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SEPTEMBER 2014 • VOL 172, NO 9

MS&T14®

Coming to Pittsburgh
October 12-16

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SEPTEMBER 2014 • VOL 172, NO 9

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October 12-16

High-Tech Materials & Processes

INCLUDED IN THIS ISSUE

- 3D Microstructural Characterization
- Advances in Structural Intermetallics
- MS&T Show Preview

ASM INTERNATIONAL

ON THE COVER:
The Roberto Clemente Bridge, also known as the Sixth Street Bridge, spans the Allegheny River in downtown Pittsburgh. It is one of three parallel bridges called The Three Sisters, all self-anchored suspension bridges. Courtesy of VisitPittsburgh.

contents

DEPARTMENTS

Check out the Digital Edition online at amp.digitaledition.asminternational.org

ASM International serves materials professionals, nontechnical personnel, and managers worldwide by providing high-quality materials information, education and training, networking opportunities, and professional development resources in cost-effective and user-friendly formats. ASM is where materials users, producers, and manufacturers converge to do business.

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materials witness

Earn quick cash while working from home

Did this headline grab your attention? We sure hope so! You may be surprised to see such a blatant come-on in a rather serious materials engineering publication. You may be wondering what it's all about. And we are about to tell you (…drumroll please). This month, ASM International is launching a very exciting membership drive called "The Power of One."

One. As in, asking one person to consider becoming part of ASM and all it has to offer. No matter where you are along the way, think about how your life and career have progressed so far. In school, many of us can remember a special teacher who said just the right words at the right time to direct us down one path or another. Next, think about your first "real job" and any promotions since then.

Most of the time, it comes down to getting one key person to believe in you. Perhaps that person is a colleague or former coworker, or maybe it is someone you met through a technical society or networking function. It probably *isn't* one of the many hundreds of casual LinkedIn "contacts" or Facebook "friends" many of us seem to have these days. Not that there's anything wrong with social media. It's a great way for people to connect and keep in touch, but there is simply no substitute for face-to-face interactions and getting to know people over time and in person.

Enter The Power of One: The premise is that one by one, ASM members have grown this organization into the largest metals-focused society in the world. Each and every new member brings a fresh perspective and new ideas into the organization. At the same time, each member benefits from the many networking opportunities, educational offerings, and detailed technical resources available in both print and online formats.

The easiest part of the membership drive is that it only takes asking one friend or colleague to check out ASM with its affordable membership, valuable services, action-packed conferences, and accredited course offerings. Have you attended a local chapter meeting lately? ASM now has 83 chapters spanning the U.S., Canada, India, Europe, the Middle East, and Singapore. Chapter meetings are a great way to get to know people at local companies, universities, and national labs. Think about inviting a coworker to attend your next chapter meeting so they can see firsthand what ASM is all about.

Many of you are no doubt still wondering about the "earn quick cash" headline. Here's the gist of it: Every current ASM member who brings in a new member will receive a $10 cash gift card. Get a few coworkers to join and—voilà—now you have some gas money or a nice dinner out! What's more, for each new member you bring in, you will also be entered for a chance to win one of the grand prizes: One member will win $3500; one chapter will win $2500; and one national committee will win $1000. The real prize? A vibrant, strong, fresh, and powerful technical society we can all be proud to be a part of. Here's to The Power of One!

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market spotlight

Global molybdenum production and use hits record high

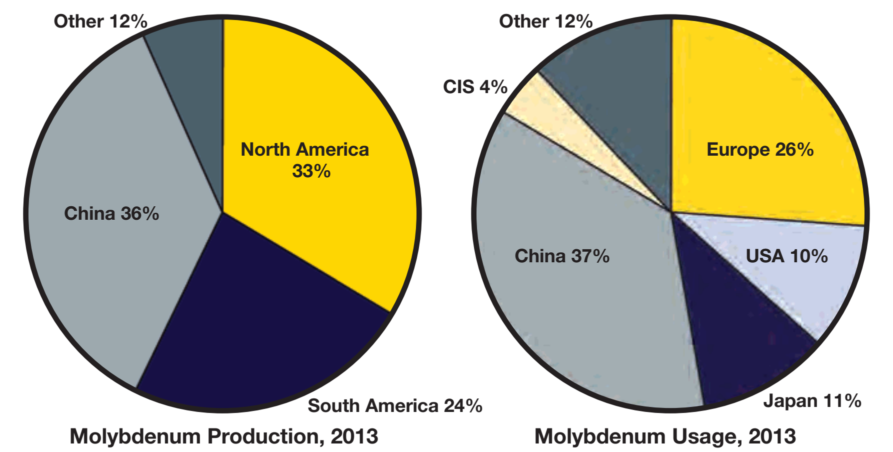
Global molybdenum production reached a new high of 539.2 million pounds in 2013, surpassing the 2012 record of 535.2 million lb. Full year figures from the International Molybdenum Association (IMOA), London, also show global molybdenum usage at 537.7 million lb, breaking the previous year's record high of 522.5 million lb. Molybdenum is added to steel and cast iron to improve strength, toughness, hardenability, and weldability for numerous applications in the automotive, shipbuilding, construction, mining, chemical, oil and gas, and energy generation industries. In stainless steels and superalloys, it improves corrosion resistance and high-temperature performance and finds uses in many industrial applications. It is also used in a variety of products from catalysts and lubricants to pigments and paint.

The greatest use of molybdenum in 2013 was in China, where it increased from 188.4 million lb in 2012 to 196.2 million in 2013. Europe recorded the second biggest share with 140.4 million lb, up from 135.9 million in 2012. Japan and the U.S. were the third and fourth largest users of molybdenum by region, recording 57.4 and 56.1 million lb respectively. Usage in the Commonwealth of Independent States (CIS) reached 23 million lb, with other countries together totaling 64.6 million lb.

China was also the biggest molybdenum producer in 2013, although output fell slightly to 194.9 million lb, compared to the previous year's record high of 207 million lb. Production in North America rose from 176.5 million lb in 2012 to 180.5 million in 2013. South America was the third largest producer, accounting for 128 million lb in 2013, up from 118.7 in 2012. Production in other countries increased slightly from 33 to 35.7 million lb in 2013.

Global usage increased from 137.5 million lb in Q3 to 138.2 in Q4. Usage in China decreased slightly from 52.9 million lb in Q3 to 51.6 in Q4. In contrast, European usage increased from 34 million lb in Q3 to 35.1 in Q4. Japan and the U.S. used 14.4 and 14.2 million lb respectively in Q4.

IMOA is a nonprofit trade association representing the interests of most of the world's molybdenum producers and converters, as well as consumers and traders. For more information, visit www.imoa.info.



feedback

Touting titanium for implants

With regard to the recent article link in the July 23 *AM&P* eNewsletter—Microscopic Analysis of Fractured Screws Used as Implants in Bone Fixation featured in a recent *Journal of Failure Analysis and Prevention*—who published this tripe? A stainless bone screw that *didn't* fail would be more newsworthy! I have published data from 40 years ago stating that 90% of stainless onlay plate screws show corrosion after seven days. This problem was well known in 1943, when the Army started using stainless for implants. If the ham-handed MDs don't twist them off during installation, the chlorides will soon get them. Thread rolling or machining also introduces stress into the metal, making it even more of a risk. Friction (fretting) with the implant itself destroys the thin protective skin on the stainless. If it lives through that, a crevice corrosion condition will exist between the parts. Three strikes, you're out. Easy solution: Switch to Ti 6-4 alloy for all implants. The cost of any material is a tiny fraction of the final cost of any device, Pt or Pb, it makes no difference.

Chuck Dohogne

Mitigating magnesium mayhem

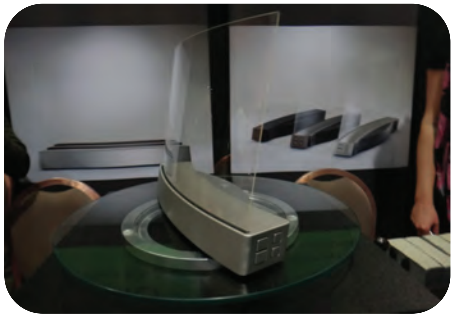
I was pleased to see the excellent article by Frank Czerwinski on magnesium ignition [Overcoming Barriers of Magnesium Ignition and Flammability, May]. It does not try to dodge around the actual flammability of this material, especially in the commonly used alloys, but instead systematically reports on the research that looks at the fundamentals of what is happening and what ameliorative steps can be taken. The connection made between oxidation associated with combustion and oxidation associated with corrosion seems obvious once made, but would not have occurred to me before I read this article. I have some personal knowledge of this subject because another participant in the gas grill industry unwisely substituted magnesium die casting alloy for aluminum die casting alloy in the fireboxes of their gas grills with rather unfortunate results. A pity they didn't belong to ASM!

Alex Gafford

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

Speaker gives crystal clear sound new meaning

ClearView Audio, Waltham, Mass., created a new glass speaker named Clio that boasts an "invisible" design consisting of an ultra-thin, curved acrylic glass transducer, which outputs sound in multiple directions. Clio's patented Edge Motion audio systems use a differentiating mechanical principal to generate sound—instead of pushing from behind, like traditional cone speakers, Edge Motion-driven speakers actuate a thin membrane along the side in a manner that creates an extremely efficient, piston-like motion in front. The speaker uses a single piece of curved acrylic glass that sits on a dock, which vibrates it in a finely tuned way so that it can play music. Clio uses a 2-in. woofer and piezoelectric actuators in its base, which stimulate two thin membranes (one per channel) running along both sides of its transparent curved transducer, producing 360° stereo sound emitted from both the front and rear faces of the 1-mm-thick acrylic material. *clearviewaudio.com.*



Clio, a new "invisible" speaker, is available in silver, bronze, or charcoal hues.

Fire-resistant paper handles the heat

Researchers from the Shanghai Institute of Ceramics, Chinese Academy of Sciences, developed a new paper that is resistant to fire and high temperatures (>450°C). It is made from a calcium phosphate compound, hydroxyapatite (HAp), $Ca_{10}(PO_4)_6(OH)_2$, and can potentially be used for both printing and writing. Chemically, the main component of the conventional paper is cellulose, a natural polymer extracted from the pulp of wood or grass. Other minor components, such as bleaching agents and additives, are also part of the mix. To have the characteristics necessary for high-performance printing, the paper must be coated with a very thin layer of inorganic material.

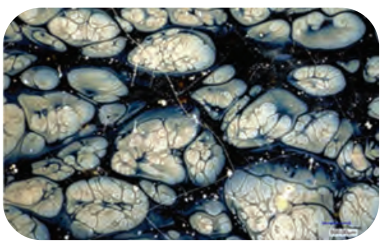
"HAp is a calcium phosphate with high biocompatibility and essentially no toxicity. It is white in color, abundant in nature, nonflammable, and high-temperature resistant. Therefore, it is an ideal candidate for fabricating paper. However, the most challenging problem is its low flexibility. To overcome this, we adopted HAp ultralong nanowires as the paper-making material," explains Professor Ying-Jie Zhu. *http://english.sic.cas.cn.*

Printing on HAp paper (top). The material is fire resistant (bottom). Courtesy of Ying-Jie Zhu.

Ancient Chinese pottery contains rare form of iron oxide

New analysis of ancient Jian wares reveals the distinctive pottery contains an unexpected and highly unusual form of iron oxide. This rare compound, called epsilon-phase iron oxide, was only recently discovered and characterized by scientists and so far has been extremely difficult to create with modern techniques. "What is amazing is that the 'perfect synthesis conditions' for epsilon-phase iron oxide were encountered 1000 years ago by Chinese potters," says Catherine Dejoie, scientist at University of Berkeley Laboratory's Advanced Light Source, Calif.

Jian wares, such as tea bowls, are famous for their shiny black glaze and variable brown and silvery surface patterns known as "oil spot" and "hare's fur." The ceramic bowls, produced by the thousands in giant kilns, were made during the Song dynasty in the Fujian Province of Southeast China between 960 and 1279 AD. Analysis reveals that hare's fur patterns contain small quantities of epsilon-phase iron oxide mixed with hematite, while oil spot patterns boast large quantities of highly pure epsilon-phase iron oxide, an unexpected finding. Marked by extremely persistent magnetization, epsilon-phase iron oxide could hold the key to better, cheaper permanent magnets used in data storage and other electronics. *lbl.gov.*



Modern replica of a Tenmoku tea bowl (top) with "oil spot" surface patterns produced by Prof. Weidong Li, Shanghai Institute of Ceramics. Close-up of the oil spot pattern from an ancient Jian ware provided by the Museum of Fujian Province.

Exceptional Performance

Consistently achieve uniform hardening and reduced distortion with Ipsen's SuperQuench®. This system tackles even the most challenging alloy by reducing the spread of hardness values and increasing the overall throughput of parts. The system's flexibility also allows the oil flow to be adapted to the section size, material and density of the load you are quenching.

System Integration

Ipsen's components are configured for maximum compatibility, making it simple to expand or modify your equipment. The ATLAS® single-chain furnace model utilizes the same push-pull chain loader as the industry standard, allowing it to integrate into existing lines with ease.

Energy Efficiency

Ipsen's Recon® Burners increase thermal efficiency up to **75%** – simply by recovering the heat from the exhaust gases to preheat the combustion air, thus reducing time to recovery of the hot zone temperature. These single-ended radiant tubes (SERT) are fitted with special ceramic inner tubes and set apart by their low noise levels, high durability, low maintenance and easy installation – allowing them to provide ideal heating while optimizing gas consumption.

Intuitive Controls

Carb-o-Prof® Control Software combines more than six decades of knowledge and expertise in a single control system. This reliable software allows you to monitor and control uniformity of the C-level within the atmosphere, maintaining a tolerance of ±0.05% C for the workpiece surface carbon content. Carb-o-Prof also delivers an extensive recipe database, time- and cost-saving simulation functions with C-Profile optimization and adaptive control that ensures you get the best part quality every time.

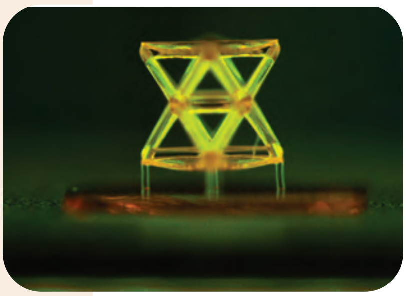
industry news

Metals Polymers Ceramics

briefs

SAE International, Warrendale, Pa., is teaming with the **University of Michigan,** Ann Arbor, to combine classroom and laboratory learning in the **Automotive Composites Technology Engineering Academy.** The five-day course will be held November 10-14 at SAE International's Troy, Mich., office and will provide an overview of composite materials in terms of material types such as carbon, glass, and natural fibers. The focus, however, will be on carbon fiber processes, typical applications, benefits, and shortcomings. Participants will learn about terminology, quality issues, costs and automotive market needs, and will gain a holistic understanding of automotive carbon fiber and its applications. training.sae.org/academies/acad08.

Engineers at **Massachusetts Institute of Technology,** Cambridge, Mass., and **Lawrence Livermore National Laboratory (LLNL),** Calif., devised a way to translate the Eiffel tower to the microscale—designing a system that could be fabricated from a variety of materials, such as metals or polymers, and that may set new records for stiffness for a given weight. The design is based on the use of microlattices with nanoscale features, combining great stiffness and strength with ultralow density, say researchers. The actual production of such materials is made possible by a high-precision 3D printing process called projection microstereolithography, as a result of the joint research. mit.edu, llnl.gov.



Microscope image of a single unit of the structure developed by the team, called a stretch-dominated octet truss unit cell, made from a polymer using 3D microstereolithography.

Super-strong steel suits military applications and more

Harry Bhadeshia of the University of Cambridge, UK, Department of Materials Science and Metallurgy, has spent the past three decades researching the nature of steel to develop new alloys for a range of applications. One of these alloys, super bainite, has been licensed to Tata Steel, Mumbai, India, and is currently being manufactured in the UK for use as super-strong armor for military vehicles and other applications.

Perforations in super bainite make the material even better at protecting armored vehicles from projectiles. Courtesy of Tata Steel.

Using precise modeling, it was found that there is no lower limit to the temperature at which bainite can be produced. By heat treating it at temperatures around 200°C for 10 or more days, a new form results—super bainite. In addition, by adding elements such as silicon and molybdenum, carbides and harmful impurity phases are prevented from forming in the steel, reducing the likelihood of cracks. Super bainite features a tensile strength of 2.5 GPa, and just 1 m^2 can support a weight equivalent to that of 2.5 billion apples. It has a higher density of interfaces than any other metal, and is the world's first bulk nanostructured metal. The strength of super bainite derives not only from its lack of carbides, but also from the its tiny iron crystals. These crystals are between 20 and 40 nm thick, comparable to the width of carbon nanotubes. In comparison, the crystals in conventional bainite are between 200 and 500 nm thick. *For more information: Harry Bhadeshia, hkdb@cam.ac.uk, www.cam.ac.uk.*

Protecting helicopters and boats with new materials

Emerging global trends impact the environment of light tactical interdiction vehicles for military, law enforcement, and homeland security operations, particularly helicopters and patrol boats. As these vehicles engage in higher-risk scenarios, they require enhanced armor protection that will not compromise their speed, agility, range, and payload capacity. Simply adding armor made from traditional materials such as ceramics, glass, aramid, and even polyethylene is no longer enough. Innovative lightweight materials that can deliver reliable protection and optimize vehicle performance, fuel efficiency, capacity, and maneuverability are necessary. DSM Dyneema, Stanley, N.C., announces Dyneema Force Multiplier Technology, which reportedly combines breakthroughs in polymer science, next-generation UHMWPE fiber technology, and unique unidirectional engineering. The new material reduces the weight of hard ballistics armor by up to 25%, offering greater vehicle agility, speed, fuel efficiency, and capacity. *dyneema.com.*

Shape memory alloys for buildings

Researchers at the Swiss Federal Laboratories for Materials Science and Technology (Empa) demonstrate that shape memory alloys (SMAs) can be used in the building industry. SMAs have the ability to return to their original shape after being severely deformed, either spontaneously or following the application of heat, making them useful not just for making eyeglass frames, but also for technical applications such as thermostats, stents, and micro-actuators. Other applications in the construction industry are possible as well, such as bridge reinforcement.

The nickel titanium alloys used to make eyeglass frames and stents are not suitable for use in the construction industry. Iron-based SMA products are much more attractive, because both the raw materials and processing costs are far less expensive.

Forging an iron-based SMA cast block: To shape the block, it is heated to roughly 1150°C. Courtesy of TU Bergakademie Freiberg, Institut für Metallformung.

However, one problem has remained a stumbling block: To activate the memory effect, current materials must be heated to 400°C, too high for applications involving concrete, mortar, and other heat-sensitive materials.

Empa researchers led by Christian Leinenbach succeeded in developing a novel iron-manganese-silicon SMA alloy that is activated at just 160°C, a temperature more suitable for use with concrete. The materials scientists designed a range of virtual alloys using thermodynamic simulations and selected the most promising combinations. These were manufactured in the laboratory and their shape memory characteristics tested, with great success. Several of the new materials met construction industry requirements, an important milestone on the path to providing economic shape memory steel alloys for real-world applications. *For more information: Christian Leinenbach, christian.leinenbach@empa.ch, +415.876.545.18, www.empa.ch.*

Materion Brush Beryllium & Composites, Elmore, Ohio, received a supply contract from **Lockheed Martin,** Bethesda, Md., for proprietary AlBeCast aluminum-beryllium investment cast components for the F-35 Lightning II's Electro-Optical Targeting System (EOTS). Materion, now pursuing qualification with Lockheed Martin for EOTS components, is the current supplier of the AlBeMet alloy for EOTS. Al-Be materials and castings feature ultra-light weight, stiffness, mechanical stability, and excellent thermal properties. materion.com, lockheedmartin.com.

Universal Stainless, Bridgeville, Pa., achieved GE Aviation's S-400 and S-1000 approvals for its Bridgeville, Dunkirk, and North Jackson facilities. The company is now confirmed as a certified materials testing laboratory for **GE Aviation,** as well as a material supplier with the requisite quality processes to meet GE's rigorous standards. univstainless.com.

briefs

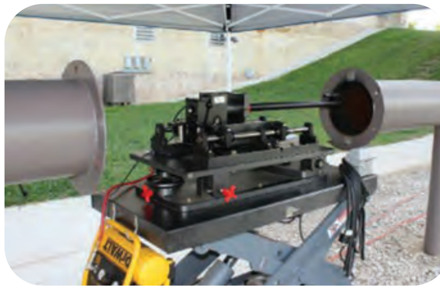
Researchers in the Department of Chemistry and Department of Physics at the **University of North Florida,** Jacksonville, received a grant from the **National Science Foundation's** Major Research Instrumentation program. Led by chemistry professor Christos Lampropoulos, the team was awarded more than $407,000 to support the purchase of a single-crystal x-ray diffractometer, used to determine the structure of small molecules and macromolecules. It will allow researchers to identify the positions of atoms within the molecular structure as well as bonds between atoms and many other details. unf.edu.

Analytik Jena AG, Germany, a manufacturer of analytical measuring technology, will acquire the Inductively Coupled Plasma Mass Spectrometry (ICP-MS) business of **Bruker Corp.** The transaction is expected to close this month. In 2013, Bruker generated revenue of approximately $12 million with its ICP-MS business, which it acquired from Varian Inc. in 2010. The global ICP-MS market is expected to be among the fastest growing markets in the area of spectroscopy with annual growth rates between 5-8% over the next five years. www.analytik-jena.de.

Bruker Corp., Billerica, Mass., acquired **Vutara Inc.,** a supplier of high-speed, 3D super-resolution fluorescence microscopy for life science applications. Vutara's estimated revenue for 2014 is expected to be approximately $2 million. Super-resolution microscopes can break the optical diffraction limit by an order of magnitude, opening up research opportunities in single-molecule, cellular, and neurobiology processes. bruker.com.

New ballistics lab supports aerospace research

Wichita State University's National Institute for Aviation Research (NIAR) recently opened a new Ballistics and Impact Dynamics Research Lab in the former Britt Brown Arena at the Kansas Coliseum in Wichita. The new lab, part of NIAR's environmental test labs, uses a custom ballistic firing device to propel 22-50 caliber rounds into components inside a concrete containment building. The test is designed to simulate the impact of a structural failure on the aircraft. The lab, led by director Paul Jonas, aims to better understand the dynamics of impact and material performance.



Wichita State University's National Institute for Aviation Research recently opened a new Ballistics and Impact Dynamics Research Lab. Courtesy of Wichita State.

"Traditional ballistic test ranges are hard to access and provide little information to designers on how to make products safer and more reliable," says Jonas. "This lab couples the material and analytical strengths of NIAR with a unique ability to capture data about the impact event and how the material behaves under those conditions."

The lab's headquarters is a control tower built on the side of the former arena, which overlooks and monitors all activities. Testing occurs within a heavily reinforced 25 × 25-ft concrete containment building designed to capture ballistic rounds and contain potential failure of pressurized oxygen bottles. The containment tower can used for drop tests up to 35 ft. High-speed cameras and data recording equipment are also essential elements of the lab.

Lab capabilities include the ability to accommodate various projectile styles including tumbling rounds, over-pressure burst testing and high-risk testing, ballistic impact of materials or structure under load, ballistic protection and impact loading, tests of pressure vessels and oxygen tanks, bonfire testing, and environmental testing. Rounds can be fired from 25, 50, 75, and 100 ft. The lab is also planning to add bird strike and high-velocity projectile capabilities later this year. *wichita.edu.*

Atomic force microscope can detect individual virus

Laser physicists at the Australian National University (ANU), Canberra, discovered a way to make atomic force microscope (AFM) probes 20 times more sensitive and capable of detecting forces as small as the weight of a single virus. The technique involves using laser beams to cool a nanowire probe to -265°C. The development could be used to improve the resolution of AFMs, advanced tools that measure nanoscopic structures and tiny forces between molecules. AFMs achieve extraordinary sensitivity measurements of microscopic features by scanning a wire probe over a surface. However, the probes—around 500 times finer than a human hair—are prone to vibration.

