

PHYSICS UPDATE

► MAGNETIC RESONANCE FORCE MICROSCOPY

(MRFM) is inching toward detecting the spin of a single electron, which will be a major milestone. Using a highly sensitive cantilever 230 μm long and a mere 55 nm thick, an IBM-Stanford team of physicists led by Daniel Rugar has now detected a force of six attonewtons (6×10^{-18} N), which should easily detect the expected force due to a single electron spin, about 80×10^{-18} N. The force due to a nuclear spin is three orders of magnitude weaker yet. The team's result was reported at the March meeting of the American Physical Society in Kansas City, Missouri. The ultimate goal of this nascent technology is to locate and chemically identify individual nuclear spins with 0.1 nm spatial resolution and thus generate three-dimensional images of molecular structures without destroying them. The marriage of magnetic resonance imaging (which requires at least 10^{14} nuclei for detection) and atomic force microscopy (which can image only a sample's surface) is being arranged by several groups. The technique uses a nanometer-scale magnetic tip on the cantilever to create an inhomogeneous magnetic field in a sample, causing spins to precess at varying rates. An RF coil is then tuned to resonate with the spins in a particular value of the magnetic field, and a spin in that "resonant slice" is detected by measuring a small oscillating force between the tip and the spin. Three-dimensional images can be formed by scanning the magnetic tip over the sample and varying the RF frequency. The IBM-Stanford group hopes to map the spins of electrons in dispersed defect sites in silicon dioxide. "The biggest villain is noise," said John Sidles of the University of Washington's School of Medicine. Sidles, who originated the concept of MRFM, stressed that many of the most interesting biological structures are unknown on the nanometer scale, and cannot be crystallized for x-ray studies. MRFM could be used to determine the binding sites of the HIV virus, for example. Also at the APS meeting, Chris Hammel represented Los Alamos National Laboratory's collaboration with Michael Roukes of Caltech in applying MRFM to multilayer electronic devices. They hope eventually to map buried structures, such as defects at interfaces between layers. (More information can be found at <http://www.aip.org/physnews/graphics/condensed/1997/mrfm/>) —PFS

► **A ONE-SIZE-FITS-ALL SUBSTRATE** for semiconductors has been demonstrated, potentially allowing researchers to deposit crystals of many previously mismatched materials onto a semiconductor surface. If the lattice spacing of a crystal differs by as little as 1% from that of the surface onto which it is deposited, defects can form that prevent the proper functioning of the material. Yu-Hwa Lo and his colleagues at Cornell University have engineered a "compliant substrate" by bonding a thin (3–10 nm) film of gallium arsenide to a bulk GaAs substrate in such a way that the film's lattice is twisted relative

to the bulk. The resulting lattice structure is more compliant to the lattice of a different crystal grown on its surface than it would be without the twist-bonded film. So far, working with crystal growers at Sandia National Laboratories and at the Materials Directorate of Wright-Patterson Air Force Laboratories, the researchers have successfully deposited crystals of InGaP, GaSb and InSb—the latter two of which had previously been unachievable. Even with lattice mismatches between crystal and surface as high as 15%, the density of defects was reduced by a factor of 10^5 compared to that for regular substrates. Moreover, if gallium nitride (mismatched by 20%) could be deposited onto this surface, the researchers believe that high-quality blue and ultraviolet semiconductor lasers might result. (F. E. Ejeckam *et al.*, *Appl. Phys. Lett.* **70**, 1685, 1997.) —BPS

► EXPLODING ATOM CLUSTERS yield high-energy ions.

Femtosecond lasers can be used to convert electromagnetic energy into kinetic energy with great pyrotechnic effect. For example, they can blow up molecules in a Coulomb explosion, imparting a kinetic energy of up to 100 eV to individual outgoing ions. Aiming femtosecond pulses at a solid can produce ions with keV energies and substantial bulk heating. Now, in the intermediate size range, scientists at the University of London's Imperial College have observed much higher energy ions (up to 1 MeV) flying away from the miniature fireball caused by shooting ultrashort (150 fs), high-intensity (2×10^{16} W/cm²) laser pulses at clusters of more than 100 xenon atoms. The pulse both ionizes the atoms and rapidly heats the free electrons. The resulting charge separation then leads inevitably to very rapid expansion of the ions in this miniplasma. The efficiency of this process is stunning, with up to 90% of the laser energy being transferred to the ions. Very high charge states were observed, with a distribution peaking around 20+ but going up to about 40+. The researchers speculate that, with a gas of deuterium and tritium clusters, tabletop fusion experiments may be possible. (T. Ditmire *et al.*, *Nature* **386**, 54, 1997.) —PFS

► **SINGLE MAGNETIC ATOMS** disrupt superconductivity on an atomic scale. As part of their microscopic study of magnetism, Ali Yazdani and his colleagues at IBM's Almaden Research Center deposited single manganese and gadolinium atoms, each of which has a magnetic moment, onto a niobium surface, which is a superconductor at low temperatures. By measuring the tunneling current that flows from the surface to the probe of a scanning tunneling microscope (STM), the researchers detected a unique change in the superconductor's properties. Nonmagnetic silver atoms had no significant effect. The researchers' model calculation indicates that the STM actually measures the presence of an unpaired electronic state localized around the magnetic atom. (A. Yazdani *et al.*, *Science* **275**, 1767, 1997.) —BPS ■