論文の内容の要旨

論文題目
Investigation of the Relationship between Morphology and the Performance in Organic Photovoltaic Devices
（有機太陽電池のモルフォロジーと性能との相関に関する研究）

氏名　尾畑　直樹

In my thesis, I have investigated influence of morphology on the organic photovoltaic (OPV) performance by using different types of devices, donors, and acceptors.

In chapter 1, I mentioned relationship between morphology and device performance. It is necessary to discuss the morphology in each device because the morphology is dependent on device configuration such as heterojunction or bulk-heterojunction type, and materials type, i.e. small molecules and polymers.

In chapter 2, I fabricated p-n heterojunction type devices composed of tetrabenzoporphyrin (BP) and titanylphthalocyanine (TiOPc) absorbing near-infrared (NIR) light through the phase transition, and an electron-accepting material, 1,4-bis(dimethylphenylsilylmethyl)[60]fullerene (SIMEF). The device harvested light absorbance both in visible and NIR region, and gave high open-circuit voltage (V_{OC}) with high-lying the lowest unoccupied molecular orbital (LUMO) level of SIMEF. I discovered that BP/TiOPc/SIMEF devices provided light absorption at NIR region through the phase transition of TiOPc with morphological changes by solvent exposure (toluene). This is easy method compared to conventional method such as solvent vapor exposure that is called solvent annealing, which takes long time over one hour to control a TiOPc molecule for the phase transition. To discuss the charge-separation interface in this two-donor device, I fabricated the BP/TiOPc device using TiOPc as the electron-accepting material, and observed that charge separation occurred at the BP/TiOPc interface. Considering this result, in the two-donor device, charge separation occurred dominantly at the TiOPc/SIMEF interface, but it can also occur at the BP/TiOPc interface (Fig. 1).

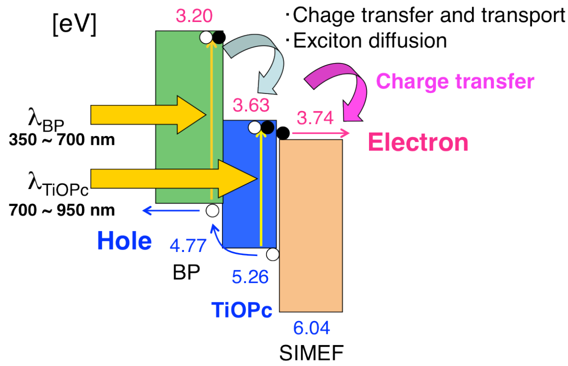

Figure 1 Two-donor device mechanism

In chapter 3, I investigated the influence of morphology of fullerene derivatives on device performance. I fabricated an acceptor layer on morphologically controlled BP layers for easily screening fullerene derivatives with different type of properties. I found that there is some difference in X-ray diffraction pattern from BP in $PC_{60}BM$-based and SIMEF-based thin films. The data indicated that the density in the SIMEF film is high enough to hinder the diffraction pattern from BP and that the density of $PC_{60}BM$ is too low to cover the diffraction from BP. In addition, the surface roughness of the $PC_{60}BM$ layer is larger than that of the SIMEF layer. I considered that the rough surface in the $PC_{60}BM$ film is due to the large-size aggregation of $PC_{60}BM$, resulting in the low density of the electron-accepting material at the donor/acceptor interface. This causes a current leakage and low V_{OC}. I suggested that the device performance is attributed to not only LUMO level, but also the morphology of the acceptor in the active layer.

In chapter 4, I investigated deterioration of polymer-based bulk-heterojunction OPV devices in addition of a photo-oxidation product (SIMEF-O_2) of SIMEF. A poly(3-hexylthiophene) (P3HT) bulk-heterojunction device fabricated with a varying SIMEF-O_2/SIMEF ratio resulted in a sharp drop of the performance with only 1% of SIMEF-O_2 that caused a decrease in J_{SC} due to acting as an electron trap. In the case of 10% amount of SIMEF-O_2, S-shaped J-V curve and low FF were obtained. The surface topography and phase image of P3HT:SIMEF:SIMEF-O_2 film showed smaller domain in the case of the larger amount of SIMEF-O_2. I considered that this loss of the bulk-heterojunction morphology in the presence of large amounts of SIMEF-O_2 induced poor charge separation and transport in the active layer, resulting in the reduction of device performance. In the absorption spectra of the P3HT:SIMEF:SIMEF-O_2 film, the decrease in absorption around 600 nm was observed. This suggested that the decrease in order of P3HT is induced, as SIMEF-O_2 is included in the P3HT:SIMEF:SIMEF-O_2 film. I concluded that the disordering of P3HT in film leads to the loss of the bulk-heterojunction morphology (Fig. 2).

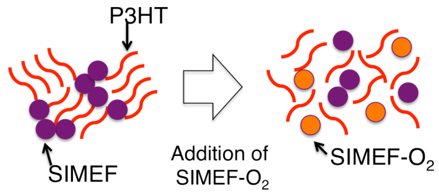

Figure 2 Polymer-based blend film in addition of oxidized fullerene

As a conclusion in chapter 5, I have investigated the influence of the morphology on the OPV performance in different types. It is important to make a vision of controlling interface morphology for high performance.