

Photophysics and Photovoltaic Device Application of Fullerene Containing Phthalocyanine Dyads

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Abstract. The use of conjugated polymers as antenna systems in photovoltaic devices with phthalocyanine-fullerene dyad compounds is described. With luminescence measurements and time resolved transmission changes, energy transfer processes are studied. The influence on photovoltaic device properties is presented.

INTRODUCTION

Photoinduced electron transfer in organic molecules is an intensively investigated process in natural as well as in artificial systems. Dyad systems composed of electron acceptor molecules covalently linked to photoactive donors are candidates to perform photoinduced electron transfer. Due to their outstanding electronic and optical properties, fullerenes as electron accepting units in combination with phthalocyanines as electron donors appear particularly promising for optoelectronic applications. Recently, charge transfer states with lifetime of 3 ns have been reported for phthalocyanine-fullerene dyad compounds in solution [1], as well as long living photoinduced charge separation in the solid state [2,3]. Besides fundamental interest in the nature of the process, charge collection after charge separation may open a possibility to use such electron transfer systems in organic photovoltaic applications. Photovoltaic devices using films of phthalocyanine-fullerene dyads were built and characterized [2,3].

In addition, energy transfer from conjugated polymers may enhance the spectral range of the dyad for the photocurrent, which improves the spectral mapping to the terrestrial solar spectrum. Photophysical studies on these processes are described in the present paper.

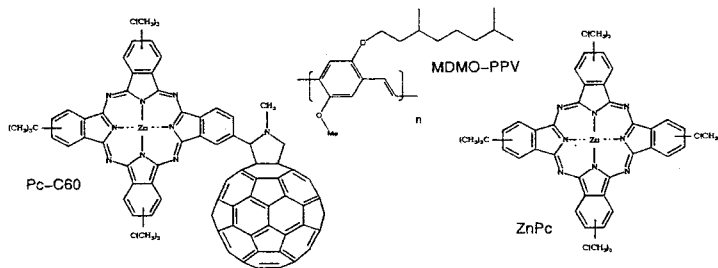


FIGURE 1. Structure of the compounds

EXPERIMENTAL

The synthesis of the dyad, abbreviated as Pc-C60, has been described elsewhere [4]. The structure together with the structure of a model compound ZnPc and the conjugated polymer MDMO-PPV [5] used for energy transfer is shown in Fig. 1.

Thin film samples for optical measurements were prepared by spin coating from toluene solution onto fused silica substrates. Luminescence was measured with excitation at 476 nm. Time resolved spectroscopy has been performed with a sub-10 fs laser system using pump and probe technique. Normalized transient transmission changes ($-\Delta T/T$) were measured by spectrally filtering the probe beam and combining differential detection with lock-in amplification. The setup of the system has been described elsewhere [6]. Photovoltaic device characteristics were measured under illumination intensity of 80 mW/cm² of white light from a solar simulator.

RESULTS AND DISCUSSION

Evidence for energy transfer from MDMO-PPV to phthalocyanine is found from luminescence measurements (Fig. 2). With excitation at 476 nm (where only MDMO-PPV absorbs), the luminescence around 600 nm from MDMO-PPV (left curve) is quenched in a 5% mixture with zinc-phthalocyanine (ZnPc), where only the luminescence of ZnPc around 720 nm is obtained (right curve).

Time resolved transmission changes of the MDMO-PPV:ZnPc mixture are shown in Fig. 3. After excitation of the polymer, the bleaching of the ground state absorption of MDMO-PPV around 500 nm decays within 10 ps, and with the same rate the bleaching of the ground state absorption of ZnPc at 700 nm appears. The inset in Fig. 3 compares time traces of the features at 540 nm and 700 nm for mixtures MDMO-PPV:ZnPc and MDMO-PPV:Pc-C60. The high similarity of the rate constants implies a similar energy transfer process from MDMO-PPV to phthalocyanine in both mixtures.

