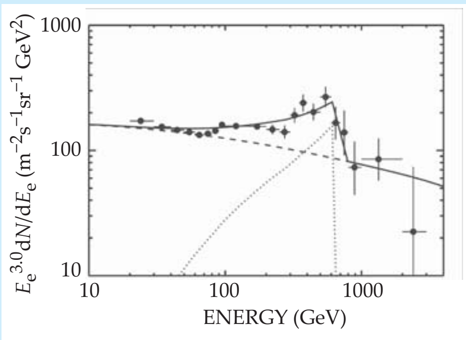
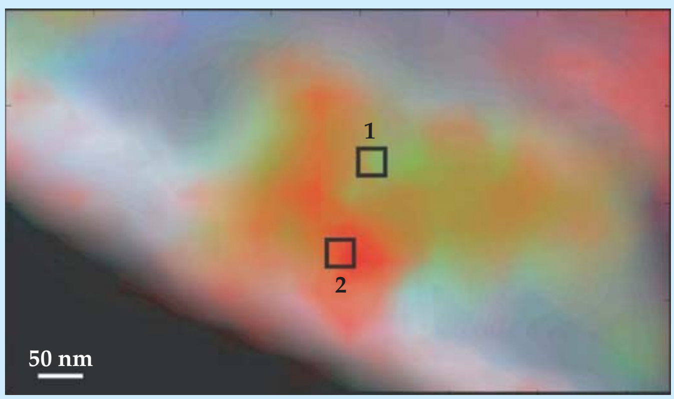
content for calibration, a neutron detector a few meters above the ground can give precise measurements of soil moisture on the time scale of minutes to a few hours. As the figure shows, the hourly soil moisture determined by a cosmic-ray neutron detector (top) agrees with that determined by time-domain reflectometry probes (middle) and with the monitored daily precipitation (bottom). (M. Zreda et al., *Geophys. Res. Lett.* **35**, L21402, 2008, doi:10.1029/2008GL035655.) —RJF

Signs of dark matter? Two groups of cosmic-ray observers have reported unexpectedly large fluxes of high-energy electrons and positrons. Those excesses suggest either that there are undiscovered astrophysical sources such as radio-quiet pulsars surprisingly nearby or that the positrons and electrons are annihilation products of WIMPs—weakly interacting dark-matter particles hundreds of times more massive than the proton. Standard cosmology predicts that dark nonbaryonic matter dominates the material content of the cosmos. But its constituent particles have yet to be identified. The ATIC balloon collaboration, led by John Wefel of Louisiana State University, reports a significant enhancement in the spectrum of cosmic-ray electrons, peaking near 600 GeV (see the figure). The peak suggests that 600-GeV WIMPs of the kind predicted by extradimensional extensions of standard particle theory might be annihilating with each other to create e^+e^- pairs in very dense concentrations of dark matter not far from our solar system. The ATIC detector cannot distinguish positrons from the much more abundant cosmic-ray electrons. But the magnetic spectrometer aboard the orbiting PAMELA satellite can. Positrons are routinely produced in collisions between cosmic rays and ordinary interstellar matter. The ratio of such positrons to cosmic-ray electrons was expected to fall steeply with increasing energy. Instead, the PAMELA collaboration, led by Piergiorgio Picozza of the University of Rome "Tor Vergata," reports that the positron fraction grows steadily with energy from 10 GeV to 100 GeV. So it appears that there must be some additional source of high-energy positrons. The collaboration will continue taking data for at least another year, hoping to find spectral structure suggestive of WIMPs or anisotropy pointing to a nearby astrophysical source. Both WIMP annihilations and pulsars are expected to produce high-energy gamma rays. So for the moment, all eyes are on the recently launched Fermi Gamma-ray Space Telescope (originally called GLAST), which is designed to pinpoint gamma-ray sources and spectral features but can also confirm the ATIC electron result with higher statistics. (J. Chang et al., ATIC collaboration, *Nature* **456**, 362, 2008; O. Adriani et al., PAMELA collaboration, http://arxiv.org/ abs/0810.4995.) —BMS



