Electrorefiner Redesigned to Treat Larger Amounts of Spent Fuel

Researchers at Argonne National Laboratory have demonstrated that the electrorefining process originally developed to treat small amounts of spent fuel from one of the Laboratory's experimental nuclear reactors could be redesigned to have greater capacity. The electrorefiner is made up of positively and negatively charged electrodes, and when current runs between the electrodes, heavy metals collect on the cathode. The radioactive wastes stay behind in a concentrated form for special handling and disposal.

The redesigned electrorefiner packs the electrodes closer together and increases their surface area. This approach reduces the cell's electrical resistance, enabling it to operate at higher currents and faster rates. Engineers are now designing a 500-pound-per-day prototype. Their goal is to develop a unit with a one-ton-per-day capacity.

Argonne engineer Ed Gay, co-inventor of the process, said the electrochemical treatment process is simple and the equipment is compact and easy to operate, making it possible to install treatment equipment with the necessary capacity in existing facilities.

Rigid/Pliable Molecules Form Useful Self-Assembled Films

A method of creating molecules that self-assemble into films with different properties on each surface has been developed by materials scientist Samuel Stupp of the University of Illinois at Urbana. The construction, dubbed "needle-and-thread architecture," involves molecules built so that one end is thin and stiff like needles, the other loose and pliable like threads, Stupp said.

Stupp and his graduate students, Vasson LeBonheur and Kenneth Walker, tested surfaces by putting drops of water on them. The needles are hydrophilic so the droplets flatten and hug the surface. The threads, however, are designed to be hydrophobic, so that water droplets stand up at nearly right angles.

With this technique tape can be made in one step. Bent into a tube, the tape could be made into an artery that binds on the outside to muscle, yet lets blood pass unhindered within. As a glue, the film (if made adhesive on both sides) could bond tightly to carbon fibers and to the matrix that holds them, creating stronger carbon composites for airplane, boat, and car bodies.

The needle-like structures bond to each other. The threads likewise bond. Then layers of needles and threads overlay one another forming a mat. Submolecules attached to each end of the needle-and-thread architecture give each mat its particular application, Stupp said.

"People talk about self-assembled monolayers. What we have created is more than a monolayer. What's remarkable is that this produces a self-assembled film that you can pick up," he said.

Stupp can layer 100 monolayers to a thickness of approximately 1 μm, though he does not understand yet how the layers link.

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Nuclear Spin Tomography Used in Materials Testing

Nuclear spin tomography, commonly used as an imaging process for diagnosing diseases of the brain, spine, and joints, has become a valuable tool in materials research. Scientists at the Fraunhofer Institute for Non-Destructive Testing Procedures in Saarbrücken, Germany, hope to use this technique to explain occurrences such as why catalytic converters in automobiles lose their efficiency, or to improve the efficiency of airplane wings.

In the fields of medicine and materials testing, necessary information is obtained by analyzing the alignment and vibratory motion of the nuclei of hydrogen atoms. However, while materials testers use superconducting magnets with field strengths of up to 14 T, in medical applications most equipment operates at 1.5 T, which is 5,000 times stronger than the Earth's magnetic field. Such high field strengths allow materials researchers to increase the resolution to within a few microns. However, the target material must be placed in a narrow, cylindrical measuring chamber. In this way the requisite magnetic field strengths and the resulting photo-quality images can be obtained.

Similarly, nuclear spin resonance, which detects ubiquitous protons, also appears ideally suited for analyzing structures already subject to the action of humidity, smog, and microorganisms. To test the safety of bridges or cooling towers, for example, scientists must determine the degree of moisture within the building material and the effects of aging. Consequently, the scientists at Fraunhofer Institute have fitted their equipment with a special attachment whose sensors are able to scan the object quickly and reliably, and thus determine the quantity and the condition of proton-containing substances. Within a short time, a colored image appears on the monitor highlighting the hardness of concrete or the extent to which the aging process in composite fibrous material has advanced. With this development, building materials can now be examined on site without the need for samples to be taken to a laboratory.

Modified from *The German Research Service, Special Science Reports,* Vol. 11, No. 01/95.

E. Pope Receives Woldemar A. Weyl International Glass Science Award

The Pennsylvania State University and the International Commission on Glass announced the presentation of the 1995 Woldemar A. Weyl International Glass Science Award to Edward J.A. Pope of MATECH, Inc. Pope will receive the award and present the Weyl Lecture at the XVII International Congress on Glass to be held in Beijing, China on October 9–14, 1995. Pope was selected for showing ingenuity, initiative, and innovative thinking in his research and development of new optical glasses and electronic and biological materials by chemical polymerization methods.

