Contact Effects in Nanoscale Devices and their effect on Dynamical Properties of Organic Transistors

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Dynamical properties of Organic Field-Effect Transistors (OFETs) are of crucial importance for almost any application. The crucial response time of a device is governed by its material parameters and its device geometry. While material parameters, as e.g. the mobility, are usually extremely difficult to improve by orders of magnitude, downscaling of the channel length has the potential for such a performance boost. In this contribution we will discuss the options, the limits and the difference in comparison to silicon devices.

Down-scaling the channel length L to the micrometer or even sub-micrometer regime allows for enhanced currents, high switching speeds and improved integration density. High-mobility oligo- and polythiophenes are applied as semiconductor, which combine the advantages of highly ordered growth with processibility from solution. Bottom contact devices with optimized parameters exhibit high switching frequencies beyond 2 MHz [1]. However, while the channel resistance drops with the shrinking channel length, the contact resistance remains unchanged and will start to dominate the device behaviour below a critical channel length. Careful and systematic contact design is required in the low channel length regime to obtain the expected improve in performance [2]. Approaches to determine directly the contact properties in sub-micron devices are discussed and the influence of important scaling parameters on the electrical performance of device with shrinking channel length are analyzed [3].

However, not direct AC data but DC measurements are usually used to optimize transistor performance. A systematic study to which extent DC parameters can actually be used to predict AC performance and AC limits of transistors are provided. The standard FET theory for long channel devices predicts a maximum device bandwidth of $\omega_B = \mu V / L^2$. This holds only for ideal situations without parasitic capacitances and not too high frequencies. A direct experimental approach is a frequency scan up to the frequency where the gate current equals the drain current to determine the true bandwidth of the device. The dependence of the bandwidth on the drain-source voltage as well as on the DC gate-source operation voltage is analyzed in detail.

A model for a correction factor to the ideal $\omega_B = \mu V / L^2$ behaviour is proposed to describe the measured bandwidth from measured DC transistor parameters correctly. Main input parameters of the model are parasitic capacitances and the bandwidth limitations by the contact resistance.

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