

## Stability Studies and Degradation Analysis of Plastic Solar Cell Materials by FTIR Spectroscopy

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### Abstract

Results of controlled degradation experiments performed with the individual components and with the actual mixture used in plastic solar cells are shown. A testing procedure for the stability and for degradation effects under illumination in controlled atmosphere using FTIR-ATR spectroscopy is presented. The method yields rapid information on the degradation processes on molecular level within a few hours.

**Keywords:** Infrared spectroscopy, Semiconducting films, Poly(phenylene vinylene) and derivatives, Fullerenes and derivatives, Solar cells

### 1. Introduction

For practical applications, the stability of plastic solar cells under ambient conditions is one of the most important parameters. In order to obtain fast results during the development stage of new device systems, a quick, reliable testing procedure for the stability and for degradation effects is necessary.

In the present study we show results of controlled degradation experiments performed with the individual components and with the actual mixture used in plastic solar cells [1]. Sample films are prepared by drop casting from solution onto the surface of a ZnSe reflection element and illuminated by laser light in an environmental cell under controlled atmosphere (oxygen or argon). The degradation process is analyzed by Fourier transform infrared (FTIR) spectroscopy using the attenuated total reflection (ATR) technique. Information on degradation effects on molecular level is obtained effectively in a few hours.

### 2. Experimental

The active part in a plastic solar cell consists of a mixture of an electron donor and an electron acceptor. As donor we used poly(2-methoxy-5-(3',7'-dimethyloctyloxy)-1,4-phenylene vinylene (MDMO-PPV) (preparation using a procedure de-

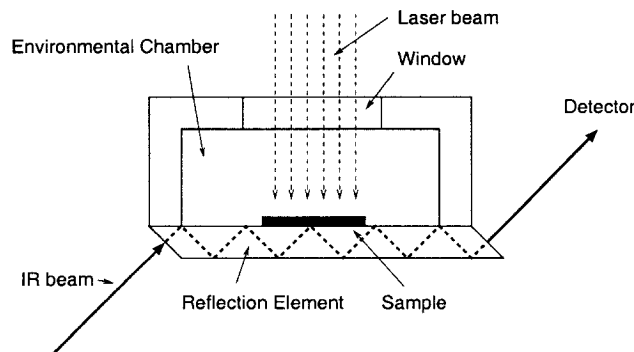
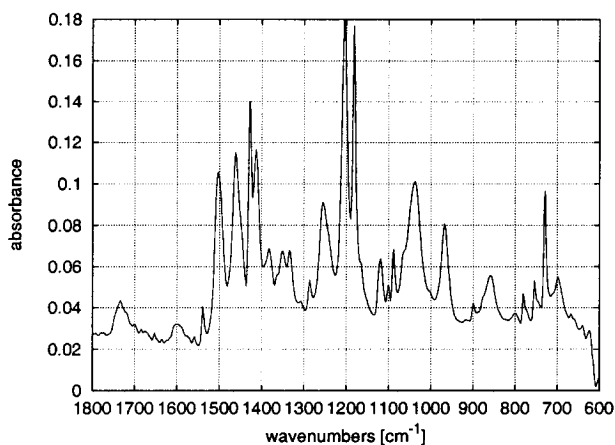
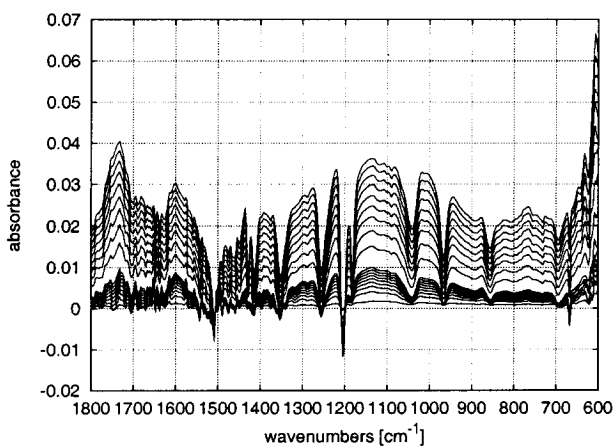


