# Short Visit Grant Scientific Report at Linz Institute for Organic Solar Cells (LIOS) under (Organisolar ) Programme

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Derya Ilicali

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# Solid State Dye Sensitized Solar Cells Using M3EH-PPV Polymer

## Objectives:

The conversion of sunlight into electricity is a clean, abundant and renewable energy source. The efficiency of conventional solar cells made from inorganic materials reached up to 24%. [1] Hybrid and photoelectrochemical (dye sensitized) solar cells have been the alternatives for conventional silicon solar cells. A hybrid solar cell consists of a combination of both organic and inorganic materials. [2,3] Organic materials are inexpensive, easily processable and their functionality can be tailored by molecular design and chemical synthesis. On the other hand, inorganic semiconductors can be manufactured as nanoparticles and inorganic semiconductor nanoparticles offer the advantage of having high absorpion coefficients and size tunability.

Dye sensitized solar cells (photoelectrochemical solar cells) are combination of different materials. Although efficiencies of 11% are reported the technological development is still hindered due to the leakage or evaporation of the electrolyte solution. The presence of an electrolyte solution in photoelectrochemical cells makes the manufacturing process difficult. Therefore, recent efforts in dye sensitized solar cell research are more focusing on replacing the electrolyte solution with a solid material to eliminate practical problems with sealing. A solid state cell exhibits a structure similar to the dye sensitized photoelectrochemical cells. P type semiconductor or “quasi solid” counterpart instead of liquid electrolyte are used in solid state DSSC. Polymeric materials as replacement for the electrolyte solution are inexpensive and can be tailored chemically to fit a wide range of technological purposes.

In this study, we fabricated solid state dye sensitized solar cells using $TiO_2$ electrodes and a polymer M3EH-PPV synthesized by Priv. Doz. Dr. Daniel Egbe from LIOS. The compact $TiO_2$ layers were prepared as described in the literature using a titanium tetra isopropoxide precursor at our laboratory Istanbul/Turkey. The solar cells were prepared and characterized in LIOS Austria.

# 1. Description of the work carried out during the visit

## 1.1 General Characterization of a Solar Cell

The current-voltage characteristics of a solar cell in the dark and under illumination are shown in Figure 1. In the dark, there is almost no current flowing, until the contacts start to inject at forward bias for voltages larger than the open circuit voltage. (a) Short-circuit current condition where the maximum generated photocurrent flows (b) Flat band condition where the photogenerated current is balanced to zero. The fourth quadrant (between (a) and (b)) the device generates power. At maximum power point (MPP), the product of current and voltage is the largest.[4]

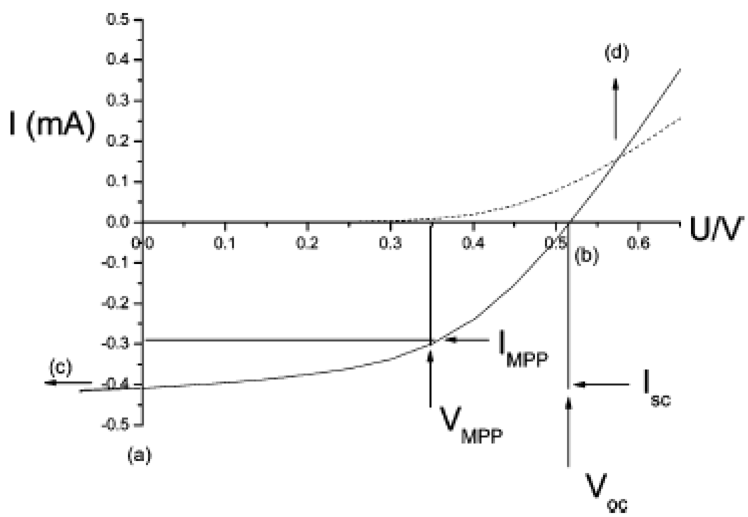



**Figure 1.** Current-voltage characteristics of a solar cell

The photovoltaic power conversion efficiency of a solar cell is determined by the following formula:

