

**COMPARATIVE STUDIES OF THE
INTERNAL ELECTRIC FIELD
PROBED BY ELECTROABSORPTION SPECTROSCOPY
IN BULK HETEROJUNCTION SOLAR CELLS**

Christoph Lungenschmied ^a, Christoph Winder ^a, Markus Scharber ^b, Attila Mozer ^a, Gebhard Matt ^a, Helmut Neugebauer ^a, Niyazi Serdar Sariciftci ^a

a Linz Institute for Organic Solar Cells (LIOS), Johannes Kepler University Linz, Altenbergerstr. 69, 4040 Linz, Austria

b Konarka Austria, Gruberstr. 40-42, 4020 Linz, Austria

Electroabsorption spectroscopy in reflection geometry [1] is used to probe the electric field induced changes in the transmission of thin organic semiconducting films sandwiched between asymmetric contacts. Indium tin oxide (ITO) is used as the higher work function electrode (wired +) and aluminum as the lower work function electrode (wired -). The change in the transmission (ΔT) due to the Stark effect is monitored using a modulation technique at various applied DC biases (V_{DC}). It is observed, that $|\Delta T|$ goes to zero at positive V_{DC} , indicating that the internal electric field (V_{int}) is cancelled by the externally applied field. For the presented study, organic semiconducting films made of poly[2-methoxy-5-(3',7'-dimethyloctyloxy)-1-4-phenylene vinylene] (MDMO-PPV), [6,6]-phenyl C61-butyric acid methyl ester (PCBM) and blends of both materials are used as the active layers of the organic diodes described above. The V_{int} of these systems was determined and compared with other device parameters like the turn-on voltage of current injection and the open circuit voltage under simulated solar illumination. The effect of anodic and cathodic interfacial layers on the internal electric field was studied in detail. To attribute any observed changes in the V_{int} to properties of the interfaces, it is necessary to ensure a homogeneous electric field across the film. MDMO-PPV spin-cast from solution results in films that provide excellent systems for these studies. Capacitance-voltage measurements confirm, that the active material is an intrinsic semiconductor containing a negligibly small concentration of free charge carriers.

A layer of poly(3,4-ethylenedioxythiophene) doped with poly(styrenesulfonate) (PEDOT:PSS), spin cast onto ITO was introduced as an anodic interfacial layer increasing the current through the device, but did not have a pronounced effect on the measured V_{int} of ~ 1.2 V. However, evaporating 0.7 nm LiF as a cathodic interfacial layer prior to depositing Al shifts the V_{int} up to almost 2 V (Fig. 1). The increase in the V_{int} is accompanied by an increase in the electroluminescence, being consistent with a decrease in the barrier to electron injection [2].

The charge transport in these materials occurs through thermally activated

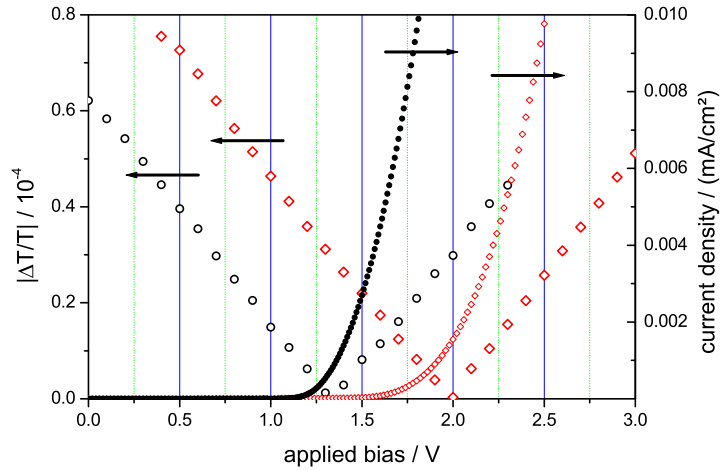


Figure 1: EA response and current density in the active layer of an ITO - MDMO-PPV - Al (circles) compared to an ITO - MDMO-PPV - LiF - Al device (diamonds).

processes. Cooling the sample with liquid nitrogen drastically decreases the charge carrier mobility of the active layer, which was observed by current-voltage and frequency dependent capacitance-voltage measurements. Experiments at room temperature as well as at 77 K are presented to point out the influence of current through the device. Effects related to the presence of charge carriers inside the active layer, including bleaching, light absorption of charge carriers and electroluminescence, can obscure the signal originating from electroabsorption. Using PEDOT:PSS and LiF/Al as electrodes in a setup with an active layer made from PCBM, a V_{int} of ~ 1.1 V is found, being consistent with a recently introduced model, that allows to fit the current-voltage characteristics of diodes of that structure [3]. In a blend of MDMO-PPV with PCBM, the measured V_{int} is lower as compared to the pristine MDMO-PPV. The reduced internal field in the blend as well as the differences between fullerene based and polymer based diodes is consistent with previous observations that a simple metal-insulator-metal (MIM) picture is not directly applicable to these devices.

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