Silicon's future shines even brighter

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SCIENCE FEATURE FROM UCSD

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SILICON'S FUTURE SHINES EVEN BRIGHTER

In another display of its uncanny abilities, silicon once again has taken center stage--except this time it has provided its own spotlight.

Long considered "optically dead," silicon now is captivating its most fervent fans with an almost mystical and previously unseen gift to emit visible light.

This illuminating feat, accomplished with acid-etched wafers of porous silicon, has set off an intellectual chain reaction in research laboratories around the world--including UCSD--among those interested in optical electronics and faster, superior computers.

"When someone tells you they made silicon luminesce, it becomes incredibly interesting to a whole range of people in the electronics industry and physics," said Karen L. Kavanagh, associate professor of materials science and engineering with UCSD's Department of Electrical and Computing Engineering (ECE).

"Everybody and his dog is trying to make a device out of this," added Michael Sailor, assistant professor of chemistry.

Recently, Kavanagh and a team of UCSD chemists led by Sailor reported in the journal Science that they had succeeded in teasing light from microscopic particles of silicon suspended in a liquid. The group further announced they had created luminescent plastic film from this suspension.

"This method of preparation opens up a new area of study for luminescent porous silicon and provides great opportunities for exploiting its properties," the researchers said.

Unveiling Silicon's Hidden Talent The fervor began last April when British and French scientists unveiled silicon's "light touch" at an international gathering of the Materials Research Society in Anaheim, Calif.

According to their report, the researchers sculpted pure silicon into a forest of very thin pillars through a simple chemical etching process. When this porous silicon was stimulated with a laser, it emitted an intense orange-yellow glow, a phenomenon never before seen in bulk silicon.

The results sent researchers scurrying back to their labs to try to understand what was happening and to see if the finding could be exploited for a new generation of opto-electric devices. Many groups confirmed the observations, although no one knows for certain what's causing the glow.

Last May, Leigh T. Canham and his colleagues at the Defense Research Agency in Malvern, England theorized that electrons confined in the silicon forest were shedding their energy in the form of light, a manifestation of the world of quantum effects. A Quantum Leap?

For several decades, microelectronic researchers have been investigating a broad range of whisper-thin materials for quantum effects--such as gallium arsenide and gallium phosphide--some of which already being used in satellite microwave receivers, fiber- optic communications systems, and compact disk players.

However, the ability to manufacture quantum wells (merely a few hundreds of atoms thick) already is placing great strains on traditional tools used in semiconductor fabrication. To cut these creations further down to size to quantum wires requires even more sophisticated and expensive technology.

Enter porous silicon. If porous silicon could be used to create cheap and efficient quantum wires, as described by the British and French scientists, the technical and economic future of a new generation of microelectronic devices would be at hand. Companies such as IBM and AT&T already are investing in that possibility.

However, not everyone agrees that silicon's glow results from anything related to quantum effects. At a recent MRS symposium in Boston, researchers from the Max Planck Institute for Solid State Physics offered evidence that surface chemical structures produced during the etching process, called siloxenes, might be responsible for silicon's luminescence. If proven, this theory could cast a large shadow over silicon's new glow.

Silicon Suspension Shines

Following the Anaheim meeting, Kavanagh and Sailor sought to confirm the European results and also find a more convenient method for coaxing light from silicon. Results came swiftly.

"We found that after a couple of weeks we could do it," said Sailor, "and we didn't have to etch it. We could use a slow electrochemical etch." As described in Science, the UCSD researchers prepared porous silicon by letting a hydrogen- fluoride solution electrochemically break away parts of a wafer of pure, semiconductor-grade silicon. This acid-treated wafer was then immersed in a liquid such as toluene or methylene chloride which, in turn was placed in an ultrasonic cleaner for up to two hours. The cleaner's high-frequency sound waves pulverized the wafer to a powder.

The resulting suspension, exposed to ultraviolet light, emitted a visible orange-yellow glow. As visualized by Kavanagh under an electron microscope, the particles appeared to have irregular shapes of varying sizes, while maintaining silicon's crystalline structure.

Subsequently, the scientists added polystyrene to the silicon suspension; the mixture was then placed on a glass slide and allowed to harden into a plastic film. When exposed to ultraviolet light, the film glowed, although to a somewhat lesser degree than the suspension.

Cause and Effect

Today, Kavanagh and Sailor's research is heading in two directions: to determine the cause of the luminescence and to create devices based upon the technology.

To help answer the question of causation, Kavanagh, Sailor and Jan Talbot, assistant professor of chemical engineering in the Department of Applied Mechanics and Engineering, are attempting to separate the silicon particles in the luminescent suspension according to size.

"By separating these particles according to size, we can then test to see if a particular size luminesces," said Kavanagh. "If we can show that the light-emitting quality is size- dependent, then that would convince most people that it is a size effect rather than some surface polymer that grew from the reaction."

To help create electrical devices from silicon's newly discovered light-emitting properties, the researchers have enlisted the help of Peter Asbeck and Harry Wieder, both with the Department of Electrical and Computer Engineering.

Meanwhile, Sailor already is seeking to patent a spinoff device from the research that one day could be used to help detect chemical impurities or toxic substances.

"It's still open to question whether you could get porous silicon to be used commercially in electro-optics," he said. "That's the big emphasis and what the engineers are all excited about.

"If that doesn't work out, all this research hasn't been a waste in my opinion. We have already found other applications for it."

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