



## CEP: Editorial - From To-Do to Done



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Cynthia Mascone  
 June 2015

I find inspiration for my editorials in all sorts of places. This month's topic came to me from a list of strange holidays, where I came across September 6, Fight Procrastination Day. You might expect this in the October issue, or later, given the nature of the celebration. By covering it now, I'm doing my part to fight procrastination.

Procrastination is the subject of much research and numerous publications, from scientific papers to self-help books and websites. You might think that such a vast amount of material on a subject would make it easy to write a mere 600 words on the topic. Alas, it turns out that this vast amount of material just makes reading about procrastination a very good way to put off writing my editorial.

Wikipedia defines procrastination as "the practice of carrying out less-urgent tasks in preference to more-urgent ones, or doing more-pleasurable things in place of less-pleasurable ones, and thus putting off impending tasks to a later time, sometimes to the 'last minute' before a deadline." My online search for "procrastination" got 12 million hits. If surfing the web is your preferred procrastination technique, this might be all you need for the rest of your life. By adding the word "overcoming," I narrowed it down to 277,000 (still plenty to keep me busy for quite a while). Some of the tips we have heard many times: remove distractions, eliminate interruptions, check your email only once an hour, break down large projects into smaller tasks and tackle one thing at a time, eliminate low-priority items from your to-do list, delegate what you can, and so on. I did, however, learn a few new tricks and twists that I might try.

Prioritize one thing each day. Write out the tasks that are causing you the most stress. To identify your top priority, ask about each task, "If this were the only thing I accomplished today, would I be satisfied with my day?"

Start a "done list." At the end of each day, write down what you've accomplished. This will help you realize how efficiently you're working and where you can improve.

Do nothing (else). Authors Roy Baumeister and John Tierney call this the Nothing Principle — to get yourself to do something, make the alternative to that task to do nothing. Writer Raymond Chandler sets aside at least four hours each day for writing with two simple rules: (1) You don't have to write. (2) If you're not going to write, you can't do anything else. Chandler likens this to keeping order in school: "If you make the pupils behave, they will learn something just to keep from being bored."

Reframe your sense of time. Researchers Daphna Oyserman of the Univ. of Southern California and Neil Lewis Jr. of the Univ. of Michigan found that people who were asked to start saving for a newborn to begin college in 18 years took four times longer to start saving than those who were told the money would be needed 6,570 days in the future. "If you see it as 'today' rather than on your calendar for sometime in the future, you're not going to put it off. Through this shift in time metrics, people can motivate themselves to accomplish their goals," Oyserman says.

I hope you read my editorials because you find them interesting, stimulating, and fun to read, not just as a way to procrastinate reading the more-technical material in the issue. With our biennial salary survey starting on p. 15, that's probably not the case this month.



# Letters

## TEACHING ETHICS

I read with great interest the article “Ethics — Examining Your Engineering Responsibility” (*CEP*, Feb. 2015, pp. 21–29). I teach chemical engineers in the final part of their degree courses like chemical process design and process analysis. We discuss briefly ethical issues.

Your article addresses one important theme — the “go fever” — and the pressure that is put on by management to proceed or carry out a scheduled chore no matter what. It will help me emphasize the importance of the professional code of ethics, as well as “moral autonomy.”

Thank you for a valuable article.

*Francisco J. Lozano G.  
Monterrey, Nuevo León, México*

## MAKING A DIFFERENCE MATTERS

I am glad that the article by Nwaynay Hlaing, *et al.*, “Humanitarian Chemical Engineering,” (*CEP*, Apr. 2015, pp. 45–50) found a place in this prestigious publication. While the technologies reported are not ground-breaking, they hammer home a few points.

First, making a difference is what matters. To chemical engineering academics in many under-developed nations, the immediate urgency is to help governments lift people out of the vicious cycle of poverty. Adapting tried-and-tested or low-cost technologies to suit local conditions and needs is perhaps the most appropriate undertaking. Publishing in high-end journals might be the last of their priorities. As such, we should not judge contributions by academics based on any single metric. Sadly, the publish-or-perish culture rampant in many nations does not encourage such “unpublishable” community work.

Second, the article reminds readers in the developed world of the sorry state of affairs in many other parts of the world. It makes us reflect on what we could have done differently in our daily and professional lives to change the status quo. To sustain our affluence, have we been blinded to the difference between wants and needs? Have we forgotten to nurture or to leave breathing space for those weaker and less endowed than us? Is the “winner takes all” mentality healthy for our civilization?

Third, and definitely most important, the article underscores a great opportunity to take a different path. The whole world is not at the same stage of development, so the late-comers must learn the lessons of the early-starters. I am particularly alarmed by the Myanmar case, where a renewable way of electricity generation is being replaced by conventional electrification, paving the way to fossil fuel addiction, and to inevitable struggles in securing their supply. Granted that cow dung alone will not satisfy the needs of a more-affluent and

less-agrarian society; but shouldn't the country be helped to latch itself onto more varieties of renewable energies?

This is where advanced nations and their technological prowess could really make an impact. Help mold a different way of life, from scratch! Not just technologically, but also culturally, *e.g.*, preserving noble features such as the strong volunteerism highlighted in the article. This is not just being overly kind to others, but doing ourselves a critical service, too: Planet Earth might fall over the cliff if everyone lived the current American lifestyle.

As with all humanitarian work, humanitarian chemical engineering also needs funding, for example, from private donations and intergovernmental development aid. More so if it is to blaze a different trail to sustainable development. This is where engineering meets politics and social sciences, and not every chemical engineer feels at home.

This article addresses the correct audience: Americans (mostly) who are among the world's best at lobbying and fundraising.

*Hak Koon Yeoh  
Petaling Jaya, Malaysia*

## LICENSURE, CONTINUED

I would like to thank Paul Wood for his letter in the April 2015 issue of *CEP* (p. 4), in which he describes some of the real-world problems with the licensing system as it exists in the U.S. While I have always encouraged people to get licensed, and from some of the management positions I have held have been able to do so very aggressively, it is important to understand that the current system has some real flaws.

The California system is an aberration and, fortunately, no other state has such irrational provisions, but it doesn't look like any state has a system that was designed by competent and experienced practicing engineers. Woods's letter tells why it is important to get licensed, and to do so as early as possible. It should also help all of us understand that it takes a lot more than a P.E. license to qualify an engineer for the kind of “responsible charge” needed to ensure the health and safety of the public and to properly protect the economic needs of the employer and/or client.

In the field of engineering, and certainly in chemical engineering, experience is the best teacher, and the more that such is understood and taken into consideration by a system, the better that system will be.

*Neil Yeoman  
Merrick, NY*

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## A Simple Approach to Separating Rare Earth Metals

Ultraviolet light is all that is needed to separate two valuable rare earth metals.

Europium and yttrium — rare earth metals used in sustainable technologies and high-tech electronics applications — are expensive to mine, so they are often obtained from recycled red lamp phosphor, a powder used in fluorescent lamps. Chemists at Katholieke Universiteit Leuven previously developed a process to recover the red lamp phosphor from fluorescent lamps and low-energy lightbulbs. However, this method recovers the bulk powder, with the two rare earth metals still together.

Separating the two rare earth metals is a complicated process, says Tom Van Gerven, head of process engineering for the sustainable systems section at KU Leuven. “The traditional method dissolves europium and yttrium in aqueous acid,” Van Gerven says. “An extractant and a solvent are then added to the aqueous liquid, creating two separate phases — an aqueous layer containing the rare earth metals and a solvent layer with the extractant. When the two layers come into contact, one of the two rare earth metals is extracted into the solvent, while the other remains in the aqueous layer.”

But, Van Gerven says, “This process leaves much to be desired in terms of efficiency and purity. It needs

to be repeated dozens of times to recover a high percentage of a particular rare earth metal, and there will still be traces of yttrium in the europium-containing liquid and vice versa.”

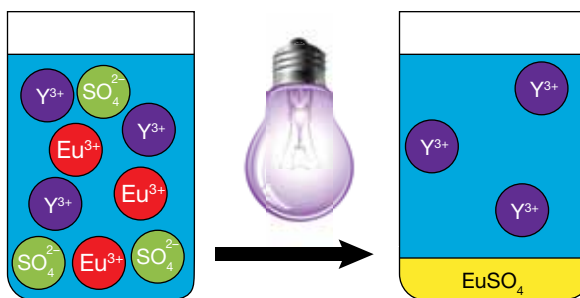
The engineers at KU Leuven have used ultraviolet light to separate europium and yttrium with much better results. The mixture of europium and yttrium — each containing three positive charges — is exposed to UV light. The UV energy is just right to neutralize one of the charges on the europium ion. Next, sulfate is added to the mixture; the sulfate reacts with europium and causes the europium to precipitate from solution. The europium precipitate is then filtered from the solution, leaving behind yttrium.

The UV process has several advantages over the solvent-based method. It does not involve harmful chemicals, has high separation efficiency (more than 95% of the europium is recovered from the solution), and yields high-purity metal products (the precipitate is 98.5% pure).

The new process is promising. However, its efficiency still needs to be improved — the focus of the next step for the KU Leuven team.

Van den Bogaert, B., *et al.*, “Photochemical Recycling of Europium from Eu/Y Mixtures in Red Lamp Phosphor Waste Streams,” *Green Chemistry*, 17 (4), doi: 10.1039/C4GC02140A, pp. 2180–2187 (2015).

► Scientists at KU Leuven have developed a new process for separating europium from yttrium that does not require the addition of solvents — only UV light and sulfate. The UV light neutralizes one of the europium ions, making it reactive with sulfate. Image courtesy of KU Leuven, Dept. of Chemical Engineering.



## A Bionic Device Mimics Natural Photosynthesis

Engineers and scientists continue to look for ways to mimic natural photosynthesis — the highly efficient process by which plants convert sunlight into chemical energy. Such developments could tap into the abundant energy stored in the sun to create fuels and chemicals.

In a recent development, engineers at the Univ. of California, Berkeley, have created a part-synthetic, part-biologic system that uses solar energy to reduce CO<sub>2</sub> into a wide range of chemical products, including fuels, polymers, and complex pharmaceutical precursors. This bionic device combines a solar cell with a genetically modified bacterium — the first example of microbial photoelectrosynthesis.

“We believe our system is a revolutionary leap forward in the field of artificial photosynthesis,” says Peidong Yang, the S. K. and Angela Chan Distinguished Professor of Energy in the Dept. of Chemistry and of Materials Science and Engineering at UC Berkeley. “Our system has the potential to fundamentally change the chemical and oil industry, in that we can produce chemicals and fuels in a totally renewable way, rather than extracting them from deep below the ground.”

Natural photosynthesis entails two main processes: water-splitting, which uses energy from the sun to decompose water into oxygen, hydrogen, and electrons; and CO<sub>2</sub> fixation, which uses the electrons produced in the first step to convert CO<sub>2</sub> into carbon monoxide. While the synthetic water-splitting process is relatively well developed, with effective catalysts for water oxidation and reduc-

tion, the CO<sub>2</sub> reduction step is not.

“When we talk about artificial photosynthesis, water-splitting is not necessarily the ultimate goal,” Yang says. “The ultimate goal is trying to use sunlight, CO<sub>2</sub>, and water, to reduce CO<sub>2</sub> and produce chemicals of high value.”

The device combines an artificial forest of sorts made of nanoscale tree-like heterostructures, consisting of silicon trunks and titanium oxide branches, with bacteria filling the voids between the nano-trees. The silicon-TiO<sub>2</sub> nanowires capture energy from the sun to generate electrons, which are passed on to the bacteria. The bacterium, *Sporomusa ovata*, produces enzymes that reduce CO<sub>2</sub> to acetate.

“Our artificial forest is similar to the chloroplasts in green plants,” Yang says. “When sunlight is absorbed, photo-excited electron-hole pairs are generated in the silicon and titanium oxide nanowires, which absorb different regions of the solar spectrum. The photo-generated electrons in the silicon will be passed onto bacteria for the CO<sub>2</sub> reduction, while the photo-generated holes in the titanium oxide split water molecules to make oxygen.”

Once the CO<sub>2</sub> has been reduced to acetate, genetically engineered *Escherichia coli* are used to synthesize high-value chemical products. For now, the *S. ovata* and *E. coli* are stored in separate containers, which allows the researchers to more easily optimize the yields of each step. In the future they will be combined into a single device.

The engineers used their bionic system to produce several products. They fed CO<sub>2</sub> and water into the nanowire-bacteria device to produce acetate (with a CO<sub>2</sub>-to-acetate efficiency of 0.38%) using ultraviolet light as the energy source. The acetate then served as the feedstock for the genetically engineered *E. coli*, which produced *n*-butanol, with a yield of

26%; polyhydroxybutyrate (PHB) polymer, 52%; and three different isoprenoid natural products, with yields up to 25%.

Although the efficiency of this proof-of-concept device is low, the team has already identified the bottleneck to higher efficiency and is working on an improved version.

“We are currently working on our second-generation system, which has a solar-to-chemical conversion efficiency of 3%,” Yang says. “Once we can reach a conversion efficiency of 10% in a cost-effective manner, the technology should be commercially viable.”

Liu, C., *et al.*, “Nanowire-Bacteria Hybrids for Unassisted Solar Carbon Dioxide Fixation to Value-Added Chemicals,” *Nano Letters*, 15 (5), doi: 10.1021/acs.nanolett.5b01254, pp. 3634–3639 (Apr. 7, 2015).

## Molecules Click into Biocompatible Hydrogels

Engineers at the Wyss Institute for Biologically Inspired Engineering at Harvard Univ. have developed a new alginate-based hydrogel that is completely biocompatible. The hydrogel is easy to make, has tunable mechanical properties, and could be used to encapsulate bioactive materials for drug delivery and other biomedical applications.

