Development of non-fused acceptor materials toward organic solar cells

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Abstract

Organic solar cells (OSCs) are attracting attention as a next-generation photovoltaic technology because of their excellent flexibility, light weight, and designability, as well as the ease of making them large-area using a printing process. We recently discovered that an original molecular unit (FT), in which the fluorene and thiophene skeletons are perpendicularly linked, is effective in (1) improving molecular rigidity and (2) suppressing intermolecular π-π stacking. These features are ideal for acceptor materials in OSCs. We developed an acceptor material TT-FT-DCI using the FT unit and found that it exhibited high power conversion efficiencies as non-fused acceptor materials. We also developed semi-transparent OSCs that selectively absorb green-light wavelengths and transmit red- and blue-wavelengths using FT units (TT-FT-ID). Under pseudo-sunlight transmitted through this photo-active layer, we confirmed that photosynthesis of agricultural crops proceeded.

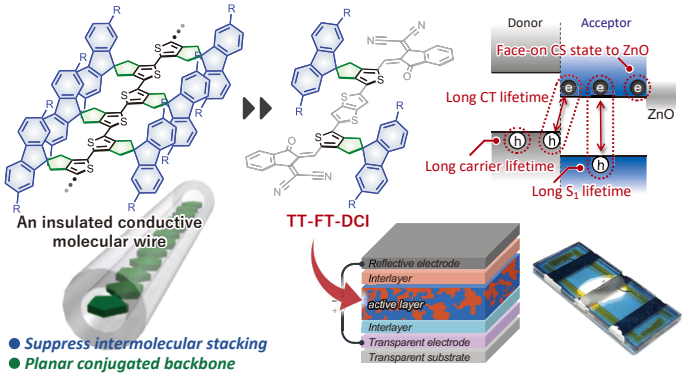
Background & Results

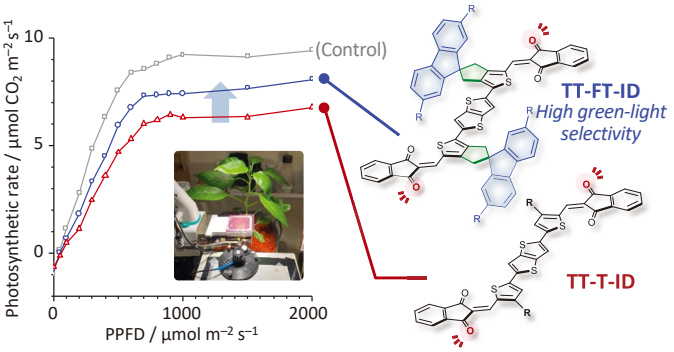
The photo-active layer of OSCs consists of a mixture of p-type organic semiconductor material (donor) and n-type organic semiconductor material (acceptor). Conventionally, fused ring π-conjugated skeleton has been considered essential for acceptor materials. However, the construction of fused ring chemical structures generally requires a multi-step synthesis process. Toward the social implementation of OSCs, non-fused ring acceptor materials, which are easy to synthesize and easy to develop derivatives, are becoming a focus of attention. In this background, a three-dimensional molecular unit (FT) with a fluorene skeleton introduced perpendicular to the thiophene skeleton has been developed through our research on insulated conductive molecular wires. The FT unit has the effect of improving the rigidity of the conjugated chain and suppressing intermolecular π-π stacking, which is consistent with the design guidelines for acceptor materials for OSCs. An acceptor material TT-FT-DCI, developed using the FT unit, was found to exhibit high power conversion efficiencies as a non-fused acceptor material.

Recently, we have developed a derivative material TT-FT-ID, which has selective absorption in the green-light wavelength region. This acceptor material was designed for combination with a donor material P3HT, which also has absorption in the green-light wavelength region, and the OSC device fabricated by combining these materials functioned as a green wavelength-selective semi-transparent OSC. Under pseudo-sunlight transmitted through this photo-active layer, we confirmed that photosynthesis of agricultural crops proceeded.

Significance of the research and Future perspective

In this research, we have developed semi-transparent OSCs with selective absorption and response in the green-light wavelength region by molecular design of acceptor materials. The new semi-transparent OSCs were found to be compatible with both photovoltaic power generation and crop cultivation. We will investigate the possibilities of this new agrivoltaic technology and will also explore innovative organic electronics utilizing the unique characteristics of organic materials.





Patent

Treatise Jinnai, Seihou; Saeki, Akinori; Ie, Yutaka et al. Effects of the rigid and sterically bulky structure of non-fused nonfullerene acceptors on transient photon-to-current dynamics. Journal of Materials Chemistry A. 2022, 10, 20035-20047. doi: 10.1039/D2TA02604J
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Keyword organic solar cells, organic semiconductors, organic functional materials