On the determination of the Transport Mechanism in Organic Semiconductors from the Field-Effect Mobility — Gernot Paasch, Nabin Baran Manik, and Thomas Lindner — IFW Dresden

The field-effect mobility is determined by the gate voltage dependence of the drain current for low drain voltage. Based on fitting analytical expressions to the measured dependencies on the gate voltage and on temperature, it has been claimed that there is a one-to-one correspondence to the transport mechanism: Either hopping in a Gaussian distribution of states, or in an exponential distribution (allegedly as an approximation to the transport mechanism: Either hopping in a Gaussian distribution of states other than a Gaussian or an exponential. We present results of the determination of the transport mechanism in organic field-effect transistors (OFETs) fabricated on ITO glass substrates using conjugated polymer/fullerene bulk heterojunction and bilayer concepts will be presented. Measurements in the dark with LiF/Al source and drain top contacts show dominantly n-type transistor behaviour. Under AM1.5 illumination, an increase in drain-source current Ids by five orders of magnitude is observed, whereas Ids becomes independent on the gate voltage. The results suggest that a photodoping effect (creation of a large free carrier concentration) from a photodoping effect (creation of a large free carrier concentration) at the conjugated polymer/fullerene heterojunction (on illumination) is strongly dominating over the gate effect.

On Space Charge Layers in Organic Semiconductors with Gaussian or Exponential Density of States — Susanne Scheiner et al.

Space charge layers (SCL) in MOS structures are decisive for the operation of field effect transistors (FET). For many organic semiconductors, transport takes place as hopping in Gaussian or exponentially distributed states. However, existing theoretical descriptions of SCL suppose a density of states other than a Gaussian or an exponential. We present results of a simulation study for a thin semiconducting layer e.g. on a metal substrate and the MOS structure as the basic module of the FET. From the calculated distributions of concentration, field and potential, and the semiconductor capacitance as a function of the surface potential or an applied gate voltage detailed, conclusions are drawn. Of special importance are: (i) the bulk Fermi energy and hence the flat band voltage depend strongly on the distribution, (ii) for broader distributions the accumulation layer becomes thinner, (iii) this can lead to an apparent contribution to a surface dipole, (iv) the total areal charge, which determines the FET current, is almost the same as that one of a delta shaped distribution if the flat band voltage shift is considered appropriately.

Transport properties of ultra thin thiophene based thin film transistors — T. Muck and V. Wagner — School of Engineering and Science, International University Bremen, Campus Ring 8, D-28759 Bremen, Germany

The aim of this study was to determine the properties of thin organic layers within a field-effect transistor geometry. Transport properties of standard OFETs are known to be crucially influenced by the first monolayer (ML). Deposition of the active material was performed by organic molecular beam deposition in ultra high vacuum. As organic semiconductor various thiophene derivatives, e.g. dihexylquaterthiophene (DH4T) were analyzed. These DH4T films were prepared at elevated temperatures (90 °C) to achieve a growth in the smectic phase of DH4T. Electrical measurements were performed on these growing liquid crystal films. By characterizing the organic transistors at different film thicknesses, the field-effect mobility and the charge transport properties were investigated. Charge transport starts at approx. 0.6 ML and the field-effect mobility shows a quadratic increase for increasing coverage due to percolation of DH4T monolayers. Saturation is observed while completing the first ML. We interpret this behavior with the growth mode of DH4T analyzed by AFM imaging and compare this with Monte-Carlo simulations. The deposition of the second monolayer influences the mobility first by worsening due to non-percolated islands and a subsequent improvement while closing the second monolayer. Additional monolayers do not increase the performance. These data allow the determination of the transport layer thickness, which is given mainly by the first two monolayers.


When downscaling the channel length of organic thin-film transistors (OTTFTs), the conductance is increasingly governed by the electrical contact resistance. We verified this behaviour for DH4T-based bottom-contact OTFTs with different contact metals (Au/Ti, Pt). The electrical behaviour of the Au contacts was hampered by the Ti adhesion layer, while the Pt contacts, although electrically superior, suffered from insufficient mechanical stability.

We report two alternative strategies to overcome these drawbacks: (i) For Au/Ti, we developed a two-layer resist technique for UV lithography. The resulting undercut guarantees smooth and homogeneous metal contact edges, confirmed by SEM, and an improved Au/DH4T contact. (ii) Sputtered Pt contacts have the necessary adhesion on SiO2 and a good contact to the organic layer. In this context we optimised an e-beam lithography process, resulting in an undercut in the resist combined with a sub-100 nm resolution for large area structures (channel width of several 100 μm). Operating devices were fabricated both by vacuum deposition of DH4T and by spin cast deposition of diluted semiconducting polymers.
Structural properties of thin P3HT/PCBM-films for organic solar cells

We have investigated thin P3HT/PCBM - (poly[3-hexylthiophene 2,5-diyl]/[6,6]-phenyl C61 butyric acid methyl ester) films, which are widely used as an active layer in plastic solar cells. Their structural properties were studied by X-ray diffraction in grazing incidence geometry. The size and the orientation of crystalline P3HT-nanodomains within the films were determined. Contrarily, PCBM crystallites were not detected in thin films. Upon annealing, the P3HT-crystallinity is increased, whereas PCBM crystallites were not found.

With these results the raise of the optical absorption and spectral photocurrent in low photon energy region can be explained. In addition, the efficiency of P3HT/PCBM solar cells is also significantly increased upon annealing.

Ultrafast transient absorption spectroscopy of perylene derivatives

The perylene derivatives N,N’-dimethylperylene-3,4,9,10-dicarboximide (MePTCDI) and 3,4,9,10-perylene-tetracarboxylic dianhydride (PTCDA) are paradigmatic and widely investigated organic semiconductors. Quantitative statements about excitonic relaxation processes require a thorough understanding of the optical transitions involved in time-resolved experiments.

We investigated matrix (SiO2) isolated molecules and thin films of MePTCDI and PTCDA by means of ultrafast pump-probe spectroscopy. A broad femtosecond white-light continuum was used to record high resolution transient absorption spectra between 1.2 eV and 2.7 eV above the lowest excited state energy. Excited state contributions below the onset of linear absorption exhibit two pronounced peaks. The observed peaks in the monomer (around 1 eV and 1.3 eV, respectively) can be clearly correlated to numerical spectra obtained by a highly correlated quantum chemical MRD-CI calculation technique.

Comparative electroabsorption studies on organic semiconductor devices with various interfacial layers

Electroabsorption spectroscopy in reflection geometry was used to probe the electric field induced changes in the transmission of thin organic semiconducting films sandwiched between asymmetric contacts. The photoactive layer of the investigated devices consisted of a soluble polyphenylene vinylene derivative, namely MDMO-PPV, spin cast on ITO coated glass substrates and covered with an Al layer as top electrode. The change in the transmission (ΔT) due to the Stark effect was monitored using a modulation technique at various applied DC voltages (VDC). It is observed, that | ΔT | goes to zero at positive VDC [ITO is +], indicating that the internal electric field is cancelled by the externally applied field.

This VDC was found to change by introducing interfacial layers. When using the same device setups in photovoltaic studies the maximum open circuit voltage (VOC) qualitatively follows the same trend. A possible correlation of the internal electric field with photovoltaic device parameters will be described.