$$\eta_e = \frac{V_{oc} * I_{sc} * FF}{P_{in}}$$

$$FF = \frac{I_{mpp} * V_{mpp}}{I_{sc} * V_{oc}}$$

where $V_{oc}$ is the open circuit voltage, $I_{sc}$ is the short circuit current, FF is the fill factor and $P_{in}$ is the incident light power density, which is standardized at 1000 $W/m^2$ for solar cell testing with a spectral intensity distribution matching that of the sun on the earth`s surface at an incident angle of $48.2^0$, which is called the AM 1.5 spectrum.[5] $I_{mpp}$ and $V_{mpp}$ are the current and voltage at the maximum power point in the fourth quadrant of the current-voltage characteristics.

## 2. Experimental

### 2.1 Fabrication and Characterization of Solid State Dye Sensitized Solar Cells Using Polymer (M3EH-PPV)

Solar cells were prepared as following: As substrates, glass sheets of 1.5x 1.5 $cm^2$ covered with ITO, from Merck KG Darmstadt, were used with an ITO thickness of about 120 nm and sheet sheet resistance < 15 $\Omega cm^{-2}$.

The ITO was cleaned by etching with an acid mixture of $HCl_{konz}$:$HNO_{3konz}$:$H_2O$ (4.6:0.4:5) for ~ 30 min. The part of the substrate which forms the contact is covered with a scotch tape preventing the etching. The scotch tape was removed after etching and the substrate was then cleaned by using acetone in an ultrasonic bath and finally with iso-propanol.

The compact $TiO_2$ layers were prepared as described in the literature using a titanium tetra isopropoxide precursor. [6] Compact $TiO_2$ layers were spincast under ambient conditions on top of the cleaned and patterned ITO substrates by using 8000 rpm resulting in approximately 100 nm thick films. After spin coating, the substrates were placed in an oven and sintered at 450 $^oC$ for 30 minutes yielding insoluble compact layers.

Polymer M3EH-PPV was obtained from Priv. Doz. Dr. Daniel Egbe from LIOS. Figure 2 shows the chemical structure of the M3EH-PPV. Blends of this polymer and PCBM was prepared by dissolving 6 mg of M3EH-PPV in chlorobenzene and varying the PCBM amount with 1:1, 1:2, 1:3 and 1:4 ratio and the blend was drop cast on sintered compact $TiO_2$ layers and 120 nm gold was evaporated as top electrodes (see figure 3). As a reference, a cell consisting of only bare

M3EH-PPV with the configuration ITO/$TiO_2$/M3EH-PPV/Au was also prepared in chlorobenzene, concentration was 6mg/ml.

