Charge transport in organic photovoltaic devices

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Charge carrier transport mechanisms in organic semiconductors are of great importance since the charge carrier mobility and lifetime are the main parameters governing the device performance and efficiency. Full understanding of charge carrier transport properties in organic electronic devices provides a possibility to learn and develop new organic compounds with required properties through chemical engineering.

The charge carrier transport studies in solution processed devices fabricated from π-conjugated polymers or other organic materials are problematic. Measuring carrier mobility from Space Charge Limited Current in diode configuration from current-voltage characteristic is indirect due to required assumptions and the integral nature of the method. Strongly time-dependent charge carrier mobility imposes a limitation of well know and used in the past Time-of-Flight (TOF) technique. Even though the non-dispersive charge transport has been observed in solution processed polymeric films, the disordered hopping transport usually dominates. Moreover, organic films often demonstrate too high level of thermally generated charge carrier concentration rendering TOF inapplicable. Often the Organic Field Effect Transistor (OFET) structures are used to study the carrier mobility since they operate in steady state. However, much larger, sometimes even a few orders of magnitude, carrier mobility is reported in OFET configuration, which is explained by high carrier concentration in the channel and different properties of DOS distribution at the interface between semiconductor and insulator.

Charge Carrier Extraction by Linearly Increasing Voltage (CELIV) is one a few techniques able to directly measure charge transport and recombination in disordered films.[1] Apart from many advantages the greatest benefit of CELIV is that it allows the relaxation of photogenerated charges to be measured within Density-of-States (DOS) distribution. The method opens up new possibilities to study the charge carrier mobility dependence on time, carrier concentration, electric field, temperature, film thickness and morphology directly in the operational devices. As it has been shown in the past, the film morphology plays a crucial on the device performance. Combining the transport studies with morphology characterizing methods (AFM, TEM, SEM etc.) allows better understanding of underlying photophysical phenomena in the organic electronic devices with a final goal to improve the performance.

We have studied the charge transport and recombination in various well known and novel organic compounds as well as in bulk-heterojunction and solid state dye-sensitized solar cells using CELIV and OFET methods.[2,3] The comparative charge transport analysis will be presented allowing the conclusions to be made about the relation between the carrier mobility/lifetime and the film structure/nanomorphology.

[1] G. Juska et al., PRL 84, 4946, 2000.

[2] A. Pivrikas et al., PRL 94, 176806, 2005.

[3] A. Pivrikas at el., Prog. Photovolt: Res. Appl. 15, 677, 2007.