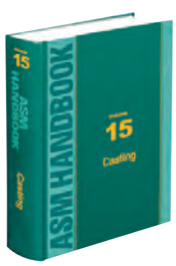
For product and production engineers. Methods of sheet metal fabrication technologies, selection of equipment and die materials, specification of forming practices for specific alloys, and new techniques for process design and control.



Volume 15: Casting

S. Viswanathan, Editorial Chair; D. Apelian, R. DasGupta, M. Gywn, J.L. Jorstad, R.W. Monroe, T.E. Prucha, M. Sahoo, E.S. Szekeres, and D. Twarog

2008 • 1256 pages

ISBN: 978-0-87170-711-6
Product Code: 05115G

Price: $297 / ASM Member: $225

Molten metal processing, solidification behavior, modeling, molding, foundry practice, and casting properties. Basic steps and equipment are described for casting processes, along with their advantages, limitations, and applications.

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1989 • 944 pages

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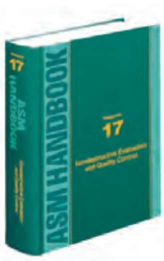
1300 illustrations and 620 tables provide detailed descriptions of various machining and grinding processes. Guidelines for proper selection of cutting tool materials and cutting fluids.



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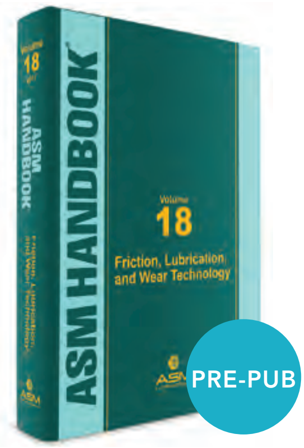

Volume 18: Friction, Lubrication, and Wear Technology

Edited by George E. Totten

2017 • Approx. 1150 pages

ISBN: 978-1-62708-141-2
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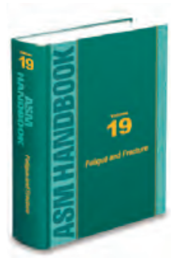

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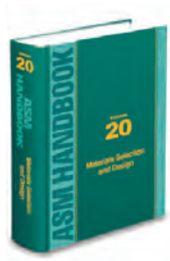

Volume 20: Materials Selection and Design

Edited by G.E. Dieter

1997 • 901 pages

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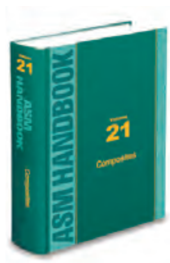
Contributions from more than 100 experts involved with design, materials selection, and manufacturing. Covers metals, ceramics, polymers, and composites and provides case histories and examples.



Volume 21: Composites

Edited by D.B. Miracle and S.L. Donaldson

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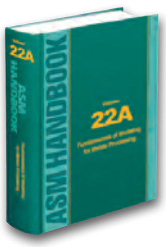

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2009 • 748 pages

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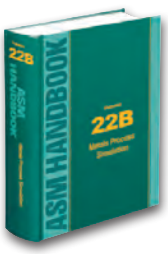

Volume 22B: Metals Process Simulation

Edited by David Furrer and Lee Semiatin

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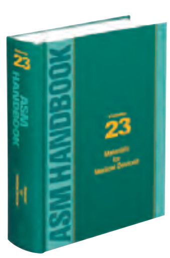
Fundamentals include input data, thermophysical properties and their measurement, phase diagrams, and microstructure. Processes include solidification, casting, metal forming, machining, joining, and heat treatment. Design topics include design optimization, error propagation and uncertainty, and cost estimating.



Volume 23: Materials for Medical Devices

Edited by Roger Narayan

2012 • 396 pages

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Implant materials covered include stainless steels, cobalt-base alloys, titanium, shape memory alloys, noble metals, ceramics, and polymers. Sections on failure analysis, biotribology and implant wear, corrosion, and biocompatibility.

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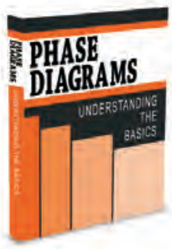

Phase Diagrams: Understanding the Basics

Edited by F.C. Campbell

2012 • 470 pages

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Exceptionally well-written text for non-metallurgists or anyone seeking a quick refresher on an essential tool in modern metallurgy. Ample illustrations for all important liquid and solid reactions. Gas-metal reactions, important in metals processing and in-service corrosion, are also discussed.

Advances in Materials Technology for Fossil Power Plants

Proceedings from the Eighth International Conference

Edited by: J. Parker, J. Shingledecker and J. Siefert

2016 • 1288 pages

ISBN: 978-1-62708-131-3
Product Code: 06839G

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The eighth in a series of conferences on the subject of materials for advanced plants, held every three years by EPRI. Boiler, turbine, and balance-of-plant material issues covered include: plant economics, advanced designs, and field experience; new materials development concepts; materials processing of advanced alloys; high-temperature materials used in boilers and turbines in steam power plants (ferritic steels, austenitic steels & alloys, and nickel-based superalloys); boiler tubes, headers, steam pipes, waterwalls, turbine rotors, blades, bolts, casings, valves, and high-temperature components; microstructural evolution and creep; corrosion, coatings, claddings; welding and fabrication; creep, fatigue, creep-fatigue, toughness, and high-temperature design rules.

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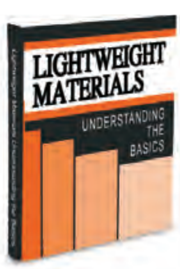


Lightweight Materials: Understanding the Basics

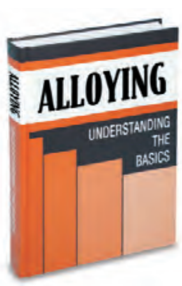
Edited by F.C. Campbell

2012 • 720 pages

ISBN: 978-1-61503-849-7
Product Code: 05355G

Price: $187 / ASM Member: $135

Learn the basics of aluminum, titanium, magnesium, beryllium, engineering plastics, polymer-, metal-, and ceramic-matrix composites, and structural ceramics. Includes basic metallurgy or materials science aspects of each material, as well as properties, processing, and applications. Guidelines for selecting materials for specific weight-critical applications.



Alloying: Understanding the Basics

Edited by J.R. Davis

2001 • 647 pages

ISBN: 978-0-87170-744-4
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A complete guide to the influence of alloy additions on mechanical properties, physical properties, corrosion and chemical behavior, and processing and manufacturing characteristics.

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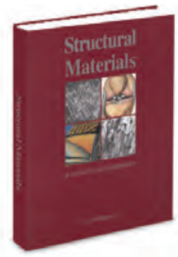
Proceedings from the Materials Science and Technology 2016 Conference, Salt Lake City, UT, October 23-27, 2016.



Structural Materials: A Textbook with Animations

By C.J. McMahon, Jr.

2004 • 470 pages

ISBN: 978-0-96465-985-8
Product Code: 05913G

Price: $107 / ASM Member: $81

A comprehensive introduction to structural materials and the underlying principles that affect their selection, properties, and performance. The book focuses on familiar applications (for example, materials selection for bicycle components) to tell a coherent story that conveys important concepts in a memorable fashion. Purchase of the book includes online access to dozens of animations and tutorials to visually demonstrate key concepts and processes.

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Worldwide Guide 2-Volume Set
Product Code: 05192G
Price: $547 / ASM Member: $405

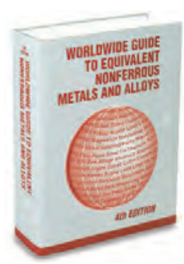
Worldwide Guide to Equivalent Irons & Steels, 5th Edition

2006 • 1416 pages

ISBN: 978-0-87170-822-9
Product Code: 05121G

Price: $307 / ASM Member: $231

Standard worldwide designations for cast irons and steels, wrought carbon and alloy steels, plus stainless, high-strength, and tool steels. Entries for more than 30,000 alloy designations. Well over 5,000 entries have been updated and over 3,000 are new additions. Newly expanded coverage for specifications and designations from Japan, China, India, and South Korea.



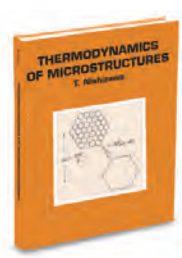
Worldwide Guide to Equivalent Nonferrous Metals and Alloys, 4th Edition

2001 • 1036 pages

ISBN: 978-0-87170-741-3
Product Code:06735G

Price: $307 / ASM Member: $231

Over 20,000 alloy designations, including a complete listing of UNS designations. Includes comprehensive treatment of current European and Japanese standards.



Thermodynamics of Microstructures

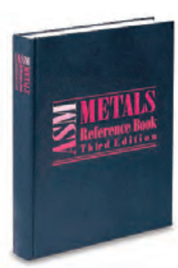
By Taiji Nishizawa, translated by Kiyohito Ishida

2008 • 308 pages

ISBN: 978-0-87170-716-1
Product Code: 05232G

Price: $207 / ASM Member: $155

Fundamental relationships governing the behavior of microstructures.



ASM Metals Reference Book, 3rd Edition

Edited by M.L. Bauccio

1993 • 614 pages

ISBN: 978-0-87170-478-8
Product Code: 06118G

Price: $167 / ASM Member: $125

Chemical compositions, physical and mechanical properties, manufacturing processes, applications, pertinent specifications and standards, and test methods.

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A "MUST-HAVE" READY REFERENCE ON METALLURGY!

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Edited by Arthur C. Reardon

2011 • 526 pages

ISBN: 978-1-61503-821-3
Product Code: 05306G

Price: $177 / ASM Member: $135

Provides a modern view of the basic principles and current practices of metallurgy. Recommended for anyone who uses, makes, buys or tests metal products.

Answer all your basic metallurgy questions in this updated reference featuring many new illustrations, examples, and descriptions.

Named as an "Outstanding Academic Title."
***- Choice: Current Reviews for Academic Libraries,* January 2013**

Elements of Metallurgy and Engineering Alloys

Edited by F.C. Campbell

2008 • 672 pages

ISBN: 978-0-87170-867-0
Product Code: 05224G

Price: $157 / ASM Member: $115

A thorough presentation of physical and mechanical metallurgical concepts along with a practical survey of all important metals, their alloys, and their engineering properties. Covers basic metallurgy, metallic material selection, and application.

Green Tribology, Green Surface Engineering, and Global Warming

By Ramnarayan Chattopadhyay

2014 • 336 pages

ISBN: 978-1-62708-064-4
Product Code: 05436G

Price: $187 / ASM Member: $135

This book describes green engineering concepts to improve energy efficiency by reducing energy losses due to friction and wear in metalworking operations and by extending component life.

PRE-PUB

Transformations: Selected Works of G.B. Olson on Materials, Microstructure, and Design

Edited by Carelyn E. Campbell, Michele V. Manuel, and Wei Xiong

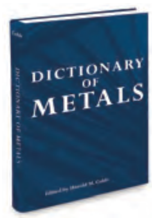
2017 • Approx. 500 pages

ISBN: 978-1-62708-137-5

Product Code: 06838G

Price: ~~$149~~ / ASM Member: ~~$129~~
Prepublication Price: $129 / ASM Member: $99
Prepublication price good through September 30, 2017!

ASM International and The Minerals, Metals and Materials Society (TMS) have collaborated to present a collection of the selected works of Dr. Greg B. Olson in honor of his 70th birthday in 2017. This collection highlights his influential contributions to the understanding of martensite transformations and the development and application of a systems design approach to materials.



Dictionary of Metals

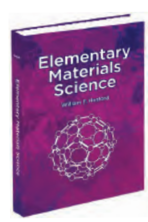
Edited by Harold M. Cobb

2012 • 374 pages

ISBN: 978-1-61503-978-4
Product Code: 05359G

Price: $157 / ASM Member: $115

Includes historical overview beginning with the seven metals of antiquity. Showcases each metallic element, the discoverer and date, naming and its meaning, major applications, significance of the discovery and physical properties.



Elementary Materials Science

By William F. Hosford

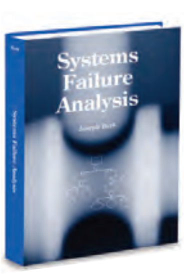
2013 • 188 pages

ISBN: 978-1-62708-002-6
Product Code: 05373G

Price: $83 / ASM Member: $65

An introduction to the subject of materials science with few equations. Intended primarily for students with limited science backgrounds and non-techinical professionals in the materials industry.

FAILURE ANALYSIS



Systems Failure Analysis

By Joseph Berk

2009 • 214 pages

ISBN: 978-1-61503-012-5
Product Code: 05278G

Price: $107 / ASM Member: $75

Complex systems failures can have hundreds of potential causes. Learn how to analyze and prevent them. Written for development engineers, quality assurance specialists, manufacturing engineers, purchasing personnel, and field service engineers. Great for organizations that produce or procure complex systems in the aerospace, defense, automotive, biomedical, electronic, and related industries.

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Price: $367 / ASM Member: $275

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1992 • 504 pages, 115 case histories

ISBN: 978-0-87170-453-5 • Product Code: 06340G

Price: $207 / ASM Member: $155

Handbook of Case Histories in Failure Analysis Volume 2

Edited by K.A. Esaklul

1993 • 583 pages, 120 case histories

ISBN: 978-0-87170-495-5 • Product Code: 06410G

Price: $207 / ASM Member: $155

Learn how others have solved failures in various industries such as automotive, aerospace, utilities, oil and gas, petrochemical, biomedical, ground transportation, off-highway vehicles, and more.

Understanding How Components Fail, 3rd Edition

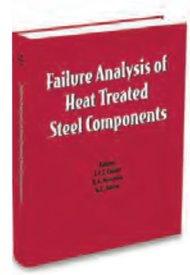
By Donald J. Wulpi
Edited by Brett Miller

2013 • 310 pages

ISBN: 978-1-62708-014-9
Product Code: 05363G

Price: $177 / ASM Member: $135

This new edition of the classic best seller preserves the content from previous editions – focusing on the metallurgical and materials evaluation for failure mode identification. Basic principles and practices are clearly explained. This is one of the first books new engineers and technicians should read.



Failure Analysis of Heat Treated Steel Components

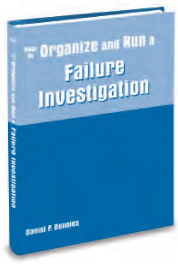
Edited by L.C.F. Canale, R.A. Mesquita and G.E. Totten

2008 • 652 pages

ISBN: 978-0-87170-868-7
Product Code: 05113G

Price: $207 / ASM Member $155

Learn how to identify causes of failures, prevent future occurrences, and improve reliability. Numerous examples helpful to designers, engineers, metallurgists, mechanical and materials engineers, quality control technicians, and heat treaters. Special focus on the demands of tool steels and aerospace materials.



How to Organize and Run a Failure Investigation

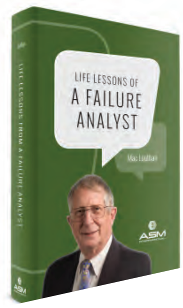
By Daniel P. Dennies

2005 • 223 pages

ISBN: 978-0-87170-811-3
Product Code: 05118G

Price: $167 / ASM Member: $125

Outlines a proven, systematic approach to failure investigation. Explains the relationship between various failure sources and the organization and conduct of the investigation.



Life Lessons of a Failure Analyst

By McIntyre R. Louthan, Jr.

2016 • 202 pages

ISBN: 978-1-62708-110-8
Product Code: 05921G

Price: $29 / ASM Member: $22

This compilation of editorials written by popular instructor of the ASM course Metallurgy for the Non-Metallurgist™ and the former editor-in-chief of the *Journal of Failure Analysis and Prevention* is applicable to failure analysts and all others looking to achieve success in almost any career.

The Failure Analysis Society—The newest affiliate society of ASM International

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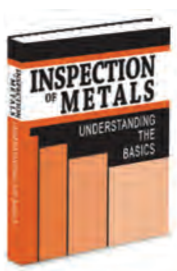
METALLOGRAPHY & MATERIALS CHARACTERIZATION



Inspection of Metals: Understanding the Basics

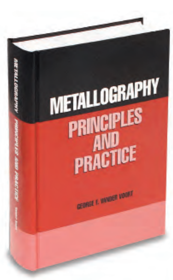
Edited by F.C. Campbell

2013 • 487 pages

ISBN: 978-1-62708-000-2
Product Code: 05372G

Price: $187 / ASM Member: $135

Emphasizes final part inspection at the manufacturing facility or on receipt at the user's facility. Provides an intermediate level overview to the different methods used to inspect metals and finished parts and a more detailed review of the specific inspection methods for important metal product forms. The advantages and limitations of each method are discussed, including when other methods may be warranted. Chapters on specific product forms (e.g., castings) compare the different inspection methods and why they are used.



Metallography: Principles and Practice

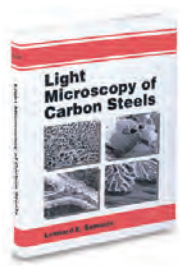
By G. Vander Voort

1984 • 752 pages

ISBN: 978-0-87170-672-0
Product Code: 06785G

Price: $177 / ASM Member: $135

A proven reference work for metallographers, engineers, and technicians as well as students. Thoroughly referenced and well-illustrated with an extensive collection of micrographs and macrographs.



Light Microscopy of Carbon Steels

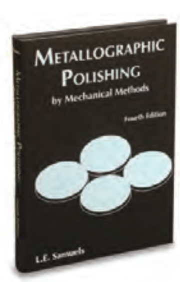
By L.E. Samuels

1999 • 502 pages

ISBN: 978-0-87170-655-3
Product Code: 06656G

Price: $237 / ASM Member: $175

"How to" book gives everyday working examples and discusses the relationship between the constitution, properties, and microstructure of various carbon steel products. Over 1,200 micrographs and 90 other figures.



Metallographic Polishing by Mechanical Methods, 4th Edition

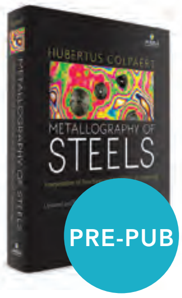
By L.E. Samuels

2003 • 345 pages

ISBN: 978-0-87170-779-6
Product Code: 06964G

Price: $157 / ASM Member: $115

ALSO SEE
ASM Handbook, Volume 9: Metallography and Microstructures, page 3



Metallography of Steels: Interpretation of Structure and the Effects of Processing

By Hubertus Colpaert

Translated and updated by André Luiz V. da Costa e Silva

2018 • Approx. 700 pages

ISBN: 978-1-62708-148-1
Product Code: 05922G

Price: ~~$199~~ / ASM Member: ~~$149~~
Prepublication price: $179 / ASM Member $139
Prepublication price good through January 31, 2018!

This book is a combination of a metallographic atlas for steels and cast irons and an introductory textbook covering the fundamentals of phase transformations and heat treatment of these materials. Every important stage of processing, from casting to cold working is clearly discussed and copiously illustrated with metallographs that show the obtained structures, both desired and those achieved when deviations occur. A valuable companion even for experienced steel practitioners.

