Concepts and Strategies for Photovoltaic Devices with Fullerenes

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Fullerene derivatives are promising as electron accepting and transporting components in organic optoelectronic devices (e.g. photovoltaic cells) based on a photoinduced charge transfer from a donor type semiconducting conjugated polymer onto these acceptor type molecules. Examples of photovoltaic device architectures, like bilayer devices or bulk heterojunction devices, are described with respect to solar energy conversion. Possible enhancement is discussed by analyzing the parameters contributing to the AM 1.5 efficiency in plastic solar cells, namely, the open circuit voltage (Voc), the short circuit current (Isc), the fill factor (FF) as well as the absorption matching to the solar spectrum.

For the open circuit voltage, it turned out that models successfully describing the situation in pristine conjugated polymer photodiodes, such as the metal-insulator-metal (MIM) or the Schottky junction picture, cannot satisfactorily explain the observed Voc in conjugated polymer/fullerene based bulk-heterojunction solar cells. Instead, the open circuit voltage in plastic solar cells is dependent on the acceptor strength of the fullerenes. The open circuit voltage of this type of cell is related directly to the energy difference between the HOMO level of the donor and the LUMO level of the acceptor components.

The short circuit current is critically dependent on the charge transport properties of the interpenetrating network. There is a strong correlation between the nanostructure of the composite film and the efficiency of of the solar cells. Strategies to improve the nanostructure, like the preparation of so called "double-cable" polymers, where the polymeric electron donor and the electron acceptor are covalently linked, will be described.

Besides problems with the fill factor, which can be improved by optimizing the contact layers, one of the limiting parameters in plastic solar cells is their mismatch to the solar spectrum. Low optical bandgap (Eg smaller than 1.8 eV) conjugated polymers may improve the efficiency of organic photovoltaic devices by increasing the absorption in the visible and near infrared region of the solar spectrum. In another approach, the high absorption around 1.8 eV typical of phthalocyanines together with the strong electron accepting properties of fullerenes makes organic molecular dyad systems, like fulleropyrrolidine-phthalocyanine (Pc-C60), where both structures are covalently linked, interesting materials for photovoltaic applications.