Utilizing the energy transfer, MDMO-PPV may be used as antenna system for photovoltaic applications of Pc-C60, extending the spectral range by the polymer absorption around 500 nm. Figure 4 shows the IPCE (incident photons converted to electrons)

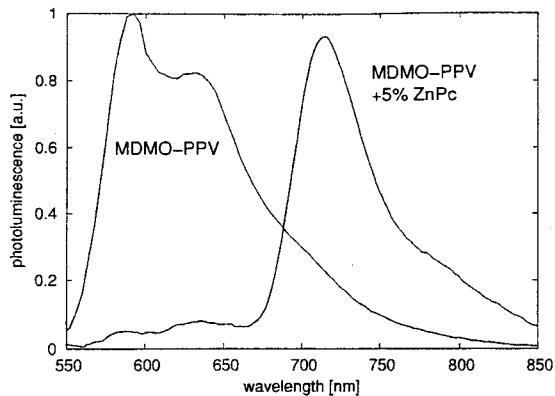


FIGURE 2. Luminescence of MDMO-PPV and of MDMO-PPV + 5% ZnPc, excitation 476 nm

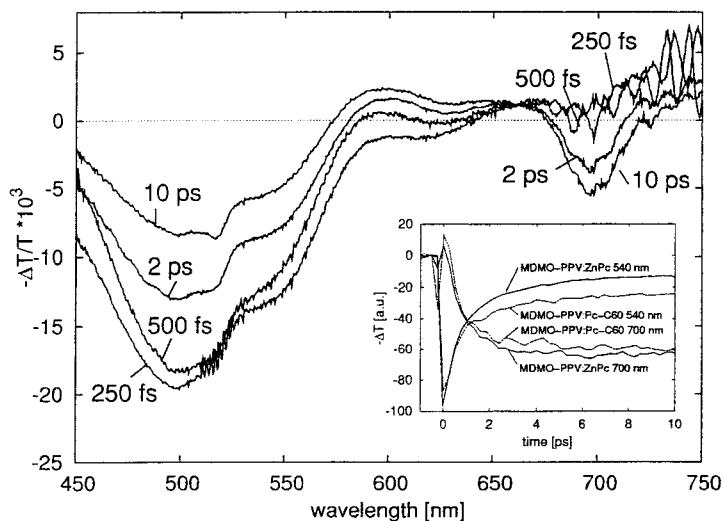


FIGURE 3. Time resolved transmission changes after excitation at 476 nm of MDMO-PPV:ZnPc. Inset: traces at 540 nm and 700 nm for MDMO-PPV:ZnPc and MDMO-PPV:Pc-C60

curves of photovoltaic devices made with Pc-C60 and with a Pc-C60:MDMO-PPV 10:1 mixture. Indeed, the absorption range around 500 nm contributes to the photocurrent. The open circuit voltage with white light illumination is increased to around 0.5 V (inset of Fig. 4). However, the short circuit current in the mixture is lower (reflected also by the lower current in the maxima of the IPCE curve), indicating charge transport problems within the device.

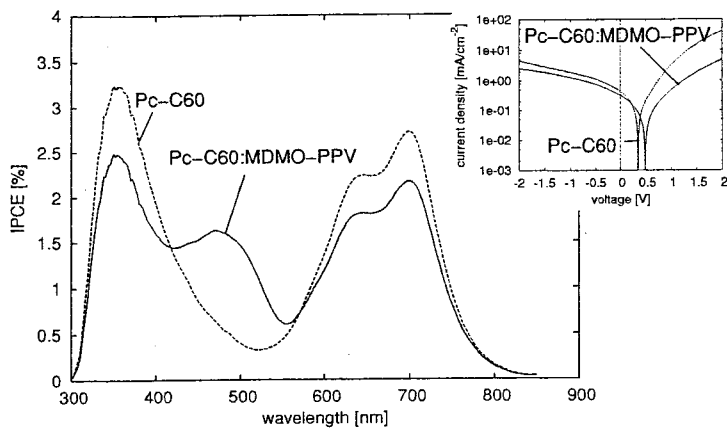


FIGURE 4. IPCE of devices with Pc-C60 and Pc-C60:MDMO-PPV. Inset: I/V characteristics

CONCLUSION

Energy transfer processes from conjugated polymers to phthalocyanine-fullerene dyads have been studied. The extension of the absorption range can be used for a better matching of the photocurrent spectrum to the solar emission spectrum. Devices with MDMO-PPV as antenna system mixed into Pc-C60 dyads show the spectral extension, however with reduction in the obtained current.

ACKNOWLEDGMENT

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