# Experimental Investigation on the Short Channel Effect of Nano-Imprinted Organic Field Effect Transistors

L. Teng [* a)], R. Kirchner [a)], M. Plötner [a)], A. Jahn [a)], A. Türke [a)], J. He [a)], Y. Ge [a)], F. Hagemann [b)], W.-J. Fischer [a)]

*a)Institute of Semiconductors and Microsystems, Technische Universität Dresden, Germany; b)SAW Components GmbH, Dresden, Germany;*

**) lichao.teng@mailbox.tu-dresden.de*

**Keywords:** Nano-imprint, Organic Transistor, Short Channel Effect, Lift-Off

**Introduction:** Organic electronics will come to a more extensive use in the future due to its low cost character. The organic field effect transistor (OFET), as the basic element of electronic systems, should be a low-cost device but still allow high performances. To speed up its switching frequency, short channels are essential owing to the relative limited charge carrier mobility in polymer semiconductors. UV based nanoimprint lithography (UV-NIL) is a cheap lithography solution with excellent resolution. It enables the fabrication of short channels in the submicron or even sub-100 nm regime.

**Fabrication:** The silicon mold with source and drain patters was made by i-line lithography and reactive ion etching (RIE). A commercial NIL tool with accurate optical adjustment system was used to ensure a homogenous residual layer. An indium-tin-oxide (ITO) layer and a $SiO_2$ layer were deposited on glass substrates as gate electrode and gate oxide, respectively. A specially developed UV-curable resist without cross-links after irradiation was applied to accelerate the lift-off process. The residual layer after imprint was removed by $O_2$-RIE. A gold layer was made using electron beam evaporation. After that, lift-off was done in acetone with ultrasound. The finished gold source and drain electrodes with channel length down to 500 nm (Figure1-b) were then spin coated with poly-3-hexyl-thiophene (P3HT) solution. After a short bake in $N_2$, the thin film p-type OFET (Figure 1-c) was ready to be tested.

**Electrical Characterization:** The output characteristic of OFETs (Figure 2) shows an obvious loss of saturation with downscaling channel lengths. This phenomenon was already observed in short channel OFETs[1]. We believe the contact resistance, the P3HT molecule order and the ratio[2] between channel length L and oxide thickness $d_{ox}$ ($L/d_{ox}$) are three responsible mechanisms for this effect. To verify their influences experimentally, we tested OFETs with 1 µm and 2 µm channel length with a self-assembling monolayer (SAM) (Figure 3) and with different oxide thicknesses (Figure 4).

**Results and Conclusions:** From figure 2, 3 and 4 we see remarkable improvements of the saturation ability. Figure 4 already shows a perfect long channel behavior for a 1 µm OFET. It indicates that the short channel effect is not an intrinsic problem for OFETs. A pure Au-P3HT contact, a SAM layer and a corresponding $L/d_{ox}$ ratio improve the saturation ability of short channel OFETs.

---

[1] Michael. D. Austin, Stephen Y. Chou, Appl. Phys. Lett. Volume 81, Number 23, Dec.2002
[2] J. N. Haddock, X. Zhang, S. Zheng, et.al, Organic Electronics 7 (2006) 45-54

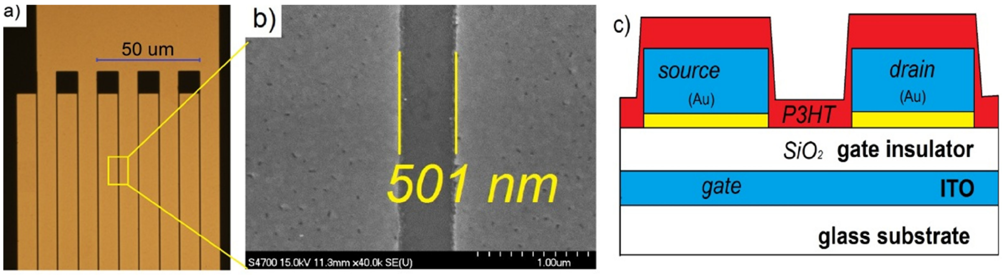


*Figure 1: The OFETs fabricated by UV-NIL:* a)&b) gold source and drain electrodes with distance (channel length L) down to 500 nm; c) bottom gate architecture of thin film OFETs with spin-coated P3HT semiconductor.