Hardness Testing, 2nd Edition

Edited by H. Chandler

1999 • 192 pages

ISBN: 978-0-87170-640-9
Product Code: 06671G

Price: $77 / ASM Member: $55

Hardness Testing: Principles and Applications

Edited by Dr. Konrad Herrmann, et al.

2011 • 262 pages

ISBN: 978-1-61503-832-9
Product Code: 05331G

Price: $157 / ASM Member: $115

Hardness testing of metals, plastics, rubber and other materials. Technical developments such as the introduction of image processing in the Brinell and Vickers method, the adaptation of hardness testing machines to process-oriented testing conditions, and the development of highly accurate and efficient calibration methods.

Optical Microscopy of Fiber-Reinforced Composites

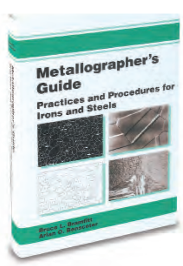
By Brian S. Hayes and Luther M. Gammon

2010 • 284 pages

ISBN: 978-1-61503-044-6
Product Code: 05303G

Price: $177 / ASM Member: $135

Optical microscopy is one of the most valuable, but under-utilized, tools for analyzing fiber-reinforced polymer matrix composites. Hands-on book covers: sample preparation, microscopic techniques, and applications. Over 180 full color images illustrate the technology's power to study the microstructure of heterogeneous, anisotropic materials.



Metallographer's Guide: Practices and Procedures for Irons and Steels

By B.L. Bramfitt and A.O. Benscoter

2002 • 354 pages

ISBN: 978-0-87170-748-2
Product Code: 06040G

Price: $257 / ASM Member: $185

Important metallurgical concepts related to the microstructures of irons and steels. More than 500 representative microstructures, and how they can be altered by heat treatment and other means.

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Atlas of Stress-Strain Curves, 2nd Edition

2002 • 816 pages

ISBN: 978-0-87170-739-0
Product Code: 06825G

Price: $307 / ASM Member: $231

More than 1400 curves normalized in appearance to aid making comparisons among materials. All diagrams include metric (SI) units, and many also include U.S. customary units captioned with standard designation, the primary source of the curve, mechanical properties, condition of sample, strain rate, test temperature, and alloy composition.

Tensile Testing, 2nd Edition

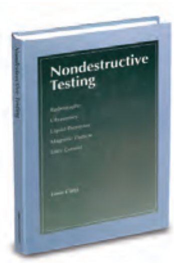
Edited by J.R. Davis

2004 • 283 pages

ISBN: 978-0-87170-806-9
Product Code: 05106G

Price: $137 / ASM Member: $105

A complete guide to the uniaxial tensile test, the cornerstone test for determining the mechanical properties of materials. Learn ways to predict material behavior through tensile testing, and how to test metals, alloys, composites, ceramics, and plastics to determine strength, ductility and elastic/plastic deformation.



Nondestructive Testing

By L. Cartz

1995 • 229 pages

ISBN: 978-0-87170-517-4
Product Code: 06390G

Price: $107 / ASM Member: $75

Problems and defects of all kinds arise in the development and use of mechanical devices, electrical equipment, hydraulic systems, and transportation mechanisms. However, an extremely wide range of nondestructive testing (NDT) methods are available to help you examine these different problems and various defects in an assortment of materials under varying circumstances.

Metallographic Etching, 2nd Edition

By G. Petzow

1999 • 240 pages

ISBN: 978-0-87170-633-1
Product Code: 06670G

Price: $127 / ASM Member: $95

An outstanding source on etchants of all types and electrolytic polishing solutions used by metallographers to reveal the structure of nearly any material to be prepared and examined.

SAVE UP TO $57

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Fatigue and Durability 2-Volume Set
Product Code: 05282G
Price: $457 / ASM Member: $375

Fatigue and Durability of Structural Materials

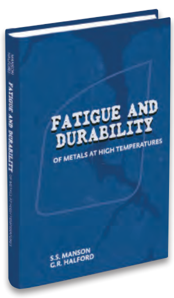
By S.S. Manson and G.R. Halford

2006 • 456 pages

ISBN: 978-0-87170-825-0
Product Code: 06987G

Price: $257 / ASM Member: $185

Focuses on metallic materials but also addresses unique capabilities of important nonmetals.



Fatigue and Durability of Metals at High Temperatures

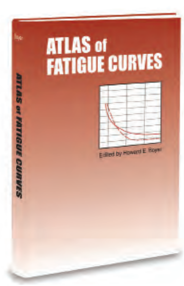
By S.S. Manson and G.R. Halford

2009 • 268 pages

ISBN: 978-0-87170-718-5
Product Code: 05206G

Price: $257 / ASM Member: $185

Written by preeminent experts, this work gives development engineers, students, and component designers an important reference on how to analyze time-dependent metal fatigue at high temperatures.



Atlas of Fatigue Curves

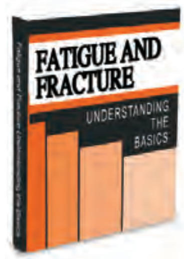
Edited by H.E. Boyer

1986 • 518 pages • Illustrated

ISBN: 978-0-87170-214-2
Product Code: 06156G

Price: $307 / ASM Member: $231

More than 500 fatigue curves for industrial ferrous and nonferrous alloys. Standard S-N curves, curves showing effect of surface hardening on fatigue strength, crack growth-rate curves, curves comparing the fatigue strengths of various alloys, effect of temperature, humidity, frequency, aging, environment and more.



Fatigue and Fracture: Understanding the Basics

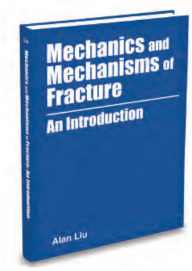
Edited by F.C. Campbell

2012 • 698 pages

ISBN: 978-1-61503-976-0
Product Code: 05361G

Price: $187 / ASM Member: $135

Covers mechanical properties of materials, differences between ductile and brittle fractures, fracture mechanics, the basics of fatigue, structural joints, high temperature failures, wear, environmentally-induced failures, and steps in the failure analysis process. Chapters devoted to fatigue and fracture of steels, aluminum alloys, titanium and titanium alloys, ceramics, polymers, and continuous fiber polymer matrix composites.



Mechanics and Mechanisms of Fracture: An Introduction

By A.F. Liu

2005 • 458 pages

"Recommended." - *Choice: Current Reviews for Academic Libraries,* June 2006

ISBN: 978-0-87170-802-1
Product Code: 06954G

Price: $167 / ASM Member: $125

Fundamental and practical concepts of fracture are described in terms of stress analysis and the mechanical behavior of materials.

Fatigue and Fracture Reference Library DVD 2012 Edition

2012 • ASM International

ISBN: 978-1-61503-981-4
Product Code: 05366V

Price: $703 / ASM Member: $601

The most comprehensive collection of fatigue and fracture technical information and data ever assembled on one disc– more than 10,000 pages in all!

A complete guide to the fatigue and fracture behavior of irons, steels, nonferrous alloys, and composites. Fundamentals, fatigue mechanisms, fatigue strength, fracture mechanics, fatigue and fracture control, and much more.

DVD can be used with any Windows platform laptop or desktop computer with a DVD drive. Articles can be printed, and text, tables, and images can be copied and pasted. Note: The files on the disc cannot be copied, so the DVD must be present in the local machine for the content to be accessed.

MANUFACTURING & DESIGN

Extrusion, 2nd Edition

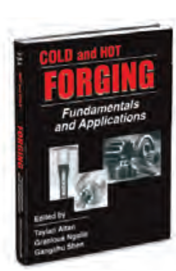
Edited by M. Bauser, G. Sauer, and K. Siegert

2006 • 608 pages

ISBN: 978-0-87170-837-3
Product Code: 06998G

Price: $257 / ASM Member: $185

Newest edition. Overview of extrusion processes, equipment, and tooling. Metallurgical fundamentals of extrusion are covered in detail.



Cold and Hot Forging: Fundamentals and Applications

Edited by T. Altan, G. Ngaile and G. Shen

2005 • 341 pages

ISBN: 978-0-87170-805-2
Product Code: 05104G

Price: $207 / ASM Member: $155

Fundamentals of forging technology, principal variables of the forging process and their interactions, and computer-aided techniques such as finite-element analysis (FEA) for forging process and tooling design.

Hot Working Guide: A Compendium of Processing Maps, Second Edition

Edited by Y.V.R.K. Prasad, K.P. Rao, and S. Sasidhara

2015 • 628 pages

IBSN: 978-1-62708-091-0
Product Code: 05445G

Price: $265 / ASM Member: $199

This is a unique source book with flow stress data for hot working, processing maps with metallurgical interpretation and optimum processing conditions for metals, alloys, intermetallics, and metal matrix composites. In the second edition, significant additions of maps on stainless steels, magnesium alloys, titanium alloys and nickel alloys have been made.

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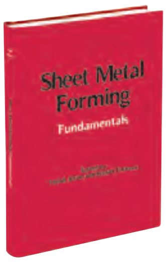
Sheet Metal Forming: 2-Volume Set
Product Code: 05351G
Price: $327 / ASM Member: $245



Sheet Metal Forming: Fundamentals

Edited by Taylan Altan and A. Erman Tekkaya

2012 • 314 pages

ISBN: 978-1-61503-842-8
Product Code: 05340G

Price: $207 / ASM Member $155

Principal variables of sheet forming – including interactions between variables – are clearly explained, as a basic foundation for the most effective use of computer aided modeling in process and die design.

Sheet Metal Forming: Processes and Applications

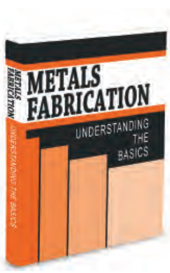
Edited by Taylan Altan and A. Erman Tekkaya

2012 • 382 pages

ISBN: 978-1-61503-844-2
Product Code: 05350G

Price: $207 / ASM Member: $155

The latest developments on the design of sheet forming operations, equipment, tooling, and process modeling.



Metals Fabrication: Understanding the Basics

By F.C. Campbell

2013 • 439 pages

IBSN: 978-1-62708-018-7
Product Code: 05374G

Price: $187 / ASM Member: $135

This book can be read and understood by anyone with a technical background. It is especially useful to those who deal with metals including designers, mechanical engineers, civil engineers, structural engineers, material and process engineers, manufacturing engineers, faculty, and materials science students. This volume covers the basics of metal fabrication, delving deep into the technology of metals fabrication.

ASM Specialty Handbook® Tool Materials

Edited by J.R. Davis

1995 • 501 pages

ISBN: 978-0-87170-545-7
Product Code: 06506G

Price: $307 / ASM Member: $231

Casting Design and Performance

2009 • 272 pages

ISBN: 978-0-87170-724-6
Product Code: 05263G

Price: $197 / ASM Member: $145

For designers, manufacturing engineers, and purchasing personnel who specify and evaluate metal castings. General design principles with in-depth coverage on important design configurations of cast components, casting design influences in casting solidification and properties. Dynamic properties are described in detail for cast iron, steel, and aluminum.

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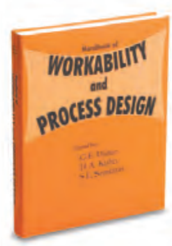

Handbook of Workability and Process Design

Edited by G.E. Dieter, H.A. Kuhn, and S.L. Semiatin

2003 • 414 pages

ISBN: 978-0-87170-778-9
Product Code: 06701G

Price: $247 / ASM Member: $185

STEELS

Advanced High-Strength Steels: Science, Technology and Applications

By Mahmoud Y. Demeri

2013 • 312 pages

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A comprehensive examination of the types, microstructures, and attributes of AHSS as well as a review of current and future applications, the benefits, trends, and environmental and sustainability issues.

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1982 • 509 pages

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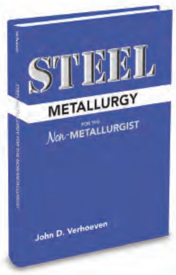

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By John D. Verhoeven

2007 • 225 pages

ISBN: 978-0-87170-858-8
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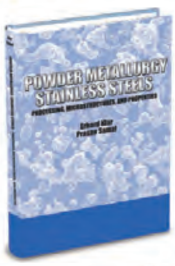

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ISBN: 978-0-87170-848-9
Product Code: 05200G

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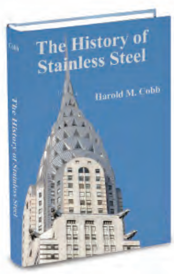

The History of Stainless Steel

By Harold M. Cobb

2010 • 384 pages • Illustrated

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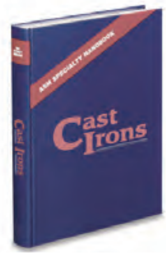

ASM Specialty Handbook® Cast Irons

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1996 • 494 pages

ISBN: 978-0-87170-564-8
Product Code: 06613G

Price: $307 / ASM Member: $231

Basic information on metallurgy, solidification characteristics, and properties, as well as extensive reviews on the low-alloy gray, ductile, compacted graphite, and malleable irons.

Steels: Processing, Structure, and Performance, 2nd Edition

By George Krauss

2015 • 682 pages

ISBN: 978-1-62708-083-5
Product Code: 05441G

Price: $207 / ASM Member: $155

This is the essential information resource for anyone who makes, uses, studies, or designs with steel. The expanded and updated Second Edition emphasizes processing, alloying, microstructure, deformation, fracture, and properties of major steel types ranging from low-carbon sheet steels, pearlitic rail and wire steels, to quench and tempered medium- and high-carbon martensitic steels. Microstructural aspects of steelmaking, hardenability, tempering, surface hardening, and embrittlement phenomena have been updated.

Stainless Steels for Design Engineers

By Michael F. McGuire

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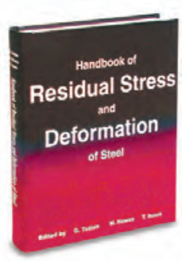
ISBN: 978-0-87170-717-8
Product Code: 05231G

Price: $187 / ASM Member: $135

Addresses selection for corrosion resistance, processing, and major applications.



Handbook of Residual Stress and Deformation of Steel

Edited by G. Totten, M. Howes, and T. Inoue

2002 • 499 pages

ISBN: 978-0-87170-729-1
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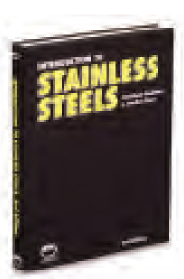
Price: $167 / ASM Member: $125

Recommended heat treating practices, methods for maintaining temperature uniformity during heating, tips for preventing oxide formation, and techniques for measuring residual stresses.



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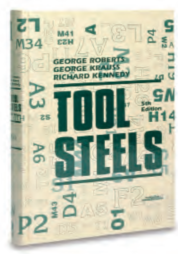
Purchase, design, and manufacture of castings (including casting and molding, heat treatment, and quality assurance), materials selection for mechanical and chemical properties, and materials selection for processing properties.



Tool Steels, 5th Edition

By G. Roberts, G. Krauss, and R. Kennedy

1998 • 364 pages

ISBN: 978-0-87170-599-0
Product Code: 06590G

Price: $207 / ASM Member: $155

Contains a significant amount of information from the past two decades presented in an easy-to-use outline format, making this a "must have" reference for engineers involved in tool-steel production, as well as in the selection and use of tool steels in metalworking and other materials manufacturing industries.

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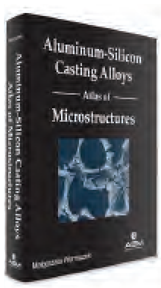

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By Małgorzata Warmuzek

2016 • Approximately 186 pages

ISBN: 978-1-62708-108-5
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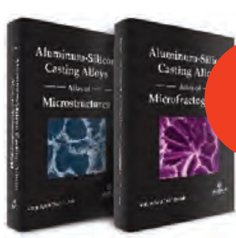
This atlas provides engineers and researchers who work with aluminum castings with a practical and substantive tool for the visual analysis of the microscopic images of the microstructure of the aluminum casting alloys, as examined during routine laboratory procedures.



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By Małgorzata Warmuzek

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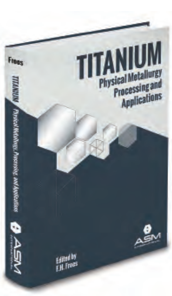

Titanium: Physical Metallurgy, Processing, and Applications

Edited by F.H. Froes

2015 • 404 pages

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Product Code: 05448G

Price: $187 / ASM Member: $135

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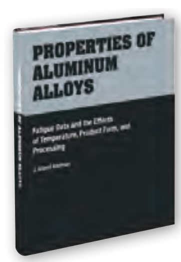

Properties of Aluminum Alloys: Fatigue Data and the Effects of Temperature, Product Form, and Processing

Edited by J.G. Kaufman

2008 • 574 pages

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Product code: 05156G

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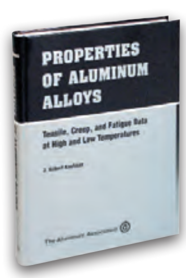
One of the most comprehensive collections of fatigue data yet available for aluminum alloys, temperatures, and products. The data, including over 1000 curves and numerous tables, are presented in a consistent format, conveniently arranged by alloy and temper.



Properties of Aluminum Alloys: Tensile, Creep, and Fatigue Data at High and Low Temperatures

Edited by J.G. Kaufman

1999 • 311 pages

ISBN: 978-0-87170-632-4
Product code: 06813G

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Co-published by the Aluminum Association and ASM International.

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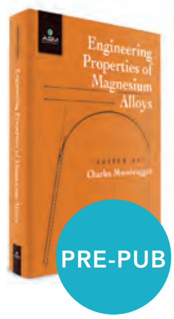

Engineering Properties of Magnesium Alloys

Edited by Charles Moosbrugger

2017 • Approx. 175 pages

ISBN: 978-1-62708-143-6
Product Code: 05920G

Price: ~~$199~~ / ASM Member: ~~$149~~
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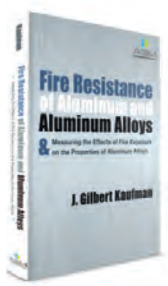
Written for engineers, scientists, teachers, and students engaged in the design process of material selection and material elimination. While focused on mechanical properties for structural design, the physical properties that are germane to corrosion behavior and electrical applications are represented. Datasheets for individual magnesium alloys provide a handy quick reference to specific properties and performance. Topics such as the alloy designation system and product forms are addressed.



Fire Resistance of Aluminum and Aluminum Alloys

& Measuring the Effects of Fire Exposure on the Properties of Aluminum Alloys

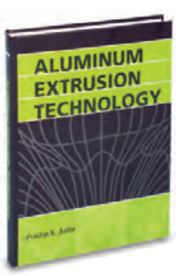
By J. Gilbert Kaufman

2016 • 138 pages

ISBN: 978-1-62708-106-1
Product Code: 05917G

Price: $149 / ASM Member: $109

Contains valuable information about the fire resistance of aluminum and aluminum alloys including what occurs when aluminum is in a fire and how the effects of fire damage are evaluated. All aspects of aluminum's fire resistance are described, and reliable methods to estimate the extent of damage resulting from exposure to fire are presented, most notably the relationship between hardness and electrical conductivity with strength.



