Carrier and Spin Dynamics in Organic Photovoltaic Thin Films Studied by Simultaneous Optical and Electrical Detection

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Photovoltaics based on organic materials has been a center of focus in research in material developments toward decarbonization and sustainable society. For improvement of the energy conversion efficiency, it is of much importance to quantify how many charged carriers are generated by the incident photon, how fast they move in response to an electric field, and how efficiently they are collected by the electrodes. In amorphous/semicrystalline organic films, however, this is actually a difficult task because the photocarriers transport among inhomogeneous local sites, which gives rise to a broad distribution of the energy and mobility. Conventional electrical measurement of carrier dynamics has a critical problem that an effect of highly mobile carriers is overestimated since the photocurrent is linear to the product of the mobility and concentration of carriers. This is one reason for large variations in measured quantities (such as mobility) for an identical material among devices and methods.

We have been tackling this problem by simultaneous optical and electrical detection (SOED) for an identical thin film device.[1] Transient optical absorption is detected simultaneously with transient photocurrent, former of which quantitatively tracks decay of the total carrier concentration by recombination / electrode collection. This technique enables us to differentiate whether the photocurrent decay is due to extinction of charged species itself or change in the mobility distribution towards lower side, latter of which is mainly due to so-called trapping. Furthermore, magnetic field effect (MFE) on SOED signals allows us to selectively observe the spin selective dynamics of paramagnetic pair species such as electron-hole pairs.

In the talk, our recent results listed below will be discussed.

1) Non-geminate electron-hole pair dynamics in a bulk heterojunction (BHJ) thin film.
2) Electrode collection dynamics in a real BHJ solar cell device.
3) Spin selective geminate recombination in a dye-doped poly(*N*-vinylcarbazole) film.

These results demonstrate significance of trapping for carrier and spin dynamics in organic film materials.

References

[1] T. Miura, R. Akiyama, S. Kobayashi, T. Ikoma, *J. Phys. Chem. C* **125**, 22668 (2021).