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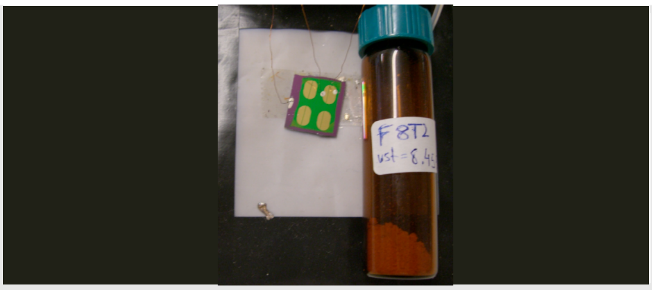
A new trend is emerging to make electronic devices out of cheap plastic materials. Ultralow-cost, lightweight and flexible electronic devices for flexible displays, circuits and memories that can be printed on anything and placed anywhere are appearing in the commercial world at a considerable pace.



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Plastic Circuits

Instead of silicon, organic (or plastic) electronics is based on organic semiconductors. These are either small molecules or polymers. In all cases, their structure is such that electrons/holes can move either between stacked adjacent molecules or along polymer chains.

The advantages of organic materials rely on the easiness of processability and on the possibility of chemical manipulation to attain desired properties. Since organic semiconductors can be made soluble in common solvents, solution processing technologies, such as inkjet or screen printing are being developed. One of the most ambitious approaches for producing low-cost organic electronic devices and systems is reel-to-reel printing. In this process, lithographic patterning and film etching steps are removed from production costs, as well as vacuum deposition steps, if all layers of the circuits are printed. By combining the technology of fully-printed organic circuits with flexible substrate technology, ultra-low costs will be achieved. The main drawback is the low field-effect mobility which is typical of such materials. Mobilities of the order of 1 to 10 $cm^2/V\,s$ are attainable in small molecule highly purified materials, but only values in the range of 0.001 to 0.1 $cm^2/V\,s$ are obtained for polymers.

Applications include radio frequency identification (RFID), thin film transistors (TFT) backplanes for matrix displays, row drivers for displays, indicators, simple displays, sensors, actuators and energy sources, such as printed batteries and photovoltaics.

The target of this research area in our group is to demonstrate the possibility of fully pattern all components of all plastic integrated circuits, namely source, drain and gate contacts, the dielectric and, particularly, the polymer channel.

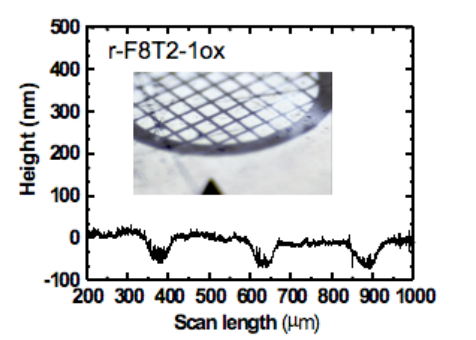

Fig.1. Profile and pattern of a thin film of a cross-linkable polymer obtained with a transmission electron micrsocope (TEM) grid as a shadow mask (thickness: 60 nm). The darkest areas correspond to dips formed by removal of unexposed film upon washing.

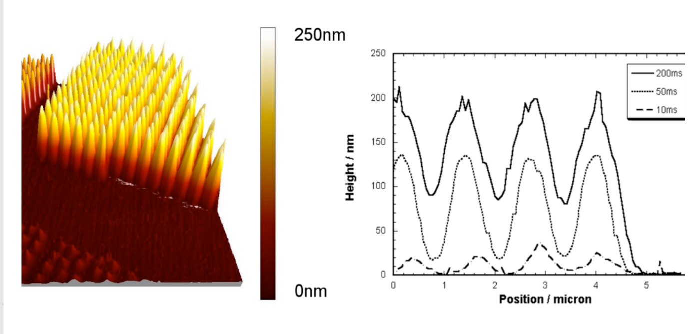

Fig.2. Pattern and height profile of a thin film of a cross-linkable polymer obtained with a scanning near field optic micrsocope (SNOM). These experiments demonstrate th possibility of producing nanometer size patterns for applications such as integrated circuits and photonic structures.

Results

New materials behaving as semiconductors have been designed and synthesized. These include perylene derivatives to be deposited by sublimation, and new p-type cross-linkable polymers which are deposited by spin coating and patterned upon exposure to UV light (turning them into an insoluble form) (Figs.1 and 2) — the scanning near field optical microscope (SNOM) patterning is carried out at the University College London under collaboration with Dr. Franco Cacialli.

FETs based on sublimed thin films of perylene and perylene derivatives usually show n-type behaviour. For instance, in FETs based on the newly prepared PetTCDI-C8H electron field-effect mobilities up to 0.04 cm^2/V s are obtained.

In order to use spin coating followed by a photolithography technique to fabricate discrete FETs and circuits we need to develop materials to form the different parts: semiconducting channel, conducting contacts and dielectric. Under this goal, we have been investigating the use of photocross-linkable semiconducting polymers, such as F8T2Ox1 to form the semiconducting channel. Tested in air FETs based on these crosslinked polymers show p-type behaviour (as observed for the soluble derivative F8T2) though the hole field-effect mobility is around 10^{-4} cm^2/V s, which is an order of magnitude smaller than for similar FETs based on F8T2. Research is in progress to improve this performance and to integrate these materials in simple circuits such as inverters.

References

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