Aluminum Extrusion Technology

By P.K. Saha

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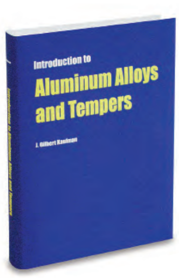
Practical information and reviews of important theoretical concepts in the different areas of extrusion technology. Intended for technical and engineering personnel, as well as research students in manufacturing.



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Advantages and limitations of aluminum alloys and temper combinations in terms of the relationship of their composition, process history, and microstructure to service requirements.

Beryllium Chemistry and Processing

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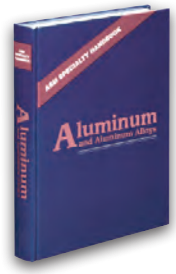
2009 • 680 pages

ISBN: 978-0-87170-721-5
Product Code: 05223G

Price: $257 / ASM Member: $191

Beryllium compounds of industrial interest, alloying, casting, powder processing, forming, metal removal, joining, and other manufacturing processes are covered. Environmental degradation of beryllium and its alloys both in aqueous and high temperature condition, plus health and environmental issues.



ASM Specialty Handbook® Aluminum & Aluminum Alloys

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Edited by J.R. Davis

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ASM Specialty Handbook® Magnesium and Magnesium Alloys

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1999 • 314 pages

ISBN: 978-0-87170-657-7
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Edited by J.R. Davis

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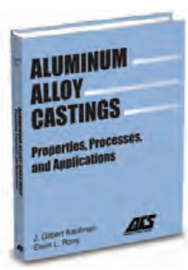
Product Code: 06178G

Price: $307 / ASM Member: $231

The compositions, properties, processing, performance, and applications of nickel, cobalt, and their alloys.



Aluminum Alloy Castings: Properties, Processes, and Applications

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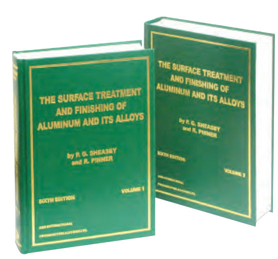

The Surface Treatment and Finishing of Aluminum and Its Alloys, (2 Volume Book + CD)

By P.G. Sheasby and R. Pinner

2001 • 1387 pages

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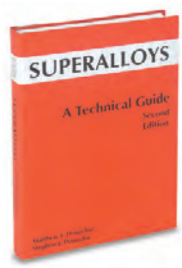

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Blaine Geddes, Hugo Leon, and Xiao Huang

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An introduction for understanding the compositional complexity of superalloys and the wide range of alloys developed for specific applications. The basics of alloying, strengthening mechanisms, and structure of superalloys are explained in optimizing particular mechanical properties, oxidation/corrosion resistance, and manufacturing characteristics such as castability, forgeability, and weldability.

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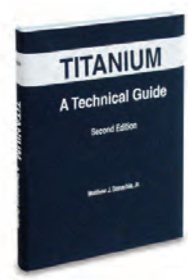

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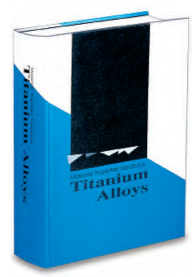

Materials Properties Handbook: Titanium Alloys

Edited by R. Boyer, E.W. Collings, and G. Welsch

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Compares joining methods, explains the fundamental parameters of brazes, and surveys the metallurgy of braze alloy systems.

Principles of Soldering

By Giles Humpston and David M. Jacobson

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ISBN: 978-0-87170-792-5
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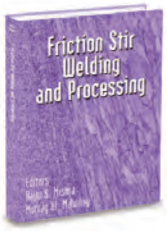
Price: $167 / ASM Member: $125

The fundamental characteristics of solders, fluxes, and joining environments and the impact these have in the selection and successful use of soldering.



Friction Stir Welding and Processing

Edited by R.S. Mishra and M.W. Mahoney

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Price: $157 / ASM Member: $115

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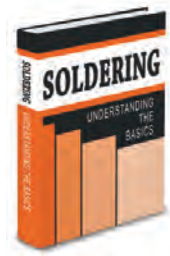
Edited by F.C. Campbell

2011 • 346 pages

ISBN: 978-1-61503-825-1
Product Code: 05329G

Price: $187 / ASM Member: $135

Extends ASM's Understanding the Basics series into fabrication technologies. An introduction to welding, brazing, soldering, fastening, and adhesive bonding. Addresses metallurgical issues that must be understood during welding, including joining systems of materials that are the same, similar, or different.



Soldering: Understanding the Basics

By M.M. Schwartz

2014 • 184 pages

IBSN: 978-1-62708-058-3
Product Code: 05338G

Price: $187 / ASM Member: $135

Covers various soldering methods and techniques as well as the latest on solder alloys, solder films, surface preparation, fluxes and cleaning methods, heating methods, inspection techniques, and quality control and reliability.

Brazing, 2nd Edition

By M.M. Schwartz

2003 • 421 pages

ISBN: 978-0-87170-784-0
Product Code: 06955G

Price: $157 / ASM Member: $115

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Each data sheet gives the chemical composition of the alloy, a listing of similar U.S. and foreign alloys, its characteristics, and the recommended heat treating procedure. A wide variety of additional heat treating data is included, such as representative micrographs, isothermal transformation diagrams, cooling transformation diagrams, tempering curves, and data on dimensional change.

Heat Treater's Guide: Practices and Procedures for Nonferrous Alloys

1996 • 669 pages

ISBN: 978-0-87170-565-5
Product Code: 06325G

Price: $307 / ASM Member: $231

Quick access to recommended heat treating information for hundreds of nonferrous alloys, plus composition, trade names, common name, specifications (both U.S. and foreign), available product forms, and typical applications. Information is presented by alloy group in the datasheet format established in the companion edition on irons and steels.

Heat Treatment of Gears: A Practical Guide for Engineers

By A.K. Rakhit

2000 • 209 pages

ISBN: 978-0-87170-694-2
Product Code: 06732G

Price: $167 / ASM Member: $125

Heat treat distortion of gears is discussed in detail for the major heat treat processes. A case history of each successful gear heat treat process is included.

Vacuum Heat Treatment
By Daniel H. Herring • Publisher: BNP Media

Volume I: Principles, Practices, and Applications
2012 • 536 pages
ISBN: 978-0-976-75650-7
Product Code: 75025G
Price: $154.99 / ASM Member: $139.49

Volume I is a comprehensive introduction and technical resource for vacuum processes and equipment, focusing on subjects that engineers, heat treaters, quality assurance personnel, and metallurgists need to know.

Volume II: Applications, Equipment, and Operation
2016 • 1076 pages
ISBN: 978-0-692-76738-2
Product Code: 75192G
Price: $154.99 / ASM Member: $139.49

Volume II covers new topics and expands on those in Volume I, making this two-volume series the comprehensive resource on the subject of vacuum heat treatment.

Atmosphere Heat Treatment
By Daniel H. Herring • Publisher: BNP Media

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ISBN: 978-0-692-28393-6
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Price: $154.99 / ASM Member $139.49

Volume 1 emphasizes fundamental principles, materials, metallurgy, applications, and equipment.

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2015 • 824 pages
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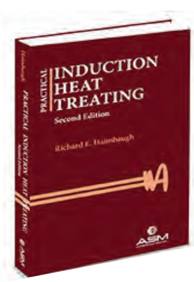
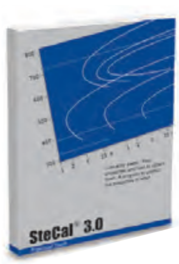
Volume 2 focuses on furnace atmospheres, quenching practices, testing, safety, conservation, maintenance, and specification compliance.



Practical Induction Heat Treating, Second Edition
By R.E. Haimbaugh
2015 • 365 pages
ISBN: 978-1-62708-089-7
Product Code: 05505G
Price: $207 / ASM Member: $155

This book is a quick reference source for induction heaters and ties in the metallurgy, theory, and practice of induction heat treating from a hands-on explanation of what floor people need to know. New material has been added including updated information on quenching methods, applications, inspection for quality control, and updated material on power supplies.



SteCal® 3.0 (CD + Booklet)
By P. Tarin and J. Pérez
2004 • Microsoft Windows format
ISBN: 978-0-87170-796-3
Product Code: 07482A
Price: $447 / ASM Member: $335

Use for predicting the properties obtained from heat treating low-alloy steels. An excellent tool for heat treaters to use in estimating and refining heat treating parameters for unfamiliar steels, or comparing the properties of two steels of different composition to arrive at the most appropriate composition for a particular application.

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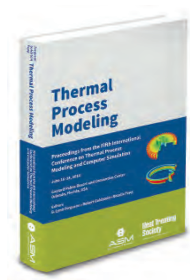
1991 • 804 pages • 1839 diagrams
ISBN: 978-0-87170-415-3
Product Code: 06150G
Price: $307 / ASM Member: $231

Nonferrous Alloys
Edited by G. Vander Voort
1991 • 474 pages • 500 diagrams
ISBN: 978-0-87170-428-3
Product Code: 06190G
Price: $307 / ASM Member: $231

Heat Treating Reference Library DVD, 2012 Edition
2012 • ASM International
ISBN: 978-1-61503-840-4
Product Code: 05347V
Price: $703 / ASM Member: $601

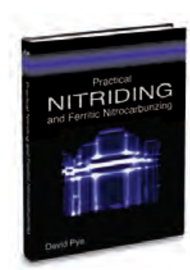
A complete guide to the heat treating of steels and nonferrous alloys. More than 3000 articles, data sheets, and diagrams from the ASM Handbook and other authoritative sources—more than 15,000 pages of content.

The DVD can be used with any Windows platform laptop or desktop computer with a DVD drive. Articles can be printed, and text, tables, and images can be copied and pasted. Note: The files on the disc cannot be copied, so the DVD must be present in the local machine for the content to be accessed.



Thermal Process Modeling: Proceedings of the 5th International Conference on Thermal Process Modeling and Computer Simulation
Edited by B.L. Ferguson, R. Goldstein, and R. Papp
2014 • 329 pages
ISBN: 978-1-62708-068-2
Product Code: 05447G
Price: $168 / ASM Member: $139

This collection of papers represents the heart of the 5th International Conference on Thermal Process Modeling and Computer Simulation. Thermal processes are key manufacturing steps in producing durable and useful products, with solidification, welding, heat treating, and surface engineering being primary steps.



Practical Nitriding and Ferritic Nitrocarburizing
By David Pye
2003 • 256 pages
ISBN: 978-0-87170-791-8
Product Code: 06950G
Price: $207 / ASM Member: $155

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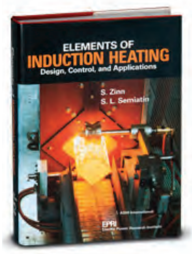


Elements of Induction Heating: Design, Control, & Applications

By S. Zinn, S.L. Semiatin

1988 • 335 pages

ISBN: 978-0-87170-308-8
Product Code: 06522G

Price: $107 / ASM Member: $75

Practical Heat Treating, 2nd Edition

By J.L. Dossett and H.E. Boyer

2006 • 296 pages

ISBN: 978-0-87170-829-8
Product Code: 05144G

Price: $147 / ASM Member: $105

An excellent introduction and guide for design and manufacturing engineers, technicians, students, and others who need to understand why heat treatment is specified and how different processes are used to obtain desired properties. Clear, concise, and non-theoretical language.

Surface Hardening of Steels: Understanding the Basics

Edited by J.R. Davis

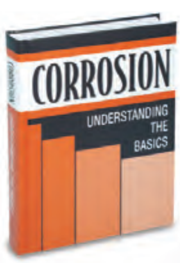
2002 • 364 pages

ISBN: 978-0-87170-764-2
Product Code: 06952G

Price: $147 / ASM Member: $105

A practical selection guide to help engineers and technicians choose the most efficient surface hardening techniques that offer consistent and repeatable results. Emphasis is placed on processing temperature, case/coating thickness, bond strength, and hardness level obtained.

CORROSION



Corrosion: Understanding the Basics

Edited by J.R. Davis

2000 • 563 pages

ISBN: 978-0-87170-641-6
Product Code: 06691G

Price: $197 / ASM Member: $145

A "how to" approach to understanding and solving the problems of corrosion of structural materials. Written for those with limited technical background. Provides more experienced engineers with a useful overview of the principles of corrosion and can be used as a general guide for developing a corrosion-control program.

Handbook of Corrosion Data, 2nd Edition

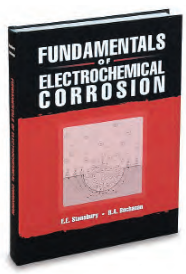
Edited by B. Craig and D. Anderson

1995 • 998 pages

ISBN: 978-0-87170-518-1
Product Code: 06407G

Price: $307 / ASM Member: $231

Includes "Corrosion of Metals and Alloys" and "Corrosion Media." The first part contains summaries on the general corrosion characteristics of major metals and alloys in various corrosion environments. The second part is organized alphabetically by chemical compound and the data for each corrosive agent/compound are in tabular form.



Fundamentals of Electrochemical Corrosion

By E.E. Stansbury and R.A. Buchanan

2000 • 487 pages

ISBN: 978-0-87170-676-8
Product Code: 06594G

Price: $157 / ASM Member: $115

Stress-Corrosion Cracking: Materials Performance and Evaluation, Second Edition

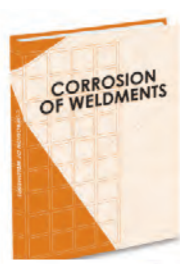
Edited by Russell H. Jones

2016 • 473 pages

ISBN: 978-1-62708-118-4
Product Code: 05509G

Price: $199 / ASM Member: $149

This new second edition serves as a go-to reference on the complex subject of stress-corrosion cracking (SCC), offering information to help metallurgists, materials scientists, and designers determine whether SCC will be an issue for their design or application; and for the failure analyst to help determine if SCC played a role in a failure under investigation.



Corrosion of Weldments

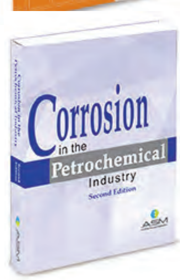
Edited by J.R. Davis

2006 • 236 pages

ISBN: 978-0-87170-841-0
Product Code: 05182G

Price: $207 / ASM Member: $155

Details the many forms of weld corrosion and the methods used to minimize weld corrosion.



Corrosion in the Petrochemical Industry, Second Edition

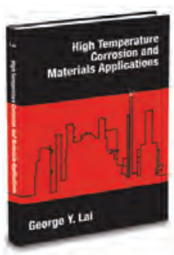
Edited by Victoria Burt

2015 • 426 pages

ISBN: 978-1-62708-094-1
Product Code: 05503G

Price: $219 / ASM Member: $165

A comprehensive guide to understanding and preventing corrosion in the petrochemical industry. Written for engineers, production managers and technicians, this book explains how to select the best material for a corrosion-sensitive petrochemical application, and how to choose among various prevention methods. Included in the second edition are new articles on corrosion inhibitors and high-temperature environments.



High-Temperature Corrosion and Materials Applications

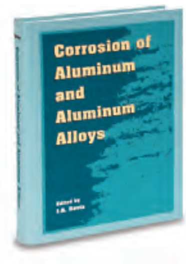
By George Y. Lai

2007 • 480 pages

ISBN: 978-0-87170-853-3
Product Code: 05208G

Price: $237 / ASM Member: $175

Covers oxidation, nitridation, carburization and metal dusting, corrosion by halogen and halides, sulfidation, erosion and erosion-corrosion, hot corrosion in gas turbines, boilers and furnaces, stress-assisted corrosion and cracking, molten salt corrosion, liquid metal corrosion and embrittlement, and hydrogen attack.



Corrosion of Aluminum and Aluminum Alloys

Edited by J.R. Davis

1999 • 313 pages

ISBN: 978-0-87170-629-4
Product Code: 06787G

Price: $167 / ASM Member: $125

Presents comprehensive coverage of the corrosion behavior of aluminum and aluminum alloys, with emphasis on practical information about how to select and process these materials in order to prevent corrosion attack.

COATINGS & SURFACE ENGINEERING

Protective Coatings for Turbine Blades

By Y. Tamarin

2002 • 244 pages

ISBN: 978-0-87170-759-8
Product Code: 06738G

Price: $53 / ASM Member: $42

Addresses the problem of surface protection for aircraft engine turbine blades. Based on the author's 30-plus years of work on the development and application of coatings to protect against oxidation and hot corrosion. Describes and details a methodology for optimizing turbine blade surface protection.

Volume 5B: Protective Organic Coatings

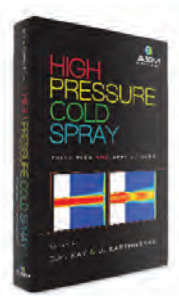
Edited by Kenneth B. Tator

2015 • 545 pages

ISBN: 978-1-62708-081-1
Product Code: 05437G

Price: $297 / ASM Member: $225

This completely new volume addresses a need for comprehensive information on organic coatings, including coating materials, surface preparation, application processes, industrial uses, and coating evaluation and analysis methods. This volume is essential for industrial coating users, specifiers, and contractors. The content in this volume has been written and reviewed by leading industry experts, making this latest ASM Handbook the definitive resource on this important topic. Plus, Volume 5B is the first volume in the ASM Handbook series to be printed in full color.



High Pressure Cold Spray: Principles and Applications

Edited by C.M. Kay and J. Karthikeyan

2016 • 324 pages

ISBN: 978-1-62708-096-5
Product Code: 05446G

Price: $199 / ASM Member: $179

A highly practical and useful "go-to" resource that presents an in-depth look at the high pressure cold spray process and describes applications in various industries. Applications of cold spray processes including protective coating production, development of performance enhancing layers, repair and refurbishing of parts, and NNS fabrication are elaborated in each industry with illustrative case studies by cold sprayers actively involved in the field.

Surface Engineering for Corrosion and Wear Resistance

Edited by J.R. Davis

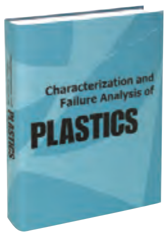
2001 • 279 pages

Co-published by IOM Communications and ASM International

ISBN: 978-0-87170-700-0
Product Code: 06835G

Price: $107 / ASM Member: $75

Provides practical information to help engineers select the best possible surface treatment for a specific corrosion or wear application. Covers process comparisons, and dozens of useful tables and figures compare surface treatment thickness and hardness ranges; abrasion and corrosion resistance; processing time, temperature, and pressure; costs; distortion tendencies; and other critical process factors and coating characteristics.



Characterization and Failure Analysis of Plastics

2003 • 482 pages

ISBN: 978-0-87170-789-5

Product Code: 06978G

Price: $247 / ASM Member: $185

Covers the performance of plastics and how it is characterized during design, property testing, and failure analysis. Selected by *Choice* magazine for its excellence in scholarship and presentation, the significance of its contribution to the field, and value as an important treatment of the subject.

Composite Filament Winding

Edited by S.T. Peters

2011 • 174 pages

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Product Code: 05286G

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Topics include capabilities and limitations of filament winding, practical issues such as fiber and resin handling, winding theory, software and numerical control, history of the process, and more.