Ph.D. students Giovanni Guccione (left) and Harry Slatyer examine their gold-coated nanowire probe in the Quantum Optics Laboratory at Australian National University.

The team used a 200-nm-wide silver gallium nanowire coated with gold as the force sensor. The laser makes the probe warp and move due to heat. However, the probe cannot be used while the laser is on, as the laser effect overwhelms the sensitive probe. The laser must be turned off and any measurements quickly made before the probe heats up within a few milliseconds. By making measurements over a number of heating and cooling cycles, an accurate value can be determined. *www.anu.edu.au.*

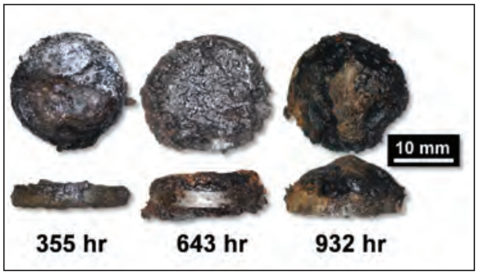
Study points to impending corrosion failures at gas stations

According to the National Institute of Standards and Technology (NIST), Gaithersburg, Md., a hidden hazard lurks beneath many of the roughly 156,000 gas stations across the U.S.—corrosion in parts of underground gas storage tanks that could result in failures, leaks, and groundwater contamination. In recent years, field inspectors in nine states have reported many rapidly corroding gas storage tank components such as sump pumps. The incidents are generally associated with use of gasoline-ethanol blends and the presence of bacteria that convert ethanol to acetic acid, a component of vinegar.

Following these findings, a NIST laboratory study demonstrated severe corrosion—rapidly eating through 1 mm of wall thickness per year—on steel alloy samples exposed to ethanol and acetic acid vapors. Gas stations may need to replace submersible pump casings, typically made of steel or cast iron, sooner than expected. Such retrofits could cost an estimated $1500 to $2500 each. The study focused only on sump pump components, located directly below access covers at filling stations. The pumps move fuel from underground tanks to fuel dispensers.

Much of the U.S. fuel infrastructure was designed for unblended gasoline. However, ethanol is now widely used as a gasoline additive due to its oxygen content and octane rating. For the study, researchers developed new test methods and equipment to examine copper and steel alloy samples either immersed in ethanol-water solutions inoculated with bacteria, or exposed to the vapors above the medium. Corrosion rates were measured over 30 days.

The study confirmed damage similar to that seen on sump pumps by field inspectors. The worst damage was found on steel exposed to the vapors. Copper in both the liquid and vapor environments also sustained damage, but corrosion rates were slower. Although slower, localized corrosion was observed on cold-worked copper, used in sump pump tubing. Stress-corrosion cracking is a concern for bent copper tubing because it would greatly reduce tube lifetime and result in leaks. Test equipment developed for the study could be used in future investigations of special coatings and biocides or other ways to prevent failures and leaks. *nist.gov.*



Optical micrographs of severe corrosion on steel alloy samples exposed to ethanol and acetic acid vapors—conditions typical of underground gas storage tanks—after 355 hours, 643 hours, and 932 hours. Courtesy of NIST.

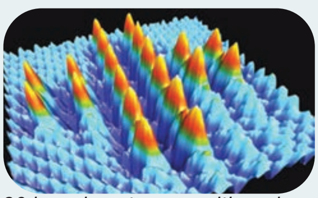
industry news

Emerging Technology

briefs

Sensitive electro-optical imaging systems will achieve new levels of sensitivity performance due to a breakthrough "super black" material launched at the **Farnborough International Air Show** in July by **Surrey NanoSystems,** London. Vantablack is said to be revolutionary in its ability to be applied to lightweight, temperature-sensitive structures such as aluminum while absorbing 99.96% of incident radiation, believed to be the highest ever recorded. The new material is the result of applying Surrey's low-temperature carbon nanotube growth process to the **UK Technology Strategy Board's** Space for Growth program, working with the **National Physical Laboratory** and **Enersys' ABSL Space Products** division. surrynanosystems.com.

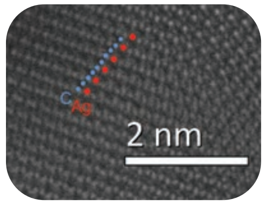
Together with teams from Finland and Japan, physicists from the **University of Basel,** Switzerland, were able to place 20 single atoms on a fully insulated surface at room temperature to form the smallest Swiss cross ever made. This is a big step towards next-generation atomic-scale storage devices. www.unibas.ch.



20 bromine atoms positioned on a sodium chloride surface using the tip of an atomic force microscope at room temperature, creating a 5.6-nm Swiss cross. The structure is stable at room temperature and was achieved by exchanging chlorine with bromine atoms. Courtesy of University of Basel.

MS&T14 highlights covetic nanomaterials

Covetic nanomaterials are metals that contain a highly stable and tenacious nanocarbon phase, increasing the thermal and electrical conductivity of the alloy. This phase is unusual because it survives remelting in air, is detectable by energy dispersive spectroscopy but not combustion infrared detection, and has little effect on overall density even at 4 wt% concentration. MS&T14 will feature two lectures on October 15 to share new information about the structure and processing of copper and aluminum. Details are available at tinyurl.com/MSandT-2014-Nano.



High-resolution transmission electron microscope image of Ag cv. 3%.

10:00 a.m. Graphene-like Nanocarbon Structures in Metal Matrices: Structure, Processing, and Applications

10:40 a.m. The Production and Properties of Copper and Aluminum Covetic Nanomaterials

From coconuts to car parts

Essentium Materials LLC, College Station, Texas, is making automotive trunk liners and battery pack covers (load floors) for electric cars using a composite material made of coconut husks combined with recycled plastics. The new material is greener and more economical, as well as stronger and stiffer, than traditional all-synthetic plastic fibers.

Approximately 50 billion coconuts fall from trees annually worldwide. The husk and shell, typically discarded, are now being used to make automotive parts such as this Ford Focus electric vehicle load floor made with coconut fiber composite. Courtesy of Essentium Materials and SPE Automotive Div.

Researchers estimate that replacing synthetic polyester fibers with coconut husk fibers, known as *coir,* will reduce petroleum consumption by 2-4 million barrels annually. In addition, the improved performance and lighter weight will lead to increased fuel economy, saving up to 3 million gallons of gasoline per year in the U.S. alone, says inventor Elisa Teipel.

The team worked with several manufacturing companies to develop different material blends and processing techniques. Essentium now works in the Philippines with local groups to extract fibers from husks and shells, with labor conducted close to the plants where coconut milk and meat processing occur. Fibers are separated from the husk, shipped to the U.S. and combined with other fibers, and turned into a felt-like material that is formed into vehicle parts. The work is supported by a $1 million grant from the National Science Foundation through its small business innovation research program in the directorate for engineering. *essentiummaterials.com.*

Material bends like microscopic hair

Engineers at Massachusetts Institute of Technology, Cambridge, fabricated a new elastic material coated with microscopic, hairlike structures that tilt in response to a magnetic field. Depending on the field's orientation, the microhairs can tilt to form a path through which fluid can flow. In addition, the material can even direct water upward, against gravity.

A new material designed by MIT researchers is a flexible polymer skin coated with microhairs (white lines) that tilt in response to a magnetic field. Courtesy of the researchers.

Each microhair, made of nickel, is about 70 μm high and 25 μm wide. Researchers fabricated an array of the microhairs onto an elastic, transparent layer of silicone. In experiments, the magnetically activated material directed not just the flow of fluid, but also light — similar to how window blinds tilt to filter the sun. Researchers say the work could lead to waterproofing and anti-glare applications, such as smart windows for buildings and cars. *mit.edu.*

industry news

Energy Trends

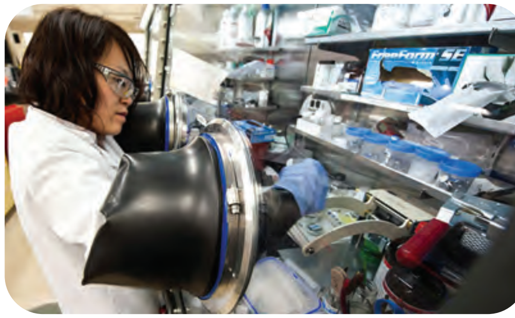
briefs

The U.S. Department of Energy (DOE), Washington, will extend funding totaling $14 million over four years for an **Energy Frontier Research Center (EFRC)** first established at DOE's **Brookhaven National Laboratory** in 2009. Dubbed the Center for Emergent Superconductivity, the EFRC is led by Brookhaven with partners from the **University of Illinois** at Urbana-Champaign and DOE's **Argonne National Laboratory,** Chicago, with the aim of understanding the fundamental nature of superconductivity in complex materials—a potentially transformative property that could revolutionize energy distribution and storage. energy.gov, anl.gov, bnl.gov, illinois.edu.

To help design more sustainable buildings, **Dow Corning Corp.,** Midland, Mich., introduced an air and water barrier system. Evaluated by the Air Barrier Association of America, the Dow Corning Silicone Air Barrier System is a suite of compatible high-performance silicone technologies designed to work together to better protect the entire building envelope and improve energy efficiency. The system meets NFPA 285 and is NFPA Class A/UBC Class 1 per ASTM E84. It can be used on both new construction and renovation projects, and its low-VOC formula makes it suitable for green construction. dowcorning.com.

Nanotubes boost batteries

Researchers at the DOE's National Renewable Energy Laboratory (NREL), Golden, Colo., are turning to extremely tiny tubes and rods to boost power and durability in lithium-ion batteries, the energy source for cell phones, laptops, and electric vehicles. If successful, the batteries will last longer and perform better, leading to a cost advantage for electric vehicles.



NREL Scientist Chunmei Ban assembles a lithium-ion battery in the materials lab at the Solar Energy Research Facility at NREL. Courtesy of Dennis Schroeder, NREL.

Scientists created crystalline nanotubes and nanorods to attack the major challenges inherent in lithium-ion batteries—they can get too hot, weigh too much, are not great conductors of electricity, and do not rapidly charge and discharge. NREL's most recent contribution toward much-improved batteries are high performance, binder-free, carbon-nanotube-based electrodes. The technology has attracted interest from industry and is being licensed to NanoResearch Inc. for volume production. *nrel.gov.*

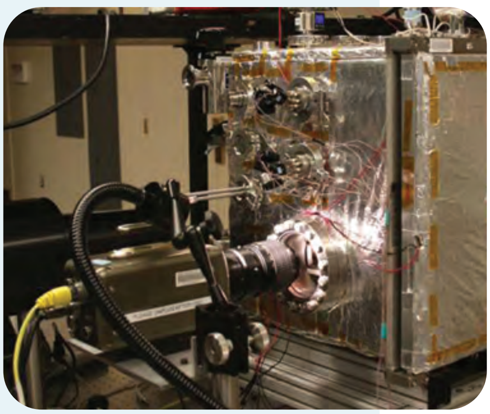
Two-bladed wind turbines save materials, costs

Several major wind-power companies are testing a departure from the industry's standard three-bladed turbine design by eliminating one of the blades and spinning the rotor 180° to face downwind. By some estimates, two-bladed turbines could cost 20% less to build and install while generating the same amount of power as conventional turbines.

Two-bladed wind turbines, like this one in China, could lower the cost of wind power.

China's Ming Yang Wind Power recently announced plans for the largest test of the new design to date. It will erect a six-megawatt, two-bladed turbine in China this year that will generate as much power as the largest commercial offshore turbines. Ming Yang plans to build another in Norwegian waters next year.

Two-bladed turbines cost less because they use fewer materials. Removing one blade also makes the rotor lighter, which in turn makes it possible to place the rotor on the downwind side of the tower. Conventional rotors face the wind and must resist bending back into the tower, but downwind rotors can use lighter and even hinged blades that bend away from heavy gusts. Light, flexible rotors translate into further materials savings in the gearbox, tower, and foundation. The 140-m-diameter rotor, gearbox, and generator for Ming Yang's prototype weigh just 308 tons—about 40 tons less than those of Siemens' conventional six-megawatt offshore turbines. *http://ir.mywind.com.cn.*



Generating electricity one drop at a time

Last year, Massachusetts Institute of Technology, Cambridge, researchers discovered that when water droplets spontaneously jump away from superhydrophobic surfaces during condensation, they can gain electric charge in the process. Now, the same team demonstrated that this process can generate small amounts of electricity that might be used to power electronic devices. The device itself could be simple, consisting of a series of interleaved flat metal plates, explains researcher Nenad Miljkovic. Although initial tests involved copper plates, he says any conductive metal would do, including aluminum, which is less expensive. *For more information: Nenad Miljkovic, 617.981.9247, nmiljkov@mit.edu, web.mit.edu.*

Experimental chamber as seen from the front, with high-speed camera looking in from the left. Courtesy of Nenad Miljkovic and Daniel J. Preston.

Bouncing water creates efficient power

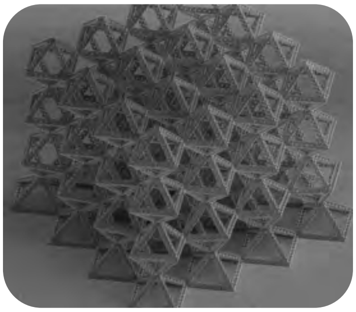
In a Brigham Young University lab, Provo, Utah, mechanical engineering professor Julie Crockett analyzes water as it bounces like a ball and rolls down a ramp. This phenomenon occurs because Crockett and her colleague Dan Maynes created a sloped channel that is superhydrophobic—extremely difficult to wet. “Our research is geared toward helping to create the ideal superhydrophobic surface,” says Crockett. “By characterizing the specific properties of these different surfaces, we can better pinpoint which types of surfaces are most advantageous for each application.”

Superhydrophobic surfaces cause water to bead up like a ball. Courtesy of Jaren Wilkey.

The superhydrophobic surfaces researchers are testing in the lab fall into one of two categories—surfaces with micro posts or surfaces with ribs and cavities one-tenth the size of a human hair. To create these microstructured surfaces, a process similar to photo film development that etches patterns onto CD-sized wafers was used. Researchers then add a thin water-resistant film to the surfaces, such as Teflon, and use ultra-high-speed cameras to document the way water interacts when dropped, jetted, or boiled on them. Slight alterations in the width of the ribs and cavities, or the angles of the rib walls, significantly change the water’s responses. *For more information: Julie Crockett, crockettj@byu.edu, byu.edu.*

Nanotrusses as future structural materials

An elaborate fractal structure is the latest example of what Julia Greer, professor of materials science and mechanics at California Institute of Technology, Pasadena, calls a fractal nanotruss. Her group developed a three-step process for building such complex structures very precisely. A direct laser writing method called two-photon lithography is first used to “write” a 3D pattern in a polymer, allowing a laser beam to crosslink and harden the polymer wherever it is focused. At the end of the patterning step, the parts of the polymer that were exposed to the laser remain intact while the rest is dissolved away, revealing a 3D scaffold. The polymer scaffold is then coated with a continuous, very thin layer of a material, which can be a ceramic, metal, metallic glass, semiconductor, or “just about anything,” Greer says. In this case, they used alumina or aluminum oxide to coat the scaffold. In the final step, they etch out the polymer from within the structure, leaving a hollow architecture.



An elaborate fractal structure could be used for structural engineering materials. Courtesy of L. Meza, et al., Caltech.

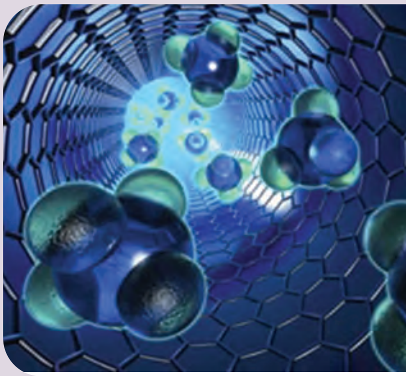
Taking advantage of some of the size effects that many materials display at the nanoscale, these nanotrusses can have unusual, desirable qualities. For example, intrinsically brittle materials, like ceramics, including the alumina shown, can be made deformable so that they can be crushed and still rebound to their original state without global failure. *For more information: Julia Greer, 626.395.4127, jrgreer@caltech.edu, caltech.edu.*

Metco joins Oerlikon Group

The Oerlikon Group, Switzerland, acquired Metco from Sulzer AG ahead of schedule. Oerlikon Balzers and Oerlikon Metco now form Oerlikon’s Surface Solutions Segment. Oerlikon Balzers is a global technology leader in the PVD thin film business, while Oerlikon Metco is involved in the thermal spray and surface applications business. Oerlikon Metco officials say they plan to emulate Oerlikon Balzers’ service approach to further grow the thermal spray service business. *oerlikon.com/metco.*

briefs

Researchers from **Isfahan University of Technology,** Iran, produced biocompatible materials based on a metallic alloy to modify tissue engineering materials properties. The nanostructure is corrosion resistant and connects well with bones. A combination of nanostructured bilayer coatings was used in production. In addition to increasing corrosion resistance in the substrate sample (magnesium alloy), the method improves connectivity of the artificial implant with the bone. Cells cannot tell the difference between the bone and implant due to the chemical similarity between the surface of bioactive glass used in the coating and the inorganic section of the bone. www.iut.ac.ir/en.



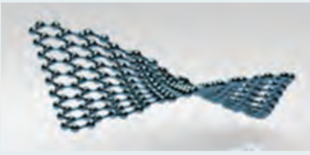
A new biocompatible nanocoating resists corrosion and connects well with bones.

Saint-Gobain, France, finalized the acquisition of **Phoenix Coating Resources Inc.,** Mulberry, Fla. Phoenix manufactures ceramic ingots used to produce high-resistance thermal coatings on metal parts for the aeronautics industry. The aim is to improve the energy efficiency of aircraft engines by enabling them to operate at higher temperatures. The acquisition allows Saint-Gobain to expand its range of aerospace coatings. saint-gobain-northamerica.com.

industry news

NANOTECHNOLOGY

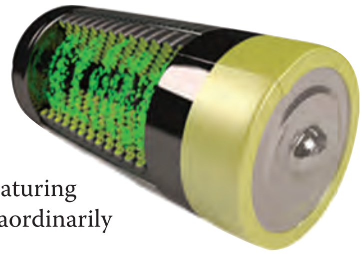
briefs



The University of Manchester, UK, will host Graphene Week 2015 next June. Isolated at Manchester in 2004, graphene has captured the attention of scientists worldwide with its potential to revolutionize the materials world due to its incredible properties. As the world's first 2D material, it is ultra-light, yet immensely tough; it is 200 times stronger than steel, but is incredibly flexible; and it is fire retardant yet retains heat. The university is also building a $28.3 million National Graphene Institute (NGI), set to open in spring 2015. www.manchester.ac.uk.

A project at **IBM,** Armonk, N.Y., aims to build transistors with carbon nanotubes, which are expected to replace silicon transistors around 2020. According to the semiconductor industry's roadmap, transistors will then require features as small as 5 nm to keep up with the continuous shrinking of computer chips. The company recently made chips with 10,000 nanotube transistors and is now working on a transistor design that could be built on silicon wafers used today with minimal changes to existing design and manufacturing methods. Simulations suggest that these new microprocessors could be five times as fast as silicon ones using the same amount of power. ibm.com.

Ramping up lithium-sulfur batteries



Novel nanofibers hold promise for advanced lithium-sulfur batteries. Courtesy of LMU.

Chemists at the Nanosystems Initiative Munich Cluster at Ludwig Maximilian University of Munich (LMU) and at the University of Waterloo, Ontario, synthesized a new material that could lead the way to state-of-the-art lithium-sulfur batteries. They produced a novel type of nanofiber featuring a highly ordered and porous structure that gives it an extraordinarily high surface-to-volume ratio.

"The high surface-to-volume ratio and high pore volume are important because they allow sulfur to bind to the electrode in a finely divided manner, with relatively high loading. This enhances the efficiency of the electrochemical processes that occur in the course of charge-discharge cycles. And the rates of the key reactions at the sulfur electrode-electrolyte interface, which involve both electrons and ions, are highly dependent on the total surface area available," explains chemistry professor Thomas Bein.

To synthesize the carbon fibers, chemists prepared a porous, tubular silica template, starting from commercially available, but nonporous fibers. This template is then filled with a special mixture of carbon, silicon dioxide, and surfactants, which is heated at 900°C. Finally, the template and the SiO_2 are removed by etching. During this process, the carbon nanotubes—and pore size—shrink more than they would without the confining template, and the fibers themselves become more stable. *www.en.uni-muenchen.de.*

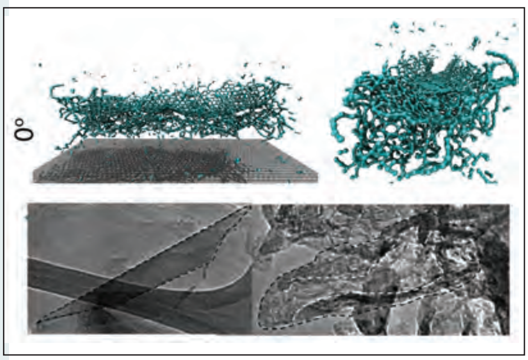
BNNT LLC, Newport News, Va., has made its new boron nitride nanotubes (BNNTs) available. BNNTs are as strong as their more famous cousin, carbon nanotubes, but are superior in many ways. For example, they have a much higher resistance to heat, high voltage, and neutron radiation. Unlike most nanotube products, which occur in powder form, the new BNNTs are cotton-like in appearance. At the molecular scale, they are thin—about 3-5 nm in diameter—as well as highly crystalline, few-walled, and feature aspect ratios approaching one million. bnnt.com.

Shooting nanoribbons

The Rice University lab of materials scientist Pulickel Ajayan, Houston, discovered that nanotubes that hit a target end-first generally turn into ragged clumps of atoms. But nanotubes that happen to broadside the target unzip into handy ribbons, which can be used in composite materials for strength as well as in applications that take advantage of their desirable electrical properties.

Researchers fired pellets of randomly oriented, multiwalled carbon nanotubes from a light gas gun built by the lab of materials scientist Enrique Barrera with funding from NASA. Pellets impacted an aluminum target in a vacuum chamber at about 15,000 mph. When the resulting carbon rubble was inspected, nanotubes that smashed into the target end-first or at a sharp angle simply deformed into crumpled tubes. But ones that hit lengthwise actually split into ribbons with ragged edges.

According to Ajayan, the process eliminates the need to clean chemical residues from nanoribbons produced through current techniques. "One-step, chemical-free, clean, and high-quality graphene nanoribbons can be produced using our method. They are potential candidates for next-generation electronic materials," he says. *For more information: Pulickel Ajayan, 713.348.5904, ajayan@rice.edu, rice.edu.*



Molecular simulations and electron microscope images show what happens to a carbon nanotube when the end of it strikes a target directly at about 15,000 mph—they split into useful nanoribbons. Courtesy of Ajayan Group/Rice University.

Validating Models Using 3D Microstructural Characterization

R.W. Fonda, FASM*
D.J. Rowenhorst
Naval Research Laboratory, Washington

In order to take full advantage of the promise of recent computational efforts, new microstructural models that consider realistic shapes, connectivities, and distributions are required. This can only be achieved through 3D characterization.