In 1989 Pope received his PhD degree in Materials Science and Engineering at the University of California—Los Angeles and he started his company, MATECH Advanced Materials, a research laboratory for the development of new materials utilizing sol-gel processes. He is Adjunct Professor of Materials Science and Engineering at the University of Utah. He has published over 45 papers and six books, and has three patents. Pope has recently

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developed the technology for encapsulating living microorganisms in a sol-gel derived glassy matrix for applications such as transplantation of bioartificial organs, environmental remediation, and pharmaceutical production.

Environmental Cleanup Research Leads to Better Understanding of Geological Formations

Researchers at Oak Ridge National Laboratory (ORNL) found that a "soil-to-glass" environmental cleanup process they tested can mimic some of the processes of magma formation and cooling. The process, *in situ* vitrification (ISV), uses electrodes to heat soil contaminated with radioactive elements to temperatures up to 1600°C. Upon cooling, the molten soil transforms to a mixture of glass and crystals in the ground, trapping the radioactive material. Researchers at ORNL have tested ISV with and without radioactive materials.

"ISV melts can provide artificial magmas in a controlled, monitored environment," said Mike Naney, a geochemist with ORNL's Environmental Sciences Division. "The molten rock, crystals, and gases produced by the melting are formed at temperatures similar to those in crustal magma chambers that supply lava to volcanoes," he said. By studying the cooling and crystallization in artificial magmas, researchers learn how certain rocks form during the cooling of crustal magma chambers and lava lakes.

Using thermocouples, the ORNL researchers measured the temperature profile of the ISV magma. Temperatures ranged from 100°C several feet away from the melt to 1500°C in the molten soil. They observed vigorous bubbling and rapid convection of heat by circulation of heated liquid and gases at the melt surface. After the artificial magma cooled, they obtained samples by diamond-core-drilling the rocklike product. Then they analyzed the textures and chemistry of the minerals that formed during crystallization of the melt.

The soils studied melt to form a basalt-like liquid, abundant in calcium, magnesium, iron, and silicon. As the molten basalt cooled, minerals containing calcium, magnesium, and iron precipitate out, leaving a liquid replete in silicon. The last of the remaining liquid cooled, solidifying into a mixture of glass and crystals with the composition of granite.

"Our observation of small amounts of granite filling spaces between the larger feldspar and pyroxene crystals that form the predominantly basalt-like rock provides information on granite formation in the crust of the earth," Naney said. "The same phenomenon in natural magmas would trap granite liquid between interlocking crystals of a basalt, preventing migration and coalescence of the granite liquid to form large masses."

Titanium Nitride Coating Increases Durability of Kevlar

Laurie Atagi, a postdoctoral fellow with Los Alamos National Laboratory's Polymers and Coatings Group, has developed a method for encasing bundles of Kevlar fibers in a film of titanium nitride, a material used to coat tools to protect them from wear and tear. Once encased

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in a sheath of titanium nitride, "ordinary" Kevlar fibers—used in everything from bullet-proof vests to sporting equipment—become "extraordinary" fibers.

Kevlar is a versatile thread with high tensile strength that can support great weight and endure extreme pulling force. When compressed, however, the fibers buckle. This buckling point becomes a weak link and compromises the integrity of the thread. The sheath of titanium nitride, less than half a micron thick, can suppress buckling and increase durability of the thread.

Atagi used plasma-enhanced chemical vapor deposition to accomplish the task. By using this technique she was able to put the titanium film on Kevlar fiber bundles at temperatures ranging from 150 to 250°C, well below the breakdown temperature of Kevlar, which is 400°C.

By using microwaves to excite a mixture of molecules into a plasma state, then introducing the Kevlar into the plasma, Atagi was able to deposit a film of titanium nitride onto the fiber bundle.

"At first I was getting coatings that were about three microns thick," said Atagi, "but at that thickness I was having problems getting the coating to adhere to the Kevlar because the coating would bunch up and slough off."

A coating of less than a half of a micron seemed to work best, she found, and will match contours and topical features with virtually no distortion. In addition, the plasma-assisted process is easily controlled and highly efficient.

"There are a variety of practical applications for this technology," Atagi said. "For example, some soccer shoes have Kevlar uppers. The shoes are subject to a lot of twisting and compression forces when they're being used. Coated Kevlar could extend their lifespan." Atagi said a similar technique could be used for other fibers.

