A study of the electrical transport (current-voltage) characteristics of nanostructured organic semiconductors: DH4T

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Organic field effect transistors (OFETs) have been favoured as key components in molecular electronics which require both mechanical flexibility and ease of fabrication. Parallel lithographic approaches, such as nanoimprint lithography (NIL), have become indispensable as fabrication techniques that can provide low costs, high reproducibility and high resolution. Furthermore, the nanostructuring of materials by NIL has been employed to harness the potential of increased efficiency in organic light emitting diodes. This may be accomplished in two ways: nanostructuring induced by micro and nano-electrode arrays or via direct nanostructing into the material.

In this report, we tackle the key factors which influence field effect mobilities with decreasing channel lengths, such as solvent effects and subsequent device stability issues. The effective mobilities and on/off ratios of OFETs are routinely and successfully gauged via I-V characterization. As such, variations and deviations in I-V curves can be attributed to nanostructure and solvent effects for solution processed OFETs. Field effect transistors, with varying channel lengths, based on solution processed dihexylquaterthiophene (DH4T) and structured by a mix and match approach of NIL, e-beam and photolithography were investigated. Three solutions of DH4T: dichloromethane, tetrahydrofuran (THF) and toluene were investigated. The best I_{ds} - V_{ds} characteristics, field-effect mobility and on-off ratio values were obtained for DH4T-toluene (Figure 1, Table 1). Stability studies clearly demonstrated that the OFETs functioned, and I-V characteristics were reproducible, for up to one week in ambient conditions without encapsulation. Moreover, the field effect mobility and on/off ratio for DH4T OFETs with channel lengths of 100 nm were found to be $\mu_{FE} \approx 2 \times 10^{-5} cm^2\ V^{-1}\ s^{-1}$ and $I_{on}/I_{off} \approx 2 \times 10^2$ respectively.

Solvent	**Toluene** C_7H_8		**Dichloromethane** CH_2Cl_2		**Tetrahydrofuran** C_4H_8O	
Purity	pa	up	pa	up	pa	up
Field-effect mobility μ_{FE}, $cm^2/(V\ s)$	**9×10^{-3}**	**9×10^{-3}**	2×10^{-4}	2×10^{-4}	3×10^{-4}	3×10^{-4}
on-off ratio I_{on}/I_{off}	**$\sim 10^4$**	**$\sim 10^4$**	$\sim 10^1$	$\sim 10^2$	$\sim 10^1$	$\sim 10^2$

Table 1. Parameters of the solution-processed DH4T – based OFETs for the different pure analytical (pa) and ultra pure (up) solvents. Channel dimensions: $W = 1$ mm, $L = 40$ µm.

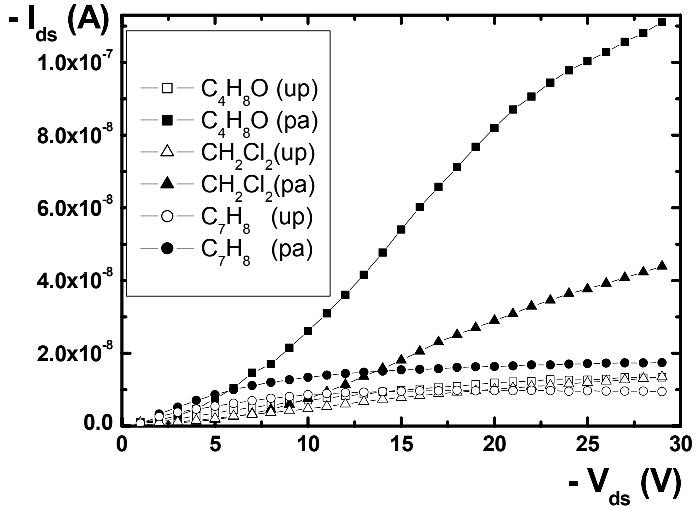

Fig.1. I_{ds} - V_{ds} characteristics of the ultra pure (up) and pure analytical (pa) grade tetrahydrofuran (C_4H_8O), dichlormethane (CH_2Cl_2), and toluene (C_7H_8) – based DH4T OFETs with Ti/Au contacts and L = 40 μm. The measurements have been performed just after OFET preparation at V_{gate}= 0 V.

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