The microstructures present in any given material are typically described through characterizing observations of 2D sections through that material. Next, the proposed 3D structure is generated either through extrapolation from those 2D observations or statistical analysis of observed characteristics. However, the data obtained from 2D observations is unable to reveal actual 3D characteristics of real microstructures. Even relatively simple microstructures exhibit complexities only revealed through 3D analysis, and more complex microstructures present in many advanced alloys often preclude accurate determination of the 3D structure from 2D sections.

A material's microstructural characteristics are often used to predict its behavior. Further, a material's properties are directly related to its constituent microstructures, and this fact is used to develop models and formulae that relate microstructural features to properties that depend on them. However, real microstructures typically exhibit complex shapes and morphologies, a distribution of characteristic feature sizes, and variations in spatial arrangements and connectivities often unpredicted based on 2D sections. For example, while the largest particle size can be determined from a big enough 2D sampling section, the smallest particle size cannot be differentiated from off-centered sectioning of larger particles. Many properties are also more dependent on either smaller or larger feature sizes than on the average feature size used in most empirical models.

Recent efforts, most notably integrated computational materials engineering (ICME) and the Materials Genome Initiative (MGI), are using computational models to improve and accelerate new material discovery, development, and deployment. These programs require models that can accurately predict the microstructures generated by a specific thermomechanical processing route for a certain composition and, from this, predict the corresponding mechanical properties generated by that microstructure. Coupling such models to selected experimental trials for verification/validation purposes can dramatically streamline new material discovery. Accurate descriptions of relevant microstructural characteristics, however, cannot be obtained through 2D techniques. Characterizing materials in 3D is necessary to reveal the actual distributions of relevant microstructural characteristics and thereby enable development of realistic models to predict the behavior of new materials.

Grain size distributions

One of the simplest and most widely used microstructural characteristics is material grain size, which indicates the amount of work introduced into the material and the degree of recovery and/or recrystallization. Because grain size reflects both the amount of grain boundary area and the typical dimension of easy dislocation propagation, it is an important factor in many equations. In particular, the Hall-Petch relationship is an equation that expresses the relationship between a material's grain size and its strength.

A number of models have been developed to predict grain size distributions. In 1957, Feltham[1] demonstrated that a log-normal distribution can be used to describe grain size distribution. Eight years later, Hillert[2] combined the theory of Ostwald ripening with grain growth theory to develop an alternative grain size distribution. In 1974, Louat[3] developed an additional theory to predict grain size distributions based on a random diffusion-like motion of grain boundaries. These are the most common theories used to model grain size distribution of a material.

Direct validation of predicted grain size distributions is difficult. While there are interpolations from 2D measurements, they typically

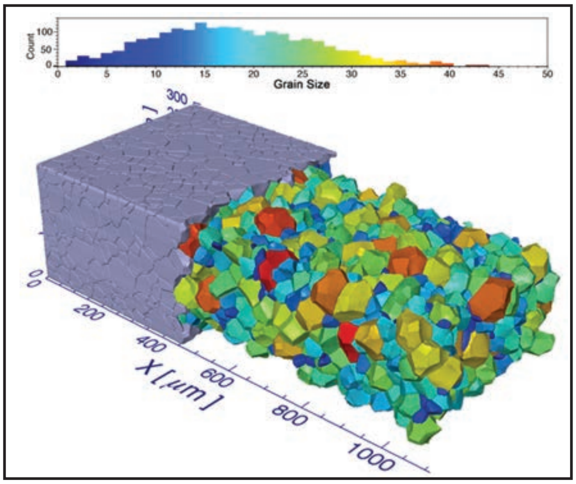


Fig. 1 — *3D reconstruction of grains in a β-titanium alloy colored according to grain size.*

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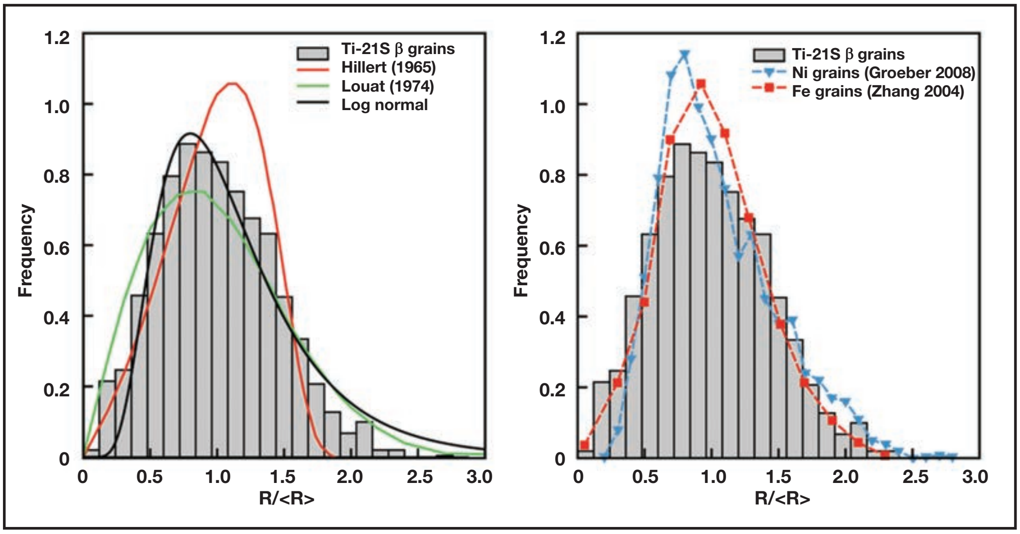

Fig. 2 — *Comparisons between the equivalent sphere radius grain sizes obtained from β-titanium 3D reconstruction and grain size distributions predicted by common models (left) and measured in other alloys (right).*

make poor assumptions such as spherical grain shapes. However, the increase in 3D microstructural analysis has led to a number of datasets that can make direct comparisons to these models. One example shown in Fig. 1 is the serial sectioning of a β-titanium alloy, wherein 200 serial sections spaced 1.5 μm apart were stacked to reconstruct the grain morphology of more than 4000 grains.

Figure 2 plots the normalized grain size distribution and shows significant differences between the models and the experimentally determined distribution of equivalent sphere radii[4]. While the log-normal distribution fits the peak of the distribution well, it underestimates the number of small grains and significantly overestimates the number of large ones. Because a material's mechanical behavior relies more heavily on the smaller and larger tails of the grain size distribution, such variations are not acceptable.

Further discrepancies exist between this data and the two grain growth theories developed by Hillert and Louat. The Hillert distribution predicts a much sharper distribution, severely underestimating the number of large grains, while the Louat distribution is much broader, predicting a much larger population of smaller grains. Other 3D data sets acquired of the grain structures in a nickel-base superalloy[5] and recrystallized alpha iron[6] demonstrate similar shortcomings of these models in reproducing the important tails of grain size distributions. What is unclear from the small collection of 3D experimental data is whether grain size distribution is somewhat common for all alloy systems, or if there are significant deviations from these distributions that depend on intrinsic properties (such as interfacial energy anisotropies) or extrinsic conditions (such as degree of cold work before recrystallization).

Cementite precipitate morphology case study

The differences between the expectations derived from 2D analyses and the reality revealed through 3D analyses become more evident when dealing with complex shapes, connectivities, and nonuniform distributions. This was demonstrated in an early 3D study by Kral and Spanos[7]. Analysis of cementite morphologies that were visible on 2D section surfaces was performed and is shown in Fig. 3a-b. From this, it was concluded that cementite precipitates form in a variety of morphologies, with the prevalent morphologies being grain boundary allotriomorphs (which impinge to form grain boundary films), Widmanstatten sideplates, intragranular Widmanstatten precipitates, and intragranular idiomorphs.

Grain boundary allotriomorphs are oblong precipitates, generally viewed as two abutting spherical caps, located at the grain boundary that grow to impinge each other and form a continuous film along the grain boundary as precipitation progresses. Widmanstatten sideplates are elongated precipitates that nucleate at the grain boundary and extend into the matrix. Elongated precipitates that lie wholly within the grain are called intragranular Widmanstatten plates. Idiomorphs are equiaxed precipitates typically located within the matrix grain, but occasionally located at the grain boundary.

Figure 3c shows the actual 3D microstructure of this alloy, which was revealed through serial sectioning and

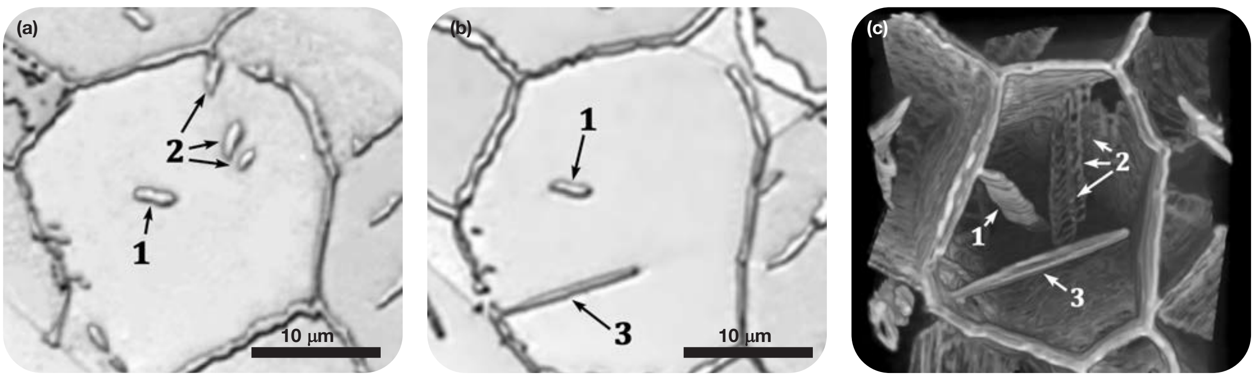

Fig. 3 — *Optical micrographs of cementite precipitation in an austenite grain, showing different morphologies and connectivities to the grain boundary of the cementite precipitates (a, b), and 3D reconstruction of that grain demonstrating that all intragranular precipitates have the same morphology and connectivity (c).*

3D reconstruction. This reconstruction demonstrated that all precipitates within the grain interior had a similar lath morphology connected to the grain boundary cementite film. In other words, the morphologies identified from the 2D analyses as Widmanstatten sideplates, intragranular Widmanstatten precipitates, and intragranular idiomorphs were actually a single precipitate morphology—a Widmanstatten sideplate. The different apparent morphologies observed on the 2D surface resulted from sectioning these Widmanstatten precipitates in different orientations.

The 3D reconstruction of the grain boundary cementite precipitate film exhibits an unexpected characteristic—holes in the grain boundary films appeared more irregular than expected from the growth and impingement of allotriomorphic precipitates. Etching away the matrix to expose the cementite grain boundary film demonstrates that grain boundary precipitates initially exhibit a dendritic morphology instead of the classical allotriomorphic morphology reported from 2D analyses. Further precipitation causes impingement of the dendrite arms to form the observed grain boundary film. Random 2D cross-sections of the dendritic structure reveal a row of dendrite arm cross-sections, appearing to be isolated allotriomorphs at the grain boundary. Only 3D analysis allows the correct dendritic morphology to be identified.

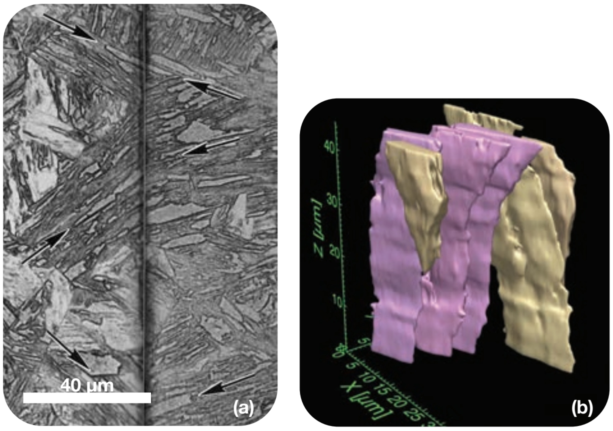

Fig. 4 — *Optical micrographs from two perpendicular surfaces showing typical appearance of the coarse martensite on each face and selected martensite constituents with large dimensions on both faces (a), and 3D reconstruction of two coarse martensite orientations (b, indicated by color).*

Coarse martensite case study

Another example of the importance of 3D analysis for accurate determination of microstructural features involves a coarse martensitic component observed in low carbon steels[8]. This coarse martensite, called *coalesced bainite* by some researchers[9], typically exhibits a flat interface at one end and either a rough face or a tapered morphology at the other. Analysis of coarse martensite on two perpendicular faces of the sample, as in Fig. 4a, demonstrate that individual precipitates can exhibit large dimensions in those two directions, indicating a plate morphology. In addition, the occasional observation of large, approximately equiaxed martensite constituents on a single 2D surface suggest that these were martensite plates observed nearly parallel to the broad face of the plate.

However, serial sectioning and 3D reconstruction of this coarse martensite, shown in Fig. 4b, reveals that the actual morphology of the typical coarse martensite constituent[10] is that of a lath—a long, thin precipitate with a moderate width. The observed length of a 2D surface varies with sectioning orientation, and lath orientations near 45° can even exhibit the long dimensions on two perpendicular surfaces that were originally used to identify and confirm a plate morphology. Further, 3D reconstruction of the 2D equiaxed morphology, initially thought to be plan-view images of the martensitic plate, demonstrate that these are cross-sections of a similar, but thicker, lath morphology[11].

Conclusions

As ICME, MGI, and other microstructure-based modeling efforts become more prevalent, it is increasingly important to develop and apply accurate microstructural models to correctly predict a material's behavior. These models are often limited by knowledge of the morphology, connectivity, and distribution of features within the actual structure. Current models are typically based on a uniform distribution of an average feature characteristic (such as grain size) determined from 2D polished sections. To take full advantage of the promise of recent computational efforts, new microstructural models that consider realistic shapes, connectivities, and distributions are required. This can only be achieved through 3D characterization.

Even relatively simple microstructural features such as grain size distributions cannot be determined accurately through 2D analysis. Grain size is a critical component of many microstructure-dependent property models, so accurate representation of grain size is important. Characterizing the more complex microstructural features prevalent in many advanced alloy systems and modeling their influence is even more difficult from 2D sections, and requires 3D analysis. Both microstructure evolution models and microstructure-dependent property models need to have accurate microstructures as input.

The three different cementite precipitate morphologies proposed from 2D observations all exhibit different growth rates and properties, and the grain boundary precipitates grow and impinge at different rates than the actual precipitate morphologies observed through 3D analysis. Similarly, the correct lath morphology of the coarse martensite found in low carbon steels through 3D analysis will grow and affect the properties of the alloy differently than the plate morphology assumed from 2D and even two-surface analyses. Predictions based on 2D observations cannot accurately represent the real structure of a material. Instead, 3D analysis is required to determine the correct morphology, connectivity, and distribution of the characteristic features. ❍

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Acknowledgments

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Structural Intermetallics:
Alloy Design, Processing, and Applications

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Structural intermetallics offer a number of attractive choices to address an urgent need for materials that can endure harsh environments for extended periods.

Maintaining our current standard of living will require not only an abundant energy supply, but also one that is environmentally benign. This reality is motivating the drive toward enhanced efficiency in energy production. The majority of energy sources that involve thermal production—including fossil, nuclear, and even concentrated solar power—require increased operating temperatures and materials that can withstand an aggressive, high-temperature environment for long periods. Structural intermetallics offer a number of attractive materials choices to address these needs.

A myriad of intermetallic alloy phases are available, with unique capabilities ranging from electronic properties (such as permanent magnet and thermionic emission characteristics) to specific chemical behavior (for use in catalysts and sensors, and for corrosion and oxidation resistance). However, the use of intermetallic alloys in structural applications has lagged after substantial progress in the 1980s and 90s. One reason is that the fundamental characteristics that impart intermetallics with exceptionally high modulus and strength present challenges to achieving useful ductility and fracture toughness. However, the outlook for structural applications is changing. As the fundamental understanding of deformation behavior and defect structure has evolved, it has provided valuable guidance to enable advances in alloy design and materials processing. These advances have moved some intermetallics, such as Ti aluminides, from the laboratory into full scale structural applications. Later this month, the structural intermetallics symposium at Materials Science & Technology 2014 in Pittsburgh will highlight some of these advances as well as progress in newer refractory metal silicide alloys for ultrahigh temperature applications. See sidebar for details.

Commercial applications

Titanium aluminide alloys based on the γ-TiAl phase have been widely studied[1,2] and cast components are being introduced into gas turbine engines and turbochargers (Fig. 1). These commercial successes are the result of a multifaceted design approach to modify the natural highly ordered structure to overcome pure TiAl's brittle nature. Lattice-distorting and partitioning alloying elements have been introduced, phase transformations and secondary phases are incorporated, and casting techniques and heat treatments are being used to homogenize and control grain structure. First principle calculations are also helping to develop new compositions. Resistance to dislocation movement, which dominates the fracture and fatigue crack growth behavior and limits the extent of structural applications, is also influenced by deformation twinning that results in cyclic hardening during fatigue.

Fig. 1 — *Cast 50-mm diameter TiAl automotive turbocharger.*

In most structural applications, components must be joined. Solid state joining by diffusional annealing of a foil interlayer can be an effective technique if there is control over the intermetallic phases that can form within the diffusion zone. A novel surface halogen treatment significantly improves the high temperature oxidation resistance of TiAl-type alloys. For Ti-Ni shape memory alloys, a refined and uniform intermetallic precipitate structure is favored by short annealing times.

Iron and nickel aluminides were researched extensively in the 1980s and 90s in an attempt to take advantage of their attractive high temperature corrosion resistance[3,4]. Extensive efforts were made to develop Fe_3Al, FeAl, Ni_3Al, and NiAl for a variety of structural applications. Great progress was made in increasing the high temperature creep strength of NiAl[5], but it did not displace single crystal superalloys for high temperature applications. Commercial applications include FeAl heating elements, Fe_3Al porous hot gas filters, and cast Ni_3Al rolls for

*Member of ASM International

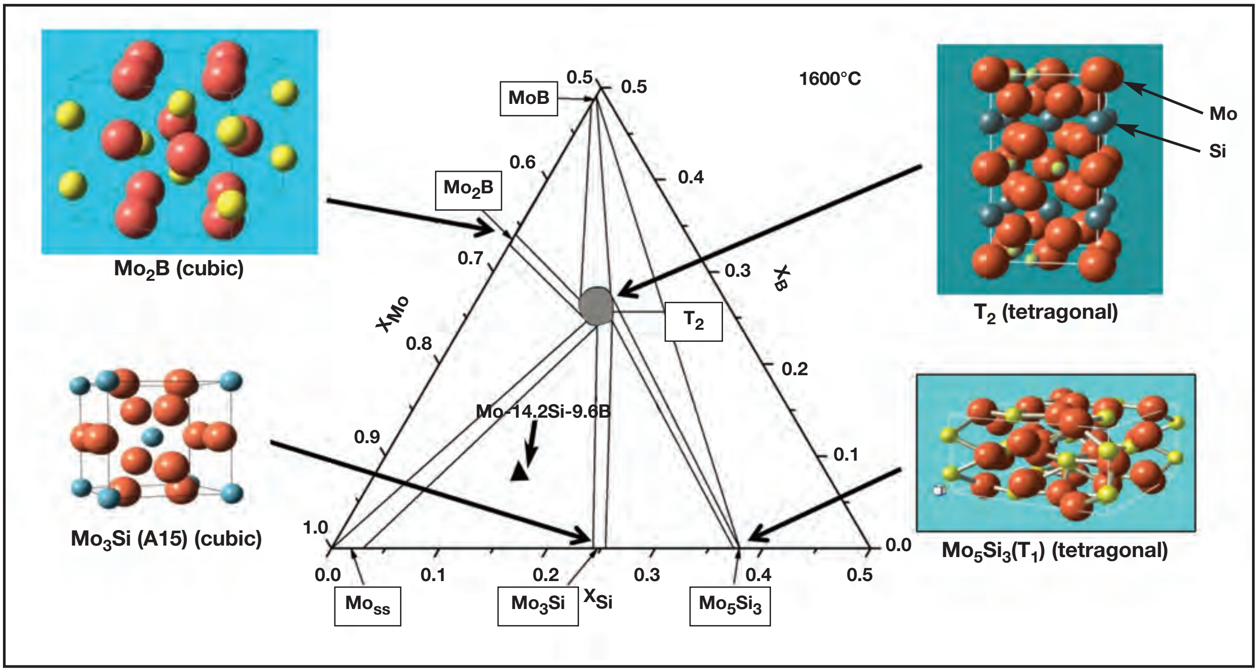

Fig. 2 — *Mo-rich portion of the Mo-Si-B ternary system featuring the Mo bcc (matrix) phase in equilibrium with the borosilicide (T_2) and silicide (Mo_3Si) phase.*

processing steel[6]. They demonstrated exceptional oxidation lifetimes with oxide dispersion strengthened Fe_3Al, but the relatively high thermal expansion coefficient for Fe_3Al and FeAl makes system design a challenge[7]. A new wave of research is now investigating new aspects of these aluminides. For example, for Fe-Al alloys, a eutectoid reaction from Fe_5Al_8 to an ultrafine (<100 nm) lamellar structure of $FeAl_2$ and FeAl yields a microstructure that can rapidly form a passivating α-Al_2O_3 scale upon oxidation without any internal oxidation.

Advances in strengthening phases

Another advance for intermetallics involves applying a wider range of strengthening phases for Fe- and Ni-base alloys. In Ni-base superalloys, the principal strengthening phase has always been γ' (Ni_3Al). However, in a number of alloy compositions such as alloy 263, the η (Ni_3Ti) phase also develops after long-term exposure. Based on a thermodynamic modeling analysis, composition modifications involving small additions of V and Ta yield an increase in the η phase volume fraction above 750°C from 5% up to 15%, which is expected to increase the high temperature strength.

Application of σ phase in new steels for ultra-supercritical steam power generation is another surprising development. Usually, σ phase formation is very sluggish so that it only develops in a microstructure after hundreds of hours of high temperature exposure and coincides with a shortening of the rupture life. However, with cleverly designed alloys and annealing processes, when σ phase is dispersed along grain boundaries, it can serve as a valuable microstructural component to enable a significant enhancement of creep resistance.

In a similar manner, austenitic steels strengthened with Heusler phases, Fe_2Nb laves phase, NiAl, and Ni_3Al precipitates are potential candidates to economically provide high strength and corrosion resistance for service above 700°C[8]. In this case, thermomechanical treatments are used to produce a refined and uniformly dispersed precipitate nanostructure in order to achieve enhanced performance. Further chemistry changes are being investigated in some high Mn compositions in order to avoid environmental embrittlement. In addition, nanostructured steels are being developed with high levels of P-group elements. In order to achieve ultrahigh temperature capability well beyond the limit of current Ni-base superalloys, refractory metal silicide intermetallics offer a number of attractive characteristics. Yet they also present challenges with regard to developing robust environmental resistance and innovative processing to achieve multiphase microstructure designs and morphologies with both high temperature strength and room temperature toughness[9-13]. Processing is an important component in alloy synthesis because the requirement for high temperature stability means that microstructure modification following the initial alloy synthesis is difficult.

