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Degradation of bulk heterojunction solar cells operated in an inert gas atmosphere: a systematic study

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Abstract. We present a systematic study on the degradation of polymer / fullerene bulk heterojunction solar cells. Degradation behavior of photovoltaic devices based on poly [2-methoxy, 5-(3',7'-dimethyl-octyloxy)]-p-phenylene vinylene (MDMO-PPV) mixed with the soluble methanofullerene derivative [6,6]-Phenyl C_{61}-butyric acid methyl ester (PCBM) were investigated under inert gas atmosphere in the dark at room temperature, under enhanced temperature and under enhanced temperature together with illumination by white light at 80 mW/cm² light intensity. The influence on the degradation for exchanging the top electrode (Au instead of Al) was also investigated. Photothermal defect localization was performed on sealed polymer / fullerene photovoltaic devices.

Keywords: Organic Solar Cells, PPV and Derivatives, Fullerenes and Derivatives, Degradation, Thermosensorical Defect Localization

1. Introduction

Polymer photovoltaics offer great technological potential as a renewable, alternative source for electrical energy. The demand for inexpensive renewable energy sources is the driving force to new approaches in the production of low cost polymer photovoltaic devices. In the last couple of years, enhanced efforts have been put into the development of solar cells based on organic molecules and conjugated polymers.[1]

Thus far, the efficiency of polymer solar cells under AM1.5 illumination has been increased to > 2.5 % [2], utilizing a soluble poly (phenylene vinylene) derivative as hole conductor and a methanofullerene as electron conductor. Although 2.5 % is a very promising value for an all organic system, one of the deficiencies of these systems is the rather poor stability under atmospheric conditions. The utilization of all organic photovoltaic devices needs at least lifetimes in the order of several thousand working hours for an industrial application.

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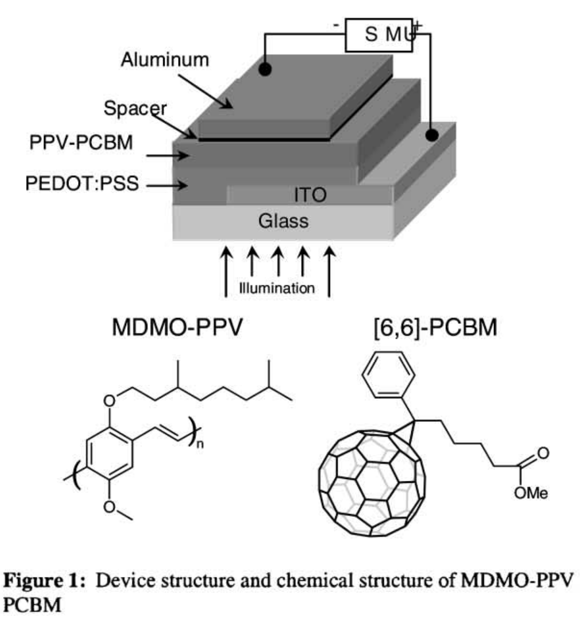

Figure 1: Device structure and chemical structure of MDMO-PPV and PCBM

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In our work we investigate the degradation behaviour of bulk heterojunction polymer / fullerene based photovoltaic devices under inert gas atmosphere to study changes in the behaviour of IV - curves under different thermal and electrical stressing, but always under exclusion from atmospheric oxygen.

Furthermore, thermosensorical defect localization (TDL) allowed to resolve electrically defect mechanisms and reveals film inhomogeneities due to different production technologies. This technique also will allow to monitor IV - curves with a local resolution below 100 μm^2.

2. Experimental

Degradation was measured on the doctor bladed bulk heterojunction MDMO-PPV / PCBM solar cells under dry argon atmosphere inside a glove box system. The device structure and the structures of poly [2-methoxy, 5-(3',7'-dimethyl-octyloxy)]-p-phenylene vinylene (MDMO-PPV) and the solubilized C_{60} derivative [6,6]-Phenyl C_{61}-butyric acid methyl ester (PCBM) are shown in Fig. 1. Current degradation was measured with a Keithley SMU 2400 steadily sweeping IV- curves between –2V and +2V. Illumination (AM1.5 simulated irradiation with 80 mW/cm²) was provided by a Steuernagel solar simulator.

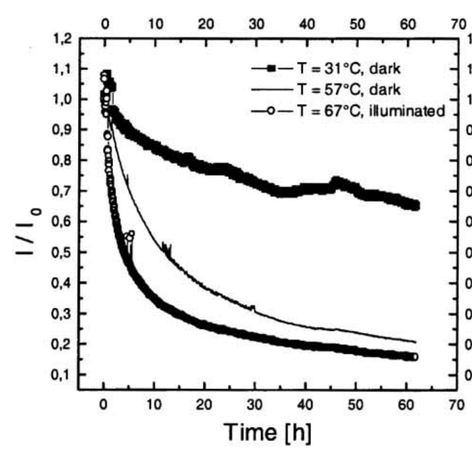

Figure 2: Degradation behaviour of a MDMO-PPV / PCBM solar cell under different conditions

3. Results

Figure 2 shows the degradation behaviour of a standard polymer / fullerene solar cell at + 1V forward bias under different thermal conditions. It is shown that degradation in the dark at room temperature is much slower than under enhanced temperature in inert gas atmosphere. The fastest degradation is observed for the highest temperature under illumination with 80 mW/cm² white light.

TDL, a high resolution lock in thermography combined with a focal plane array (FPA) infrared camera implemented by Thermosensorik GmbH, Germany, allows to detect the temperature resolution of hot spots in a range of 10 μK. Thus defects of sealed plastic solar cells can be monitored under current stressing through a glass sealing. Figure 3 shows an infrared picture from a sealed 6 cm x 6 cm plastic solar cell. With this technique it is possible to monitor inhomogeneities in the current flow of polymer solar cells. Lighter spots indicate an enhanced temperature and detect therefore higher current density flowing through this area, indicating shunts in the bulk active layer of the polymer solar cells.

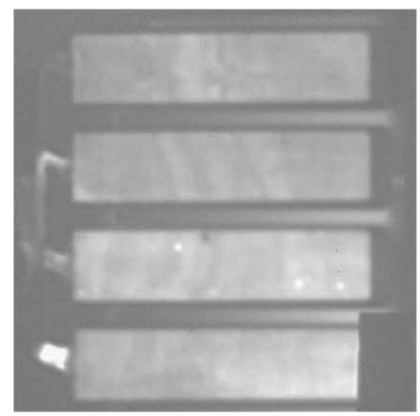

Figure 3: TDL infrared picture of a sealed plastic solar cell

4. Conclusion

Enhanced temperatures accelerate the degradation of MDMO-PPV / PCBM solar cells. Illumination with bright light may even speed up the degradation at high temperatures. Further investigations to identify degradation mechanisms have to be done.

Electrically induced defects can be visualised and investigated by TDL. Furthermore, TDL allows to monitor the quality and homogeneity of photoactive films and to compare different production technologies (i.e. spin casting vs. doctor blading).

5. References

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