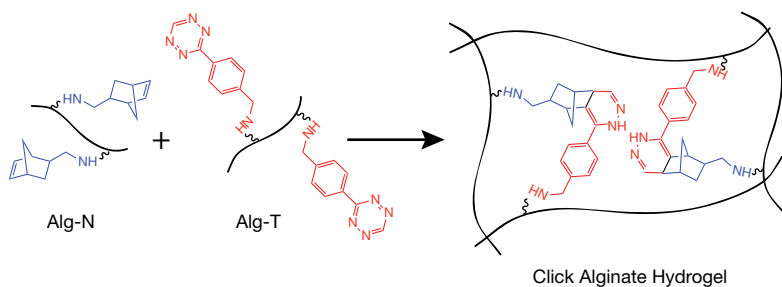
“It’s injectable, so it can be used to deliver cells or drugs to specific

places in the body, such as a location that has suffered a wound or has been invaded by a tumor,” says Neel Joshi, an associate professor of chemical and biological engineering in Harvard’s School of Engineering and Applied Sciences (SEAS). “We are already using it for lots of different things in the laboratory, due to how easy it is to synthesize.”

Hydrogels are made of polymers linked together into a 3D network to form a flexible, gelatin-like material. Their likeness to biological tissue — a soft, flexible network structure full of water — makes them especially useful for biomedical applications, such as drug delivery, cell encapsulation, and tissue engineering.

Alginate — a polysaccharide found in brown algae — can be cross-linked to form such hydrogels. These hydrogels are typically made via a reversible ionic crosslinking method in which divalent cations such as Ca<sup>2+</sup> form ionic bridges between adjacent polymer chains. Gels made with this method, however, are weak, and they lose mechanical integrity over time due to the reversible nature of the crosslinks. In addition, calcium-crosslinked hydrogels often exhibit inconsistent physical properties, and leached calcium from these hydrogels can stimulate the immune system, which is undesirable for *in vivo* applications.

Scientists have turned to covalent crosslinking strategies to overcome



▲ Scientists used aqueous carbodiimide chemistry to modify the alginate backbone (black lines) with tetrazine (T) and norbornene to produce Alg-T and Alg-N. These polymers can then be mixed together to form a hydrogel. Image courtesy of Harvard Univ.



these challenges. However, the reagents used to make the covalently crosslinked hydrogels are not selective enough to be biocompatible. Encapsulated cells and other biomolecules, therefore, can be damaged or modified through unintended reactions with these reagents.

The Wyss engineers used click chemistry to crosslink alginate polymers. In click chemistry reactions, two molecules are designed to rapidly react only with one another. Since the discovery of click chemistry by Karl Barry Sharpless, Nobel Laureate and chemistry professor at the Scripps Research Institute, several click pairs have been identified.

“Sharpless came up with a few click pairs and many of them required the use of a lot of catalyst that could

be toxic to biological systems, so they weren’t especially widely used,” says Rajiv Desai, a doctoral student of biomedical engineering at the Wyss Institute. “But then others discovered new click pairs that do not require such toxic catalysts,” he continues. “We used one of those click pairs that is completely nontoxic and doesn’t require any kind of catalyst or input of energy.”

They chose the click pair of tetrazine and norbornene. This pair can be crosslinked via the bio-orthogonal inverse electron-demand Diels-Alder click reaction. The engineers used conventional carbodiimide chemistry to introduce the click functional groups onto the surface of the alginate. They prepared separate solutions of tetrazine-modified alginate (Alg-T)

and norbornene-modified alginate (Alg-N) and mixed them together to form a gel. Then they varied the ratio of Alg-N to Alg-T (N:T ratio) to tune the mechanical properties of the hydrogel.

To demonstrate the utility of the new hydrogel for biomedical applications, Desai and his team evaluated the viability of cells encapsulated in the click alginate hydrogel over three days and compared the results to those of an ionically crosslinked hydrogel. The viability of cells encapsulated in the click alginate hydrogels was much higher than in the ionically crosslinked gels. *In vivo* tests of the click and ionically crosslinked hydrogels were also performed. After one month, the ionically crosslinked hydrogels lost some structural integrity, which

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allowed fibroblasts and immune cells to infiltrate the hydrogel, while the click-crosslinked hydrogel showed no evidence of breakdown.

“Our work allows us to make covalently crosslinked gels that are biologically friendly,” Desai says. “That was not possible before. If you wanted to make an alginate gel that was biologically friendly, you needed to use calcium crosslinking, which isn’t a covalent bond.”

Desai, R. M., *et al.*, “Versatile Click Alginate Hydrogels Crosslinked via Tetrazine-Norbornene Chemistry,” *Biomaterials*, 50, doi: 10.1016/j.biomaterials.2015.01.048 (May 2015).

## Nature-Inspired Coating Wards Off Water and Light

The layered nanostructures of a lotus leaf that repel water and those in a moth’s eyes that reflect light form the basis for a new superhydrophobic glass coating that holds potential for solar panels, lenses, detectors, and windows, among other applications.

Developed by scientists at the Oak Ridge National Laboratory (ORNL), the new coating consists of an interconnected network of nanoscale pores embedded in a nanostructured silica framework. The coating can be customized to be superhydrophobic, fog-resistant, and antireflective.

Lotus leaves repel water and self-clean when it rains. A moth’s eyes are antireflective; they are covered with nanostructures that create a tapered refractive-index profile, which gradually increases from the surface to the cornea, says Tolga Aytug, a member of the materials chemistry group at ORNL. “Combined, these features provide truly game-changing ability to design coatings for specific properties and performance.”

Coatings that suppress the reflection of light are critical for many applications. They can increase

the efficiency and power output of photovoltaic devices; enhance the light extraction from light-emitting diodes; and increase transmissivity of flat-panel displays, architectural windows, and lenses. To realize this potential, the coatings need to reduce reflection over a wide range of incidence angles. However, a single material that can do this and that can be applied to glass has not yet been developed.

Scientists have instead turned to layered designs and subwavelength structures, in which the refractive index varies stepwise from that of the ambient medium to that of the glass substrate. Methods used to make these coatings are either expensive (*e.g.*, photolithography, e-beam lithography, and nanoimprint lithography) or not conducive to high-volume manufacturing (*e.g.*, colloidal self-assembly).

“We demonstrate a novel approach that enables dramatic suppression of light reflection losses at the glass-air interface over a broad range of wavelengths and incident angles,” Aytug says. “Unlike other step-index antireflective coatings, this monolithic coating has a controllable porous submicron structure that offers significant advances, such as tunability of the refractive index, ability to optimize the coating for any glass substrate-ambient material system, tailored wettability, and compatibility with current industrial-scale manufacturing practices.”

In the first step of the fabrication process, a glass film made of silicon oxide ( $\text{SiO}_2$ ), boric oxide ( $\text{B}_2\text{O}_3$ ), and sodium oxide ( $\text{Na}_2\text{O}$ ) is deposited, via magnetron sputtering, onto a transparent glass substrate. The film is then annealed at temperatures ranging from 625°C to 710°C, which causes the glass coating to spinodally (without nucleation) separate into two interpenetrating phases — a sodium-borate-rich phase and a silica-rich

phase. The surface is then etched to selectively dissolve the sodium-borate-rich phase, leaving behind a porous three-dimensional network of high-silica-content glass. For a given glass composition, the structure and dimensions of the final coating can be controlled by adjusting the heat-treatment temperature and time and the etch conditions (*i.e.*, etchant type, concentration, and etch duration). These processing variables can also be adjusted to gradually vary the pore fraction and pore size, from the air-film interface to the bulk-film medium, in order to achieve a graded refractive-index profile.

“We developed a method that starts with depositing a thin layer of glass material on a glass surface followed by thermal processing and selective material removal by etching,” Aytug says. “This produces a surface consisting of a porous three-dimensional network of high-silica-content glass that resembles the microscopic structure of coral.”

Scanning-electron micrographs of the films reveal a network of nanoscale pores, with dimensions smaller than the wavelength of visible light, within a silica-based skeleton. The volume fraction of pores (and their size) progressively decreases from the surface of the film exposed to air to the center. Water contact angles ranged between 150 deg. and 170 deg. — *i.e.*, water droplets roll off of the film’s surface. The coating is also mechanically and thermally stable.

The scientists are now in discussions with glass companies to license the technology. In addition, they are developing a similar coating for polymer surfaces. The current method is not amenable to polymers because of the high annealing temperatures.

Aytug, T., *et al.*, “Monolithic Graded-Refractive-Index Glass-Based Antireflective Coatings: Broadband/Omnidirectional Light Harvesting and Self-Cleaning Characteristics,” *Journal of Materials Chemistry C*, doi: 10.1039/C5TC00499C (Apr. 23, 2015).

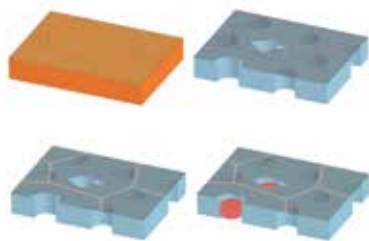


## Leakproof Graphene Finds a Home in Water Filtration

Exhibiting a treasure chest of extraordinary properties, graphene has the potential to transform a wide range of applications, from electronics and photonics, to energy generation, drug delivery, and sensors, among others.

One such application is water filtration. Graphene's thin profile, high strength, and imperviousness to atoms as small as helium make it a potentially ideal membrane for water filtration and desalination. The drawback, however, is that current processes to make films of graphene large enough to serve as membranes often create defects and tears through which contaminants could leak.

Engineers at the Massachusetts Institute of Technology, Oak Ridge National Laboratory, and King Fahd Univ. of Petroleum and Minerals have developed a way to repair these defects that combines chemical deposition and polymerization techniques. They then used a process they previously



▲ Engineers have successfully sealed leaks in graphene. First, they fabricated graphene on a copper surface (top left) — a process that can create intrinsic defects in the graphene, such as surface cracks. Then they lifted the graphene and deposited it on a porous surface (top right), which creates additional holes and tears. Next, they used atomic layer deposition to deposit hafnium (gray) to seal intrinsic cracks (bottom left). Finally, they plugged the remaining holes with nylon (red) via interfacial polymerization (bottom right). Image courtesy of MIT.

developed to create tiny, uniform pores in the leakproof material.

“We’ve been able to seal defects, at least on the lab scale, to realize molecular filtration across a macroscopic area of graphene, which has

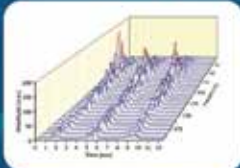
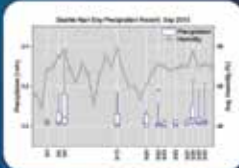
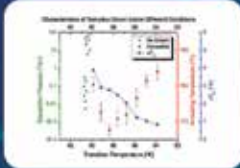
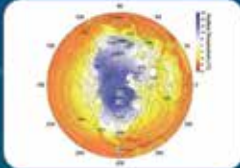
not been possible before,” says Rohit Karnik, an associate professor of mechanical engineering at MIT.

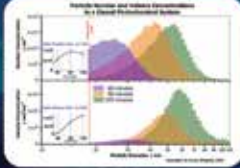
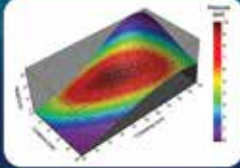
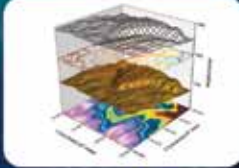
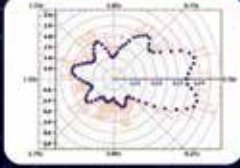
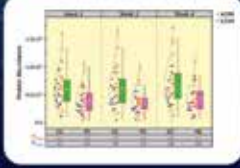
To fabricate the graphene membrane, the engineers grew a layer of graphene on copper foil, then

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removed the graphene and transferred it to a polycarbonate track etch (PCTE) membrane with 200-nm pores. Mass-transport measurements and electron microscopy showed that the graphene contained nanometer-scale defects formed during chemical vapor deposition (CVD) of graphene on copper, and large tears generated during graphene transfer to the PCTE substrate. The researchers used a two-step process to repair these defects and tears. First, they used atomic layer deposition (ALD) to seal the intrinsic defects with hafnium. Then they filled the larger defects via an interfacial polymerization reaction.

They characterized the viability of the repair process by measuring diffusion of potassium chloride across the membrane. Transferring the original graphene film onto PCTE reduced the flux of the PCTE membrane alone from 100% to 65%; the addition of hafnium reduced the flux to 40%, and the subsequent interfacial polymerization further reduced the flux to 8%.

After repairing the leaks, the engineers introduced uniform pores into the film by high-energy gallium-ion bombardment to nucleate isolated defects, then used acidic potassium permanganate to etch the defects into sub-nanometer pores. The resulting membrane is about the size of a penny; this is significant, because materials must be able to be manufactured at the centimeter scale or larger in order to be used as filtration membranes.

The researchers pumped water through the defect-sealed porous graphene membrane and found that water flowed through at rates comparable to those that current desalination membranes can achieve. When they evaluated the ability of the nanoporous membrane to reject solutes, including NaCl and MgSO<sub>4</sub>, under forward osmosis, they found that it was able to filter out most large-molecule contaminants.

While the results are promising,

graphene is not yet ready to be used commercially, the researchers say. “Advancing graphene membranes for desalination and nanofiltration will require additional effort in optimizing the pore-generation and defect-sealing processes, manufacturing of the membranes at larger scales, and investigating other factors that impact performance, such as biofouling and scaling,” they explain.

O’Hern, S. C., *et al.*, “Nanofiltration Across Defect-Sealed Nanoporous Monolayer Graphene,” *Nano Letters*, 15 (5), doi: 10.1021/acs.nanolett.5b00456, pp. 3254–3260 (Apr. 27, 2015).

## Onions Flex their Muscles Outside of the Kitchen

**O**nions — the pungent root vegetable that can make even the most seasoned chef shed tears — are at the heart of a new artificial muscle that can expand, contract, and bend in different directions. The new material could be useful for a range of applications, including microfluidic devices and miniature robots.