For Mo-Si-B alloys, microstructure designs involving a continuous molybdenum solid solution, Mo(ss) matrix with dispersions of Mo_3Si and Mo_5SiB_2 intermetallics can achieve

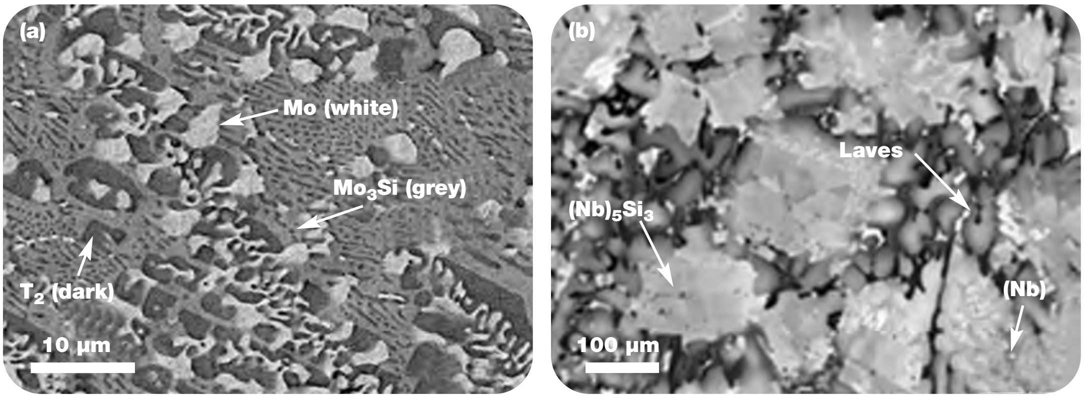

Fig. 3 — *SEM backscattered image of as-cast Mo-14.2Si-9.6B (a), directionally solidified Nb alloy (Nb-19Ti-2Hf-13Cr-2Al-4B-16Si) with dispersions of $(Nb)_5Si_3$ and $(Nb)Cr_2$ (b).*

useful toughness (Figs. 2 and 3a). The processing routes to synthesize this microstructure are based on innovative powder processing and directional solidification[14-16]. Recent developments include incorporation of TiC particle dispersions that enhance high temperature mechanical properties, reduce density to levels comparable to levels for Ni-base superalloys, and facilitate casting[17]. To achieve full density in powder processing, minor additions of elements such as Fe promote rapid sintering. The borosilica scale that develops during high temperature oxidation provides some protection, but the recession rate must be reduced, and at low temperature (i.e., 700°C) a pesting reaction develops before the borosilica can provide full coverage[18]. Both low and high temperature oxidation reactions can be inhibited by a pack cementation coating involving codeposition of B and Si that also resists calcia-magnesia-alumina-silica (CMAS) and water vapor attack[19,20].

For Nb silicides, the main alloy constitution is based on the Nb-Si-Ti system, but also includes additions of Cr and Hf. The main microstructure phases include Nb(ss) and Nb_5Si_3 with minor amounts of an $NbCr_2$ Laves phase (Fig. 3b)[10]. The Nb_5Si_3 phase features a structure of either the T_1 or T_2 phase in the Mo-Si-B system (Fig. 2) depending on temperature and composition. Again, this microstructure can be achieved through either powder processing or by solidification. However, inadequate oxidation resistance remains a significant issue with Nb-base alloys. Recent progress reveals that silicide surface layers formed due to oxidation of an $Nb_3Fe_3CrSi_6$ phase offer the potential to impart oxidation resistance[21]. Another approach to achieving effective oxidation resistance involves applying a pack cementation coating based on incorporating compatible Mo-Si-B phases.

Progress in processing

The importance of processing as a principal means of achieving certain microstructure designs is highlighted for a variety of intermetallic phases for structural applications. The synthesis of Co-W and Ni-Mo alloys provides an example of the application of high energy ball milling to form intermetallic phases such as Co_3W and Ni_3Mo with high hardness. In another example of the use of high energy ball milling, a systematic study of alloying reactions between equiatomic mixtures of Al and elements from Groups IV and V documents the intermetallic phase products and associated microstructures. Analysis of the reaction products from ball milling can often be understood by evaluating the relative free energies of formation of the competing phases as illustrated for intermetallic phase formation in Ni-Al alloys.

The pioneering research into structural intermetallics has now matured and is beginning to yield an economic benefit with increased commercialization. These advances are spurring a new wave of research that will be reported later this month at MS&T14. Structural intermetallics provide attractive materials opportunities that will help meet the energy challenges of the 21st century. ❍

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Combustion Driven Powder Compaction Green Manufacturing Enables **Higher Performance Parts**

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Manassas, Va.

A new and economical method produces near-net and net shape high-density powder metal components at higher compaction pressures than traditional processes.

Conventional manufacturing from wrought bar stock typically involves extensive machining, creates significant material waste (scrap metal), and requires numerous steps to obtain the final part geometry. As a more efficient alternative, powder metallurgical (PM) processes are now available to cost effectively fabricate both simple and complex shapes with minimal material waste.

Traditional PM methods involve pressing powders at relatively low compaction pressures, typically <50-55 tsi[1-3]. However, a new PM method called *combustion driven higher pressure powder compaction* (CDC) for near-net or net shape manufacturing[4-7] was recently developed by Utron Kinetics. CDC offers a unique way of forming near-net or net shape high-density powder metal components both cost effectively and at relatively higher compaction pressures (up to 150 tsi) using powders of various sizes and morphologies.

CDC also works with difficult-to-press metallic powders, ceramics, and composites by employing rapid high-pressure powder consolidation. Unique advantages of CDC include improved densification in both as-pressed and sintered conditions, reduced part shrinkages, enhanced materials properties with wrought-annealed equivalent behavior, improved machinability and weldability, and the capacity to fabricate both single and layered material combinations. Other benefits include rapid powder metal alloy development to improve material properties and performance, minimal need for post-process machining, and significant potential for cost reduction in parts manufacturing. Major progress has occurred during the past several years in both R&D of unique powder materials[5-7] and cost effective production methods.

Advanced applications

Various powders have been compacted into both simple and complex shapes and successfully processed. Powder materials include: Ferrous (steels, stainless steels); nonferrous (copper alloys, titanium and Ti alloys, aluminum alloys); superalloys such as Inconel 625; refractory materials including Mo-Re, W-Re, Re, Ta, Ta-W, TZM, Mo, Nb, and W-base composites[5,7]; ceramics (e.g., silicon carbide, boron carbide, tantalum carbide, hafnium carbides, tungsten carbides); composites (carbides with metal matrix composites); and various other combinations depending on the application (Figs. 4-7). Commercial high performance ap-

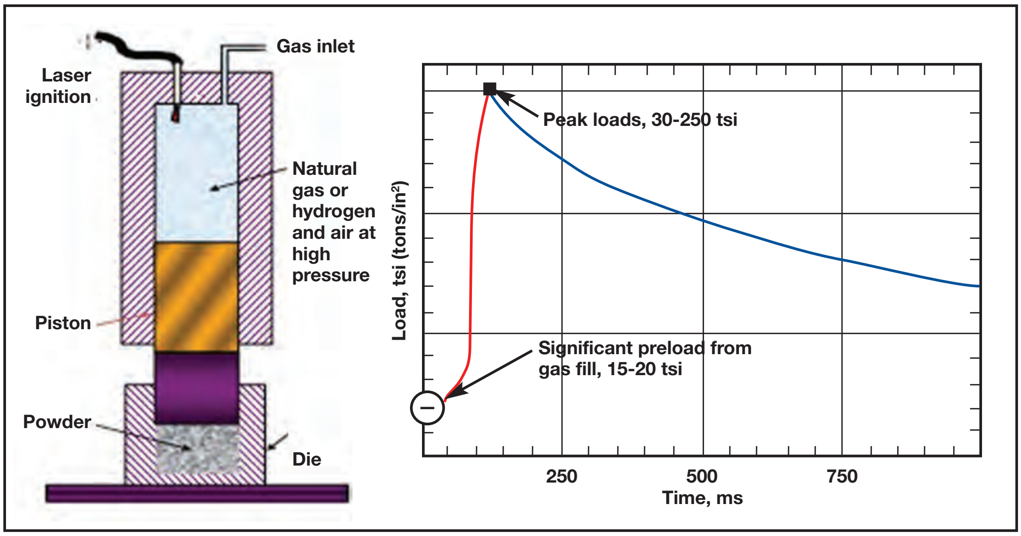

Fig. 1 — *Combustion driven higher pressure powder compaction (CDC) process schematic and rapid pressing cycle time for near-net or net shape CDC fabrication. CDC converts chemical energy directly to mechanical energy for high efficiency. A pressurized mixture of natural gas and air is ignited to drive a piston (ram). Fill gas creates preload and pushes the piston or ram down, pre-compressing and removing entrapped air from the powder. An ignition stimulus is applied, causing combustion and rapid pressure rise, further compressing the metal powder to its final net shape.*

Fig. 2 — *Various CDC presses. Left to right: 300-ton manual press, 400-ton manual press, 400-ton automated press.*

plications using CDC manufacturing include aerospace and automotive parts, rocket motor components, x-ray targets, sputtering targets, and other high-density parts using advanced refractory materials[5]. Other innovative applications involve high performance reactive materials and components, power transmission parts (e.g., gears and bearings), permanent and soft magnets with superior magnetic properties[6], RF microwave components such as flanges, seals, and windows, fuel cell electrodes/parts, optical mirror and heat sink substrates, vacuum seals, armor ceramics, and dissimilar powder pressed layered parts.

High performance PM parts often require demanding material properties, in addition to reliable performance, cost effectiveness, and tight tolerances for geometry, dimensions, and surface finishes. Some of these include high vacuum leak resistance, erosion resistance, electron emission attributes, RF voltage hold-off, high temperature endurance, and high electrical and thermal conductivity attributes. Low alloy steels such as FLN2-4405 are popular rotorcraft transmission materials, while stainless steels are useful for corrosion resistance. Popular candidate materials for RF applications include copper-base alloys, stainless steels, and microwave absorbing ceramics such as SiC, moly-rhenium, tungsten with barium and other electron-emitting compounds in the structure, ceramics such as beryllium oxide (e.g., waveguide windows), OFHC copper, niobium, aluminum, magnesium diboride, and Nb_3Sn or $(Nb,Ta)_3Sn$.

Refractory materials such as W, Mo, Ta, Ta-W, and Nb are useful for various high temperature applications. Examples include advanced superconducting cryogenic components (e.g., Nb in superconducting accelerator structures), optical mirror substrates and heat sinks (e.g., Cu, Mo, Mo/Cu), x-ray targets (W), erosion-resistant, high temperature rocket motor components, electrode components (Mo/Re, W, W/Re, Mo, or Re-base materials), Ta and Ta-W alloys for advanced defense parts and capacitors, and high performance fuel cell electrodes made of stainless steels and other corrosion-resistant materials.

CDC fundamentals

Combustion driven compaction (CDC) converts chemical to mechanical energy during the controlled combustion of natural gas or hydrogen and air. The process then uses this energy to compact powders at higher compaction pressures than traditional PM methods, up to 150 tsi. Such controlled combustion reactions that combine natural gas or hydrogen with environmentally friendly end products using the CDC method result in a "green" manufacturing technology. In operation, the following steps occur: The chamber is filled to high pressure with a mixture of natural gas and air; as the chamber is being filled, the piston or ram is allowed to move down, precompressing and removing entrapped air from the powder; the gas supply is closed and an ignition stimulus is applied, causing the pressure in the chamber to rise dramatically, further compressing the metal powder to its final net shape (Fig. 1).

The CDC process is unique in that chemical energy is directly converted to mechanical energy for rapid powder

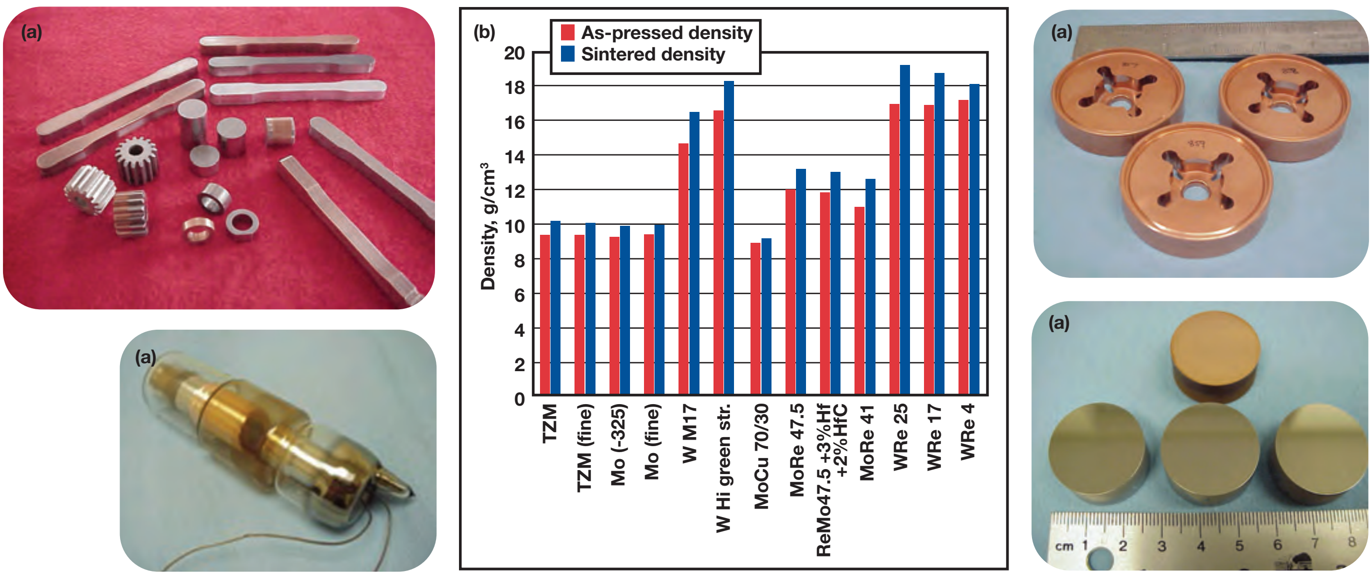

Fig. 3 — *Examples of CDC geometries using Cu-base alloys for linear collider accelerator applications, and refractory materials such as Mo for disks and W for x-ray tubes. CDC near-net shape copper has wrought-equivalent properties including high density, excellent thermal and electrical conductivity, mechanical strength of 32,000 psi, and higher ductility of 45-48% (3a). Improved densification of CDC refractory metals (3b).*

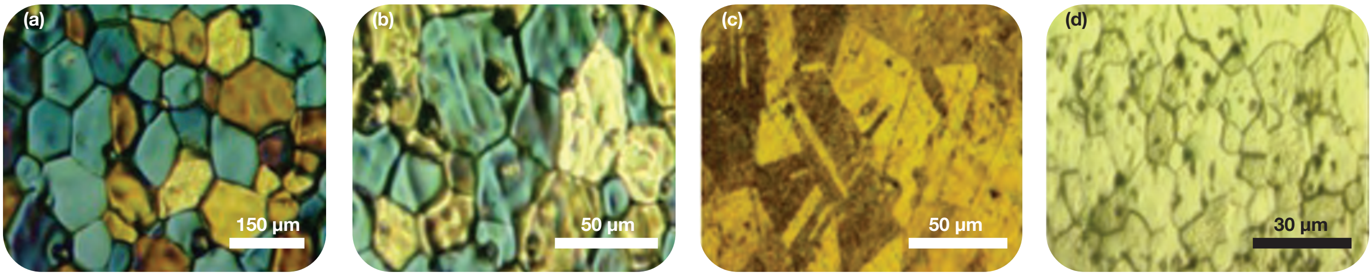

Fig. 4 — *Examples of controllable sintered microstructures under optimized processing for CDC Mo (a), TZM, a Mo alloy (b), Cu (c), and W (d).*

compaction. The process can produce either standard or super high compaction tonnages resulting in very high-density parts with improved mechanical properties. In addition to the unique loading sequence and high tonnage, the process occurs over a relatively short time frame—only a few hundred ms. Figure 3b illustrates improved densification with the CDC method compared to traditional PM processes when compacting iron powders, as one example.

Another benefit is that the CDC press itself is relatively simple and compact. For example, a 4137 MPa (300 ton) mechanical or hydraulic press is typically two floors tall and contains many moving parts and complex hydraulics. A 300-ton CDC press is not much larger than a phone booth and has one moving part (Fig. 2). When the fill gas is ignited, the ram rapidly presses down but does not slam into the tooling or powder. The process is not only fast and powerful, but also smooth and continuous. The CDC process routinely operates at compaction loads of 2069 MPa (150 tsi) in sharp contrast to conventional compaction processes, which are generally limited to 690 MPa (50 tsi).

Because the CDC press directly converts chemical energy into mechanical compaction energy, it is highly energy efficient and capable of producing enormous compaction loads. To date, several presses of increasing size have been constructed, including manual 300, 400, and 1000-ton presses as well as an automated 400-ton press in full operation (Fig. 2). Based on application needs, it is possible to further scale up the CDC press to very high tonnages without dramatically increasing the press size.

CDC material properties

The CDC process operates at compaction pressure loads of 15 to 150 tsi compared to conventional PM pressing by mechanical or hydraulic methods, which are generally limited to 50 or 55 tsi. It is widely accepted that controlled higher compaction pressures generally make a large difference in part quality, both in the unsintered and

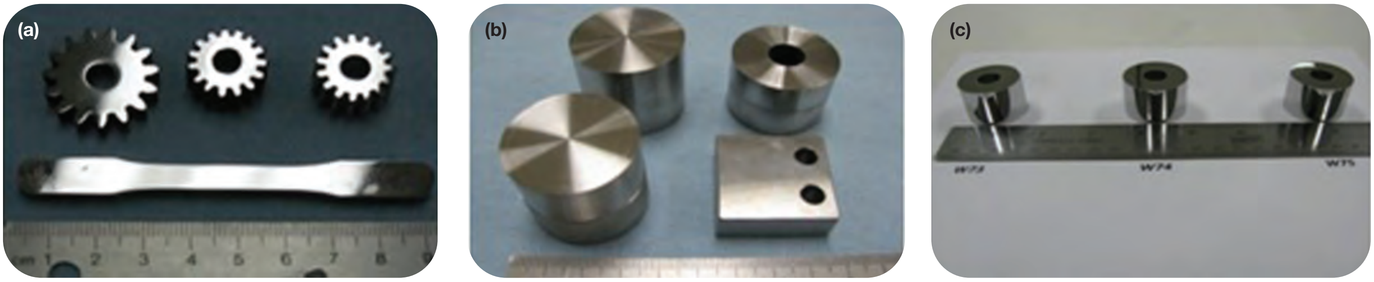

Fig. 5 — *CDC compacted and sintered/heat treated advanced stainless steel parts (Custom 465) for naval applications feature wrought-equivalent properties of 250 ksi tensile strength and 17-25% ductility for improved toughness[6].*

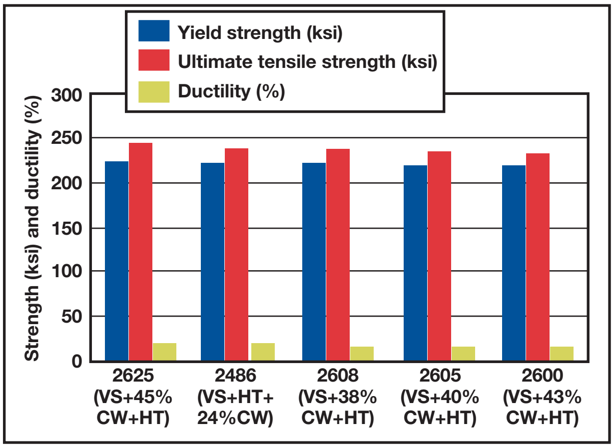

Fig. 6 — *CDC optimized Custom 465 stainless steel exhibits properties and fine-grained microstructures equivalent to wrought materials.*

sintered state. Another benefit of high part density is minimal dimensional change (shrinkage) after sintering. CDC optimized high-density PM parts exhibit exceptional properties equivalent to wrought products in terms of mechanical strength and toughness as well as high temperature resistance and ductility (Figs. 3-6). The CDC method also features the ability to press a variety of powder types, including composite materials, to yield much higher pressed and sintered densities than those achievable by conventional lower pressure PM methods.

Future applications

Potential commercial and military applications for CDC higher pressure compaction near-net or net shape manufacturing technology are endless. Some examples include high vacuum grade microwave tube components, vacuum flanges and fittings, cryogenic compatible metallic lightweight (aluminum) and composite seals, RF ceramics for microwave compatibility and absorbers, dissimilar bonded structures, and high temperature components for rocket motors. Other potential applications include reactive fragments, warhead parts, shaped charge liners, military ammunitions/projectiles/penetrators, advanced armor, high performance magnets (both soft and permanent magnets), heat-resistant tiles, engine parts, leading edge components, heat shields, igniter components, x-ray targets and tubes, and automotive/aerospace piston rings, valve seats, and gears. ❍

Fig. 7 — *Thin-walled (60 mil wall thickness) bonded Nd-Fe-B magnets for automotive and other applications[6].*

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Materials Science & Technology 2014

October 12-16
David L. Lawrence Convention Center
Pittsburgh

The MS&T partnership of ACerS, AIST, ASM, and TMS brings together scientists, engineers, students, suppliers, and other professionals to discuss current research and technical applications, and to shape the future of materials science and technology. NACE International will co-sponsor MS&T14.

Plenary Session

Drivers for Advanced Manufacturing: Energy, Sustainability and Economics

October 13, 8-10 a.m., Spirit of Pittsburgh Ballroom

Advanced manufacturing (AM) encompasses a range of emerging technologies that will speed materials improvements from the laboratory to the shop floor. These technologies form the basis for the proposed National Network of Manufacturing Institutes (NNMI), with current Institutes centered on the following AM technologies:

- Digital design/ICME/ Materials Genome Initiative
- Additive manufacturing
- Lightweight and modern metals manufacturing innovations
- Next-generation power electronics

Speakers

Yves Bréchet
Grenoble Institute of Technology

Alex King
Director, Critical Materials Institute

Alan Taub
Professor, Materials Science and Engineering, University of Michigan

Education Short Courses

Fundamentals of Glass Science & Technology
Saturday and Sunday, October 11–12
9:00 a.m. – 4:30 p.m. | 9:00 a.m. – 2:30 p.m.
Instructor: Arun K. Varshneya, Professor of Glass Science & Engineering, Alfred University

Basic glass science and technology is covered to broaden or improve understanding of glass as a material of choice. This one and a half day course covers glass science (commercial glass families, glassy state, nucleation and crystallization, phase separation, glass structure); glass technology and batch calculations; glass melting and forming; glass properties such as density, hardness, viscosity, thermal expansion coefficient, chemical durability, and engineering principles such as annealing, strength, and strengthening; and finally, elementary fracture analysis.

Recent Innovations in Electroceramics and Their Applications
Sunday, October 12, 8:00 a.m. – 4:30 p.m.
Instructor: R.K. Pandey, Texas State University

Electroceramics are now an integral part of many emerging technologies due to recent innovations. Because of the advent of multifunctional oxides, multiferroics, energy harvesting, micro-electromechanical systems (MEMS), nanostructured ceramics, spintronics, radhard electronics, bioelectronics, detectors, and sensors, electroceramic materials are more important than ever and will likely impact many emerging technologies. This course aims to expose students to the current state of knowledge in this field with emphasis on practical applications and invention potential.

Understanding Why Ceramics Fail and Designing for Safety
Sunday, October 12, 8:00 a.m. – 4:30 p.m.
Instructors: Steve Freiman, Freiman Consulting Inc. and John J. (Jack) Mecholsky, Jr., University of Florida

Engineers who use ceramic components, whether in electronic, optical, or structural applications, recognize that their brittleness can result in damage and possible mechanical failure. In this course, the practical fracture mechanics background necessary to understand brittle failure is explored, and some unique characteristics of ceramic materials that must be taken into account in their design and use are described. Microstructural effects, which have a major influence on both fracture toughness and strength, are also explored in some detail.