Elements 110 and 111 Detected

Physicists at the Darmstadt-based Society for Heavy-Ion Research, GSI, have detected two chemical elements, one with the atomic number 110, and the other, 111. The isotope of the element 110 possesses an atomic weight of 269, that of the element 111, an atomic weight of 272. Chemically the element 110 is a "heavier" relation of the elements nickel, palladium, and platinum; the element 111, as a relation of copper, silver, and gold, a so-called ekagold. However, in contrast to these stable elements, the newly discovered elements are considerably more short-lived, decaying in less than 1 ms after creation into known isotopes of lighter elements and emitting alpha particles. During the decay of the element 111 a characteristic x-ray emission was also observed.

To produce the element 110, nickel atoms were ionized by the removal of electrons from their atomic shell before being accelerated and beamed onto a foil made of lead. During the fusion of these particles, the newly-formed nucleus has a particularly low energy state, thus rendering its immediate decay through fission less probable. The element 111 was likewise produced from nickel and bismuth.

In order to create and identify a single

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atom of the element 110, billions of nickel atoms were beamed onto ultrathin lead foils over a period of days. The task of extracting one nucleus with the atomic number 110 from this flow of nickel ions was performed with the aid of the 11-meter-long velocity filter *SHIP*, which guided the atoms produced by fusion onto a detector system. This device measured the impact of each atom and enabled the decay process of the implanted atoms to be monitored over a period of minutes. The energy of the alpha particle emitted from the nucleus serves as a means to identify the atom by leaving behind a sort of fingerprint which provides information about the creation, binding strength, and decay of the atom.

Modified from Günter Siegert, *The German Research Service, Special Science Reports*, Vol. 11, No. 01/95.

Solvents Used to Control GaAs Quantum Dot Sizes

Shreyas Kher of Duke University has found a way to potentially create quantum dots in carefully controlled sizes. This achievement prompted a collaboration with scientists at the University of North Carolina to investigate the tiny dots that may be useful in devices such as optical computers. Scientists want to incorporate quantum dots in very small and fast computers that would operate on light rather than electricity. The optical properties of the quantum dots can be changed by altering the size of the particles.

Kher discovered his method of making quantum dots while looking for a safe way to produce gallium arsenide. Kher's process is confined to a single reaction chamber and it involves no gases. "You don't actually make one compound, isolate it, and then react that with another compound," he said. "Everything reacts in the same setup." To make the gallium arsenide, arsenic powder is first mixed with an alloy of sodium and potassium metal to generate sodium and potassium arsenides. Both the sodium and potassium arsenides are then combined with gallium trichloride. The reaction yields gallium arsenide plus two simple and benign byproducts—sodium chloride (common salt) and potassium chloride. The process uses solvents, such as diglyme, that restrict the growth of the resulting gallium arsenide crystals to a range of widths in the nm range. The type of solvent used determines how large the crystals grow. When the dots are surrounded in a protective suspension, they can remain stable for at least one year.

The diglyme, because of its structure, wraps around the gallium trichloride. Kher said, "What actually happens, we think, is that the solvents remain bound to the surface of the growing particle and they limit the particle to a certain size." The average width of a quantum dot using diglyme as a solvent is about 10 nm, while the average using dioxane is about 36 nm. Monoglyme produces an intermediate sized particle averaging about 17 nm, Kher said.

The final step in the process is to replace the original solvent with methanol. The methanol surrounds the quantum dots in a protecting suspension, forming a colloid.

Richard Superfine, a physicist at the University of North Carolina, said his group wants to test the dots for their nonlinear optical properties. Those properties

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can be "changed dramatically," for example, on exposure to light of a certain intensity. After initial exposure, the material may then react differently to a second burst of light. Referring to glasses that darken in bright light, Superfine said, "Because light is shining on the material, it changes how other light transmits through the glass." He said that such effects might allow quantum dots to be fashioned into devices such as optical transistors.

Chemical Composition Causes Children's Fingerprints to Disappear Sooner Than Adults'

Michelle Buchanan of Oak Ridge National Laboratory's (ORNL) Chemical and Analytical Sciences Division and Art Bohanan of the Knoxville's Police Department are working together to determine why children's fingerprints disappear from surfaces after a short time while prints from adults last much longer. Buchanan and other researchers believe that a difference in chemical composition is responsible.

"Children's fingerprints contain more volatile chemicals, such as free fatty acids, while adult prints display longer lasting compounds," Buchanan said.