Developed by scientists at National Taiwan Univ., the artificial muscles consist of a layer of epidermal cells of an onion with a gold coating on both sides. When current flows through the gold electrodes, the onion cells bend and stretch, much like a biological muscle.

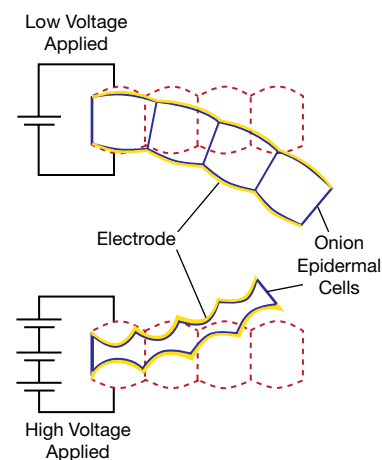
“The initial goal was to develop an engineered microstructure in artificial muscles for increasing the actuation deformation, that is, the amount the muscle can bend or stretch when triggered,” says Wen-Pin Shih, a professor of mechanical engineering and bioengineering. “One day, we found that the onion’s cell structure and its dimensions were similar to what we had been making.”

Until now, artificial muscles have been able to bend or contract, but not

both. Shih set out to change this by developing a material that could do both. The thin, transparent layer (epidermis), which sits under the onion’s brittle surface skin and is made up of block-shaped cells arranged in a tightly packed lattice, seemed promising.

Shih and his team separated the epidermal cells from the rest of the onion and then freeze-dried the material for 24 hours to remove water. Micrograph images of the freeze-dried onion epidermis showed that the tightly packed block cells remained intact. To give the material elasticity, the researchers treated it with a dilute solution of sulfuric acid to remove the hemicellulose, a protein that makes the cell walls rigid. Next, they sputtered gold onto both sides of the onion epidermal cell layer (24 nm on the top, 50 nm on the bottom). They then cut the cell layer into a rectangular strip (25 mm by 5 mm).

“We intentionally made the top and bottom electrodes different thicknesses



▲ The artificial muscles are made of onion epidermal cells coated on both sides with gold. The layers of gold are asymmetric — thicker on the top than the bottom — to facilitate bending. When a low voltage is applied, the onion cells flatten out; because the gold layer on the top of the cells is thinner and thus more flexible than the bottom gold layer, the tops of the cells elongate more than the bottoms, forcing the material to bend downward. At higher voltages, the flattened top and bottom layers of the actuator cave in, causing the cells to contract and bend upward. Image courtesy of Shih Lab, National Taiwan Univ.

so that the cell stiffness becomes asymmetric from top to bottom,” Shih says. The asymmetry enables a more-prominent bending actuation, he explains.

When a voltage is applied to the two electrodes, the onion cells bend and either contract or elongate. Changing the magnitude of the applied voltage causes the gold-coated onion cell to bend (or curl) in different directions. No deformation occurs when no voltage is applied. When a low voltage (0–50 V) is applied, the actuator elongates and bends downward. This elongation occurs because the original curved structure of the onion cells flattens out. Because the gold layer on the top of the onion cells is thinner than the layer on the bottom, the top is more flexible than the bottom. This flexibility allows the top of the cells to elongate more than the bottom, forcing the material to bend downward. At higher voltages (50–1,000 V), the flattened top and bottom layers of the actuator cave in, causing the cells to contract and bend upward.

To demonstrate the application of the new material, the researchers combined two onion muscles into a pair of tweezers, which they used to pick up a cotton ball weighing 0.1 mg.

Shih and his team are now working to improve their botanical muscle. “Our next step is to reduce the driving voltage and the actuating force,” Shih says.

Chen, C.-C., *et al.*, “Onion Artificial Muscles,” *Applied Physics Letters*, 106, doi: 10.1063/1.4917498 (May 2015).

## Bird of Paradise Inspires Colorful Films

**T**he brilliant colors found in nature continue to provide templates for synthetic materials that could improve a range of applications from solid-state lighting and bioimaging to sensors and

smart building facades.

Scientists at the Univ. of California, San Diego (UCSD) and the Univ. of Akron have developed colorful materials by mimicking bird feathers — which possess some of the greatest diversity of colors found in nature. While other materials have been developed that mimic nature’s structure-based color, this is one of the first to copy the melanin-like structures of bird wings.

Birds get their iridescent color from the periodic arrangement of micro- and nano-scale physical features covering the wing surface. In particular, the wings of the bird of paradise are covered with arrays of melanosomes, which are sub-micrometer-sized organelles in spherical, rod-like, or disk-like shapes that produce pigments called melanins. These features interact with light hitting the wing (*e.g.*, through interference, diffraction, reflection) and alter the wavelength, and thus color, of the exiting light.

“We synthesized and assembled nanoparticles of a synthetic version of melanin to mimic the natural structures found in bird feathers,” says Nathan Gianneschi, a professor of chemistry and biochemistry at UCSD. “We want to understand how nature uses materials like this, and develop function that goes beyond what is possible in nature.”

To create melanosome-like materials, the scientists synthesized nanoparticles of polydopamine, the most common synthetic melanin. They designed the synthetic melanin nanoparticles (SMNPs) with diameters that match the dimensions of natural melanosomes (120–180 nm for rod-like structures). They then used a vertical evaporation-based self-assembly technique to make colored films. By varying the concentration of the nanoparticle solution, they obtained a range of different colors (red, orange, yellow, and green). The films reflect pure colors of light, with



▲ Chemists produced nanoparticles of synthetic melanin and dried them into thin films to create a range of pure hues. The arrangement of the particles, rather than different kinds of pigments, determines the colors. Image courtesy of UCSD and the Univ. of Akron.

the thickness of the polydopamine layer determining the specific hue.

The bio-inspired films have a high refractive index and exhibit broad absorption spanning from the UV to the visible range, similar to natural melanins. The colors are exceptionally uniform across the films.

“We have demonstrated a biomimetic approach for generating structural colors via evaporation-induced self-assembly of well-defined SMNPs,” says Ming Xiao, a graduate student at the Univ. of Akron. “We show the unique advantage of using melanosomes to generate colors found in the animal kingdom, and also offer numerous new opportunities toward multifunctional photonic devices and biocompatible products,” Xiao continues. “In the future, increased control of the self-assembly process will be investigated to obtain large-scale films capable of producing the full color spectrum. Ongoing studies will explore alternative assembly procedures and use analogous SMNPs with various morphologies and compositions.”

Xiao, M., *et al.*, “Bio-Inspired Structural Colors Produced via Self-Assembly of Synthetic Melanin Nanoparticles,” *ACS Nano*, doi: 10.1021/acsnano.5b01298 (May 4, 2015).

CEP

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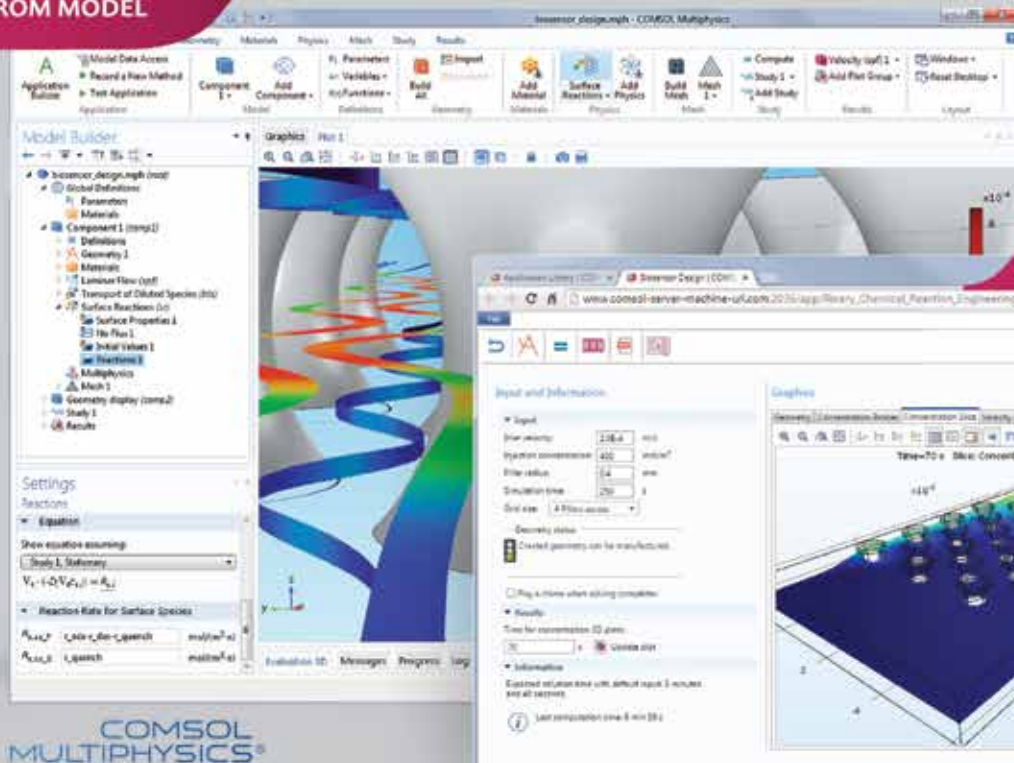


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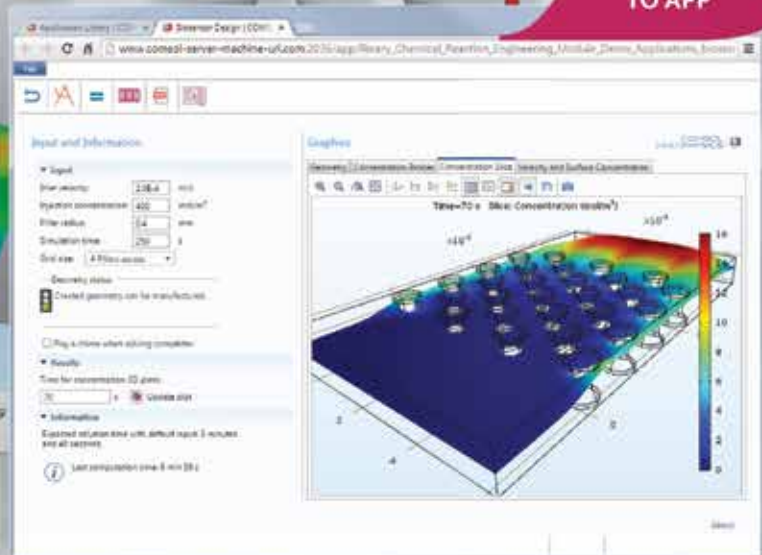
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## New Model Optimizes Water Use in Shale Gas Development

**M**ajor water-use challenges related to shale gas development in the U.S. include source water acquisition, wastewater production, water reuse and recycle, and transportation, storage, and disposal. As the production of natural gas from shale reserves continues to grow, so will these challenges. As such, efficient water management and wastewater treatment are becoming increasingly important.

In the June *AICHE Journal* cover story, “Investment Optimization Model for Freshwater Acquisition and Wastewater Handling in Shale Gas Production,” Linlin Yang, Ignacio E. Grossmann, and Meagan Mauter of Carnegie Mellon Univ., and Robert Dilmore of the National Energy Technology Laboratory, discuss a new mixed-integer linear programming (MILP) model to optimize water use in the hydraulic fracturing of shale gas in the Marcellus and Utica shale plays. The objective of the model is to minimize the capital and operating costs and maximize profit.

Water plays an integral role in shale gas development enabled by hydraulic fracturing. Hundreds of millions of gallons of water must be sourced in a well field development area, which contains dozens of wellpads. Freshwater is delivered to each wellpad, which contains several wells, by truck or pipeline, and can be stored in impoundments in preparation for hydraulic fracturing. During each stage of the fracturing process, water is mixed with sand and chemical additives to create a fracking fluid, which is then pumped into the well. The used fracking fluid, which contains various contaminants, is subsequently recovered over the span of multiple weeks.

Fracturing of the wells produces large volumes of high-salinity wastewater with the gas over the lifetime of the well. The wastewater can be either disposed of in brine-disposal wells, or reused (flowback) at the next well. Depending on the constituents in the stream, flowback typically goes through primary treatment to remove such contaminants as suspended solids, oil and grease, bacteria, and divalent ions to prepare the stream for reuse. The treated flowback water is blended with freshwater and then used to fracture the next well. The volume of freshwater used for blending depends on the total dissolved solids (TDS) concentration of the flowback.

The researchers have developed an MILP model to determine the optimal design of the water-use systems that maximize profit of shale gas development. The goal is to determine the location and capacity of impoundments, the type of piping, the treatment facility desalination technology, the fracturing schedule, and the sources

from which to obtain freshwater. The model accounts for revenue from gas sales, capital costs of impoundment, piping, and treatment facilities, and operating costs of water acquisition, pumping, treatment, and disposal, and estimates the volume of wastewater that can be reused by blending with freshwater through an MILP approximation.

To illustrate the use of the new model, the authors apply it to a case study with 14 wellpads, each of which becomes available at a different time over a 3-yr period. The study system includes five nearby interruptible river sources, four ponds, and two impoundments serving the wellpads. Model variables include completion rate (20–40 stages/wk), pipe-line type (overland and buried), and desalination technology (membrane distillation, thermal distillation, and thermal distillation with crystallization). The optimized design and fracturing schedule result in a gross profit of \$1.03 billion from \$1.12 billion in natural gas revenue. Water-related costs total \$81.5 million, about 7% of the total revenue.

The authors then consider several scenarios within the case study to gain insight into the impact of different assumptions. All scenarios use thermal distillation as the desalination technology. Through these scenarios, they demonstrate the importance of simultaneously optimizing the well-completion schedule with water acquisition, transportation, storage, and treatment. They also conclude that desalination can be cost-effective if the desalination facility is shared by other wells in the same region. (The model assumed that the desalination facility could be shared by other operators that have around 200 wells to be completed during the same time period.)

