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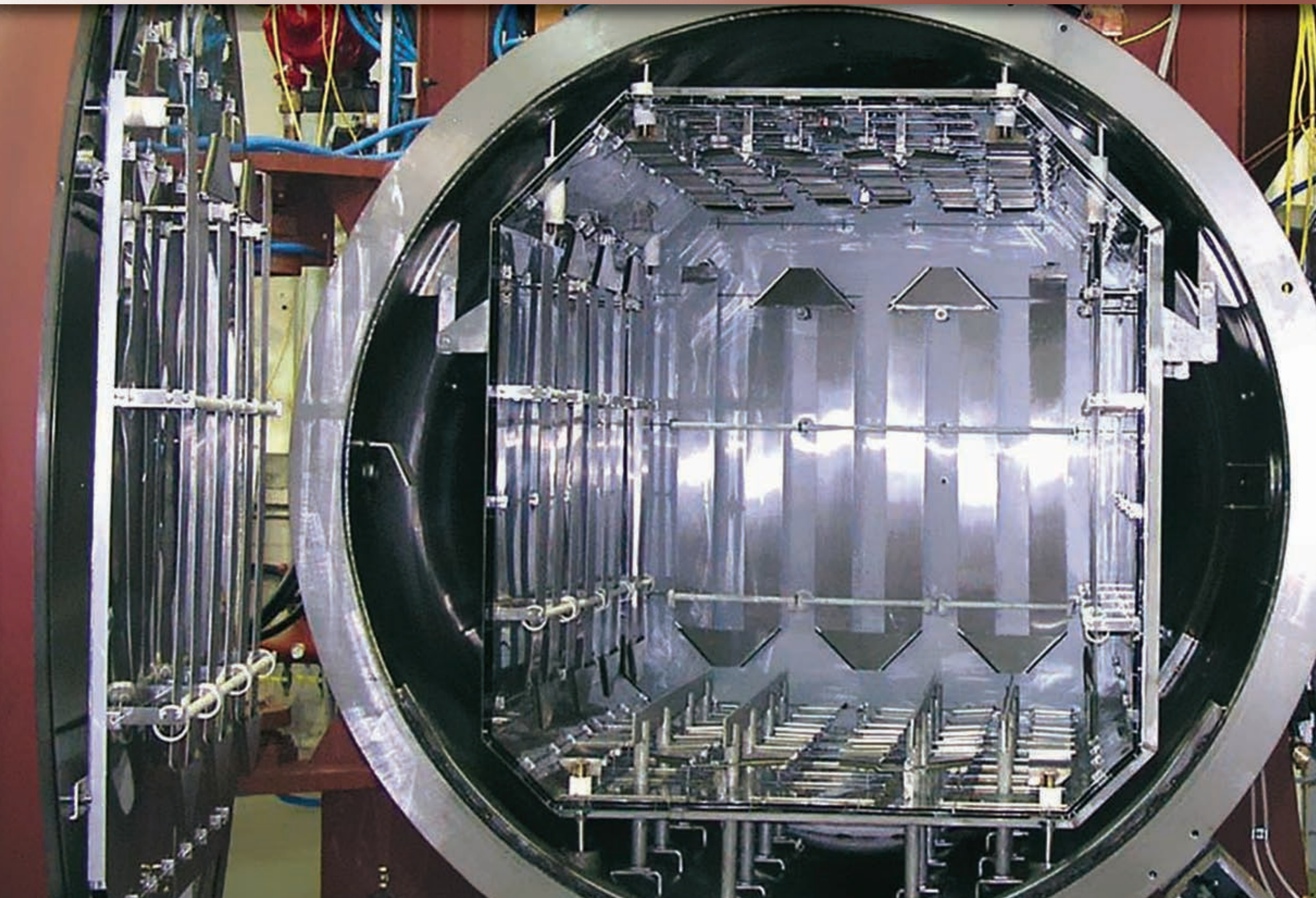

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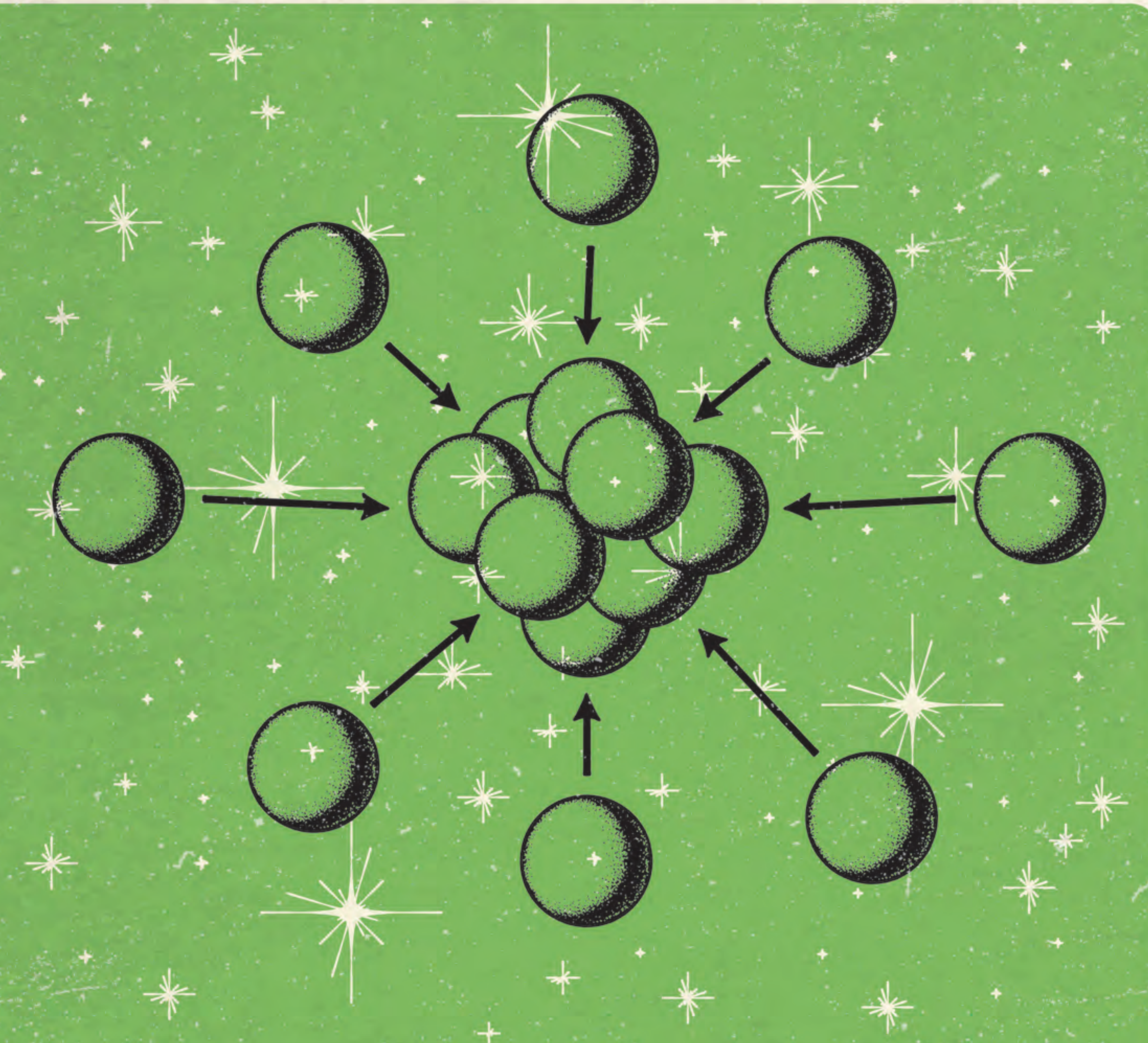

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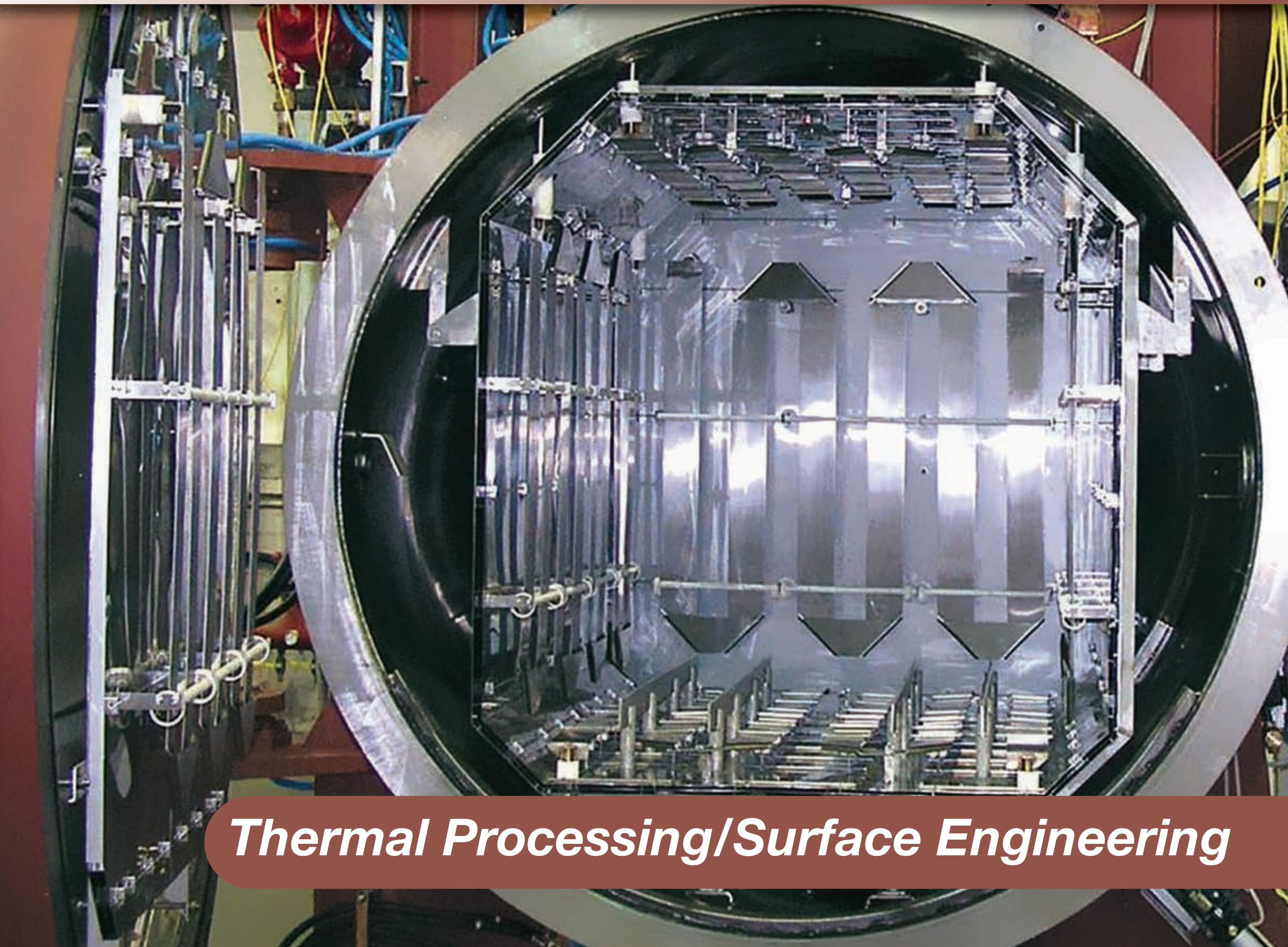

Thermal Processing/Surface Engineering

Vacuum Aluminum Brazing •

Heat Treat Process Control •

3D Printing of Copper Components •

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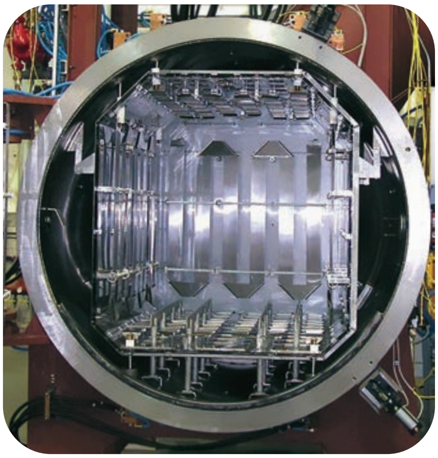

ON THE COVER:
Example of a batch vacuum aluminum brazing furnace. Batch furnaces tend to be simpler in design than semi-continuous furnaces due to one loading/unloading door, as well as less expensive and easier to maintain. Courtesy of Ipsen USA, Cherry Valley, Ill. ipsenusa.com.

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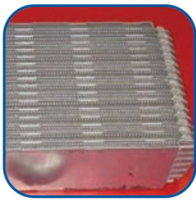

DEPARTMENTS

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materials witness

Standing on the edge of a revolution

Although some people may feel that additive manufacturing—aka 3D printing—is overly hyped these days, it's clear that many others believe we are truly on the edge of another Industrial Revolution. The ability to design and print complex parts layer-by-layer is being compared to the transformative power of the cotton gin and steam engine. It's creating a lot of buzz and significant research is being poured into figuring out the best way to take advantage of this amazing technology.

Tuskegee Airman Lt. Col. Leo Gray (left) with Frances Richards and Donald Baldwin (of GE) at AeroMat 25.

In fact, I just returned from a week at the 25th AeroMat Conference and Exposition in Orlando, Fla., which featured a theme of "the latest word in aerospace materials." Several presentations discussed additive manufacturing, including an excellent and well attended plenary session starring William Frazier, FASM, of NAVAIR, and David Abbot of GE Aviation. Frazier's talk, "The Transformative Potential of Additive Manufacturing," called the quickly developing technology "disruptive, transformative, and enabling," and said it will change the very way we do business. He spoke in detail about potential benefits, using the Navy's challenges and goals as concrete examples. While discussing the country's aging weapons systems and aircraft, he bluntly stated that it is simply too expensive and time consuming to make replacement parts for old systems using traditional subtractive techniques.

In contrast, the Navy's bold vision is to one day be able to print parts on demand, where and when they are needed. He also affirmed that we have a long way to go toward reaching that goal. He stressed that using additive methods, rather than subtractive processes, enables shorter lead times, mass customization, reduced part counts, more complex shapes, less material waste, and the ability to reverse engineer parts as needed. Frazier mentioned that although the Navy is implementing additive processes for blade and vane tip repairs, the biggest roadblock is the need for faster, low cost part qualification and certification. Other challenges include the need for validated models and in situ nondestructive inspection as the additive process is taking place, as well as a way to account for machine-to-machine variability.

David Abbott then spoke about additive manufacturing efforts at GE Aviation and interestingly points out that design engineers will need to change the way they think about designing parts from the outset—that these new additive processes will revolutionize the way we *think* in addition to how parts are physically made. He also said that by 2020, GE plans to additively produce 40,000 fuel nozzles per year. Abbott stressed the need for companies to learn from each other—he is a part of EWI's additive manufacturing consortium and is also involved with America Makes, the National Additive Manufacturing Innovation Institute.

On a celebratory note, ASM and ATI partnered to put on a VIP reception featuring Lieutenant Colonel Leo Gray, one of the 27 remaining Tuskegee Airmen from World War II. Gray shared some very interesting, funny, and personal stories from his time flying P-51 Mustangs over Germany, during nearly four years of active duty. The event was enjoyed by all and serves as a stark reminder of why aerospace innovation remains such an important endeavor.

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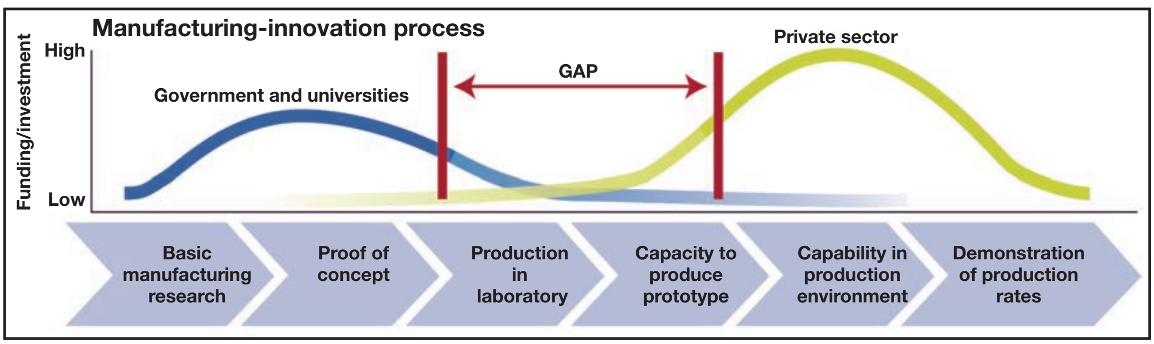
market
spotlight

Report explores nanomanufacturing and U.S. competitiveness

Nanotechnology is defined as the control or restructuring of matter at the atomic and molecular levels with a size range of roughly 1-100 nm. The U.S. National Nanotechnology Initiative (NNI), launched in 2001 to primarily focus on R&D, represents an investment of nearly $20 billion, including the request for fiscal year 2014. As research continues and other countries increasingly invest in R&D, nanotechnology is moving from the laboratory to commercial markets, mass manufacturing, and the global marketplace. Today, growing markets and expanded nanomanufacturing activities are becoming increasingly competitive in a global context, although the potential environmental, health, and safety (EHS) effects remain largely unknown. A new report from the U.S. Government Accountability Office (GAO)—*Nanomanufacturing and U.S. Competitiveness: Challenges and Opportunities*—explores U.S. competitiveness in nanomanufacturing and related issues.

Key actions were identified by forum participants who contributed to the report. To enhance U.S. nanomanufacturing competitiveness, the following needs must be addressed: Strengthen U.S. innovation by updating current innovation-related policies and programs; promote U.S. innovation in manufacturing through public-private partnerships; and design a strategy for attaining a holistic vision for U.S. nanomanufacturing. Critical policy issues identified by the experts include development of international commercial nanomanufacturing standards, the need to maintain support for basic R&D in nanotechnology, and development of a revitalized, integrative, and collaborative approach to EHS issues.

Report participants believe that the U.S. likely leads in sponsorship and overall quality of nanotechnology R&D today as well as some areas of nanomanufacturing, such as nanotherapeutic drug development and semiconductor device design. However, they cautioned that the U.S. faces global competition and is struggling to compete in some industry areas, for example, advanced batteries. To access the free report, call 866.801.7077 or visit gao.gov.



Challenges facing U.S. nanomanufacturing include: A key U.S. funding gap in the middle stages of the manufacturing-innovation process; lack of commercial or environmental, safety, and health (EHS) standards; lack of a U.S. vision for nanomanufacturing; extensive prior offshoring in some industries, which may have had unintended consequences; and threats to U.S. intellectual property. Courtesy of GAO, adapted from Executive Office of the President.

feedback

Appreciating metallurgical history

I would like to tell Charles Simcoe how much I enjoy reading his "Metallurgy Lane" articles in every issue. The history of metallurgy is very interesting to some of us and it is difficult to find articles like these. I will also make a point of visiting the blogspot given at the end of the articles, metals-history.blogspot.com.

Paul Shewmon, Professor Emeritus
The Ohio State University

Missing historical marker

I noticed in Charles Simcoe's letter ["Feedback" department, March] that the Cambria Iron Works in Johnstown, Pa., did not have an asterisk indicating it is an ASM Historical Landmark. In the early 1970s, the ASM Pittsburgh Chapter arranged to have the site of Kelly's Converter (Cambria Iron Works) designated as such. In fact, I was chairman of the chapter during 1972-73 and was present at the ceremony when the ASM plaque was placed at the park along the Stonycreek River at the foot of the Johnstown Incline. The plaque went missing after the severe flood that hit Johnstown in July 1977. As an aside, William Kelly's original converter was on display for numerous years in the lobby of the Bethlehem Steel office in Johnstown, but alas, Bethlehem Steel is no more.

Samuel J. Manganello
ASM Pittsburgh Chapter

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

Get more bounce in your running shoes

Infinergy is the world's first expanded thermoplastic polyurethane (ETPU). This closed-cell particle foam exhibits excellent resilience and especially high durability over a wide temperature range. Courtesy of BASF/adidas.

Runners always stress the need for good cushioning when it comes to running shoes. This is the function of the midsole—in just a few milliseconds, it absorbs the kinetic energy generated by the runner as the foot lands—and returns some of it to the runner while the foot is pressed down. Runners previously had to choose between wearing hard, elastic competition shoes or very soft training shoes with a lot of cushioning. But that is about to change.

In less than three years, adidas and BASF, both in Germany, resolved this dilemma with the development of adidas BOOST technology using an expanded thermoplastic polyurethane (ETPU) material called Infinergy from BASF. To produce this innovative material, researchers expanded BASF's thermoplastic polyurethane (TPU), Elastollan, using an innovative procedure that preserves the benefits of TPU while adding foam properties. The material does not lose its resilience even when under continuous load. During high-frequency fatigue testing using dynamic loads at five cycles per second and a constant pressure of 250 kilopascals, the material performed about 75% better than expanded polyethylene (EPE). After 40,000 load cycles, the thickness of the ETPU test piece was still 37 mm (from a 40 mm starting figure), whereas the EPE material remained permanently compressed and thickness was reduced to about 9 mm. *adidas-group.com, basf.com.*

Cardboard cathedral built in New Zealand

The opening and dedication of New Zealand's cardboard cathedral was a major milestone in the ongoing recovery of Christchurch, which was hit by a 6.3 magnitude earthquake that leveled much of the downtown area in 2011.

