Electrochemical Process Makes Ultrasmall Si Nanoparticles

Researchers at the University of Illinois—Urbana-Champaign have developed a process for converting bulk silicon into ultrasmall, nano-sized particles. As reported in the April 3 issue of *Applied Physics Letters*, the nanoparticles—which are about 1 nm in diameter and contain about 30 silicon atoms—can be formed into colloids, crystals, films, and collimated beams for applications in the electronics, optoelectronics, and biomedical industries.

To create the nanoparticles, the researchers begin with a silicon wafer, which they pulverize using a combination of chemistry and electricity. "We use an electrochemical treatment that involves gradually immersing the wafer into an etchant bath while applying an electrical current," said Munir Nayfeh, a professor of physics and a researcher at the university's Beckman Institute for Advanced Science and Technology. "This process erodes the surface layer of the material, leaving behind a delicate network of weakly interconnected nanostructures. The silicon wafer is then removed from the etchant and immersed briefly in an ultrasound bath." The main contents of the etchant bath are hydrogen fluoride (HF) and hydrogen peroxide (H_2O_2).

Under the ultrasound treatment, the fragile nanostructure network crumbles into individual particles of different size groups, Nayfeh said. The slightly larger, heavier particles precipitate out, while the ultrasmall particles remain in suspension, where they can be recovered.

"The assembly of ultrasmall silicon nanoparticles on device-quality silicon crystals provides a direct method of integrating silicon superlattices into existing or future down-scaled microelectronics architectures," Nayfeh said. "This could lead to the construction of single-electron transistors and electric charge-based memory devices, optimized to work at high temperature." The nanoparticles also could form the basis for novel semiconductor lasers. Nayfeh and his colleagues have demonstrated stimulated, directed emission from within the walls of a microcrystallite reconstructed from the nanoparticles. The emission was dominated by a deep-blue color.

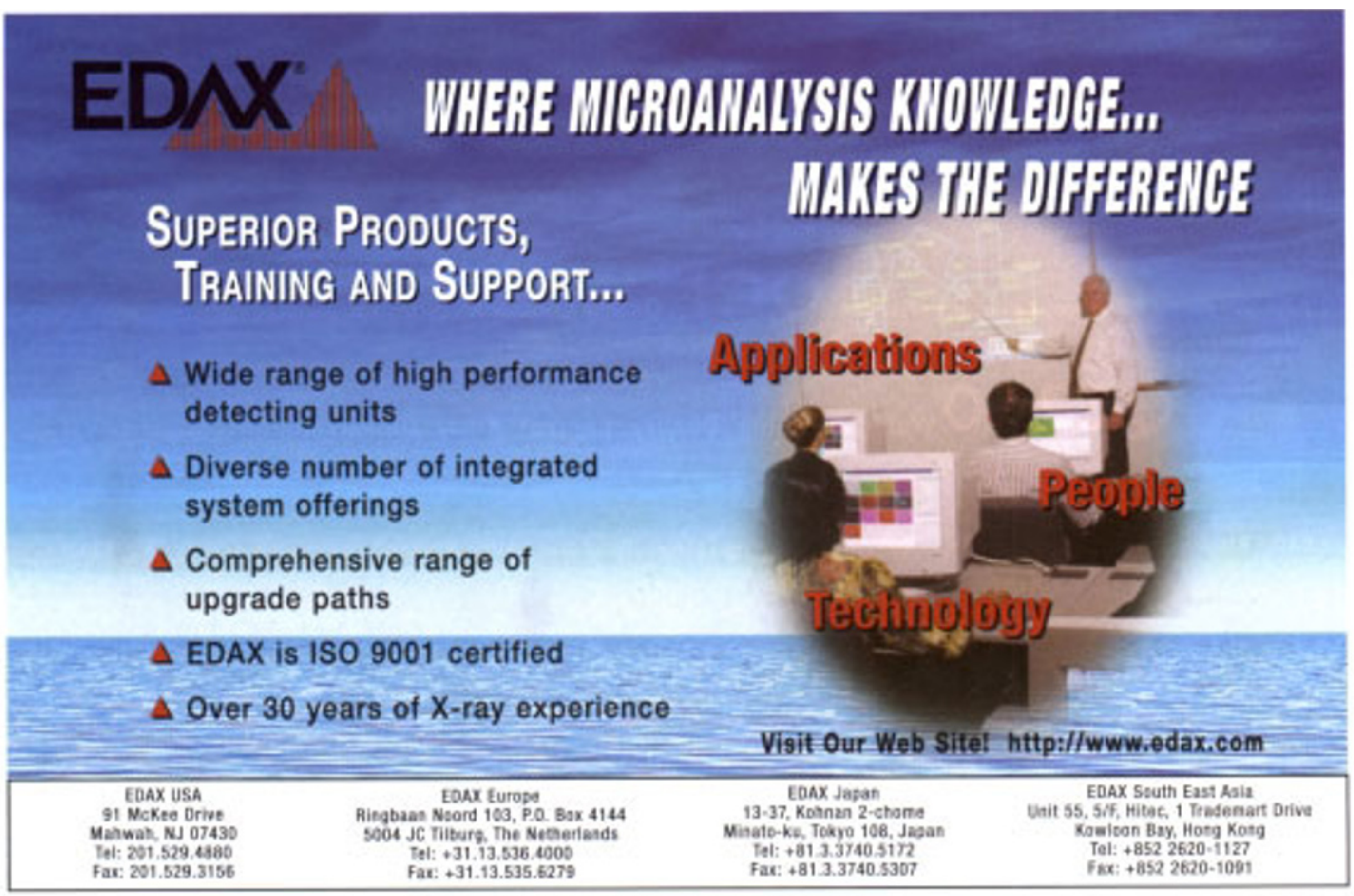
"This type of laser could possibly replace the wires used to communicate between components in a circuit," Nayfeh said. "The blue color might also be useful for underwater communications systems."