“Transporting freshwater by truck is relatively expensive and adversely impacts the environment,” the authors say. “However, combining truck hauling with pipeline transportation can add flexibility to guarantee freshwater supply so that fewer freshwater sources need to be accessed by pipeline transportation and less capital investment is required for impoundment construction.”

“Finally, we show that wells with a high flowback rate have higher wastewater handling costs, as expected. Even so, with implementation of proper recycling schemes, the flowback water can be blended for fracking fluid use to reduce freshwater supply costs. Furthermore, we demonstrate a potentially significant role for centralized desalination technology in reducing the costs of flowback and produced-water management, particularly when salt removal aids water reuse,” they say.

CEP

## High-Performance MOFs Improve the Economics of Industrial Gases

The highly commoditized industrial gas sector relies on energy-intensive processes to produce, separate, and store industrial gases. The power required to compress gases accounts for up to 50% of the cost of the delivered gas. And, gas-separation adsorption units recover only a fraction of the feed product, necessitating processes with large waste or recycle streams.

Enter NuMat Technologies, an Illinois startup that has developed synthetic adsorbent materials to address these challenges. The company uses proprietary algorithms to design metal-organic frameworks (MOFs) for low-pressure gas storage and a unique supercritical activation technology to produce customized MOFs at industrially relevant scales.

Metal-organic frameworks, an emerging class of adsorbents, are porous crystalline structures made of metal ions (corners) linked together by organic molecules (linkers). Varying the metal corners and organic linkers allows a near-infinite number of MOFs to be made — each with different performance characteristics. This unprecedented level of tunability enables scientists to create materials with gas-separation and storage properties that are not possible with incumbent materials such as zeolites and activated carbon. In addition, MOFs can have vast internal surface areas that provide an extraordinary density of accessible adsorption sites. While the highest reported surface areas of zeolites and carbons approach 1,000 m<sup>2</sup>/g and 3,000 m<sup>2</sup>/g, respectively, the current world record, which is held by MOFs that NuMat designed for gaseous hydrogen storage, exceeds 7,000 m<sup>2</sup>/g — the equivalent of 1.5 football fields

packed into each gram of material.

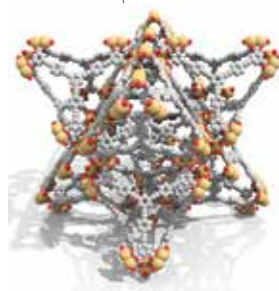
Industry, academia, and funding agencies have responded to the promise of MOFs with significant investments to address a range of complex storage and separation challenges. These include the integration of MOFs into low-pressure natural gas and hydrogen transportation systems, low-power carbon sequestration processes, and high-value separation units (*e.g.*, H<sub>2</sub>/N<sub>2</sub>, Xe/Kr). However, key commercialization challenges remain, including the complexity of designing materials, process scalability, and overall system design.

Founded at Northwestern Univ. with funding from the National Science Foundation and venture investors, NuMat has pioneered the discovery and design of MOFs. NuMat uses proprietary mathematical models to create millions of hypothetical MOF structures from starting reagents, stores these in a database, and then employs cloud computing technology to rapidly determine MOF performance — in effect, conducting centuries' worth of experimentation in days. This method significantly reduces MOF development cycle time and costs, and supports a platform for producing tailor-made, application-specific materials. The company has also designed and produced materials for the low-pressure storage of hazardous gases. These materials have been implemented in multiple full-scale prototypes, and are undergoing testing.

For MOFs to retain their ultrahigh surface areas, innovative manufacturing processes with tight control over

reaction, separation, agglomeration, and handling are needed. NuMat achieves this with its proprietary supercritical activation technology, which involves the gentle extraction of solvent from MOF pores to evacuate the material without causing structural damage. The process protects pores from being crushed, permitting the use of mechanical formation equipment, and controls particle sizes to ensure uniform mass-transfer characteristics and consistent system performance.

As a platform technology, MOFs have the potential to fundamentally transform the economics of separating, storing, and transporting gases. Industry has taken notice. Bill Kroll, chairman of Matheson TriGas and senior management director of Taiyo Nippon Sanso Corp., says his company, as a global supplier of gases and gas handling equipment, routinely monitors innovations that could advance the field. “MOFs show unique promise as an emerging material technology, and NuMat is at the forefront of commercializing MOF-enabled systems,” he says.



▲ NuMat designs and produces MOFs — porous structures comprised of metal ions (orange) linked together with organic molecules (gray, red) — for gas storage and separation. The company can produce a granulated MOF product (blue powder) using a scalable pre-pilot process with a capacity of 20 lb/day.

This technology was funded through the NSF Small Business Innovation Research Program.

This article was prepared by the National Science Foundation in partnership with CEP.



## What's New

### HEAT TRANSFER Heat Exchanger Cools Adhesives Quickly



Because it can take six to 18 hr to form and package a standard batch of adhesives, manufacturers try to shorten the time-to-cool period prior to forming in order to increase productivity and reduce costs. The Kenics heat exchanger is able to cool viscous, hot-melt adhesives quickly. The exchanger consists of a continuous string of static mixer elements within each exchanger tube. Fluid flow is directed radially toward the pipe walls and back to the center of the element to continuously mix the fluid and eliminate radial temperature, velocity, and material composition gradients. The system is designed to remove 100°F of heat from molten materials flowing at 4,000 lb/hr.

**Chemineer**

[www.chemineer.com](http://www.chemineer.com)

### BIOPROCESSING Clarification System Handles High-Cell-Density Cultures



Continuous improvements in growth media and cell lines have enabled higher concentrations of biomass in bioprocesses, creating a challenge for

purification systems. The Sartoclear Dynamics clarification system is suitable for harvesting mammalian cell cultures with high cell densities. This single-use unit consists of prefilled bags containing ultrapure diatomaceous earth (DE) that come in sizes ranging from 0.5 kg to 10 kg. A quick-connect adapter for dust-free powder transfer allows the DE to be mixed directly into the cell culture fluid. The porous filter aid prevents blockage of the filters, which maximizes filter performance. Used in combination with precipitation, this technology transforms harvesting from a two-stage process to a single-stage operation — saving space and time.

**Sartorius Stedim Biotech**

[www.sartorius.com](http://www.sartorius.com)

### Batch Medium Is Robust and Adaptable



The EX-CELL Advanced product line is designed to address the needs of the evolving pharmaceutical and biopharmaceutical industries, where speed to market is paramount. Additionally, it streamlines regulatory compliance and offers the supply chain security needed in the biopharmaceutical environment. The first offering in the line is the EX-CELL Advanced Chinese Hamster Ovary (CHO) fed-batch medium. This batch media system is said to outperform other commercially available media, handling significantly higher concentrations without compromising protein quality. It can be scaled up and adapted easily, so users

can get their processes up and running quickly and efficiently.

**Sigma-Aldrich Corp.**

[www.sigma-aldrich.com](http://www.sigma-aldrich.com)

### MATERIALS AND CHEMICALS

#### Biofunctional Extract Helps Maintain Skin's Cellular Rhythm



This product capitalizes on research that suggests skin temperature, sebum production, pH, electrical charge potential, and transepidermal water loss (TEWL) are influenced by an individual's circadian clock. This biofunctional, called Chronogen YST, is an extract derived from yeast protein that may help to maintain skin's cellular rhythm and guard against UV damage *in vitro* for optimal skin function and appearance. Based on study results, the manufacturer recommends the biofunctional for use in daytime skincare formulations to help skin boost its natural defenses against UV-induced damage, and for nighttime and anti-aging skincare formulations to aid skin regeneration (which slows with age).

**Ashland**

[www.ashland.com](http://www.ashland.com)

#### Polyurethane Dispersions Improve Coating and Adhesive Formulations

These UV-curable water-based polyurethane dispersions (PUDs) are free of solvents, surfactants, and tin

catalysts. They are supplied at approximately 40% solids content, and are compatible with other water-based coatings. Because they are resistant to water, chemicals, and staining, they are ideal for use in coatings for wood, plastics, paper, paperboard, and metal, as well as in adhesives. After the removal of water and UV curing, CN9500 and CN9501 contribute coating properties such as good flow and leveling and a low minimum film-formation temperature (MFFT). Both offerings are dry to the touch (after water removal), and they create a warm appearance on wood, are non-yellowing, and are easily matted to a low-gloss finish. CN9500 provides a balance of flexibility and hardness, while CN9501 provides high hardness and abrasion resistance without brittleness.

**Sartomer**

[www.sartomer.com](http://www.sartomer.com)

## ENVIRONMENTAL, HEALTH, AND SAFETY

### Fire Protection Fittings Bend around Corners Easily



PEX Press fire protection fittings and mounting bracket are made of a high-performance, flexible polymer. Unlike rigid pipe, these flexible fittings can be easily bent for installation around corners. Eight fittings are available in two sizes (0.75 in. and 1 in.) and in four configurations (straight adapters, elbows, tees, and wall tees). The mounting bracket can be used with all sprinkler pendant styles and with every sprinkler configuration, which eliminates the guesswork behind properly aligning sprinkler pendants during

installation. The wall-tee fitting does not require a bracket, and is designed to efficiently feed back-to-back rooms with one plumbing line and one fitting. These cost-effective offerings help to speed up installation.

**Viega**

[www.viega.us](http://www.viega.us)

## INSTRUMENTATION

### Sunshade Accommodates Large Field Instruments



Most process instrument sunshades are designed to shield individual instruments or small-scale field equipment. The CubeShade, a large (600 mm high by 550 mm wide by 500 mm deep) sunshade with a 165-L shading capacity, can accommodate and protect large or multiple instruments, such as electronic monitoring systems, explosionproof junction boxes, and analyzers. The shade is constructed of a glass-fiber-reinforced sheet-molding compound (SMC) that combines chopped glass fibers, fillers, polyester resin, and a catalyst. The SMC material is resistant to UV and corrosion from salt and common petrochemicals, and it has high rigidity and mechanical strength. The shade's structural sidewalls protect equipment from low-angle sun, as well as provide partial protection

from weather, dust or sand, and accidental impact.

**Intertec**

[www.intertec.info](http://www.intertec.info)

## FLUIDS AND SOLIDS HANDLING

### Pin Mill Reduces Friable Solids



This pharmaceutical-grade pin mill, Model CIM-18-S316, grinds friable powders, flakes, and granules into particles of controlled size ranging from coarse to fine. Conventional pin mills have a static outer disc that is removable and an inner rotating disc that is not. In contrast, both of the discs in the CIM-18-S316 can swing away from the unit on cantilevered arms, providing full access to both sides of both discs and to the mill housing for rapid cleaning and sanitizing. The inner disc's high-speed rotation creates centrifugal force that accelerates bulk material entering the central inlet of the opposing stationary disc. As materials travel to the periphery of the discs, they pass through five intermeshing rows of precision-machined rotating and stationary impactor pins. The desired particle-size distribution is obtained by controlling the rotor speed. Because the mill housing is vertically oriented, the mill occupies a smaller footprint than horizontal units.

**Munson Machinery Co.**

[www.munsonmachinery.com](http://www.munsonmachinery.com)



## Product Digest

### this month's topic **Laboratory Equipment**

#### **Oil Analysis System Evaluates Equipment Condition**



Corrosion and wear are the root causes of most mechanically induced equipment downtime. To prevent equipment failure, the MiniLab 53 onsite oil-analysis system allows operators to evaluate the condition of their machinery. It includes tests to monitor lubricant chemistry, contamination, and machinery wear, and provides machine wear data and trend analyses that enable users to make immediate, condition-based determinations about equipment status. To analyze fluid chemistry, the FluidScan IR technology measures total acid number (TAN), total base number (TBN), soot, oxidation, nitration, and sulfation. To analyze fluid contamination, the LaserNet Fines (LNF) particle counter determines particle count and size distribution, as well as counts of nonmetallic particles; it is also able to identify types of wear debris, wear modes, and potential sources of particles. A removable viscometer and handheld infrared (IR) spectrometer enable portable oil-condition monitoring. MiniLab 53 integrates seamlessly with Emerson's AMS Machinery Health Manager OilView software. **Spectro Scientific**  
[www.spectrosci.com](http://www.spectrosci.com)

#### **Reaction Monitors Sample under Batch and Continuous Conditions**

The ReactIR Series includes five robust *in situ* sampling technologies that are appropriate for monitoring batch and continuous reactions with

difficult chemistry, including corrosive, acidic, caustic, and abrasive slurries. Users can sample and study different phases of chemical reactions under high and low temperatures, as well as at high pressure and vacuum. The DST Fiber Conduit enables liquid-based reaction monitoring of high-temperature and high-pressure chemistry, and provides flexibility for interfacing with lab reactors and process flow cells without the need for alignment. The DST Series AgX Fiber Conduit is also suitable for liquid-based reaction monitoring, but offers a wider range of analytical performance. The manufacturer recommends the low-cost K4 Conduit to Sentinel as the best option for liquid-based reaction monitoring at high temperatures and pressures. The DS Micro Flow Cell is suitable for continuous flow chemistry monitoring. For gas-phase reactions and headspace monitoring, the DST Fiber to Gas Cell is suitable.

**Mettler Toledo**

[www.mt.com](http://www.mt.com)

#### **Calorimeters Offer Automated Operation Options**



Two new isothermal titration calorimeters (ITCs) support researchers studying a variety of biomolecular interactions. ITCs directly measure the heat that is released or absorbed during a biomolecular-binding event to simultaneously determine and quantify all the binding parameters in a single experiment. The manual MicroCal PEAQ-ITC and the fully automated MicroCal PEAQ-ITC deliver precise

and high-quality data at high speeds. The associated software is intuitive to operate. Optional automation enables quicker screening and improves laboratory efficiency, and automated data analysis allows even non-experts to evaluate data with confidence.