Buchanan enlisted a volunteer group of youths, ages 4 to 17, to shake vials of alcohol between their thumb and forefinger to collect chemicals from their skin. She took similar samples from adults, ages 19 to 46. She tested the samples using gas chromatography/mass spectrometry, which is a very sensitive method of analyzing and identifying chemicals.

"We see a marked difference in the chromatograms," Buchanan said. Buchanan sees this research laying the groundwork for noninvasive diagnostic procedures, "It has been reported that a number of compounds present in the skin's surface are indicators of some diseases. We hope to improve sampling techniques to develop methods to detect target compounds that can tell us more about what's going on inside the body."

Bohanan envisions a one-touch patch test to enable the detection of drugs at the scene. "Forensic evidence is often lost or tainted because of delays in analysis or accidents along the way," Bohanan said.

Stanford Research Supports d-Wave Theory to Describe High-Temperature Superconductivity

Heat capacity measurements at Stanford University indicate that the force that binds electrons into pairs making superconductivity possible in high-temperature superconductors is strong in some directions but drops to zero in others. The results performed by Aharon Kapitulnik, professor of applied physics, and graduate student Kathryn Moler are consistent with, and significantly strengthen, the evidence that the electron-pair binding in high-

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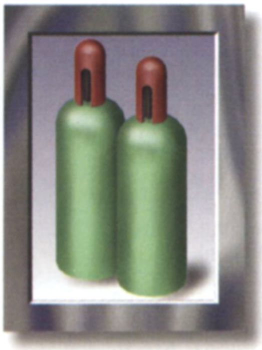

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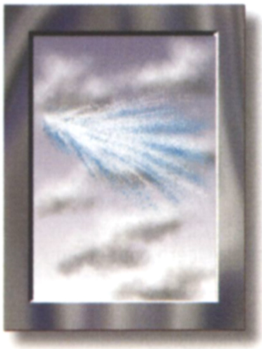

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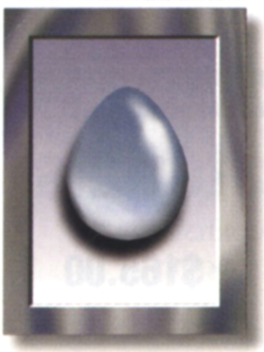

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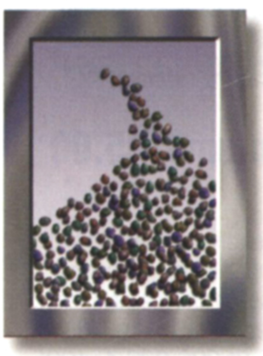
Direct Liquid Injection (DLI) sub-systems utilize a micropump, vaporizer and electronics control unit to deliver 0.001 to 10 cc/min liquid in a smooth pulse-free manner. Liquid Precursor Delivery Systems (LPDS) are integrated/configurable systems that provide a custom delivery solution using a positive displacement metering pump and vaporizer.



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temperature superconductors takes the form of d-wave binding. The electron-pair binding force in conventional superconductors is the same in all directions, called an "s-wave" configuration.

The two Stanford researchers took a sample of the cuprate superconductor YBCO weighing a few milligrams. They attached this to a layer of sapphire that was bonded to a large block of copper that was maintained at a constant temperature. They then repeatedly heated the superconducting sample by two hundredths of a degree Celsius and measured how long it took to cool down when exposed to an external magnetic field of varying strengths and orientations.

"We found two effects," Moler said. "One, that we expected, is present regardless of the orientation of the field relative to the direction of the layers of copper oxide that carry the superconducting current. But the second effect was new and appeared only when the magnetic field is perpendicular to the layers."

This new measurement was larger than predicted by the s-wave model. If the electron-pair binding force is positive in all directions, as it is in the s-wave model, then it should not have this effect on heat capacity. To produce these variations, the binding force must go to zero in some directions, the Stanford researchers said. The d-wave theory is not the only model that fits their observations, but it is the one that both fits and has the most experimental support, the scientists said.

R.M. German Named Outstanding Researcher

The Powder Metallurgy (P/M) Lab of The Pennsylvania State University presented the 1995 Penn State Engineering Society Outstanding Research Award to Randall M. German, Brush Chair Professor in Materials at Penn State. The Award honors individuals who, by their contributions to knowledge, have brought recognition to themselves and Penn State. German has been director of the P/M Lab since 1991. His teaching and research focus is on particulate materials processing. □

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