Optical Microscopy of Fiber-Reinforced Composites

By Brian S. Hayes and Luther M. Gammon

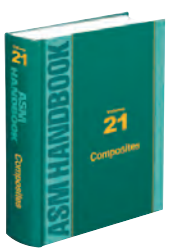
2010 • 284 pages

ISBN: 978-1-61503-044-6

Product Code: 05303G

Price: $177 / ASM Member: $135

Optical microscopy is one of the most valuable but under-utilized tools for analyzing fiber-reinforced polymer matrix composites. Covers sample preparation, microscopic techniques, and applications. The power to study the microstructure of heterogeneous, anisotropic materials is illustrated with over 180 full color images.



Volume 21: Composites

Edited by D.B. Miracle and S.L. Donaldson

2001 • 1201 pages

ISBN: 978-0-87170-703-1

Product Code: 06781G

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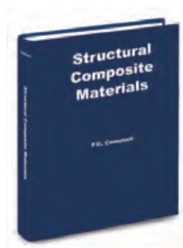
Price: $207 / ASM Member: $155



Structural Composite Materials

By F.C. Campbell

2010 • 630 pages

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All aspects of continuous and discontinuous fiber-reinforced polymer, metal, and ceramic composites are described in terms of fabrication, properties, design, analysis, and in-service performance.

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Edited by Richard J. Ross

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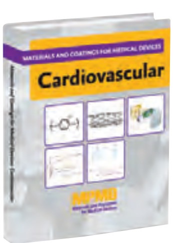
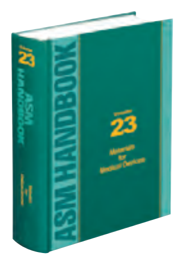


Materials and Coatings for Medical Devices: Cardiovascular

2009 • 452 pages
ISBN: 978-1-61503-000-2
Product Code: 05269G

Price: $307 / ASM Member: $231

A unique volume of engineering property data with detailed biological response information, in a consistent data sheet format, for the materials and coatings for cardiovascular medical devices. The emphasis is on materials and coatings used in FDA-approved implantable devices.



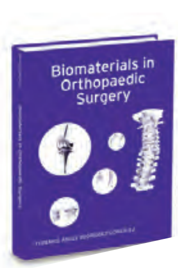
Volume 23: Materials for Medical Devices

Edited by Roger Narayan
2012 • 396 pages
ISBN: 978-1-61503-827-5
Product Code: 05285G

Price: $297 / ASM Member: $225

State-of-the-art reference for implant materials including stainless steels, cobalt-base alloys, titanium, shape memory alloys, noble metals, ceramics, and polymers. Examples of materials- and mechanical-based failures of medical devices. Covers biotribology, implant wear, clinical wear, and biological aspects. Corrosion effects, corrosion products, mechanically assisted corrosion, and corrosion fatigue. Biocompatibility of ceramics and polymers.

Volume 23 is a replacement for the *Handbook of Materials for Medical Devices* edited by J.R. Davis (ASM, 2003). It features new content that greatly expands the scope and depth of coverage, including a more in-depth discussion of materials and focus on applications.



Biomaterials in Orthopaedic Surgery

By Federico Ángel Rodríguez-González
2009 • 236 pages
ISBN: 978-1-61503-009-5
Product Code: 05233G

Price: $137 / ASM Member: $105

Biomaterials (metallic, nonmetallic, and bone allografts) used for orthopaedic applications and the engineering and clinical aspects of their use and performance. Case studies and specific applications include internal and external bone fracture fixation, hip and knee joint replacements, spine implants and disc prostheses, and the application of structural bone allografts for patients with bone tumors.

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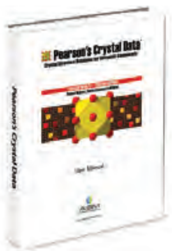

Pearson's Crystal Data: Crystal Structure Database for Inorganic Compounds®*

Edited by Pierre Villars and Karin Cenzual

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Binary Alloy Phase Diagrams, 2nd Edition

Edited by T.B. Massalski, H. Okamoto, P.R. Subramanian, and L. Kacprzak

1990 • 3589 pages

ISBN: 978-0-87170-403-0 (3-Volume Set)
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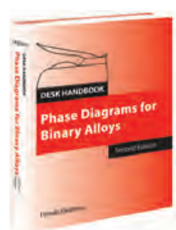

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By Hiroaki Okamoto

2010 • 855 pages

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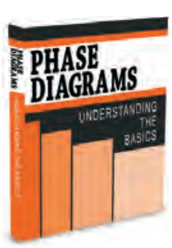

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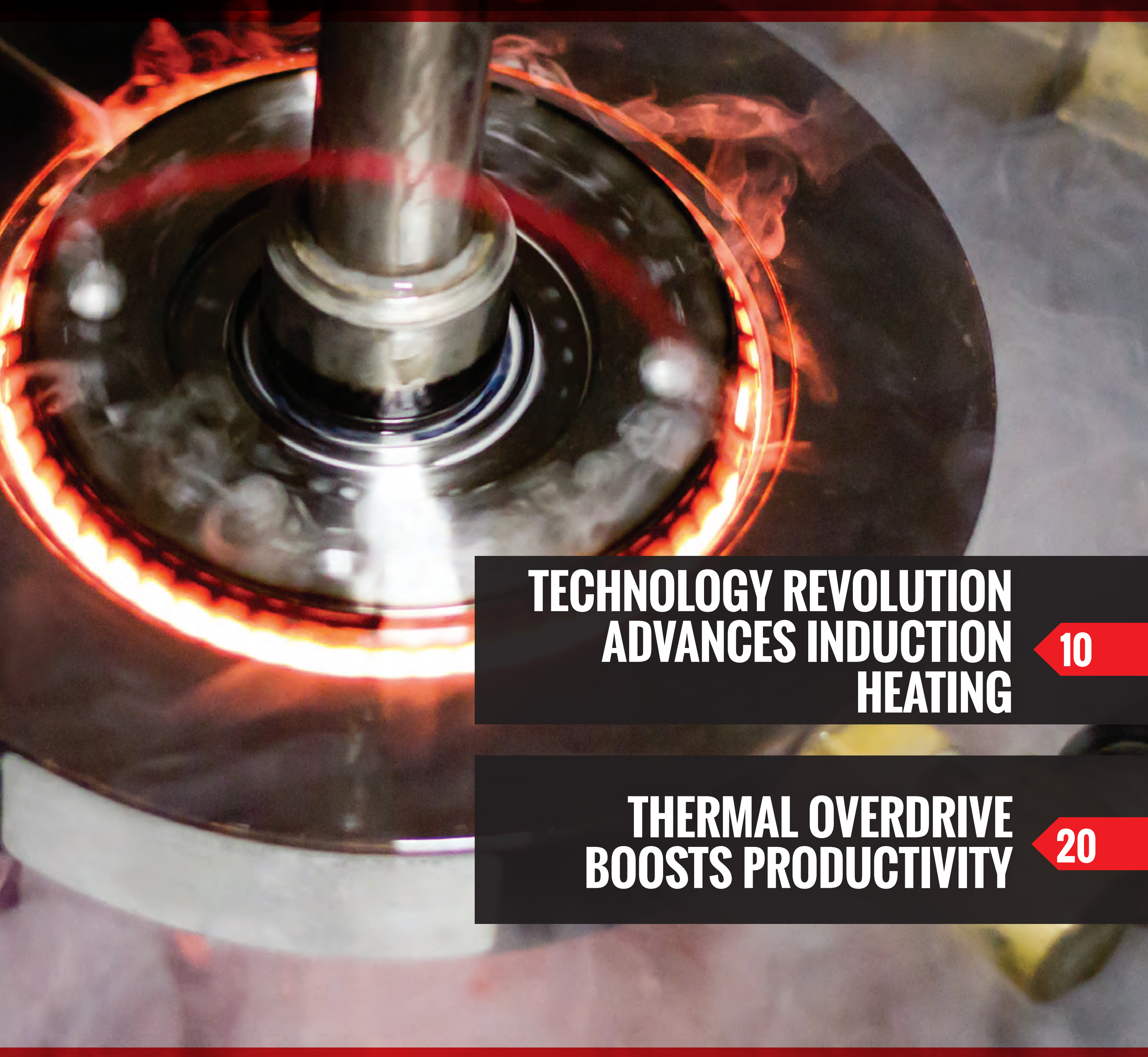
HTPRO

BUSINESS AND TECHNOLOGY FOR THE HEAT TREATING PROFESSIONAL



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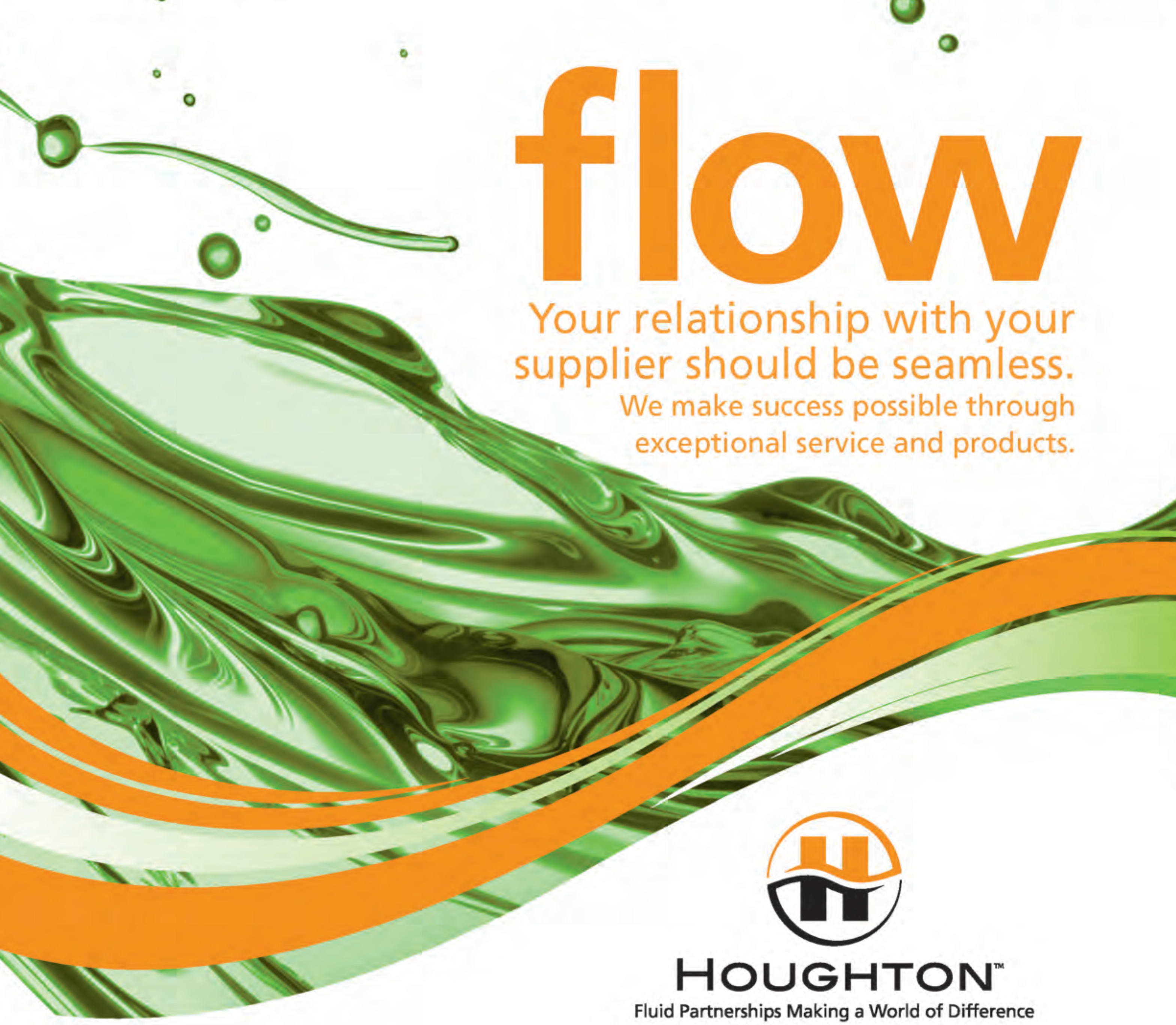

HTS Heat Treating Society
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BUSINESS AND TECHNOLOGY FOR THE HEAT TREATING PROFESSIONAL

DEPARTMENTS

ABOUT THE COVER

Austenitization of a steel component with teeth for single-shot hardening using an encircling inductor. Courtesy of Inductoheat Inc., inductoheat.com.

EDITORIAL OPPORTUNITIES FOR HTPro IN 2017

The editorial focus for *HTPro* in 2017 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 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.

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OFF-HIGHWAY INDUSTRY NO LONGER A LATE HEAT TREATING TECHNOLOGY FOLLOWER

After working 43 years in the heat treating industry, I've seen a major shift in the need for timely heat treat technology transfer. Years ago, off-highway vehicles were typically third in line for technology transfer, with high-tech aerospace leading the way, high-volume automotive a close follower, and the lower-volume off-highway industry in last place. Consider vacuum carburizing as an example. Used by the aerospace industry in the 1970s, it was adopted by the automotive industry for transmission gear heat treating within the last 15 years, but only used relatively recently in production applications for larger components by the off-highway industry. Besides product volumes and component sizes, there were valid reasons for being a late follower. Off-highway vehicle customers have always sought high productivity and reliability, while also being very cost conscious. This paved the way for using reliable, existing materials and processing technology to meet their needs.

The Vision 2020 work led by the U.S. Department of Energy's Office of Industrial Technologies (OIT) in the 1990s alerted the heat treating industry that more modern technology was needed to allow them to remain globally competitive. Assisted by the OIT, commercial and captive heat treaters collaborated to develop a Vision 2020 for the heat treating industry. This led to creation and publication of the ASM Heat Treating Society's 1999 Research and Development Plan, which identified advanced technologies needed by the industry. Publication of the plan triggered broad interest in heat treating technology needs. Industry-university research consortia were developed, such as the Center for Heat Treating Excellence at Worcester Polytechnic Institute in Massachusetts, and the Thermal Processing Technology Center at the Illinois Institute of Technology in Chicago. Off-highway industry experts joined aerospace and automotive experts as consortia members working on advanced heat treating technology.

Paralleling the consortia efforts, off-highway vehicle designs have advanced to provide customers additional productivity and fuel efficiency, often introducing new materials and processing streams. These customer requirements have increasingly driven recognition of the need for heat treating technology advances and adoption to create value. For example, today's gas atmosphere furnaces have improved productivity and controls. Vacuum carburizing and high-pressure gas quenching have made significant advances. Heat treat modeling in furnace and induction processes, as well as computational fluid dynamics, are regularly used to optimize improved microstructures, reduced distortion, and superior part performance on critical parts for off-highway applications and products. Special processing technologies, such as laser processing, have been adopted where the technology can provide unique results not possible with standard thermal processing.

Large amounts of heat treating data, analytics, and modeling have also been successfully used to optimize improvements in thermal processing efficiencies and quality. As is evident from the recent technology roadmap ("Advancing Thermal Manufacturing: A Technology Roadmap to 2020," asminternational.org/web/tmi-atc/tmi-atc-roadmap), the off-highway industry is now leading some of these efforts and is no longer a "late follower" of heat treating technology.

Bob Gaster
John Deere Senior Staff Engineer, retired

Ipsen

First-Time Heat Treater Streamlines Production, Reducing Lead Times by Nearly 85%

Customer Story

A manufacturer of Aerospace-grade fasteners wanted to streamline their production process and shorten lead times while still keeping costs low. They realized that to meet their objectives they needed to bring heat treatment in-house.

While the decision to bring heat treatment in-house made sense, this would be their first vacuum furnace. Ipsen's TITAN® product line appealed to them as it was built on the principle that everyone can be a heat treater, whether you are new to the industry or an expert. As such, all TITAN furnaces are carefully designed and crafted with the end user in mind.

"We used to send our products to a local heat treater before bringing them back in-house to finish the production process ... In the end, this strategy just wasn't working for us. It created long lead times and a convoluted in-house workflow that simply wasn't sustainable."

However, they not only needed a heat-treating system that could run their required processes, but also a company that had the resources to support them throughout the process. This included assistance with on-site installation, expert training and timely field support. In the end ...

Discover this customer's winning outcome:
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HTS NAMES NEW BOARD MEMBERS FOR 2017

The Heat Treating Society (HTS) board, at the recommendation of the HTS Awards and Nominating Committee, named new officers including **Eric Hutton** to serve as vice president for the 2017-2019 term; **Chuck Faulkner** and **Marc Glasser** to serve on the HTS board for the 2017-2020 term; **Joseph Fignar** to serve as emerging professional board member for the 2017-2018 term; and **Jonah Klemm-Toole** to serve as student board member for the 2017-2018 term. **Thomas Wingens** who served a partial term on the board has been reappointed to serve a full term during 2017-2020. Terms begin October 1. Continuing on the board are **Nathan Chupka** (member), **Robert Cryderman** (member), **Michael Pershing** (member), **Joseph Powell** (member), **Olga Rowan** (member), and **Craig Zimmerman** (member). **Stephen Kowalski** becomes past president and **Jim Oakes** becomes president on October 1. Leaving the board are **Roger Jones** (past president), **Timothy De Hennis** (member), **Hannah Noll** (emerging professional board member), and **Blake Whitley** (student board member).


Oakes

Jim Oakes is vice president of business development for Super Systems Inc. (SSi), Cincinnati. Since joining SSi in 2005, Oakes has overseen marketing, helped develop product innovation strategies, and drives SSi's commitment to quality and continuous improvement in the company's heat treating-related products. Prior to joining SSi, he worked at Oracle Corp., Redwood City, Calif., helping organizations leverage technology to become more competitive and improve processes with enterprise software solutions. Oakes serves on the Metal Treating Institute board and is a member of several committees focused on bringing value back to members. He has been involved with ASM for many years at the chapter level and contributed to the revised ASM Handbook on heat treating.


Hutton

Eric Hutton is vice president of operations, Aerospace, Defense and Energy (ADE) North America East for Bodycote International. He is responsible for sales and operations for Bodycote aerospace plants located in New England, Ohio, and South Carolina. Before joining Bodycote ADE in 2015, he served as vice president of operations for Bodycote's North American automotive businesses. His B.A. in marketing is from Bob Jones University, Greenville, S.C., and his M.S.M. is from Walsh College of Accountancy, Troy, Mich. Hutton has 20 years of experience in commercial heat treating and his background in the automotive and aerospace industries and executive experience with Bodycote provide a valuable foundation for being part of the HTS leadership. He has been involved with HTS activities for many years, including the Heat Treat Conference and HTS committees, and he is a member of the ASM Detroit Chapter.


Faulkner

Chuck Faulkner is production marketing manager – heat treatment, metal forming and metal forging at Houghton International in Valley Forge, Pa., having joined the company in 1983. With over 34 years of experience in the metalworking fluids industry and over 21 years as a global product marketing manager, he has had exposure to many forms of heat treating processes. Faulkner has been chair of the HTS Exposition Committee since 2013, was co-chair of the successful HTS Heat Treat Mexico 2016 conference, and will co-chair that event again in 2018. Faulkner is a member of the Forging Industry Association and Precision Metalforming Association. He has a B.A. in organizational management from Eastern College, St. Davids, Pa., and is a member of the ASM Philadelphia Chapter.