Designing Aluminum Structures
Sunday, October 12, 8:30 a.m. – 4:30 p.m.
Instructor: Randy Kissell

This seminar explains how to use the Aluminum Association's Aluminum Design Manual (ADM), a guide to the design of alu-

Short Course coverage continues on page 38

Technical Program

	Mon a.m.	Mon p.m.	Tue a.m.	Tue p.m.	Wed a.m.	Wed p.m.	Thu a.m.
BIOMATERIALS							
Bioinspired Materials Engineering				•	•	•	•
Corrosion of Biomaterials		•					
Nanomechanics of Biomaterials	•	•	•				
Next Generation Biomaterials	•	•	•				
Surface Properties of Biomaterials V				•	•	•	•
CERAMIC AND GLASS MATERIALS							
Amorphous Materials: Common Issues within Science and Technology						•	
Ceramic Matrix Composites		•	•		•	•	
Computational Design of Ceramic Materials	•	•	•	•	•		
Glass and Optical Materials	•	•	•	•	•	•	•
Innovative Processing and Synthesis of Ceramics, Glasses, and Composites		•	•				
Multifunctional Oxides				•	•	•	•
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Built in 1764, the Fort Pitt Block House is the only surviving structure of the original Fort Pitt, and is not only the oldest building in Pittsburgh, but also the oldest west of the Allegheny Mountains. Courtesy of Jenn Murray/ VisitPittsburgh.

"The Workers," a sculpture tribute to Pittsburgh's steel history, depicts two steelworkers over a metal ladle and resides at Riverside Park on the city's south side. Courtesy of Andrew Wagner/VisitPittsburgh.

	Mon a.m.	Mon p.m.	Tue a.m.	Tue p.m.	Wed a.m.	Wed p.m.	Thu a.m.
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NANOMATERIALS							
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Controlled Synthesis, Processing, and Applications of Structural and Functional Nanomaterials		•	•	•	•		
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Measurement and Modeling of High Strain-rate Deformation		•					
Multifunctional Materials for Aerospace and Defense: Challenges and Prospects						•	
Processes, Applications, and Performance of Materials in Additive Manufacturing				•	•	•	•
Sintering and Related Powder Processing Science and Technologies	•	•	•	•	•	•	
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Advances in Smart and Functional Coatings and Thin Films	•						
Surface Protection for Enhanced Materials Performance: Science, Technology, and Application	•	•	•	•	•	•	

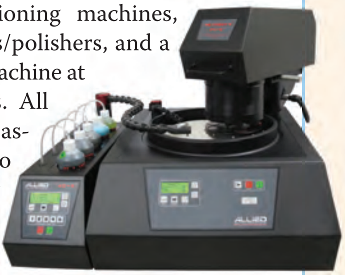
Station Square is an historical attraction designed to commemorate the city's celebrated steel history. The state-of-the-art Fountain at Bessemer Court features a Waltzing Waters Liquid Fireworks Show of hundreds of multicolored water jets choreographed to music and soaring up to 40 feet high. Courtesy of Roy Engelbrecht.

2014 EXHIBITOR SHOWCASE

Visit these key exhibitors and more at MS&T14 in Hall A of the David L. Lawrence Convention Center in Pittsburgh.

See exhibition dates and times on next page.

Allied High Tech Products Inc.

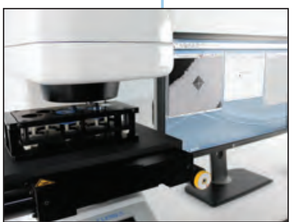


For over 31 years, Allied High Tech Products has provided quality products for metallographic sample preparation and analysis. Allied manufactures state-of-the-art equipment including sectioning machines, mounting systems, grinders/polishers, and a precision tabletop milling machine at its California headquarters. All design, manufacturing, and assembly takes place in-house to ensure the highest quality equipment is produced. Allied is a national Carl Zeiss Microscope dealer and carries a full line of hardness testers from Mitutoyo as well. Quality consumables are also available. Visit our website for more information, an online account for purchasing, or to download the current catalog. **alliedhightech.com**

Booth 415

Clemex Technologies Inc.

Clemex will attend MS&T, October 12-16 in Pittsburgh. Visit Booth 425 to see our new product solution for micro-hardness testing and other image analysis measurements. An innovative technique has been applied to the Clemex CMT.HD, allowing a seamless combination of micro-hardness testing with automated quantification of microscopic images such as grain size, phase area percentage, coating thickness, and more. For 25 years, Clemex has provided manufacturers and researchers with image analysis software and hardware to make quantification of microstructures less demanding and more effective. We specialize in automating the measurement of objects using digital images from microscopes and other precision optical devices. Contact us: 450.651.6573, info@clemex.com, **clemex.com/coating.**



Booth 425

Saudi Aramco

Owned by the Saudi Arabian Government, Saudi Aramco is a fully integrated, global petroleum enterprise, and a world leader in exploration and producing, refining, distribution, shipping, marketing, and petrochemicals manufacturing. The company manages proven reserves of 260.2 billion barrels of oil and manages the fourth-largest gas reserves in the world, 284.8 trillion cubic feet. In addition to its headquarters in Dhahran, Saudi Arabia, Saudi Aramco has affiliates, joint ventures, and subsidiary offices in China, Japan, India, the Netherlands, the Republic of Korea, Singapore, the United Arab Emirates, the United Kingdom, and the United States. For more information, visit **saudiaramco.com.**

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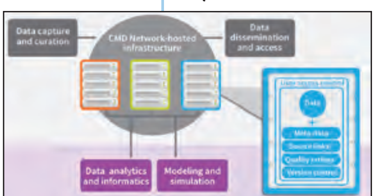
Booth 327

Computational Materials Data Network

The Computational Materials Data Network, founded by ASM International, supports and serves the materials community in its pursuit of the goals of the U.S. Materials Genome Initiative and the promise of ICME. Leveraging ASM's knowledge and experience in materials data, CMD Network is playing an integral role in multiple efforts where the data management standards of the future are being defined. Current development projects include the Structural Materials Data Demonstration Project, Materials Data Laboratory Pilot Project, and the Center for Hierarchical Materials Design. Visit our booth to see the latest demonstration databases and learn how the CMD Network can help you. **cmdnetwork.org.**



Booth 218

Maney Publishing

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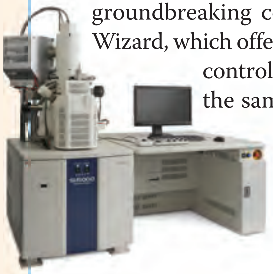
Booth 621

Hitachi High Technologies America Inc.

Visit Hitachi High Technologies America Inc. (Booth 318) to see the new SU5000 FE-SEM, equipped with Hitachi's groundbreaking computer-assisted technology, EM Wizard, which offers a new level of SEM operation and control. Expert or novice, the result is now the same: Highest quality nano-scale images at everyone's fingertips!



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- Robust "draw-out" specimen chamber accommodates large specimens (~200 mmf, ~80 mmH).
- Rapid sample exchange; evacuation to observation in 3 minutes or less.

hitachi-hta.com

Booth 318

Exhibition dates and times*

Tuesday, October 14

Show hours: 11 a.m. – 6 p.m.

Lunch: 12 – 2 p.m.

Poster session: 2 – 6 p.m.

Happy hour reception: 4 – 6 p.m.

Wednesday, October 15

Show hours: 9 a.m. – 2 p.m.

Poster session: 9:30 – 10:30 a.m.

Lunch: 12 – 2 p.m.

**Times are subject to change*

JEOL USA Inc.

JEOL is a world leader in electron optical instrumentation for scientific and industrial R&D. Core products include high resolution electron microscopes for materials, failure analysis, forensics, product inspection, nanotech, and semiconductor applications: SEMs and FE-SEMs for observation/analysis, TEMs for atomic-level imaging and high-speed mapping, surface analyzers for materials characterization, correlative microscopy solutions, specimen prep equipment, and other analytical instruments. JEOL is also well known for long-term applications and service expertise.

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What can we help you achieve? **jeolusa.com**

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Booth 501

Exhibition

MS&T14 brings together professionals from nearly every field of materials science: Metals, polymers, ceramics, and composites. Many industries are represented including automotive, aerospace, instrumentation, medical, oilfield, and energy. The exhibition at MS&T14 is a great opportunity to reach potential customers from all markets in a single venue.

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*Exhibitor list current as of August 6.

Education Short Courses, *continued*

minum structures and structural components. Compliance with Part I of the ADM, the Specification for Aluminum Structures, is required by all U.S. building codes. This seminar explores the aluminum specification so it can be used as confidently as steel or concrete. Because many engineers are unaware what aluminum alloys and products are available, how they are specified, or what their properties are, this course begins by familiarizing students with aluminum.

Microstructures 101 and Beyond
Sunday, October 12, 8:30 a.m. – 4:30 p.m.
Instructor: Frauke Hogue, Hogue Metallography

This is a one-day version of the five-day class presented to rave reviews at ASM International's headquarters in Materials Park, Ohio, for the past 10 years. The focus is on practical interpretation, rather than theory, phase diagrams, and thermodynamics. There are no prerequisites. Slides of more than 100 microstructures will be reviewed to find out and discuss what each structure tells about the type of material, manufacturing methods used, heat treatment, mechanical properties, and sometimes even failure modes.

State of Materials Design via Additive Manufacturing
Sunday, October 12, 8:30 a.m. – 4:30 p.m.
Instructor: Reginald F. Hamilton

This course explores additive manufacturing (AM) from a materials design perspective. The selection of a specific process is based on feature resolution and fabrication rate. For example, electron beam processes that use wire feeding are capable of producing large features at high fabrication rates. Powder-fed processes produce reasonable feature resolution, while powder-bed technologies produce the highest feature resolution. Present applications primarily take advantage of AM for net-shape part fabrication and the fast production of net-shapes of complex structural hierarchy. A fundamental understanding of the relationships between processing, microstructure, properties, and performance will advance AM implementation for shape memory alloys.

Advanced High-Strength Steels
Sunday, October 12, 8:30 a.m. – 4:30 p.m.
Instructor: Mahmoud Y. Demeri

Based on the book with the same name, this course is a comprehensive review of the science, technology, and applications of advanced high-strength steels (AHSS). *Advanced High-Strength Steels: Science, Technology and Applications* is included with this course. Learn about the types, many microstructures, thermal processing, deformation, mechanisms, properties, performance, benefits, challenges, trends, sustainability, economics, applications, and evolving grades of AHSS. The high strength and remarkable ductility of AHSS make them suitable for a variety of uses in automotive, construction, aerospace, railway, marine, and military applications.

Lectures and Special Events

Sunday, October 12

ACerS Frontiers of Science and Society — Rustum Roy Lecture, 5:00 – 6:00 p.m.
Wolfgang Rossner, Siemens AG, Germany, "Ceramics for Innovation and Sustainability"

Welcome Reception, 6:00 – 7:30 p.m.
Network with your colleagues, meet new people, and learn about the exciting membership offerings of the organizing societies.

Monday, October 13

MS&T Plenary Session, 8:00 – 10:00 a.m.
"Drivers for Advanced Manufacturing"

ASM Leadership Awards Luncheon, 11:30 a.m. – 1:00 p.m.
ASM's organizational unit awards as well as awards and scholarships of the ASM Materials Education Foundation will be presented. ASM's incoming Committee/Council chairs will also be recognized for their leadership. ASM Committee and Council members meeting during MS&T, and awardees, will receive an invitation to attend. Others may purchase tickets via meeting registration.

ASM/TMS Distinguished Lectureship in Materials and Society, 1:00 – 2:00 p.m.
Robert E. Schafrik, GE Aviation, "Materials for a Non-Steady State World"

Alpha Sigma Mu Lecture, 2:30 – 4:00 p.m.
Alexander McLean, University of Toronto, "The Development of Materials: Signals from the Past – Guidance for the Future"

ASM 101st Annual Business Meeting, 4:00 – 5:00 p.m.
Officers will be elected for the 2014-2015 term and other ASM business will be transacted. All ASM members and guests are welcome.

Women in Materials Science and Engineering Reception, 5:30 – 6:30 p.m.
Enjoy the chance to network with professionals and peers in a relaxed environment.

ASM Canada Council Suite, 9:00 p.m. – 1:00 a.m.
Come experience Canadian hospitality!

Tuesday, October 14

Young Professional Tutorial Luncheon, 12:00 – 2:00 p.m.
Enjoy a lecture and networking opportunity aimed at early-career professionals. Open to all MS&T meeting attendees. An optional boxed lunch can be purchased for $45 via meeting registration.

ASM Edward DeMille Campbell Memorial Lecture, 12:45 – 1:45 p.m.
Ian M. Robertson, University of Wisconsin-Madison, "Hydrogen Embrittlement Understood"

MS&T14 Exhibit Happy Hour Reception, 4:00 – 6:00 p.m.
Network with colleagues and build relationships with qualified attendees, buyers, and prospects.

MS&T Young Professionals Reception, 4:30 p.m. – 6:00 p.m.
Attend this reception to meet and network with fellow young professionals.

ASM Awards Dinner and President's Reception, 7:15 – 11:30 p.m.
Come celebrate the wonderful accomplishments of this year's award recipients and the 2014 Class of Fellows. Tickets, which include the President's Reception following the dinner, can be purchased via the registration form.

Metallurgy Lane

Aluminum: The Light Metal—Part I

Aluminum, one of the most widely used structural metals in modern industry, is produced in quantities exceeded only by steel. Its light weight, corrosion resistance, high strength after heat treatment, and global availability of bauxite ores make aluminum attractive for everything from kitchen utensils to spacecraft.

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.

Two young men living an ocean apart—both just 22 years old—invented the same novel process for reducing aluminum from its ore. One was an American chemist, Charles Martin Hall, and the other was a French metallurgist, Paul Heroult. Both lived from 1863 to 1914. Their new process would remain the world's method for making aluminum for the next 100 years and beyond, and propelled aluminum and its alloys into second place as the most widely used structural metal, just after steel.

The driving force behind the search for low-cost aluminum was not demand for the product, but knowledge of the vast resource of aluminum-containing minerals in easy reach within the earth's crust. It had long been known that large deposits of aluminum-containing clays constituted great quantities of aluminum, especially in ores called *bauxite* named after a region in France called Baux where the ore was first identified. Bauxite is widely scattered around the globe, mostly in tropical climates.

Charles Martin Hall

Charles Martin Hall in 1905, age 42. Courtesy of alcoa.com.

Charles Martin Hall was born in Thompson Township, Geauga County, Ohio, in December 1863. The Hall family moved to Oberlin, Ohio, about 35 miles southwest of Cleveland, when the children were old enough for college. Even though Oberlin College is primarily a liberal arts school, a number of science courses were taught including chemistry by Professor Frank Fanning Jewett, and Hall took his courses.

After graduating in spring 1885, Hall set up his now-famous experiments in a woodshed behind the family home with the assistance of his sister Julia, also an Oberlin chemistry student. In just a few weeks in the winter of 1886, Hall developed his method for making aluminum. His invention entailed dissolving aluminum oxide in the mineral cryolite. The molten bath was contained in a pot lined with graphite and with graphite electrodes inserted into the bath. A low voltage/high amperage electric current was passed from the electrodes to the lining, where aluminum metal was separated from the oxide. Aluminum collected at the bottom of the pot and was drained off periodically.

He immediately started applying for patent protection for his invention, which required finding money and hiring a patent attorney. His patent was formally filed on July 9, 1886. However, the U.S. Patent Office notified Hall that another application for the same process had been filed on April 23, 1886, by a Frenchman named Paul L.T. Heroult, meaning that Heroult's patent application predated Hall's by more than two months. This patent interference was resolved when Hall proved that he had reduced his invention to practice on February 23, 1886, where Heroult had only his filing date of April 23, 1886. Hall, therefore, became the inventor of record in the U.S. by a mere two months.

Paul Heroult. Courtesy of alcoa.com.

Hall then set out to find financial supporters to carry his process into production. His first successful contact was with the Cowles brothers who owned the Cowles Electric Smelting and Aluminum Co. of Cleveland. The Cowles had a process for making an alloy of copper containing aluminum called aluminum bronze. Hall joined the Cowles Co. at their plant in Lockport, N.Y., with a salary of $75 per month for three months. If his experiments were satisfactory after that time, he would receive $750 and the company would continue to support his work. An option for further rewards was never fulfilled due to disagreements between Hall and the brothers. Hall parted company with the Cowles before making progress in aluminum production.

However, Hall had worked with a manager at the Cowles plant, Romaine C. Cole, who had done some work on aluminum for a testing company in Pittsburgh named Hunt and Clapp. When it became clear to Hall that the Cowles were not supporting him, Cole recommended that they contact Captain Alfred E. Hunt. Cole arranged a meeting with some of Hunt's acquaintances in July 1888 to

An aluminum plaque at 3220 Smallman Street, Pittsburgh, commemorates the birthplace of aluminum. Courtesy of alcoa.com.

Bauxite ore. U.S. public domain image.

discuss forming a company to support Hall's experiments in scaling up the process to pilot production. Hall joined the group a week later when a second meeting was held with Hunt presiding. This meeting of Hall, Cole, Hunt, and a small group of Pittsburgh men known to Hunt from the steel industry and from his testing laboratory formed the technical and financial support of what would become the American aluminum industry. Hunt and the other financial supporters agreed to organize an entity called The Pittsburgh Reduction Co. and to raise $20,000 to build and equip a pilot plant to demonstrate the value of Hall's process for producing low-cost aluminum.

Next to Hall, Hunt was the most important man involved in developing aluminum as a commercial business. While Hall and others were primarily interested in technology and production, Hunt carried the burden of financing, managing, marketing, and selling the product. Alfred Ephrehem Hunt was born in Massachusetts in 1856 and graduated from MIT in mining and metallurgy in 1876. In 1883, he and George Clapp bought out the owners of The Pittsburgh Testing Laboratory and renamed it Hunt and Clapp.

The pilot plant

Hall and Cole built a pilot plant on Smallman Street in Pittsburgh and began to set up reduction cells and a motor-generator set to provide electricity. Their first production run after numerous startup problems yielded a few marble-sized particles on Thanksgiving Day 1888. Thus, the modern world of aluminum was born.

It turned out that Hall and Cole were not compatible as fellow workers in running the pilot plant, so Cole was replaced by a young worker from Hunt's testing laboratory, Arthur Vining Davis. Hall and Davis soon increased production at the pilot plant to 50 pounds per day, selling at $8 per pound. By adding two new dynamos, production increased to 450 pounds per day, but the price had dropped to $2 per pound. Realizing the need to achieve production levels to obtain economies of scale, and in need of funds to meet daily obligations, the company's principals approached the Mellon Bank for a $4000

Interior of the Smallman Street works of the Pittsburgh Reduction Co., circa 1889. Courtesy of alcoa.com.

loan. The Mellon brothers, Andrew and Robert, supplied a larger loan of $25,000 and later took a position in the company by buying 60 shares from Hall at $100 per share.

The move to New Kensington

The Pittsburgh Reduction Co. soon outgrew the pilot plant on Smallman Street and the Mellon brothers encouraged them to locate a production plant in New Kensington, northeast of Pittsburgh. By now, Hall had discovered that by increasing the size of the reduction pots and therefore the electric current, he could maintain the heat to keep the molten bath at the necessary temperature without an outside heat source. In addition, after scaling up the operation, less energy was needed per pound of aluminum produced. The Mellons purchased a stock offering at this time of 500 shares at $60 per share. This allowed them seats on the board of directors. The Mellons were now insiders and not simply bankers providing loans.

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

Andrew Mellon. Courtesy of Carnegie Museum of Art, Historic Pittsburgh image collection.

Arthur Vining Davis. Courtesy of alcoa.com.

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Editorial Opportunities for *HTPro* in 2014

The editorial focus for *HTPro* in 2014 reflects some key technology areas wherein opportunities exist to lower manufacturing and processing costs, reduce energy consumption, and improve performance of heat treated components through continual research and development.

November Atmosphere/Vacuum Heat Treating

To contribute an article to one of these issues, please contact Frances Richards at frances.richards@asminternational.org. To advertise, please contact Erik Klingerman at erik.klingerman@asminternational.org.

ABOUT THE COVER:
Flow controllers ensure reliable control of liquids and gases with high repeatability and reaction speed to deliver optimum results in heat treating applications. Christian Bürkert GmbH & Co. KG (Bürkert), burkert.com.

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TMI ATC Project Moving Forward

The Thermal Manufacturing Industries Advanced Technology Consortium (TMI ATC) AMTech project led by ASM International was formed to lead and coordinate a national effort that identifies common thermal manufacturing needs across industries and solicits input from key stakeholders. Roadmapping workshops will identify technologies ready for implementation in thermal manufacturing industries, as well as high-priority areas for development.

In support of this effort, a diverse group of experts including Heat Treating Society members are being surveyed to identify barriers and opportunities for advancement in thermal manufacturing. This information will provide a picture of the state of thermal manufacturing, and help shape the process for conducting workshops. Planned workshops include one at Furnaces North America, October 9–10 in Nashville, Tenn., with a stronger focus on heat treating, and one at MS&T 2014, October 16–17 in Pittsburgh, with a stronger focus on other thermal processes (melting, drying, curing, etc.).

CALL TO ACTION!

Please provide your responses to the following survey questions keeping in mind your specific area/expertise in thermal manufacturing:

- What is your role/area of activity in thermal manufacturing?
- What are the major opportunities for advanced manufacturing technology in your area of thermal manufacturing?
- What specific technology or technologies would make the largest impact?
- What are the primary barriers to implementation of advanced manufacturing technology in your area of thermal manufacturing (e.g., cost, lack of available technologies, staff constraints)?
- What needs can the TMI ATC fulfill for you?
- What type of engagement would be most valuable to you?
- What financial and resource commitments are you willing to make to participate in TMI ATC?

HTS will be represented at these workshops, so please provide your input by sending responses to stan.theobald@asminternational.org.

Stan Theobald
Senior Director, Business Development
ASM International

First ASM HTS/Surface Combustion Emerging Leader Award to Be Presented in 2015

The ASM HTS/Surface Combustion Emerging Leader Award was established in 2013 to recognize an outstanding early-to-midcareer heat treating professional whose accomplishments exhibit exceptional achievements in the heat treating industry. The award was created in recognition of Surface Combustion's 100-year anniversary in 2015.

The award acknowledges an individual who sets the "highest standards" for HTS participation and inspires others around him/her to dedicate themselves to the advancement and promotion of vacuum and atmosphere heat treating technologies.

Rules for submitting nominations:
- Candidates must be a member and an active participant in ASM International and HTS.
- Nominees must be 40 years of age or younger and employed full time in the heat treating industry for a minimum of five years.
- Candidates must be submitted by an ASM International or HTS member.
- Three letters of recommendation must be submitted with the nomination form. Nominations should clearly state the nominee's impact on the industry and/or service and dedication to the future of the HTS.
- The award shall be presented to one recipient every two years at the General Membership Meeting at the HTS Conference and Exposition.
- **Recommendations must be submitted to ASM Headquarters no later than April 1 in the year in which the award is to be presented.**
- **The first award will be presented in 2015**.
- Winner receives a plaque and $4000 cash award funded by Surface Combustion.

A selection committee consisting of five members will be appointed every two years by the HTS Awards and Nominations Committee. Three members of the selection committee will be appointed by Surface Combustion. The selection committee will submit a report for approval by the HTS Awards and Nominations Committee and the HTS Board, which shall include the rationale and documentation used for award selection.

For rules and nomination form for the ASM HTS/Surface Combustion Emerging Leader Award, visit the Heat Treating Society Community Website at http://hts.asminternational.org and click on Membership & Networking and HT Awards.