A temporary cathedral made out of cardboard opened in New Zealand last year in the heart of Latimer Square to replace a neo-Gothic structure that was destroyed in the massive Christchurch earthquake in 2011. The cardboard structure was designed by Japanese architect, Shigeru Ban, and is built from cardboard tubes measuring 600 mm in diameter coated with water-resistant polyurethane and flame retardants. The innovative cardboard cathedral has a simple A-frame structure that rises 78 ft (24 m) and can accommodate 700 people. Despite being made from cardboard, the cathedral can last up to 50 years. The Anglican Church in New Zealand plans to use the cardboard structure for at least 10 years while building a more permanent replacement for the original cathedral. The cardboard church has a concrete base with tubes holding up the two sides of the A-frame structure. Containers were also placed to secure the walls of the cathedral. On one end of the cathedral, a polycarbonate roof and stained glass protect the structure from the elements. *www.cardboardcathedral.org.nz.*

Safer football helmets prevent concussions

University of California Los Angeles professor Vijay Gupta is applying his expertise in materials science, mechanical engineering, and bioengineering to protect the brain from forces that cause concussions and traumatic brain injury. He created a polymer that could diminish the force of helmet-to-helmet hits on a football field or shockwaves from explosive devices on a battlefield. To test out his material, Gupta uses lasers and a grandfather-clock-sized hammering machine. To improve on the shock-absorbing ability of the standard football helmet without radically changing its design, Gupta added a 2-mm-thick wafer of a firm but flexible polymer he devised to reinforce the helmet's foam padding. Then Gupta and his students used the hammering machine to drop a weight on top of the helmet from a specified height to generate a range of G-forces. They measured the force felt by using a sensor. The new design has yielded promising results and achieves up to a 25% percent reduction in the force a person would feel. This translates to a similar reduction in the probability of getting a concussion. *ucla.edu.*

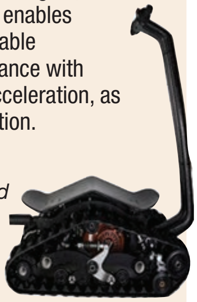
This 2-mm-thick polymer wafer shows promise as a way to decrease concussion risks.

industry news

Metals Polymers Ceramics

briefs

BPG Werks, Boston, creators of the innovative all-terrain dual tracked vehicle (DTV) called the Shredder, harnessed a high-performance polymer, VICTREX WG, from **Victrex,** UK, to construct a strong and efficient overmolded steel drive shaft segment gear. Replacing a coated brass gear, the rugged thermoplastic enables more durable and reliable transmission performance with smooth torque and acceleration, as well as reduced vibration. victrex.com.



BPG Werks specified the VICTREX WG polymer for its DTV Shredder. Courtesy of Victrex.

The Copper Development Association (CDA), New York, launched the latest video in its *Do it Proper With Copper* series: Soldering of No-Lead Copper Alloy Fittings, Valves and Components. The video not only demonstrates proper soldering techniques for new alloys, but also offers an explanation as to why they must be treated differently from the old ones. "The answer lies in the metallurgy, or physical properties of the alloy," says project manager David Powell. "Some of the new alloys, especially those containing silicon, have much lower thermal conductivity than their earlier counterparts, or than the copper parts that they are being joined with." copper.org.

Alcoa Inc., New York, signed a long-term agreement to supply aluminum sheet to **Spirit AeroSystems Inc.,** Wichita, Kan., in a contract valued at approximately $290 million over five years. Spirit is one of the largest designers and manufacturers of aerostructures for commercial, military, business, and regional jets in the world. Alcoa will provide Spirit with aluminum sheet products for fuselage skins from its Davenport, Iowa, facility. alcoa.com, spiritaero.com.

Nanocrystalline ceramic for military windows

Scientists at the U.S. Naval Research Laboratory, Washington, developed a method to fabricate nanocrystalline spinel that is 50% harder than the current spinel armor materials used in military vehicles. With the highest reported hardness for spinel, it demonstrates that the hardness of transparent ceramics can be increased simply by reducing the grain size to 28 nm. This harder spinel offers the potential for better armor windows in military vehicles.

Spinel windows serve as electro-optical/infrared deckhouse windows in a new class of U.S. Navy destroyers, such as the USS Elmo Zumwalt pictured here. Courtesy of U.S. Navy and General Dynamics.

To create the new spinel, researchers sinter commercial nanopowders into fully dense nanocrystalline materials. While sintering is a common method used to create large ceramic and metal components from powders, the team is the first to succeed in making harder spinel through the enhanced high pressure sintering (EHPS) approach, according to researchers. The EHPS approach uses high pressures (up to 6 GPa) to retard bulk diffusion rates, break powder agglomerates, and reposition nanoparticles very close to each other to help eliminate porosity in the sintered ceramic. The increased surface potential of nanoparticles can then be exploited for surface-energy-driven densification without coarsening. *www.nrl.navy.mil.*

Recycling is key to energy efficiency in metal manufacturing

The production of iron, steel, and aluminum is a highly energy-intensive process, accounting for 10% of total manufacturing energy use. Recycling in the manufacturing process of these metals is a key driver of energy efficiency improvement. Primary production, in which steel is made from iron ore and aluminum from bauxite ore, is energy intensive. However, secondary production, which involves the use of recycling scrap to make steel and aluminum, is much more energy efficient. The Environmental Protection Agency estimates that secondary steel production uses about 74% less energy than the production of steel from iron ore, while the U.S. Department of Energy reports that secondary aluminum production requires 90% less energy than primary production.

Secondary production accounts for nearly 60% of U.S. aluminum production, counting both old and new scrap. Similarly, recycling is used in most steel production. According to the U.S. Geological Survey, 40% of U.S. steel production in 2011 came from basic oxygen furnaces, whose inputs are almost 80% pig iron (molten iron), whereas 60% of production came from electric arc furnaces, which use more than 90% scrap. *eia.gov.*

New steel competes with AISI 4340

A newly designed and patented, quenched and tempered high strength low alloy steel (M-Steel), by Advanced Materials Development Corp., Ontario, reportedly exhibits strength superior to AISI 4340 steel at the same level of ductility and toughness. Further, the cost of raw materials of the M-Steel is lower than the cost of AISI 4340 steel, while the cost of melting, hot forging/rolling, annealing, and heat treatment are similar. To verify the mechanical properties, an ingot of the M-Steel with a 6-in. diameter and weighing 125 lb was air melted, homogenize annealed, and hot forged to bars. Next, bars were normalized and stress relieved. Tensile and impact specimens were machined from the bars and then normalized, gas quenched, and tempered at 450°-500°F. ASTM tensile and impact tests show a hardness HRC of 54-55, yield strength of 243-255 ksi, ultimate tensile strength of 287-300 ksi, elongation of 9-10%, reduction of area of 32-35%, and Charpy V-notch impact toughness energy of 15-18 ft/lb. Properties varied depending on austenizing and tempering temperatures.

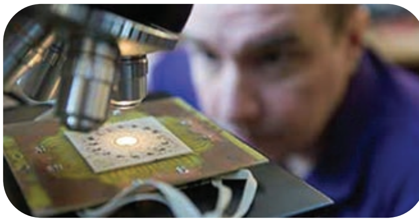
After the heat treatment, M-Steel had a tempered martensite microstructure comprised of martensitic lathes, retained austenite, and carbides as centers of growth of the martensitic lathes, and ASTM grain size of 7-8. M-Steel can be welded by conventional methods in annealed and normalized conditions. *For more information: Gregory Vartanov, 289.400.1154, supersteel@cogeco.ca.*

The earth's crust works like a pressure cooker—minerals typically do not form under standard conditions, but at high temperatures and pressures. However, an environment of extreme heat and pressure is considered to be highly unsuitable for organic molecules. Scientists at **Vienna University of Technology,** Austria, found that under such seemingly hostile conditions, organic materials with remarkable material properties, such as Kevlar, can be synthesized. At 200°C and 17 bars, the team synthesized organic polymers, which are usually extremely hard to create and require highly toxic additives. Instead of hazardous solvents, water vapor was used, making the new method eco-friendly as well. www.tuwien.ac.at/en.

The Vienna team prepares an experiment using a reactor and infrared probe. Courtesy of Vienna University of Technology.

Ultrasonic waves make nimble hands for microscopic tasks

Researchers from the Universities of Bath, Bristol, and Dundee, all in the UK, discovered that ultrasonic waves can be used to grab several microparticles at a time, essentially creating a pair of invisible "ultrasonic hands" that can move tiny objects, such as cells, under a microscope. Using plastic spheres the size of biological cells, objects could be moved along independent paths and then carefully brought together. These capabilities provide new tools to study cells that could help biologists and medical personnel perform a variety of delicate tasks such as sorting or assembling cells into patterns for tissue engineering, stem cell work, and regenerative medicine.



Researchers create ultrasonic hands that can grip microparticles. Courtesy of University of Bath.

"Sophisticated microparticle manipulation is possible using a relatively simple desktop apparatus that can be used with a standard microscope system. We believe this has the potential to radically improve results in bioscience labs where pinpoint positioning of cells is a useful research tool," says Charles Courtney of the University of Bath's mechanical engineering department. *www.bristol.ac.uk.*

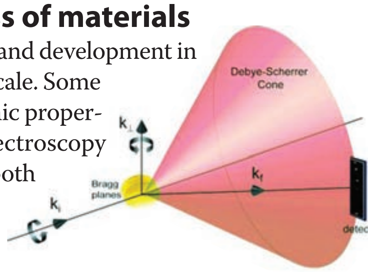
Multiscale modeling project targets aerospace costs

The EU CRASHING project, funded by the Clean Sky Joint Technology Initiative (JTI-Clean Sky) within the EU's 7th Framework Program, aims to develop new methods of testing aerospace materials through multiscale computer simulation to save time, money, and lives. The two-year project will address costs by building on recent progress in multiscale modeling. CRASHING focuses on composite materials used in current aircraft design, as well as innovative materials with potential future applications.

Computer models will provide accurate simulations of what happens when an aircraft crash lands, is hit by ice, or is exposed to other extreme impacts. Hopefully CRASHING will lead to a significant reduction in the number of physical tests required for aircraft certification and reduce development time for new structural components. The project is being led and coordinated by the IMDEA Materials Institute in Spain, which is responsible for development and validation of multiscale models at different levels. The other consortium partner, Carlos III University of Madrid, is in charge of experimental characterization of materials under impact. *materials.imdea.org.*

Rotational x-ray tracking opens up new class of materials

Over the past 20 years, there has been increasing interest and development in measuring slow dynamics in disordered systems at the nanoscale. Some techniques developed during recent years to study the dynamic properties of these materials include x-ray photon correlation spectroscopy (XPCS) and speckle visibility spectroscopy (SVS). However, both techniques are limited in that they require specialized x-ray facilities and nanoscale resolution.



Bragg scattering geometry for the experiment. Courtesy of M.Liang, et al.

Scientists at the University of Illinois at Urbana-Champaign, Argonne National Lab, Centre for Free-Electron Laser Science, Germany, and University College London, UK, developed a new technique called rotational x-ray tracking (RXT). The technique was used to study small crystalline particles that become immobilized when they form a colloidal gel under certain conditions. Instead of characterizing the gel as an immobile colloidal dispersion, scientists showed how particles in the gel actually undergo angular motion. The precise nature of the rotational motion uniquely measures the nanoscale elastic properties of the gel network. These findings open up an entirely new class of dynamic systems and materials, according to researchers. *iucr.org.*

briefs

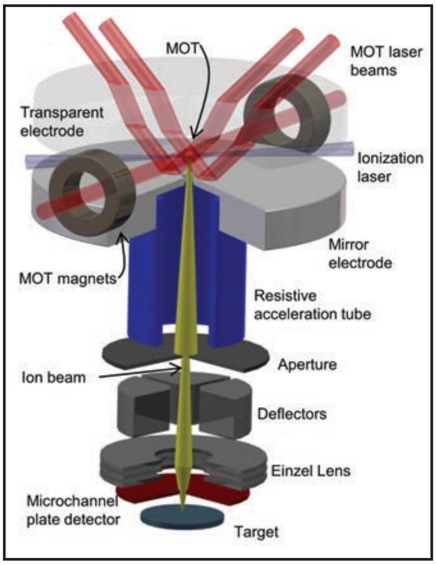
The **Innovative Technology Partnerships Office at NASA Goddard Space Flight Center,** Greenbelt, Md., will collaborate with **Rolls-Royce,** Indianapolis, to develop braze joint performance prediction methods for critical structures subject to complex loading conditions. Rolls-Royce will establish a braze failure assessment diagram (FAD) that can be used to define acceptable stress combinations and margins of safety for braze joints and braze repair structures. NASA will receive verification of its FAD methodology for failure prediction of structural brazed joints on actual industrial applications. nasa.gov, rolls-royce.com.

Submissions are welcome for the **Buehler Microstructure of Materials Calendar 2015,** with publication open to anyone who has achieved a level of excellence in materials preparation. Photomicrographs can include microstructural details or hardness indents of any metallic, nonmetallic, geological, or bio-related materials. Images must be obtained through a light optical microscope or hardness tester and cannot be digitally colored or enhanced. Selected entries will receive an honorarium of $200. Submission deadline is July 31. For more information: 847.295.6500, calendar@buehler.com.

WuXi PharmaTech Inc., Shanghai, expanded its materials characterization testing facility in St. Paul, Minn. The new 20,000-sq-ft laboratory offers expanded capacity for existing services, such as particle identification and extractable/leachable testing, and adds a new service—dynamic light scattering for nanoparticle characterization. These services are required by the FDA for filings of medical devices or biologics. wuxiapptec.com.

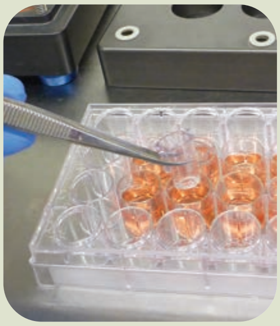
New microscope sees what others miss

Researchers at the National Institute of Standards and Technology (NIST), Gaithersburg, Md., built the first low-energy focused ion beam (FIB) microscope that uses a lithium ion source. The team's new approach opens up the possibility of creating a whole category of FIBs using any one of up to 20 different elements, greatly increasing the options for imaging, sculpting, or characterizing materials.



Although the new microscope's resolution is not as good as a scanning electron microscope (SEM) or helium ion microscope, it can image nonconductive materials and can more clearly visualize the chemical composition on the surface of a sample than the higher-energy SEMs and FIBs. Further, by analyzing the energy with which the ions scatter, researchers have shown that the microscope should be able to not only see that adjacent materials are chemically different, but also identify the elements that make them up. *nist.gov.*

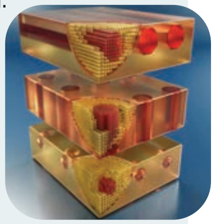
The NIST focused lithium ion beam microscope traps and cools a gas of lithium atoms to a few millionths of a degree above absolute zero (MOT section). Another laser ionizes the atoms and then electric fields accelerate them, straightening out their flight and focusing them on a target. Courtesy of NIST.



Instron, Norwood, Mass., partnered with Professor El Haj, director of the Institute of Science and Technology in Medicine at Keele University, UK, to study regenerative medicine. As this field becomes more established, it is critical to investigate and understand the relationship between cells and their mechanical environment. El Haj is working with an interdisciplinary group to pursue translational research for regenerative medicine, and Instron will provide the instrumentation needed to study the in vivo environment on the benchtop. instron.com.

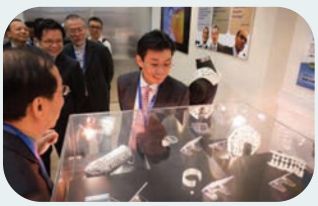
briefs

Researchers at **University of California Santa Barbara** created a compound semiconductor of nearly perfect quality with embedded nanostructures containing ordered lines of atoms that can manipulate light energy in the mid-infrared range. More efficient solar cells, better biological imaging, and the ability to transmit massive amounts of data at higher speeds are potential applications. Erbium, which can absorb light in the visible as well as infrared wavelength, is key to the technology. Erbium was paired with antimony and the resulting compound was embedded as semimetallic nanostructures within the semiconducting matrix of gallium antimonide. engineering.ucsb.edu.



An artist's concept of nanometer-size metallic wires and metallic particles embedded in semiconductors. Courtesy of Peter Allen.

Nanyang Technological University (NTU), Singapore, launched a new $30 million 3D printing facility to study medical devices and tissue printing, among other applications. The NTU Additive Manufacturing Centre (NAMC) also signed a $5 million joint laboratory agreement with **SLM Solutions,** Germany, a 3D printer manufacturer. Named **SLM Solutions@NAMC,** the lab aims to develop next-generation 3D printers that can print very large parts using new types of materials. It will also develop platforms that can print multiple materials in a single build. www.ntu.edu.sg.



3D-printed jewelry displayed at the NTU Additive Manufacturing Centre debut. Courtesy of NTU.

New method enables industrial scale graphene production

Researchers at Massachusetts Institute of Technology (MIT), Cambridge, and the University of Michigan, Ann Arbor, discovered a way to produce graphene in a process that lends itself to scaling up, by making graphene directly on materials such as large sheets of glass. Currently, most methods first grow the material on a film of metal, such as nickel or copper, explains MIT mechanical engineering professor A. John Hart. "To make it useful, you have to get it off the metal and onto a substrate, such as a silicon wafer or a polymer sheet, or something larger like a sheet of glass," he says. "But the process of transferring it has become much more frustrating than the process of growing the graphene itself, and can damage and contaminate the material."

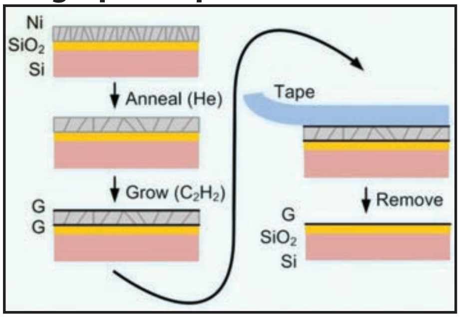


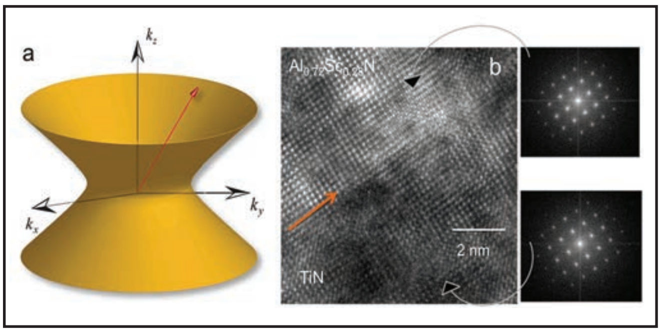
Illustration of a new process for making graphene directly on a nonmetal substrate. Courtesy of the researchers.

The new work, Hart says, still uses a metal film as the template—but instead of making graphene only on top of the metal film, the process makes it on both sides. The substrate in this case is silicon dioxide, with a film of nickel on top. Using chemical vapor deposition (CVD) to deposit a graphene layer on top of the nickel film yields graphene on both sides. The nickel film can then be peeled away, leaving just the graphene on top of the nonmetallic substrate. This eliminates the need for a separate process to attach the graphene to the intended substrate. *For more information: A. John Hart, 617.324.7022, ajhart@mit.edu, mechanosynthesis.mit.edu.*

Hyperbolic metamaterials one step closer to reality

Researchers at Purdue University, West Lafayette, Ind., took another step toward practical applications for *hyperbolic metamaterials,* ultrathin crystalline films that could bring optical advances including powerful microscopes, quantum computers, and high-performance solar cells. New developments are similar to advances that ushered in silicon chip technology, says Alexandra Boltasseva, associate professor of electrical and computer engineering.

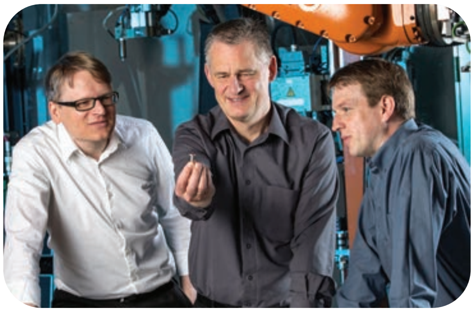
Metamaterials have engineered surfaces that contain features, patterns, or elements, such as tiny antennas or alternating layers of nitrides that enable unprecedented control of light. Under development for about 15 years, metamaterials owe their unusual potential to precision design on the nanometer scale. Optical metamaterials harness clouds of electrons called surface plasmons to manipulate and control light. However, some of the plasmonic components under development rely on using metals such as gold and silver, which are incompatible with the complementary metal-oxide-semiconductor (CMOS) manufacturing process used to construct integrated circuits and do not transmit light efficiently. Now, researchers created superlattice crystals from layers of titanium nitride and aluminum scandium nitride. The superlattices were created with epitaxy, and the layers were grown inside a vacuum chamber using magnetron sputtering. *purdue.edu.*



A metamaterial's hyperbolic dispersion of light, left. At center is a transmission electron microscope image showing the interface of titanium nitride and aluminum scandium nitride in a superlattice. Two images created using fast Fourier transform to see individual layers in the material, right. Courtesy of Purdue University.