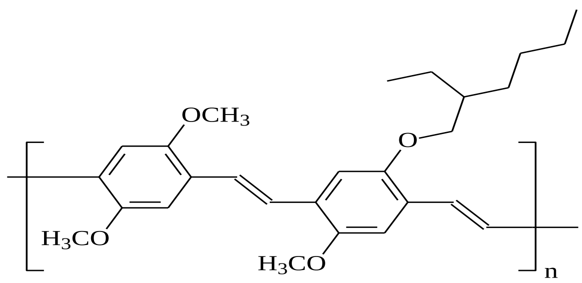



**Figure 2.** Chemical structure of M3EH-PPV.

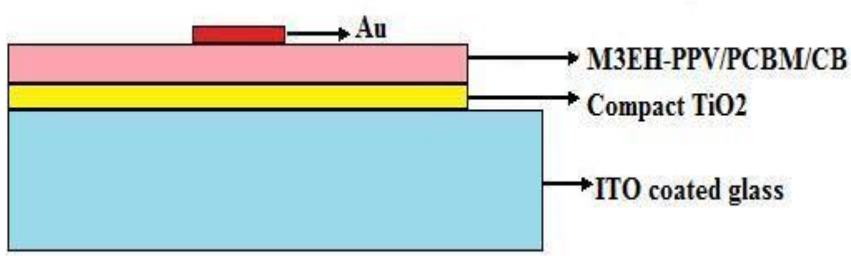
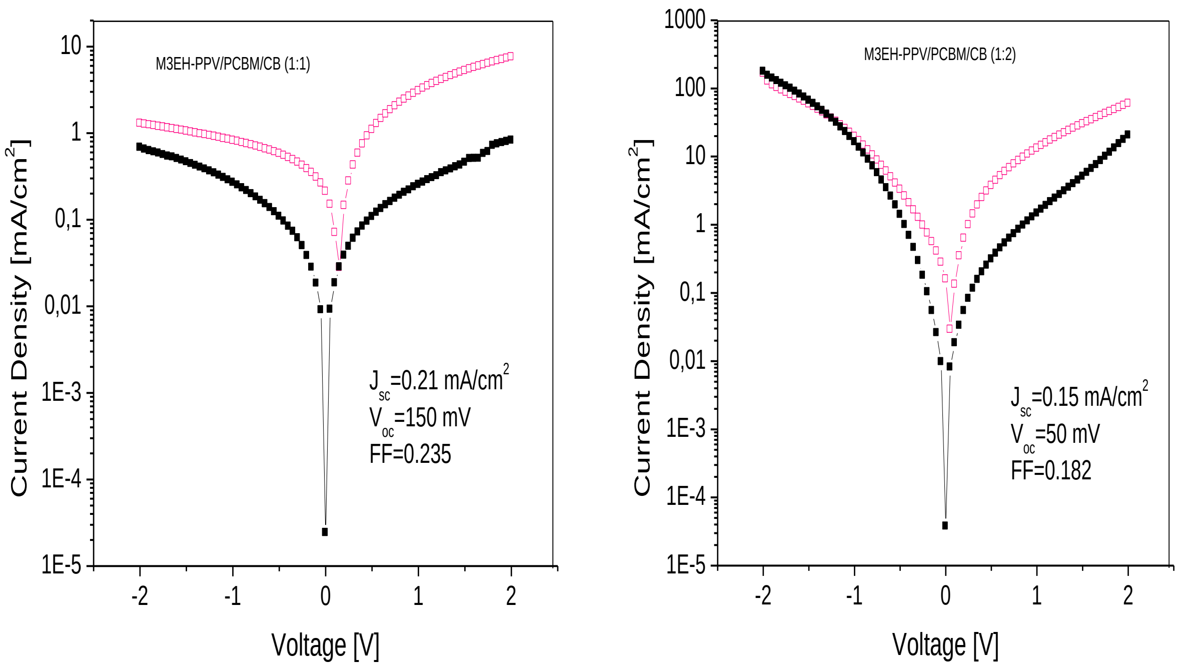



**Figure 3.** Schematic description of the investigated solid state dye sensitized solar cell

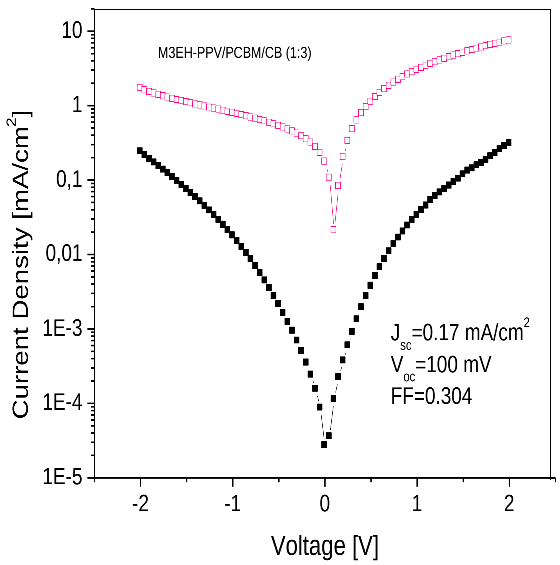
All current–voltage (I–V) characteristics of the PV devices were measured (using a Keithley SMU 236) under nitrogen in a dry glove box immediately after production. A Steuernagel solar simulator, simulating AM1.5 conditions, was used as the excitation source with an input power of 100 $mW/cm^2$ white-light illumination.

