High Dielectric Constant Materials for Homojunction Organic Photovoltaics

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Solution processed bulk heterojunction (BHJ) organic photovoltaics (OPV) have experienced substantial increase in power conversion efficiency (PCE), but also face the challenges in morphology optimisation, energy loss control and device upscaling. The high exciton binding energy and short exciton diffusion length limit charge separation and transport in organic semiconductors. A high dielectric constant (ε) is a key factor for lowering the exciton binding energy of semiconductors and if sufficiently high can lead to free charge carriers on photoexcitation in a homojunction device.

To overcome the inherently low dielectric constant of organic materials, ethylene glycol-based moieties have been introduced as a solubilising-groups on organic semiconductors to increase the low-frequency ε up to 9. On the other hand, intermolecular interactions between the chromophores can be enhanced by the glycol-based units, leading to a higher film density. Further investigation has revealed that charge separation depends on the electronic polarisation at optical frequencies. To this end, the focus of the current work is the development of organic materials with a high optical-frequency ε for the implementation in homojunction OPV devices.

In this work, a family of π-conjugated oligo-fluorene based materials with various conjugation lengths have been synthesized. The conjugation length is manipulated to broaden the spectrum and absorption onset and unveil the dependence of the optical frequency ε on conjugation, molecular geometry and intermolecular interactions. The physical and optoelectronic properties as well as dielectric constant at both low- and optical frequency have been measured. The glycolated materials are thermally stable, and the glycol solubilising groups have efficiently increased the dielectric constant at low frequency without detrimentally affecting optoelectronic properties. A large low-frequency dielectric constant of 15 has been achieved. In addition, homojunction devices have been fabricated and demonstrated that an external quantum efficiency (EQE) can be measured close to the absorption onset.