Two-step bonding technique suitable for industrial use

Adhesive bonding technology is an effective way to seamlessly join two parts, even those made of different materials. However, because liquid adhesives need time to cure, they cannot be applied in every production step. Researchers at the Fraunhofer Institute for Manufacturing Technology and Advanced Materials IFAM, Germany, created a two-step method in which adhesive is deposited on one of the parts and then dried to form a non-sticky layer. During a subsequent step, the adhesive is hardened and parts are bonded together. The technique can be used to create a high-strength adhesive bond suitable for industrial use, which is not easy because the adhesives must fulfill different and sometimes contradictory requirements.



Matthias Popp, Andreas Hartwig, and Andreas Lühring won a 2014 Joseph von Fraunhofer prize for their work on two-part bonding techniques. Courtesy of Dirk Mahler/Fraunhofer.

"Once the adhesive is applied, it can't be tacky and it has to withstand long storage times," explains chemical engineer Andreas Lühring. "It also has to be very reactive and harden quickly during joining." The concept combines resins and hardening agents that melt at different temperatures.

The resulting hot melt adhesive can be used to manufacture fastening bolts, for example. The material is heated and applied to the fastener. After it cools, it solidifies again. The fastener can then be transported and stored. To harden the actual adhesive, it must be heated to more than 150°C in a controlled manner. In this way, two parts can be bonded to each other within seconds.

"There is one disadvantage to reactive adhesives like these. They can be stored for a long time, but not indefinitely," says group manager Matthias Popp. To address this issue, a visual monitoring method was added—if the substance has lost its functionality, it changes color. These pre-applicable structural adhesives are also suitable for other applications, including a variable construction kit that offers adhesives based on different materials and hardening principles. The different compositions are tailored to yield the best productivity and characteristics for a wide variety of applications. *www.fraunhofer.de.*

New adhesive outperforms gecko feet

The ability to stick objects to a variety of surfaces such as drywall, wood, metal, and glass with a single adhesive has been the elusive goal of numerous researchers until now. A team from University of Massachusetts Amherst developed a new, more versatile version of their invention, Geckskin, which strongly adheres to a wider range of surfaces, yet releases easily like a gecko's feet. Unlike other gecko-like materials, the invention does not rely on mimicking the nanoscopic hairs found on gecko feet, but instead builds on *draping adhesion,* which derives from the gecko's integrated skin-tendon-bone system. The new ability was created by combining soft elastomers and ultra-stiff materials such as glass or carbon fiber fabrics. *umass.edu.*

UMass Amherst researchers compared three versions of Gecksin to the abilities of a living Tokay gecko on several surfaces. One exceeds the gecko's performance on all tested surfaces.

industry news briefs

Plastic Omnium Auto Exteriors, France, is building a new facility to supply the **Volkswagen** plant in Chattanooga, Tenn., creating 300 jobs over the next three years. The automotive supplier is spending $65 million on the 27-acre facility, to be located next to the plant. Plastic Omnium has 110 plants in 30 countries, including 15 in North America. The company makes bumpers, fenders, and plastic body panels for car manufacturers around the world. plasticomnium.com.

Shiloh Industries Inc., Valley City, Ohio, a supplier of lightweighting, noise, and vibration solutions, signed an agreement with **FinnvedenBulten AB** to acquire 100% of the shares of **Finnveden Metal Structures (FMS).** With the $56.6 million acquisition, Shiloh adds stamping and magnesium die casting capabilities. Shiloh provides design, engineering, and manufacturing of engineered welded blanks, complex stampings, modular assemblies, and high-pressure aluminum die cast and machined components serving the body-in-white, chassis, emission, powertrain, structural, and seating needs of automotive OEM and Tier 1 customers. shiloh.com.

Liquidmetal Technologies Inc., Rancho Santa Margarita, Calif., signed an amended sublicense agreement with **Visser Precision Cast LLC (VPC),** Denver. Under the new agreement, Liquidmetal is freed from its commitment to use VPC as its exclusive contract manufacturer, and VPC is freed from its commitment to use Liquidmetal as its exclusive sales and R&D channel. Liquidmetal develops bulk alloys and composites that employ the performance advantages offered by amorphous alloys—unique materials that retain a random structure when they solidify. VPC offers amorphous casting, precision machining, and additive manufacturing (direct metal laser sintering) services. liquidmetal.com, visserprecisioncast.com.

industry news

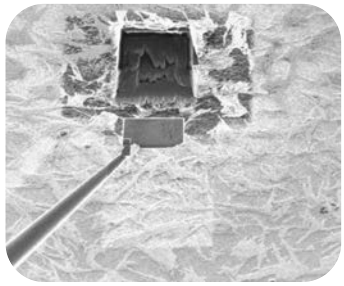
ENERGY TRENDS

Toward solving the world energy crisis

Northwestern University, Evanston, Ill., scientists discovered that a surprising material, selenide, is the best at converting waste heat to useful electricity. This outstanding property could potentially provide enormous energy savings. Researchers found that the crystal form of the chemical compound tin selenide conducts heat so poorly through its lattice structure that it is the most efficient thermoelectric material known. Unlike most thermoelectric materials, tin selenide has a simple structure, which provides the key to its exceptional properties. The efficiency of waste heat conversion in thermoelectrics is reflected by its figure of merit, ZT. Tin selenide exhibits a ZT of 2.6, the highest reported to date at around 650°C. The material's extremely low thermal conductivity boosts the ZT to this high level, while retaining electrical conductivity. *northwestern.edu.*

Impurity size could help or hinder superconductor performance

North Carolina State University, Raleigh, researchers found that impurities can either hurt performance—or possibly provide benefits—in a key superconductive material expected to find use in a host of applications, including future particle colliders. Impurity size determines whether it helps or hinders the material's performance. "Bismuth strontium calcium copper oxide (Bi2212) is the only high-temperature superconductor that can be made as a round wire, and is expected to have applications in magnets for a wide range of uses," says Ph.D. student Golsa Naderi.

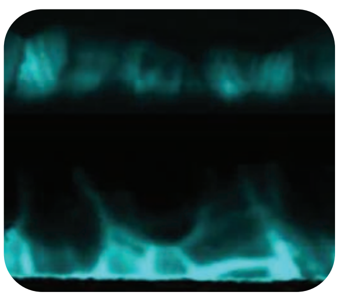


Impurity size can either hurt performance—or possibly provide benefits—in the superconductive material Bi2212. Courtesy of Golsa Naderi.

To use Bi2212 for potential applications, it needs to be formed into a multifilamentary wire, which contains 500-1000 Bi2212 filaments embedded in silver, and then heat-treated to nearly 900°C. However, this processing results in impurities in the material. These impurities largely consist of porosity and bismuth strontium copper oxide (Bi2201). Researchers found that nanoscale impurities, from 1.2 to 2.5 nm wide, appear to improve Bi2212's performance as a superconductor. *ncsu.edu.*

Thin-film solar cell mystery solved

Treating cadmium-telluride (CdTe) solar cell materials with cadmium-chloride improves their efficiency, but researchers have not fully understood why until now. A research team from Oak Ridge National Laboratory, Tenn., the University of Toledo, Ohio, and the National Renewable Energy Laboratory, Golden, Colo., used electron microscopy and computational simulations to explore the physical origins of the unexplained treatment process.
Using state-of-the-art electron microscopy techniques to study the thin films' structure and chemical composition after treatment, researchers found that chlorine atoms replaced tellurium atoms within the grain boundaries. This atomic substitution creates local electric fields at the grain boundaries that boost the material's photovoltaic performance instead of damaging it. *ornl.gov, utoledo.edu, nrel.gov.*

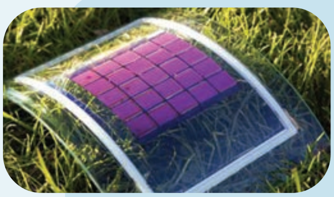


Cross-sectional electron beam-induced current maps show the difference in cadmium telluride solar cells before (pictured above) and after (below) cadmium chloride treatment. The increased brightness after treatment indicates higher current collection at grain boundaries. Courtesy of ORNL.

briefs

The U.S. Department of Energy will support the application of advanced materials and manufacturing techniques to develop next-generation hydropower technologies with a $4.4 million grant. As part of the **Clean Energy Manufacturing Initiative,** the funding will help researchers develop low cost, integrated hydropower turbine-generator sets that can produce cost-competitive electricity at low-head sites. The funding will also help pioneer new designs that apply advanced materials and innovative manufacturing techniques to next-generation, low-head hydropower systems. energy.gov.

Jyllian Kemsley, senior editor at *Chemical & Engineering News,* by the **American Chemical Society,** Washington, points out in a recent article that radiation can cause a range of problems from temperature misreadings in electronic devices to nuclear power plant explosions. These problems could be solved by finding the right materials to deal with high-radiation environments. In the case of nuclear power plants, steel might be better than zirconium for housing fuel pellets. For other applications, however, scientists found that although radiation punches holes in carbon nanotubes, when bundled together, radiation can make them 100 times more rigid. acs.org.

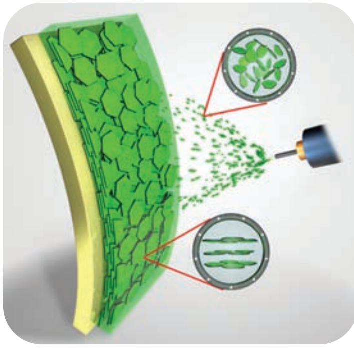


Plastic solar cells are lightweight, mechanically flexible, and offer many advantages over inorganic solar cells.

MatHero, a new project coordinated by **Karlsruhe Institute of Technology (KIT),** Germany, aims to make organic photovoltaics competitive with their inorganic counterparts by enhancing efficiency, reducing production costs, and increasing their lifetime. MatHero—new materials for highly efficient and reliable organic solar cells—covers the complete value chain of organic solar cell fabrication, from polymer design and synthesis to module fabrication and characterization to stability assessment. The project goal is an environmentally compatible printed organic solar module initially for use in off-grid applications. kit.edu.

Simple spray gun technique makes self-assembling nanoparticle films

Researchers at Kyushu University, Japan, developed a simple approach to apply a surface coating of thin, flat nanoplatelets using a common spray gun that can be purchased from an art supply store to create a surface coating in which nanoplatelets spontaneously self-assemble into "nanowalls." The nanowalls act as rigid barriers that prevent oxygen from reaching the surface, and are effective at low and high humidity levels. Using this scalable and simple processing method, researchers achieved extremely fine and highly ordered nanoscale features that are conventionally achieved with complex and energy-intensive manufacturing techniques. *For more information: H-J Sue, 979.845.5024, hjsue@tamu.edu, engineering.tamu.edu.*



A simple approach applies a surface coating of thin, flat nanoplatelets using a common spray gun to create a surface coating in which nanoplatelets spontaneously self-assemble into nanowalls.

Reducing solar panel glare

The glare from solar farms could be a thing of the past, thanks to scientists at Loughborough University, UK. They developed a multilayer anti-reflection (AR) coating for glass surfaces, which reduces the sun's reflection from photovoltaic panels while at the same time improving their efficiency. The coating is applied using the same technology as that used to deposit AR coatings on spectacles. The design, developed by Michael Walls, Piotr Kaminski, and Fabiana Lisco, reduces reflection by more than 70% across the wavelength range accepted by PV panels and consists of only four alternate layers of zirconium oxide and silicon dioxide, with the whole stack less than 300 nm thick. Coatings are deposited using magnetron sputtering by a machine developed by UK-based Power Vision Ltd. *For more information: Michael Walls, +44.0.1509.635201, j.m.walls@lboro.ac.uk, www.lboro.ac.uk.*

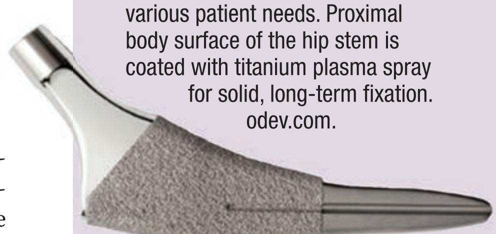
Brush-turkey eggs inspire germ-resistant coatings

The Australian brush-turkey buries its eggs in rotting vegetation to incubate them. While bacterial decomposition heats the eggs, it does not infect them. University of Akron, Ohio, scientists found that the eggshell surface—dotted with nanospheres—blocks bacteria. Because water provides a breeding ground for bacteria, researchers applied water to the eggshell to determine its hydrophobicity. Like water on a freshly polished car, water on the brush-turkey egg beaded up. "Most bacteria grow best when water is available, and these eggs appear to reduce water on their surface," says visiting assistant professor Liliana D'Alba, noting that conversely, water spreads across the shell surface of eggs without nanospheres, such as chicken eggs. The eggs' rough surface could serve double-duty, preventing bacteria from infecting the eggs by both limiting water and averting bacteria, according to researchers. The eggshells' robust surface provoked ideas for developing a synthetic coating to benefit medical, food processing, and manufacturing industries. *uakron.edu.*

Biologist Liliana D'Alba watches an Australian brush-turkey bury its eggs in rotting vegetation.

briefs

Ortho Development, Draper, Utah, received U.S. FDA approval for its Ovation Tribute hip stem intended for cementless use in total hip replacement and hemiarthroplasty procedures. The hip stem, a femoral hip prosthesis, reduces bone loss and length of surgery. The stem includes a minimal broach-only instrumentation platform and is available in a range of sizes with both standard and extended neck offset options in order to provide options for various patient needs. Proximal body surface of the hip stem is coated with titanium plasma spray for solid, long-term fixation. odev.com.



Ovation Tribute hip stem for cementless use in total hip replacement and hemiarthroplasty procedures. Courtesy of PRNews/Ortho Development Corp.

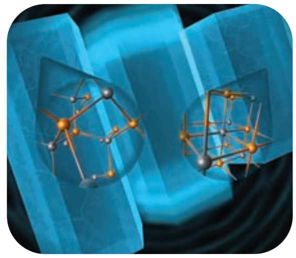
Dow Corning, Midland, Mich., introduced MAINCOTE IC Acrylic Resins, a new category of liquid insulation coatings that offers low thermal conductivity in an easy spray application. Thermal insulation coatings formulated with the new resins offer a solution to unintended heat loss and corrosion under insulation (CUI). The resins are designed for use with low thermal conductivity fillers, and coatings formulated with them can replace the thick mechanical insulation that can mask CUI. Fiberglass and other industrial insulation materials typically require a separate moisture barrier or jacketing to prevent corrosion issues. dow.com/coatingmaterials.

Ranga Pitchumani, professor of mechanical engineering at **Virginia Tech,** Blacksburg, developed a type of coating that has little to no affinity for water and emulates the Lotus effect. Using a two-step technique, "We produced a low cost and simple approach for coating metallic surfaces with an enduring superhydrophobic (strong water repellant) film of copper," explains Pitchumani. This template-free process allows the coating material to be made of the same material as the substrate, preserving its thermal and electrical properties. vt.edu.

industry news

Nanotechnology

Technique sheds light on martensitic transformations

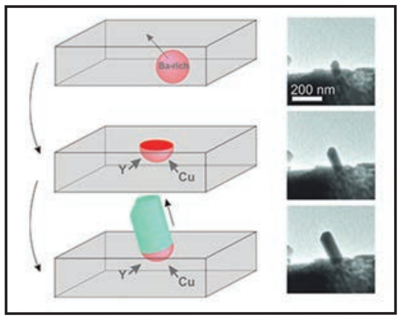


The transformation of cadmium sulfide nanocrystals from a hexagonal arrangement (left) to a cubic one (right). A slightly compressed intermediate state is portrayed in the middle. Courtesy of Greg Stewart/SLAC.

Researchers at SLAC National Accelerator Laboratory, Menlo Park, Calif., made the first direct measurements of a small and extremely rapid atomic rearrangement, associated with a class called martensitic transformations that dramatically change the properties of many important materials, such as doubling the hardness of steel and causing shape-memory alloys to revert to a previous shape. Using high-pressure shock waves and ultrashort x-ray pulses at the Linac Coherent Light Source (LCLS), researchers observed details of how this transformation changed the internal atomic structure of a model system, perfect nanocrystals of cadmium sulfide. In the process, they saw for the first time that the nanocrystals pass through a theoretically-predicted intermediate state when undergoing this change.

"To design and engineer new materials with desired properties, we would like to understand the detailed microscopic pathways they follow as they transform," says Aaron Lindenberg, assistant professor at SLAC and Stanford. "The martensitic transformation is especially important because it occurs in so many important materials. Our technique should ultimately help us see what's happening in other atomic transformations as well." *For more information: Aaron Lindenberg, 650.725.2640, aaronl@stanford.edu, lcls.slac.stanford.edu.*

Microcrucible crystal growth mechanism observed



Schematic of molten barium-rich nanoparticles moving to the surface of an yttrium- and copper-rich matrix.

Researchers from University of Bristol, University of Birmingham, both in the UK, and the National Institute for Materials Science, Japan, successfully grew nanowires of a phase of the superconductor yttrium barium copper oxide that have a constant cross-sectional area. Their syntheses proceeds via the so-called "microcrucible mechanism" of crystal growth, which was first proposed to account for the growth of certain macroscopic metal oxide whiskers in 1994, but had never been witnessed.

The observation was made using a high-resolution transmission electron microscope with video capture and an in-situ furnace. Researchers directly viewed molten nanoparticles of barium carbonate migrating through a porous yttrium and copper-rich matrix, catalyzing nanowire outgrowth from nanosized microcrucibles on reaching the surface. *www.bristol.ac.uk.*

Nanowire transistors enable next-generation electronics

A new approach to integrated circuits—combining atoms of semiconductor materials into nanowires and structures on top of silicon surfaces—shows promise for a new generation of fast and sturdy electronic and photonic devices. Using this approach, engineers at the University of California Davis demonstrated 3D nanowire transistors that open further opportunities for integrating other semiconductors, such as gallium nitride, on silicon substrates. "Silicon can't do everything," says Saif Islam, professor of electrical and computer engineering. Circuits built on conventionally etched silicon have reached their lower size limit, which restricts operation speed and integration density. Additionally, conventional silicon circuits cannot function at temperatures above 250°C (~480°F), or handle high power or voltages, or optical applications. Researchers created silicon wafers with "nanopillars" of materials such as gallium arsenide, gallium nitride, or indium phosphide on them, and grew tiny nanowire "bridges" between the nanopillars. *For more information: Saif Islam, 530.754.6732, sislam@ucdavis.edu, ucdavis.edu.*

briefs

A team led by researchers from the **University of California Los Angeles** developed a process to control molecular growth within the "building block" components of inorganic materials. The method uses nanoparticles to organize components during a critical phase of the manufacturing process and could lead to innovative new materials, such as self-lubricating bearings for engines. It could also make mass production of such materials more feasible. For example, the method could be used for aluminum-bismuth alloys. Aluminum and bismuth cannot be completely mixed, but with the nanoparticle-controlled process, researchers created a uniform and high performance aluminum-bismuth alloy. ucla.edu.

A Swedish-German research team successfully tested a new method of producing ultra-strong cellulose fibers at **Deutsches Elektronen-Synchrotron's (DESY)** research light source PETRA III in Germany. The novel procedure spins extremely tough filaments from tiny cellulose fibrils by aligning them in parallel during the production process: Nanometer-sized cellulose fibrils are fed together with water through a small channel. Two additional water jets coming in perpendicular from left and right accelerate fibril flow. Following acceleration, all nanofibrils align themselves more or less parallel with the flow. Salt is then added to the outer streams, which makes the fibrils attach to each other, thereby locking the filament structure. Once the filaments dry, they shrink to form a strong fiber. www.desy.de.

Artist's impression of the production of ultra-strong cellulose fibers. Courtesy of DESY/Eberhard Reimann.

Understanding Key Process Parameters of **Vacuum Aluminum Brazing**

Craig Moller*
Jim Grann
Ipsen USA
Cherry Valley, Ill.

Successful part brazing relies on proper joint design, part cleanliness, and correct fixturing of part assemblies. Routine furnace maintenance allows repeatable, quality brazing results over time.

The American Welding Society defines brazing as:

"A group of welding processes that produces coalescence of materials by heating them to the brazing temperature in the presence of a filler metal having a liquidus above 840°F (450°C) and below the solidus of the base metal. The filler metal is distributed between the closely fitted faying surfaces of the joint by capillary action.[1]"

The *solidus* is the highest temperature at which the metal is completely solid—the temperature at which melting starts. The *liquidus* is the lowest temperature at which the metal is completely liquid—the temperature at which solidification starts.

Types of aluminum brazing

Flux brazing involves the flow of flux into the joint, which is then displaced by the liquidus filler metal to remove oxides on the part, creating a strong, solid braze. Flux comes in several different forms—paste, liquid, or powder. Some brazing rods are coated with flux or have flux cores in order to apply necessary flux during brazing. Flux brazing processes include torch brazing (manual and automatic), induction, salt bath (dip brazing), and controlled atmosphere brazing (CAB).