Ultrasound's role in wire bonding. In almost all integrated circuit chips, the wires that connect the internal circuitry to the external packaging are attached by a process called wire bonding. In that technique, ultrasound is used in combination with heat and pressure to weld the tip of the wire, usually gold, to the surfaces to be connected. It's been known for 40 years that ultrasound can make metals easier to work, an effect called acoustic softening. But the process of working the metal can have its own impact on the metal's hardness. Thus it's been difficult until now to get a clear picture of what's going on, and wire bonding has remained a largely empirical process. By placing gold microballs under different levels of applied force and ultrasound and measuring their resulting deformation, a team of researchers from the University of Waterloo in Canada and Tsinghua University in Beijing has succeeded in separating the softening contributions of the ultrasound from the effects of the mechanical force. The researchers were also able to quantify the residual effects of ultrasound on gold, and they found residual softening that increased with greater ultrasound amplitude above a certain threshold. They attribute the residual effects to the net balance between ultrasound's dynamic annealing and its potential opposing effect on activating and multiplying dislocations. (I. Lum et al., *J. Appl. Phys.*, in press.) —RJF

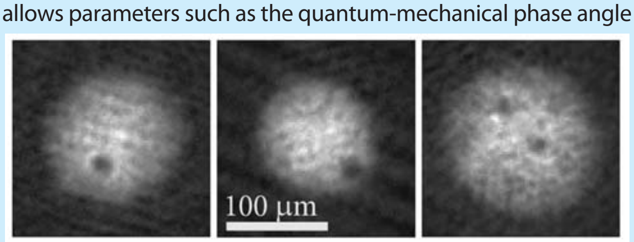
A catalyst caught in the act. Catalysts are ubiquitous in today's chemical industry, but there remains much to be learned about the specific mechanisms by which many of them work. Though such knowledge could lead to improved or new catalysts, obtaining atomic-scale information about in situ chemical changes in a hot environment at atmospheric pressure has presented a difficult challenge. A Dutch team led by Frank de Groot and Bert Weckhuysen of Utrecht University has recently demonstrated the potential of a new approach to imaging catalysts at work: scanning transmission x-ray microscopy. As a catalyst and reactants interact, the valence states and chemical bonding of the participating atoms evolve. STXM detects those changes by looking at the absorption of x rays by the atoms' inner electron shells. The researchers demonstrated the technique by looking at the iron-based catalyst for the Fischer–Tropsch process, in which hydrogen and carbon monoxide are converted to hydrocarbon chains. Soft x rays used in STXM are strongly attenuated in matter, so the research team used a nanoreactor of thickness 50 μm; the reactor was connected to gas lines and mounted on an adapter that was scanned in 35-nm steps through the focus of a monochromatic x-ray beam. In that way, two-dimensional absorption maps at various x-ray energies could be recorded.



The researchers paid particular attention to energies near the absorption edges of carbon, oxygen, and iron. Analyzing the maps they obtained, the researchers could extract the carbon hybridization states and determine the extent to which the iron atoms, which started off in iron oxide, had been reduced, formed other oxides, or reacted with the silicon dioxide substrate or with carbon. The figure maps the distribution of the inferred iron compounds, each represented by a different color. With better optics and detection techniques, the team hopes to improve on its current 40-nm resolution and perhaps provide time-resolved and 3D imaging of complex chemical reactions in situ. (E. de Smit et al., *Nature* **456**, 222, 2008.) —RJF

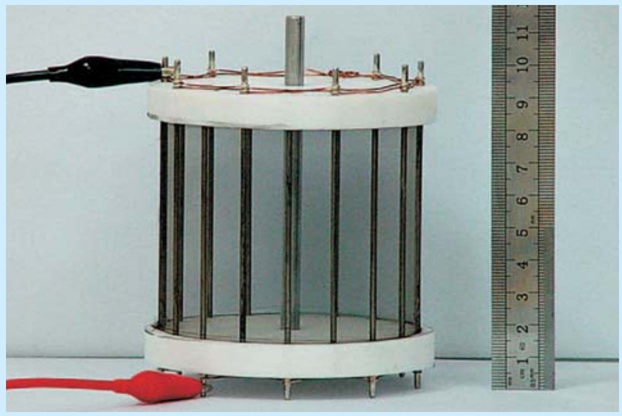
In-ground carbon dioxide capture. As concern over global warming continues to grow, pressure and funding are increasing to find ways to reduce the growth and, in time, the actual levels of atmospheric carbon dioxide (see PHYSICS TODAY, August 2008, page 26). Peter Kelemen and Jürg Matter of Columbia University's Lamont-Doherty Earth Observatory have proposed a new approach for CO_2 sequestration: accelerating the natural carbonation of exposed mantle rock. In many places around the globe—perhaps most dramatically in Oman—sections of the upper mantle have been raised through subduction or tectonic spreading. The resulting outcrops, termed ophiolites, are rich in peridotite, a rock primarily composed of the minerals olivine and pyroxene. (For more on the Oman ophiolite, see PHYSICS TODAY, January 2005, page 21.) Strongly out of chemical equilibrium with the atmosphere, the mantle rock naturally reacts with water and CO_2 to form silicates, carbonates, and iron oxides. Kelemen and Matter find that atmospheric CO_2 reacts with peridotite surprisingly quickly, at a rate of about 4×10^7 kg/yr for the 500-km-long Oman ophiolite. The researchers suggest several options for boosting that reaction rate even higher, starting with increasing the interaction volume by drilling and fracturing the peridotite. Some fracturing will happen spontaneously as the hydration and carbonation reactions expand the rock volume and give off heat. When the two scientists incorporate into their model the effects of raising the CO_2 concentration near the rock and elevating the peridotite temperature, they estimate a potential increase of 10^9 in the reaction rate, or 2×10^9 tons of CO_2 captured and sequestered each year per cubic kilometer of ophiolite. The researchers call for further modeling and field testing of what could be a permanent storage solution. (P. B. Kelemen, J. Matter, *Proc. Natl. Acad. Sci. USA* **105**, 17295, 2008.) —RJF

