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Self-Assembly of Semiconductor Organogelator Nanowires for Photoinduced Charge Separation

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Abstract A novel concept of general validity involving the self-assembly of an n-type organogelator into a p-type amorphous polymer matrix to realize interpenetrating donor-acceptor nanostructures suitable for charge generation and charge transport is reported (Figure 1). The self-assembly and interface generation were carried out either step-wise or in a simultaneous way. Fabrication steps of multi-layer organogel/polymer photovoltaic devices were optimized with respect to morphology and surface roughness in thin films.

We describe an innovative concept to create a nanostructured donor-acceptor interface by combining hydrogen bond-directed self-assembly of an n-type organogelator, perylene bisimide (PBI) with an amorphous p-type polymer, *poly*(vinyl-dimethoxytetraphenylbenzidine) (*p*vDMTPD) (Figure 2).[1] Due to non-covalent hydrogen-bonding and π-π-stacking interactions, the PBI organogelator [2] forms well defined nanowires with favorable *J*-type packing of the dyes during gelation process in suitable solvents (Figure 1a). These unique structural features are more or less maintained in the xerogel, obtained after the removal of the solvent, if sudden aggregation leading to loss of structures during drying process is avoided. Such a self-organized, nanostructured functional material incorporated into another functional material, without hindering the self-assembly process to a large extend, provides a large interface area suitable for charge separation (Figure 1b). It also provides charge percolation pathways on the nanometer scale. The self-assembly process and interface generation were carried out either step-wise or in a simultaneous way. Morphology of the donor-acceptor network in thin films obtained via both routes were studied by a combination of scanning electron microscopy and atomic force microscopy. Additionally, photoinduced charge separation and charge transport in these systems were tested in organic solar cells. Fabrication steps of multi-layer organogel/polymer photovoltaic devices were optimized with respect to morphology and surface roughness by introducing additional smoothening layers and charge injection/blocking layers. An inverted cell geometry was used here in which electrons are collected at the bottom electrode and holes at the top electrode. The simultaneous preparation of the interface exhibits almost three-fold improvement in device characteristics compared to the successive method. The device characteristics under AM1.5 spectral conditions and 100 mW/cm^2 for the simultaneous preparation route are: short circuit current J_{sc} = 0.28 mAcm^{-2}, open circuit voltage V_{OC} = 390 mV, fill factor *FF* = 38% and a power conversion efficiency η = 0.041 %.

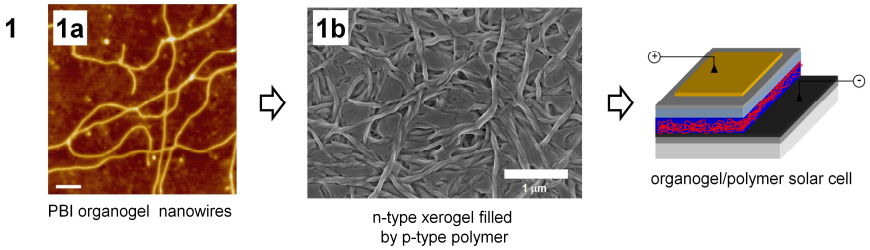

Figure 1: Schematic representation of organogel-polymer concept for realization of an interpenetrating organic bulk heterojunction. **(a)** AFM height image of PBI organogel nanowires from diluted gel solution (scale: 100 nm). **(b)** SEM surface image of a PBI-xerogel/*p*vDMTPD blend film (doctor-bladed from 2.0 wt-% $CHCl_3$ solution) as active layer for photovoltaic devices (scale 1 µm).

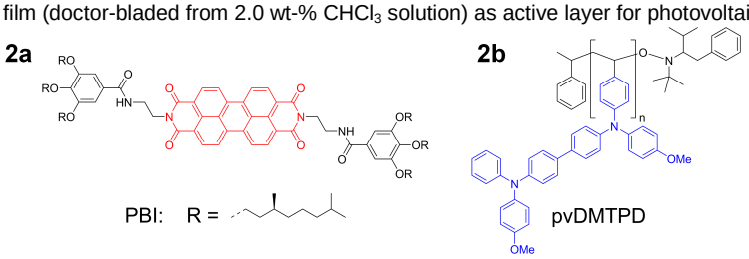

Figure 2: Molecular structures of **(a)** n-type perylene bisimide organogelator (PBI) and **(b)** amorphous p-type polymer (*p*vDMTPD).

References

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[2] F. Würthner, C. Bauer, V. Stepanenko, and S. Yagai, Adv. Mat. 20 (2008), 1695-1698.