Vacuum aluminum brazing (VAB) is performed in a vacuum furnace and is considered fluxless brazing because flux is not used to create joints. Fluxless brazing processes can be performed using inert gas atmospheres or in vacuum furnaces. Application examples include semiconductor manufacturing and ceramic to copper brazing. Due to the vacuum's clean environment, flux is not needed. Magnesium is used as an additive, or *getter*, in vacuum aluminum brazing.

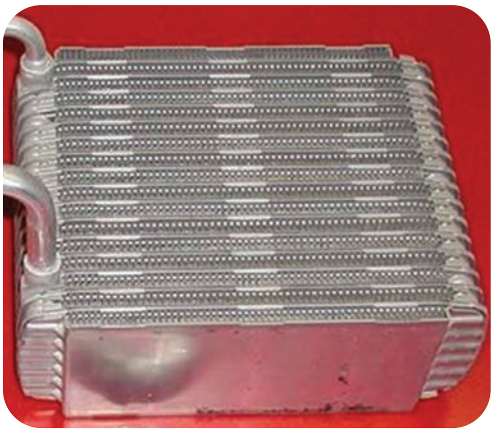


Fig. 1 — *Vacuum aluminum brazed radiator. Courtesy of API Tech.*

Vacuum aluminum brazing advantages

Brazing has many advantages compared to other metal-joining processes. Because it does not melt the base metal of the joint, brazing allows for more precise control of tolerances and provides a clean joint without the need for additional finishing. The meniscus (crescent shaped) formed by the filler metal in the brazed joint is ideally shaped for reducing stress concentrations and improving fatigue properties. Applications well suited for brazing include:

- Parts with very thin or very thick cross sections
- Compact components with many junctions to be sealed (e.g., heat exchangers) or deep joints with restricted access
- Dissimilar metals such as copper and stainless steel
- Assemblies with a large number of joints

VAB minimizes part distortion because parts are uniformly heated and cooled compared to localized joining processes. VAB also creates a continuous hermetically sealed bond. Components with large surface areas and numerous joints can be successfully brazed this way. Hardening can be accomplished in the same furnace cycle if hardenable alloys are used and the furnace system has a forced cooling system, which reduces cycle time.

Vacuum furnace brazing offers extremely repeatable results due to critical furnace parameters attained with every load—vacuum levels and temperature remain uniform. Capillary joint paths (even long paths) are effectively purged of entrapped gas during initial evacuation of the furnace chamber resulting in more complete joint wetting.

VAB is ideal for oxide-sensitive materials, as corrosive flux residue is eliminated. Post-brazed parts are clean with a matte grey finish. The process is relatively nonpolluting and does not require post-braze cleaning. Examples of VAB parts (Fig. 1) often include heat exchang-

**Member of ASM International*

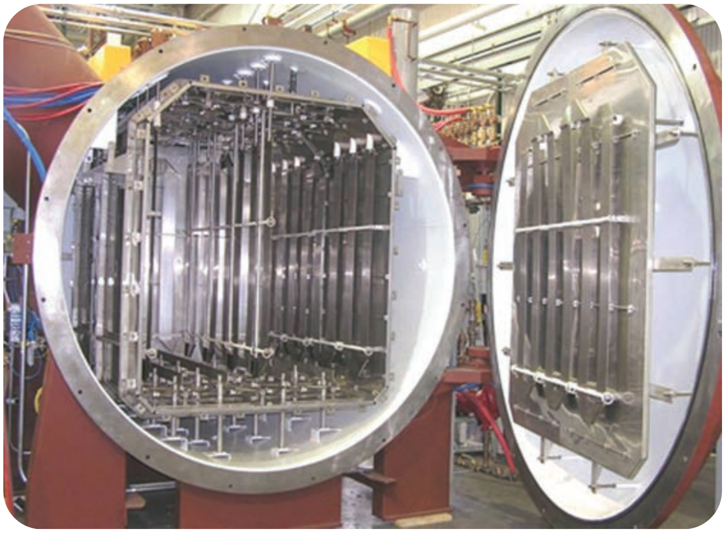


Fig. 2 — *Batch vacuum aluminum brazing furnace.*

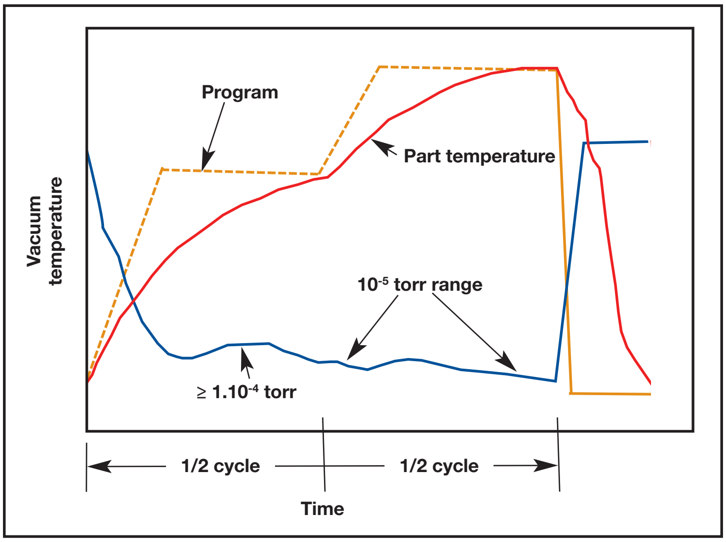


Fig. 3 — *Typical vacuum aluminum brazing cycle.*

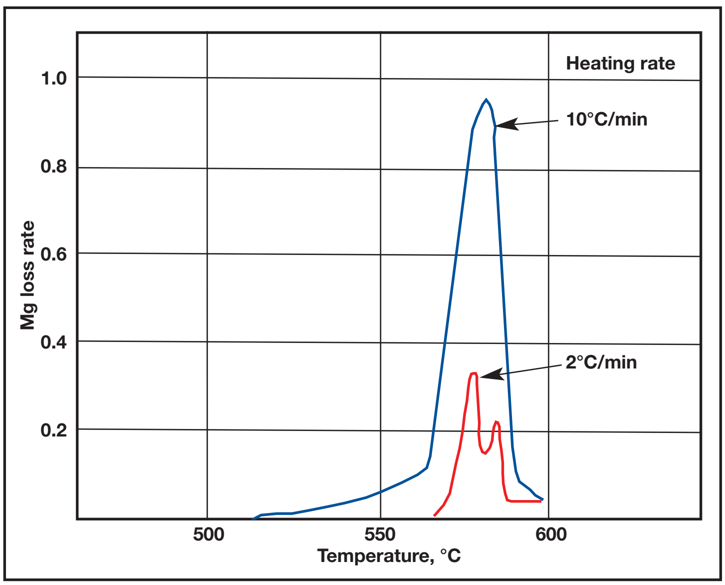


Fig. 4 — *Magnesium vaporization in vacuum vs. temperature.*

ers, condensers, and evaporators used in automotive, aerospace, nuclear, and energy industries.

Vacuum aluminum brazing furnaces

Typical VAB furnaces are either single-chamber (batch type) or multiple-chamber (semi-continuous). Batch type furnaces are usually loaded horizontally, but can be designed for vertical loading. Semi-continuous furnaces are horizontally loaded and are typically automated using load carriers and external conveyor systems.

Batch furnaces tend to be simpler in design (one loading/unloading door), less expensive, and easier to maintain (Fig. 2) than semi-continuous furnaces. Semi-continuous furnaces have higher production rates because of the multi-chamber design and operate more efficiently by not having to cool heating zones or heat cooling zones.

The VAB process is typically a relatively short cycle due to the fast pumping and heating characteristics of the furnace, excellent temperature uniformity at soak temperatures, and high thermal conductivity of the aluminum parts being brazed. Figure 3 shows a typical VAB cycle.

Vacuum pumping capacity must be adequately sized in order to minimize pump downtime of a new load to a deep vacuum level, so as to initiate the heating cycle and have adequate throughput to keep up with outgassing taking place during the heating cycle. This outgassing takes place due to magnesium vaporization. Deep vacuum level is an important process parameter because it ensures a relatively pure environment for brazing (less PPM of oxygen).

Magnesium plays key role

A key component of VAB is magnesium use as an additive to the filler metal and/or base metal of the parts to be brazed. It is necessary in this fluxless brazing environment because:

- Magnesium vaporizes at roughly 1058°F (570°C) and acts as a "getter" for oxygen and water vapor, thus improving the brazing vacuum purity
- Magnesium reduces alumina oxide on aluminum's surface, promoting uniform accelerated wetting of joint surfaces

The following reactions occur during the vacuum brazing process:

$$Mg + H_2O \rightarrow MgO + H_2$$
$$Mg + O_2 \rightarrow 2\ MgO$$
$$3\ Mg + Al_2O_3 \rightarrow 3\ MgO + 2\ Al$$
$$Mg + N_2 \rightarrow Mg_3N_2$$

Magnesium vaporization in a vacuum environment can be seen in Fig. 4. Also known as a "mag burst," magnesium vaporization produces heavy outgassing for a short period. Figure 4 shows that slower heating rates reduce the magnesium vaporization rate. Due to this gas load, vacuum pumps must be adequately sized to maintain a good working vacuum (10^{-4} to 10^{-5} torr range).

Precise temperature control and uniformity are also important process parameters. Accepted temperature uniformity during a brazing cycle is +/- 5°F (3°C) of set point. Aluminum brazing has a very narrow window of acceptable brazing temperatures. The governing rule for aluminum brazing is that the filler metal must liquidize before the base metal reaches its solidus temperature. This temperature difference may be as small as 10°-18°F (5°-10°C). Figure 5 shows the small process window available for aluminum brazing. For example, a base metal 6061 alloy will have a solidus temperature of 1099°F (593°C) and a liquidus temperature of 1206°F (652°C). The brazing temperature range would be 1049°-1085°F (565°-585°C) depending on the filler metal used.

Using a heating step at a soak temperature just below the solidus point of the filler metal ensures that all the parts and joints to be brazed reach the correct temperature at approximately the same time. At this time, the ramp to brazing temperature starts, filler metal begins to melt, and capillary wetting of the braze joints occurs.

The time duration of braze temperature must be kept to a minimum as melted filler metal is vaporizing in the deep vacuum while trying to wet the braze joints. Too much loss of filler metal to vaporization will result in poor joint wetting and subsequent loss of joint strength and sealing ability. After the brazing temperature soak duration is complete, an immediate vacuum cooling cycle follows, which solidifies the filler metal in the braze joints and stops material vaporization.

The type of precise temperature control and uniformity needed for VAB is achieved through the use of several heating control zones around the parts while at the same time maintaining the surface temperatures of the heating elements as near to the part temperature as possible. A large delta in temperature between the heating elements and the parts would result in overheating of the parts' surface, possibly above the solidus temperature for the material as the filler metal begins to melt.

Braze joint fundamentals

Figures 6 and 7 show typical braze joints used in aluminum component construction. In general, the difference between the favorable and unfavorable types of joints is the amount of overlapping that results in good braze joints. A stronger braze joint has a large surface area wetted by the filler material. Too much overlapping is detrimental to the joint because the filler material will not cover the entire surface when it flows into the joint.

Braze joint strength is dependent on two primary mechanical characteristics: Joint wetted surface area and the size of the gap into which the filler metal flows. In Figs. 6 and 7, improved joint surface area characteristics are shown. Figure 8 illustrates the importance of a proper joint gap.

Gaps between 0.003-0.008 in. (0.08-0.2 mm) work best for vacuum furnace brazing. Joint gaps are controlled by the manufacturing tolerances of the parts to be brazed and by proper clamping (pre-loading) of the part assemblies to be brazed.

Fixturing and cleaning parts

Part assemblies must be fixtured properly for brazing

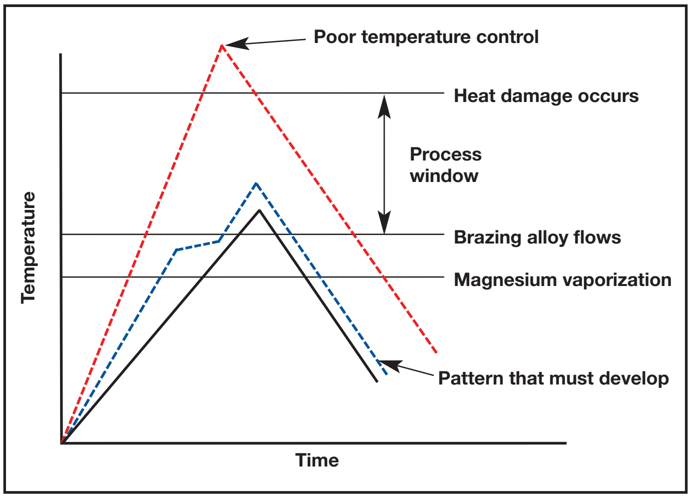


Fig. 5 — *Temperature vs. brazing cycle steps.*

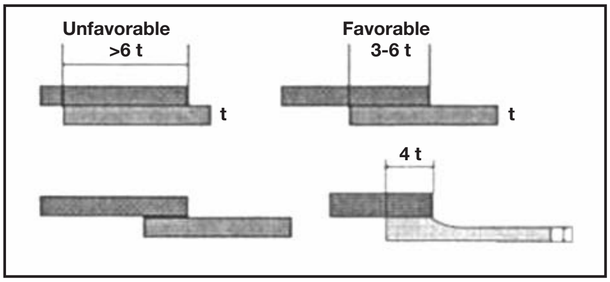


Fig. 6 — *Lap joints*[2].

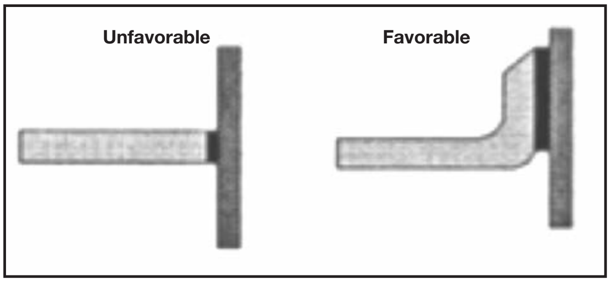


Fig. 7 — *T joints*[2].

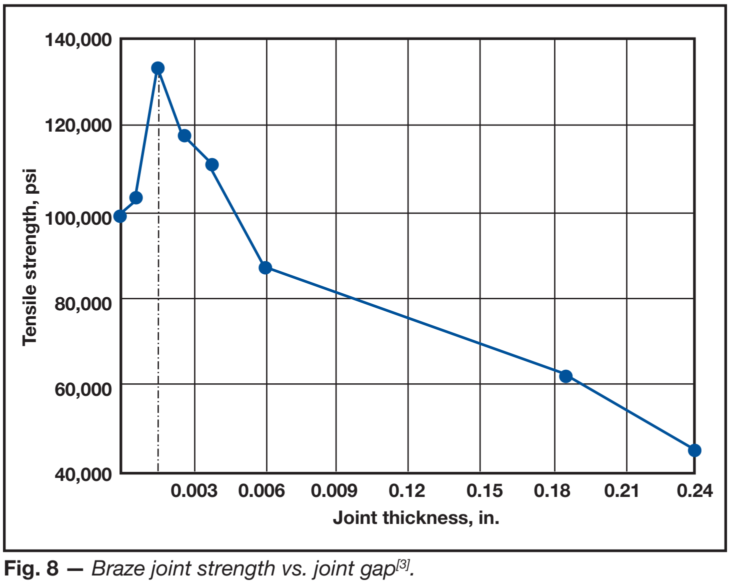


Fig. 8 — *Braze joint strength vs. joint gap*[3].

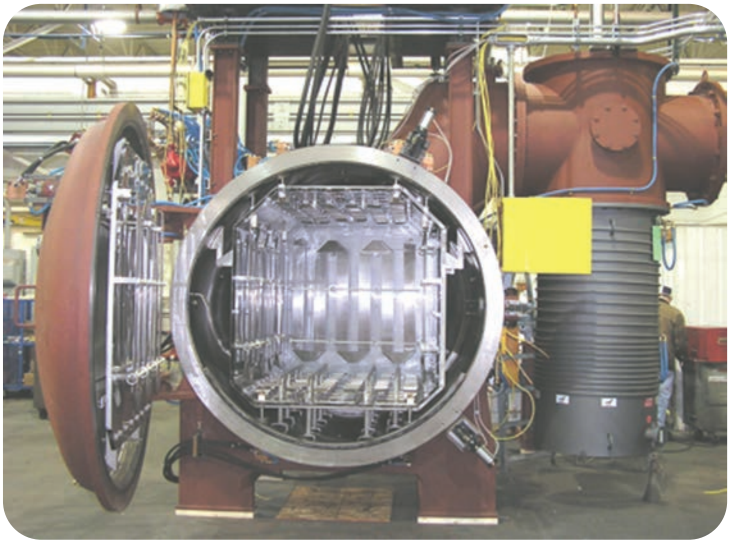


Fig. 9 — *Large diffusion pump on a vacuum aluminum brazing furnace.*

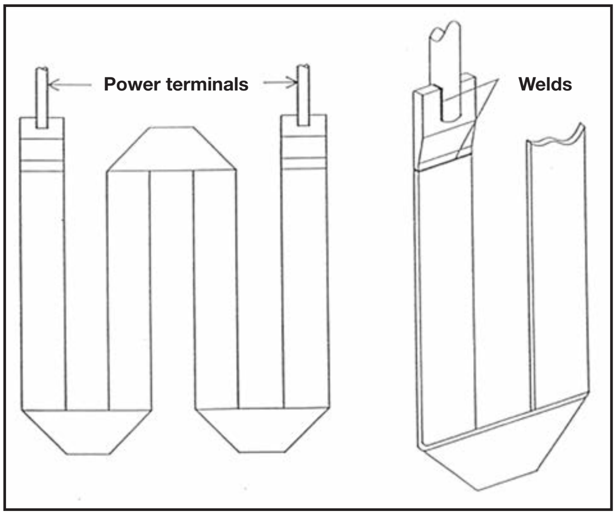


Fig. 10 — *Wide band heating element.*

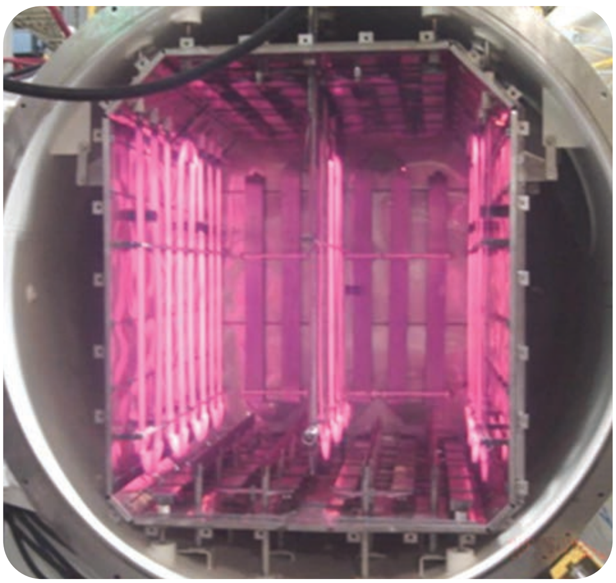


Fig. 11 — *New vacuum aluminum brazing furnace.*

in order to maintain joint gaps, joint alignment, flow passage alignment, and overall assembly tolerances. Fixturing materials must be chosen carefully due to different coefficients of expansion for varying materials. Fixture designs are also extremely part dependent, thought out in great detail, and are proprietary in some cases because they are an integral part of the manufacturing process.

Along with proper joint design and fixturing, brazing requires part assemblies to be cleaned properly prior to assembly then properly handled in order to avoid contamination prior to brazing. All grease, oil, and particulates must be cleaned off the parent and filler metal surfaces, and assemblers must be careful not to transfer oils from their skin to these surfaces when stacking parts together. Typical cleaning methods include vapor degreasing, hydrocarbon wash, aqueous washing, acid etching, and vacuum de-oiling.

Furnace characteristics

As noted previously, one key process parameter of VAB is a deep vacuum level and adequate pumping throughput to keep up with the significant outgassing that takes place during the heating cycle due to magnesium vaporization. Typical VAB furnaces include large diffusion pumps and backing pumps to accomplish these requirements. Figure 9 shows typical pumping arrangements for these furnaces. The pumping capacity required for a given aluminum brazing furnace depends on the load, specifically the load surface area being brazed. The larger the load surface area, the larger the required pumping capacity. Due to the fact that most of the magnesium vaporization occurs in the 10^{-4} to 10^{-5} torr range, diffusion pump(s) must handle the gas load during mag burst with adequate backing pumps.

To facilitate vacuum pumping in the furnace, the cooling jacket around the vacuum vessel runs at higher than ambient temperatures. This warm wall design helps prevent water vapor condensation inside the vessel when the door is open for loading/unloading. Water vapor is the enemy of aluminum brazing—it slows pumping speed and breaks down, releasing oxygen into the furnace. The warm wall design lessens the bonding strength of the magnesium oxide that forms during brazing and ultimately condenses on the chamber's inner wall, making it easier to mechanically clean.

