Novel Organic Transistor Concepts for Active-Matrix Backplanes

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Molecular doping has become a key technology for the design of highly efficient organic light emitting diodes (OLEDs) and organic photovoltaic (OPV) (Lüssem et al., Phys. Stat. Sol. (a) 210, 9, 2013). In contrast to OLEDs and OPV, doping is much less commonly used in organic field-effect transistors (OFETs), despite the excellent prospects here as well (Khim et al. Adv. Funct. Mat. 24, 6252, 2014, Lüssem et al., Nat. Commun. 4, 2774, 2013).

There are several reasons that explain the reluctance to include organic doping in OFETs. Most commonly, doped organic layers are prepared by co-evaporation of the matrix and the dopant, which allows for doping ratios in the range of a few wt.%. These relatively large doping concentrations led to low ON/OFF ratios if the channel region is doped. Furthermore, a quantitative model of doping has been missing so far, which slowed down adoption of doping in organic transistors additionally.

In this contribution, we discuss a new process capable of reducing the doping concentration down to a molar ratio of 10^{-5} (Tietze et al., Adv. Funct. Mat., in press, DOI: 10.1002/adfm.20140454, cf. **Fig. 1a**). Experimental UPS data obtained at these low concentrations is used to develop a statistical description, which describes the doping properties for a wide range of host/dopant combinations with very high precision (Tietze et al., Phys. Rev. B 86, 035320, 2012).

Based on this improved understanding, we furthermore discuss novel doped organic transistor concepts. We will show that doping can be used to improve conventional OFETs (Lüssem et al., Nat. Commun. 4, 2774, 2013, Hein et al., Appl. Phys. Lett 104, 013507, 2014), increase the transconductance of novel vertical organic transistors (Fischer et al. Appl. Phys. Lett. 101, 213303, 2012), and design ambipolar FETs (cf **Fig. 1b**). The use of these transistors in active-matrix backplanes is critically discussed and possible driving circuits are proposed that take advantage of the increased performance of doped transistors.

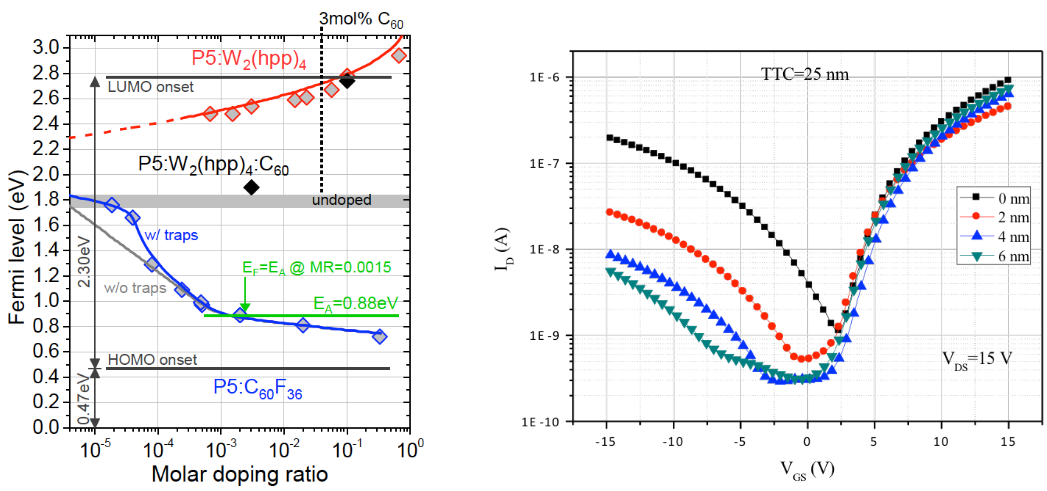

Fig 1: (a) Fermi level of n- (red) and p- (blue) doped pentacene films. The experimental data is shown as symbols, whereas the modeling results are shown by solid lines. (b) Ambipolar transistors based on p- and n-doped pentacene films.