Physics Update

A phase change for high-density data storage. Using electron beams instead of optical beams, scientists at Hewlett Packard have read individual, rewritable bits in a thin indium–selenium layer. That layer, a buffer layer of gallium–selenium, and a silicon substrate, form the principal parts of a pn-junction diode. The read–write cycle goes like this: Short, high-power bursts from an electron beam are used to write a 1 by melting and quenching a small region of the InSe surface and turning it from a crystalline to a glassy phase. The amorphous blob can be erased by the use of a longer, lower-power beam pulse. Raised just above the crystallization temperature, the InSe recrystallizes, apparently by regrowing epitaxially from the surrounding crystal matrix. A beam pulse of still lower power can read the bit as either a 1 (the amorphous blob yields little or no detectable current in the pn-junction diode) or a 0 (the crystalline material yields a high diode current). Thus far, the HP researchers have written with a laser beam rather than an electron beam (their electron beam isn't yet strong enough), but they have employed an e-beam for reading and erasing. The phase-change medium can respond to reading rates of at least a million bits per second per electron beam, and more than 100 write-erase-rewrite cycles have been carried out successfully on single bits. The researchers hope to reduce the bit size from its current 150 nm across to perhaps 10 nm. (G. A. Gibson et al., *Appl. Phys. Lett.* **86**, 051902, 2005.) —PFS

Molecular distortion on a metal surface. Scientists in Germany and France have recently determined the precise structure of a large organic semiconductor molecule after it chemically binds to a metal surface. The organic–metallic interface is very important in science, especially in the fields of catalysis, biosensing, and molecular electronics, but large molecules are difficult to study because of their tortuous shapes and many internal degrees of freedom. The researchers began with a superclean silver surface in ultrahigh vacuum. When the planar molecule (called PTCDA) adsorbed onto the surface, it reacted chemically and became bound to the surface. Next, x rays from the European Synchrotron Radiation Facility in Grenoble, France, were used to create normal-incidence standing waves at the surface. Because atoms at the wave field's antinodes exhibit more photoemission than those at nodes, the resulting atomic-scale ruler allowed the researchers to determine where the component parts of the molecule were relative to the nearby metal surface, and learn a bit about the bonds as well. Surprisingly, the normally flat molecule showed some bending, mostly because of the readiness of some oxygen atoms to unexpectedly bind to surface silver atoms. Another discovery was that the molecule forms two types of bonds with the surface. (A. Hauschild et al., *Phys. Rev. Lett.* **94**, 036106, 2005.) —PFS

Stalactites have geometry as destiny. Scientists at the University of Arizona brought together ideas and techniques from physics, chemistry, and geophysics to derive a mathematical theory that explains the morphology of cave stalactites (the carrot-like formations hanging down from cave roofs). With an understanding of the growth of speleothems—the collective name for limestone cave formations—weather features from thousands of years ago could be deciphered from the layering in these underground repositories, much as tree rings or ice core samples contain clues to past climate. Stalactites are composed of calcium carbonate precipitated from water entering the cave after percolating through carbon dioxide–rich soil and rock. Treating stalactite growth as a free-boundary problem (meaning that no a priori assumptions about shape were made), the researchers linked the fluid dynamics and chemistry to determine a precipitative growth rate, which in turn led to the discovery of a universal geometrical shape. A quantitative comparison with real stalactites (see photo) in Arizona's Kartchner Caverns showed very good agreement except at the tips, where the model no longer applies because drop formation and detachment are not included. (M. B. Short et al., *Phys. Rev. Lett.* **94**, 018501, 2005.) —PFS

An "orbital glass" of electron clouds can appear at low temperatures. In the modern picture of quantum mechanics, electron orbitals—which have various shapes including spheres and dumbbells—are thought of as clouds and represent the general region within which one may find an electron at any given time. A typical electronic transition, say between the degenerate states of a vertically oriented dumbbell and a horizontal one, occurs in femtoseconds. Now, scientists from Germany and Moldova have found evidence that these and other orbital processes can slow dramatically—by up to 14 orders of magnitude—for electrons in low-temperature, single-crystal $FeCr_2S_4$, a mineral with a relatively simple crystalline structure. The researchers found evidence that these frozen electron orbitals have glassy characteristics, including a residual entropy at 0 K, a hump in the crystal's temperature-dependent specific heat, and broadened relaxation dynamics. In contrast to conventional glasses, a complete freeze of the electron clouds is precluded by quantum-mechanical tunneling: The clouds keep making transitions between different low-energy configurations without requiring thermal energy input. (R. Fichtl et al., *Phys. Rev. Lett.* **94**, 027601, 2005.) —BPS ■

© 2005 American Institute of Physics, S-0031-9228-0503-310-7