VAB furnaces must maintain a low leak-up rate to prevent the outside atmosphere from entering the furnace during brazing. Vacuum quality contains a very low PPM of oxygen throughout the brazing cycle. Good design practices for vacuum chambers that have a low leak-up rate typically include minimal use of pipe thread joints, using a 63 micro-finish or better on sealing surfaces for O-rings, and using the correct O-ring material for the sealing area's temperature.

Heating elements

Other important process parameters include precise temperature control and temperature uniformity. Placing the sensing junctions of thermocouples near the heating elements results in faster and more accurate control of process parameters. Using many heating control zones arranged within the hot zone provides exceptional temperature uniformity [+/- 5°F (3°C)]. The wideband design provides a substantial radiating surface to the processed parts, which facilitates faster heating and better temperature uniformities. Batch-type VAB furnaces that contain 10 to 20 individually controlled heating zones are common.

Heating element surface area as a percentage to load surface area is also important. The larger the surface area of the heating elements, the lower the watt density on that surface, resulting in element temperatures only slightly above load temperature at steady-state soaking conditions. This ensures that the load's outside surface does not become overheated (Fig. 10). Vacuum furnaces that can process two loads side by side also use center heating element banks between the two loads. This design enables even heating of all surfaces on dual workloads.

Furnace maintenance

The majority of maintenance time spent on a VAB furnace is devoted to cleaning magnesium oxide deposits that form inside the chamber and hot zone during the brazing process. Figs. 11 and 12 show before and after photos of typical VAB furnaces.

Magnesium oxide deposits tend to retain water vapor. Excess retention of water vapor slows down vacuum pumping. Eventually, magnesium oxide will build up enough to negate the furnace's ability to pump in acceptable parameters and may prevent reaching the required vacuum levels for quality brazing. This is when magnesium oxide needs to be removed from the furnace system.

Mechanical cleaning is usually used to remove magnesium oxide. Scraping magnesium oxide from chamber walls and hot zone shields must be done with non-ferrous scrapers to avoid creating a spark that could ignite. If the build-up is too heavy and difficult to scrape off, an air burnout cycle may help crack apart large clusters. After most of the oxide is removed from the furnace chamber and hot zone, a normal vacuum burnout further conditions the furnace prior to placing it back into production. Cleaning of diffusion pump(s) should be performed following specific instructions from the manufacturer.

Other maintenance activities include changing vacuum pump oils every two to six months, replacing dynamic seals such as door seals and poppet valve seals every year, and replacing jack panel (work thermocouple) parts every year. Control thermocouple replacement should follow applicable guidelines. Vacuum sensing gages also must be replaced, cleaned, or rebuilt as required.

Summary

Vacuum aluminum brazing includes several key process parameters. Deep vacuum levels, precise temperature control, and excellent temperature uniformity are all provided by optimum furnace design and controls. Successful part brazing relies on proper joint design with regard to joint surface area and joint gaps, part cleanliness, and correct fixturing of part assemblies. Following a routine furnace maintenance program allows repeatable, high quality brazing results over time. ❍

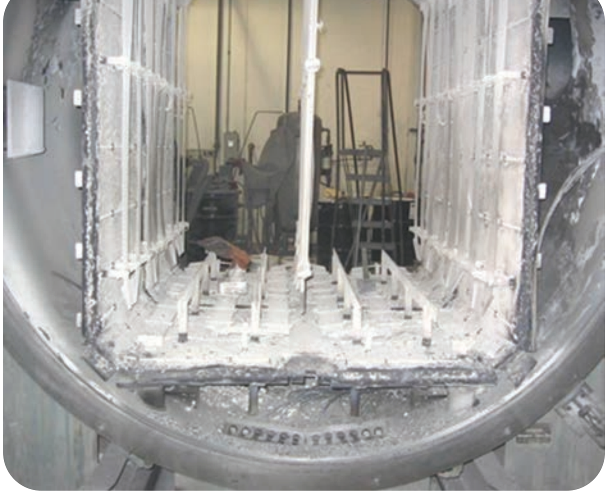


Fig. 12 — Four-year-old vacuum aluminum brazing furnace.

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Fabricating Copper Components with Electron Beam Melting

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The ability to make components from copper and copper alloys via additive manufacturing is spurring a range of novel applications.

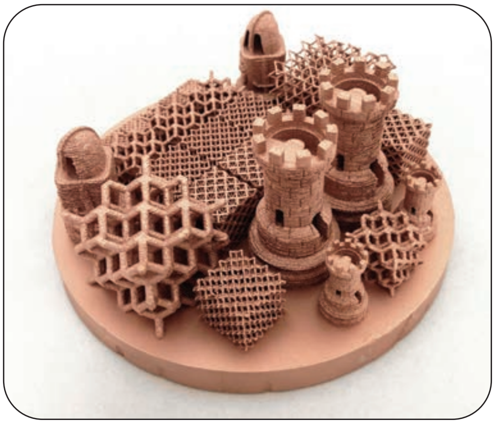
Direct fabrication of fully dense metal structures using the electron beam melting (EBM) process developed by Arcam AB, Sweden, has been successfully demonstrated for a wide range of materials including Ti-6Al-4V[1,11,9], cobalt chromium[7,6], titanium-aluminide[4,8], H-13 steel[2], and nickel-base alloys[10]. A growing interest in additive manufacturing (AM) to build components from copper and copper alloys[5,13,12] is spurring a variety of applications including novel radio frequency (RF) accelerating structures.

A critical issue for high average power, high brightness photoinjectors—the technology of choice for generating high brightness electron beams used in many of today's linear accelerators—is efficient cooling. RadiaBeam Technologies is exploring the use of AM to fabricate complex RF photoinjectors with geometries optimized for thermal management: Spatially optimized internal cooling channels can be fabricated without the constraints typically associated with traditional manufacturing methods.

However, several properties of pure copper present significant processing challenges for direct metal AM. For one, pure copper has a relatively high thermal conductivity (401 W•m−1•K−1 at 300K) which, while ideal for thermal management applications, rapidly conducts heat away from the melt area resulting in local thermal gradients. This can lead to layer curling, delamination, and ultimately, build and part failure. Additionally, copper's high ductility hinders post-build powder removal and recovery. Particles also tend to agglomerate, reducing overall flowability and impeding powder deposition. Because Cu is sensitive to oxidation, great care must be taken in handling and storage before, during, and after part fabrication.

Fabrication methods

Initial experiments focused on developing stable parameters for processing copper using EBM. An Arcam model S12 at North Carolina State University, and an Arcam model A2 at the University of Texas El Paso, fabricated the samples for these experiments. EBM hardware is described elsewhere in detail[3,4,5,6]. A circular start plate made of oxygen free, high conductivity (OFHC) copper measuring approximately 150 x 10 mm leveled on a 10-mm-thick bed of loose



copper powder was the build substrate. Initially, the electron beam scans the start plate surface at high power and high speed, raising the plate temperature to 500°-600°C. Fast scan rates allow maintenance of a relatively high temperature throughout the build process, reducing internal stresses caused by thermal gradients.

Processing each layer typically requires two separate parameter steps called *themes,* which contain all of the required process parameters, such as beam speed and power, and focus offset. The first step is *preheating,* which raises the powder temperature and causes it to lightly sinter together. This mechanical bond facilitates the next step, *melting,* which is divided into two sub-steps: *contours* and *hatching.* The contours step uses relatively low current and speed to trace the outline of each layer with a proprietary control step called *multi-beam,* which uses the high scan rate capabilities to jump between multiple locations on the contour, approximating multiple beams that are able to simultaneously maintain multiple (~60) melt pools. This approach improves surface finish compared to single-spot contouring while maintaining productivity. In the hatching step, beam current and speed are increased and the beam is rastered to melt the area between contours. With each layer, the hatch direction is rotated 90° and spacing between hatch lines is offset by 0.05 mm.

EBM process parameters

Preliminary efforts in parameter development focused on evaluating and optimizing powder raw material. Powders from three manufacturers were obtained. Two high-purity 99.99% Cu powders (A and B) were atomized in argon, while a third low-purity 99.8% Cu

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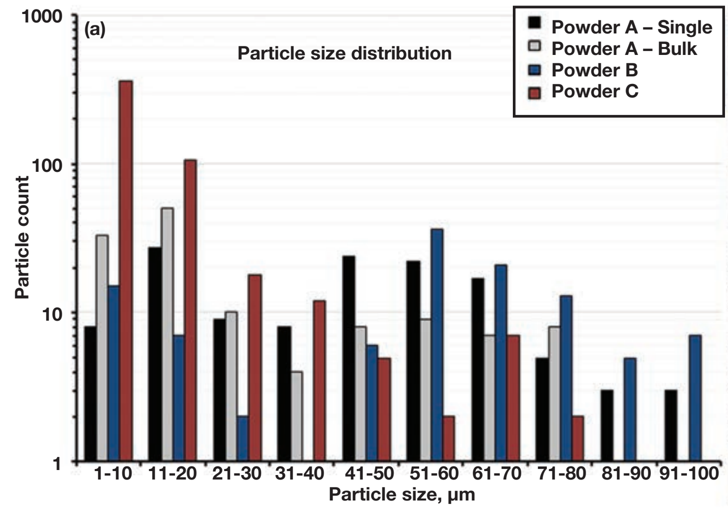

(b)

	Apparent Density (g/cm³)	Volumetric Flow Rate (cm³/s)
Powder A	4.05	0.599
Powder B	5.80	0.704
Powder C	4.65	0.699

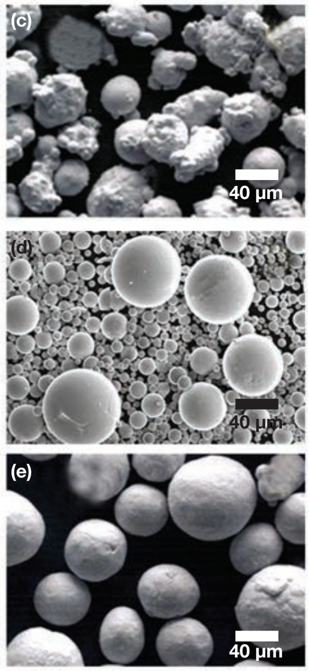

Fig. 1 — *Measurements of particle size distribution for each powder type (1a). Table defines average apparent density and average volumetric flow time (1b). Micrographs show shapes of three different powder types—powder A (1c), powder B (1d), and powder C (1e).*

powder (C) was atomized in air. Particle morphology and size distribution are important considerations in developing EBM process parameters. Figure 1a shows two distributions for powder A—one separating the satellite particles from the distribution measurement, and one including them in the overall particle diameter. Powder B has a skewed distribution with small particles, while powder C shows a bimodal distribution with an average size of roughly 55 µm. Particles that are too large are not deposited by the raking system, while those that are too small may be charged and scattered by the beam and may also require special handling and storage considerations. The relative packing density, as well as the contact area between particles, can have a significant influence on flowability, thermal conductivity, and melt pool liquid flow. Apparent density and volumetric flow rate of the three high-purity copper powder types, shown in Fig. 1b, were analyzed according to ASTM standards B703-10 and B855-06, respectively[14,15]. An Arnold meter consistently measured equal volumes of powder. Flow time (in seconds) of the sample was then measured using a calibrated Hall flowmeter.

Subsequent microscopic analysis explains some of the differences in flow times and apparent densities for the different powders. Powder A particles, shown in Fig. 1c, are irregularly shaped and exhibit a higher flow time than powder B and C particles, which are nearly spherical. For particles of relatively equal size, improved flow tends to come at the cost of reduced packing. For all powder types, another cause of poor flow characteristics involves small satellite particles attached to the surface of larger ones.

Microstructural and elemental powder analysis

All powder samples were mounted, ground, polished (0.03 µm alumina), and etched using a solution of 100 mL water, 8 mL sulfuric acid, 4 mL sodium chloride, and 2 g potassium perchlorate. For imaging, a Reichart MF4 A/M optical metallograph with digital image converter was used. Polished and etched samples were also observed in a Hitachi H-8500 field emission SEM. Residual Vickers microindentation hardness values were measured in a Struers Doramin A-300 digital test station.

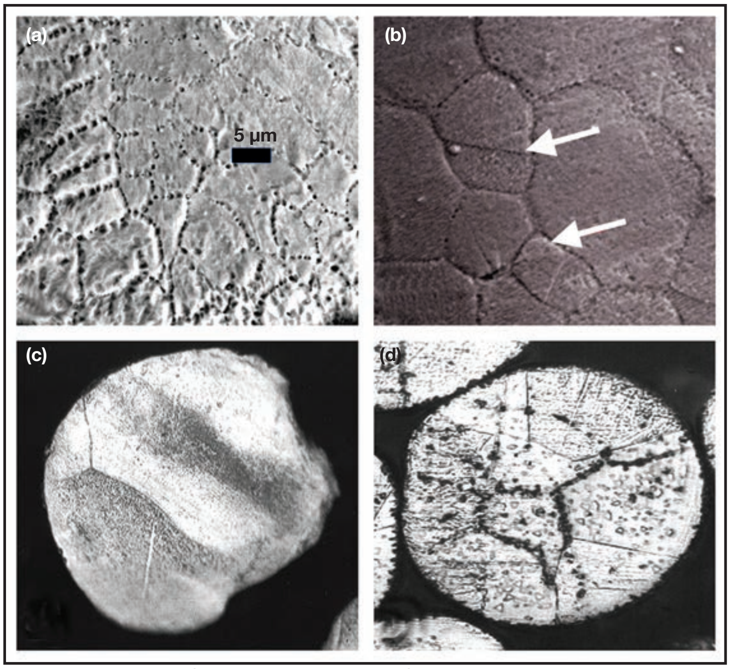

Fig. 2 — *Magnified SEM image of powder C section showing high concentration of oxides at the grain boundaries (a), and powder B section showing some oxides at the grain boundaries indicated by arrows (b). Optical microscopy views of embedded, polished, and etched Cu particles of powder B, new (c) and used after several EBM build cycles (d), showing a nearly equiaxed grain structure with increased oxygen in the grain boundaries.*

Oxygen content in the powder plays a significant role in the EBM process. The three powders were analyzed for oxides and it was found that powders A and C had the greatest concentration due to the manufacturing processes used. Figure 2a shows an SEM image of a cross-section for a powder C particle with small equiaxed grains with no-

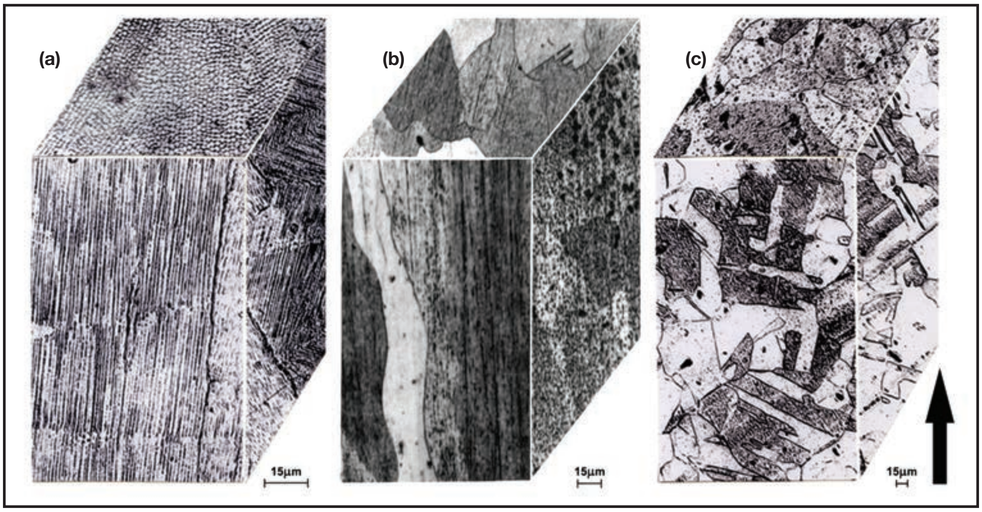

Fig. 3 — *3D construction shows EBM-built Cu components from a mixture of 99.80% Cu powder C and a prior, high oxide powder A (a); 99.99% Cu powder B (b); and 99.99% Cu powder B built at elevated temperature (c). Arrow denotes build direction.*

TABLE 1 — SUMMARY OF MEASURED EBM FABRICATED COPPER MATERIAL PROPERTIES

	EBM Ti6Al4V*	Wrought Ti6Al4V (ASTM F1472)	EBM Copper	Wrought C10100 Copper
Density	>99.9%	—	8.84 g/cm^3	8.90 g/cm^3
Electrical conductivity @ 20°C	—	—	97% IACS	102% IACS
Thermal conductivity	—	—	390 W/m*K	391 W/m*K
Yield strength (Rp 0.2)	950 MPa	860 MPa	76 MPa	69 MPa

Summary of measured EBM-fabricated copper material properties compared to wrought copper and the Arcam-developed titanium alloy.
**Arcam Ti6Al4V Material Data Sheet, (www.arcam.com/CommonResources/Files/www.arcam.com/Documents/EBM%20Materials/Arcam-Ti6Al4V-Titanium-Alloy.pdf)*

table oxide (Cu_2O) in the grain boundaries and a corresponding SEM image for 99.99% Cu powder B (Fig. 2b) with a lower density of grain boundary oxides (arrows). While the atomization and rapid solidification of the powder manufacturing process itself incorporates various oxide concentrations, residual oxygen and water vapor in the EBM system is also absorbed in the unconsolidated powder during processing. This feature is shown in Figs. 2c and 2d, which compare optical metallographic cross-section views for the initial (precursor) powder B and used powder particles, showing recognizably increased oxides at the grain boundaries.

Evident from these figures is that the powder parameters (especially the oxide or oxygen content), combined with the EBM build parameters, must be carefully considered in order to fabricate products with desirable properties, particularly high electrical conductivity.

EBM processing of copper samples

Powder A was selected for further study. Although this powder exhibited relatively poor raking characteristics due to its irregular shape, its significantly lower cost made it an attractive candidate for EBM parameter development. EBM parameters were assigned to each cylinder based on a previous feasibility study[5] designed to provide a starting point for subsequent parameter optimization. The EBM process was operated in automatic mode, in which parameters such as beam current and speed are calculated for each layer and adjust with changes in part geometry to maintain a stable process. The desired surface temperature is specified and a "speed function" is selected.

Both substrate starting temperature and desired surface temperature are critical for the build, as over-melting or over-sintering makes powder recovery difficult or impossible. These temperatures also affect surface quality, porosity, and microstructure. The speed function is a parameter that adjusts beam rate during hatching, with higher values resulting in higher beam speeds. Other adjusted parameters include hatch spacing and contours functions. An experiment was designed where 24 cylinders in six builds were fabricated with 24 different sets of process parameters. The goal was to find a set of process parameters to produce fully dense copper cylinders with an acceptable surface finish and desired microstructure.

Early experiments resulted in cylinders with severe delamination, hypothesized to be caused by a significant thermal gradient within each layer. The high thermal conductivity of the copper powder (particularly after sintering/melting) was suspected to be the cause. To balance heat transfer throughout the build area, three stainless steel plates (210 × 210 × 10 mm) were installed under the copper start plate. After analyzing all specimens, a parameter set was developed to consistently produce acceptable parts. From this theme, samples were prepared for examination of metallurgical, mechanical, thermal, and electrical properties. Finally, prototypes of the RF photoinjector were fabricated for field testing.

Sample evaluation

Figure 3 shows corresponding and comparative 3D optical metallographic image composites illustrating oxide influenced, directionally solidified microstructures or microstructural architectures. In Fig. 3a, using a mixture of the high-oxide containing powder C and powder A, EBM processing produces columnar oxide architectures oriented in the build direction (arrow). In contrast, Fig. 3b shows columnar grain structures intermixed with columnar oxides when the high-purity powder B was employed. In Fig. 3c, powder B was again used to build a smaller com-

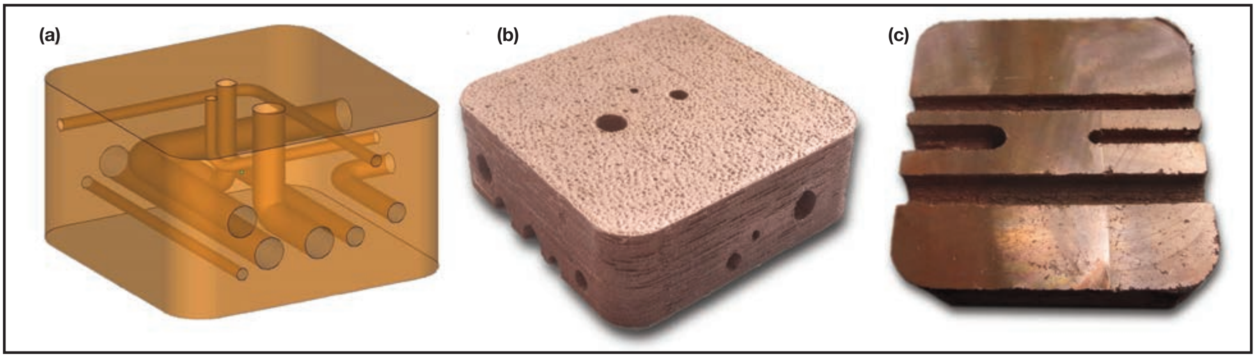

Fig. 4 — *3D CAD model of the cooling channel test block shows internal cooling channel geometry (a); photographs of the sectioned EBM-fabricated test blocks show cooling channels of 1.5, 4, and 7 mm in diameter (b and c).*

ponent than in Fig. 3b and the part temperature was considerably higher, producing a component with a more conventional Cu equiaxed grain structure containing coherent annealing twins. This structure does not show any directionally solidified microstructure.