Glasser

Marc Glasser is director of metallurgical services and manager of the metallurgical lab at Rolled Alloys in Temperance, Mich. With over 35 years of experience in materials engineering, he specializes in heat resistant alloys and the welding of those materials. Previously, he worked over 10 years at Unilever Foods as principal and senior materials scientist. He is a member of the HTS Technology and Programming Committee and is an annual speaker at the ASM Heat Treat Conference. Glasser has been active in various ASM Chapters throughout his career and is currently with the Detroit Chapter. He has an M.S. in materials science from the NYU Tandon School of Engineering and a B.S in materials engineering from Rensselaer Polytechnic Institute. Glasser has authored seven published papers and holds two patents.


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 the student metallurgist on the SAE Formula Student Penn State Racing Team. He interned at ArcelorMittal and with the Penn State Applied Research Laboratory, and completed an independent research project that culminated in a peer-reviewed article.

Fignar is a process engineer at Honda Transmission Manufacturing where he is responsible for Fe/Ni-base heat treatment of transmission gears and components. He continues to be active in ASM International and has an ongoing interest in student outreach and development of hands-on approaches to engineering and metallurgical education.

Jonah Klemm-Toole is a Ph.D. student working in the Advanced Steel Processing and Products Research Center (ASPPRC) at Colorado School of Mines. Klemm-Toole joined the ASPPRC in August 2013 after working at Power Systems Manufacturing (PSM) for five years on reconditioning of industrial gas turbine components. Prior to working at PSM, he earned his B.S. degree in materials science and engineering at the University of Florida. Klemm-Toole also worked as a welder for seven years throughout high school and college.

Klemm-Toole

Thomas Wingens is president of Wingens International Industry Consultancy in Pittsburgh and Stuttgart, Germany. He holds an engineering degree (Dipl.Ing.) in materials science at the University of Applied Science in Dortmund/Germany and a MBA from the University of Economy and Management in Stuttgart. Wingens started his professional career in 1987 as a metallurgist and heat treater in the Thyssen Specialty Steel mill in Germany and has worked in management and executive positions at leading companies in the metal and heat treat industry such as Bodycote, Ipsen, Tenova Group, Seco/Warwick, and IHI Group and has executed research projects with ThyssenKrupp Germany, Volvo Corporate Research Sweden, and Böhler Voestalpine Steel Austria. He is a member of ASM and AIST in the U.S. and their equivalent societies in Germany (VDI, VDEH, AWT).

Wingens

KEOUGH RECEIVES GEORGE BODEEN HEAT TREATING ACHIEVEMENT AWARD

Keough

John R. (Chip) Keough, FASM, proprietor, Joyworks LLC, Ann Arbor, Mich., is the recipient of the 2017 George H. Bodeen Heat Treating Achievement Award. Established in 1996, the award recognizes distinguished and significant contributions to the field of heat treating through leadership, management, or engineering development of substantial commercial impact. Keough is recognized "for advancing business growth by emphasizing fundamental materials knowledge in the heat treating industry and for passionately supporting the next generation of engineers through materials education."

A registered professional engineer in the state of Ohio, Keough double majored in mechanical engineering and materials/metallurgical engineering at the University of Michigan. He now serves as adjunct professor in the material science and engineering department at his alma mater. In addition to academia, he has made significant contributions to industry. At TRW Turbine, Keough was lead engineer in the process commercialization of single crystal casting of super alloy turbine blades. After serving 30 years as CEO and then chairman of Applied Process Inc., Keough stepped into his current role of director and consultant. His business model for the company is built on a foundation of materials education. Through this model, his leadership at Applied Process, and his committee work with ASTM and ISO, he helped establish worldwide acceptance of austempered cast irons.

He has 10 patents and numerous awards, including Fellow of ASM International (1999) and the Foundry Educational Foundation E.J. Walsh Award (2014). In addition to years of committee work, he has served as a member of the HTS Board (1993-2003 and 2010-2013), the ASM Board of Trustees (2013-2016), and is currently a trustee on the ASM Materials Education Foundation Board. He is also president and chairman of the Keough Family Foundation, which annually supports the ASM Education Foundation's Teachers Materials Camp in Ann Arbor.

The Bodeen award will be presented at the HTS general membership meeting on Wednesday, October 25, at the ASM Heat Treating Society Conference and Exposition in Columbus, Ohio.

ROTHLEUTNER RECEIVES ASM/HTS SURFACE COMBUSTION EMERGING LEADER AWARD


Rothleutner

Established in 2013, 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 acknowledges an individual who sets the highest standards for ASM Heat Treating Society participation and inspires others to dedicate themselves to the advancement and promotion of vacuum and atmosphere heat treating technologies such as carburizing, carbonitriding, nitriding, annealing, and through hardening. The award will be presented at the HTS general membership meeting on Wednesday, October 25, at the ASM Heat Treating Society Conference and Exposition in Columbus, Ohio.

Lee Rothleutner, principal development engineer at The Timken Company, North Canton, Ohio, is recognized "for sustained contributions to research of alloy interactions during heat treatment and dedication to advancing the heat treating industry."

YI WINS HTS/BODYCOTE BEST PAPER IN HEAT TREATING AWARD


Yi

The winner of the 2017 HTS/Bodycote Best Paper in Heat Treating Award is entitled, "Effect of Pretreatment on the Sensitization Behavior of Al 5083 H116" by **Gaosong Yi,** a Ph. D. student in metallurgical engineering at the University of Utah. He received assistance from his advisor, Michael L. Free. His research project included three parts: characterization of Mg-rich precipitates formed in Al 5xxx alloys aged in low temperatures, modeling the precipitation behavior of Mg-rich precipitates, and mitigating the intergranular corrosion behavior of Al 5xxx alloys using pretreatment methods.

The award will be presented at the general membership meeting on Wednesday, October 25, at the ASM Heat Treating Society Conference and Exposition in Columbus, Ohio.

The ASM Heat Treating Society established the Best Paper in Heat Treating Award 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 includes a plaque and $2500 cash prize endowed by Bodycote Thermal Process-North America.

FERDON EARNS CHTE DISTINGUISHED SERVICE AWARD

The Center for Heat Treating Excellence (CHTE) at the Worcester Polytechnic Institute (WPI), Mass., presented its 2017 Distinguished Service Award to **Steve Ferdon.** The award is granted to an individual who has made significant, commendable, and long-standing contributions to the promotion of CHTE. A member of the ASM Heat Treating Society, Ferdon is the director of global engineering technology in the fuel systems business unit at global power leader Cummins Inc. He received the award from Richard Sisson, George F. Fuller professor of mechanical engineering at WPI and technical director of CHTE, at a formal ceremony during CHTE's biennial meeting on the WPI campus.

SOLICITING PAPERS FOR ASM HTS/BODYCOTE BEST PAPER 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, 2018.** Submissions should be sent to Mary Anne Jerson, ASM Heat Treating Society, 9639 Kinsman Rd., Materials Park, OH 44073, 440.338.5151 ext. 5539, maryanne.jerson@asminternational.org.

MARK YOUR CALENDARS

As HTS gears up for its big event in Columbus, Ohio, this October, plans are in the works for other heat treating conferences as well.

PLAN TO ATTEND:

Heat Treat 2017 • Columbus, Ohio • October 24-26

SAVE THE DATE:

Thermal Processing In Motion
Including the 4th International Conference on Heat Treatment and Surface Engineering in Automotive Applications
Spartanburg, South Carolina • June 5-7, 2018

Heat Treat Mexico
Queretaro • September 25-28, 2018


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REVOLUTION—NOT EVOLUTION—NECESSARY TO ADVANCE INDUCTION HEAT TREATING

Modern, high quality equipment must be readily available and flexible enough to allow for easy retooling and reprogramming to process a variety of parts.

Gary Doyon,* Valery Rudnev, FASM,* Collin Russell,* and John Maher*
Inductoheat Inc., Madison Heights, Mich.

Factors traditionally used by commercial heat treaters to evaluate induction equipment include technical capability, quality, price, delivery, and longevity. However, in light of recent industrial trends, an even more important factor is flexibility[1-3]. In the past, parts suppliers would often have a particular part contract for many years. Today, contracts can move from supplier to supplier much more frequently, so winning a contract over the competition could require a supplier to assess new induction equipment that can perform the job, purchase and setup the equipment, and complete a production part approval process (PPAP) to be in production in a short period of time. Modern, high quality, and reliable equipment must be readily available and must allow easy retooling and reprogramming to process different parts.

In discussing induction shaft hardening even a decade ago, it was not uncommon to assume a part geometry similar to that shown in Fig.1. Today, however, lightweighting initiatives are common in automotive, off road, and agricultural vehicle designs, as well as aerospace and other industries. To minimize weight and optimize industrial properties and residual stress distribution in shaft-like metallic components, designers must drill holes, reduce cross sections, make grooves, undercuts, and shoulders, and use custom shapes and alloys to accomplish these goals.

This article focuses on the technical revolution taking place in induction heating, which for the first time enables preprogramming of induction equipment to change frequency and power during the heating cycle in the same manner as machinists have been programming CNC machines for years. This is illustrated through a case study of induction hardening a shaft-like component such as that shown in Fig. 1, representative of a wide variety of other shaft-like parts that are now routinely induction hardened (Fig. 2)[1].

Fig. 1 — Representative shaft-like component induction hardened a decade ago.

**Member of ASM International*

THE CASE FOR SCAN HARDENING

Many steel shafts are strengthened using induction scan hardening. Scan-hardening systems are commonly associated with lower capital cost compared with static, or single shot, hardening and also offer process flexibility with respect to workpiece length and, to some extent, variations in shaft diameter. In scan hardening, the inductor or workpiece (or both) can move linearly relative to each other during the hardening cycle. Depending on workflow orientation, the system can be built vertical, horizontal, and at an angle, though vertical scan hardening is the most popular

Fig. 2 — Examples of the variety of part geometries in modern shaft-like components.

design for a number of reasons such as a reduced equipment footprint.

A small portion of a component's full hardened length is heated at a given instant in time, enabling the hardening of elongated parts using relatively small (and generally less expansive) power supplies. Scanning systems offer the ability to vary scanning speed and power during the process, which controls the amount of heat applied to different areas of the shaft. Induction scanners incorporate a number of different elements, with inductor design and power supply having the most significant impact on hardening results[2, 3].

SCAN HARDENING DRAWBACKS

Common geometrical irregularities and discontinuities of parts can distort the magnetic field generated by an inductor, potentially causing temperature variations and excessive shape distortion. For example, scan hardening shafts with large diameter changes, multiple holes, and sharp shoulders can produce unwanted deviations in hardness patterns and metallurgically undesirable structures. In addition, significantly different hardness case depths along the length of a component are often specified for multifunctional, complex geometry components (e.g., components having both solid sections and hollow sections with variable wall thickness). This requires a corresponding variation of localized heat generation depth during scanning. Unfortunately, the majority of commercially available medium- and high-frequency power sources are designed to deliver a certain frequency, which cannot be instantly and deliberately changed during scan hardening.

In many cases, the available frequency may be considerably higher or lower (in folds) than the optimal value for a particular portion of the shaft. If it is significantly higher than desirable (Fig. 3, center), it produces a smaller than ideal depth of heat generation (current penetration depth), which might not be sufficient for proper austenitization of the subsurface region at the required hardness depth. Therefore, additional time is required for thermal conduction to provide heat flow from the workpiece surface toward the required depth. This is commonly accomplished by reducing both scan rate and power density (otherwise, the surface can be overheated). This adds unnecessary cycle time and can lead to undesirable metallurgical and mechanical issues related to excessive peak temperatures and unwanted distribution of residual stresses.

In contrast, a frequency lower than optimal (Fig. 3, right) produces an exceedingly deep austenitized layer resulting in a deeper than needed hardness pattern and excessive distortion. Scan rate and power density are increased to suppress thermal conduction, reducing the negative impact of using a lower than desirable frequency.

A single, optimal frequency rarely exists to accommodate the wide variety of part geometries, which is why conventional scan hardening with fixed frequency must always compromise between achieving the desired metallurgical quality, production rate, and process capability. While process modifications to suppress or promote thermal conduction can help reduce the negative impact of using non-optimal frequencies, they often cannot eliminate it and can also negatively affect the metallurgical quality of heat treated components, transient and residual stress distribution, and distortion characteristics[2, 3].

CASE STUDY: CONVENTIONAL SCAN HARDENING

Induction scanning is often used to harden components containing multiple diameter changes and variable case pattern requirements along the length of the shaft. To illustrate, consider induction scan hardening of a 25-mm (1-in.) SAE 4140 steel stepped shaft with several geometric variations along its length, the most significant being a 5 mm (0.2 in.) diameter reduction. Figure 4 shows the required case

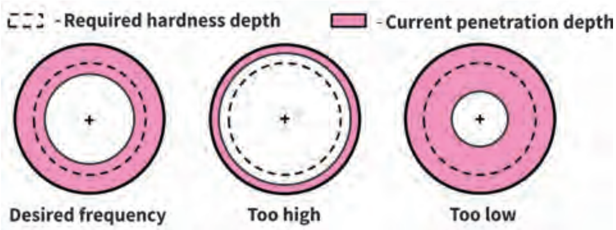

Fig. 3 — Effect of non-optimal selected frequencies on depth of current penetration (heat generation) in induction surface hardening of a solid shaft; (left) desired frequency, (center) frequency too high results in shallower depth of heat generation, and (right) frequency too low results in excessively deep heat generation.

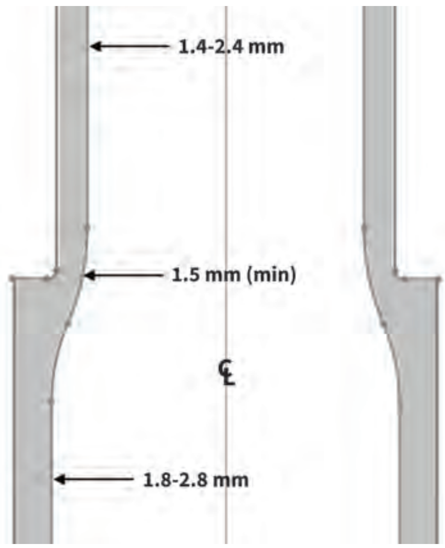

Fig. 4 — Example of hardness specification for a multi-diameter shaft.

pattern in the diameter transition area. A single-turn profiled inductor is used due to the sharp case pattern run-out specification at the end of the shaft.

Hardening using a conventional (fixed frequency) scan hardening system requires selecting a single frequency for the entire hardening process. Required case depths along the length of the shaft on the order of 2 mm (0.08 in.) necessitate using a nominal frequency of 30 kHz to achieve near-optimal hardening results in the straight regions of the shaft. Figure 5 shows an instantaneous temperature distribution during the initial stage of scan hardening[3].

The fixed frequency recipe used in scan hardening this portion of the shaft is shown in Fig. 6. As the part is translated downward and the diameter transition approaches the top of the coil, the scan rate is increased to address the inherent tendency to overheat the external corner of the diameter transition. The scan rate is then reduced to zero for a short dwell time with the bottom face of the coil positioned just above the diameter transition. This helps improve heating of the internal corner of the diameter transition and compensates for the heat sinking and electromagnetic decoupling occurring in this area. After a 2-sec dwell, the scan rate returns to a steady 8 mm/s (0.3 in./s), with the exception of a very brief period where a faster scan rate is used to mitigate the risk of overheating in the area directly above the diameter transition.

Figure 7 shows the case pattern in this region of the shaft. While case depths above and below the diameter transition meet customer specifications, the case depth in the internal corner of the diameter transition is only 0.9 mm (0.035 in.), failing to meet the required 1.5 mm (0.06 in.) minimum.

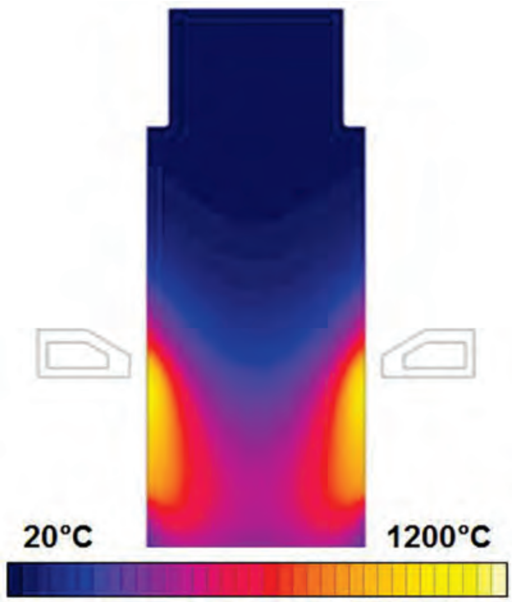

Fig. 5 — Temperature pattern during initial stage of scan hardening a stepped shaft.

Fig. 6 — Typical process recipe for scan hardening using a constant frequency.

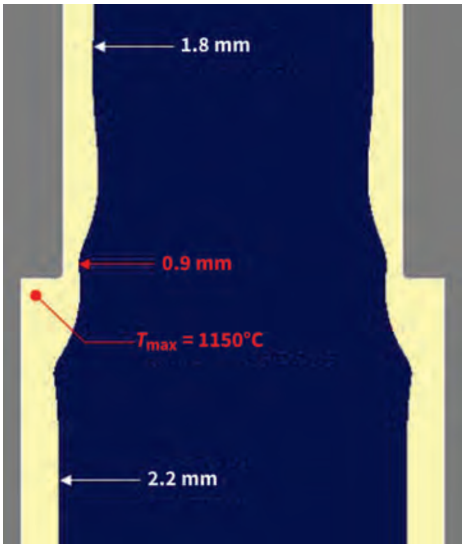

Fig. 7 — Hardness pattern obtained in multi-diameter shaft using constant frequency.

In contrast, a severe heat surplus at the neighboring external corner produces a peak temperature of 1150°C (2100°F), which is troublesome. Such surface overheating is associated with severe grain coarsening, ultimately resulting in poor mechanical properties. Further, overheating is one of the most common causes of crack initiation and propagation, as it weakens the grain structure and increases steel brittleness and sensitivity to developing intergranular cracking[2]. Grain boundary liquation/insipient melting are associated with liquation of low-melting phases and impurities concentrated at grain boundaries, leading to their degradation. A network (chains) of liquated areas at grain boundaries is shown in Fig. 8. Grain boundary liquation is magnified by segregation of Mn, S, Cu, and some other elements to austenite grain boundaries.

Overcoming insufficient case depth in the internal corner of a diameter transition and excessive heating of the

neighboring external corner can be difficult or impossible to overcome using conventional fixed frequency hardening systems.

