

Device Physics: OPV

Polymer solar cells are promising alternatives for conventional energy sources. Due to the lower cost of manufacturing, easy processing and flexibility of polymers, solar cells made of organic materials may compete with current inorganic solar cells. The most efficient polymer solar cells to date are based on this bulk-heterojunction architecture. Bulk-heterojunction solar cells use a nanoscopically phase-separated blend of an electron donating and an electron accepting material in the active layer. This leads to donor and acceptor domains separated by a large interfacial area.

Power Conversion Process

The power conversion process in polymer heterojunction solar cells can be described in the following basic steps: Exciton generation, exciton diffusion, charge transfer, charge pair dissociation, and charge transport and collection (see Figure 1).

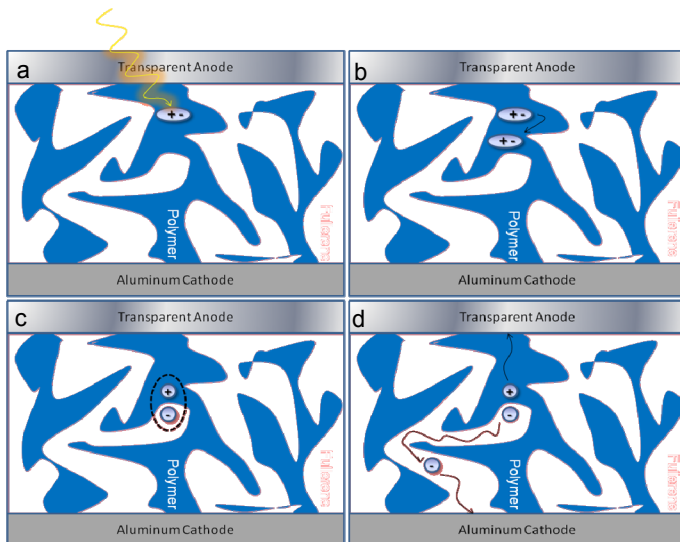


Figure 1 Steps involved in the power conversion process

a) Light Absorption and Exciton Generation

Light is absorbed in the donor material, e.g., a conjugated polymer, and excitons (strongly bound electron-hole pairs) are created on the polymer chain.

b) Exciton Diffusion and Charge Transfer

The electrically neutral excitons diffuse to the interface between donor and acceptor. Excitons dissociate only at energetically favorable acceptor molecules, such as the fullerenes, when the energy gain is larger than the exciton binding energy. At the interface a charge transfer reaction can take place; a hole is left on the polymer and electron on the fullerene.

c) Geminate Charge Pair Dissociation

The hole and the electron are bound together by Coulombic interactions, and can be dissociated with the help of an electric field. Therefore the photocurrent in organic solar cells strongly depends on the applied

voltage. Recombination of the geminate pairs is a major loss mechanism in organic solar cells.

d) Charge Transport and Collection

The electrons and holes are transported to the respective electrode primarily by drift and diffusion processes. Conformational and chemical defects in the polymer chains and molecules restrict the charge carriers to small segments. The charge transport in OPV is therefore a hopping process.

Role of Disorder

The low mobility of the charge carriers in polymer solar cells may explain the longevity of the charge carriers in comparison with those in devices based on inorganic semiconductors. Charge pair dissociation at the D-A interface may be facilitated by a hop of one of the charges in the pair to a polymer segment with lower energy. Thus energetic disorder may reduce geminate pair recombination. The reduced recombination rate increases the time available to extract the photogenerated charges from the device. Provided that uninterrupted pathways exist to the two electrodes, the photogenerated electrons and holes may be collected in an external circuit before they recombine. However, the mobility of the charge carriers must be high enough to prevent high losses due to non-geminate recombination. For materials with a low mobility, this puts a restraint on the thickness of the active film. In order to be able to optimize the performance of solar cells, a detailed understanding of the parameters that effect the recombination dynamics of the photogenerated charge carriers is therefore necessary.

Parameters

Parameters like material blend ratio, blend concentration, layer thickness, and annealing temperature all have an effect on OLED and OPV device performance. To speed up the evaluation of the effect of these parameters on device performance, CSEM has built a High Throughput Apparatus (HTA-7). Originally designed for material screening and performance optimization, this tool enables a systematic study of the effect of these parameters. Subsequently, the generated parameter dataset serves as input to numerical models describing the underlying physics of the organic devices.