Table 1 shows initial testing results of the physical properties. Bulk thermal conductivity (W/m*k) measurements were recorded at ambient conditions using the ThermTest TPS 2500S thermal constants analyzer (ISO/DIS 22007-2.2). Electrical conductivity (% IACS), also carried out in ambient conditions, was measured with a Verimet Eddy current conductivity meter. Tensile testing was carried out on ASTM E8 subsize specimens fabricated in the *XYZ* and *XZY* orientations per ASTM F2921.

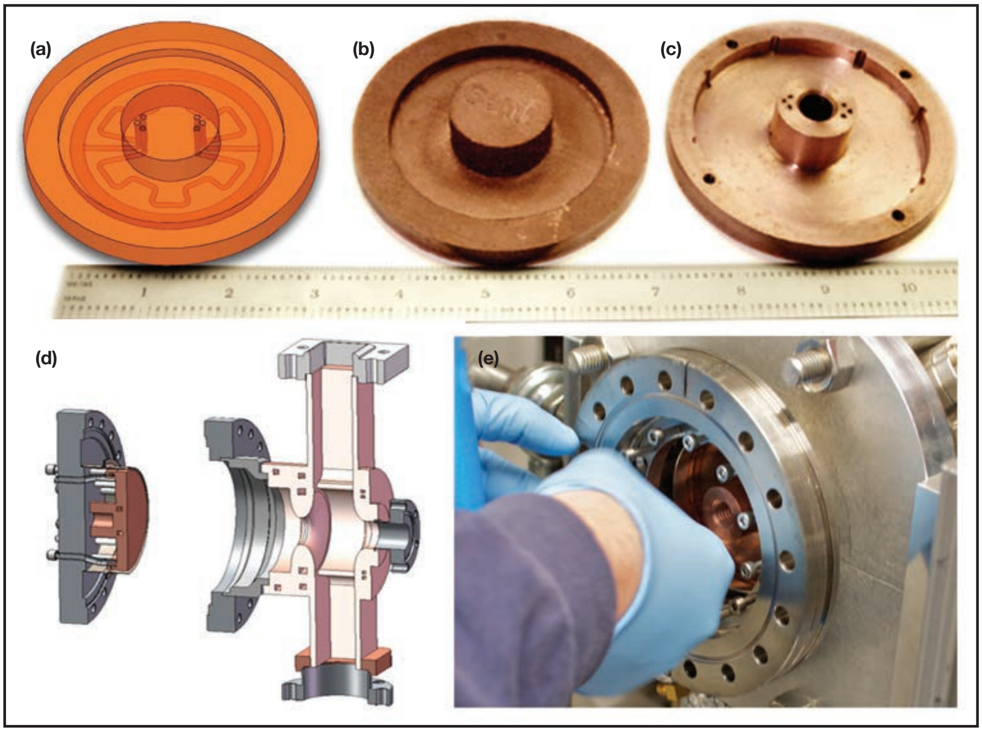

Fig. 5 — *CAD rendering shows internal cooling channels of proposed EBM fabricated cathode offered as a standard drop-in replacement by RadiaBeam (a); photograph of the cathode blank in the as-EBM condition (b), and after final machining (c); CAD rendering of the RadiaBeam prototype freeform cathode and freeform photoinjector (d); and installation in the UCLA Pegasus 1.6 cell Photoinjector (e).*

Prototype fabrication and field testing

The final step in this feasibility study was to demonstrate the ability to fabricate a complex geometry that incorporates internal cooling channels. The block shown in Fig. 4 was fabricated with three different channel sizes running straight through the part in three orthogonal directions that curve through the part with 90° elbows. This design also demonstrates the ability to clean sintered powder from internal cooling channels.

Cathode high power RF testing

In order to verify RF performance of the EBM copper, a copper cathode suitable for testing in the UCLA Pegasus 1.6 cell photoinjector also was fabricated using the process parameter sets developed during initial experiments. An example is shown in Fig. 5. Figure 5 also shows the cathode in the as-EBM condition, after final machining, and being installed in the Pegasus photoinjector (Fig. 5e). No other heat treatment was carried out on the EBM cathode prior to final machining.

The EBM copper cathode performed as well as other cathodes conventionally machined from wrought oxygen-free (OFE) copper material during high power RF testing. Stable operation with 70 MV/m peak electric fields on the cathode was achieved after two hours of RF conditioning. A photoelectron beam with energy of 3.3 MeV and charge of 60 pC was measured, along with a cathode quantum efficiency of ~$2x10^{-5}$. These numbers are consistent (given the operating gradient) with conventional OFE copper cathodes measured in the past at the Pegasus Laboratory.

Conclusions

Although the high thermal conductivity of copper presents challenges for direct AM processes, fully dense copper components with complex geometries were demonstrated. Of particular interest is the ability to fabricate internal cooling channels and mesh structures to optimize thermal management. In addition to EBM processing parameters, oxidation of the copper powder was found to hinder the ability to make completely successful parts. Higher vacuum and care in the reuse of powder is a critical concern because high oxygen or dense oxide content produces columnar oxide architectures, which may significantly affect both thermal and electrical conductivity. ❍

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ASM Materials Education Foundation

2013 ANNUAL REPORT

Mission:
To excite young people in materials, science, and engineering careers.

"I am 16 and I am the oldest child from a family of six. I have given much thought to what I want to do in the future. I enjoy science very much and have been exploring possible majors I might enjoy. When I first applied to the Eisenman Camp, I had never considered a career in materials science. This week has given me so much insight into the careers in the materials world. I would like to thank you for allowing me to partake in such an eye-opening experience. Your generosity has given me the chance to further my investigation into my future and for that I am extremely grateful."

Alison Haas
2013 Eisenman Materials Camp student
Clarkston High School

LETTER FROM THE DIRECTOR

I am pleased to share with you the annual report for fiscal year 2013. We have put together a few of ASM Materials Education Foundation's key achievements from 2013 to highlight how your donations made a difference in the lives of students and teachers who were impacted through our Materials Camps and scholarships.

I encourage you to visit asmfoundation.org where you will find an audited financial statement and donor list for fiscal year 2013. I also encourage you to stay up-to-date with our achievements by reading our quarterly e-newsletter.

I am excited about what 2014 and beyond has in store and hope that you share in my excitement!

Thank you for your continued support and generosity.

Nichol Campana
Director of Development and Operations

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"Thank you for a fantastic week at the ASM Eisenman Camp! I truly learned a lot of information and loved using all the equipment and technology. I'm even considering becoming a junior mentor in the future because of the impact this amazing camp had on me. I'll never forget any of the friends or amazing people I met at this camp and I just wanted to say thank you to everyone for making this possible!"

Thomas Holtslander
2013 Eisenman Materials Camp student
WT Woodson High School

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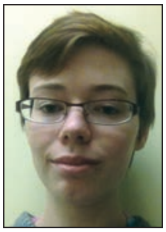
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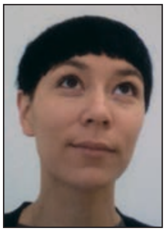
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2013 National Merit Scholar Liani Lye

Liani will graduate from California Academy of Math & Science, Carson, Calif., this year. She was selected based upon her outstanding academic achievements, the diversity of her activities, and her interest in pursuing a career in materials engineering.

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Bringing materials outreach to future engineers and scientists.

The City of Materials website (cityofmaterials.com) is an interactive environment where students of all ages can experience how Materials Science and Engineering impacts their daily lives. Explore the city on a "virtual city tour" or head to the Science Center and learn about types of materials. You can also access "Materials Radio" and discover more about the world of materials!

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Girls Living in a Material World: How to Redesign for Life Skills
Rhonda Owens, Dickson BOE, Tenn. (Grades 6-12)

White Powder Lab, Alessandro La Gamba
St. Cecilia Catholic School, Ontario, Canada (Grades 1-8)

Using Ultrasonics to Study Engineered Materials
Maurice Stephenson, Venice High School, Calif. (Grades 9-12)

Crystal System, Denis Kogan
The Brooklyn School for Career Development 753K, N.Y. (Grades 9-12)

Junkyard Robots, Vicki Joule
Alliance High School, Neb. (Grades 10-12)

Little Cars, Sondra Lawson
Jimmy Carter Middle School, N.M. (Grade 8)

Building Efficiency
Nathan Moore, Santa Fe School for the Arts & Sciences, N.M. (Grades 7-8)

Whatever Floats Your Boat
Valencia Greenwood, Bingman Head Start, Texas (Preschool 3-4)

500 AWARDS SCIENCE & ENGINEERING FAIRS

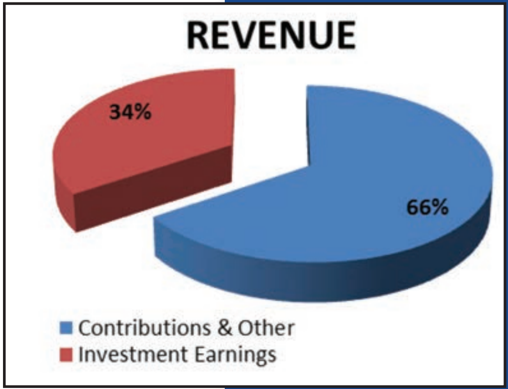
ASM Foundation in partnership with Intel has participated since 2001 presenting one "Most Outstanding Exhibit in Materials Science" award at approximately 500 regional science & engineering fairs throughout the world.

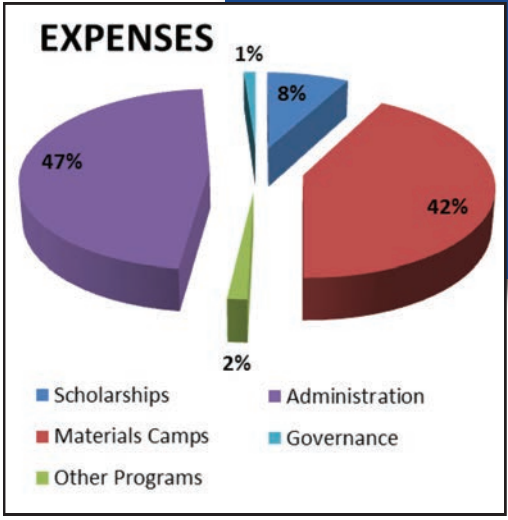
2013 INCOME AND EXPENSES

Revenue		
Contributions & Other	$706,670	66%
Investment Earnings	$370,430	34%
	$1,077,100	**100%**

Expenses		
Scholarships	$102,777	8%
Materials Camps	$548,258	42%
Other Programs	$19,198	2%
Administration	$606,750	47%
Governance	$14,555	1%
	$1,291,538	**100%**

Audited Financials (prepared 6/16/2014)





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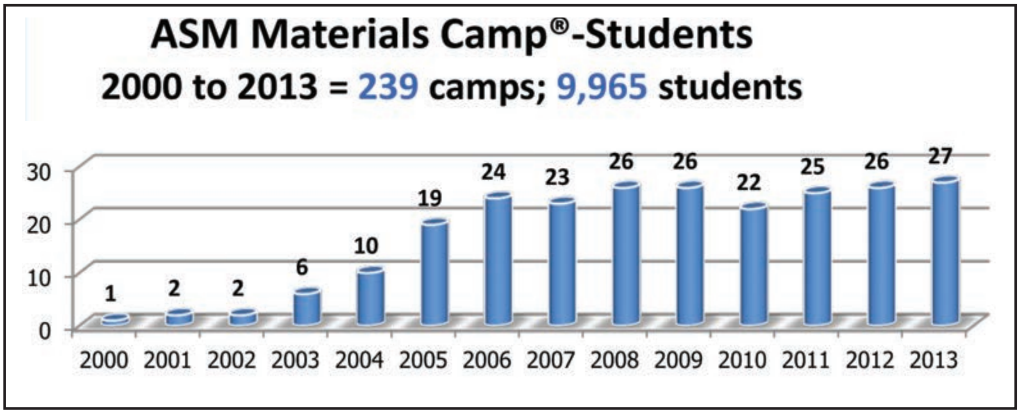
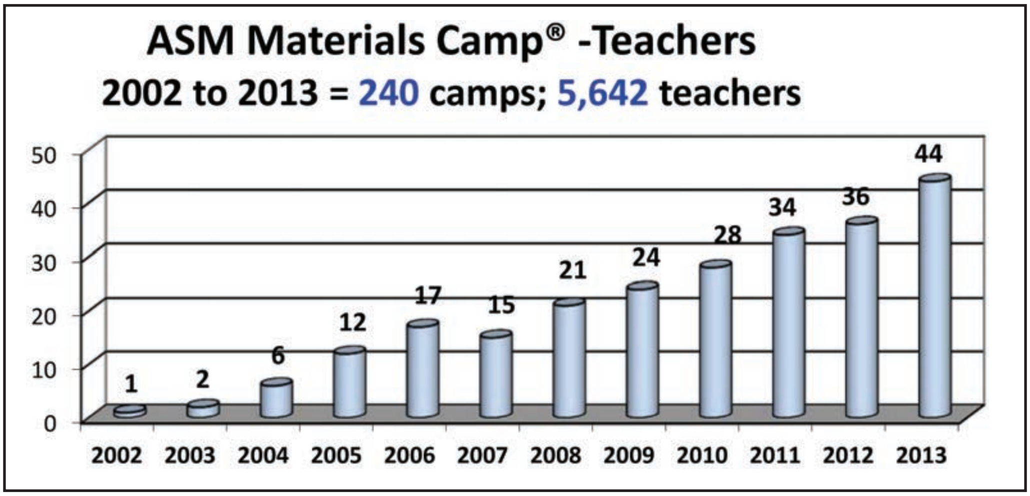


NACE INTERNATIONAL FOUNDATION

2013 NACE cKIT PROGRAM

NACE cKit with tools and supplies includes a 4-hour hands-on learning activity provided to all teachers attending ASM Materials Camp.



"We have worked with metals, polymers, glass, and other materials and it has been so much fun you don't realize you are actually learning a great deal. One of the really cool aspects is that the projects we are taught can be done fairly quickly. So the students can start and then see the end result in the same class time."

Becky Howard
2013 Meridian, Miss. Materials Camp – Teachers
Marion Park Alternative

2013 KISHOR M. KULKARNI HIGH SCHOOL TEACHER OF THE YEAR
Caryn Jackson
Tolles Career and Technical Center in Plain City, Ohio

Caryn Jackson teaches science at Tolles Career and Technical Center in Plain City, Ohio. Her students are generally not on a career path that involves a college degree. Instead, Tolles, like most career centers, is focused on preparing its students for immediate careers. It initially took Jackson a couple of years to convince her administration to allow her to teach materials science at her school. She prevailed and has now been successfully teaching materials science in her building for about four years.

"Mrs. Jackson's ability to move students toward a genuine interest in materials education is one I have rarely seen and is as natural to her as breathing. One will often find Mrs. Jackson in the cafeteria or in the library tutoring students who are struggling. In her classroom, she conducts labs so that all students are able to participate and truly understand the concepts of materials. On a humorous note, I never know what lab materials she will carry in each morning. Her arms are always full as she walks to her classroom to prepare for labs. Some days I will ask, but I better be prepared for an extensive answer about everything students are about to learn that day! Our district has now gone from offering two-semester sessions of Materials Science to seven full-year sessions in just three years. Students are excited, engaged, and they are telling their friends, 'Science is FUN!'"

Tonya N. Ramey
Academic/Assessment Supervisor
Tolles Career & Technical Center

2013 ASM FOUNDATION PACESETTER AWARD

Thermal Spray Technologies Inc. (TST), is committed to enhancing the knowledge and expertise of materials engineering among teachers and young people. TST supports educational opportunities throughout the year, encouraging future leaders to understand and pursue careers in materials science and engineering. TST's collaboration with ASM Materials Education Foundation has enabled educators to team up and appreciate the opportunities that lie within the materials science and engineering industry. ASM's materials camps have a strong impact on teachers and help them develop upcoming professionals in materials science and engineering; it is truly one of ASM's most impressive programs. TST is honored to support such an effective educational program.

TST THERMAL SPRAY TECHNOLOGIES INC.

2013 GEORGE A. ROBERTS AWARD

Dr. Donald R. Muzyka is retired President and CEO, Special Metals Corp., New Hartford, N.Y. He has been active in ASM since joining in 1963 and was elected a Fellow in 1977. He has been involved in many Chapter activities and was Chairman of the Lehigh Valley Chapter in 1976-1977. He served on many ASM committees including the Diamond Decade, Awards Policy, Nominating, Finance, and Investment. He was a Trustee in 1982-84. He was President of ASM in 2003, served as VP in 2002, and Past President in 2004. Muzyka joined the Board of the ASM Materials Foundation in 2000 and has served as a Trustee. He was Treasurer from 2004 to 2010.

The duties of a Foundation Board Member include working with students, raising money and "running the business." Muzyka has been involved with all three. In particular, since he retired in 2000, he has been active in assuring that the ASM/Lehigh Univ. Student and Teacher Materials Camps have sufficient funding. He tries to inspire the students into studying materials through a presentation at the closing of each Student Camp at Lehigh. He has also been successful in encouraging several individuals, companies, and Foundations to volunteer at and/or financially support ASM Materials Camps.

Muzyka earned his B.S. in Mechanical Engineering from the Univ. of Mass. in 1960. He received his M.S. in Metallurgy from RPI in 1966 and his Ph.D. in Materials Science from Dartmouth in 1967. He devoted his entire career, spanning more than 40 years, to the specialty metals industry, starting as a metallurgist at Pratt & Whitney Aircraft in 1960. After completing his graduate studies in 1966, he joined Carpenter Technology where he was appointed Vice President Technical in1979. In 1982, he joined Cabot Corp. where he became manager of Cabot Refractory Metals. He completed his career at Cabot as VP Corporate R&D. Muzyka joined Special Metals as President in 1990; he became President and CEO after taking the company public in 1996. He retired on September 1, 2000.

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Course	Date	Location
Corrosion	9/8-11	ASM World Headquarters
Vacuum Heat Treating	9/9-10	ASM World Headquarters
Oilfield Metallurgy	9/9-11	ASM World Headquarters
How to Organize and Run a Failure Investigation	9/15-16	Hilton Garden Inn Irvine East / Lake Forest Foothill Ranch, CA, USA
Scanning Electron Microscopy	9/15-18	IMR Test Labs Lansing, NY, USA
Principles of Failure Analysis (3-day)	9/17-19	Hilton Garden Inn Irvine East / Lake Forest Foothill Ranch, CA, USA
Heat Treatment, Microstructure & Performance of Carbon & Steel Alloys	9/22-24	ASM World Headquarters
Metallographic Techniques	9/22-25	ASM World Headquarters
Advanced Metallographic Techniques	9/29-10/2	ASM World Headquarters
Introduction to Thermal Spray	10/6-7	ASM World Headquarters
Super Alloys	10/6-8	ASM World Headquarters
Practical Interpretation of Microstructures	10/6-9	ASM World Headquarters
Thermal Spray for Gas and Oil Industries	10/8	ASM World Headquarters
Practical Fracture Mechanics	10/20-21	IMR Test Labs Lansing, NY, USA
Metallurgy for the Non-Metallurgist	10/20-23	ASM World Headquarters
Applied Techniques in Failure Analysis	10/20-23	ASM World Headquarters
Practical Fractography	10/22-23	ASM World Headquarters

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ASM INTERNATIONAL

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Metallurgy Lane

The History of Alloy Steels: Part I

The widespread use of alloy steels beginning in the early 1900s spurred the need to acquire and share information about heat treating, which previously had been a guarded art.

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

Carbon is the single most potent element added to iron, even though it is not thought of as an *alloy* because the word "steel" is defined as carbon in iron. Amounts as small as 0.05% have profound effects on the behavior of iron, and 0.15 to 0.25% additions are sufficient to make mild structural steel. Most heat treated alloy steels contain 0.30 to 0.40% C. Carbon has two characteristics that account for its powerful effects from such small amounts: It is very low in density, so therefore a great number of atoms are present in small amounts (by weight), and its atoms are smaller than iron atoms, so they do not substitute for iron in the crystal lattice, but take up a unique position in the holes between the iron atoms. It is this interstitial position of carbon atoms in the iron lattice—along with the crystal lattice transformation from face centered cubic (fcc) to body centered cubic (bcc) on cooling—that makes steel such a marvelous material for construction, power transmission, and tools in the modern era.

