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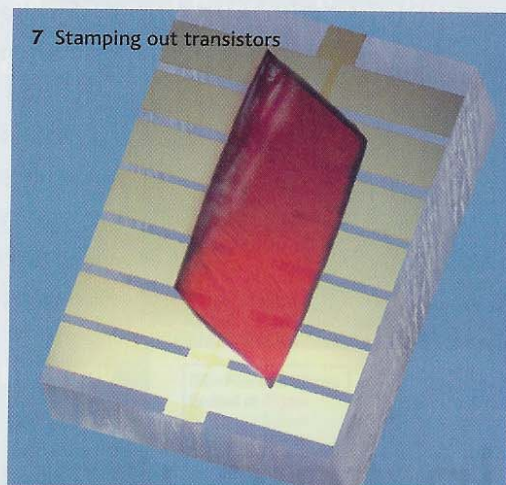
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### Update

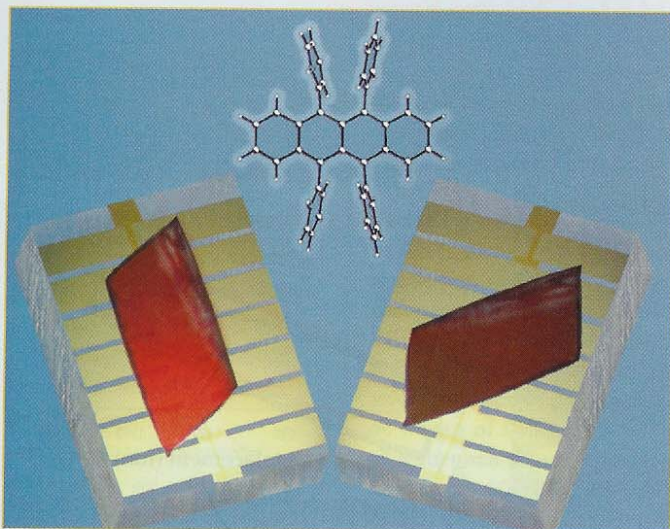
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# Stamping out transistors

ELECTRONIC MATERIALS



Two views of the organic semiconductor on the transistor stamp showing the variation with orientation. (Courtesy of John A. Rogers.)

**Organic transistors fabricated using a stamping technique have surprising properties [Sundar *et al.*, *Science* (2004) 303, 1644].**

The fabrication method used by the researchers from Bell Laboratories, Rutgers University, and the University of Illinois, Urbana-Champaign starts with an elastomeric substrate, made from polydimethylsiloxane (PDMS), which is patterned with the transistor circuitry (source/drain electrodes, gate dielectric, and gate electrode) by photolithography. At room temperature and without applied

pressure, this 'transistor stamp' is brought into contact with an organic single crystal of rubrene. "Van der Waals wetting forces naturally pull these two elements together," explains John A. Rogers of the University of Illinois, "in a manner that is completely nondestructive to the organic and which is completely reversible." The fabrication method avoids many of the problems inherent in processing organic transistors, which are fragile and easily damaged.

The organic transistors produced in this way have the highest mobility recorded to date, of up to  $15 \text{ cm}^2/\text{V}\cdot\text{s}$ , and excellent transistor characteristics. "The mobility we measured in these single-crystal devices was about 50-100 times larger than in thin-film plastic transistors," says Rogers. The results suggest that scattering at grain boundaries has a significant effect on traditional organic transistors. Since the stamp and the crystal are only held together by van der Waals forces, the crystal can be removed and replaced repeatedly. This allowed the researchers to explore the dependence of the device properties on orientation, yielding a surprising result. "We found a huge dependence upon transport direction in the currents that we measured," says Rogers. "This anisotropy was unexpected and indicates that transistor performance depends strongly on how the electrodes are oriented relative to the packing of molecules in the crystal." The anisotropy of the devices indicates that adjusting fabrication processes could create organic transistors with improved performance. Although the fabrication technique was devised to investigate the physics of the organic devices, the same approach might be useful for manufacturing, says Rogers. "We are exploring that possibility," he adds.

Cordelia Sealy

## New avenue to nanoscale architecture

NANOTECHNOLOGY

One of the major challenges to the use of organic molecules as building blocks for nanoscale electronic circuits is their assembly into a predetermined architecture with atomic-scale precision. Researchers from the University of Aarhus, Denmark, CEMES-CNRS, France, and the University of Quebec, Canada have devised a simple template that does just this [Otero *et al.*, *Angew. Chem. Int. Ed.* (2004), in press].

By creating a striped, periodic supergrating using controlled oxidation of a Cu(110) surface at high temperature, individual 'Lander

molecules' can be arranged into well-ordered long chains. The oxidation process (exposing clean Cu(110) surface to  $4\text{-}6 \times 10^{-6}$  Torr of oxygen at 625 K), which creates one-dimensional bare Cu stripes alternating with Cu-O regions, can be varied to control the dimensions of the supergrating. The finest nanopattern achieved by the researchers consists of bare Cu troughs  $2 \pm 0.3$  nm wide separated by  $5 \pm 2$  nm wide Cu-O regions. This is significantly better than the current limits of photolithography, claim the researchers. The template also extends over several hundreds of nanometers.

Lander molecules ( $\text{C}_{90}\text{H}_{92}$ ), which consist of a polyaromatic hydrocarbon central board with four lateral 'spacer legs', only adsorb onto the bare Cu regions of the Cu-O/Cu template. The molecules form well-ordered, one-dimensional molecular chains with the central board aligned along the [1 $\bar{1}$ 0] direction of the template. The template, therefore, not only provides specific adsorption sites, but also controls the orientation of the molecules with respect to the direction of the molecular chain. Longer, 'Violet Lander' molecules ( $\text{C}_{106}\text{H}_{104}$ ) align along the structure.

"This last result is especially important because this geometry is needed to obtain electronic interconnections between molecules in nanoelectronic applications," explains Flemming Besenbacher of the University of Aarhus. Since this approach does not rely on scanning tunneling microscopy manipulations or weak, hydrogen-bond-directed assembly, the molecular structures have enhanced thermal stability up to 350 K. "Our method, thus, opens a new avenue to explore in the quest for the fabrication of suitable nanoscale architectures," he says.

Cordelia Sealy