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Printable silicon for ultrahigh performance flexible electronic systems

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research news

By carving specks of single crystal silicon from a bulk wafer and casting them onto sheets of plastic, UI scientists have demonstrated a route to ultrahigh performance, mechanically flexible thin-film transistors. The process could enable new applications in consumer electronics – such as inexpensive wall-to-wall displays and intelligent but disposable radio frequency identification tags – and could even be used in applications that require significant computing power.

"Conventional silicon devices are limited by the size of the silicon wafer, which is typically less than 12 inches in diameter," said John Rogers, a professor of materials science and engineering and co-author of a paper that appeared in the June 28 issue of the journal Applied Physics Letters. "Instead of making the wafer bigger and costlier, we want to slice up the wafer and disperse it in such a way that we can then place pieces where we need them on large, low-cost substrates such as flexible plastics."

This approach has important advantages compared with paths for similar devices that use organic molecules for the semiconductor. Single-crystal silicon has extremely good electrical properties (roughly 1,000 times better than known organics) and its reliability and materials properties are well known from decades of research in silicon microelectronics.

To demonstrate the technique, Rogers and his colleagues fabricated single-crystal, microstructured silicon objects from wafers using conventional lithographic patterning and etching processes. The processing sequence generated objects of various shapes as small as 50 nanometers on a side. The researchers then used two approaches for transferring the objects to substrates to create high performance, thin-film transistors.

"In one approach, we used procedures that exploit high-resolution rubber stamps for transfer printing," said co-author Ralph Nuzzo, a professor of chemistry and director of the Frederick Seitz Materials Research Laboratory on the UI campus. "In the other approach, the objects were dispersed in a solvent and then cast using solution-based printing techniques."

Both approaches can be implemented in a manufacturing environment, and would scale nicely to large-area formats, Nuzzo said. Separating the processing of the silicon from the fabrication of other transistor components enables the devices to be integrated with a wide range of material types, including low-cost plastics.

Fabricating circuits by continuous, high-speed printing techniques could offer different capabilities than can be achieved with existing silicon technologies, Rogers said. "We can think in terms of unconventional electronics – putting devices in places where standard silicon chips can't go due to expense or geometry."

Not only could huge, wall-sized displays be built at far less cost, components could be printed on the insides of windshields and other non-flat surfaces. While current fabrication techniques favor flat chips, printing-based methods remove that constraint.

"Another aspect of low-cost electronic printing is embedding information technology into places where it didn't exist before," Nuzzo said. "By inserting electronic intelligence into everyday items, we could exchange information and communicate in exciting new ways."

An example, he said, would be low-cost radio frequency identification tags that could take the place of ordinary product bar codes. Such tags could ease congestion in supermarket checkout lines and help busy homemakers maintain shopping lists.

"You can let your imagination run wild," Nuzzo said. "The functionality of an electronic circuit doesn't have to be wired to a chip – it can be integrated into the architecture itself."

Other co-authors of the paper were visiting scholar Etienne Menard, postdoctoral researcher Dahl-Young Khang and graduate student Keon-Jae Lee. The Defense Advanced Research Projects Agency and the U.S. Department of Energy funded the work. ◆

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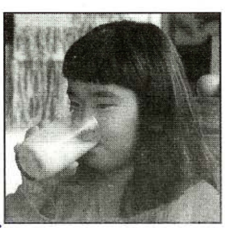

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