### 3. Results of Solid State Dye Sensitized Solar Cells Using Polymer (M3EH-PPV)

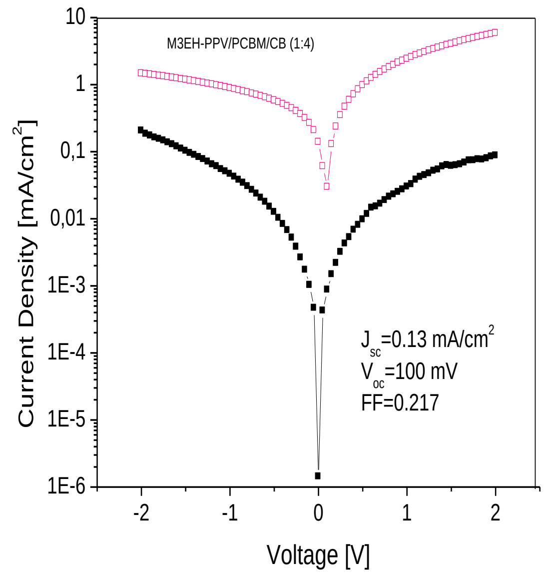
Solar cells were prepared using the above configuration. Figure 4 shows the photovoltaic characterization of the M3EH-PPV/PCBM solar cells with different blend ratios. It was observed that the cells with different PCBM ratios exhibited similar current values. As a reference, a cell consisting of only compact $TiO_2$ and M3EH-PPV with the configuration of ITO/$TiO_2$/M3EH-PPV/Au was prepared. This cell showed an $J_{sc}$ of 0.07 mA/cm$^2$ and a $V_{oc}$ of 1037 mV (see figure 4).



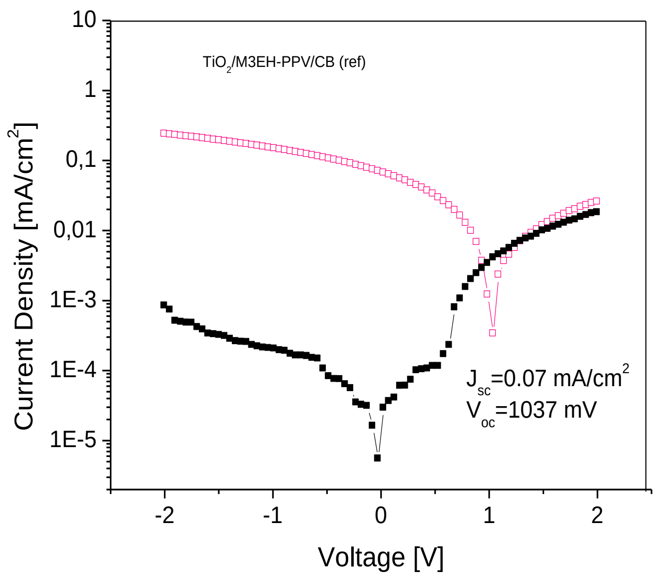

(a) (b)




(c)




(d)




(e)

**Figure 4.** Current-voltage characteristics of $TiO_2$/M3EH-PPV/PCBM solar cells with (a) 1:1 (b) 1:2 (c) 1:3 (d) 1:4 blend ratio, (e) reference cell $TiO_2$/M3EH-PPV

## 4. Description of the Main Results Obtained

We prepared solid state dye sensitized solar cells using a polymer M3EH-PPV which was synthesized by Priv. Doz. Dr. Daniel Egbe and coworkers.

We will continue the collaboration with the host institute. Future collaboration includes photo physical characterization, mobility measurements, morphology characterization and further devices with new materials.

## References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[6] L. Kavan and M. Graetzel, *Elect. Chimi. Acta*, 40, 643, 1995.