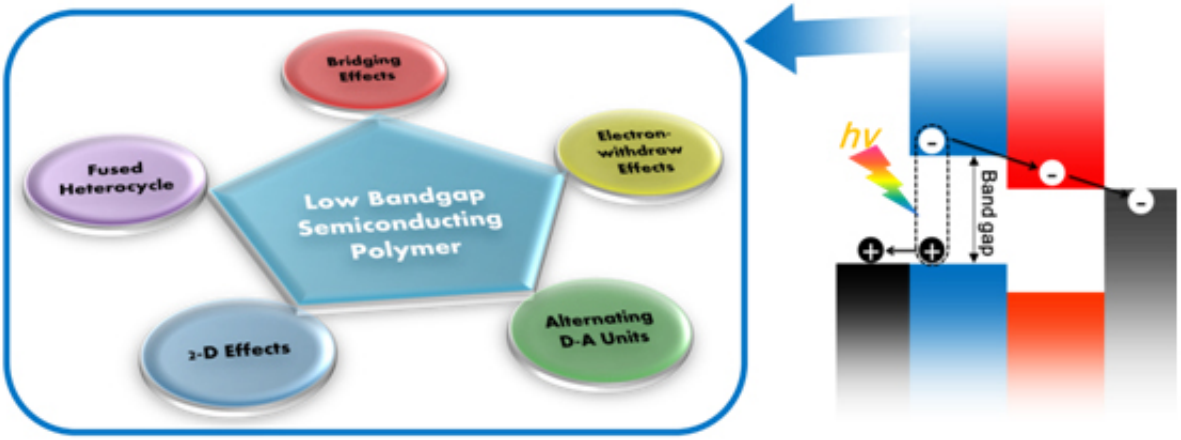
Organic semiconductors for future photovoltaics

Organic semiconductors based photovoltaics devices are able to absorb light of different wavelengths and converted it into electricity or electrical signal. By converting the light into electricity, the organic solar cells represent a clean, cost-effective and easy processing solution to address the energy crisis problems; by converting the photons of different energies into electrical signals, the organic photodetectors shows their potentials in the flexible, high sensitivity, and high speed multicolor sensing applications.



For both photovoltaic devices, the crucial materials are the organic semiconductors, which are the major light harvester in the devices. As soon as the photons are absorbed, bounded electron-hole pairs (termed as excitons) are formed in the organic semiconductors. By carefully adjusting the energy levels of each material, both electron and hole can be collected at the cathode and the anode, respectively. To realize fully utilization of solar energy, low-band-gap polymeric semiconducting materials are of top interest where the low-band-gap ensures photons of lower energy being absorbed and thus exploiting the sun-irradiation to near infrared. Moreover, the incident photon-to-current conversion at different wavelength (from ultraviolet to infrared) also opens a door for organic photodetectors. By far, the spot has been focused on development of low-band-gap semiconducting polymers with controllable or minimized band gap. And there has been developed five effective design rules for approaching low-band-gap semiconducting polymers with advanced photoelectrical properties such as high molar absorptivity, suitable energy levels, high charge carrier mobility and high solubility in organic solvents.

The semiconducting properties of conjugated polymer (alternating single bond and double bonds) are originated from the ?-conjugated structure, where the ?-electron has certain degree of delocalization. Thus by tuning the freedom of ?-electrons, the delocalization and distribution of electrons in the polymer system would be changed, which gives rise to different energy levels as well as energy band gap. From this angle, the idea of fused heterocycles structure and

groups/atoms bridging adjacent rings for maintaining a high planarity have been developed for facilitating ?-electron flowing along the polymer backbone and enhance the delocalization. In addition, strategies of introduction of electron withdrawing units for lowering energy levels, electron donor-electron acceptor (D-A) units copolymerization for narrowing band gap and 2D conjugation for broadening absorption and enhanced hole mobility have also been developed.

The prime design strategies for the current successful molecular structures lie in the D-A system construction, where the combination of D and A units are properly selected. Moreover, the relative strength of the D and A units in the conjugated system would also impose significant effects on the absorption coefficient of the intramolecular charge transfer band, and the electron distribution in the conjugated system. This study also reviews the widely employed D units in high performance D-A polymers, all of which are designed by hybridizing electron-rich aromatic rings into fused structures for combining the intrinsic advantages from the individual aromatic rings, as well as enhancing the planarity and rigidity of the D units. One of the remarkable advantages of the highly planar structure is the formation of the ‘‘face-on’’ orientation of the polymer, which benefits the ? conjugation in the vertical-structured solar cells. In terms of A units, strong electron-withdrawing units may increase the ? electron delocalization, while too strong electron-deficient property, on the other hand, results in deep energy levels hindering electron collections.

Low-band-gap semiconducting polymers, with facilely tunable energy levels, exhibit huge potential for realizing the multi-color photodetection with single polymers blended with fullerene derivatives, which circumvent the limited sub-bands covered by inorganic materials. Moreover, the low bandgap semiconducting polymers also enable the utilization of photons at longer wavelength, which eventually give rise to higher photon-electricity conversion efficiency for solar cells.

Publication

Low bandgap semiconducting polymers for polymeric photovoltaics.
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