Vortices spontaneously arise as a Bose–Einstein condensate forms. In an emptying bathtub, water forms a whirlpool around the drain. But circular flow can't persist to the very center of the vortex; there must be a water-free funnel. In 1985 Wojciech Zurek, following on work of Tom Kibble, suggested that "topological defects" analogous to the whirlpool could be generated spontaneously in a system undergoing a second-order phase transition. For a fast enough process in a large enough system, small regions independently change state, being unable to communicate with other, relatively far off regions. That independence allows parameters such as the quantum-mechanical phase angle



to arrange themselves in vortex structures. Researchers have seen spontaneous vortex formation in, for example, superfluid helium-3, nonlinear optical systems, and superconductors (see the article by Kibble, PHYSICS TODAY, September 2007, page 47). Now a new system can be added to the list: the Bose–Einstein condensate. Deliberately inducing a vortex in a BEC is nothing new, but recent joint experimental work at the University of Arizona and numerical work at the University of Queensland in Australia represents the first study of spontaneous vortex formation in that particularly clean system. In the experiment, Chad Weiler and colleagues tweaked standard procedures to maximize the chance of their observing spontaneously formed vortices. After a trapped atomic gas transitioned to a BEC over the course of a few seconds, the group removed the trapping potential and imaged the escaping condensate. The vortices are revealed by dark, zero-density spots in the figure; the rightmost image shows two vortices, the others a single vortex. Continuing experiment and simulation together, Weiler and colleagues hope, will shed light on the universality of spontaneous topological defect formation in phase transitions. (C. N. Weiler et al., *Nature* **455**, 948, 2008.) —SKB

Nanotube loudspeakers. In typical loudspeakers, a coil surrounds the apex of a flexible cone; when a varying current flows through the coil, the cone moves toward and away from a fixed permanent magnet and produces pressure waves we hear as sound. But researchers from Tsinghua University and Beijing Normal University have demonstrated a radically simpler loudspeaker design based on nanotubes: They showed that a thin film of nanotubes can reproduce sounds over a wide frequency range—including the full human audible range—with high sound pressure level, low total harmonic distortion, and no magnets. The team created the film by drawing nanotubes from a so-called



superaligned array grown on a wafer, a technique the group introduced six years ago (see also PHYSICS TODAY, October 2005, page 23). The resulting film, only tens of nanometers thick but up to 10 cm wide, is transparent and has a nearly purely resistive impedance. When electrodes are placed along its ends and an alternating current is applied, the film produces clear tones that can be as loud as a conventional speaker. Moreover, since the film is flexible, the nanotube speaker can be configured into arbitrary shapes or mounted onto curved substrates; the figure shows an omnidirectional cylindrical loudspeaker 9 cm in diameter and 8.5 cm high. The film can even be stretched with essentially no degradation of the sound reproduction. The researchers attribute the sound generation not to vibration but to a thermoacoustic effect first proposed nearly a century ago: Thanks to the nanotube film's extremely low heat capacity per unit area, changes in the current flowing through the film are reflected in the film's temperature, and those temperature changes excite pressure waves in the surrounding air. The mechanism is independent of the sign of the current, which leads to a frequency doubling of the input signal, but that drawback can be overcome by applying a constant current bias. A movie at http://blogs.physicstoday.org/update/acoustics shows a nanotube loudspeaker being periodically stretched with almost no noticeable effect on the sound intensity. (L. Xiao et al., *Nano Lett.*, in press, doi:10.1021/nl802750z.) —RJF ■