Process & Manufacturing

Umeå Univ.: Organic complementary circuits made easy

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Facile fabrication of organic complementary circuits

Complementary circuitry is often seen as the Holy Grail in the context of electronic circuit design. A complementary circuit is a combination of n- and p-type transistors that offers a number of unique advantages, among which the associated low power-consumption has made this architecture largely predominant in all kinds of microelectronic devices. However, a significant hurdle in the realization of organic complementary circuits stems from the necessity to combine in the same device either two different semiconductors, or two different metal electrodes, or both. Unlike what often stated in the literature, the employment of ambipolar semiconductors does not constitute a viable solution, because it loses the main advantage of complementary circuitry, namely its ability to low power consumption.

A research group at **Umeå University** (Sweden) has recently developed an alternative photoinduced and resist-free patterning method that makes use of a solution processable blend between well-known n-type (PCBM) and a p-type (P3HT) organic semiconductors. After exposure of selected areas of a film of the blend to laser light, PCBM is photochemically transformed into a poorly soluble, high-mobility dimeric state. Thereafter, the film is dipped into a developer solution that selectively removes the non-irradiated PCBM. In the end, the irradiated film areas are n-type because PCBM is the majority component of the blend, while the non-exposed parts are p-type because P3HT is the sole remaining compound. The principle of the method is illustrated in Figure 1.

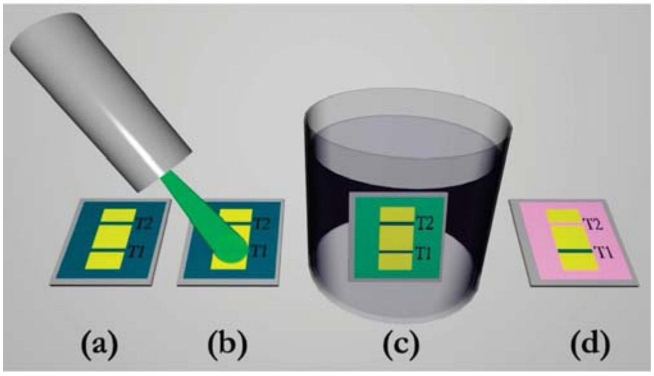

Figure 1: Steps of the technique. (a) Array of two transistors with the initial PCBM:P3HT blend; (b) Transistor T1 is irradiated by a laser; (c) The entire system is dipped into the developer; (d) non-irradiated PCBM is dissolved (transistor T2 and the rest of the system) while the irradiated PCBM remains in the channel of transistor T1.
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The practical interest of the technique was demonstrated by realizing and characterizing a complementary inverter comprising one n-channel and one p-channel transistors (Figure 2).

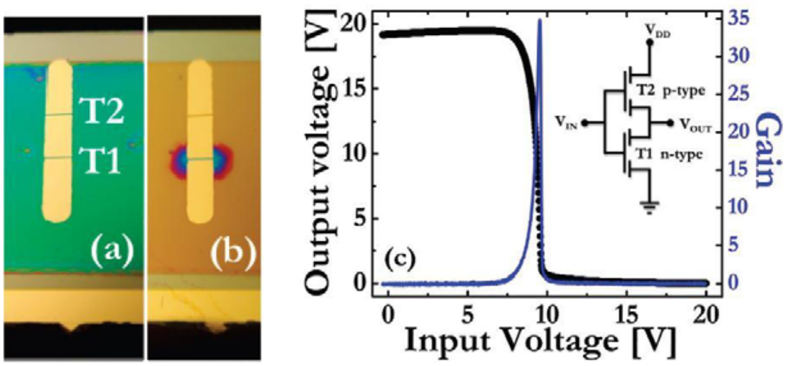

Figure 2: (left) Photographs of the inverter with two transistors T1 and T2 before (a) and after (b) laser irradiation and treatment in the developer. (right) Transfer curve (left) and gain (right) of the complementary inverter.
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The technique significantly simplifies the realization of organic complementary circuits. It only requires the deposition of a single semiconductor element, made of a blend of two organic semiconductors. The blend is converted to either p-type or n-type, depending on whether the film is or is not exposed to laser illumination. A major interest of the technique is that the illumination step can also serve for patterning the circuit.

The technique developed in this work offers a real interest for practical application in the field of printed organic electronics. However, there are a few drawbacks or weak points that would need further development before the technique can be put into application. In particular, all the devices described in the paper were made in a bottom gate configuration on Si/SiO_2 substrates. The extension of the technique to plastic, flexible, substrates will probably pose the problem of solvent compatibility. It is also worth mentioning that the laser-patterning step may induce some reduction of the high throughput authorized by printing fabrication techniques.

"Facile Fabrication of Efficient Organic CMOS Circuits" ; A. Dzwilewski, P. Matyba,, L. Edman: ***Journal of Physycal Chemistry B*** **114**, 135 (2010).