Supramolecular assembling as an approach to efficient small-molecular photovoltaic devices

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Session: Flexible solar cells (ORAL)

Here we report on our efforts in designing novel electron acceptor materials based on derivatives of fullerenes, perylene- and naphthalene bisimides and their application in small molecular organic solar cells.

1. ***Bilayer photovoltaic devices***. We synthesized novel perylene bisimides (Py-PDI) and naphthalene bisimides (Py-NDI) comprising pyridyl groups in their molecular frameworks as well as pyridyl-substituted pyrrolidinofullerenes (PyFs) that form a family of compounds capable of the supramolecular association with such electron donor molecules as zinc phthalocyanine (ZnPc). To evaluate the performance of these new materials we also prepared reference compounds missing any chelating substituents: CyHex-PDI, Bu-PDI and PCBM. All these derivatives were tested as electron acceptor materials in bilayer organic photovoltaic devices where ZnPc served as a donor component. The obtained I-V data and IPCE spectra indicated that the materials possessing chelating Py groups strongly outperform the reference compounds in the photovoltaic devices. This effect was attributed to the complex formation between the Py-containing electron acceptor compounds and ZnPc molecules at the interface. This facilitates strongly the photoinduced charge separation. The complex formation between PyF and ZnPc was proved absorption spectroscopy for the thin films and by fluorescence quenching experiments in solution. Thus, we demonstrated the feasibility of the interface engineering by supramolecular association between small molecular donor and acceptor materials in the photovoltaic devices.

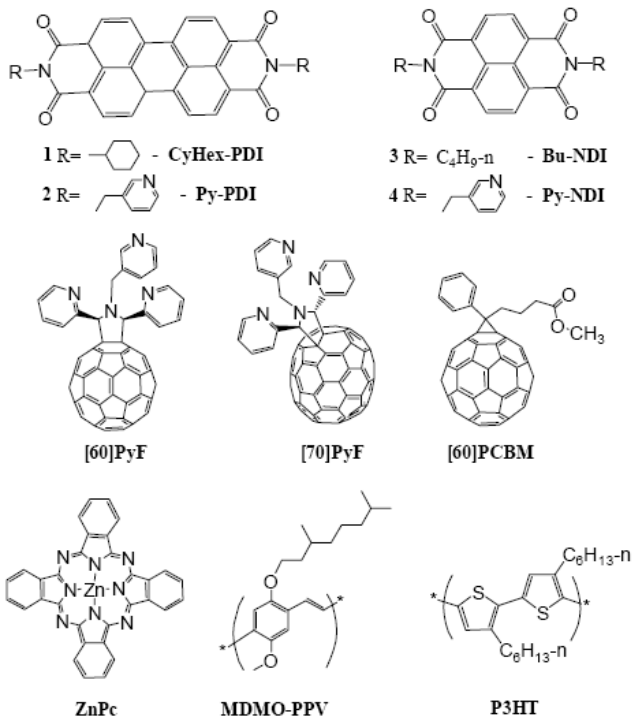

Fig. 1 Molecular structures of the materials

2. *Multicomponent photovoltaic devices.* For better light harvesting in organic solar cells, we suggest the device architecture, called "multicomponent" solar cell. The active layer of these cells comprises a ZnPc layer with a fullerene/polymer bulk heterojunction layer spin-coated on top. The best results were obtained using a mixture of PCBM and PyF as acceptor material; the latter component was shown to form the self-assembled complexes with ZnPc at the interface between the layers that crucially improve the device performance. Reasonably high power conversion efficiencies (2-2.6%) were achieved with two investigated polymer materials: MDMO-PPV and P3HT. The photovoltaic devices demonstrated a wide-range spectral response (350-850 nm) that makes promising their application as organic photodetectors.

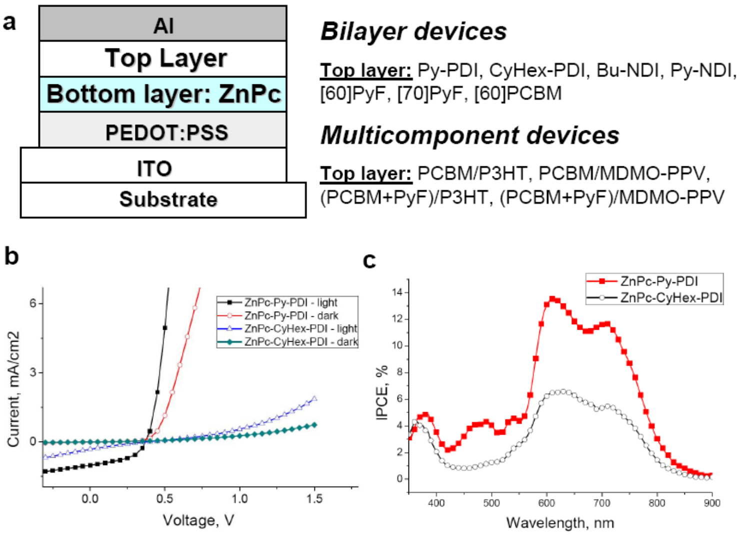

Fig. 2 Schematic layout of the devices (a); the I-V (b) and IPCE data illustrating the superior performance of Py-PDI over CyHex-PDI

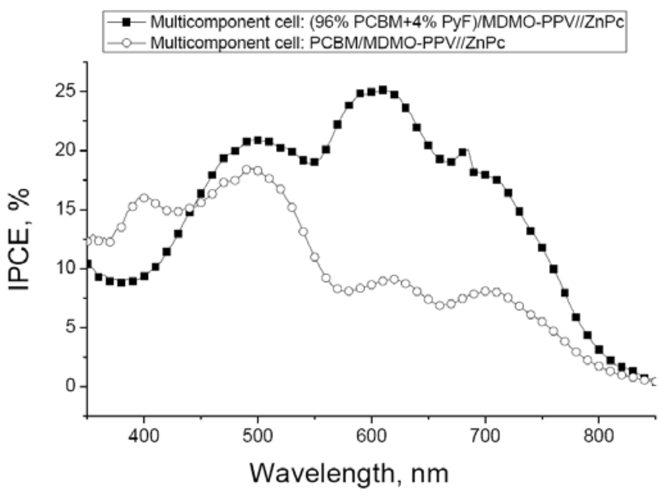

Fig. 3 IPCE spectra demonstrating the effect of the small amount of PyF (4%) added to PCBM (96%) on the photocurrent generation in the multicomponent cells