Investigation of electronic structure at cathode interfaces in Sub-phthalocyanine acceptor based organic solar cells

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Subphthalocyanine (SubPc) acceptor based organic solar cells (OSCs) exhibited superior device efficiency of over 8% [1]. However, the energy loss at the cathode/organic hetero-interfaces, e.g., formation of energy barrier, has not been clarified yet. In this study, we investigated the electronic structures at SubPc/buffer/Ag heterointerfaces by means of synchrotron based ultraviolet photoelectron spectroscopy (UPS).

The SubPc/buffer/Ag heterostructures were formed by depositing buffer materials on Ag and subsequently depositing SubPc onto buffer/Ag stack structure in a step-by-step way in a vacuum deposition chamber. A series of pyridine based acceptor molecules (BCP, TPBi and TAZ) were applied as the buffer layers.

For all buffer/Ag stack structures, metal induced gap states within the HOMO-LUMO gap were observed. These states were located near the LUMO levels and their density of states reached to the Fermi level. Thus, the gap states act as shallow donors, which enhance the electron conductivity of the buffer layers. Since the work function of the buffer/Ag stack structures showed fairly small values (3.3-3.5 eV), which corresponds to the electron affinity of the SubPc layers (~3.3 eV), the buffer layers have a role of promoting a smooth carrier injection from cathodes to acceptor layers. Nevertheless, the energy difference between LUMO of SubPc and Fermi level of buffer is estimated to be ~0.6 eV. The carrier injection barrier of the system was quite huge as compared with that of C_{60}/buffer/Ag heterostructure (~0.2 eV). The difference in the barrier height might be caused by the density of disorder originated tail states in the acceptor layers and/or acceptor/buffer heterointerfaces [2] since structural disordering is easily introduced in non-planar aromatic systems (SubPc). We consider the disorder originated tail states, which were located at the deep energy position, caused the carrier injection barrier at the SubPc/buffer/Ag heterostructures.

Keywords: energy level alignment; organic solar cells; ultraviolet photoemission spectroscopy

References

[1] K. Cnops et al., Nat. Comm. 5, 3406 (2014).
[2] T. Sueyoshi et al., APL 95, 183303 (2009).