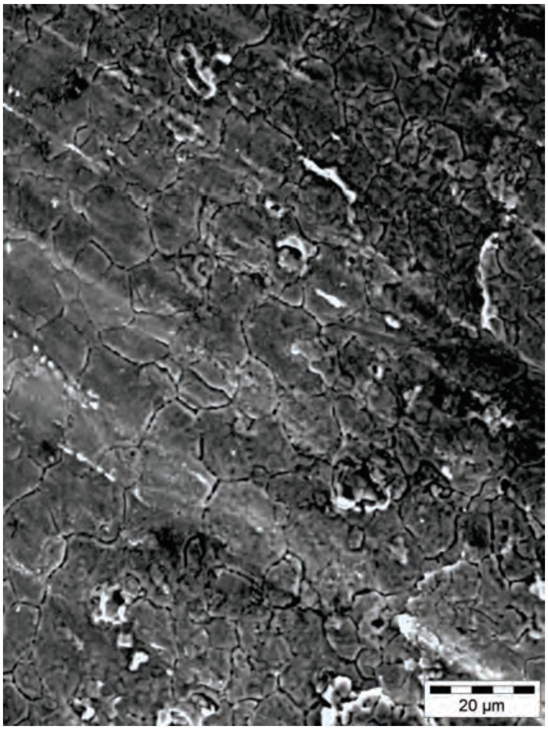

Fig. 8 — Grain boundary liquation caused by overheating.

Fig. 9 — Statipower IFP inverter.

SCAN HARDENING BREAKTHROUGH

Applied frequency has the greatest effect on depth of heat generation. Therefore, it is advantageous to apply various combinations of frequency, power, and scan rates at various stages of the scan hardening cycle when addressing the geometrical subtleties of induction heat treated components to maximize the production rate and improve the metallurgical quality of heat treated components. Unfortunately, the majority of current inverters do not have such capability.

A new generation IGBT-type inverter (Statipower-IFP) developed by Inductoheat (Fig. 9) eliminates this limitation and simplifies achieving the required hardness pattern. The patented technology is specifically developed for induction heating needs. It enables instant, independent adjustment of frequency (5 to 60 kHz) and power (up to 450 kW) in a preprogrammed manner (Fig. 10) during the heating cycle, optimizing electromagnetic, thermal, and metallurgical conditions[2-4].

CASE STUDY: SCAN HARDENING USING IFP TECHNOLOGY

The capability of IFP inverter technology is illustrated in scan hardening the stepped shaft discussed previously. In the diameter transition area, a frequency reduction promotes deeper heat generation in the internal corner while reducing the risk of overheating the adjacent external corner. The process recipe is shown in Fig. 11. While the variation of scan rate versus time is unchanged from the fixed frequency process, the inverter's output frequency is reduced to 12 kHz when the coil approaches the diameter transition.

The hardness pattern resulting from the variable frequency process is shown in Fig. 12. The hardened case depth in the internal corner of the diameter transition is nearly twice that of the conventional method, increasing to an acceptable value of 1.7 mm (0.066 in.). Further, the peak temperature in the neighboring external corner decreases by

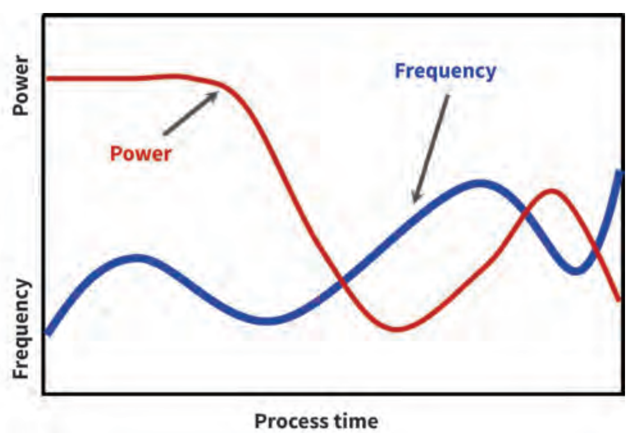

Fig. 10 — Simultaneous variation of frequency and power during modern scan hardening cycle.

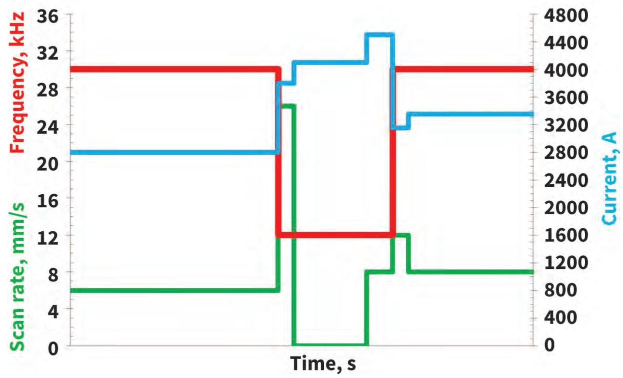

Fig. 11 — Process recipe using Statipower IFP power supply.

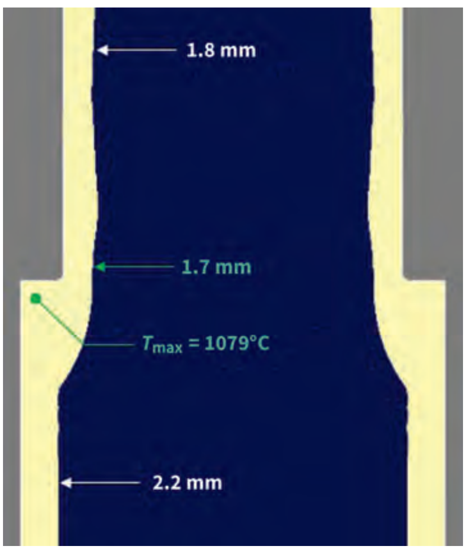

Fig. 12 — Hardness pattern obtained in multi-diameter shaft applying variable frequency, power, and scan rate.

more than 70°C (125°F), substantially reducing the potential for excessive grain coarsening and incipient melting in the external corner.

While reducing the peak temperature from 1150° to 1080°C (2100° to 1975°F) by switching from 30 kHz to a 30 kHz/12 kHz combination is notable, the lower peak temperature still might be of concern to some metallurgists who would like to see it lower. This can easily be achieved using a 30 kHz/5 kHz frequency combination, ensuring improved metallurgical quality and low distortion characteristics of heat treated products.

EXPANDING HORIZONS FOR IFP TECHNOLOGY

The new inverter technology effectively addresses industry needs for cost-effectiveness and enhanced process flexibility, greatly expanding induction equipment capabilities and further improving metallurgical quality of heat treated components. The ability of the technology to instantly change frequency by more than tenfold offers considerable benefits in several induction applications including through hardening, surface (case) hardening, hardening and tempering/stress relieving, spin hardening of gear-like components using circular inductors, and tooth-by-tooth hardening of large gears, just to name a few.

Through hardening. When through heating (i.e., through hardening) various diameter bars and cylindrical shaped parts with multiple diameters, such as sucker rods, care must be taken to avoid eddy current cancellation, which occurs because eddy currents circulating in opposing sides of the heated workpiece are oriented in opposite directions and could cancel each other, dramatically reducing heating efficiency. Under certain conditions, a workpiece can become semitransparent to the electromagnetic field, absorbing a negligible amount of energy and thereby making heating it impossible regardless of the applied coil power. The ability of IFP inverters to vary output frequency more than tenfold compared with conventional power sources eliminates this problem. For example, at austenitizing temperatures, 86% of generated power is concentrated within 2.3 and 7 mm (0.09 and 2.7 in.) at a frequency of 60 and 5 kHz, respectively. This means that IFP technology maximizes energy efficiency and throughput when through heating 8 and 25 mm (0.312 and 1 in.) diameter parts by applying 60 and 5 kHz, respectively. Energy efficiency is significantly improved and metallurgical conditions of the parts can be markedly enhanced only by reprogramming a process recipe.

Surface (case) hardening. Processing 12 mm (~0.5 in.) diameter pins with nominal hardness case depth of 1.8 mm (0.07 in.) requires a frequency in the 50-60 kHz range. If the product changed to a 30 mm (1.2 in.) diameter part with a nominal 5 mm (0.2 in.) hardness case depth, a lower frequency such as 5 to 7 kHz is required to ensure more in-depth heat generation. This would maximize the metallurgical quality of the product without compromising the production rate. IFP technology can easily accommodate such required changes.

Hardening and tempering/stress relieving. Because tempering temperatures are below the Curie point where steel retains its magnetic properties, a skin effect is always pronounced in induction tempering. This results in shallower heat generation, and potentially can lead to a surface over-tempering effect and reversal of useful compressive residual stresses at the workpiece surface, particularly when similar frequencies are used for hardening and tempering. Therefore, it is advantageous for induction machines utilized for both hardening and tempering operations to use higher frequencies for hardening and lower frequencies for induction tempering and stress relieving, requirements that are met using IFP technology.

Spin hardening of gear-like components using encircling inductors. The ability to independently and instantly change

both output power and frequency during the heating cycle allows heat treaters to use a lower frequency for preheating root areas, while higher frequency helps to ensure sufficient heating of tooth flanks and tips when spin hardening moderate size gears, pinions, and sprockets.

Tooth-by-tooth hardening can be applied to external and internal gears and pinions. The inductor is symmetrically located between two flanks of adjacent teeth. Induction-hardened gears can be fairly large, with diameters easily exceeding 3 m (10 ft), and can weigh several tons. Gears used in wind turbines are an example of a product where tooth-by-tooth induction scan hardening is effectively applied. However, this technique presents a challenge of controlling end/edge effects to avoid edge overheating and cracking. The capability of IFP inverters to instantly change power and frequency can help achieve required hardness patterns, particularly in the end zones.

CONCLUSION

Metal parts producers have taken advantage of the benefits of induction heat treating for many years. However, equipment with the technical capability for process flexibility that enables obtaining the desired heating pattern on complex shapes on the first try has been elusive. Inductoheat's revolutionary IFP technology meets this goal. **~HTPro**

Note: Statipower is a registered trademark, and IFP is a trademark of Inductoheat Inc.

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UNDERSTANDING THERMAL OVERDRIVE IN INDUSTRIAL OVENS

A temperature management system is essential to accurately monitor and control the heat treating process for maximum productivity and product quality.

Mike Grande
Wisconsin Oven Corp., East Troy, Wis.

The heating rate to heat a load in an oven depends on several variables. The oven must have a sufficient volume of recirculated air to transfer heat from the oven heating system (burners and electric heaters, for example) to the load through convection. Because air has mass, it can carry a significant amount of heat energy. For example, a typical oven recirculation fan rated at 20,000 cfm and operating at 600°F (315°C) moves 24 tons (22,000 kg) of air per hour. Using a common rule of thumb based on a 100°F (55°C) air temperature rise as air passes through a heating system, this volume of air delivers about 1,000,000 Btu/h (293 kW) of energy to the load.

However, even with a properly sized recirculation fan, the load's heating rate is limited by its configuration, more specifically by part cross sectional thickness and the ratio of part surface area to its weight. Heat energy is transferred to the surface of the part by the heated air, and then moves through the part by conduction. Because load configuration is a fixed entity, it is a limiting variable with respect to load heat-up rate. In other words, a load can only heat up so fast because it only absorbs heat at a certain maximum rate.

Another variable affecting the load heat-up rate is the set point temperature of the recirculated air. The heat transfer rate is initially high when a cold part is placed in an oven and exposed to hot recirculated air, and the part initially heats up very quickly. As the part heats up and approaches the set point temperature, the temperature difference between the air and the load narrows (Fig. 1). As a result, the rate of heat transfer from the air to the load slows greatly.

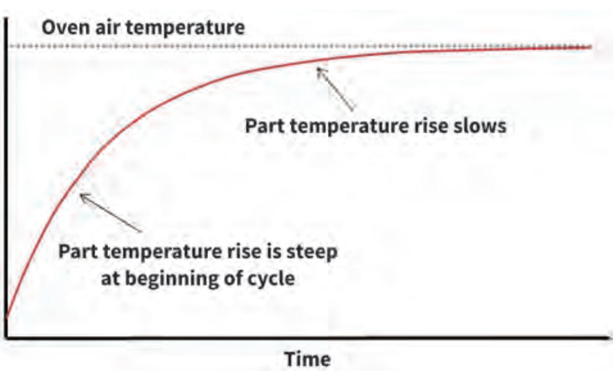

Fig. 1 — Typical heat-up curve for a part in a convection oven.

One of the tools used to overcome this is a controlled heat head—also known as *thermal overdrive.* It is helpful to review how a traditional convection oven system is designed in order to understand overdrive.

SINGLE PROBE TEMPERATURE CONTROL

Traditional oven temperature control maintains temperature at the desired set point during the heating cycle by means of a control thermocouple located in the heated airstream (Fig. 2). The thermocouple sends a signal to a closed-loop controller, which adjusts the heat source as required to maintain the desired air temperature. To heat the load, it is soaked in the oven chamber long enough for heat to transfer from the air to the load; physics dictates that the load attains the temperature of the heated air and no hotter. Because the heat transfer rate to the load depends on the ΔT between the hot air and the load itself, the heating rate slows greatly as the load gets close to the desired temperature, as shown at the top of the curve in Fig. 1. This strictly limits the potential heating rate, with a corresponding constraint on production rate.

In addition, thicker parts take longer to heat than thinner ones, requiring different heating times for different parts, which presents a risk of under heating loads that contain thicker parts. To avoid under heating and resultant product quality issues, the heating time for the thickest load is often

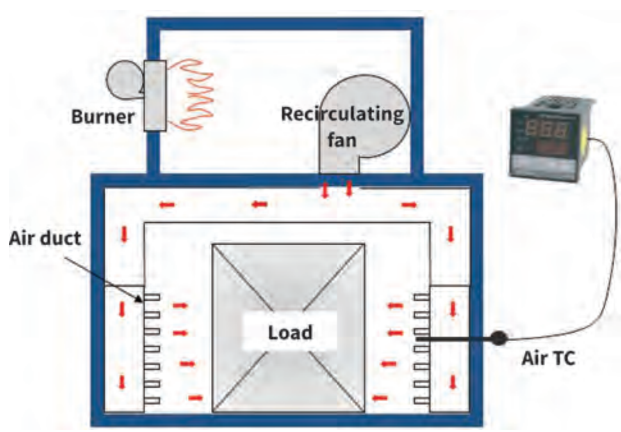

Fig. 2 — Traditional temperature control using an air thermocouple (TC).

mandated as the heating time for all the loads, regardless of part thickness. This results in wasted production capacity and unnecessary energy use.

USING THERMAL OVERDRIVE

A common strategy used to accelerate load heating rate is to incorporate thermal overdrive. This involves temporarily setting the oven recirculated air temperature above the desired target part temperature by a predetermined amount, which forces the part to heat more quickly than if the oven is set at the desired part temperature. Figure 3 shows that to quickly reach a desired part temperature of 250°F (120°C), the oven air temperature is temporarily set at 300°F (150°C). The temperature difference of 50°F (30°C) is referred to as the thermal heat head. After the part temperature approaches the desired temperature, the oven set point is automatically reduced to the desired part target temperature. This approach helps overcome the physical limitations of part configuration, enabling faster heating rates and increased production throughput in a batch heating system.

To use thermal overdrive, certain precautions must be taken to avoid overheating parts. Part thermocouples are imbedded in the load prior to heating (Fig. 4) and wired to a control system that uses the overdrive function. This enables the control system to do real-time monitoring of part temperature during the entire heating cycle, and ensures overheating does not occur. Thermocouples must be strategically located in the regions of the part anticipated to heat up first and last. Generally, these are the thinnest and thickest sections of the part, respectively.

A control system using thermal overdrive incorporates both oven air temperature and load temperature into an algorithm that measures the difference between them and applies the maximum allowable temperature difference (within user specified limits) during the heat-up phase of the cycle. The user can also set the maximum allowable load heating rate, peak allowable load temperature, and ramp rate of the air temperature. The system calculates and applies the fastest load heating rate possible without exceeding these parameters. Systems using overdrive typically use several thermocouples located throughout the load—in the thickest and thinnest areas, as well as other random locations. Overdrive

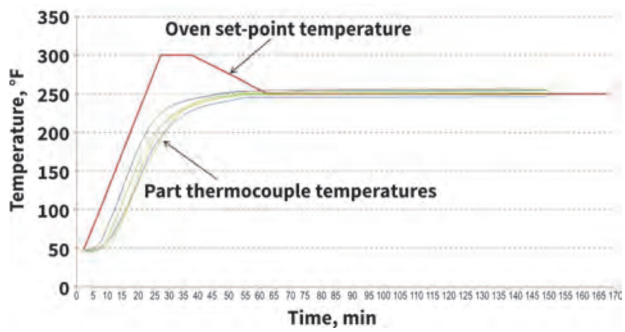

Fig. 3 — Part heating rates using the heat head (thermal overdrive) function.

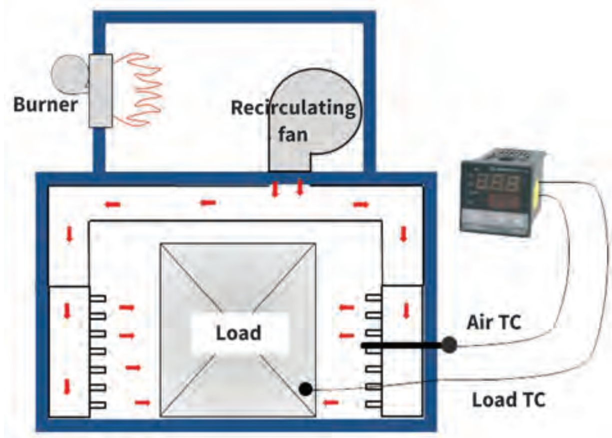

Fig. 4 — Thermocouples embedded in a load enable use of thermal overdrive.

allows any of the thermocouples to be used as the input to the temperature control loop, and can switch between them as necessary. This ensures that no part of the load exceeds the target temperature.

Thermal overdrive is an important temperature management technique that uses the latest control technology to maximize oven production rates without the risk of product overheating. **~HTPro**

For more information: Mike Grande is vice president of sales and engineering, Wisconsin Oven Corp., 2675 Main St., East Troy, WI 53120, 262.642.3938, mgrande@wisoven.com, www.wisoven.com.

ASM Heat Treating Society

HEAT TREAT 2017

29th Annual Conference & Exhibition

OCTOBER 24-26
GREATER COLUMBUS CONVENTION CENTER
COLUMBUS, OHIO

The ASM Heat Treating Society will hold its 29th conference and exhibition next month in Columbus, Ohio, where more than 5000 people are expected to gather to exchange ideas, information, and insights on heat treating technology and how it can be employed to improve the quality of metals and alloys and add value to products made from them. In addition to a strong technical program, the three-day event also includes networking opportunities, social activities, and for the first time, a series of educational courses on the basics of heat treating and related introductory topics.

Based on abstract submissions, more than 125 presentations of original, unpublished work will be delivered during the technical program in session tracks such as additive manufacturing, induction heat treating, big data/IoT, automotive lightweighting, microstructure, quenching and cooling, surface engineering, and vacuum technology. Conference attendees will also have access to representatives from nearly 200 suppliers of heat treating solutions, services, and equipment, as well as an additional 200 exhibitors that are co-locating with ASM during the Gear Expo.

