Scientists construct complementary circuits from organic materials

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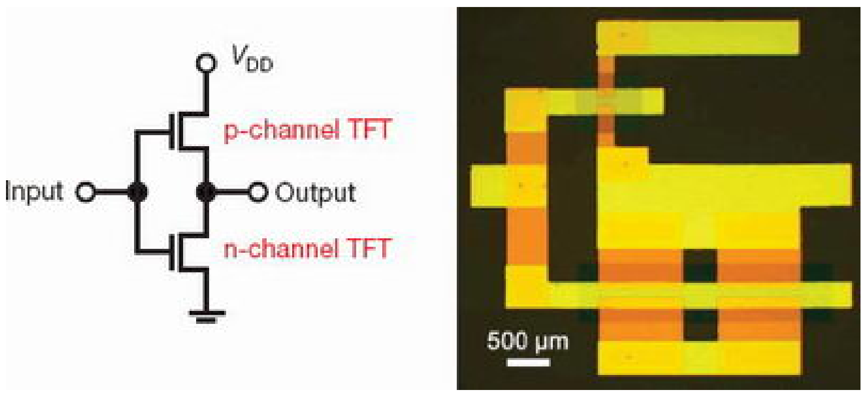

The circuit diagram and the photograph of a complementary inverter made of one p and one n channel thin film transistor (TFT), i.e. a transistor with either a p or n conductive semiconductor layer. A complementary circuit like this saves energy because in each of the two logical states - either high input energy and low output voltage or the contrary - one or other of the two transistors (p or n) blocks the current flow. This energy saving is an important advantage of complementary circuits as compared to unipolar circuits, which consist of only p channel transistors or n channel transistors. Image: Max Planck Institute for Solid State Research

A flat screen that can be rolled up and put into a jacket pocket - organic transistors with low energy consumption could make this possible. Scientists at the Max Planck Institute for Solid State Research in Stuttgart and at the Universities of Stuttgart and Erlangen have constructed complementary circuits from organic transistors characterised by low supply voltages and low consumption values. These energy-saving electronic components consist of two different transistor types.

The new organic electronic components can be operated with significantly lower voltages than previous organic circuits - voltages, such as those supplied by normal household batteries from 1.5 to 3 volts (*Nature*, February 2007).

Transistors made from organic materials have an advantage over normal silicon transistors. They can be constructed on flexible surfaces, such as plastic film, making organic circuits ideal for portable and mobile devices. However, until now, organic transistors have also had a big disadvantage: they consumed too much energy. Scientists have now constructed energy-saving organic circuits.

To this purpose, they make use of two principles: on the one hand, they use self-organising organic monolayers as the insulator for the transistor. Certain organic compounds deposit themselves under specific conditions on a substrate with an active surface. The coating consists of a layer of organic molecules less than 3 nm thick. This monolayer lowers the operating voltage of the transistor as this is directly dependent on the thickness of the insulator. On the other hand, the scientists linked p channel transistors and n channel transistors in complementary circuits. Up to now, organic circuits have mostly been realised in the form of unipolar circuits, which consist of transistors of just one type only (either p channel or n channel). In this kind of unipolar circuit, there is a constant undesirable cross-current, whereas with the complementary construction, one of the two transistors blocks the flow of the current - an opportunity to save energy. According to Dr. Hagen Klauk of the Max Planck Institute for Solid State Research, "Complementary circuits have been standard in silicon technology for 25 years. We believe that organic electronics can also benefit from the advantages of complementary circuit technology. And by combining it with self-organising monolayers, we could lower the supply voltage to that of small batteries."

The scientists thus created organic field effect transistors on a glass substrate. A field effect transistor has three circuit points - gate, source and drain. Irrespective of the voltage at the gate, a current flows from the source to the drain electrode through the charge carrier formed in the semiconductor. The scientists use the air-stable organic compounds: pentacene; and hexadecafluoro copper phthalocyanine. Between the gate and the semi-conductor layer there is an insulator, in this case a very thin self-organising monolayer. Aluminium is used for the gate electrode. Applying aluminium in a defined pattern to the glass substrate makes possible the construction of complementary circuits.

The researchers made different electronic circuits, including complementary inverters, NAND gates and ring oscillators. Of particular importance: the materials used allowed them to make the transistors and circuits at temperatures up to 90 degrees Celsius. A relatively low temperature is necessary for electronic components to allow a change to flexible and transparent plastic substrates. The scientists demonstrated that their method was also suitable for this purpose: they built these transistors on PEN, polyethylene naphthalate. Hagen Klauk explains why that was an advantage: "Silicon transistors need a substrate that is resistant to the high temperatures created in the manufacture of the transistors. In contrast, organic transistors can be created at temperatures less than 100 degrees Celsius - plastics can therefore be used as the substrate. These are flexible and nevertheless robust." Organic complementary circuits can consequently be used everywhere where products need to be simultaneously robust and mobile, for example in a portable, battery-powered flat screen.

Citation: Hagen Klauk, Ute Zschieschang, Jens Pflaum, Marcus Halik, Ultralow-power organic complementary circuits, *Nature*, 15 February 2007

Source: Max Planck Institute for Solid State Research