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TCAD Simulation of OTFT Small-Signal Parameters

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INTRODUCTION

Advances in fabrication techniques have led to organic thin-film transistors (OTFTs), which are increasingly interesting for electronic applications. The associated design of organic circuits results in the need for a solid modeling of device behavior.

Up to now, research has mainly targeted the modeling of static IV characteristics [1][2][3][4]. In the following, we report simulations of OTFT small-signal parameters, which are important for the dynamic performance.

SIMULATION ENVIRONMENT

The work is based on the commercial device simulator ISETCAD that we modified to account for the special nature of organic semiconductors according to Refs. [1][2]. Input variables are the device geometry, material properties, and the nature of the interfaces.

DEVICE LAYOUT

Figure 1 shows the layout of the simulated pentacene OTFT. The device has a channel length of 20 um, a channel width of 100 um, and an oxide thickness of 190 nm. Figure 2 shows the finite element mesh used for the numeric computations.

STATIC OFET CHARACTERISTICS

The simulation of static output and transfer characteristics can be employed to extract valuable knowledge from experimental IV data. By fitting the threshold voltage and the sub threshold region (Figure 3 and Figure 4), one can quantify the properties of fixed charges and traps at the insulator-semiconductor interface [3][4]. Typical values are reported in Ref. [4] with a trap concentration of $N_t = 1 \times 10^{12}$ cm^{-2} at a level 0.15 eV above the valence band. The analysis of penetacene OTFTs fabricated by the group of B. Nickel has led to values of 8×10^{11} cm^{-2} at 0.16 eV (Figure 4). The measured devices have an excellent mobility in the order of $\mu = 2$ cm^2/Vs.

SIMULATION OF AC SMALL-SIGNAL OTFT PARAMETERS

Small-signal parameters are vital for modeling the transient behavior of transistors. We have set up an environment in ISETCAD which is able to simulate these parameters for different OTFT layouts and material combinations.

Figure 5 shows the low-frequency source gate CV characteristic of the pentacene OTFT and illustrates the influence of interface traps and charges. Figure 6 reports the simulated AC small-signal transconductance g_m, the output conductance g_d, and the source gate capacity C_{sg} at a frequency of 2 kHz. By fitting small-signal measurements, it is possible to extract transistor properties such as trap release times, which govern the dynamic device behavior.

CONCLUSION

In conclusion, we have shown that the ISETCAD method allows for an effective simulation of OTFT small-signal parameters. Based on these results, transient simulations of organic inverter circuits and ring oscillators can be performed. We plan to present further results at the conference in May.

ACKNOWLEDGEMENT

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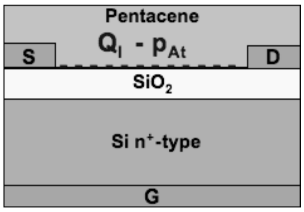

Fig. 1. Layout of simulated pentacene OTFT with channel length of 20 um, width of 100 um, and oxide thickness of 190 nm.

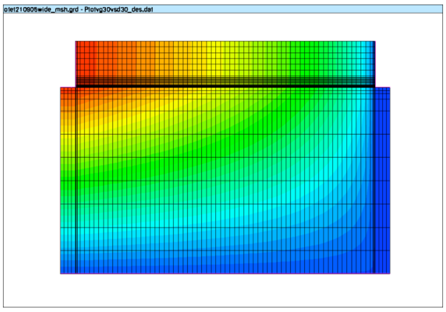

Fig. 2. Numeric mesh and simulated potential for V_g=-30 V and V_{sd}=-30 V.

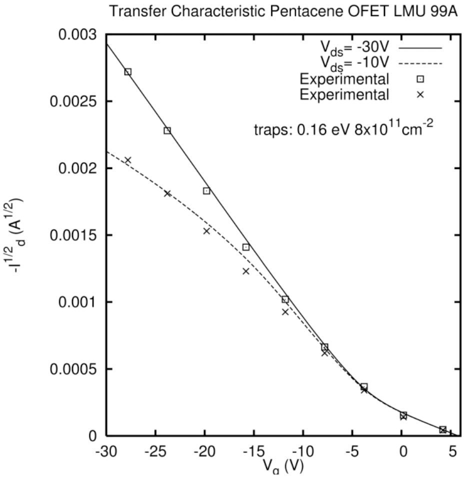

Fig. 3. Simulated and experimental OTFT transfer characteristics with an extracted mobility of $\mu_p = 2.0$ cm^2/Vs.

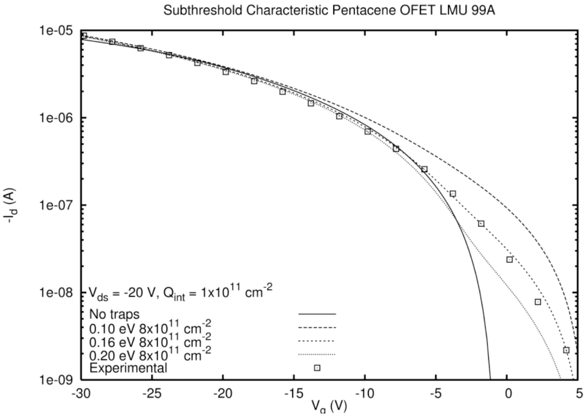

Fig. 4. Extraction of the trap energy by fitting the experimental data with ISETCAD.

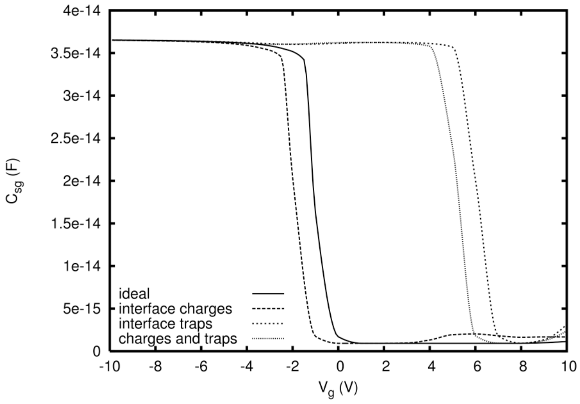

Fig. 5. Simulation of the low-frequency CV characteristics of C_{sg} showing the influence of interface charges (1×10^{11} cm^{-2}) and interface traps (8×10^{11} cm^{-2}, 0.16 eV above valence band).

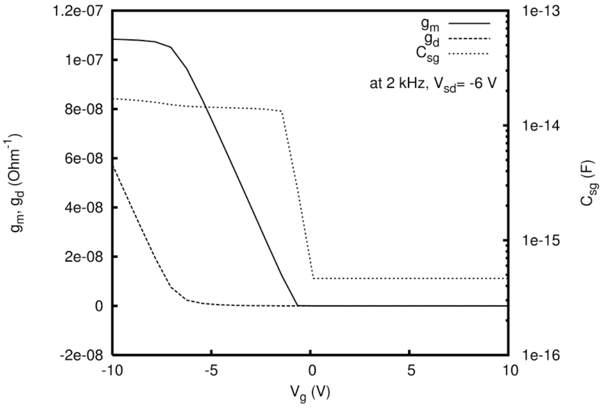

Fig. 6. Simulated AC small-signal parameters g_m, g_d and C_{sg} at 2 kHz and Vsd=-6 V.