Fig. 1. Setup for the degradation measurements

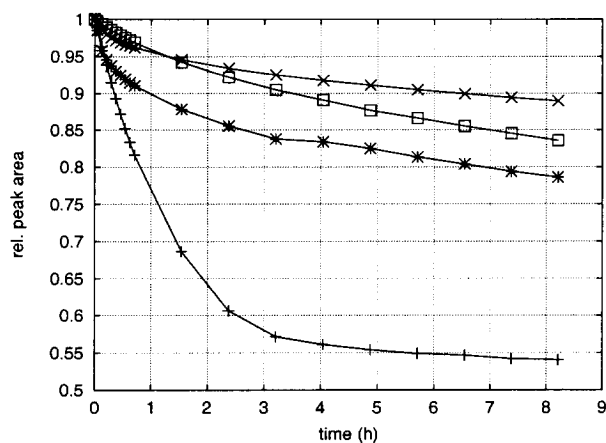
scribed in [2]). As electron acceptor C<sub>60</sub> (MER Corp.) and 1-(3-methoxycarbonyl)-propyl-1-phenyl-(6,6)C<sub>61</sub> (PCBM) [3] were investigated. Films of the sample materials were casted from *o*-dichlorobenzene (Aldrich Corp.) solution onto the surface of a ZnSe reflection element (Harrick Scientific Corp.) and dried under dynamic vacuum for several hours. The reflection element was mounted in a purgeable cell with a glass window (Fig. 1). The cell was flushed with oxygen or argon. The sample was illuminated by laser light from an argon laser (488 nm, 30 mW/cm<sup>2</sup>, Coherent Innova 400). The illumination conditions resemble the part of the solar spectrum which is resonant with the band gap of the polymer. FTIR spectra with a resolution of 4 cm<sup>-1</sup> were recorded consecutively (5 minutes for each spectrum) using a Bruker IFS66S spectrometer with a DTGS detector.

Fig. 2. ATR spectrum of MDMO-PPV/C<sub>60</sub> 1:3Fig. 3. Difference spectra during degradation of MDMO-PPV/C<sub>60</sub> 1:3 in oxygen atmosphere, reference spectrum before degradation

### 3. Results and Discussion

Figure 2 shows the ATR absorption spectrum of a mixture of MDMO-PPV/C<sub>60</sub> 1:3, Fig. 3 the difference spectra during degradation under illumination in oxygen atmosphere. In Fig. 4, the time dependence of specific absorption bands for MDMO-PPV (1506 cm<sup>-1</sup>) and C<sub>60</sub> (1182 cm<sup>-1</sup>) are shown. For comparison, the results of similar experiments with the individual components are displayed in Fig. 4. As can be seen from the time dependence of the single component studies, the degradation in oxygen atmosphere occurs much faster for MDMO-PPV compared to C<sub>60</sub>. With the polymer, a constant value of the band area at 1506 cm<sup>-1</sup> is reached after about 3 hours, whereas C<sub>60</sub> shows a slower decrease of the 1182 cm<sup>-1</sup> band even after 8 hours. Using PCBM, the results are similar.

Within the solar cell mixture, the degradation rate of MDMO-PPV is lower compared to the rate of the pure sample, but still higher than with C<sub>60</sub>. For practical applications, especially the stability of the polymeric part of the mixture has to be improved.

Fig. 4. Time dependence of absorption bands: × C<sub>60</sub> 1182 cm<sup>-1</sup>, + MDMO-PPV 1506 cm<sup>-1</sup>, □ MDMO-PPV/C<sub>60</sub> 1:3 1182 cm<sup>-1</sup>, \* MDMO-PPV/C<sub>60</sub> 1:3 1506 cm<sup>-1</sup>

As degradation products, carbonylic structures can be seen from their absorption bands between 1600 and 1800 cm<sup>-1</sup> [4]. Aromatic (1600 – 1700 cm<sup>-1</sup>) as well as aliphatic C=O groups (above 1700 cm<sup>-1</sup>) with additional weaker absorption around 1000 to 1200 cm<sup>-1</sup> are formed [5].

With argon, no significant degradation is found during the measurement time of about 8 hours. This result emphasizes the importance of protection technologies (by additives and/or by protection layers) to exclude oxygen from the active region of plastic solar cells.

### 4. Acknowledgement

This work is performed within the Christian Doppler Foundation's dedicated Laboratory for Plastic Solar Cells. The work is supported by the "Fonds zur Förderung der wissenschaftlichen Forschung" of Austria, Projects No. P11457-CHE and P-12680-CHE.

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