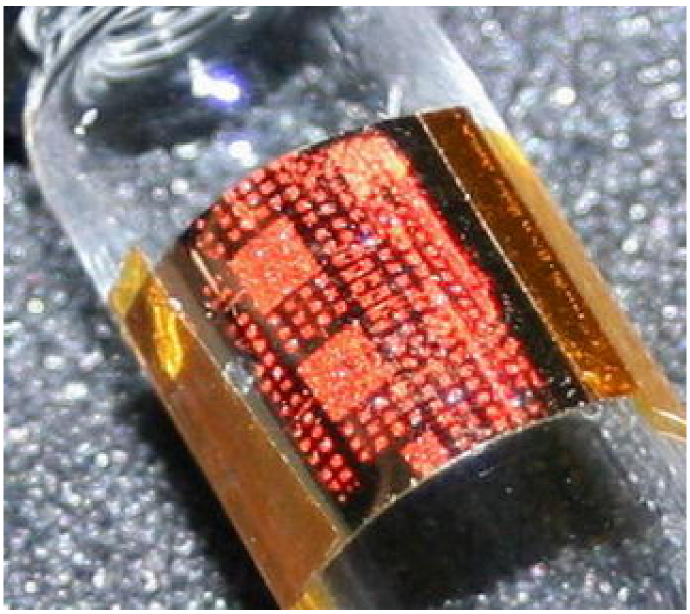
Flexible electronics advance boosts performance, manufacturing

December 13 2006



Flexible organic transistor array. Credit: Stanford University

Flexible electronics made with organic, or carbon-based, transistors could enable technologies such as low-cost sensors on product packaging and "electronic paper" displays as thin and floppy as a placemat. But the best mass-producible organic transistors so far have only milquetoast performance, and products using them have yet to come to market. In a study published in the Dec. 14 issue of the journal *Nature*, researchers at Stanford and the University of California-Los Angeles point the way toward manufacturing truly useful flexible electronics with high-performance organic transistors.

"This work demonstrates for the first time that organic single crystals can be patterned over a large area without the need to laboriously handpick and fabricate transistors one at a time," says Stanford chemical engineering Associate Professor Zhenan Bao.

The study's lead author is Alejandro Briseno, who was a master's student at UCLA performing part of this research at Stanford. He is now a doctoral student at the University of Washington. The study's other authors are Stefan C. B. Mannsfeld, Mang M. Ling, Shuhong Liu, Colin Reese, Mark E. Roberts and Bao at Stanford, and Ricky J. Tseng, Yang Yang and Fred Wudl at UCLA.

Single-crystal organic transistors are fast-engineers say they have a high "charge carrier mobility." This means that when they are "switched on," electrical current can move through the crystal very quickly. Organic thin-film transistors, carbon-based versions of the kind of transistor commonly found in flat panel computer monitors, have only about a third the charge mobility. Researchers have nevertheless favored the thin-film transistors because they could be manufactured en masse, while single-crystal devices always had to be made by manual selection and placing of individual crystals.

Stamping feat

The trick to being able to manufacture-rather than handcraft-large arrays of single-crystal transistors was to devise a method for printing patterns of transistors on surfaces such as silicon wafers and flexible plastic. The first step is to put electrodes on these surfaces wherever a transistor is desired. Then the researchers make a stamp with the desired pattern out of a polymer called polydimethylsiloxane. After coating the stamp with a crystal growth agent called octadecyltriethoxysilane (OTS) and pressing it onto the surface, the researchers can then introduce a vapor of the organic crystal material onto the OTS-patterned surfaces. The vapor will condense and grow semiconducting organic single crystals only where the agent lies. With the crystals bridging the electrodes, transistors are formed.

In the experiments reported in the paper, the team made arrays out of several different crystal materials including rubrene (it makes the fastest transistors) and even "buckyballs," soccer balls made out of 60 carbon atoms each. In some cases, the researchers were able to make simple grid patterns with crystals in areas as small as 8 hundred-millionths of a square inch (49 square microns). Although not nearly as packed as modern silicon processors or memory chips, with up to 13 million crystals per square inch, the team's patterns could still yield richly functioning circuits and high-resolution displays, Bao says.

In other experiments reported in the paper, the researchers showed that the transistor arrays printed on plastic continue to work well even after significant bending, a key finding for anything that will be used in flexible electronics.

Several further advances will be necessary before the team's progress translates into commercial technologies. Among them is controlling how the crystals line up across the electrodes when the crystals form. Another key step will be ensuring better electrical contact between crystals and electrodes.

Still, the results show that organic single-crystal transistors are now feasible for making a variety of useful devices. "Until now, the possibility of fabricating hundreds of [organic single-crystal] devices on a single platform [had] been unheard of and essentially impossible from previous methods," says lead author Briseno. "All of this can now be accomplished on an area the size of a human fingernail."

Source: Stanford University