HTS Names New Board Members for 2015

The HTS Board, at the recommendation of the Awards and Nominating Committee, named new board members including **Timothy DeHennis**, **Eric Hutton**, and **Zbigniew Zurecki Sr.**, to serve on the HTS Board for the 2014–2017 term; **Lee Rothleutner** to serve as student board member for the 2014–2015 term; and **Piyamanee Komolwit** to serve as young professional board member for the 2014–2015 term. Terms begin September 1, 2014. Remaining on the board are **Roger A. Jones** (president), **Steve Kowalski** (vice president), **Thomas Clements** (past president), **John Keough** (board liaison), **William Disler** (member), **Robert Goldstein** (member), **Richard Howell** (member), **Stephen Mashl** (member), **James Oakes** (member), and **Jin Xia** (member).

Tim DeHennis is a senior metallurgist at The Boeing Co., Military Aircraft Div. in Philadelphia. With the company for more than 15 years, he is responsible for technical oversight of the manufacture of gears, bearings, and other flight critical components, support of failure investigations, and process development including investigating low pressure carburizing, high-pressure gas quenching, and corrosion resistant gear and bearing materials. Tim is currently Boeing Materials Engineering's subject matter expert and prime technical contact pertaining to heat treatment and gear manufacturing of CH-47 Chinook helicopter components. He received his B.S. in materials science and engineering from Pennsylvania State University in 1999, and is currently pursuing an M.S. degree from Drexel University in the same discipline.

Eric Hutton is vice president of operations, Automotive North America, Bodycote Thermal Processing Inc., Detroit, responsible for sales and operations of 11 Bodycote plants located in the U.S., Canada, and Mexico. Before joining Bodycote in 1998, he was employed at Michigan Induction. He received his B.A. in marketing from Bob Jones University and his MSM from Walsh College of Accountancy. Eric has 20 years of experience in commercial heat treating, and his well-rounded background in the automotive industry and executive experience with Bodycote provides a valuable foundation for working with HTS leadership. Eric has been involved in Heat Treating Society activities including the Heat Treat Conference and Expo and HTS Committees, and is a member of the ASM Detroit Chapter.

Zbigniew Zurecki is research associate at Air Products & Chemicals Inc., Allentown, Pa. He has spent the past 30 years in research aimed at the development of new industrial gas application technologies for processing metals in the heat treating, powder and process metallurgy, thermal spray coatings, combustion, metalforming, and electronics packaging industries. His new technological alternatives resulted in improved product quality and increased productivity of industrial operations. Zbigniew has over 30 U.S. patents with multiple foreign derivatives, and has authored papers in about 60 publications. He is a graduate of Politechnika Warszawska, Poland, with a degree in mechanical technologies, and of Drexel University with a degree in materials engineering.

Piyamanee Komolwit is senior engineer, surface technology, Kennametal, Latrobe, Pa. Joining the company in 2010, she is technical lead for the heat treatment competency team, responsible for global heat treatment capability, quality control on heat treatment processes, and related equipment and consumables at all Kennametal plants. Prior to that, she was research associate, Carnegie Mellon University, Pittsburgh, and research assistant, Thailand Environmental Institute, Bangkok. Piyamanee earned a Bachelor of Engineering in metallurgical engineering at Chulalongkom University, Bangkok, Thailand, in 1996; an M.S. in environmental management at the University of San Francisco in 2002; and an M.S. and Ph.D. in materials science and engineering at Carnegie Mellon University in 2005 and 2009, respectively. She coauthored several conference papers. She served as a volunteer for various ASM activities and served as a member of the executive committee of the ASM Pittsburgh Chapter.

Lee Rothleutner is a graduate research assistant and Ph.D. candidate in materials science and engineering (2015) at the Colorado School of Mines, Golden. His research focuses on linking structure, processing, and properties in ferrous alloys. Specific areas of interest include induction processing, phase transformations, precipitation, and fatigue. Lee also earned a B.S. and M.S. in materials science and engineering at Colorado School of Mines in 2009 and 2012, respectively. He served as student representative to the Advanced Steel Processing and Products Research Center (ASPPRC) Industrial Advisory Board and as a teaching assistant for a statistical process control (SPC) course. He authored and coauthored several journal papers and conference presentations. Lee served in the U.S. Coast Guard (2000–2005).

Heat Treating Society Looking for Volunteers

Get Involved! Serve on a Heat Treating Committee!

The HTS Board is seeking enthusiastic, committed members to serve on various HTS Committees. HTS committees monitor technical advances and other areas of member interest to bring new information to members through products and services including conference and exposition programming, course development, reference and periodical publications, and research and development planning and implementation. The Board is currently looking for members for the following committees:

Awards and Nominating Committee
Education Committee
Technology & Programming Committee
Exposition Committee
Finance Committee
Membership Committee
Research and Development Committee

Interested members should review the Committee Purpose on the HTS website and contact sarina.pastoric@asminternational.org.

Pershing Receives CHTE Award for Outstanding Service

Diran Apelian, director of WPI's Metal Processing Institute (left) and Michael Pershing.

Michael Pershing, senior technical steward, Caterpillar Inc., Mossville, Ill., received the Center for Heat Treating Excellence (CHTE), WPI, Worcester, Mass., Award for Outstanding Service. Each year, CHTE acknowledges the accomplishments of a person, who in the judgment of the board made significant, commendable, and long-standing contributions to the promotion of CHTE. Criteria include membership in good standing for a minimum of three years and exceptional contributions to CHTE. Pershing is a member of the Heat Treating Society.

Soliciting Papers for ASM HTS/Bodycote 'Best Paper in Heat Treating' Contest

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

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

To view rules for eligibility and paper submission, visit the Heat Treating Society website at hts.asminternational.org/portal/site/hts/HTS_Awards.

Paper submission deadline is December 12. Submissions should be sent to Sarina Pastoric, ASM Heat Treating Society, 9639 Kinsman Rd., Materials Park, OH 44073, 440.338.5151 ext. 5513, sarina.pastoric@asminternational.org.

CALL FOR PAPERS

HT 2015 – 28th ASM Heat Treating Society Conference and Exposition October 20-22, 2015 Cobo Convention Center Detroit

ASM HEAT TREATING SOCIETY 2015 CONFERENCE & EXPOSITION

The ASM Heat Treating Society and the American Gear Manufacturers Association once again are co-locating to create an exciting mix of education, technology, networking, and exposition opportunities – all at the 28th Heat Treating Conference and Exposition and Gear Expo. It is the event recognized by industry, academia, and government professionals as the premier heat treating gathering in North America. The event will offer a full technical program covering a broad scope of heat treating technology, networking opportunities, and a first-hand look at equipment, supplies, and services from exhibitors.

HTS 2015 organizers are seeking original, previously unpublished, noncommercial papers for oral and poster presentations. Technical areas of interest include, but are not limited to, the following:

- Advances in Heat Treating
- Aluminum, Titanium, Copper Alloys, Refractory Metals
- Applied Energy
- Atmosphere Technologies and Process Controls
- Brazing
- Cleaning Processes and Control
- Deep Cryogenic Treatment of Metals (and Some Non-Metals)
- Emerging Technology
- Energy Conservation
- Equipment Innovations
- Global Issues
- Heat Treating in Additive Manufacturing Processes
- Heat Treating of MMC, CMC, and Ceramic Materials
- Heat Treating Processes for Production of Advanced High Strength Steels
- Heat Treatment for Producing Nanostructured Steels
- Lean Heat Treating Processes
- Light Metals
- New Processes for Bainitic Alloys
- Processes and Applications
- Quenching and Cooling
- Surface Engineering
- Thermal Processing of Carbon Fiber Composite Materials
- Vacuum Processes and Technology

Abstract submission deadline: January 26, 2015. Visit the HTS website for details on submitting an abstract: hts.asminternational.org, and click on Events tab.

Developing Gas Quench Steel Hardenability Standards

Because alloy steel hardenability is such an important factor in part manufacturing, the Center for Heat Treating Excellence (CHTE) is conducting research aimed at learning more about the performance of gas quenching systems used to harden newer alloy steels. The primary goal of the study is to establish a standard method to evaluate gas-quench steel hardenability. Heat transfer coefficients will be determined for different gas pressures and during the cooling phase.

"The world is improving its alloys," notes Richard D. Sisson, George F. Fuller professor of Mechanical Engineering at WPI and director of CHTE. "New alloys are being developed to be much harder and to be processed by gas quenching, and we need to understand how these alloys perform. We also need to be able to characterize how fast new furnace designs can cool the part."

Another objective of the research project is to evaluate the cooling performance of high-pressure gas-quench systems. Researchers will explore what equipment is needed and what conditions are required to ensure the desired hardenability standard.

CHTE member Lynn Ferguson of DANTE Solutions explains, "Newer furnaces with higher cooling capability can quench using gas pressures of 10 to 20 bar. High-pressure gas quenching (HPGQ) is gaining market share in the United States, but because gas quenching is a slower process than oil quenching, hardenability becomes more critical."

CHTE member Lynn Ferguson, FASM, president of DANTE Solutions.

Professor Yiming (Kevin) Rong, Higgins Professor of Mechanical Engineering and director of the Computer-Aided Manufacturing Laboratory at WPI.

High-pressure gas-quenching nozzles in vacuum furnace chamber.

Though it is a slower process, HPGQ is displacing oil quenching, especially in Europe, because it avoids part discoloration, quenching vapors, potential for fires, and other cleanliness and environmental issues associated with the use of oil.

The project is being conducted through simulation and lab testing, with much of the work being carried out simultaneously. Researchers are working with commercial software companies like DANTE Solutions, Dassault Systèmes Simulia Corp. (ABAQUS) and Sente Software Ltd. (JMatPro), whose software can simulate the response of heat-treated parts. Specifically, simulations help researchers understand the relationship between steel hardenability and cooling performance in gas-quench systems. The simulations also help predict the actual behavior of the parts given the amount of gas used.

Currently, lab testing is being conducted at WPI and will eventually be conducted in manufacturing facilities. Notes Kevin Rong, Higgins Professor of Mechanical Engineering and director of the Computer-Aided Manufacturing Laboratory at WPI, and principal investigator for the project, "In our testing to date, we compared liquid quenches with gas quenches to identify how the microstructures of the material behave and determine the differences. The findings have been interesting."

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

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

CHTE also periodically undertakes large-scale projects funded by the federal government or foundations. These endeavors keep members informed about leading edge technology.

CHTE current research portfolio
Other projects now in progress include:
Nondestructive Testing for Hardness and Case Depth, Induction Tempering, Gas Quench Steel Hardenability, Enhancements to CHTE Software (CarbTool, CarboNitrideTool, and NitrideTool), and Cold Spray Nanomaterials (supported by ARL).

For more information about CHTE, its research projects, and member services, visit wpi.edu/+chte, call 508.831.5592, or email Rick Sisson at sisson@wpi.edu, or Diran Apelian at dapelian@wpi.edu.

DEVELOPMENTS IN MICROALLOYED, COARSENING-RESISTANT STEELS FOR HIGH TEMPERATURE CARBURIZING

THERE IS GROWING INTEREST IN STEELS MICROALLOYED WITH TITANIUM, NIOBIUM, AND MOLYBDENUM FOR USE IN HIGH-TEMPERATURE CARBURIZING APPLICATIONS.

Marvin McKimpson,* Caterpillar Technical Center, Mossville, Ill.

There is growing interest in steels, particularly carburizing steels, that have improved resistance to austenite grain coarsening during heat treating. The driver for much of this interest is the increased use of low-pressure (i.e., vacuum) carburizing furnaces in commercial heat treating operations. These furnaces are capable of processing steels at higher temperatures and substantially shorter cycle times than conventional atmosphere furnaces. The higher-temperature capability is due to both furnace construction and a lower potential of the furnace to cause intergranular oxidation in the steels being processed.

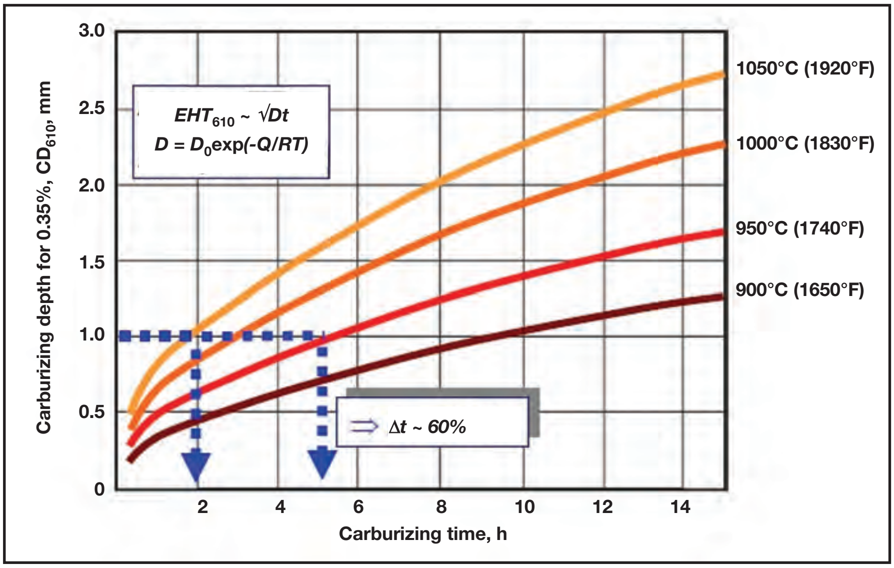

Fig. 1 — *Effect of carburizing temperature on carburizing time.*

Figure 1 shows that increasing carburizing temperature from 950° to 1050°C (1740° to 1920°F) potentially can shorten carburizing time by up to 60%[1]. However, when carburized above 950°C, many current commercial steels show excessive austenite grain size coarsening. For example, Fig. 2 shows the grain growth in a commercially available modified SAE 4120 steel vacuum annealed at 1100°C (2010°F) for 10 hours. The large grain size is apparent, with grains approaching 1 mm in size. Such grain coarsening degrades both the toughness and fatigue resistance of carburized components, and is generally not acceptable for commercial products.

Grain coarsening control

Most commercial carburizing steels rely on submicron aluminum nitride (AlN) precipitates to control grain size coarsening during heat treating. The nitrides pin austenite grain boundaries, restricting grain growth. Unfortunately, at temperatures above 950°C, the particles begin to coarsen and dissolve, allowing austenite grain growth. Research organizations worldwide are exploring ways to improve coarsening resistance of these steels by incorporating submicron precipitates (generally either nitrides or carbides) having greater thermal stability than AlN. The additional precipitates both increase the volume fraction of particles available to retard austenite grain boundary migration and resist precipitate coarsening (i.e., Ostwald ripening) more effectively than AlN.

**Member of ASM Heat Treating Society*

Only a few elements, primarily titanium, boron, and niobium, form nitrides, carbides, and carbonitrides likely to be useful for improving austenite grain coarsening resistance. Early research focused on using titanium nitride (TiN) due to its high thermodynamic stability. This work showed that titanium additions to steel can substantially improve grain coarsening resistance. Unfortunately, as is well known within the industry, even small titanium additions often lead to large cuboidal TiN or Ti(N,C) inclusions that degrade both the toughness and fatigue resistance of the steel. Accordingly, using titanium for grain size control in commercial alloys is likely to require very careful control of steelmaking practices.

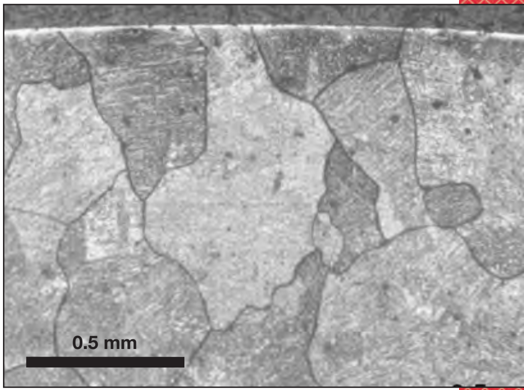

Fig. 2 — *Grain growth in modified SAE 4120 steel vacuum annealed at 1100°C (2010°F) for 10 hours. Source: Ref 2.*

Recent work has focused on using niobium, or a combination of niobium and titanium, to improve austenite grain coarsening resistance. Consider, for example, a carburizing steel with microalloy additions of both titanium and niobium. If titanium levels are sufficiently low to avoid formation of large cuboidal TiN particles in the melt (typically 0.02 wt% or lower), only small TiN precipitate particles form in the steel as it cools through the austenite temperature region. Then, as the steel is hot worked, niobium carbide (NbC) and/or carbonitride precipitates also form, sometimes on preexisting TiN nuclei. For example, Fig. 3 shows a TiN cuboid approximately 30–40 nm in size (gray phase) containing numerous coprecipitated Nb(C,N) particles (white phase).

Molybdenum additions

Additional research indicates that supplementing titanium and niobium microalloy additions with molybdenum can be particularly attractive for improving austenite grain coarsening resistance. For example, a recent U.S. Department of Energy study shows that a modified SAE 4120 steel containing nominally (wt%) 1.1 Cr, 0.4 Mo, 0.02 Ti, 0.06 Nb, and 260 ppm nitrogen has substantially better coarsening resistance during simulated carburizing cycles than a similar modified SAE 4120 steel without Ti and Nb additions[2]. Figure 4 shows the prior austenite grain size of this quenched and tempered microalloyed steel after various thermal cycles. After holding at 1050°C for 8 hours, the material still exhibits an ASTM grain size number of 6 or finer. For comparison, the control material with no Ti or Nb additions shows a duplex prior austenite grain size ranging from ASTM grain size number 5 down to 2 after holding at 900°C (1650°F) for 8 hours.

Researchers at the Colorado School of Mines, Golden, are working to better understand the role that molybdenum plays in improving austenite grain coarsening resistance. In a recent study, Enloe looked at several microalloy-modified SAE 4120 steels containing nominally (wt%) 0.01 Ti, two different levels of Nb (0.04 and 0.1), and two different levels of Mo (0.01 and 0.3)[4]. These steels were given various thermal processing sequences and examined using a combination of optical and electron microscopy, precipitate extraction, and atom probe tomography. Results show that molybdenum additions cause a significant decrease in the rate of carbide and nitride precipitate coarsening. In addition, molybdenum tends to partition from the precipitates to the austenite during extended holding times at elevated temperature. However, molybdenum enrichment at the precipitate-matrix interface is not observed. Accordingly, the observed decrease in carbonitride particle coarsening is probably not due to Mo segregation at this interface.

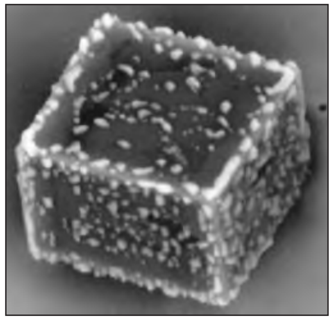

Fig. 3 — *A 30–40 nm cuboidal titanium-nitride (TiN) particle (gray) containing fine niobium carbonitrides Nb(C,N) (white). Source: Ref 3.*

Commercialization

Despite extensive ongoing research, commercialization of microalloyed coarsening-resistant steels appears to be proceeding slowly due to several factors. Because these alloys are likely to be of greatest value to companies interested in low-pressure carburizing, market pull for these materials is somewhat smaller than that for other steels. In addition, because development of microalloyed, coarsening-resistant steels is a dynamic international research topic, a careful review of global patent literature may be needed before determining how new intellectual property can be

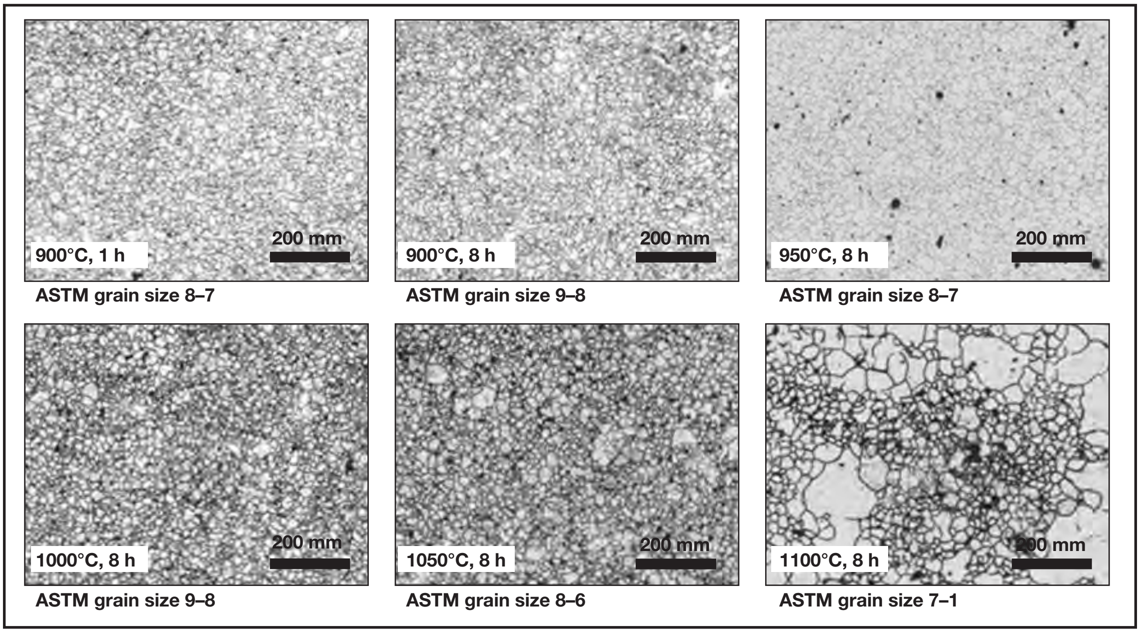

Fig. 4 — *Grain size observed in a microalloyed carburizing steel as a function of thermal exposure conditions. Note: The first number in the ASTM grain size nomenclature indicates the smallest grain size, the second number the largest grain size. Source: Ref 2.*

protected most effectively. Finally, optimized steelmaking practices, including hot working, are critical for successful commercialization of these alloys, and this optimization can be challenging with the small heat sizes typically used for new steel compositions targeted toward emerging markets.

Nevertheless, progress is being made. The German company Buderus Edelstahl GmbH is active in this area and has reportedly supplied custom heats of microalloyed case-hardening steels to some customers. Recent work at Buderus is described by Hippensteil [5]. Other industrial activities related to commercialization are summarized by Mohrbacher [6]. The potential benefits of microalloy additions for pinning austenite grain boundaries could also extend beyond carburizing alloys. Jansto notes that rolled medium- and high-carbon steels can also benefit from such additions[3]. In this case, the microalloy additions minimize grain coarsening and grain size variations caused by temperature fluctuations and inhomogeneities during reheating and hot rolling. This, in turn, can facilitate development of new, ultrafine grain steels with improved toughness, strength, and uniformity compared with current products. HTPRO

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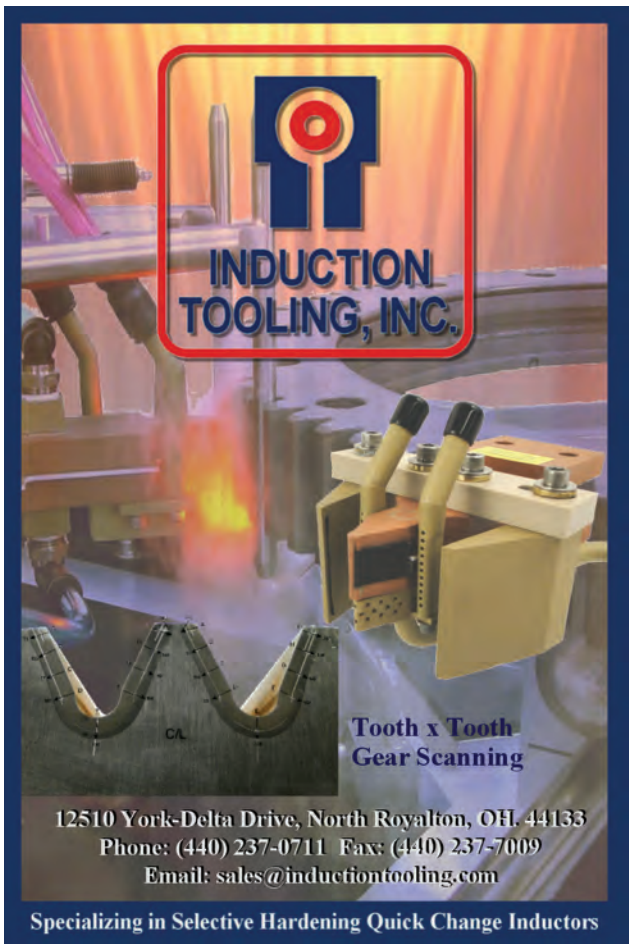


PART 2

OPERATIONAL PRINCIPLES OF FLOWMETERS

ONCE A "SET IT AND FORGET IT" TECHNOLOGY, FLOW MEASUREMENT IS AN INCREASINGLY IMPORTANT PART OF QUALITY CONTROL SYSTEMS IN THE HEAT TREATING INDUSTRY.