The first alloy steel contained chromium and was patented in 1865 by American metallurgist Julius Baur and manufactured by the Chrome Steel Co. of Brooklyn, N.Y. This alloy steel was never successful, but the publicity prompted an interest in chromium alloy steels by French metallurgist Henri-Ami Brustlein. He soon learned that to alloy chromium with steel, the chromium ore needed to be refined to produce a master alloy of iron-chromium-carbon. This master alloy would readily dissolve into the melt of the crucible process, otherwise the recovery of chromium would be too erratic to control the alloy content. Brustlein produced and sold chromium alloy steels for tools, cannon shells, and armor plate over a period of about 15 to 20 years before anyone else entered the field. For his work in developing alloy steel and related heat treatments and applications, Brustlein deserves to be called the Father of Alloy Steels.

The first use of alloy steel in the U.S. was for the axle of the famous Ferris Wheel at the 1893 Chicago World's Fair. Courtesy of Library of Congress.

Nickel steel development

While Brustlein was developing chromium steels, other French metallurgists were learning to smelt nickel-containing ore from New Caledonia, a French territory in the South Pacific. The resulting ferronickel was then used to add nickel to steel. The production of nickel steel was observed in France in 1888 by James Riley, an Englishman who made arrangements for similar steels to be made at The Steel Company of Scotland in 1889. He immediately tested these steels and reported their properties in the *Journal of the Iron and Steel Institute.* One of his steels containing roughly 0.2% C and 5% Ni developed strength properties of considerable interest for many different structural and machine applications. This steel, processed by rolling and annealing, was about 40% stronger than similar steel without nickel.

The first alloy steel employed in regular industrial production in the U.S. was 5% nickel steel, used for bicycle chains (1898), followed the next year by bicycle tubing. The first use of alloy steel in the emerging automotive industry was a 5% nickel steel axle by Haynes and Apperson. Somewhat later, nickel steels (3.5%) became popular for the structural components of large bridges, including the Manhattan and Queensboro Bridges in New York City. In 1900, about 3000 tons of alloy steel were produced in the U.S.

Shortly after nickel steels came into use, more complex alloy steels containing both chromium and nickel were being tested by Krupp in Germany and by the Compagnie des Forges de la Marine in France. These nickel-chromium steels could be hardened in large sections by heat treating so they became very popular for armor and large forgings. After the turn of the century, the straight nickel steels rapidly declined in use in favor of the nickel-chromium steels and the newly developed chromium-vanadium steels.

Queensboro Bridge made of nickel steel, New York City, circa 1908. Courtesy of Library of Congress.

Henry Louis Le Chatelier of France developed high-temperature platinum-platinum/rhodium thermocouples, useful for measuring critical temperatures in steel.

Henry Clifton Sorby of England, an early pioneer of metallography. Courtesy of University of Sheffield.

Automobiles usher in alloy steel era

It was the automobile that initiated the Age of Alloy Steel. The number of alloy steels used in the auto industry increased throughout the decade of 1910-1920. Walter Jominy, a metallurgist from the University of Michigan who worked for the Studebaker Automobile Co., published a list of 12 alloy steels in 1920 that he said filled all the needs for building automobiles.

World War I provided additional emphasis on the use of alloy steels and on the process of heat treatment. The quantity of alloy steel made in the U.S. reached more than 1 million tons in 1918, and the widespread use of alloy steel increased the need to both acquire and share information about heat treating, which previously had been a guarded art. William Park Woodside, a former blacksmith, began holding meetings in Detroit to exchange information among heat treaters in the early auto industry. These meetings lead to the formation of a formal group called the Steel Treaters Club, which eventually became the American Society for Steel Treating.

These early groups formed chapters in various industrial regions across the country and published data sheets on the technical aspects of heat treating. Soon they provided a publication called *Transactions* for serious researchers to publish their papers. In 1930, the American Society for Steel Treating published a magazine called *Metal Progress* (now *Advanced Materials & Processes*). It became the most popular source of information in all of metalworking, not just heat treating. The society changed its name in the early 1930s to the American Society for Metals and later to ASM International.

Bicycles at the turn of the century used 5% nickel steel in their chains, the first widespread industrial use of an alloy steel. Courtesy of State Library of Queensland.

The early science of steel

The first interest in examining the nature of steel came just after the midpoint of the 19th century. Henry Clifton Sorby of Sheffield, England, examined polished and etched surfaces of meteorites and several commercial steels during 1863-1866. Sorby discovered that the microstructure of steel was complex and he found an area that he called "pearly." Later, Floris Osmond of France and Adolf Martens of Germany published their examination of polished and etched surfaces of steel in the *Journal of the Iron and Steel Institute* of Great Britain. Their work reawakened Sorby's interest in an area he had worked on more than 20 years earlier. Sorby immediately began a new examination of the microstructure of steels. He published his work in the British *Journal of the Iron and Steel Institute* in 1887. This new work by Sorby, along with that of Osmond and Martens, is considered the true beginning of the field of metallography, the study of the internal structure of metals. From this point forward, the ever increasing research into how the behavior of metals relates to their structure has been the foundation of our modern technological age.

A second major development at this time was a new measuring tool for high temperatures invented by Henry Louis Le Chatelier of France, which used platinum-platinum/rhodium thermocouples. Osmond immediately put the new thermocouple to use in measuring the so called *critical temperatures* in steel. These temperatures—where changes were noted in the rates of cooling or heating—were first pointed out by Russian metallurgist D.K. Tchernoff. He stated that steel could not be hardened upon quenching until it was first heated above the uppermost critical temperature. These temperatures were believed to represent important internal changes in steel. The study of critical temperatures as a function of a steel's carbon content lead to the field of binary phase diagrams, which was the next advance in understanding the complexity of steel.

For more information: Charles R. Simcoe can be reached at crsimcoe@yahoo.com. For more metallurgical history, visit metals-history.blogspot.com.


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MS&T 2014 Lecturers Announced

Continuing the grand tradition of ASM International events, three distinguished lecturers will speak at the 2014 Materials Science & Technology Conference and Exhibition (MS&T14) to be held October 12-16 at the David L. Lawrence Convention Center in Pittsburgh. MS&T brings together the strengths of four major materials organizations: ASM International, The American Ceramic Society (ACerS), The Association for Iron & Steel Technology (AIST), and The Minerals, Metals & Materials Society (TMS).

2014 ASM/TMS Distinguished Lectureship in Materials and Society
Monday, October 13, 1:00 – 2:00 p.m.

Robert E. Schafrik, Ph.D., FASM
General Manager, GE Aviation (retired)
Materials for a Non-Steady State World

Since antiquity, human society has greatly benefited from advancements in materials, and expectations for continued improvements are a cornerstone of societal progress in the modern world. Expectations for successful introduction of new products continue to rise nonlinearly—implementation of the appropriate material solution is the key to success. This presents great challenges to the materials community. The top challenges include: increasing the speed of development, high reliability of the end product, exceeding expectation in product performance, and attractive value proposition for the end user. These challenges are being addressed by the aero engine community. The successful algorithm, from a materials viewpoint, has three key elements: forward-looking materials strategy, development guided by senior design engineers, and partnership with the supply chain. A critical constituent of each element is nurturing the materials team to incorporate vision and creativity with expert knowledge of materials science and engineering. This presentation will discuss these elements with examples of how it was successfully, and less than successfully, employed. It will conclude with go-forward challenges that will facilitate further advancements in materials contributions to society.


Schafrik


McLean


Robertson

2014 Alpha Sigma Mu
Monday, October 13, 2:30 – 4:00 p.m.

Prof. Alexander McLean, FASM
Professor Emeritus, University of Toronto
The Development of Materials: Signals from the Past—Guidance for the Future

In the quest for novel processing technologies and the development of new materials, there are several synergistic triumvirates that provide a foundation for progress. These include the generation, validation, and application of knowledge; innovative studies involving measurements, models, and manufacturing; and collaborative interdisciplinary endeavors between academia, industry, and government agencies. In the final analysis, successful developments depend on recognition of the premise that high quality products require high quality processing and both depend on the availability of high quality people. In this presentation, these concepts are illustrated with examples drawn from historical figures and events including Plato, the Battle of Trafalgar, Lord Kelvin, and Alexander Graham Bell. Through this fabric of history runs the vital thread of communication, a thread that provides a lamp for the future and light along the path called progress.

2014 Edward DeMille Campbell Memorial Lecture
Tuesday, October 14, 12:45 – 1:45 p.m.

Dr. Ian M. Robertson, FASM
Dean, College of Engineering, University of Wisconsin
Hydrogen Embrittlement Understood

Hydrogen embrittlement is ubiquitous, occurring in all but a handful of metals. Although the phenomenon is well documented, the root cause of hydrogen embrittlement at the fundamental level remains poorly understood. The primary candidate mechanisms in non-hydride forming systems are decohesion, which results from hydrogen reducing the cohesive strength

...in this issue

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of the lattice; and hydrogen-enhanced localized plasticity, in which hydrogen attached to the dislocation shields its interaction with other elastic obstacles. The latter mechanism is supported directly by experiment, but the connection between hydrogen enhancing the velocity of dislocations and hydrogen-induced failure has remained tenuous.

Recent advances in experimental tools are providing new opportunities to discover the fundamental processes responsible for hydrogen-induced failure. Using these new tools, it has been found that hydrogen accelerates the evolution of the microstructure and stabilizes it in unanticipated states. Based on these observations, it is proposed that hydrogen accelerates the evolution of the dislocation microstructure by the hydrogen-enhanced plasticity mechanism, which work hardens the matrix to an unexpected degree at low strains and stresses and it redistributes the hydrogen to regions of greatest dislocation activity. It will be demonstrated that these two consequences dictate the fracture mode and the fracture path. These observations suggest a possible metallurgical solution to producing alloys with a higher tolerance to hydrogen.

2013 ASM Historical Landmarks—Dedication Ceremonies

Joining a list that includes iconic structures such as the Statue of Liberty and the Eiffel Tower—the Department of Energy's Savannah River Site, Weber Metals, and Alcoa Cleveland Works have officially been dedicated as Historical Landmarks by ASM International.

Savannah River Site

Designation of the Savannah River Site (SRS) occurred on May 13, in Aiken, S.C., with the presentation of a historical plaque by Prof. C. Ravi Ravindran, president of ASM International. Ravindran noted that the award recognized SRS "for advancing the materials technologies necessary to produce tritium, plutonium, and other isotopes for national defense, research, and medical applications."

Savannah River National Laboratory director, Dr. Terry Michalske, joined Ravindran at the presentation, acknowledging that the designation validated the work of people who contributed to decades of research, development, and execution. "This is really a tribute to the can-do spirit of a lot of people who looked at things and said 'we can do that,'" explains Michalske. "That's as true today as it's ever been, and it's a fitting recognition for the quality of work that's been done here."

The plaque will be permanently placed near the former M Area facilities, where fuel and target assemblies were once produced for the site's production reactors.

ASM President C. Ravi Ravindran (left) presents the ASM Historical Landmark plaque to executive vice president and director of SRNL, Terry Michalske.

Weber Metals

Dr. Alton D. Romig Jr., FASM, vice president and general manager at Lockheed Martin and a past president of ASM (left), congratulates Weber Metals president and CEO Rick Creed after presenting the company with a Historic Landmark plaque in front of Weber's 38,000-ton hydraulic forging press, which was declared an ASM Historical Landmark in Paramount, Calif., on April 16. The event was attended by Weber leadership, officials from Weber's parent company Otto Fuchs Metallwerke, and citizens of Paramount.

Alcoa Cleveland Works

Alcoa Cleveland Works' 50,000-ton hydraulic press received designation as an ASM Historical Landmark by ASM International and the Forging Industry Association at a dedication ceremony on May 9 before more than 100 employees and 20 industry guests. The ceremony was attended by several ASM past trustees and members of the Cleveland Chapter, as well as Dr. Sunniva Collins, ASM vice president.

Michael A. Kinney, manufacturing director of Alcoa Forgings and Extrusions (left), and Dr. Sunniva Collins, FASM, ASM vice president, unveil the Alcoa plaque.

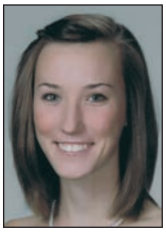
Nominations are currently being accepted for the 2015 Historical Landmark Award until February 1, 2015.

Official ASM Annual Business Meeting Notice

The Annual Business Meeting of members of ASM International will be held in conjunction with MS&T14 on:
Monday, October 13
4:00 – 5:00 p.m.
David L. Lawrence Convention Center, Pittsburgh
The purpose of the ASM Annual Business Meeting is the election of officers for the 2014-15 term and transaction of other society business.

Student Board Members for 2014-2015 Announced

The ASM Board of Trustees values the insights, ideas, and participation of Material Advantage students. The Student Board Member program provides the opportunity to attend four Board Meetings where the students will meet and work with leading technical professionals and gain leadership skills that will benefit them throughout their career. The next deadline for submissions is **April 15, 2015.** Details can be found on the ASM website.



Virginia K. Judge
Colorado School of Mines

Ginny Judge is a recent graduate of the Colorado School of Mines (CSM) located in Golden. This fall, she will begin her graduate career with the Advanced Steel Processing and Products Research Center at CSM in pursuit of a master's degree in metallurgical and materials engineering. She began her undergraduate career interested in biomaterials, however as she delved deeper into her studies she became more interested in steel and physical metallurgy. With this new focus and a love for the academic environment, Ginny decided to continue her education with CSM. Throughout her collegiate career, she has enjoyed being an active member of ASM and is excited to serve as a Student Board Member on the national level.

Anthony Lombardi
Ryerson University

Anthony Lombardi is a third year Ph.D. candidate in mechanical engineering at Ryerson University, Toronto, under the supervision of Prof. C. (Ravi) Ravindran. He is the recipient of the prestigious NSERC Alexander Graham Bell Canada Graduate Scholarship - Doctoral (CGS-D). He also received the NSERC Michael Smith Foreign Study Supplement and used it towards his four-month research at the Indian Institute of Technology – Madras. Lombardi's research explores optimization of heat treatment parameters to improve mechanical properties and minimize tensile residual stress, thereby eliminating potential in-service cylinder distortion in aluminum engine blocks. He aspires to be a professor of advanced materials, specifically in the development of light alloys for automotive components and the optimization of manufacturing processes such as casting, heat treatment, and welding. Lombardi—an avid car enthusiast—applies his research to improving automobile performance and efficiency.

Myrissa N. Maxfield
Virginia Polytechnic Institute

Myrissa Maxfield is a proud Hokie, attending Virginia Polytechnic Institute and State University in Blacksburg. She is majoring in materials science and engineering and plans to pursue minors in foundry engineering, engineering science, mechanics, and math. She is very interested in metallurgy, specifically metal casting. Undergraduate research familiarized her with SEM technology and lead to her current special interest in metallography. Myrissa is president of Virginia Tech's chapter of the American Foundry Society and an active member of the student chapter of the Materials Engineering Professional Society. She enjoys reaching out to other students through these groups to spark their interest in metallurgy. Myrissa attended a number of conferences, held several internship positions, and made numerous industry connections, all of which helped develop her knowledge and leadership skills.

Seeking Nominations for Thermal Spray Hall of Fame

The Thermal Spray Hall of Fame, established in 1993 by the Thermal Spray Society of ASM International, recognizes and honors outstanding leaders who have made significant contributions to the science, technology, practice, education, management, and advancement of thermal spraying. For a copy of the rules, nomination form, and list of previous recipients, visit tss.asminternational.org and click Membership & Networking and then Society Awards. Or contact Sarina Pastoric at sarina.pastoric@asminternational.org. Nominations are due **September 30, 2014.**

ASM Geodesic Dome Design Competition!

ASM International Student Board Members are pleased to announce a new design competition open to all Material Advantage students at MS&T 2014! In an effort to bring "our home at the dome" to chapters and students across the country, student teams will design and build miniature geodesic domes. The competition will take place during MS&T and focus on the following areas: mechanical strength, aesthetics, and a design presentation. Top prizes are $1000, $750, and $500!

General Guidelines:

- Competition is open to graduate and undergraduate Material Advantage students.
- Each team of two to five students will design and build a geodesic dome out of their material of choice.
- A maximum of three domes may be submitted from each Material Advantage Chapter.
- Total project costs must not exceed $300.
- Dome must comply with geometric restrictions.
- Project teams are responsible for transporting their dome to MS&T14 in Pittsburgh. Teams may apply for shipping reimbursement up to $100 from ASM.

Register your team and find complete details on the new ASM website at asminternational.org/students3.

From the President's Desk
The New Logo, Walking the Talk

Entering our next century, ASM International adopted a new logo, new vision, and new aspirations. Prior to unveiling our new logo, we established brand guidelines and engaged all the stakeholders and employees at Materials Park, as well as members, customers, the ASM Foundation, affiliate societies, and sister societies in communicating the new logo and our enhanced outlook. Ongoing tasks in this endeavour include updating our product branding, affiliate logos, chapter logos, building signage, and more. Next, we sought feedback and the response was mostly positive. The fresh and modern look resonates well with younger members and many long-time members and customers have expressed enthusiasm in embracing our heritage of metals and materials. ASM volunteers and our sister societies note that they appreciate the hard work, new look, transparency, and communication. Of course, we can always do more.

> *Change is the law of life. And those who look only to the past or present are certain to miss the future.*
> John F. Kennedy

I visited Materials Park on December 5, 2013, and February 27, 2014, with a focus on reviewing and energizing efforts to embrace renewal and revitalization, reflecting the new centennial and new look. Time and again, ASM has demonstrated a unique ability to "think outside the box." I am humbled and energized by the very high caliber and professionalism of ASM trustees, including student board members. The Board has always welcomed innovative proposals with due consideration for selectivity, risk, and resources. I sincerely hope that the new logo will inspire innovation and advancement in member and chapter development, quality of content and delivery, positioning of ASM as an information gateway, embracing student camp alumni as future members, and partnering with sister societies, all with an eye for the bottom line.

I continue to be mesmerized by the passion of ASM volunteers as I visit the chapters. My recent travels included trips to the U.S. Naval Research Laboratory and National Academy of Engineering in Washington, University of Connecticut, Pratt & Whitney in East Hartford, Conn., and dedication of the Savannah River Site, Aiken, S.C., as an ASM Historical Landmark. I also visited ASM Chapters in these locations and came across many exemplary volunteers whom I will identify in my next newsletter.

C. (Ravi) Ravindran
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NIST Celebrates 100th Anniversary of Metallurgy Division

In late May, the National Institute of Standards and Technology (NIST), Gaithersburg, Md., celebrated 100 years of its metallurgy division and 50 years of its polymers program. NIST researchers Bob Shull and Chad Snyder spent several months coordinating speakers and entertainment to commemorate a century of materials science advances at the National Bureau of Standards (NBS), which became NIST in 1988. The festivities included a day full of interesting lectures and stories of technology advances, and an evening reception in the NIST courtyard.

Associate director for laboratory programs Willie May kicked off the celebration with a warm welcome and a bit of history from 1901, when NBS was first established. Eric Lin, MS&E division chief, then thanked the sponsors (including ASM) and talked about NIST's dedication to public service, technical excellence, and an open and dynamic working environment. Lin turned things over to Isaac Sanchez, a mainstay in the polymers division during the 1970s and 80s, who shared several entertaining stories.

In the next lecture, Richard Fields spoke about some of the disaster investigations NIST has been involved with from its early days to recent times. He shared how tragedies drove the creation of the metallurgy division: From 1902 to 1912, 41,578 train derailments occurred, with roughly 13,000 deaths each year. The division was established in 1913 to improve train safety, knowledge that was later transferred to shipbuilding. Fields also spoke about bridge collapses, airline accidents, and the Twin Towers investigation, and how such tragedies can lead to new standards and technologies. Several other interesting speakers rounded out the day, followed by the lively courtyard reception catered by Dogfish Head Alehouse. The 100th anniversary celebration was thoroughly enjoyed by all.

Laurie Locascio (Director of the NIST Material Measurement Laboratory), Willie May (Associate Director of NIST for Laboratory Programs), Robert Shull (NIST Fellow), and Lawrence Kushner (Deputy Director of NBS in 1979).

Eric Lin, MS&E Division Chief.

Attendees enjoyed a day of festivities at NIST's 100th anniversary celebration of its metallurgy division.

Chapter News

Cleveland Spotlights Additive Manufacturing

The ASM Cleveland Chapter hosted a one-day symposium that drew 115 attendees to learn about the latest technology involving Additive Manufacturing (AM). AM is a fast-growing industry slated to change the course of manufacturing. It is estimated that AM can significantly reduce development time and cost for many parts. Additionally, parts can be made with complexities impossible to achieve with standard subtractive manufacturing techniques. Where subtractive manufacturing consists of machining parts from bulk material stock, AM builds parts from scratch by placing "drops" of material where needed. Local experts gave presentations on six different aspects of AM including laser hot wire, electron beam freeform fabrication, ultrasonic lamination, and the manufacture of nonmetallics. Speakers represented Fabrisonic, Lincoln Electric, rp+m, NASA, and *Industry Week.*

Company representatives from ExOne discuss the intricacies of 3D manufactured powder parts.

Hartford Camp—Joint Effort

On April 21, the Hartford Chapter held its eighth Hartford Area Materials Camp at the Institute of Materials Sciences on the University of Connecticut (UConn) campus in Storrs. The 86 high school students and 9 teachers attending were awakened to the excitement of materials at eight learning stations. Photos show students engaged at the Casting and Material Advantage Explorations stations. Camp staff volunteers included professionals from local industry and UConn Material Advantage Chapter (MAC) students. Local companies donated "wow" items to be taken away from each station and safety glasses worn by all participants. MAC members served as tour guides and ran the learning center. The Chapter also gave a T-shirt and ASM Hartford calculator and pen to each participant.

