Student Paper

Near-ideal Subthreshold Behavior in Organic Single Crystal Field-Effect Transistors due to Low Interface and Bulk Trap Densities

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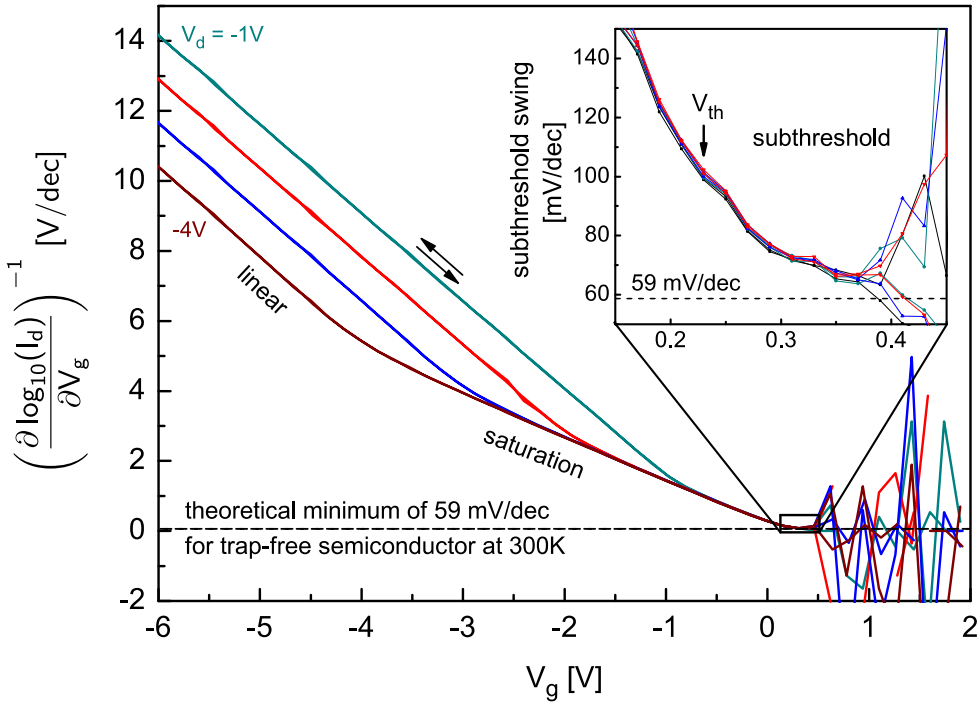
We present measurements of rubrene single crystal field-effect transistors (FETs) with hole mobilities of 14 cm^2/Vs, threshold voltages of 0.23 V and unprecedented low subthreshold swing of 65 mV / decade, very close to the theoretical value of 59 mV / decade at room temperature. A low subthreshold swing is not only desirable for applications, e.g. for low power consumption and fast switching speed, but it is directly associated with a low density of deep trap states in the transport channel. The precise measurement of the subthreshold swing therefore allows us to assess the quality of the semiconducting material and its interface to the gate dielectric.

We show detailed measurements and present an in-depth analysis of the deep trap states around the turn-on voltage by using both, analytical models and full numerical simulations. From this analysis, a very low trap density is derived: 5×10^{12} $cm^{-3}eV^{-1}$, corresponding to $D_{it} = 3\times10^{9}$ $cm^{-2}eV^{-1}$. Such low trap densities indicate that organic single crystals in combination with a proper gate dielectric are on par with the best inorganic semiconductor materials.

We further discuss a method to derive the dominant Fermi energy at the turn-on voltage, which enables us to narrow down the energy range of the traps probed in the subthreshold regime. Accordingly, the extracted traps of very low density were found at ~0.7 eV above the valence conducting level.

These results for the organic FET devices are in close agreement with previously obtained bulk trap densities from space charge limited current measurements. Remarkably, this shows that no additional trap states are formed at the surface when a full FET structure is built, provided a proper dielectric material is employed.



Inverse logarithmic slope of the measured drain current versus gate voltage. The inset shows the subthreshold region: the subthreshold swing approaches a value very close to the theoretical limit of 59 mV/decade.