**Malvern Instruments**

[www.malvern.com](http://www.malvern.com)

#### **High-Speed Disperser Mixes Small Batches**



High-speed dispersers are useful for wetting solids and creating a uniform, air-free suspension or solution under vacuum. The HSM-100LH-3 vacuum high-speed disperser is designed for laboratory- and pilot-scale mixing of batches up to 5 gal. It can be supplied with a vacuum-rated mixing vessel, a heating/cooling jacket, and a mixer cover with sight/charge ports. Interchangeable sawtooth disperser blades with diameters of 2 in. to 4 in. are available. The disperser is suitable for variable-speed operation up to 4,800 rpm, and can achieve rapid turnover and vigorous flow patterns over a wide range of fluid viscosities. The mixing head is raised by an air/oil hydraulic lift with pushbutton controls. Safety limit switches prevent mixer

operation when the head is raised or when a mixing vessel is not in place. All of the wetted parts are made of Type 316 stainless steel.

**Charles Ross & Son Co.**

[www.mixers.com](http://www.mixers.com)

### **Flashpoint Tester Boasts Ease of Use**



The Herzog OptiFlash employs the Pensky-Martens closed-cup test method to determine the flashpoint of petroleum products, biodiesels, solvents, fluxed bitumen, foods, and beverages. This new model is said to be easier to use, easier to clean, and safer to operate than previous flashpoint offerings from the manufacturer. It can measure flashpoints up to 400°C, and it complies with leading global standards. An intuitive user interface and built-in automation eliminate the need for manual tasks such as installing the flashpoint and temperature sensors and installing the test cup for each test. Users can disassemble the cup cover without any tools, which allows for easy cleaning; this also improves reliability, because users can perform a quick cleaning before processing a new sample.

**PAC**

[www.paclp.com](http://www.paclp.com)

### **COD Analyzer Eliminates the Need for Hazardous Reagents**



PeCOD is a chemical oxygen demand (COD) analyzer that overcomes many of the limitations of other COD analysis methods, such as the commonly used dichromate technique. The PeCOD rapidly processes samples and provides accurate results in 15 minutes, versus several hours for other methods. This system is also safer, because it does not require sample pretreatment with boiling sulfuric acid containing dichromate, mercury, and silver salts. At the core of the unit is a nanotechnology-based sensor, which consists of a UV-activated nanoparticle titanium dioxide photocatalyst. The high electrochemical potential of the titanium dioxide surpasses the modest chemical potential of the dichromate method.

**ManTech, Inc.**

[www.mantech-inc.com](http://www.mantech-inc.com)

### **Mass Spectrometer Identifies Small Molecules**

The 6545 Q-TOF mass spectrometry system is suitable for trace-level analysis of small-molecule compounds in applications such as food safety, environmental testing, and pharmaceuticals manufacturing. This midrange unit includes advances in hardware and software that make it both more reliable and easier to use than previous models. Hardware updates include ion shaping optics, high-voltage power supplies, and

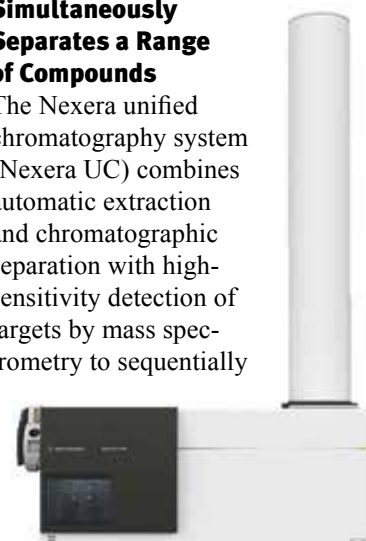
longer-life parts to increase robustness. The device's software leverages particle swarm technology to quickly optimize the instrument and increase its sensitivity by up to five times, allowing it to identify small-molecule and low-intensity compounds.

**Agilent Technologies**

[www.agilent.com](http://www.agilent.com)

### **Chromatography System Simultaneously Separates a Range of Compounds**

The Nexera unified chromatography system (Nexera UC) combines automatic extraction and chromatographic separation with high-sensitivity detection of targets by mass spectrometry to sequentially



analyze up to 48 samples. With a wide range of separation modes, this unit can separate a diverse range of compounds — a capability that single systems based on gas or liquid chromatography alone are not able to achieve. It eliminates the need for complicated sample pretreatment and enables highly reliable and stable analysis of delicate samples that are susceptible to oxidation or dissociation when exposed to air. Because it is fully automated, the risk of human error is reduced or eliminated. Nexera UC is suitable for a variety of applications in the food, polymers, specialty chemical, and pharmaceuticals industries, as well as in research laboratories.

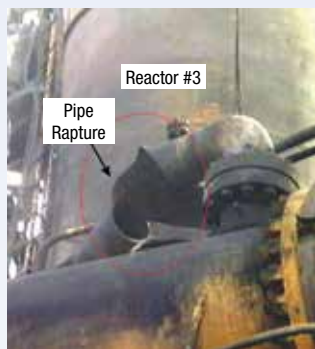
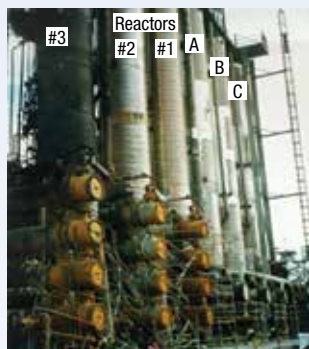
**Shimadzu Scientific Instruments**

[www.ssi.shimadzu.com](http://www.ssi.shimadzu.com)

## Conduct of Operations

In January 1997, a pipe in a hydrocracking unit at a refinery in California ruptured, releasing a flammable mixture of hydrocarbons and hydrogen. The gas mixture ignited, causing a fire and explosion. There was one fatality, and 46 people were injured. One of the causes of the incident was excess temperature in one of the hydrocracking reactors. The specified maximum allowable temperature in the reactors was 800°F (425°C), and operators were supposed to shut down the system if the temperature exceeded this value. The reactor and the pipe that ruptured were thought to have reached a temperature greater than 1,400°F (760°C).

Temperature excursions in excess of the specified 800°F (425°C) maximum had occurred previously, but the system had not been shut down. This led operators to believe that these excursions were acceptable. Also, some of those temperature excursions were not investigated, and recommendations from investigations that were conducted were not all implemented.



In April 1998, flammable chemicals were released from a 2,000-gal batch reactor into a building at a specialty chemicals plant in New Jersey, and an explosion ensued. The release occurred because operators were unable to control the temperature of the batch, and the runaway reaction partially vented through the reactor manway into the production building. Nine people were injured, two seriously, and chemicals were released into the surrounding community. It is believed that the initial temperature of the batch was higher than normal, making it more difficult for operators to control the batch temperature with the available cooling.

Operators had difficulty controlling the batch temperature of eight of the previous 32 batches produced. The temperature and the rate of temperature rise for individual steps of the process were beyond the limits specified by the procedure. In some cases, the temperature exceeded the limit of the reactor temperature recorder (300°F or 150°C). Operators were able to regain control of the temperature of those batches before a runaway reaction occurred. Those previous temperature excursions were not investigated, and no action was taken in response to them.



## What Can You Do?

Although these two incidents occurred in completely different types of manufacturing plants, they have one important thing in common. In both, the process had exceeded specified safe operating limits before the incident. The abnormal conditions became accepted — this is called normalization of deviation. These warning signs were either not investigated, or actions recommended by the investigation were not implemented. Conduct of operations can be summarized in two simple concepts: (1) Say what you intend to do (procedures). (2) Always do what you say. This means, for example, that if your operating procedures say to shut down if a critical safety parameter exceeds a specified value, you *must always* shut down.

- Know the critical safety parameters for the process at your plant, the consequences of exceeding them, and what to do if they are exceeded.
- Always take the required actions if critical safety limits are exceeded.
- If critical safety parameters are exceeded, report it to management so an appropriate investigation can be conducted.

### What are your plant's critical safety control limits?

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LORRAINE KASPRZAK

ADVANTAGE MARKETING CONSULTING SERVICES, LLC

## Build Your Negotiating Skills

**F**or many of us, having to negotiate for anything can be akin to driving a notoriously congested, pothole-filled highway in rush-hour traffic. We know it is not for the inexperienced or faint-hearted and therefore approach it expecting the worst possible outcome.

Just as you can learn to navigate in heavy traffic with your sanity intact, you can learn to be a skilled negotiator who achieves successful outcomes. These tips can help you approach your next negotiation with confidence, whether you are trying to reach agreement on a starting salary or the terms for a multimillion-dollar construction project.

**Cultivate a confident mindset.** You must be willing and ready to act assertively and in your, or your company's, best interests during the bargaining process. Believe you can get what you want from the negotiation.

**Be prepared.** Understand the issues and risks involved and set your goals. Prepare a list of the outcomes you must have and those you're willing to concede in the negotiation. Rob Jickling, vice president at Toronto-based Oneira Corp., negotiates contracts for the large-scale projects his engineering, procurement, and construction management (EPCM) firm executes. He goes into every contract negotiation knowing which project tasks must be done by his firm if a project is to have a successful outcome. For instance, it may be acceptable for the client to handle some tasks, such as site preparation, in-house. Additionally, Jickling does not let Oneira Corp. take on excessive risk. "We're an extension of the client's team and expect to be treated like valued team members. We're not paid to take on all the project risk," he says.

**Understand the other party's perspective.** You will make better decisions in the negotiating process if you know the other party's situation and what matters most to them. What problem is the other party trying to solve? What challenges and pressures have they faced solving it? What common ground do you share with them? Where do you differ?

**Listen and ask questions.** Skillful negotiators will always spend more time listening and asking probing, open-ended questions than they do speaking. When you adopt this approach, you often learn key information about the other party that you can use to reach a more-effective agreement.

**Give something only if you get something in return.** If the other party expects you to give something up, you need to get a concession in return. For instance, if you are negotiating a contract to sell pumps and the buyer wants

60-day terms rather than the usual 30 days, tell him the price is going up by 10%. "Don't let the other guy convince you that he'll let you make it up on the next deal," says Kevin Shulman, president of Shulman Associates, an Iselin, NJ, sales training and client development firm.

**Negotiate scope, not price.** Never cut your price just to make the deal, both Jickling and Shulman advise. This only serves to devalue you and your product or service in the other party's eyes. If, for example, the other party has a smaller-than-expected budget for a proposed project, then negotiate to reduce the project work scope as a way to reduce overall cost.

**Ask for more than you expect to get.** Let's say you are negotiating your compensation package for a new job. You've done your homework, so you know the pay range for the position and how much you need for the job change to be worth your while. "Don't be afraid to ask for more than you're willing to settle for. The other party will likely negotiate you down, so you'll end up getting what you want. Just don't be a pig about it by asking for something totally unrealistic," says Shulman.

**Be willing to walk away.** Not every deal will work out and you should never be afraid to walk away from the table if the deal isn't working for you. "You can't operate in a fear state," says Jickling. "You must believe you can survive without a particular project."

**Pay attention to the contract's fine print.** It amazes Jickling how many people will sign contracts and not negotiate the terms and conditions. He typically negotiates changes so that terms are more realistic, which allows his firm to put forth its best efforts. Terms such as "time is of the essence" and "highest standard of care" are not boilerplate language in a typical contract. These terms can be difficult to comply with once your project is underway.

**Be patient.** Good negotiators are never in a rush to conclude the deal. "If you are patient, the other party often becomes very willing to make concessions just to get the process moving more quickly. Remember that whoever is in control of time has the advantage in the negotiation," Shulman says.

**Don't take it personally.** Complex agreements or ones in which you have a personal interest can be difficult and frustrating to negotiate. Successful negotiators do not get sidetracked by the other party's difficult behavior. They keep their emotions in check and concentrate on what is necessary to reach an agreement. "Focus on what it takes to create long-lasting business," advises Jickling.

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## Profile Building Entrepreneurial Excellence



“I see myself becoming *the* entrepreneurial chemical engineer,” says Christina Borgese, Director of Engineering and Development at PreProcess, Inc., a consulting company that she co-founded. Her company helps entrepreneurs commercialize their novel technologies by applying chemical engineering know-how and recruiting experts from around the world. “Creating new products, harboring new ideas — that excites me,” she says. “You never know who is calling next, or what new project you will be working on that nobody has ever done before.”

Borgese, a California native, has an unfailingly positive attitude and great ambition for her company. Even at such a young age, her career and volunteer work make her a stand-out ChemE; in July 2013, she was named one of *Manufacturing Engineering* magazine’s 30 under 30.

She grew up in Laguna Beach, CA. While in high school, she was interested in pursuing politics. “I served as a congressional page in the House of Representatives,” she says. Delivering messages for a summer on Capitol Hill gave Borgese her first taste of how closely politics, business, and technology are aligned in the real world.

Rather than pursuing a degree in business, she decided on chemical engineering. “What initially got me into chemical engineering is that I love problem-solving,” she says. She figured, “If I studied chemical engineering, and got a strong technical background, I could go into any other area.” Borgese received a full scholarship from the Univ. of California, Santa Barbara, and enrolled as a chemical engineer. She was also accepted into the university’s technology management program, which emphasizes the importance of entrepreneurship in commercializing new technologies — a concept that would later become integral to her career.

After earning her BS in chemical engineering, Borgese landed a process engineering position with Clorox in Pleasanton, CA, in 2005. Marc Privitera, a research fellow at Clorox, recruited her. “My time at Clorox prepared me for understanding customer needs,” she says. Working on consumer products required a quick turnaround to get products on the shelf. Borgese discovered how much she loved the quick pace of Clorox, and decided that she wanted to amplify this in her next career move.

When Privitera left Clorox to pursue an opportunity with a startup called BioFuelBox in 2007, Borgese applied to work there as well. According to Borgese, Privitera initially advised her not to make such a bold jump so early in her career. “He said, ‘Look, it’s risky.’ I said, ‘I know, I don’t care,’” she recalls. More than anything, she wanted to pursue an opportunity in this emerging environment.