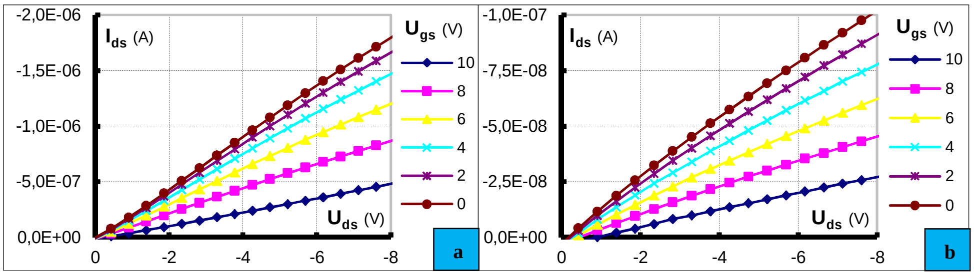


*Figure 2: Output characteristic of P3HT-OFETs with 100 nm thick $SiO_2$ gate insulator:* a) channel=1µm long (L) and 1.3mm wide (W); b) L=2µm, W=0.3mm wide. No saturation was observed due to the short channel effect.

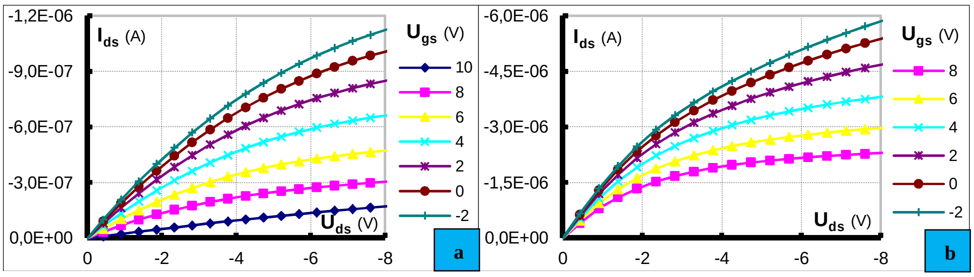


*Figure 3: Output characteristic of P3HT-OFET with a SAM layer on 100 nm thick $SiO_2$ gate insulator*: a) L=1µm, W=1.3mm; b) L=2µm, W=1.3mm. An obvious improvement of the saturation performance is visible.

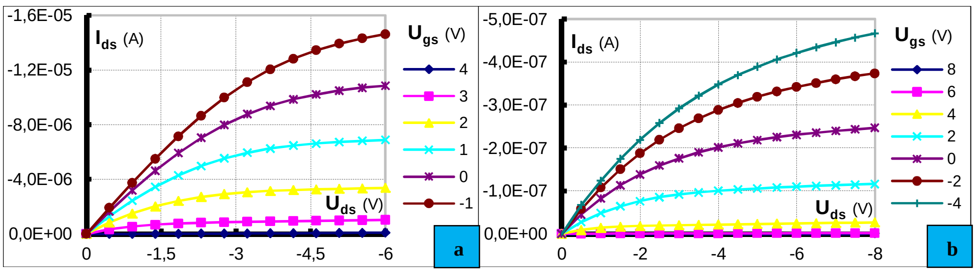


*Figure 4: Output characteristic of P3HT-OFET with 20 nm thick $SiO_2$ gate insulator*: a) L=1µm, W=0.9mm; b) L=2 µm, W=0.25mm. It shows almost a standard FET performance. The short channel effect is avoided.