Numerical Simulation of Organic Field-Effect-Transistors

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INTRODUCTION

Organic field effect transistors (OFET's) have been gaining attention over the past years for different applications including organic displays and all-polymer integrated circuits. To understand the basic device operation and to optimize the device structure, analytical models [3] or numerical simulations [1], [2], [4], [5] will be used increasingly. In this paper we have been evaluated physical and numerical models regarding the simulation of OFET's. Our simulation results will be compared with other simulations and with measurements.

NUMERICAL MODEL

For the simulations of organic field effect transistors we have used our 2D/3D simulation program SIMBA whereas only the conventional drift-diffusion-model was taken into consideration. The basic equations Poisson equation, continuity equations and the transport equations are solved numerically by using a box method for the discretization [6]. Beneath these equations, some special models for organic semiconductors must be used. The carrier mobility is either assumed to be constant or modeled by the following equation

$$\mu_{p,n}(E,T) = \mu_0 \cdot \exp\left(c \cdot \left(\left(\frac{\sigma}{kT} \right)^2 - 2.25 \right) \cdot \sqrt{E} \right) , \quad (1)$$

where σ means the width of the density of states (DOS) and c is a fitting parameter [4].

SIMULATION RESULTS

Several simulations have been carried out to calculate the behaviour of OFET's. As an example we present some results for a pentacene OFET from [5]. For our simulations we have used constant mobilities. In Figure 1 the schematic view of the device is illustrated. In Figure 2 the simulated output characteristics are shown. They agree very well with the simulation results from the program ATLAS and with measurements from [5]. The calculated hole densitiy at $V_{DS} = -100V$ and $V_{GS} = -40V$ is shown in Figure 3.

Many other simulations have been carried out to test several mobility models and to calculate the influence of material and device parameters. Output characteristics and drain current as a function of doping are shown in Figures 4 and 5.

Simulation results for different Wide/Length ratios (w/L) in comparison with measurements are shown in Figure 6.

CONCLUSION

The simulations have demonstrated that a drift-diffusion model can be used as a first step to describe the behaviour of organic field effect transistors with numerical simulations.

Further investigations must be done, especially to include trap models to get a better accordance with measurements.

REFERENCES

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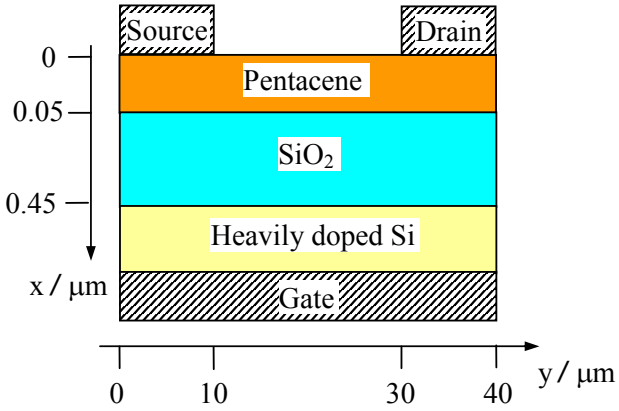

Fig. 1. Schematic view of the device, used for simulations [5], channel wide: 220 µm, doping: $N_A = 2.09 \cdot 10^{17}\,cm^{-3}$.

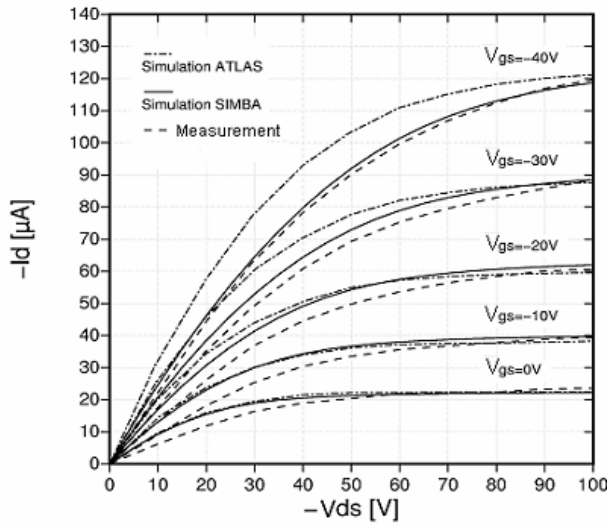

Fig. 2. Measured and simulated output characteristics (with (constant mobility) for the example from [5]