At BioFuelBox, Borgese served as Senior Process

Engineer, where she helped develop the world’s first commercial-scale supercritical biodiesel reactor. The cost-effective process converted impure oils and greases — which originated from grease traps found in commercial kitchens — to low-sulfur biodiesel. Borgese says that one of the team’s greatest accomplishments was “taking the technology from a test tube to commercial scale in just 14 months.”

At the startup, she took on many responsibilities that she never would have had the chance to tackle at a larger company. “I was involved in process conception, development, scaling, hiring of the construction crew — everything.”

Despite winning a World Economic Forum Technology Pioneer award in 2010, the startup ultimately ceased operations after it was unable to secure a new round of funding.

But Borgese was not dissuaded from the world of entrepreneurship. Later in 2010, she and Privitera launched a consulting company, PreProcess, Inc. The lessons that she learned from her time at BioFuelBox have fueled her successes with PreProcess.

At PreProcess, Borgese takes the new ideas of entrepreneurs and pushes them toward commercialization. “When pursuing commercialization, there’s a lot of chaos. I learned a process for creating clarity from that chaos and finding a path.” This process involves breaking down complex technologies into traditional chemical engineering unit operations, such as reacting, separating, or drying. “From there, you can identify which steps are the greatest risks from a technological standpoint,” she says. Those steps are where the team focuses its expertise to create new solutions. “You apply the chemical engineering playbook to create something new and sustainable.”

PreProcess has a unique method of assembling project teams. “We bring in best-in-class people. We pull in people from all over the world, with the ability and technical background specifically for that area.” These experts know how to self-motivate, collaborate, and connect from anywhere in the world via virtual tools.

Borgese tackles the challenges of running a consulting company with confidence. “It’s interesting because the challenge of the technology is actually what draws me to engage it,” she says. “We started this company because we wanted to address significant technical hurdles. How can we take this idea and translate it into a great product? I see that challenge as a positive thing.”

Outside of work, Borgese is an active volunteer with student AIChE chapters. She even created an Engineering Bootcamp for new graduates — a three-day course that teaches the basics of the practical application of process engineering.

CEP



**TERRY McMAHON**

McMAHON TECHNOLOGY ASSOCIATES

# The U.S. Chemicals Industry in Perspective

If the U.S. economy were a professional sports league, the chemicals industry would be a franchise player. A healthy economy needs a core of financially strong, internationally competitive industries making products that can be sold in any geographic market. These industries provide highly compensated employment opportunities, which in turn creates flourishing communities and intellectual capital potential. Improved production processes and higher-quality products do not develop in a vacuum, but rather in the context of solving day-to-day production problems. Without domestic manufacturing, these opportunities are lost. Franchise industries are also export machines. This last quality is vital to a healthy economy — chronic trade deficits are a harbinger of decline.

The agriculture, aerospace, and chemicals industries have historically been among the U.S.'s largest net exporters. Agriculture is a huge and highly varied enterprise, not a typical industry (in the manufacturing sense), and it is heavily subsidized (by the taxpayers). Aerospace is also heavily subsidized by the taxpayers. The chemicals industry, on the other hand, despite being highly scrutinized and regulated, generates substantial net exports, makes major domestic investments in research and development, and attracts a large amount of foreign investment in domestic plants and equipment — to say nothing of the well-compensated jobs and intellectual capital opportunities.

Recently, the U.S. chemicals industry has drawn the attention of a particularly aggressive breed of “financial engineers” who believe that they comprehend the business but fall well short on that score. Their *modus operandi* is: “Get In, Get the Money, Get Out.” The proxy challenge is a favored *get-in* step.

The chemicals industry requires patient capital (*i.e.*, long-term capital), which makes it an easy target for financial engineers with a meager knowledge of the business of chemistry. The industry was built by technical leadership with a keen appreciation of the requirements for a healthy industry, both now and in the future. The average chemical worker in the U.S. is backed by more than \$375,000 in fixed capital, according to a recent Census Bureau report. Over the last half-century, U.S. chemical workers have increased their hourly output, in terms of physical product, more than sevenfold, making them the most productive chemical workers worldwide. By coincidence, process automation technology began to blossom just over 50 years ago. R&D investments to maintain optimal production processes and a competitive product line are also crucial. Short-term

savings realized by starving these vital functions (plant and equipment, as well as R&D) mean a slow death for this economic engine. The chemicals industry has also generally been managed very conservatively, with relatively low levels of corporate debt. Thus, another easy source of savings is to load up on debt to temporarily fill corporate treasuries. Exploiting these so-called savings is the *get-the-money* step.

The final step — *get out* — is relatively straightforward. The financial engineers simply declare a special dividend and unwind their equity position while the glow of the special payout still blinds the analysts. The financial engineers think they are helping, but they scoop up their winnings and never look back. We, with a longer-term stake, are left to pick up the pieces.

Consider the computer leasing industry. It emerged from the woodwork in the late 1960s, enjoyed a brief but meteoric rise based on an accounting ploy that completely befuddled the stock analysts, and left equity and bond holders with massive losses in the space of a few years. This happened because the leasing firms and their investors had little understanding of the rapidly evolving computer business.

So, who keeps management honest? We need a special breed of corporate directors who can balance short-term demands and long-term prosperity. In his book *The Idea Factory: Bell Labs and the Great Age of American Innovation*, author Jon Gertner describes the quality of industrial leadership that produced the great flowering of technology that occurred in the mid-20th century (see Process Automation Corner, *CEP*, Sept. 2012, p. 17). Gertner's book should be required reading for prospective directors.

In the summer of 1954, I worked as a production control lab analyst in a titanium dioxide pigment plant. I was 19 and had just completed my freshman year at MIT. Experienced foremen wanted to see how I performed the pigment quality assays so they could gauge the reliability of my work. All production workers got weekly bonuses for plant output above a baseline, and the foremen wanted to push their crews while maintaining pigment quality. In those days, I could save enough in three months to cover half of my college costs (MIT's annual tuition was \$900 in 1953–54 and room and board at my fraternity was about \$80/month). We need to preserve these opportunities for meaningful participation in the industrial economy, to hone professional skills, and to save a substantial fraction of college costs in a few months for future generations.

**CEP**



# Software & Information Technology

## Risk Manager Measures Cyber Security Risk



The need to prevent and reduce the risk of cyber attacks has jumped to the top of many industrial facilities' priority lists. The Industrial Cyber Security Risk Manager simplifies the task of identifying cyber security risk. The digital dashboard proactively monitors, measures, and manages cyber security risk for control systems at refineries, power plants, and other automated production sites. Expertise in cyber security is not necessary — complex cyber security indicators are translated into clear measurements and key performance indicators (KPI), which are disseminated through an easy-to-use interface. Users can create customized risk-notification alerts and perform detailed threat and vulnerability analyses to target insecure network and system configurations, rogue devices, intrusion attempts, malware, and other threats.

**Honeywell Process Solutions**  
[www.honeywellprocess.com](http://www.honeywellprocess.com)

## EHS Suite Solves Complex Challenges

Version 5 of this comprehensive environmental, health, safety (EHS) and sustainability software suite is designed for such tasks as incident management, management of change (MOC), compliance management, training documentation, performance metric collection, risk analysis, and corrective-action tracking. Its intuitive controls and reporting enable users to easily adopt and implement the software to solve complex EHS and

sustainability challenges. The ability to perform risk and cause analyses makes this a powerful prevention tool that puts ownership and accountability in the hands of all employees. A workflow that is simple to follow streamlines critical MOC processes. Compliance management tasks that can be vulnerable to mistakes are made more visible to ensure that regulatory compliance is achieved. Additionally, the software helps users track and prioritize employee training and performance metrics. The risk-analysis and corrective-action functions increase personnel awareness of hazards and ensure completion of the necessary remediation actions.

**KMI**  
[www.kminnovations.com](http://www.kminnovations.com)

## Software Runs Numerous Tests



RheocalcT v1.2.19, for use with the company's DV2T viscometer and DV3T rheometer, features the Test Wizard for rapid test creation, improved layout and navigation, and additional import/export functions. The Test Wizard reduces the time and effort needed to set up popular tests, such as time to stop, time to torque, speed ramp or shear rate ramp, and temperature profiling. It can create a thix index test (to calculate the ratio of viscosity at a low speed versus viscosity at a higher speed) or a curing test (to automatically reduce speed at preset torque values). Additionally, the wizard can create and run a yield stress

test for the DV3T rheometer. Layout and navigation have been improved with the addition of a favorites bar, and importing and exporting have been simplified and enhanced. The software should be run on a device with at least two universal serial bus (USB) ports to support viscosity testing with concurrent temperature control.

**Brookfield Engineering**  
[www.brookfieldengineering.com](http://www.brookfieldengineering.com)

## Electronic Logging Streamlines Shift Changes



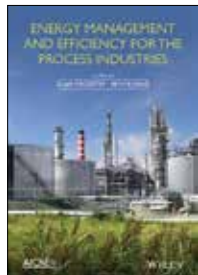
Shift handover can be a risky time for a plant, because poor communication can quickly result in process upsets. Logbooks log-management software enables operators to electronically document activities to streamline shift changes, drive actions, and accelerate decision-making. Operators can identify priorities for the next shift and access documentation of events from the previous shift — ensuring that quality, safety, and throughput are protected. A consistent approach to operator logs supports safety improvement efforts, as well as audits and corrective-action processes. A consolidated graphical view makes it easy to obtain complete and accurate information. Task scheduling gives management confidence that critical tasks are prioritized as such while important but not urgent tasks, such as training, reviews, and routine maintenance, are completed and documented.

**Emerson Process Management**  
[www.emersonprocess.com](http://www.emersonprocess.com)



# Books

## ENERGY MANAGEMENT AND EFFICIENCY FOR THE PROCESS INDUSTRIES



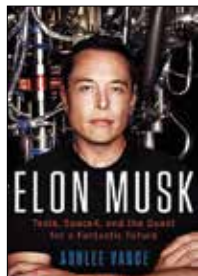
**Alan P. Rossiter and Beth P. Jones, Eds., AIChE, New York, NY, and John Wiley & Sons, Hoboken, NJ, \$99.95, 400 pages, April 2015, ISBN: 978-1-118-83825-9**

At some point in their careers, many engineers find themselves in an energy-management role, but few have a clear understanding of the methodologies

available to capture energy savings. This book is written for engineers and managers in that position. It introduces a framework for an industrial energy-management program, provides illustrations, and discusses the basic principles of robust and sustainable energy improvements. With a foreword by Charles D. McConnell, former assistant secretary of the U.S. Dept. of Energy, the book compiles contributions from leading experts in diverse fields.

The book is divided into two sections that provide both management and technical recommendations. The management section offers guidance on how to design and implement energy-management programs, with advice on the organizational design, human interaction, and technical aspects of energy management. The second section deals with the technical aspects of significant process equipment and systems, through the lens of energy efficiency as well as process requirements.

## ELON MUSK: TESLA, SPACEX, AND THE QUEST FOR A FANTASTIC FUTURE



**Ashlee Vance, HarperCollins, New York, NY, \$28.99, 400 pages, May 2015, ISBN: 978-0-062-30123-9**

This biography of Elon Musk — the man behind PayPal, Tesla Motors, SpaceX, and SolarCity — describes him as the most daring entrepreneur of our time and compares him to famous innovators such as Thomas Edison,

Henry Ford, Howard Hughes, and Steve Jobs. It describes Musk's dedication to inventing a future that is as rich and far-reaching as a science fiction fantasy.

Based on exclusive access to Musk, his family, and his friends, the author traces the story of Musk's journey from his difficult upbringing in South Africa to his ascent to the pinnacle of the global business world. The book details the events that led to the creation of Tesla, SpaceX, SolarCity, and Musk's \$5-billion fortune, including Musk being forced out of PayPal, fending off a life-threatening case of malaria,

and dealing with the death of his infant son.

The book serves to inspire innovators at a time when many American companies are focused on making easy money and conservative choices. The author makes the argument that Musk's success heralds a return to the ambition and invention that made America an economic and intellectual powerhouse.

## BIOMASS PELLETIZATION: STANDARDS AND PRODUCTION



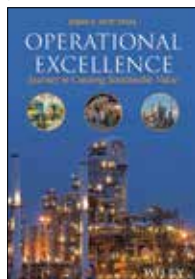
**A. Garcia-Maraver and J. A. Perez-Jimenez, Eds., WIT Press, Billerica, MA, \$172, 194 pages, April 2015, ISBN: 978-1-78466-062-8**

Biomass derived from agricultural and forestry residues is slated to play an important role as a renewable and sustainable energy source. Some applications involve pelletizing the biomass to

create a homogeneous solid biofuel.

This book compiles information about the use of energy from biomass, with a focus on the use of pellets. It describes the changes that forestry and agricultural biomass must undergo as it is converted into thermal energy and analyzes the inputs and outputs of the process. The book provides standards and guidelines, and highlights ways to determine biofuel quality. Professionals and researchers interested in working with biomass will find this book useful.

## OPERATIONAL EXCELLENCE: JOURNEY TO CREATING SUSTAINABLE VALUE



**John S. Mitchell, AIChE, New York, NY, and John Wiley & Sons, Hoboken, NJ, \$69.95, 344 pages, March 2015, ISBN: 978-1-118-61801-1**

Many organizations are embracing the tenets of operational excellence with the goals of achieving the best results in their field and gaining and sustaining safety

and operational performance. Operational excellence includes organizational leadership, structure, and working culture imperatives, which are integrated with the application of vital principles, systems, and tools to gain improvements that can be demonstrated by key performance indicators (KPI).

The book defines operational excellence, explains its principles and objectives, and introduces processes and procedures for developing, implementing, and sustaining an operational excellence program. Those who have a program in place and are seeking improvements, as well as those who have only heard of this term, can benefit from this book.

