

Self-organized Liquid Crystalline Materials for Organic Photovoltaics: Opportunity and Challenge

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The crystalline silicon photovoltaic cells, though efficient, appear too expensive to compete with primary fossil energy. The organic photovoltaic (OPV) technology would hold a promise for cost reduction since the OPV materials are potentially cheap, easy to process, and capable of being deposited on flexible substrates and bent while their inorganic competitors, e.g. crystalline silicon, would crack. However, currently widely used OPV materials suffer from the scattering of electron/exciton at the grain boundaries or poor morphology, resulting in poor device performance. A challenge for OPV with the possibility of significant cost reduction is to make them in a desired macroscopic order to improve charge transportation etc. One route to accomplish this goal is to induce liquid crystal (LC) phase in efficient OPV materials since LCs can respond easily to external stimuli and their alignment can be manipulated by external fields and surface effects. Among all LCs, the discotic LCs having superior absorption in solar energy bands as well as capable of being homeotropically aligned, i.e. the columns formed by intermolecular strong π - π self-assembly are perpendicular to the electrode surface, would be a

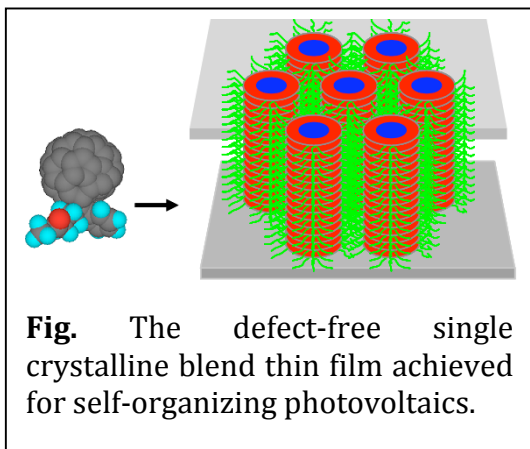


Fig. The defect-free single crystalline blend thin film achieved for self-organizing photovoltaics.

desirable candidate to meet this challenge. Unfortunately, such discotic LCs are difficult to achieve their homeotropic alignment due to high viscosity although the alignment technology of rod-shaped LCs is well established in the Liquid Crystal Display industry. In order to make discotic LC with more efficient absorption of sunlight, it is logical to use porphyrin as the building block of discotic materials since it is the basic structure of the best photoreceptor in nature, chlorophyll. Porphyrin and its derivatives have many desirable features such as highly conjugated disc plane, high stability, efficient absorption of sunlight, and the small gap between the highest occupied molecular orbital (HOMO) and lowest unoccupied molecular orbital (LUMO) energy levels. Another important feature of LC porphyrins is the long exciton diffusion length. Siebbles et al. discovered that the exciton diffusion length in a nematically organized *meso*-tetra(4-*n*-butylphenyl)porphyrin layer exceeded 40 nm which are much larger than the other materials. In contrast, the exciton diffusion length in most organic materials is only a few nanometers. For example, an exciton diffusion length of 5~8 nm has been concluded with conjugated polymers.

It is also well understood that discotic LCs as active components in high efficient PV cells are critically dependent on the supramolecular arrangement of the blend made from an electron donor component and an electron acceptor component. Compared with donor and acceptor bilayer PV cell, a blend can offer a much larger interface between donor and acceptor,

which results in a more efficient dissociation of excitons in a supramolecular arrangement. So a challenge is to develop self-organized LC blend thin films such as homeotropically aligned discotic LC-PCBM blend thin film (Fig.). Actually it is difficult even maintaining the LC phase in the blend.

In my talk, I will focus on our recent progress on self-organized liquid crystalline materials for organic photovoltaics.

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