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KEYNOTE SESSIONS

Boris

TUESDAY, OCTOBER 24

Paul Boris, COO of Vuzix, is an expert in the Industrial Internet of Things (IIoT), including how manufacturers now have the ability, even with minor investment, to have IIoT projects in their factories that can provide actionable results. He will be discussing IIoT in his presentation, "The Industrial IoT is Here – and Manufacturers at ALL Levels Can Implement and Find ROI Quickly."

Johnson

WEDNESDAY, OCTOBER 25

Mark Johnson, director of the Advanced Manufacturing Office in the Office of Energy Efficiency and Renewable Energy, will provide an overview of government initiatives centering on the domestic development of new energy-efficient manufacturing processes and materials technologies that can reduce the energy intensity and life-cycle energy consumption of manufactured products.

Rogers

THURSDAY, OCTOBER 26

John "Jay" Rogers, CEO and co-founder of Local Motors, will provide his perspective on the future of the car manufacturing industry. This disruptive car company is redefining the development of connected hardware by pairing micro-manufacturing with co-creation. Local Motors is the first company to utilize direct digital marketing, as evidenced when it debuted the world's first 3D-printed car, the Strati, in September 2014.

The Solutions Center at Heat Treat 2017 focuses on solving actual customer problems with FREE presentations given by HTS exhibiting companies. Presentations will include products and/or services that can help attendees solve a particular manufacturing problem, or improve productivity. Presentations will be offered from 9:30 a.m. – 4:30 p.m. on Tuesday – Thursday in the Solutions Center - booth #1631.

SPECIAL SYMPOSIUM SESSIONS

These special sessions pay tribute to heat treating industry icons, including highlights of their contributions to the heat treating industry and the impact of their work on the future.

GEORGE BODEEN SYMPOSIUM: TAKING THE HEAT TREAT BUSINESS INTO THE FUTURE

Tuesday, October 24

Presented by Roger J. Fabian, FASM, retired Bodycote

INDUCTION HEAT TREATING IN HONOR OF GEORGE PFAFFMANN

Wednesday, October 25

Presented by Aquil Ahmad, retired Eaton Corp. and Ron Akers, Ajax Tocco Magnethermic

INDUCTION HEAT TREATING IN HONOR OF FRED SPECHT

Thursday, October 26

Presented by Edward Rylicki, Ajax Tocco Magnethermic

EXHIBITION HOURS

Tuesday, October 24

9:00 a.m. – 6:00 p.m.

Expo Welcome Reception

5:00 – 6:00 p.m.

Wednesday, October 25

9:00 a.m. – 5:00 p.m.

Thursday, October 26

9:00 a.m. – 4:00 p.m.

EDUCATION COURSES

METALLOGRAPHY INSIGHTS

An overview of sample preparation procedures and optical and electron microscopy techniques. Course includes a live demonstration of equipment and procedures from cutting and mounting to grinding/polishing, cleaning, and hardness testing.

GENERAL METALLURGY

An introduction to the metallurgy associated with the making, shaping, and heat treating of steel and its role in the development of strength, hardness, toughness, ductility, and other properties.

GENERAL HEAT TREATING

An introduction to heat treating for people requiring a basic understanding of the process and an ability to "speak the language." Participants will learn about the influence of time, temperature, and atmosphere and the link between microstructure and mechanical properties.

QUENCHING BASICS

A brief overview of common quenching methods, such as spray and salt quenching, and how they work.

MATERIALS SELECTION AND HEAT TREATMENT OF GEARS

A full-day course presented jointly by ASM International and the American Gear Manufacturers Association.

PREDICTIVE MAINTENANCE WITH AUGMENTED REALITY

This two-hour workshop sponsored by Ipsen Inc. focuses on PdMetrics, a predictive maintenance platform for heat treating furnaces that uses real-time monitoring and augmented reality to optimize performance and minimize downtime.

TECHNICAL PROGRAM

Tuesday, October 24

- Advances in Heat Treating I
- Applied Technology I
- Microstructure Development I
- Thermal Mechanical Processing/Welding
- Advances in Heat Treating II
- Applied Technology II
- Automotive Lightweighting
- Quenching and Cooling
- Advances in Heat Treating III
- Atmosphere Technology
- Microstructure Development II
- Vacuum Processes and Technology

Wednesday, October 25

- Induction Heat Treating
- Processes and Applications
- Quenching and Cooling II
- Vacuum Processes and Technology II
- Induction Heat Treating II
- Internet of Things
- Processes and Applications II
- Quenching and Cooling III
- Vacuum Processes and Technology III
- Atmosphere Technology II
- Induction Heat Treating III
- Processes and Applications III

Thursday, October 26

- Processes and Applications III
- Additive Manufacturing/3D Processing
- Applied Technology/Miscellaneous
- Induction Heat Treating IV
- Surface Engineering/Nitriding

NETWORKING OPPORTUNITIES

From the exhibitor networking reception on Tuesday to a special social event on Wednesday, Heat Treat attendees will have the opportunity to build business relationships and network with over 5500 key contacts in the heat treating industry.

INSIDE:

Stroll through the 100-year-old historic North Market and experience culinary treats. Participating food artisans:

- The Fish Guys
- Little Eater
- Lan Viet Market
- Sarefino's Pizzeria
- Firdous Express
- Steam
- Pastaria
- Pistacia Vera
- Jeni's Splendid Ice Creams
- Taste of Belgium

OUTSIDE:

The party continues with bourbon tastings from Watershed Distillery, Middle West Spirits (OYO), delicacies from Hot Chicken Food Takeover Truck, Dos Hermanos Taco Truck, and libations from the Seventh Son Brewery Trailer. For entertainment, musical group Lieutenant Dan's New Legs will perform. Networking event tickets cost $75.

Title Sponsor:

Surface® Combustion

NEW!

VIP Guided Industry Tour Sign up for the 1st VIP Guided Industry Tour at Heat Treat 2017! This is a joint tour with AGMA and is limited to the first 300 attendees. You'll have exclusive access to 10 companies showcasing their industry products and services. Pre-registration and pre-qualification are required to receive your ticket. Tours will be Tuesday & Wednesday from 3:30 – 4:30 p.m.

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Advanced Energy
AFC Holcroft
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Airflow Sciences Corp.
Airgas
AJAX TOCCO
A.L.M.T. Corp.
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ASMNEWS

ASM ANNOUNCES 2017 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 2017. 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 10, in Pittsburgh, during Materials Science & Technology 2017.

Mr. Aquil Ahmad, FASM
Senior Principal Engineer/Chief Metallurgist
Eaton Corp., West Bloomfield, Mich.

For improvements in product reliability from sustained research and development in the commercialization of peening technologies, quantitative ultrasonic inclusion measurement, and advances in induction heat treating of highly stressed products.

Dr. Gary H. Bray, FASM
Senior Technical Specialist
Arconic Inc., Murrysville, Pa.

For prolific and sustained contributions to the development and commercial application of new aerospace aluminum alloys, enabling improved aircraft performance, and to the understanding and characterization of fatigue and fracture properties.

Mr. Craig D. Clauser, P.E., FASM
President
Craig Clauser Engineering Consulting Inc.
West Chester, Pa.

For application of materials engineering principles in a variety of technical areas, including embrittlement of steel, the science and practice of steel making and processing, and fracture and failure analysis.

Ms. Jacqueline M. Earle, FASM
Product Support Manager, Retired
Caterpillar Inc., Cary, N.C.

For outstanding technical contributions developing innovative solutions and applying new materials to heavy equipment, saving time and money, and sustained leadership, dissemination of knowledge, and volunteerism at the highest level.

Ms. Cheryl Hartfield, FASM
Solutions Manager
Zeiss, Pleasanton, Calif.

For sustained technical innovation and outstanding leadership in defect analysis and characterization methods that enabled the advancement of next-generation semiconductor devices with multiple industry applications.

Dr. Paul D. Jablonski, FASM
Metallurgist
National Energy Technology Laboratory, US DOE, Albany, Ore.

For sustained excellence in materials processing and heat treatment, leading to CALPHAD-based methodology for efficient homogenization of alloys through utilization of computational thermodynamics and kinetics.

In This Issue

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HIGHLIGHTS 2017 CLASS OF FELLOWS

Prof. Diana A. Lados, FASM

Milton Prince Higgins II Distinguished Associate Professor and Director, Integrative Materials Design Center, Worcester Polytechnic Institute, Mass.

For developing and implementing a new integrative design paradigm in materials science and engineering research, education, and application through unique collaborations between university, industry, and government.

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Professor

Xi'an Jiaotong University, China

For original and distinguished contribution to clarifying the mechanisms of microstructure formation in thermal sprayed coatings and mentoring a large number of advanced graduates in the field of thermal spray.

Prof. Michele V. Manuel, FASM

Rolf E. Hummel Professor of Electronic Materials and Department Chair

University of Florida, Gainesville

For outstanding leadership and technical contributions in thermodynamics-based alloy design and its associated methods as applied to light metals.

Prof. Dr. Sanjay Mathur, FASM

Director, Institute of Inorganic Chemistry

University of Cologne, Germany

For pioneering contributions in precursor-based synthesis of advanced ceramics and technology transfer achievements in the field of chemical nanotechnologies and engineering of functional materials for energy and sensing applications.

Dr. Alan R. Pelton, FASM

Chief Technical Officer

G. Rau Inc., Santa Clara, Calif.

For sustained and outstanding contributions leading to the development, understanding, and use of nitinol shape memory alloys in engineering components, especially related to medical and healthcare applications.

Dr. Prabhakar G. Renavikar, FASM

Deputy General Manager, VQA & Materials Engineering

Tata Motors Ltd., India

For long-term vision and dynamic leadership in the development and implementation of alternate materials for automotive vehicles and in the promotion of ASM International activities in India.

Mr. Mark A. Rhoads, FASM

Materials Consulting Engineer

GE Aviation, Cincinnati

For technical leadership, development, and application of ferrous alloy shaft, bearing, and coating materials and processes that have found critical applications in aero engines currently in service.

Prof. Christopher A. Schuh, FASM

Danae and Vasilis Salapatas Professor of Metallurgy

Massachusetts Institute of Technology, Cambridge

For leadership in the fields of materials science, engineering, and education, including the successful integration of fundamental science into the design, fabrication, and commercial implementation of advanced materials products.

Dr. David A. Shifler, FASM

Program Officer

Office of Naval Research, Arlington, Va.

For longstanding contributions to corrosion engineering as a researcher, mentor, and program manager, and for leadership of materials research and development across government laboratories, academia, and industry.

Dr. Daniel J. Sordelet, FASM

Senior Engineering Specialist

Caterpillar Inc., Peoria, Ill.

For innovative laboratory development of new surface engineering materials, techniques, and processes, and the successful application of them to the full production of real-world components.

Prof. David C. Van Aken, FASM

Curators' Distinguished Teaching Professor

Missouri University of Science and Technology, Rolla

For distinguished contributions in metallurgical engineering education and the development of new manganese steels for lightweight military armor and automotive steel.

Prof. Timothy P. Weihs, FASM

Professor

Johns Hopkins University, Baltimore

For fundamental understanding, development, invention, and successful commercialization of reactive metallic materials and structures and for innovation in mentoring and educating future materials engineers and entrepreneurs.

MS&T17 Technical Meeting and Exhibition
MATERIALS SCIENCE & TECHNOLOGY

Official ASM Annual Business Meeting Notice

The Annual Business Meeting of members of ASM International will be held in conjunction with MS&T17 on:

Monday, October 9
4:00 - 5:00 p.m.
The Westin Convention Center
Pittsburgh

The purpose of the ASM Annual Business Meeting is the election of officers for the 2017-18 term and transaction of other Society business.

Nomination Deadline for the 2018 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 2018 is **November 30, 2017.** 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 ext. 5509 or christine.hoover@asminternational.org.

ASM Nominating Committee Nominations Due

ASM International is seeking members to serve on the 2018 ASM Nominating Committee. The committee will select a nominee for 2018-2019 vice president (who will serve as president in 2019-2020) 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 ext. 5500 or leslie.taylor@asminternational.org, or visit asminternational.org/about/governance/nominating-committee.

FROM THE PRESIDENT'S DESK

From time to time, ASM presidents receive questions from our constituents, the answers to which bear wider communication to our full membership. Following are a few recent exchanges.

Frazier

What is ASM's mission statement? Why is it hard to find on the ASM website?

Our current mission statement is included at the bottom of our homepage ("Who We Are"): ASM International, the world's largest association of materials-centric professionals, informs, educates, and connects the materials community to solve problems and stimulate innovation around the world. During the 2016–2017 annual planning cycle, the ASM Board and management determined that the current mission statement is sufficient for purposes of guiding the ASM Renewal. The positioning of the statement on our website—along with the entire look and feel of the website—are scheduled for revision in 2018, following completion of upgrading ASM's digital infrastructure this year.

Why is ASM pulling out of MS&T? We have heard there will be a replacement event in 2020. What is the vision for the new event?

The Board made the decision this past spring to hold a separate event in 2020 after thoughtful deliberation of the management team's analysis and recommendations. ASM will continue to partner with MS&T between 2017 and 2019. The basic reasons ASM is leaving MS&T are as follows:

a. Lack of ASM brand recognition; students and professionals do not recognize that MS&T is ASM's annual event, and they do not recognize ASM's role in bringing technical programming and industry representation to the event;
b. Lack of control of event location; the need to compromise among the four societies has led to some MS&T locations that are not optimal for ASM members and industry participants;
c. Limitations on partnerships/co-locations; ASM has not been able to gain agreement among the MS&T partners to support co-locations that would be beneficial for ASM and industry participants (as an example, ASM requested to partner with the Heat Treating Conference & Exposition, but this was not accepted by the partner societies);
d. Poor return on effort and investment compared to other ASM events; and
e. Lack of flexibility with regard to scheduling, programming, and new initiatives.

ASM made several proposals to our sister societies for revising MS&T, but we were not able to come to an agreement that all the societies could embrace. Therefore, ASM determined that holding its own annual event was the only viable option. ASM is committed to partnering with our sister societies when it is in the best interest of our members and the profession as a whole. We have several ongoing collaborations that are quite successful and mutually beneficial, and we look forward to working with them on new opportunities to benefit the materials community.

Our vision for 2020: Our Society has pulled together the ASM program committees, affiliate societies, and partners under one roof to deliver content that our members and industries demand. The event will focus on new materials, applications, and processes in key growth markets. In doing so, we will build closer, stronger relationships with our affiliates and rebuild our technical committee structure. The new conference will enable generation of technical content that can be delivered to our members and customers in digital and paper formats. The new event will also encourage emerging professionals to engage with ASM—and stay engaged—by providing them an opportunity to grow professionally. A programming committee for the 2020 event has been formed with members from the affiliate boards and ASM events.

Why does ASM hold an annual meeting? Will the new 2020 event support the annual meeting and awards presentation?

The annual meeting serves several purposes by offering: a) a face-to-face meeting where members have the opportunity to bring action items forward; b) an opportunity to recognize the contributions of our members, volunteers, and leaders in our profession; and c) a forum for substantive interaction among our Society's volunteer leaders who contribute countless hours on an ongoing basis. The new ASM event in 2020 will support the ASM annual meeting and awards presentation.

William E. Frazier, FASM
frazierwe@gmail.com

ASM Indian Institute of Metals Announces Recipients of 2017 ASM/IIM Visiting Lectureship


Kalidindi

The cooperative Visiting Lecturer program of ASM International and the Indian Institute of Metals (IIM) is pleased to announce the individual named to participate in the 2017 Visiting Lecturer program: **Prof. Surya R. Kalidindi, FASM,** professor, Georgia Institute of Technology, Atlanta. 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 individual who has been named to participate in the 2017 ASM/IIM Visiting Lecturer North American Program: **Dr. Satyam Suwas,** Indian Institute of Science, Bangalore. 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 9 in Pittsburgh during MS&T17.

Program Aims to Recognize ASM Volunteers

The Volunteer Profile program was established by the ASM Volunteerism Committee in 2010 with a goal of formally recognizing outstanding volunteers who are the backbone of ASM International. We are currently accepting nominations for individuals who have exhibited exceptional volunteerism within a Chapter, committee, council, or affiliate society of ASM International to be featured in a Volunteer Profile article in an upcoming issue of *AM&P.* To view previous profiles or nominate a volunteer, visit asminternational.org/membership/volunteers/volunteer-profiles.

FROM THE FOUNDATION

Materials Camps: Continuing the Leadership


Shipley


Copley

"Tell me and I forget, teach me and I may remember, involve me and I learn." These timeless words are attributed to Benjamin Franklin.

Almost 20 years ago, Franklin's wisdom served as the seed for what has now become the ASM Materials Education Foundation's flagship Materials Camp program. ASM leaders at that time were among the first to recognize students' declining interest in math and science based careers. But what to do? The answer was a weeklong ASM Materials Camp held in the laboratories at the Dome. Students studied real-world materials and answered practical questions using professional equipment. They found that science could be interesting, and we dare say, even fun! The success of this first camp in 2000 led to many more across the country. Recognizing that science teachers could benefit from a similar experience and resources, the Foundation soon began camps for them, along with ongoing follow-up support.

We are proud of our accomplishments. We say "our" because all ASM members share in this success. We are proud of our Society. And we are even more proud that we are not resting on our laurels, but are developing even more programs to inspire students. We encourage you to learn more about your Foundation on the website. If you would like to become more involved, you will find many opportunities. Financial support is always appreciated, but volunteers are also needed. If your Chapter leads a Camp, that is a good place to start. If your Chapter does not have a Camp, maybe you would like to help start one?

Roch J. Shipley, FASM
ASM Materials Education Foundation Trustee and Treasurer

Steve Copley, FASM
ASM Materials Education Foundation Past President and Trustee

Taylor Receives ASM Presidential Honor

In June, longtime ASM employee Leslie Taylor, manager of the executive office, was honored with an ASM presidential coin and plaque. The presentation was made by ASM President William Frazier. His letter of appreciation reads as follows: "It is my distinct pleasure and honor to have the opportunity to thank you for your sustained, outstanding service to ASM International. I do so on behalf of all the past and present trustees and ASM International members who have relied on your faculty for making facile the complex and difficult business of navigating the governance and operations of our great Society. On a personal note, we have known and worked together for over 15 years. I have come to rely on your keen insight and assiduous attention to detail. Your extensive knowledge of ASM policies and procedures, your discerning judgement and discretions have proven to be invaluable. Thank you for your service to ASM International. Thank you on behalf of myself, Vice President Frederick Schmidt, and all the ASM trustees who have or have had the privilege of working with you."

From left, Bill Mahoney, Leslie Taylor, and Bill Frazier.

WOMEN IN ENGINEERING

*This profile series introduces leading materials scientists from around the world who happen to be females. Here we speak with **Katherine Faber,** Simon Ramo Professor of Materials Science at the California Institute of Technology. Faber was recently selected as the ASM Edward DeMille Campbell Memorial Lecturer for 2019.*

Faber

What part of your job do you like most?

I love working with students in a research setting. It is both humbling and uplifting to watch students' different approaches to solving problems. I enjoy challenging them and being challenged by them. It is extremely satisfying to see them grow to be my colleagues with successful careers of their own.

What is your engineering background?