## HIGH INTEGRITY SYSTEMS AND SAFETY MANAGEMENT IN HAZARDOUS INDUSTRIES



**J. R. Thomson, Butterworth-Heinemann, Waltham, MA, \$156, 360 pages, Jan. 2015, ISBN: 978-0-128-01996-2**

The design of processes related to hazardous industries, such as oil and gas production, hydrocarbon refining, nuclear power, and chemical and pharmaceutical manufacturing, deserves special attention. This concise reference covers the design standards and processes necessary to build and manage high-integrity systems, as well as best practices in design, operations, maintenance, and regulation.

Case studies illustrate how the complex multidisciplinary enterprises that are used to design and operate hazardous plants can sometimes fail, including the subtlety and fragility of robust safety cultures. Engineers who design, build, and operate hazardous plants and students studying engineering management will find this book useful.

## THE ENGINEERING BOOK: FROM THE CATAPULT TO THE CURIOSITY ROVER, 250 MILESTONES IN THE HISTORY OF ENGINEERING



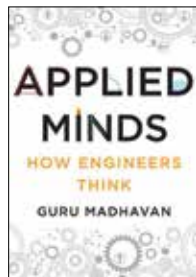
**Marshall Brain, Sterling, New York, NY, \$29.95, 528 pages, May 2015, ISBN: 978-1-459-0809-8**

Engineering is the source of some of the world's greatest inventions, from the simple catapult to the advanced jet engine. The author of this book, creator

of the popular *How Stuff Works* series and a professor at the Engineering Entrepreneurs Program at North Carolina State Univ., provides a detailed look at 250 engineering milestones, from ancient times to the present day. Topics include architectural wonders like the Acropolis, the Great Wall of China, and the Eiffel Tower; transportation advances such as the high-speed bullet train; medical innovations, including the artificial heart and kidney dialysis; developments in communications, such as the cellphone; as well as air conditioning, Wi-Fi, the Large Hadron Collider, the self-driving car, and more.

The milestones are ordered chronologically, allowing the book to serve as a leisure read or as a reference for a particular breakthrough of interest or time period. The book is heavily weighted toward the 20th century because of the numerous milestones that occurred during this eventful time in engineering.

## APPLIED MINDS: HOW ENGINEERS THINK



**Guru Madhavan, W. W. Norton & Co., New York, NY, \$26.95, 256 pages, Aug. 2015, ISBN: 978-0-393-23987-4**

This look inside engineers' minds reveals the thought processes that help engineers design efficient and innovative solutions, with the hope of helping readers harness these tools for their own applications.

The book draws parallels between seemingly disparate achievements, such as Dubai's Burj Khalifa — the world's tallest building — and Microsoft's Office Suite, to provide a holistic view of the diverse field of engineering and engineering professionals. It explores the unique mental tools engineers use to accomplish these feats, and focuses on the engineer's ability to transform problems into opportunities. The author shows how the concepts of prototyping, reliability, standards, optimization, and feedback are put to use in various engineering fields and applications. Equal parts personal, practical, and profound, this book peeks into the inner workings of complex systems and celebrates the men and women who shape our world.

## YOUR FIRST LEADERSHIP JOB: HOW CATALYST LEADERS BRING OUT THE BEST IN OTHERS



**Tacy M. Byham and Richard S. Wellins, John Wiley & Sons, Hoboken, NJ, \$25, 288 pages, April 2015, ISBN: 978-1-118-91195-2**

Both first-time leaders and seasoned professionals who are looking to fine-tune their skills can benefit from this book's practical leadership advice. It includes tools to ensure success, as well as information gathered from Develop-

ment Dimensions International's (DDI's) extensive experience and research, which has aided in the development of leaders around the world.

The first part of the book introduces the concept of a catalyst leader as one who sparks energy, passion, and commitment in others, and it provides tips on how to become a catalyst leader. Because leaders must communicate frequently, clearly, authentically, and sometimes in difficult situations, the book offers advice on how to make these interactions successful. The second part of the book is devoted to critical core leadership competencies, including coaching for success, hiring the best employees, turning appraisals into discussions that propel performance, and handling difficult employees.

# 15 AIChE

## Spring Meeting, Austin, TX

Chemical engineering practitioners from industries worldwide joined with the global process safety community at AIChE's 2015 Spring Meeting and 11th Global Congress on Process Safety, April 26–30 in Austin, TX. Held at the Austin Hilton and Austin Convention Center, the meeting offered more than 200 technical sessions across eight topical conferences and special program tracks, and attracted more than 2,000 participants from 49 countries. Debuting this year, the Big Data Analytics Topical Conference explored issues related to the collection, analysis and use of vast amounts of new data available to the chemicals industries. The meeting continued its coverage of shale gas and tight oil, including process safety considerations, with the Executive Panel on Opportunity Crudes. At the Process Development Div. Plenary Session, experts presented theory, tools, and commercialization know-how related to new processes. Recently inaugurated programs devoted to Manufacturing in the 21st Century, Emerging Technologies in Clean Energy, and Upstream Engineering and Flow Assurance returned to the Spring Meeting, as did conferences on gas utilization and refinery processes, the Kister Distillation Symposium, and the annual Ethylene Producers' Conference. Receptions, luncheons, student workshops, and other special sessions rounded out the program.



Photo by Douglas Clark

▲ Some of AIChE's most engaged young members gathered at a mixer organized by the Institute's Young Professionals Committee.



Photo by Douglas Clark

▲ AIChE Foundation trustees Eduardo Glandt (left) and Syamal Poddar chat during a Welcome Reception held in the exhibition area.



▶ Marvin O. Schlanger, Chairman and Chief Executive Officer at CEVA Group, set the stage for the Spring Meeting and Global Congress on Process Safety with his opening keynote address entitled "Chemical Engineering: Is This the Golden Age?" Schlanger also received AIChE's Government and Industry Leaders (AGILE) Award, in recognition of his creativity and innovations as a leader of CEVA Group, LyondellBasell, ARCO Chemical, and other companies that employ chemical engineers.

## 11<sup>TH</sup> GLOBAL CONGRESS ON PROCESS SAFETY

Nearly 1,000 process safety professionals from hundreds of organizations worldwide gathered in Austin for the 11th Global Congress on Process Safety (GCPS). Organized by AIChE's Center for Chemical Process Safety (CCPS), Safety and Health Div., and Design Institute for Emergency Relief Systems (DIERS), the GCPS incorporated the programming of the 30th CCPS International Conference, the 49th Loss Prevention Symposium, and the 17th Process Plant Safety Symposium. In addition to launching a new DIERS Symposium, the Global Congress also offered the Process Safety Management Mentoring (PSM<sup>2</sup>) Forum for young professionals entering the field, and Process Safety Spotlight sessions featuring international process safety perspectives. This global emphasis was also evident in sessions conducted in Spanish, Portuguese, and Chinese, and at a session about process safety in Japan. The GCPS co-hosted some of the Spring Meeting's major events, including the opening keynote address.

▶ Shakeel Kadri, Executive Director of the Center for Chemical Process Safety, welcomed attendees at the Global Congress' opening plenary session. The 2015 GCPS coincided with the 30th anniversary of the establishment of CCPS, and included programming based on CCPS's Vision 20/20 objectives for global process safety excellence.



◀ Rainer Hoff (left), Chair of this year's GCPS, received the Institute's thanks from AIChE President Cheryl Teich at a gathering of AIChE leaders.



▲ Daily luncheons were among the meeting's highlights. Left: On Monday, Wesley Lohec, Vice President for Health, Environment, and Safety at Chevron, spoke at the GCPS luncheon about challenges in sustaining effective process safety. CCPS Executive Director Shakeel Kadri discussed process safety culture at Tuesday's GCPS luncheon. Right: Wednesday's luncheon, sponsored jointly by the Spring Meeting and the GCPS, featured Al Sacco, Dean of the Edward Whitacre Jr. College of Engineering at Texas Tech Univ. Sacco shared his unique perspectives on process safety, based on his experiences aboard the space shuttle Columbia.

Spring Meeting and Global Congress on Process Safety photos by Callie Richmond, except where indicated.



▲ At the Executive Panel on Opportunity Crudes in a Changing Market, experts delved into the engineering, economics, and process safety factors involved in shale gas and tight oil extraction and handling. Panelists included (from left): Michael Webber, Deputy Director of the Energy Institution at the Univ. of Texas at Austin; Terry Higgins, Executive Director of Global Refining and Special Projects at Hart Energy; Steve Arendt, Vice President of ABS Consulting; and Carl Weaver, Senior Research Design and Development Engineer at Baker Hughes.



▲ One of the meeting's highlights was a panel discussion on big data analytics. Sharing their expertise in the technical challenges and business opportunities presented by the burgeoning availability of massive amounts of electronic data were (from left): Deborah Grubbe, President and Owner of Operations and Safety Solutions; Michael Firstenberg, Director of Industrial Security at Waterfall Security Solutions; Lloyd Colegrove, Fundamental Problem Solving Director at Dow Chemical; and Ted Wasserman, Product Manager at Tableau Software.



▲ At the Fuels and Petrochemicals Div. Welcome Session, David Rosenthal, Owner of the Reliability Strategy and Implementation Consultancy and AIChE's 2012 president, discussed reliability as "The Next Revolution in Process Manufacturing."



▲ AIChE President Cheryl Teich (center) congratulates Spring Meeting Program Chair Joseph Powell (left) and Co-Chair Wendy Young-Reed (right) on the successful conference.



▲ At the Spring Meeting Luncheon, Markus Scheller, Site Manager at BASF, advised attendees to "Never Underestimate the Importance of People."



▲ Panelists at the Engineering Diversity Initiatives Workshop included (from left): Chastity Harmon, Manager of University Relations and Diversity Outreach at Praxair; Audrey Goins Brichi, Manager of Diversity and Inclusion at Chevron; Karen Horting, Executive Director of the Society of Women Engineers (SWE); Zenaida Gephart, Associate Professor at Rowan Univ.; and Rodolfo Jimenez, STEM Coordinator at the Univ. of Texas at Austin. See the related article on p. 55.

► AIChE past director Rosemarie Wesson (left) talks with Mary Kathryn Lee, past chair of the Minority Affairs Committee, at a Board of Directors' reception for AIChE leaders.



▲ Friends and colleagues, old and new, enjoyed the meeting's many social events and receptions.

## AIChE Thanks the Meeting's Corporate Sponsors

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## *AICHE Financial Statements, Year Ended December 31, 2014*

### **Statement of Activities**

#### **Revenue:**

|                                           |             |
|-------------------------------------------|-------------|
| Dues and other membership revenue .....   | \$4,377,376 |
| Publication sales and subscriptions ..... | 2,330,223   |
| Industry technology groups .....          | 7,661,088   |
| Meetings and technical programming .....  | 6,146,627   |
| Education services .....                  | 2,980,207   |
| Financial services .....                  | 733,473     |
| AIChE Foundation contributions .....      | 1,305,829   |
| Other revenue .....                       | 376,866     |

**Total operating revenue and support \$25,911,689**

#### **Expenses:**

##### **Program related:**

|                                          |             |
|------------------------------------------|-------------|
| Membership .....                         | \$3,295,609 |
| Publications .....                       | 2,302,552   |
| Industry technology groups .....         | 6,619,140   |
| Meetings and technical programming ..... | 3,733,097   |
| Education services .....                 | 3,040,797   |
| Financial services .....                 | 189,277     |
| Other program support .....              | 1,194,570   |

**Total program related \$20,375,042**

##### **Support services:**

|                                  |             |
|----------------------------------|-------------|
| General and administration ..... | \$3,787,924 |
| Fundraising .....                | 1,172,295   |

**Total support services \$4,960,219**

**Total operating expenses \$25,335,261**

**Change in net assets from operations ...\$576,428**

#### **Non-operating activity:**

|                                                                                  |             |
|----------------------------------------------------------------------------------|-------------|
| Investment return, net .....                                                     | \$799,749   |
| Pension related changes other than net periodic pension cost .....               | (1,206,419) |
| Postretirement related changes other than net periodic postretirement cost ..... | (194,953)   |

**Total Non-operating Activity \$(601,623)**

**Change in total net assets (25,195)**

Net assets at beginning of year ..... 17,951,533

**Net assets at end of year \$17,926,338**

AIChE's net asset level remained relatively flat in 2014. Operations contributed \$0.6M to the total net assets. Operating businesses that exceeded budget include: Industry Technology Groups (\$351K), Education (\$268K), Publications (\$147K), and Membership (\$70K). Below the operating line, investment returns in the Permanent Fund contributed \$0.8M to the overall results. The Pension Plan adjustment for 2014 was a charge of \$1.2M to the pension plan liability, mainly resulting from a decrease in the interest rates, bringing our Plan to an 84% funded level at year-end. Overall the 2014 net assets remained at the 2013 level of \$18M.

### **Statement of Financial Position**

#### **Assets:**

|                                   |             |
|-----------------------------------|-------------|
| Cash and cash equivalents .....   | \$2,819,414 |
| Investments, at fair value .....  | 21,030,547  |
| Accounts receivable, net .....    | 2,712,779   |
| Prepaid expenses and other .....  | 272,165     |
| Pledges receivable, net .....     | 329,799     |
| Property and equipment, net ..... | 2,280,939   |

**Total assets \$29,445,643**

#### **Liabilities and Net Assets:**

##### **Liabilities:**

|                                                      |             |
|------------------------------------------------------|-------------|
| Accounts payable .....                               | \$1,827,798 |
| Deferred revenue: dues, subscriptions and other ..   | 5,009,249   |
| Accrued expenses:                                    |             |
| Employee vacation and other benefits .....           | 445,307     |
| Pension and other postretirement benefit costs ..... | 3,189,474   |
| Other .....                                          | 1,047,477   |

**Total liabilities \$11,519,305**

##### **Net assets:**

|                              |              |
|------------------------------|--------------|
| Unrestricted .....           | \$16,160,852 |
| Temporarily restricted ..... | 631,826      |
| Permanently restricted ..... | 1,133,660    |

**Total net assets \$17,926,338**

**Total liabilities and net assets \$29,445,643**

This is a condensed version of the 2014 financial statements of the American Institute of Chemical Engineers.