Daniel H. Herring,* The Herring Group Inc., Elmhurst, Ill.

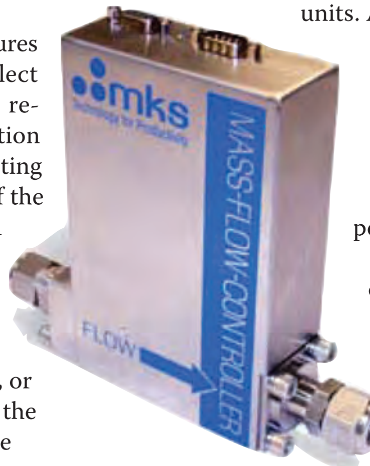
In most heat treating applications, important flowmeter selection criteria include reliability, accuracy, ruggedness, ease of calibration, and ease of maintenance. Given the high accuracy and reliability of today's instruments, users can run their processes more economically. Part 1 of this article (June 2014 *HTPro*) discussed the most commonly used flow measurement instruments and compared their operating principles. This article covers selection basics, sizing, mass flowmeter overview, and FAQs about flowmeters.

Flowmeter Selection Basics

There are many flowmeter features that must be considered to select the one that best meets the requirements of the application (Table 1). The first step in selecting a flow sensor is to determine if the required flow rate information should be continuous or totalized, and whether these data are needed locally or remotely. If remotely, should the transmission be analog, digital, or shared? And, if shared, what is the required minimum data-update frequency? Once these questions are answered, the properties and flow characteristics of the process fluid (gas or liquid), and the properties and configuration of the piping that will accommodate the flowmeter should be evaluated.

*Member of ASM International

Next, determine the required flowmeter range by identifying the minimum and maximum flows (mass or volumetric) that will be measured and the required flow measurement accuracy. Typically, accuracy is specified in percentage of actual reading, percentage of calibrated span, and percentage of full-scale units. Accuracy requirements should be separately stated at minimum, normal, and maximum flow, otherwise meter performance might not be acceptable over its full range.



Representative mass flowmeter. Courtesy of MKS Instruments.

Flowmeter sizing

When purchasing a new flowmeter to measure gas flow in heat-treating applications, it is important to remember the distinction between the operating range and design range of the instrument. Some variable-area flowmeters offer full-scale operation, while others offer a limited range such as "not below 25% and not above 90% of scale capacity." For example, a flowmeter rated for 0 to 2000 cubic feet per hour (cfh) only provides accurate readings when the flow is between 500 and 1800 cfh.

If flow measurement must cover a wide flow range, select a flowmeter that has a high turndown. An alternative, but costly, approach is to install several flowmeters of different sizes with automatic or manual switching based on flow range.

A rule of thumb for sizing a flowmeter is to purchase one "in the middle third," that is, size it so the actual flow will be no less than 33% and no higher than 67% of the scale selected. This enables compensating for unexpected changes in flow requirements that might occur during actual operation. Over the life of a

Frequently Asked Questions

Is it easier to control a gas or a liquid?
Liquids are easier to measure and control because of their small compressibility. For most volumetric flow applications, it is not necessary to closely control the incoming pressure in liquid systems. By their nature, liquids are easily captured and measured to a high degree of accuracy. By comparison, gases, due to their compressibility, require more complex sensing and control methods.

Should I have my flowmeters recalibrated?
If a change in operating conditions is permanent, such as the desire to constantly operate at a different pressure, then recalibration of the flow measurement device is strongly recommended. As a rule, flowmeters used in heat-treating applications are designed for a maximum temperature of 150°F (65°C) and an operating pressure up to 50 psig (345 kPa). However, application-specific flowmeters have maximum operating pressures outside these ranges.

Is it necessary to maintain flow devices?
All flowmeters eventually require maintenance, and some units require more maintenance than others, so this factor should be considered when selecting a unit. However, in most heat-treating operations, the equipment manufacturer has already made that choice for you, so understanding what maintenance is required and when it should be performed is of paramount importance.

Flowmeters have moving parts and require internal inspection, especially if the fluid is dirty or viscous. For example, in furnaces using endothermic gas, flowmeters often become contaminated with soot (carbon) and must be cleaned by *carefully* disassembling the flowmeter and cleaning all internal moving parts, plus replacing the dirty fluid in the flowmeter tube. CAUTION: This involves isolating the flowmeter, or performing maintenance when the unit is shut down, and must be done in a safe manner

TABLE 1 — COMMONLY USED FLOW MEASUREMENT INSTRUMENTS BY FEATURE

Gas flow meter type	Special installation requirements	Mechanical flow reading level/ scale type	Electronic flow reading	Typical full-scale accuracy, % of reading	Typical turndown	Pressure drop
Metal tube	Vertical mounting	Easy/linear	Available	3.5	3:1	Low
Metal cylinder tube	Vertical mounting	Easy/linear	Available	1–2	25:1	Low
Glass or plastic tube	Vertical mounting	Easy/linear	No	1–2	10:1	Low
Vane	None	Easy/linear	No	2–5	5:1	High/average
Moving orifice	Straight pipe upstream and downstream	Complex/ square root	Available	2–3	3:1–10:1	Low/average
Piston (with spring)	None	Easy/linear	No	1–5	5:1	Low/average
Orifice	Straight pipe upstream and downstream	Hard/square root	Available	0.5–2	3:1–10:1	High
Venturi	Straight pipe upstream and downstream	Hard/square root	Available	0.5–2	3:1–10:1	Average
Rotary impeller (Roots type)	None	Moderate/linear, total flow counter	Available	0.5–2	10:1–20:1	Average
Turbine	Straight pipe upstream and downstream	Moderate/linear	Yes	0.5–3	10:1–20:1	Average
Thermal mass	Straight pipe upstream and downstream	Not applicable	Yes	1–2	10:1–100:1	Average/high

heat-treating furnace, process requirements and operating conditions often change, sometimes dramatically, and gas measurement must remain accurate.

For a variable-area rotameter, if it is necessary to know the proper flow rate, be aware that a change in temperature, pressure, or specific gravity of the gas from that for which the meter was calibrated will cause a serious error in the indicated scale reading. It is quite common in a heat treat shop to find flowmeters operating at pressures and temperatures different from those for which they were calibrated.

Mass flowmeters

Thermal-mass flowmeters also are used by heat treaters. In most industrial-grade devices, gas enters the flow body and divides into two flow paths. Most of the flow goes through the laminar-flow bypass, creating a pressure drop that forces a known fraction of the flow through the sensor tube (Fig. 1). A power supply is used to direct a constant amount of heat into the gas stream. Resistance temperature-detector (RTD) coils are placed around the bypass sensor tube at its upstream and downstream ends. Heat is transferred to the molecules of the flowing gas, independent of pressure and temperature fluctuations.

The gas flow carries heat from the upstream coil to the downstream coil. Therefore, the downstream coil has a higher temperature and more resistance than the upstream coil. The coils are legs of a bridge circuit with the resultant output voltage proportional to the difference between the coils' resistance, which, in turn, is proportional to the mass flow rate. The two other parame-

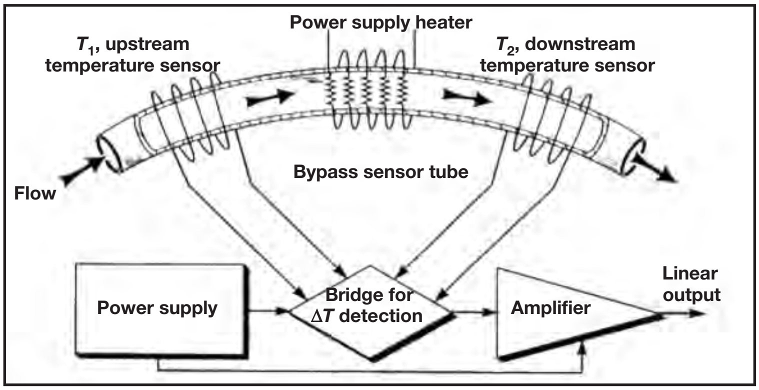


Fig. 1 — *Sensor tube measurement component of a thermal-mass flowmeter. Courtesy of Omega Engineering Inc.*

as many of the gases involved are asphyxiants, as well as being flammable, toxic, and possibly life threatening.

Also, electromagnetic flowmeters and all flow measurement devices that use secondary instruments such as pressure sensors to actuate a control valve or send a signal to a remote source must be periodically inspected, calibrated, repaired, and/or replaced. Improper location of the flowmeter itself, the secondary sensor, or readout devices can result in measurement errors and hidden costs.

Is it really necessary to learn about flowmeters to be in control, stay in control, operate safely, and keep operating costs as low as possible? Simply stated, YES.

ters, heat input and coefficient of specific heat, are constant.

Another type of mass flowmeter uses one flow channel with a temperature sensor located in the path of the flow. The technology is simpler, but often less accurate, and is limited to higher flow rates.

Accuracy and repeatability

Thermal-mass flowmeters are gas-specific devices, and they must be calibrated using either the actual gas or a reference gas. This inconvenience led to the development of many "fixes," and drives the development of smarter devices. However, primary calibration using the actual gas or a gas of similar molecular characteristics is currently the only way to ensure accuracy.

Two factors that determine the accuracy of mass flowmeters and mass flow controllers are flow calibration and repeatability. Proper instrument calibration ensures starting point accuracy. Repeatability is the measure of continuous performance-to-specification over the lifetime of the device. Most mass flowmeters and mass flow controllers have an accuracy of ±1% of full scale and a repeatability of ±0.25% of full scale.

Several factors affect repeatability. Highly stable materials and electronic components, as well as precise internal voltage and current regulation are used to compensate. Sensor and bypass design also play a major role in preventing errors caused by contamination and clogging. For example, U-type sensor tubes exhibit residual stresses from bending, which can cause long-term strains and unraveling of sensor coils. These sensors are also more likely to develop drift due to contaminant deposits.

Consideration should also be given to the bypass element. Accuracy is degraded by changes in temperature if the bypass is an orifice (or venturi), as opposed to a pure laminar-flow element. With an orifice bypass, the pressure drop is proportional to the square of the bypass flow. In this case, the ratio of bypass flow to sensed flow is not a constant, but instead is a complex nonlinear function having temperature-dependent terms such as gas viscosity. Both the nonlinearity and temperature dependence of the orifice bypass can seriously degrade the accuracy of a mass flow controller.

Mass flowmeters for use with vacuum furnaces

A common heat processing application of thermal mass flowmeters and mass flow controllers is maintaining a specified gas flow rate into a vacuum chamber when the process requires a partial pressure of additive gas. Typically, a throttle valve or an orifice-limiting device is used to control the output of a vacuum pump. This is an extremely pressure-sensitive method and can result in inefficient gas delivery and poor product quality. Mass flow controllers automatically compensate for changes in system pressure caused by vacuum pump fluctuations and deliver a precisely controlled gas flow rate to the chamber. HTPRO

For more information: Daniel H. Herring (The Heat Treat Doctor) is president, The Herring Group Inc. P.O. Box 884, Elmhurst, IL 60126-0884, 630.834.3017, email: dherring@heat-treat-doctor.com, heat-treat-doctor.com.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ASMnews®

ASM's **2014 Class of Fellows**

In 1969, ASM established the Fellow of the Society honor to provide recognition to members for their distinguished contributions to materials science and engineering and to develop a broadly based forum of technical and professional leaders to serve as advisors to the Society. Following are the members recognized by their colleagues for 2014. Additional Fellows may be elected to this distinguished body in subsequent years. The solicited guidance, which the Fellows provide, will enhance the capability of ASM as a technical community of materials science and engineering professionals in the years ahead. Awards will be presented at ASM's annual Awards Dinner, Tuesday, October 14, in Pittsburgh, during Materials Science & Technology 2014.

Mr. John F. Clayton, FASM
Principal
FAMEX Engineering, Ontario, Canada

For technical excellence in the field of forensics and failure analysis, demonstrating a long and distinguished set of achievements in solving materials problems across a wide range of industries, while mentoring others and disseminating the fundamentals of materials failure analysis through publications and presentations.

Prof. Zhigang Zak Fang, FASM
Professor
University of Utah, Salt Lake

For sustained and high impact contributions to the hard metals industry through development of novel cemented carbide and polycrystalline diamond structures, and processing and development of low cost titanium and metal hydrides for energy applications.

Dr. James C. Foley, FASM
R&D Manager
Los Alamos National Laboratory, N.M.

For significant contributions to research and development in the field of nonferrous materials, including beryllium alloys, uranium alloys, amorphous alloys, and lead-free solders.

Dr. David R. Forrest, FASM
Technology Manager
Department of Energy, Washington

For outstanding technical leadership in emerging materials technologies such as nanomaterials and molecular manufacturing, with demonstrated technical expertise in material processing, computational modeling, and nondestructive testing.

Dr. Michael T. Hahn, FASM
Engineer 5
Northrop Grumman Aerospace Systems, Redondo Beach, Calif.

For outstanding contributions to a wide variety of metallurgical advancements for improving the performance and cost effectiveness of various aircraft alloys, including aluminum, titanium, and steel alloys as well as composites, ceramics, and coatings in the commercial and noncommercial aircraft industries.

Continued on next page

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.

...in this issue

Submit news of ASM and its members, chapters, and affiliate societies to
Joanne Miller, editor, *ASM News* | ASM International | 9639 Kinsman Road | Materials Park, OH 44073
P 440.338.5151 ext. 5662 | **F** 440.338.4634 | **E** joanne.miller@asminternational.org

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F 440.338.4634 | **E** MemberServiceCenter@asminternational.org | **W** asminternational.org

ASM INTERNATIONAL

Mr. Don Hashiguchi, FASM
Manager, Process Engineering
Materion Corp., Elmore, Ohio

For the development of inert gas atomized beryllium and aluminum-beryllium alloys used in aerospace, space, and science applications.

Prof. Hani Henein, FASM
Professor
University of Alberta, Edmonton

For scientific and engineering achievements in developing the understanding between structure and processing for a wide range of metallic alloys and processing methods targeting industrially relevant materials in the energy and aerospace fields while mentoring students and creating innovative teaching methodologies.

Dr. Alan F. Jankowski, FASM
Professor
Texas Tech University, Lubbock

For pioneering the use and application of deposition technology to synthesize engineered nanostructures such as nanolaminates and metallic glasses in order to investigate physical properties, phase transformations, and energy conversion.

Dr. Mary C. Juhas, FASM
Associate Vice President
The Ohio State University, Columbus

For significant technical and scientific contributions to the physical metallurgy of friction-stir welding in joining lightweight alloys, and for groundbreaking and sustained international leadership in promulgating engineering education.

Nomination Deadline for the 2015 Class of Fellows is Fast Approaching!

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

Criteria for the Fellow award are:

- Outstanding accomplishments in materials science or engineering
- Broad and productive achievement in production, manufacturing, management, design, development, research, or education
- Five years current, continuous membership
- Deadline for nominations for the class of 2015 is **November 30, 2014.**

Complete information including the rules, interpretive comments, and user-friendly online nomination forms are available on the ASM website at asminternational.org/membership/awards/asm-fellows or by contacting Christine Hoover at 440.338.5151, ext. 5509 or christine.hoover@asminternational.org.

Prof. Leijun Li, FASM
Professor
University of Alberta, Edmonton

For contributions to understanding the welding metallurgy of steels and superalloys and the fundamental mechanisms that explain ultrasonic consolidation in metal-matrix composites.

Dr. Ivan E. Locci, FASM
Principal Research Engineer
The University of Toledo, Ohio,
and NASA Glenn Research Center,
Cleveland

For significant contributions to high temperature materials and process development for the gas turbine engine industry through the use of advanced electron microscopy techniques.

Mr. John J. Marcin, FASM
Manager
United Technologies-Pratt & Whitney,
Marlborough, Conn.

For important contributions to investment casting of turbine airfoils and for developing new superalloy casting techniques to enable production of turbine airfoil designs with significantly higher temperature capability.

Prof. Javad Mostaghimi, FASM
Professor
University of Toronto

In recognition of pioneering developments related to thermal plasmas and thermal spray coatings.

Dr. Ashim Kumar Mukhopadhyay, FASM
Scientist G
Defense Metallurgical Research
Laboratory, Hyderabad, India

For sustained and significant technical and scientific contributions in the areas of physical and mechanical metallurgy of aluminum alloys, and for the development and commercial production of these materials for structural applications.

Dr. Mariappan P. Paranthaman, FASM
Distinguished Research Staff
and Group Leader
Oak Ridge National Laboratory, Tenn.

For the development of novel epitaxial buffer layers on textured templates, enabling high critical current density superconductor films, and developing mesoporous architectures destined for high performance energy storage applications.

Mr. Gregory J. Petrus, FASM
President
Forged Right First LLC, Hinckley, Ohio

For significant contributions to physical metallurgy through development of innovative solutions using simulation tools for enhancing metalworking and heat treating, in order to exploit a wide array of materials structure-property-processing relationships.

Dr. Bruce A. Pint, FASM
Distinguished Research Staff
Oak Ridge National Laboratory, Tenn.

For groundbreaking contributions to the fundamental knowledge of high temperature oxidation mechanisms in alloys and coatings, and for contributions to heat resistant alloy design and development through the incorporation of minor elements to control and improve high temperature stability and overall oxidation resistance.

Dr. Claudia J. Rawn, FASM
Associate Professor
University of Tennessee, Knoxville

For significant technical contributions to the study of structure-property relationships of materials for energy-related materials via in situ x-ray and neutron diffraction.

Dr. Sergei A. Shipilov, FASM
Senior Consultant
Metallurgical Consulting Services Ltd., Ontario, Canada

For continuous international contributions to materials science, particularly in the advancement of fundamental knowledge of corrosion science and engineering, environment enhanced cracking, and understanding the interactions between the environment, a material's microstructure, and the applied and residual stresses acting on a failing component.

Dr. Jaimie S. Tiley, FASM
Senior Materials Engineer
Air Force Research Laboratory, Wright-Patterson AFB, Ohio

For providing outstanding leadership and scientific support in the development and execution of complex materials-related research programs that have successfully created and transitioned new materials and technologies.

Dr. William E. Vanderlinde, FASM
Senior Technical Expert
Laboratory for Physical Sciences, College Park, Md.

For outstanding technical leadership and management and significant contributions to the development of next-generation tools for microelectronic circuit failure analysis and fault isolation.

Prof. Haiyan Wang, FASM
Program Director, Professor
National Science Foundation, Arlington, Va., and Texas A&M, College Station

For innovative research at the frontier of nanostructured materials and applications including high temperature superconductors, thin film solid oxide fuel cells, in situ transmission electron microscopy, and multifunctional ceramic composites, and for exceptional potential in inspired education and future leadership.

Dr. Priti Wanjara, FASM
Team Leader
National Research Council Canada, Montreal

For distinguished scientific and engineering contributions in the development and application of materials processing technologies for manufacturing materials in the aerospace, automotive, marine, and power generation industries.

Mr. Michael J. Weimer, FASM
Chief Consulting Engineer-Materials
GE Aviation, Cincinnati

For outstanding and sustained achievements in materials science and engineering in the aerospace industry, with special recognition for the development and implementation of gamma-titanium aluminum alloys in gas turbine engines.

Dr. Andrzej Wojcieszynski, FASM
Technical Director
ATI Powder Metals, Pittsburgh

For advances in powder metallurgy that resulted in the development of corrosion and wear resistant alloys for high performance applications.

Dr. Dongming Zhu, FASM
Senior Materials Engineer
NASA Glenn Research Center, Cleveland

For technical achievements in the design and characterization of novel and advanced materials for gas turbine engine components, specifically in the areas of thermal and environmental barrier coatings.

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, can contact Sarina Pastoric at sarina.pastoric@asminternational.org. Nominations are due **September 30.**

From the President's Desk

ASM Membership, A Lifelong Phenomenon

Thanks to visionaries William Park Woodside and William Hunt Eisenman, ASM International is now a global society with 30,000 members supported by 83 chapters in the U.S., Canada, India, Europe, the Middle East, and Singapore.

Leadership Days: Chapter leaders met in Minneapolis, July 17-19. They ignited the ASM spirit with ideas such as sustaining memberships with increased representation and seed grants for regional conferences. I chaired the opening session of this conclave of effervescent materials professionals determined to participate in our advancement. I reviewed my presidential focus and vision: Membership and customer development were at the top of the list, followed by ASM's position as an information leader, partnerships with related societies, lifelong learning, students as future leaders, and managing our finances with a shared vision. I was also keen to celebrate their successes and listen to their ideas.

If your actions inspire others to dream more, learn more, do more and become more, you are a leader.
John Quincy Adams

New Initiatives: ASM is proactive in keeping up with the ever changing needs of materials professionals and fulfilling needs unique to specific geographical regions and key industrial sectors. Our society is the key driver of many government projects, in particular the Computational Materials Data Network and Thermal Manufacturing Industries Advanced Technology Consortium. ASM is proud to lead a national effort with a major grant from NIST through the AMTech Program to create a roadmap for the future. I also value the currency and quality of ASM's content and delivery methods. We are pleased to launch two new ASM Handbooks on heat treatment of ferrous materials in October, and soon as an online resource.

Membership Drive: The time has come to celebrate the value of ASM membership with renewed enthusiasm. We are launching a major membership drive starting this month, along with incentives for recruitment. I seek active participation of our members, trustees, past presidents, and employees in this effort. Membership and chapter development go hand in hand: I salute ASM Canada Council Chair Erhan Ulvan as he invigorates chapter leaders with monthly teleconferences, and I applaud India Council Vice Chair Prem Aurora for championing a major regional ASM event (MET-14 and HTS) and facilitating new chapters. ASM members advance together and make the world better for humanity.

C. (Ravi) Ravindran
ravi.ravindran@asminternational.org

ASM Indian Institute of Metals Announces 2014 Recipients of Two Visiting Lecturer Programs


Atre


Baan


Berndt


Charit

The cooperative Visiting Lecturer program of ASM International and the Indian Institute of Metals (IIM) is pleased to announce the five distinguished individuals named to participate in the **2014 ASM/IIM Visiting Lecture Program:** Prof. Sundar V. Atre, Oregon State University; Prof. Maria Kocsis Baan, University of Miskolc, Hungary; Prof. Christopher C. Berndt, FASM, Swinburne University of Technology, Australia; Prof. Indrajit Charit, University of Idaho; and Dr. Alberto Vomiero, National Research Council, Italy. The award carries with it an $800 honorarium to be used for travel expenses within India during the lecturer's visit and a certificate of recognition to be presented at the ASM Leadership Awards Luncheon scheduled for October 13 in Pittsburgh during MS&T14.