The benign nature of silicon also makes the nanoparticles useful as fluorescent markers for tagging biologically sensitive materials. The light from a single nanoparticle can be readily detected.

The researchers report that a patent application has been filed.

"Left-Handed" Composite Materials Respond to Electromagnetic Radiation

Physicists at the University of California—San Diego have produced a class of composite materials called "left-handed" because they reverse many of the physical properties observed in ordinary materials in response to electromagnetic radiation. Lead scientists Sheldon Schultz and David Smith described their findings in March at a meeting of the American Physical Society in Minneapolis. The scientists pro-



duced a composite material from a series of thin copper rings and ordinary copper wire strung parallel to the rings. The composite is among a new class of materials called "metamaterials," so called for the way in which the mixing or arrangement of two or more materials at a very fine level can affect the electromagnetic properties of the resulting composite.

This class of materials has the ability to reverse properties such as the Doppler effect, which is the change in the observed frequency of a wave as the source moves relative to the observer. In ordinary materials, the Doppler effect is manifested as an increase in the frequency of emitted radiation as a source approaches. Maxwell's equations, which describe the relationship between magnetic and electric fields, suggest that microwave radiation or light would show the opposite effect in this new class of materials, shifting to lower frequencies as the source approaches.

Similarly, Maxwell's equations suggest that a lens made of such materials, instead of dispersing electromagnetic radiation, would focus it as it passes through.

Schultz said, "If these effects turn out to be possible at optical frequencies, this material would have the crazy property that a flashlight shining on a slab can focus the light at a point on the other side."

The scientists demonstrated the ability to reverse these properties by beaming microwave radiation through the composite material. Their results verified that the composite had negative electric permittivity and negative magnetic permeability. In most known materials in nature, these qualities are positive.

Steel-Recycling Innovation Includes Aluminum to Control Impurities

When steel producers recycle steel scrap, tin from tin-plate scrap and copper from domestic incinerator scrap accumulate in the steel, posing a major problem for the steel industry unless controlled properly. Such impurities have harmful effects on ductility, causing defects in the worked material. Scientists at Leeds University have discovered that the controlled addition of aluminum to molten steel during recycling forms alloys with the tin and/or copper, rendering both harmless.

The method is simple, cheap, and environmentally friendly. The source of aluminum can be pure metal, an alloy, or a compound capable of dissociation at the operating temperature. However, one source is aluminum cans, currently recycled separately from steel cans. "Why go to the trouble of separating them when they contain the very ingredient we want to add?" said team leader Bob Cochrane. "An obvious extension of our process would be to charge mixed loads of scrap, saving on sorting costs."

The addition of a metal as an alloying agent is a radical departure from conventional treatments, which extract the unwanted metals by chemical or electrochemical methods in de-tinning plants. These methods are expensive and use environmentally unfriendly chemicals. De-tinning plants also have limited capacity, and environmental considerations are increasingly putting constraints on their expansion.

Furthermore, Cochrane said that a com-