A Vertical Organic Transistor with Areal Current Densities in the kA/cm^2 Regime

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The field-effect charge carrier mobility of materials used in Organic Field-Effect Transistors (OFETs) has constantly increased in the last years, being now in the range of 10 cm^2/Vs. Such values are typically obtained from OFETs with large channel length, where a parasitic contact resistance plays a minor role. For an application relevant transistor layout, meaning short contact and channel length in the range of some microns, the apparent or effective mobility stays much behind the intrinsic one.

Here, a model for the contact resistance is presented which includes charge injection from the electrodes into a semiconductor layer and the subsequent charge transport of charge carriers within the bulk material of a staggered thin-film transistor [1]. Incorporating the full contact geometry, the nonlinear contact resistance can be determined and be used to show its impact onto the performance of short channel OFETs. Although nonlinear contributions to the contact resistance, most releavant for small device geometries, are rather beneficial for current output and switching speed, the apparent mobility and thus the transistor performance is still far below the optimum.

A way to overcome these issues is to change from mainly lateral charge transport to mainly vertical charge transport [2]. The Organic Permeable Base Transistor (OPBT) is such a vertical organic transistor using three planar electrodes (emitter, base, and collector) stacked in a sandwich geometry as known from organic light-emitting diodes or organic solar cells [3]. These electrodes are separated by thin organic semiconductor layers. The operation mechanism is related to nano-size openings in the base electrode which can control the current flow between the outer two electrode. By using that approach, current densities in the range of 1 kA/cm^2 can be achieved at moderate voltages [4], which is much higher than the current an OFET can drive within the same device area.

References:

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