Spring in Chicago

The Chicago Regional Chapter held two successful meetings this spring. Their May 13 event, was held at Northern Illinois University (NIU) DeKalb College of Engineering and Engineering Technology. The evening included a tour of the engineering labs at NIU DeKalb, with a particular focus on equipment and projects for additive manufacturing, followed by dinner and a talk by NIU associate professor, Federico Sciammarella. His lecture, Measurement Science in Additive Manufacturing, described a NIST-sponsored project to integrate experimental and predictive tools to enhance component repeatability.

The Chapter's Trustee night on March 11 was held at the Naperville campus of NIU. ASM vice president Sunniva Collins was the featured speaker, covering Orbital Welding for Critical Applications. Also that evening, an award was presented to Ralph Daehn in recognition of years of dedicated leadership to the chapter. Daehn will soon relocate to Montana.

Left to right: David Rollings (chapter chair), Federico Sciammarella (evening's speaker), his father Cesar Sciammarella (research faculty at NIU and emeritus at IIT), Guiru Nash (past chapter chair), and Jim Mikoda (incoming chapter chair).

George F. Vander Voort (left) and Frederick E. Schmidt (outreach chair) attended Chicago's March 11 meeting to hear a presentation by ASM vice president Sunniva Collins (center). All three are ASM Fellows and Vander Voort and Schmidt are officers of Alpha Sigma Mu, the international honor society for materials science and engineering.

ASM Medical Materials Database

Neurological Module Release

The June release of the ASM Medical Materials Database features a new Neurological Module, covering peer-reviewed materials-related data for neurological device design. The new module is fully integrated with the existing Medical Materials Database, which also includes Orthopaedic and Cardiovascular Modules, providing users with added value.

For more information, contact Scott Flowers at scott.flowers@asminternational.org, 800.336.5152 ext. 5230, or 440.338.515 ext. 5230.

Members in the News

Berndt as ASME Fellow

Christopher C. Berndt, FASM, TS-HoF, was elected a Fellow of ASME. His citation reads, "Prof. Berndt has been involved in teaching and research within the materials engineering and mechanical engineering disciplines for the past 35 years. He has taken on leadership roles within professional societies for the past 15 years, which includes the presidency of ASM International. He published more than 450 articles on thermal spray coating technology and has a Hirsch index of 45. He impacted many thousands of undergraduates through his teaching, as well as some 60 graduate students and post docs." Berndt is a professor of surface science and interface engineering at the Swinburne University of Technology in Australia.

ASTM Honors Garde

In May, the ASTM Committee on Reactive and Refractory Metals and Alloys honored **Anand Garde,** consulting engineer at Westinghouse Electric Co., Hopkins, S.C., with the Award of Merit and title of Fellow. Committee B10 recognized Garde for his outstanding leadership as a past chairman and dedication to the promotion of the committee through standards development and symposia events. As chairman of the B10 Symposium Subcommittee, Garde organized and chaired two ASTM symposia on Zirconium Use in the Nuclear Industry, which were held in China and India. Garde is also a member of Committee G01 on Corrosion of Metals. He is a zirconium metallurgist with 40 years of industrial experience in nuclear materials.

IN MEMORIAM

Reginald W. Smith, FASM, of Kingston, Ontario, passed away on May 3, at age 83. Born in England, he received a B.Sc. in Physics in 1953 and Ph.D. in 1956 from the University of Birmingham, UK. After three years as a post-doctoral fellow at the University of Toronto, he returned to Birmingham as associate professor and then moved back to Canada. He joined as a visiting professor at the Department of Metallurgical Engineering, Queen's University, Kingston, in 1968 and accepted the professor position a year later. After his retirement in 1995, he continued as professor emeritus. Smith published more than 230 research papers in refereed journals and conference proceedings. He also held four patents and received the Canadian Metal Physics Award. His experiment called QUELD (Queen's University Experiment in Liquid Diffusion) flew in the NASA space shuttle in 1992, and QUELD II flew in the Russian MIR station in 1996-98.

Word has been received at ASM Headquarters of the death of Life Member **Ji Young Chang** of Murrysville, Pa. (Pittsburgh Chapter).

For a list of upcoming ASM Training Courses, see our ad on page 33 of this issue.

Augustine Named to DOE Commission

In May, Energy Secretary Ernest Moniz announced the Commission to Review the Effectiveness of the National Energy Laboratories, a congressionally mandated committee that will evaluate the Energy Department's 17 national laboratories. The Commission is being established pursuant to the 2014 Consolidated Appropriations Act. ASM Life member, **Norman R. Augustine**, is among those named to serve. Augustine is chairman of the U.S. Human Space Flight Plans Committee, NASA, and retired chairman and CEO of Lockheed Martin. He has received the DOD's highest civilian decoration five times, the Distinguished Service Medal.

VOLUNTEERISM COMMITTEE

Profile of a Volunteer

Arun Kumar
IT CIP Master Black Belt
Flowserve Corp.

Arun Kumar first became a member of ASM International 23 years ago after completing his B.S. degree in metallurgical engineering and M.S. in manufacturing engineering. Kumar is now a continuous improvement process (CIP) manager for Flowserve Corp., a leading manufacturer of flow management solutions.

"ASM has always been my backbone," says Kumar. "It's one of the pillars for me to stand on." Both ASM and ASQ (American Society for Quality) have played key roles in his successful career. After starting out in foundries and on the manufacturing end, Kumar began to develop expertise in quality improvement and IT process management while discovering a talent and passion for mentoring others.

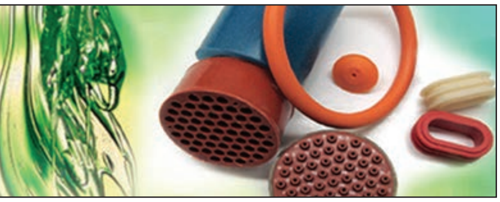
He is currently president of the North Texas ASM chapter and proud of their local activities, especially the close relationships with nearby universities including University of Texas at Arlington, UT Dallas, University of North Texas, Southern Methodist University, and others. "We engage students with ASM through research competitions where we gave out $2500 in awards in 2013-2014. It's a way to spread the word about the society and inspire long-term membership after graduation," explains Kumar.

In addition to providing information on metals and metallurgy around the world, Kumar values ASM as a networking resource. "It's about people helping people find jobs or connections," he reflects. "ASM is a conduit to transfer knowledge, but it's not just about technical skills. It's about people skills, attitude, and how you contribute to an organization."

As a member of the national Volunteerism Committee, Kumar wants to involve the next generation by building consistency and connections between chapters. At the local level, he sees the need to develop a thriving and involved membership to track and encourage both members and nonmembers who attend meetings, and develop a "move forward" plan for strong chapter leadership into the future.

products & literature

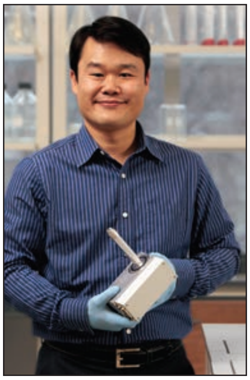
Dow Corning Corp., Midland, Mich., introduced two new Silastic brand **fluoro liquid silicone rubbers** (F-LSRs) to expand design options and provide processing efficiency for fuel-resistant automotive components. Meeting key market needs for both performance and cost control, Silastic F-LSRs combine the fuel, oil, and solvent resistance of fluorosilicone rubber (FSR) with the processing benefits of liquid silicone rubber (LSR). Both Silastic F-LSRs exhibit excellent resistance to nonpolar hydrocarbon fuels, oils, and solvents and offer process cost savings as well. Silastic FL-60-9201 F-LSR provides flexibility for dynamic seals such as diaphragms and membranes, while Silastic FL-70-9201 F-LSR provides high modulus with low compression set for static seals such as O-rings and gaskets. dowcorning.com.



FLIR Systems, Wilsonville, Ore., introduced the FLIR A6700sc—an economical **compact thermal imaging camera,** which incorporates a cooled Indium Antimonide (InSb) detector that operates in the 3-5 μm waveband. A broadband version operating on the 1-5 μm waveband is also available. Both versions produce crisp thermal images of 640 × 512. Achieving a high thermal sensitivity of <20 mK, the camera captures the finest image details and temperature difference information. Precise camera synchronization and triggering make it well suited to high speed, high sensitivity applications. The camera supports image frame rates up to 480 frames per second when operating in windowing mode. flir.com/US.

Green Belting Industries Ltd., Mississauga, Ontario, released a unique problem solving product—HVMT Orange **masking tape** that can survive the abrasion and heat associated with gas fueled HVOF (high velocity oxy fuel) coatings. It delivers clean coating lines and no adhesive residue. The tape is flame retardant, self-extinguishing, highly abrasive resistant, and very flexible and conformable. greenbelting.com.

Unitel Technologies Inc., Mt. Prospect, Ill., joined with Inorganic Polymer Solutions Inc., Blacksburg, Va., to commercialize a 100% VOC-free **inorganic coating.** Its performance is not affected by high temperatures, oxygen-deficient conditions, or marine environments. CeramiGuard provides a new option to fight corrosion with two steps in one: An acid phosphate gel provides the passivation layer while an alkaline colloidal gel forms the protective refractory ceramic top-coat. Underlying chemical reactions occur simultaneously. The unique advantage of this new coating is that the ceramic is formed by an in situ chemical reaction and not by conventional high temperature processing of inorganic powders. uniteltech.com, polymersolutions.com.



Thermo Scientific, Waltham, Mass., introduced the UltraDry Compact EDS **x-ray detector.** Small enough to fit in the palm of the hand, it features a maintenance-free design that eliminates the need for liquid nitrogen. The detector handles collection rates up to one million x-rays per second with detection sensitivity to boron and EDS energy resolutions of 129 eV Mn. The streamlined design makes it suitable for tabletop SEMs, as well as a tight fit on new SEMs or as a cost-effective replacement EDS for existing SEMs. thermoscientific.com.

Carl Zeiss Microscopy, Peabody, Mass., released its first **automated digital microscope,** the ZEISS Smartzoom 5. It is comprised of an optical engine (including a zoom, camera, and illumination), a stand with sample stage, objective lenses, operating unit, and software. The microscope is well suited to conducting failure analyses. Once a sample is placed under the device, switching back and forth between the device and software is unnecessary as all the steps can be completed directly on the screen. The "best image" feature allows users without any prior knowledge to achieve optimal results—the system shows a preview of different illumination options and the user selects the best one. The device is factory calibrated and can be used immediately. zeiss.com.

Master Bond, Hackensack, N.J., introduces MasterSil 152, a two-component, **condensation curing system** that only requires air for complete cross-linking. It was developed for potting and encapsulation applications where additional cured silicone cannot be used. The system fully cures at room temperature in 24-48 hours, has low exotherm and low shrinkage upon curing, and features a 10:1 mix ratio by weight. MasterSil 152 combines low viscosity and electrical insulation properties with the ability to cure in sections exceeding

1-in. in thickness. Widely used in electronic and optical components, it is optically clear, can transmit light from 220-2500 μm, and has a refraction index of 1.45. As is typical for silicones, it is very flexible and can withstand thermal cycling and shock. The system is highly resistant to water and is serviceable over the -65° to 400°F temperature range. masterbond.com.

Hitachi Ltd., Tarrytown, N.Y., announces a new computer-controlled tri-axial **material fatigue testing machine** that emulates complex stress conditions that occur during operation of mechanical structures, such as those used in construction machinery and renewable energy facilities. Surface stress on mechanical structures is described as in-plane structural element deformations in the transverse, longitudinal, and diagonal directions. However, as conventional material fatigue testing machines are only able to apply two of these deformations to a test specimen, accurate reproduction of complex stress conditions is difficult. The new tri-axial testing machine is able to emulate stress states working on surfaces of mechanical structures by applying three independent loads to the test specimen using actuators that apply loads in the 0°, 45°, and 95° directions. hitachi.com.

PlastiComp Inc., Winona, Minn., introduces a line of **basalt fiber reinforced LFT composites.** These new long fiber products offer a significant increase in performance over short basalt fiber filled materials and are available in multiple resin matrices with 30-60% by weight fiber loadings. Derived from volcanic rock, the beneficial characteristics of basalt fiber include excellent corrosion resistance, high abrasion resistance, and inherent fire resistance. Basalt fiber is known for retaining its performance at cold temperatures and for not being degraded by UV or electromagnetic radiation. It is well suited for applications in marine settings, concrete contact, and underground environments. plasticomp.com.

A new brochure from Malvern Instruments Inc., Westborough, Mass., details the company's range of **detectors for gel permeation/size exclusion chromatography** (GPC/SEC). Available as standalone units, or as part of a fully integrated Viscotek multi-detection GPC/SEC system, the detectors provide highly accurate analysis of polymer and protein macromolecular features and combine to offer advanced insight into molecular structure. GPC/SEC is a central analytical technique for protein and polymer analysis because of its ability to measure defining characteristics including molecular weight, molecular weight distribution, molecular size, and structure. The range of detectors includes light scattering, refractive index, viscometry, and UV technology. malvern.com/viscotekdetectors.

Shimadzu Scientific Instruments, Columbia, Md., announces four **universal testers** that offer high-level control, tight precision, and intuitive operation for a wide variety of material testing. The new testers come standard with Trapexium X or Trapexium Lite X software to gather and display data for users in real time. Enhanced features include: Load cells with test force accuracy within ±0.5% over the range of 1/1 to 1/500 of the maximum capacity; 1 kHz sampling rate ensures no missed strength changes; one-touch crosshead stroke limiters allow simple adjustment and firm locking; faster crosshead achieves a 1600 mm/min testing speed and a 2200 mm/min return speed (20kN frame) to save time with repetitive testing; common joint for both tensile and compression makes it easier to exchange jigs; and a built-in multi-purpose tray enables placing jigs, arranging specimens, and taking notes. shimadzu.com.

Morgan Advanced Materials, UK, announces Certech **injection-molded ceramics,** engineered for investment casting of airfoils and industrial gas turbines. Cores are available in a wide range of sizes and complex designs for equiax, single crystal, and directional solidification casting. Critical airfoils required to withstand the high turbine inlet temperature in modern gas turbine engines are investment cast in nickel- and cobalt-base superalloys, with ceramic cores used to form the part's air-cooling passages. The ability to inject around quartz rods down to 0.020-in. (0.5 mm) in diameter lets users design features in the cooling passages that would otherwise be difficult to form. Ceramic cores are produced using the company's specialty P-52 and newly developed P-57 and P-59 materials, which allow production of cores with extremely thin (<0.012 in.) dimensions without sacrificing stability. morganadvancedmaterials.com.

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editorial preview

AUGUST

Failure Analysis

Highlighting:

- Preventing Corrosion Failures
- Implant Retrieval and Analysis
- Exploring Electronics Failures

Special Supplement:

International Thermal Spray & Surface Engineering newsletter covering thermal spray coatings for automotive and industrial applications.

Advertising closes July 3, 2014

SEPTEMBER

High-Tech Materials & Processes

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- Powder Compaction Manufacturing
- 3D Microstructural Characterization
- Advances in Additive Manufacturing

Special Supplement:

HTPro newsletter covering heat treating technology, processes, materials, and equipment, along with Heat Treating Society news and initiatives.

Bonus Distribution:

MS&T Conference & Exposition 2014
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Advertising closes August 4, 2014

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stress RELIEF

Old milk jugs can be recycled into filament for 3D printing, saving both money and the environment. Courtesy of Sarah Bird/MTU.

3D printing old milk jugs

A study led by Joshua Pearce of Michigan Technological University (MTU), Houghton, shows that making plastic 3D printer filament from milk jugs uses less energy—often a lot less—than recycling them conventionally. The team did a life cycle analysis on a typical milk jug made from high-density polyethylene (HDPE) plastic. After cleaning it and cutting it in pieces, it was put through an office shredder and a RecycleBot, which turns waste plastic into 3D printer filament. Compared to an ideal urban recycling program, which collects and processes plastic locally, turning milk jugs into filament at home uses about 3% less energy.

"Where it really shows substantial savings is in smaller towns, where you have to transport the plastic to be collected, then again to be recycled, and a third time to be made into products," says Pearce, associate professor of materials science and engineering. In this scenario, energy savings skyrocket to 70-80%. And, recycling your own milk jugs uses 90% less energy than making virgin plastic from petroleum. *For more information: Joshua Pearce, 906.487.1466, pearce@mtu.edu, mtu.edu.*

National Geographic Kids *claimed its ninth Guinness World Records title for the smallest magazine cover, using patented technology from IBM, Armonk, N.Y.*

The world's tiniest magazine cover

National Geographic Kids claimed its ninth Guinness World Records title for the smallest magazine cover, using patented technology from IBM, Armonk, N.Y., at the USA Science & Engineering Festival in Washington. To create the record-setting cover, IBM scientists invented a tiny "chisel" with a heatable silicon tip 100,000 times smaller than a sharpened pencil point. Using this nanosized tip, which creates patterns and structures on a microscopic scale, it took scientists just 10 minutes and 40 seconds to etch the magazine cover onto a polymer. The resulting magazine cover measures 11 × 14 μm.

National Geographic Kids let its readers vote online for their favorite design and they chose the March 2014 cover, which earned the honor of a microscopic version, visible through a ZEISS Axio Imager 2 microscope. *research.ibm.com, guinnessworldrecords.com, kids.nationalgeographic.com.*

Exclusive color developed for company's 75th anniversary

Axalta Coating Systems, Glen Mills, Pa., developed a special formulation of Diamond Red exclusively for Peterbilt, Denton, Tex. Peterbilt is celebrating its 75th anniversary this year by unveiling a limited production Model 579 truck featuring state-of-the-art aerodynamics, distinctive styling, and coated with a two-tone paint design that is a modern version of the Diamond Red color on its original 1939 model. The Imron Elite paint line is the exclusive topcoat used at Peterbilt manufacturing facilities in the U.S., Canada, and Mexico. An identical product is used in the commercial vehicle aftermarket by Peterbilt dealers and repair centers to ensure customer satisfaction and repair-in-kind quality. *axaltacoatingsystems.com, peterbilt.com.*

Peterbilt's exclusive new color, Diamond Red, is formulated to bring out the lines and details of the truck, while showcasing new effect pigments in the Imron Elite paint line from Axalta Coating Systems.

SUCCESS ANALYSIS

Specimen Name: 3D Printed Fuel Tank Simulators

Adding inserts to the 3D printed tank simulation rings.

Vital Statistics:

In early 2012, Lockheed Martin's Space Systems Co. began to look for ways to improve its satellite design. The goal: Devise a satellite that more efficiently uses the available design footprint to increase payload capacity. This effort required testing various assembly configurations and producing several simulators and prototypes to validate design changes. One of these changes involved the satellite's fuel tanks.

Before building the actual tanks for final use, Lockheed needed to test form, fit, and function—and assembly—by using tank simulators. However, producing test parts with traditional manufacturing methods was not an option given the tight deadlines and financial constraints: Machining the larger tank at 6.75 × 3.8 × 3.8 ft and the smaller one at 3.8 × 3.8 × 3.8 ft would take longer than six months and cost around $250,000. Recent advancements in large-scale 3D printing motivated Lockheed to apply Stratasys' fused deposition modeling (FDM) technique to the tank simulators. Although Lockheed owns several additive manufacturing machines, this particular application involved part sizes and project deadlines that exceeded its in-house capacity. Parts needed to be built in many pieces and bonded together, requiring an army of machines and a crew of FDM finishing experts. That's when they turned to the aerospace team at RedEye, a division of Stratasys Inc.

Success Factors:

The larger tank was built in 10 separate pieces, and the smaller in six, using polycarbonate material. Combined, the fuel tanks took nearly two weeks to print, requiring approximately 150 hours per section. Based on the sheer size of the parts, customized fixtures were needed to support the structures as they were bonded together and then shipped to a machining facility to meet specifications. Once machining was complete, final assembly took 240 hours.

Both 3D printing and traditional manufacturing methods were used to machine the 3D printed tank simulations.

"These are the largest parts we've ever built using FDM," says Joel Smith, RedEye's aerospace and defense account manager. "We completed an extensive design review to determine the best orientation and slice height to ensure we could accurately build and bond the sections together in post processing to meet the dimensional requirements."

About the Innovators:

As a division of Stratasys, RedEye is one of the world's largest providers of rapid prototyping and additive manufacturing services and has a network of more than 150 3D printers worldwide. RedEye uses Stratasys' FDM and PolyJet 3D printing technologies to help companies with all phases of product development, from conceptual modeling to production of end-use parts. Lockheed Martin's Space Systems Co. designs, develops, tests, manufactures, and operates advanced technology systems for national security, civil, and commercial customers.

The RedEye and Lockheed Martin team with the 3D printed tank simulations.

What's Next:

The tanks went through several quality assurance and accuracy measurements and were approved for the first concept assembly. Next, Lockheed will take what they learned from the first phase to optimize design and assembly to print the second iteration of tanks.

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