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Physics and Technology of Organic Transistors with Reduced Dimensions

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Organic thin-film transistors (TFTs) are of interest for applications that require electronic functionality with low or medium complexity distributed over large areas on unconventional substrates, such as flexible polymeric films. Generally these are applications in which the use of silicon devices and circuits is technically or economically not feasible. Examples include flexible displays and large-area sensor arrays. The static and dynamic performance of state-of-the-art organic p-channel transistors is already sufficient for applications in which the transistors operate with frequencies of a few tens of kilohertz.

Most organic TFTs reported to date require relatively large operating voltages, usually about 10 V or more. However, for active-matrix displays based on high-efficiency organic light emitting diodes (OLEDs), TFTs that can be operated with low voltages in the range of 2 to 3 V are required. Strategies to improve the performance of organic TFTs include improvements in the field-effect mobility of the charge carriers in the organic semiconductor layer and more aggressive scaling of the transistor dimensions. Additional advances are also required in the environmental and operational stability of organic TFTs and in the application of controlled contact doping for the reduction of the contact resistance of organic TFTs.

In this talk an overview on existing technologies to fabricate organic TFTs with reduced dimensions is presented, including optical lithography, high-resolution printing techniques and processes assisted by electron-beam lithography. Using shadow masks with a resolution of about 10 µm or stencil masks with a resolutions down to about 1 µm and taking advantage of a recently synthesized high-mobility air-stable organic semiconductor [1], p-channel organic TFTs with excellent air-stability were fabricated. The transistors employ an ultra-thin gate dielectric based on a plasma-grown oxide layer in combination with an organic self-assembled monolayer (gate capacitance ~ 1 $\mu F/cm^2$), allowing the TFTs to operate with low voltages of about 3 V [2]. The gate dielectric has a thickness of about 5 nm and allows the fabrication of organic TFTs with lateral dimensions down to about 100 nm without significant short-channel effects. However, organic transistors with reduced dimensions are often limited by the energy barrier at the interface between the semiconductor and the source/drain contacts. One approach to reduce this energy barrier is the introduction of an organic dopant into the contact area. In addition to area-selective contact doping, the feasibility of organic transistors to operate at 1 MHz is demonstrated.

[1] T. Yamamoto et al., *J. Am. Chem. Soc.* 129, 2224, **2007**
[2] U. Zschieschang et al., Adv. Materials 22, 982, **2010**