Vomiero


Murty


Mukhopadhyay

Prof. B.S. Murty, FASM, and Prof. N.K. Mukhopadhyay, both from the Indian Institute of Technology, were named to participate in the **2014 ASM/IIM North American Visiting Lectureship Program.** This award carries with it a $2000 honorarium to be used for travel expenses within the U.S. and/or Canada during the lecturer's visit and a certificate of recognition to be presented at the ASM Leadership Awards Luncheon during MS&T14.

Exciting New 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, which will then be compression tested. The competition will take place Tuesday, October 14, during MS&T on the exhibit floor. Come cheer on your team and see if the domes can take the weight!

Visit asminternational.org/students3 for more information and to register before the **September 12th deadline.** Follow the competition at #ASMDomesDay.

Brian Wright named 2014 Kishor M. Kulkarni Distinguished High School Teacher

The Teacher Award Committee of the ASM Materials Education Foundation is proud to announce the selection of **Brian Wright** of Olympia High School, Washington, as recipient of the 2014 Kishor M. Kulkarni Distinguished High School Teacher Award.

The award, $2000 plus $500 toward travel to MS&T, was established in 2007 through a generous donation by Dr. Kishor M. Kulkarni, past trustee of ASM International, and his family to recognize the accomplishments of one U.S. high school science teacher who demonstrates a significant and sustained impact on pre-college age students. The award will be presented on October 13 at the ASM Leadership Awards Luncheon at MS&T14 in Pittsburgh.

> *"Brian's most significant contribution is the inspiration he provides to students and teachers to engage in the sciences and to ask questions about the world around them."*
>
> Dr. Roumiana Petrova
> New Jersey Institute of Technology and organizer, ASM Materials Camp-Teachers

Wright achieved National Board Certification, served overseas in Turkey as a Fulbright Exchange Teacher, and performed original laboratory research at both Washington State University and Evergreen State College.

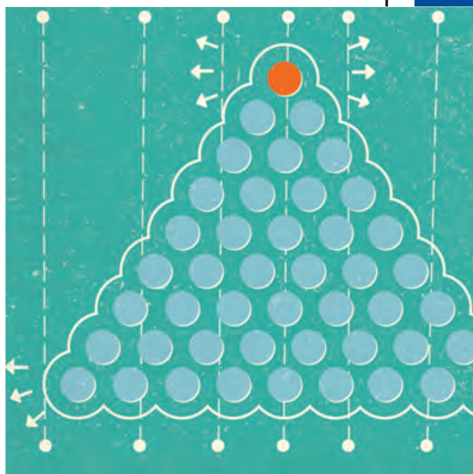
ASM Women in Materials Engineering Breakfast

Join your colleagues for the ASM Women in Materials Engineering Breakfast at MS&T on Tuesday, October 14. Listen to featured speaker Kathleen Buse, adjunct professor from the Weatherhead School of Management, Case Western Reserve University, who will present, "Why They Stay: Women Persisting in the STEM Professions." Tickets can be purchased via meeting registration at matscitech.org/register/.

THE POWER OF ONE | Membership Drive

One by one, members have grown our community into the largest metals-focused society in the world. Every new member brings fresh perspective, energy, and knowledge, while benefitting from powerful networking opportunities, education, and materials information.

Starting September 1, *you* have the power to shape ASM's future by inviting talented colleagues to join. It's easy to ask your teammates to check out ASM with its affordable membership, value-packed services, conferences, accredited education, and information resources. When you bring in new members, you are not only strengthening your ASM community, but you are also growing ASM as an effective voice for the materials science field.



The Power of One Membership Drive is rewarding your success in attracting new members with a variety of cash prizes!

Visit asmpowerofone.com for more details.

General Reward

Each current ASM member who successfully brings in a new member will receive a $10 cash gift card!*

Competitive Prize

ASM will sponsor grand prizes, one for each of the following categories. For each new member you bring in, you will be entered for a chance to win a grand prize!

Member – $3500 grand prize
Chapters – $2500 grand prize
National Committees – $1000 grand prize

**International participants will receive ASM Points equivalent to cash rewards and prizes, if qualified. Details are listed in rules and regulations at asmpowerofone.com.*

Nominations Sought for 2015 ASM/TMS Distinguished Lectureship in Materials & Society

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

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

The qualifications of the lecturer must include:

- A person experienced in national or industrial policy-making in the field of materials science and engineering.
- An eminent individual who possesses a keen sense of how technology and society are affected by development in materials science and engineering.
- A person associated with government, industry, research, or education.

Nominations may be proposed by any member of either Society. Submit your nominations for consideration by **Sept. 15.** Recommendations must be received at the headquarters of either Society.

For a complete listing of the rules and nomination form, visit asminternational.org/membership/awards or contact Christine Hoover, at 440.338.5151 ext. 5509, christine.hoover@asminternational.org. Deb Price of TMS may also be contacted at awards@tms.org.

Eisenman Materials Camp Celebrates Milestone

Mike Connelly, FASM, and Margaret Bush, served as co-curriculum leaders for the 15th anniversary of the Eisenman Materials Camp held in Materials Park, Ohio, in July. The camp brings together high school students and ASM volunteer mentors and junior mentors for a week of materials science discovery and fun.

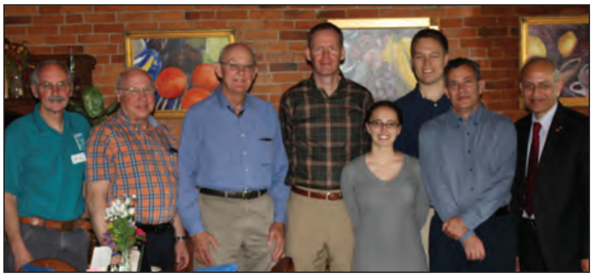

Campers bursting with energy and excitement for STEM!


ASM vice president Sunniva Collins, FASM, prepares to address camp graduates.

Judy Arner (right), helps student visually inspect samples in a holder.

Chapter News

Ravindran Visits Chapters



In the year of his ASM presidency, **C. Ravi Ravindran, FASM,** has logged many miles making the rounds to visit many ASM Chapters. He shares news of ASM strategic plans and directions, and listens to the needs and ideas of the members. In May, his travels allowed him to visit with chapter leaders from the ASM Hartford Chapter (above) and Washington D.C. Chapter (below).

IN MEMORIAM

John Stringer, FASM, died in California in July at age 80. A longtime resident of Redwood City, he grew up in England, graduated from the University of Liverpool in metallurgy, and later received his Ph.D. and D. Eng. there. He joined the Battelle Memorial Institute in Columbus, Ohio, in 1963. At age 32, he became the youngest Chair in Materials Science at the University of Liverpool. He returned to the U.S. in 1977 to work at the newly-founded Electric Power Research Institute (EPRI) in Palo Alto, Calif. He succeeded Bob Jaffee at EPRI, held various roles including Executive Technical Fellow, and retired in 2004 after 27 years. Stringer also held teaching posts at Stanford University and Lawrence Berkeley National Laboratory.

Stringer was a member of the ASM Santa Clara Valley Chapter and served on the Executive Committee, Education Committee, and San Jose State University Materials Engineering Industry Advisory Committee. He held various chair roles on the ASM Technical Programming Board (1996-2003) and helped foster ASM's Materials Solutions Symposia (1997-2004), which led to the current MS&T joint event. He was a Campbell Memorial Lecturer (1995), honored with the John Stringer Symposium on High Temperature Corrosion at ASM Materials Solutions (2001), served on the ASM Awards Policy Committee (2000-2005), and was appointed to the ASM Nominating Committee (2006).

David Lee Milam, age 63, of North Canton, Ohio, died April 29 of ALS (Lou Gehrig's Disease). He was awarded a B.S. degree in materials engineering from Brown University in June 1973 and both M.S. and Ph.D. degrees in metallurgical engineering from Purdue University. Dave moved to Canton to work at The Timken Co. as a research metallurgical engineer, a position he held from August 1978 until May 2009. He held several U.S. patents. Milam was a longstanding member of the Canton-Massillon Chapter, serving as chair from 1999-2000. Most recently, he was Student Affairs chair, judged the regional science fair, and reviewed applications to award scholarships to graduating seniors pursuing an engineering degree.

Hugh Victor Shotwell, Jr., age 78, longtime resident of Hammond, Ind., passed away on March 1. Born in Louisville, Ky., he was a graduate of the University of Kentucky and served in the Army Corps of Engineers. He retired as a metallurgical engineer from the American Steel Foundries in East Chicago after more than three decades. Shotwell was a member of ASM International for 59 years and served as chairman of the Calumet Chapter in 1969-70.

For a list of upcoming ASM Training Courses, see our ad on page 32 of this issue.

Members in the News

Scholarship Awarded to Lombardi

ASM student board member Anthony Lombardi is the winner of the 2014 MetSoc Doctoral Scholarship. This is a Canada-wide competition culminating in the selection of only one winner. The purpose of the MetSoc Doctoral Student Scholarship is to encourage and support the attainment of educational goals by a doctoral student who has demonstrated a high level of research achievement at a Canadian university. Lombardi is a third-year Ph.D. candidate in mechanical engineering at Ryerson University in Toronto. He is also a 2014-2015 student board member on the ASM Board of Trustees.

Promotion for Berndt

Christopher C. Berndt, FASM, TS-HoF, was promoted to University Distinguished Professor, Swinburne University of Technology in Australia, effective March 18, in honor of his outstanding research achievements, international recognition, and prominence in his field. The Acting Vice-Chancellor acknowledged the significance of Berndt's work in thermal spray studies within the field of materials science and engineering and his international leadership in this field. The University praised not only his research achievements, but also work he did as President of the Thermal Spray Society and ASM International.

Ravindran Receives Canadian Materials Award

ASM President C. Ravi Ravindran, FASM, was selected as the recipient of the 2014 MetSoc Distinguished Materials Scientist Award by the Metallurgy and Materials Society of CIM. This Materials Section Award recognizes members who have distinguished themselves through highly significant contributions to the advancement of materials engineering in Canada. The award will be presented at the banquet on September 30 at the Hyatt Regency Hotel Vancouver during the Conference of Metallurgists.

Simmons Donates $7.5 Million to CMU

Richard P. Simmons, FASM (left), chairman emeritus of Allegheny Technologies Inc., announced a $7.5 million gift to Carnegie Mellon University (CMU) in Pittsburgh to support a state-of-the-art auditorium to be built on the university's future David A. Tepper Quadrangle. The facility will serve as the center for major conferences, speeches, classes, and performances. "We are very grateful to Dick and Ginny Simmons for this generous gift," says CMU president, **Subra Suresh, FASM** (right).

SMDI Taps GM's Hall to Head Automotive Programs

The Steel Market Development Institute (SMDI), a business unit of the American Iron and Steel Institute (AISI), announces that **Jody N. Hall,** former Technical Integration Engineer at General Motors Co. Global Body Manufacturing Engineering Center in Warren, Mich., will succeed Ronald P. Krupitzer as vice president, Automotive Market, for the Institute. Krupitzer, who held the position for 13 years, will retire at the end of the year. Hall received her doctorate in materials science and engineering from the University of Michigan, under a General Motors Fellowship in 1994 and spent a large part of her career in applying new steels and manufacturing techniques in automotive applications.

ITA Honors Bania with Lifetime Achievement Award

Titanium metallurgist, researcher, and inventor **Paul J. Bania, FASM,** will receive the Lifetime Achievement Award from the International Titanium Association (ITA) during the organization's 30th annual conference in Chicago, September 21-24. The Award recognizes exceptional contributions to the advancement of titanium applications and technology. Bania was chosen for his outstanding efforts in developing new alloys and improving melting and mill processes used for titanium applications in aerospace, auto racing, and other industries. Bania's career includes 17 years at TIMET and forming TiPro Corp. to supply titanium to the auto racing industry.

Medical Materials Database **New Surgical Module Preview!**

ASM and Granta Design will release a preview of the upcoming ASM Medical Materials Database Surgical Module on September 18. Fully integrated with the existing database, which includes Orthopaedic, Cardiovascular, and Neurological Modules, the preview release contains records describing a representative and diverse sample of surgical devices and the materials (with specific grades, coatings, and more) used in those devices. This important new module will provide a peer-reviewed and reliable source of materials-related data for surgical device design. The full Surgical Module release will include up to five times more device records than are included in the preview, plus additional materials, drugs, and coatings.

For more information, contact Scott Flowers at scott.flowers@asminternational.org, 800.336.5152 or 440.338.5151, ext. 5230.

products & literature

Netzsch, Germany, launched the STA 449 F5 Jupiter, an economical and high-performance **testing instrument** capable of several measurement tasks. Jupiter simultaneously performs thermogravimetric analysis and differential scanning calorimetry on a single sample, yielding more information than separate tests. Combining both sets of data signals allows for differentiation between phase transformations and decomposition behaviors; distinguishing addition from condensation reactions; recognition of pyrolysis, oxidation, and combustion reactions; and other sample behaviors. netzsch.com.

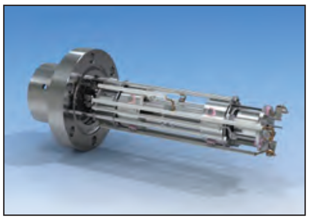
Morgan Advanced Materials, Allentown, Pa., announces new solutions in **sacrificial wear layers** to extend the life of alumina or beryllia electrostatic chucks (ESCs) for semiconductor, solar, and LED applications. Diamonex technical hardcoats are thin wear-resistant films, made of diamond-like-carbon (DLC) and other nanocomposite materials. They can be adjusted to meet specific resistivity requirements of the ESC while protecting electronic layers and extending overall part life. They have a broad range of chemical resistance, meet chamber process compatibility requirements, and can withstand high-temperature heated chuck applications. diamonex.com/wearlayers.

Oerlikon Metco, Switzerland, produces modern **carbide materials** specifically designed to resist the harshest environments of corrosion, impact, high compressive loads, deformation, cavitation, solid particle erosion, severe abrasion and complex, combined mechanisms. For example, while the company designs high-quality materials in standard cobalt matrixes for superior wear protection, matrixes of nickel-cobalt-chromium are available for environments that require corrosion resistance. The type of carbide used in the material, as well as the carbide grain size, can be tailored to specific applications. oerlikon.com/metco.

Renishaw Inc., UK, launched a new **Raman spectroscopy website** with enhanced navigation, up-to-date content, and more images. Raman spectroscopy provides information regarding the molecular vibrations present in a system and can be used as a complementary technique to IR spectroscopy to help identify a sample's "fingerprint." Often used in the pharmaceutical industry, the method is nondestructive with little sample preparation required. renishaw.com.

Teledyne Hastings Instruments, Hampton, Va., released a **mass flow unit conversion app** for iPhone, iPad, and Android-based devices. The app allows users to quickly and easily convert between mass flow units, such as sccm, slm, gm/sec, lb/hr, scfm, mole/min, and scim. The app is very flexible and allows users to select gas type as well as gas reference conditions. The free app also lets users access the informative white paper, *Best Practices for Mass Flow Controllers.* Search the Apple or Android App Stores to download. A website version of the tool is available at massflowconverter.com.

A new HMT **residual gas analyzer** (RGA) from Hiden Analytical Ltd., UK, offers a single partial pressure gauge to operate through the full vacuum spectrum from ultra-high vacuum (UHV) through millitorr. It provides process gas trend analysis, vacuum background diagnostics, and leak detection. The integral dual-detector enables monitoring at high pressure by Faraday detector and at lower pressures to UHV by electron multiplier detector, giving full conventional RGA specification with partial pressure detection down to 2 × 10E^{-13} mbar and a total dynamic range in excess of 10 decades. hidenanalytical.com.



Carl Zeiss AG, Germany, introduced LSM 880 with Airyscan, a new **confocal laser scanning microscope.** It offers high sensitivity, enhanced resolution in *X, Y*, and *Z,* and high image-acquisition speed in one system. A 1.7 × higher resolution is achieved in all spatial dimensions—140 nm laterally and 400 nm axially. Improved sensitivity leads to better image quality and increased speed. Instead of detecting signals with a single point detector, a multichannel area detector with 32 elements collects all the light from an Airy disk simultaneously. Users can take full advantage of large fields of view and the highest speed of any linear scanning confocal microscope at an unsurpassed image quality. zeiss.com.

classifieds

To advertise in the classifieds, or to order article reprints, please contact Diane Whitelaw at 440.338.5151 ext. 5240, diane.whitelaw@asminternational.org.

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editorial preview

OCTOBER

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

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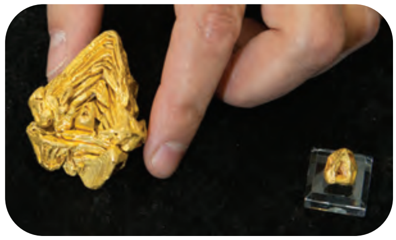
stress RELIEF

The 2015 Lincoln Navigator features ziricote wood, the first time this exotic hardwood has been used in the automotive industry. Courtesy of Business Wire.

Enhancing automobiles with ziricote wood

The Lincoln Motor Co., Dearborn, Mich., is the first automobile manufacturer to use ziricote wood, an exotic hardwood found in South America, southern Europe, and northern Africa. Ziricote accents the door panels, instrument panel, center console, and steering wheel of the 2015 Lincoln Navigator. A family resemblance can be seen from vehicle to vehicle, but because this is a natural product, no two Navigators with the Reserve Package will look exactly the same. Other than a thin protective coat, no stains or dyes are used, allowing the color and grain to shine through. The attention to detail begins with how the wood is cut—the linearity of the grain is maintained throughout the pieces to ensure harmony. Ziricote wood is an excellent match for the Lincoln Navigator for two reasons, say company officials: First, the natural pattern of the wood is in harmony with the lines of the interior. Second, the color of the ziricote wood complements the Coffee and Dune interior colors of the Reserve Package, helping the rich browns and reds really pop. *lincoln.com.*

Giant gold specimen sets single-crystal record



Neutron diffraction data collected on the single-crystal diffraction (SCD) instrument at the Lujan Center, from the Venezuelan gold sample, indicate that the sample is a single crystal.

Geologist John Rakovan, professor at Miami University, Oxford, Ohio, traveled to Los Alamos National Laboratory's Lujan Neutron Scattering Center, N.M., to peer deep inside a 217.78-gram piece of gold to see if it is in fact the world's largest single-crystal specimen. This distinguishing factor would not only drastically increase its market value, but also provide a unique research opportunity.

Rakovan used a single-crystal diffraction (SCD) instrument—a neutron single crystal diffractometer that determines the periodic atomic arrangement of single crystals, both natural and synthetic. As one of the workhorses at the Lujan Center, the high-ressure/preferred orientation (HIPPO) instrument is a general-purpose powder diffractometer that measures both the crystal structure and orientation distribution of crystals (or texture) making up a polycrystalline material based on the powder pattern of the crystals. It is the only time-of-flight neutron instrument in the world that routinely measures texture, with single crystals being the ultimate textured samples. The gold specimens are so far the largest single crystals characterized by HIPPO. *For more information: John Rakovan, 513.529.3245, rakovajf@miamioh.edu, units.miamioh.edu/geology.*

Suveen Mathaudhu, TMS Volunteer Comic-tanium Curator (left), introduced thousands of future scientists and engineers to real, imagined, and possible materials when Comic-tanium traveled to the USA Science & Engineering Festival in April 2014.

Saving the world, one material at a time

Comic-tanium is a traveling, non-profit educational exhibit that makes a connection between the real world of materials science and the fictional worlds of well-known comic book heroes, like Iron Man, Captain America, Spider-Man, Batman, and others. It was developed by the TMS Foundation, TMS, and the ToonSeum, Pittsburgh. Comic-tanium uses comic art and mythology to show how materials science and engineering actually does "save the world" every day. Its mission is to inspire young people to pursue STEM careers. Micrographs of advanced materials and schematics of lightweight cars are juxtaposed with comic panels focused on the "materials power ups" of an array of comic heroes and villains. Replicas of Batman's armor, Thor's hammer, Captain America's shield, and other artifacts make the comic pages on display come to life. Comic-tanium will be on display during MS&T14, October 12-16, at the ToonSeum. Conference attendees can stop by the TMS booth for a free ticket. The exhibit opens to the public on September 26 and runs through January 4, 2015. *tms.org/comictanium/default.aspx.*

The "dress up" station is one of the ways that Comic-tanium uses comic book mythology to make science accessible and fun, while also presenting the possibilities of materials science and engineering as a career path that can change the world.

SUCCESS ANALYSIS

Specimen Name: Smart Morphable Surfaces

Comprised of a soft polymer with a hollow center and a thin coating of a stiffer polymer, the sphere becomes dimpled when air is pumped out, causing it to shrink.

Vital Statistics:

In the 1800s, new golf balls sported smooth surfaces, but became dimpled over time as impacts left permanent dents. New balls were typically used for tournament play, but in one match, legend has it that a player ran short, had to use a dented one, and realized that he could drive the dimpled ball much further than a smooth one. Years of testing prove that a golf ball's irregular surface dramatically increases the distance it travels because it cuts drag-induced air resistance in half.

Researchers at Massachusetts Institute of Technology, Cambridge, are harnessing the same idea to reduce drag on other surfaces. Aerodynamics studies show that while a ball with a dimpled surface has half the drag of a smooth one at lower speeds, this advantage *reverses* at higher speeds. So, the ideal would be a surface whose smoothness can be altered in real-time.

Success Factors:

Pedro Reis and his team created a hollow ball of soft material covered with a stiff skin and then extracted air from the interior to make the ball shrink and its surface wrinkle. At a certain degree of shrinkage, the surface produces a dimpled pattern similar to that of a golf ball and with the same aerodynamic properties. Balls with smooth surfaces might be expected to sail through air more easily than ones with irregular surfaces. Yet the reason for the opposite result involves a small layer of air next to the surface: The irregular pattern holds airflow close to the ball's surface longer, delaying the separation of this boundary layer. This reduces the wake size, the primary cause of drag for blunt objects. Because surface texture can be controlled by adjusting interior pressure, the degree of drag reduction can be controlled at will. Due to the variability, the team named these *smart morphable surfaces* or *smorphs*.

The smorphs/Smurfs pun is intentional. Denis Terwagne, a Belgian comics fan, points out that one characteristic of Smurfs is that no matter how old they get, they never develop wrinkles. Courtesy of Pere prlpz.

In the lab, the morphable surface can have its surface texture changed at will by adjusting the pressure inside. When interior pressure is reduced, the flexible material shrinks, but the stiffer outer layer wrinkles as it shrinks, like a plum becoming a prune. Unlike a prune, the material can bounce back to a smooth state with increased pressure.

About the Innovators:

Pedro Reis is an assistant professor of mechanical engineering at MIT. His team includes former MIT postdocs Denis Terwagne and Miha Brojan.

What's Next:

Drag reduction of textured surfaces has already moved beyond golf balls: The soccer ball from this year's FIFA World Cup used a similar effect, as do some track suits worn by elite athletes. For these purposes, constant dimpling is adequate. But in other cases, the ability to alter surfaces on the fly could prove useful. For example, many radar antennas are housed in spherical domes, which can collapse catastrophically in high winds. A dome that could adjust its surface to reduce drag in strong winds might avert such failures. Another application is automobile exteriors, where the ability to adjust panels to minimize drag at different speeds could increase fuel efficiency.

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