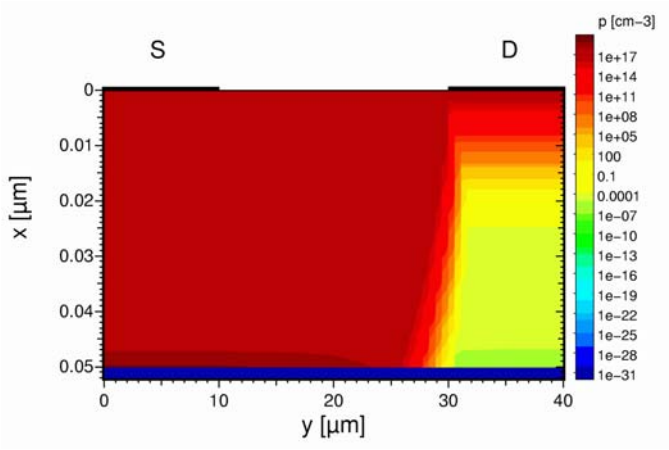

Fig. 3. Simulated hole density at $V_{DS} = -100V$ and $V_{GS} = -40V$

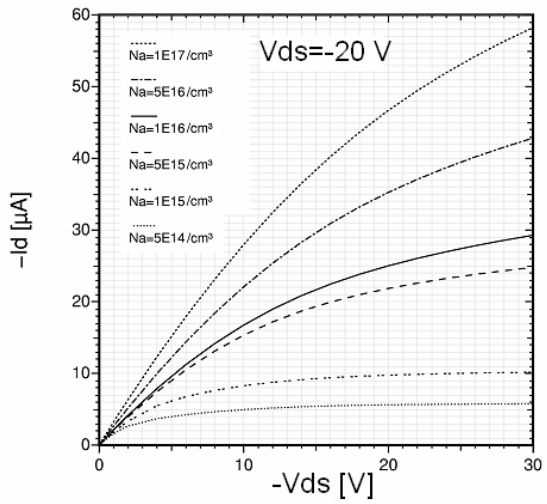

Fig. 4. Simulated output characteristics for different doping density for a P3DDT-OFET

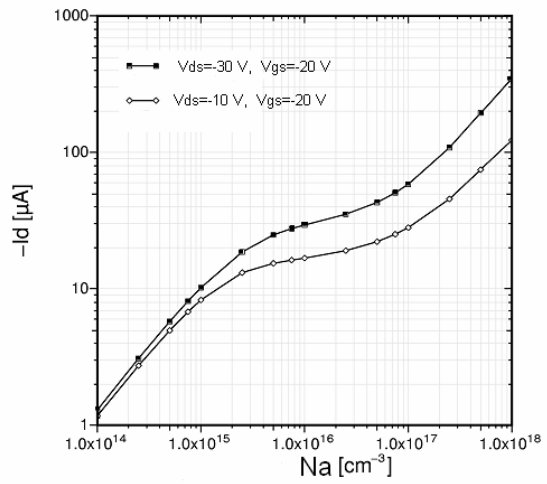

Fig. 5. Simulated drain current as a function of doping density (Na) for a P3DDT-OFET

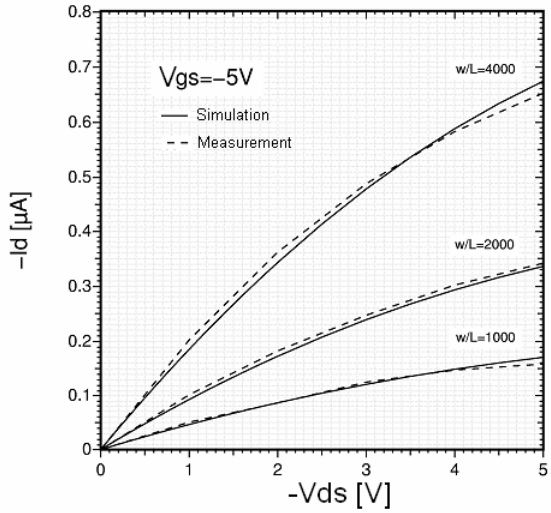

Fig. 6. Simulated output characteristics for diffenrent w/L-ratio and measurements from [1] for a P3HT-OFET