The financial statements and the full audited report are now available at [www.aiche.org/financial](http://www.aiche.org/financial).

## Leadership Opportunities

**S**avvy AIChE members make the most of their membership benefits by pursuing the many opportunities to enhance their skills and build a diverse network. However, some members may not realize that there are also opportunities to give back to the profession and raise their personal profiles in the chemical engineering community by becoming an Institute leader.

AIChE's lifeblood is its member volunteers — dedicated ChemEs who use their knowledge and experience to help shape the future of the profession. As the Institute continues to expand its reach, the need for committed volunteer leaders is growing.

AIChE offers many ways to get involved as a leader. If you have an AIChE local section in your geographic area, it probably needs someone to help organize an event, work on outreach programs, or communicate with chemical engineers in the area. If you prefer to work in a virtual setting, AIChE has 23 global committees that help shape the policies and objectives of the Institute. Examples include the Young Professionals Committee (YPC), which serves the professional development needs of members in the early stage of their careers; the Minority Affairs Committee (MAC), which promotes diversity in the profession; and the Women's Initiatives Committee

(WIC), which helps guide AIChE's support for women in the engineering workplace and in Institute activities.

AIChE also has more than 20 technical divisions and forums — whose volunteer leaders develop programs and activities that serve the interests of members in diverse sectors of chemical engineering practice.

Additionally, AIChE's Fellows Council is calling upon the Institute's Fellows to identify strategic issues that will influence the practice of chemical engineering and its impact on society into the future. AIChE Fellows are encouraged to complete the Volunteer Interest Form at [www.aiche.org/fellows-volunteer-service](http://www.aiche.org/fellows-volunteer-service).

### For International Members

With the expectation for AIChE's continued growth in both membership and programming outside the United States, the AIChE International Committee has been creating regional work groups to support chemical engineering's developing communities. If you reside or are involved in the chemical engineering practice in Africa, East Asia, Southeast Asia, Europe, Latin America, or the Middle East, your help is needed. Please contact James Abel, Membership Associate at AIChE, at [jamea@aiiche.org](mailto:jamea@aiiche.org), and he will help get you connected.

## Diversity Workshop Sets Agenda for Summit at Fall AIChE Annual Meeting

**M**embers of AIChE's Societal Impact Operating Council, Women's Initiatives and Minority Affairs committees, and other groups recently collaborated on a session devoted to improving inclusiveness in the Institute and the chemical engineering profession. The Engineering Diversity Initiatives Planning Workshop, held on April 27 at AIChE's 2015 Spring Meeting and Global Congress on Process Safety in Austin, TX, allowed participants to share personal perspectives on how AIChE can best serve underrepresented chemical engineers in the AIChE community, including lesbian, gay, bisexual, and transgender (LGBT) members, and engineers with disabilities. Discussion groups identified several opportunities for program development, which will be explored in depth at a Diversity Summit to be held at the 2015 AIChE Annual Meeting in Salt Lake City, UT, Nov. 8–12.

At the workshop, AIChE President Cheryl Teich compared creating a truly inclusive organization to that of instilling a safety culture in companies. "It's not enough to merely comply with a plan. A different level of commitment is needed," said Teich. "Inclusiveness needs to be in an organization's DNA."

Representatives from several organizations with effective

inclusiveness and diversity programs were on hand to stimulate the discussion. Audrey Goins Brichi, Manager of Diversity and Inclusion at Chevron, discussed Chevron's commitment to diversity as a business imperative. Chastity Harmon, Manager of University Relations and Diversity Outreach at Praxair, discussed Praxair's multifaceted inclusiveness strategies. Karen Horting, Executive Director of the Society of Women Engineers (SWE), talked about SWE's focus on women's professional and leadership skills development, and attention to such cultural factors as unconscious bias. Finally, Rodolfo Jimenez, STEM Coordinator at the Univ. of Texas at Austin, discussed UT's programs to mentor and prepare underrepresented youth for college engineering studies.

Some of the action items to be elaborated at the Annual Meeting's Diversity Summit include sharing of diversity best practices among AIChE groups; development of a statement highlighting the benefits of inclusiveness; online groups for engineers with disabilities; mixers for LGBT members and their allies; networking events for student members from underrepresented groups; and identification of diversity champions across AIChE communities.



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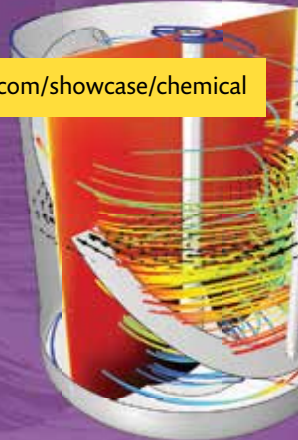
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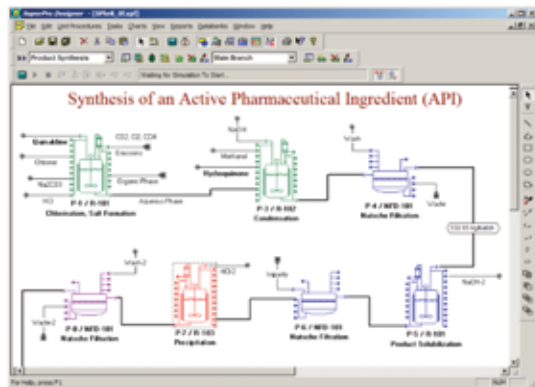
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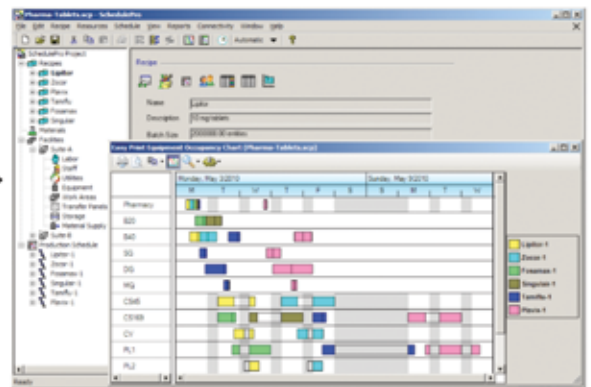
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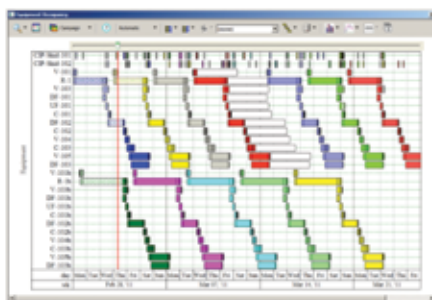


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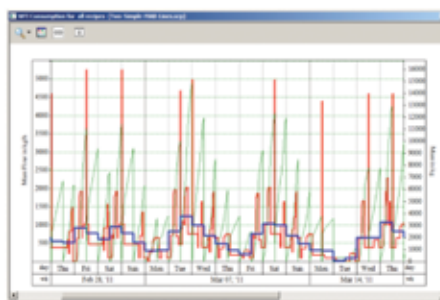
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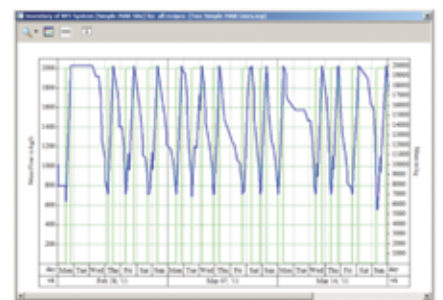
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# Calendars

## AIChE Meetings Calendar

For information and registration details, visit [www.aiche.org/conferences](http://www.aiche.org/conferences) or call Customer Service at 1-800-242-4363 or 1-203-702-7660 (outside the U.S.).

|                       |                                                                                                                                                          |
|-----------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------|
| JUNE 21–24, 2015      | <b>5th International Conference on Accelerated Carbonation for Environmental and Materials Engineering (ACEME)</b><br>Columbia University • New York, NY |
| JUNE 28–JULY 1, 2015  | <b>12th International Conference on Gas-Liquid and Gas-Liquid-Solid Reactor Engineering (GLS12)</b><br>Crowne Plaza Times Square • New York, NY          |
| AUG. 30–SEPT. 3, 2015 | <b>60th Annual Safety in Ammonia Plants and Related Facilities Symposium</b><br>The Westin Copley Place • Boston, MA                                     |
| SEPT. 16–18, 2015     | <b>4th Conference on Constraint-Based Reconstruction and Analysis (COBRA 2015) (Organized by IMES)</b><br>Heidelberg, Germany                            |
| SEPT. 28–29, 2015     | <b>Technology Challenges and Opportunities in Commercializing Industrial Biotechnology (Organized by SBE)</b><br>Bahia Hotel • San Diego, CA             |
| SEPT. 28–30, 2015     | <b>European Workshop on Process Safety</b><br>Nice, France                                                                                               |
| OCT. 1–2, 2015        | <b>7th Southwest Process Technology Conference</b><br>Moody Gardens Hotel and Convention Center • Galveston, TX                                          |
| OCT. 27–29, 2015      | <b>Offshore Technology Conference — Brazil</b><br>Riocentro Convention Center • Rio de Janeiro, Brazil                                                   |
| NOV. 3–5, 2015        | <b>2015 Global Summit on Process Safety &amp; Leadership Forum on Process Safety</b><br>Kuala Lumpur, Malaysia                                           |
| NOV. 6–10, 2015       | <b>AIChE Annual Student Conference</b><br>Salt Palace Convention Center • Salt Lake City, UT                                                             |
| NOV. 8–13, 2015       | <b>AIChE Annual Meeting</b><br>Salt Palace Convention Center • Salt Lake City, UT                                                                        |
| NOV. 17–19, 2015      | <b>2015 Carbon Management Technology Conference (CMTC 2015)</b><br>Sugar Land Marriott Town Square • Sugar Land, TX                                      |
| DEC. 1–2, 2015        | <b>Metabolic Engineering Summit (Organized by IMES)</b><br>Beijing, China                                                                                |
| MAR. 22–25, 2016      | <b>Offshore Technology Conference — Asia</b><br>Kuala Lumpur, Malaysia                                                                                   |
| APR. 10–14, 2016      | <b>AIChE Spring Meeting and 12th Global Congress on Process Safety</b><br>Hilton Americas and George R. Brown Convention Center • Houston, TX            |

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### Public Courses

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|---------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------|
| JUNE 8–10, 2015<br>NEW YORK, NY       | <b>Essentials of Chemical Engineering for Non-Chemical Engineers</b><br>Course # CH710 • Instructor: Jack Hipple                               |
| JUNE 8–11, 2015<br>MANAMA, BAHRAIN    | <b>Foundations of Process Safety</b><br>Course # CH910 • Instructors: Byron Sun, Frank Renshaw                                                 |
| JUNE 8–10, 2015<br>CHICAGO, IL        | <b>HAZOP Studies and Other PHA Techniques for Process Safety and Risk Management</b><br>Course # CH157 • Instructor: Robert Johnson            |
| JUNE 8–12, 2015<br>CHICAGO, IL        | <b>Combo Course: HAZOP Studies AND Concepts for Process Hazard Analysis (CH157 &amp; CH754)</b><br>Course # CH759 • Instructor: Robert Johnson |
| JUNE 11–12, 2015<br>CHICAGO, IL       | <b>Advanced Concepts for Process Hazard Analysis</b><br>Course # CH754 • Instructor: Robert Johnson                                            |
| JUNE 15, 2015<br>HOUSTON, TX          | <b>Spreadsheet Problem Solving for Chemical Engineers</b><br>Course # CH765 • Instructor: David Clough                                         |
| JUNE 15–16, 2015<br>HOUSTON, TX       | <b>Combo Course: Spreadsheet Problem Solving AND VBA Programming (CH765 &amp; CH766)</b><br>Course # CH767 • Instructor: David Clough          |
| JUNE 16, 2015<br>HOUSTON, TX          | <b>Excel VBA Programming for Chemical Engineers</b><br>Course # CH766 • Instructor: David Clough                                               |
| SEPT. 16–18, 2015<br>PHILADELPHIA, PA | <b>Combo Course: Flow of Solids AND Pneumatic Conveying (CH032 &amp; CH033)</b><br>Course # CH757 • Eric Maynard                               |
| SEPT. 28–30, 2015<br>SEATTLE, WA      | <b>Essentials of Chemical Engineering for Non-Chemical Engineers</b><br>Course # CH710 • Instructor: Jack Hipple                               |

### Webinars

Register and view live and archived webinars at [www.aiche.org/webinars](http://www.aiche.org/webinars).

|                                  |                                                                                                                                |
|----------------------------------|--------------------------------------------------------------------------------------------------------------------------------|
| JUNE 10, 2015<br>2:00–3:00 PM ET | <b>Introduction to Particle Characterization</b><br>Presenter: Karl Jacob                                                      |
| JUNE 25, 2015<br>2:00–3:00 PM ET | <b>Mixer Simulations, Modeling Nonideal Reactors and Mixers (Sponsored by Comsol)</b><br>Presenters: Ed Fontes, Jennifer Segui |
| JULY 8, 2015<br>2:00–3:00 PM ET  | <b>Safety Instrumented Systems</b><br>Presenter: Angela Summers                                                                |
| JULY 22, 2015<br>2:00–3:00 PM ET | <b>Semiconductors</b><br>Presenter: Kate Ziemer                                                                                |
| JULY 29, 2015<br>2:00–3:00 PM ET | <b>Benefits of Accurate Smart Drawings (Sponsored by Provenance Consulting)</b><br>Presenter: Michael Tzaperas                 |