I was trained as a ceramic engineer at Alfred University, went on for a master's degree in ceramic science at Penn State, and then worked in industry at the Carborundum Company in Niagara Falls where I got my first taste of structural ceramics. After two years, I realized that I would need a Ph.D. to have the career I wanted, so I moved west and received my Ph.D. in materials science and engineering at UC Berkeley. There I became smitten with academia and have held faculty positions at The Ohio State University, Northwestern University, and for the past three years, Caltech.

What attracted you to engineering?

Growing up during the Sputnik Era and at the start of the Space Age, I was captivated with space and took a number of astronomy courses at the Buffalo Museum of Science. One of my most prized possessions was my telescope. During high school, my interests in science broadened and I thought I wanted to be a chemist. However, between the unpalatability of organic chemistry, the excitement of problem solving, and the applications orientation of engineering, I moved in that direction. I was also influenced by my father who wanted to be one of the first aeronautical engineers. He had to discontinue his education when the Great Depression hit. However, his curiosity of all things science and engineering-related was inspirational.

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

If only I had the requisite talent, I would be an orchestral conductor, thrilled with the opportunity to lead an orchestra in Brahms's Second Piano Concerto.

How many people do you work with?

I currently have five Ph.D. students, a research scientist, and three undergraduates in my lab. But the boundaries of our laboratory don't limit the size of the group. We collaborate with Caltech mechanical engineering faculty on fracture problems and chemical engineers on porous ceramics for membrane applications. Outside of Caltech, we interact with materials folks at NASA's Jet Propulsion Laboratory on materials that might go to Mars, and at the University of Padua and the University of Erlangen on porous ceramics from preceramic polymers.

Hobbies?

Walking/hiking, theater, museums, and music.

Last book read?

Sara Paretsky's "Brush Back." Paretsky created the detective series featuring V I Warshawski, a gutsy female Chicago-born-and-bread private eye. Her books are always a fun read, especially if you know Chicago.

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

Sorby Lecture Kicks Off Special IMS Symposium

Humphreys

In celebration of the 50th anniversary of ASM's International Metallographic Society (IMS), a special symposium celebrating **Fifty Years of Metallography and Materials Characterization** is planned for October 10 and 11 during the Materials Science and Technology 2017 (MS&T17) conference in Pittsburgh. The symposium will honor past recipients of the Henry Clifton Sorby Award, IMS Buehler Technical Paper of Merit Award, and Jacquet-Lucas Award.

The recipient of the 2017 Sorby Award, **Professor Sir Colin Humphreys,** Cambridge University, UK, will lead off the symposium with his lecture "How Microscopy Can Help to Save Energy, Save Lives, Create Jobs, and Improve Our Health" on Tuesday, October 10, 2:00 to 3:00 p.m. at the David L. Lawrence Convention Center.

Humphreys gained early international recognition for development of a series of lectures to help in the public understanding of science. They were delivered—in Australia, Singapore, and the U.S.,—to live and media audiences. At Cambridge, his chief areas of interest are the development and understanding of GaN LEDs, advanced electron microscopy, and high temperature materials for aerospace applications. He was appointed a Fellow of the Royal Academy of Engineering (1994), a Fellow of the Royal Society (2011), and was knighted by Queen Elizabeth for Services to Science in 2010.

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. Humphreys will receive his award at the ASM Awards Dinner on Tuesday, October 10, 6:15 to 9:00 p.m. at the Westin hotel.

International Metallographic Contest: First Time at MS&T

Deadline: September 26

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, is heading to MS&T this year. In celebration of its 50th anniversary, IMS is taking the IMC to Pittsburgh, October 8-12, to share the excitement of the contest with all MS&T attendees. Five different classes of competition cover all fields of optical and electron microscopy:

Class 1: Optical Microscopy—All Materials

Class 2: Electron Microscopy—All Materials

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

Class 4: Artistic Microscopy (Color)—All Materials

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

Best-In-Show receives the most prestigious award available in the field of metallography, the Jacquet-Lucas Award, which includes a cash prize of $3000. For a complete description of the rules, tips for creating a winning entry, and judging guidelines, visit metallography.net.

In addition, IMS will have a special symposium at MS&T17 celebrating 50 years of metallography and materials characterization. The symposium will honor past recipients of the Henry Clifton Sorby Award, IMS Buehler Technical Paper Award, and Jacquet-Lucas Award.

MD CORNER

ASM Making Headway with New Digital Infrastructure


Mahoney

Two key components of our digital infrastructure initiative for 2017 include implementation of a customer relationship management (CRM) system—something ASM has never had before—and moving to a new association management system (AMS). The new AMS will replace iMIS, which has been our AMS platform for nearly a dozen years, but has fallen short primarily due to poor maintenance over its lifetime.

Our new CRM is Salesforce, the widely known industry leader. Our new AMS is MemberNation from Fonteva Corp. During our evaluation and selection process, we learned that Fonteva is a successful, rapidly growing enterprise software company, focused on association management. MemberNation has been successfully implemented by over 300 professional associations and is integrated within the Salesforce platform so that records can be easily exchanged between the two applications.

Coupled with our new Liferay commercial web platform, the Salesforce/MemberNation suite should provide reliable, fast, and convenient e-commerce transactions for both members and customers alike. Our Liferay platform is now in the final testing stage. Once complete, we will begin redesigning the look and feel of the ASM website, with a focus on greatly enhancing the member experience. Also, this suite will provide collaboration and community areas for posting information and commentary. These areas will be conveniently available for our chapters, affiliate societies, and emerging membership and customer segments to facilitate communications. While use of these areas will be up to members, we expect that these community folders will enable improved collaborations among member interest segments as well as enhanced functionality compared to the current chapter and affiliate websites.

Later this year, after our wring-out and final test of the system, we will most likely request that members access the new system to make sure individual profiles are current and accurate. This step should prevent some of the strange transactions and inaccurate results that have plagued our interactions with members and customers for years. Our membership and customer service personnel are looking forward to operating in our new digital environment just as eagerly as many of our frustrated members. Thank you for your patience and support with this implementation.

William T. Mahoney, ASM Managing Director
bill.mahoney@asminternational.org

Girl Scouts Become Materials Girls

In July, 15 Girl Scouts traveled to the ASM Dome to take part in demonstrations that explained materials property concepts and introduced them to engineering. The Scouts earned a Materials Girl patch by participating in the program. The day was organized by the ASM Women in Materials Engineering (WiME) committee in collaboration with the Northeast Ohio Girl Scouts council.

Members of Troop 80097 pose under the ASM Dome after receiving their Materials Girl patches.

Activities included copper plating using pennies and a backpack survivability exercise, where the girls put a variety of snack bars in a three-point bending system. With assistance from volunteers, each Scout was able to run her own experiments, make a hypothesis, document the variables, and record the outcomes. ASM volunteers Kelsey Torboli, Amber Abbott Hearn, and Tom Dietrick explained the concepts and walked the Scouts through the steps of each activity. They asked and answered questions to get the girls thinking about how materials are used and manipulated, and how engineers make decisions.

"We're thrilled with the results from the first Materials Girl event," says Kelly Sukol, ASM staff member and liaison to the WiME committee. "By the end, the girls were able to make better predictions and were eager to learn more about materials science. I wouldn't be surprised if they ran home and tried to copper plate more objects, just to see what happens." Both Scouts and their chaperones said they learned a lot and want to find out more about materials science. Troop leader Veronica Becker said, "Kathleen [one of her scouts] explained copper plating to two different people when I was with her…she got it!"

Chapters are encouraged to put on their own Materials Girl program. Guides are available from vicki.burt@asminternational.org.

CHAPTERS IN THE NEWS

Los Angeles Chapter Holds Heat Treating and Student Night Events

Ron Adams, pictured right, director of strategic business development at Bodycote, receives a pint glass with the logo of the Los Angeles Chapter from Michael Hahn, Chapter secretary. Adams spoke on "The Benefits of HIP and Heat Treatment for Additively Manufactured Components" at the June meeting.

May 2017 Student Night at the Los Angeles Chapter included students from UC Riverside, USC, Loyola Marymount University, California State University–Long Beach, and Cal Poly Pomona.

Akron Chapter Hosts Teachers Camp

In July, 22 teachers attended the 2017 Akron ASM Teachers Camp, held at the University of Akron. Sponsors included the University of Akron, National Association of Corrosion Engineering, Foundry Industry Association, and ASM Materials Education Foundation in addition to 14 suppliers of equipment and consumables. As part of the camp, teachers enjoyed tours of Akron Steel Treating and the University of Akron. This was the 10th Teachers Camp organized by the ASM Akron Chapter.

Class of 2017 Akron ASM Teachers Camp.

MEMBERS IN THE NEWS

Paranthaman Named ORNL Corporate Fellow

Paranthaman

Parans Paranthaman, FASM, has been named a Corporate Fellow of the Department of Energy's Oak Ridge National Laboratory (ORNL). He has pioneered advances in the field of materials chemistry with impacts on energy technologies such as superconductors, batteries, and solar cells. Paranthaman came to ORNL in 1993 after receiving his doctorate in chemistry at the Indian Institute of Technology and postdoctoral research at the University of Texas at Austin and University of Colorado, Boulder. He has gained international recognition for the design, synthesis, and fabrication of new materials and their translation into new energy technologies, including superconductor wires, electrodes for batteries, and additive manufacturing of low-cost magnets.

HIGHLIGHTS MEMBERS IN THE NEWS

Wagner Wins MIT Teaching Award

Mary Elizabeth Wagner, a graduate student in materials science and engineering at the Massachusetts Institute of Technology, won the School of Engineering Graduate Student Award for Extraordinary Teaching and Mentoring, established in 2006 to recognize an engineering graduate student who has demonstrated extraordinary teaching and mentoring as a teaching or research assistant.

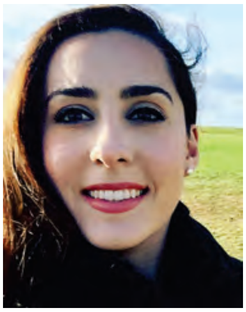
From left, Dean Ian A. Waitz, Mary Elizabeth Wagner, and award sponsor Alan Oppenheim. Courtesy of Gretchen Ertl.

Krupitzer Receives SMDI Lifetime Achievement Award

The Steel Market Development Institute (SMDI), a business unit of the American Iron and Steel Institute (AISI), presented **Ronald P. Krupitzer** with an SMDI Lifetime Achievement Award for his lasting contributions to the automotive market. The award was presented by AISI Chairman John Ferriola, CEO and president of Nucor Corp., during the Institute's General Meeting in Washington. The award recognizes individuals who have had significant impacts in advancing the competitive use of steel in the construction, automotive, and packaging markets. Throughout his career, Krupitzer was involved in the development of advanced high-strength steels. While vice president–automotive market at SMDI, he worked with North American steel producers and automotive manufacturers on research to incorporate advanced high-strength steel technologies in various automotive components and to provide technology transfer opportunities for automotive engineers and designers.

Ronald Krupitzer, right, receives the 2017 SMDI Lifetime Achievement Award from John Ferriola.

Kelly Collaborates with Manchester Scientists



Kelly

Madeleine Kelly, a post-doctoral researcher at Carnegie Mellon University (CMU), recently spent two weeks at the University of Manchester, UK, collaborating with Grace Burke, director of the Materials Performance Centre, and Xiangli Zhong, experimental officer for the university's FEI Helios PFIB Dual-Beam microscope. Kelly earned her doctorate in materials science and engineering in June. She received the Joseph Goldstein Scholar Award, sponsored by the Meteoritical Society and Springer, which along with a grant through Kelly's adviser, Professor Greg Rohrer, provided funds for the trip.

Drexel Students Inducted into Alpha Sigma Mu

Pennsylvania Alpha Chapter of Alpha Sigma Mu at Drexel University inductees with selected MSE faculty. The 2017 induction luncheon was held in June.

Drexel University Pennsylvania Alpha Chapter of Alpha Sigma Mu, faculty and chapter officers, from left, Antonios Zavaliangos, Katie Van Aken, Andrew Lang, Jamie Hart, Sarah Gleeson, and Richard Knight, FASM.

Ernst Earns Diekhoff Award for Graduate Teaching

Frank Ernst of Case Western Reserve University received the 2017 John S. Diekhoff Award for Graduate Teaching in May. Ernst, the Leonard Case Jr. Professor of Engineering, is chair of the department of materials science and engineering, director of the Case Center for Surface Engineering, and faculty director of the Swagelok Center for Surface Analysis of Materials. He is known for his open-door teaching method and makes sure his students know he considers them his "colleagues in science" by making himself approachable and seeking their most creative ideas.

Ernst

Rath Receives U.S. Naval Research Laboratory Leadership Award

The Materials Science Directorate of the Naval Research Laboratory (NRL), the US Navy's corporate research center, recently held the 25th Anniversary of its Historically Black Colleges and Universities (HBCU)/ Minority Institutions (MI) Internship Program. **Bhakta B. Rath, FASM,** received the U.S. Naval Research Laboratory HBCU/MI Internship Program 2017 Leadership Award for excellence in STEM education and diversity outreach. The program, led by NRL's Paul Charles, has been highly successful graduating 34 interns this year and hosting 326 interns to date. Supported by grants from the Office of Naval Research and the National Science Foundation, the program has steadily grown each year. College students are given intensive hands-on experience working with research scientists as mentors during a 10-week summer internship.

IN MEMORIAM

Koster

William P. Koster, FASM, died on June 6 at age 88. Koster served as ASM's president in 1992, first joining the Society in 1948. He was a co-founder of Metcut Research Associates, a materials engineering company and metallurgical laboratory in Cincinnati. He served as its president in 1978 and became COO and Chairman of the Board in 1982. Following his retirement in 1994, he continued to serve as Chairman until 2008 and as a director until 2016. Koster was involved in the design and construction of Metcut's first mechanical test machines, which lead to the company's growth into one of the world's premier materials testing laboratories. During his tenure as president, Metcut established its French subsidiary in Nantes to provide testing services to the growing European market, particularly in the aerospace industry. He was instrumental in transforming Metcut from a partnership to an employee-owned company in 1976.

Haskell Sheinberg, FASM, passed away on May 31 at age 97. He was the first in his family to attend and graduate college, earning a bachelor of science in chemical engineering from Rice University. He was proud of his brief service in the Army, after which he was posted at Los Alamos National Laboratory where his first assignment was in the plutonium group led by Art Wahl, co-discoverer of plutonium. He subsequently worked in powder metallurgy and particulate materials, fields in which he became internationally known and respected. As a member of the Special Engineer Detachment, Sheinberg worked at Los Alamos during the Manhattan Project. He gave presentations in England, the U.S.S.R., Austria, Poland, Czechoslovakia, and the U.S. In addition to ASM, Haskell was a Fellow of Los Alamos National Laboratory and the American Powder Metallurgy Institute. The 2005 dedication of the Haskell Sheinberg Conference Room in a secure area at Los Alamos recognizes his contributions to many diversified programs. He was the inventor or co-inventor of 26 domestic and foreign patents, all assigned to the Atomic Energy Commission or Department of Energy.

Sheinberg

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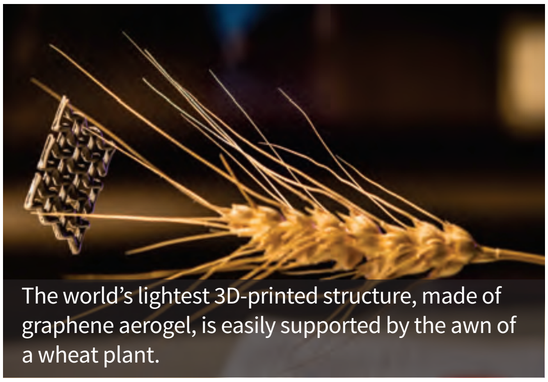


The world's lightest 3D-printed structure, made of graphene aerogel, is easily supported by the awn of a wheat plant.

INKJET PRINTER PRODUCES ULTRALIGHT GRAPHENE STRUCTURE

An incredibly lightweight graphene aerogel produced by a modified inkjet printer has earned a spot in the "Guinness Book of World Records" as the least dense 3D-printed structure in existence. Weighing in at a mere 0.5 mg/cm^3, objects made from the material are so light they can rest on the petals of a flower or atop a cotton ball. The record-breaking material is a team effort developed by researchers from Kansas State University, the University at Buffalo, and the Harbin Institute of Technology.

Only the third group in the world to successfully print graphene aerogel, the collaborators came up with an ingenious process using an inkjet printer and a water-assisted build mechanism. The printer, outfitted with two nozzles and placed in a freezer, sprays a mixture of graphene oxide and water onto a –20°C cold plate, forming a 3D ice structure that holds the graphene in place. When printing is complete, researchers transfer the workpiece to a freeze dryer where the ice and any moisture are removed. In addition to controlling the shape of printed graphene aerogels, the new process also offers control over electrical and mechanical properties. *http://bit.ly/2uh1kCM.*

3D PRINTING TAKES FLIGHT ON AIRBUS A350

Stratasys Direct Manufacturing, Los Angeles, was chosen by Airbus, France, to produce 3D-printed polymer parts for use on A350 XWB aircraft. Parts will be printed on Stratasys FDM production 3D printers using Ultem 9085. Stratasys, the parent company of Stratasys Direct Manufacturing, and Airbus have worked together since 2013 on the implementation and qualification of 3D printing technology for nonstructural flying parts as well as tools. *stratasysdirect.com.*

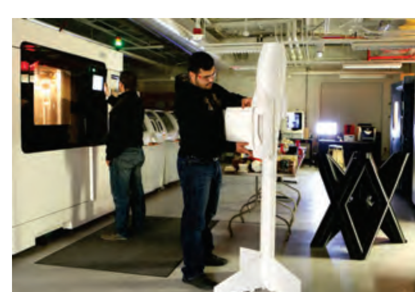
Airbus has qualified several 3D-printed polymer parts for nonstructural applications on its A350 XWB airframe. Courtesy of Airbus/Master Films/P. Pigeyre.

ATI AND GE TO DEVELOP MELTLESS TI POWDER

Allegheny Technologies Inc. (ATI), Pittsburgh, and GE Aviation, Evendale, Ohio, have entered a joint venture to reduce the cost and improve the quality of meltless titanium alloy powders for 3D printing and additive manufacturing. The team will look for ways to reduce the number of manufacturing steps, explore processes that use less costly raw materials, and pursue alloys that are currently too difficult to produce. The plan calls for construction of an R&D pilot production facility by 2019, followed by a larger scale plant that will implement the new process. *atimetals.com.*

NEW GRADUATE CERTIFICATE IN 3D PRINTING

The University of Texas at El Paso (UTEP) will begin offering a new program in the fall leading to a graduate certificate in 3D engineering and additive manufacturing (AM). The 12-month, 15 credit hour program is intended to help students take full advantage of the opportunities available to design new, innovative products using the latest AM technology. The program consists of three lecture courses that can be completed online and two hands-on design studios that will expose students to the use of more than 50 AM machines. *engineering.utep.edu.*



UTEP's W.M. Keck Center for 3D Innovation has more than 50 AM machines for plastic, metal, and electronics fabrication.