HIGHLY-EFFICIENT ORGANIC OPTOELECTRONIC CONVERSION ASSISTED BY PORALIZATION AROUND CHARGE SEPARATION SPECIES

Kunio Awaga

Research Center for Materials Science & Department of Chemistry, Nagoya university, Nagoya 464-8602, Japan, and CREST, JST

Introduction

Organic optoelectronic devices have received intense attention, but the poor mobility of organic materials always gives rise to the formation of space charges in organic thin film devices, and the space charges limit both the conduction current and the photocurrent. While most works on organic optoelectronics are now focused on improving device performance with a steady-state conduction current, a transient photocurrent (TPC) has not been utilized.

Results and Discussion

An organic radical material, 4,4'-bis(1,2,3,5-dithiadiazolyl) (BDTDA) exhibits highly oriented thin films, consisting of π-stacking chains of the BDTDA radical dimers. In our previous work,[1] we revealed steady-state photocurrent with a high on/off-gain of ITO/BDTDA (300 nm)/Al photocells at small reverse bias voltages, and ascribed it to a wide LUMO band which is expected to be formed through a large interdimer overlap between the anti-bonding orbitals of the radical dimers. In the present work,[2] we studied the photoresponse of the BDTDA photocells without applying a bias voltage, and found a gigantic transient photocurrent, which was completely different from the photoresponse under bias voltages (Fig. 1). We interpreted this transient behavior, based on the intrinsic characters of radical dimers, namely an imbalance between carrier (i.e., hole and electron) mobilities and bulk polarization.

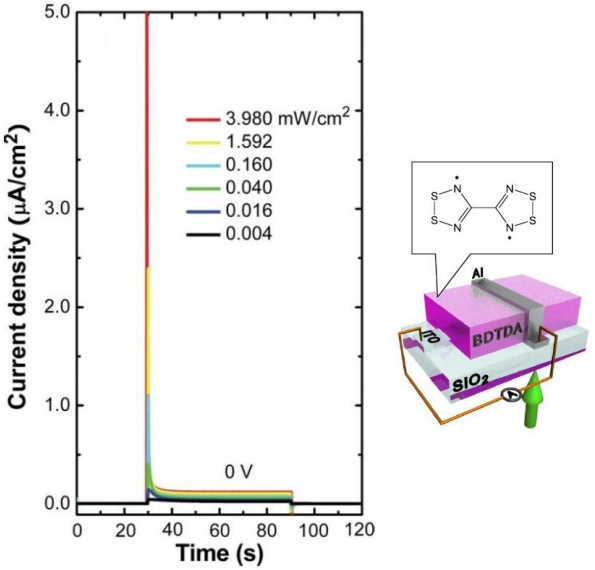

Figure 1. Photoresponse of an ITO/BDTDA (300 nm)/Al photocell (inset) under an illumination of a green laser (532 nm) under vacuum with a bias voltage of 0 V..

To reproduce anomalous TPC, we developed a Metal/Organic insulator/Organic semiconductor/Metal (MISM) structure.[3] The organic double layers between the metals induce an imbalance of carrier transports, which facilitates the generation of space charges. The dielectric polarization in the insulator, triggered by the space charges, magnifies the TPC in the semiconductor layer. Figure 2(a) shows the photoresponse of an ITO/PVDF (1μm)/ZnPc:C_{60} (30nm)/Al photocell under illumination from a modulated 532-nm laser (300 Hz) with different intensities. Upon laser illumination, a large TPC is successfully produced, and a negative TPC appears just after the illumination. Both the positive and negative TPC increase with increases in the light intensity. Figure 2(b) shows the photoresponse under a high frequency modulation of 1 kHz, with a light intensity of 31.8 mW/cm^2. Continuous current oscillation is stably observed without degeneration.

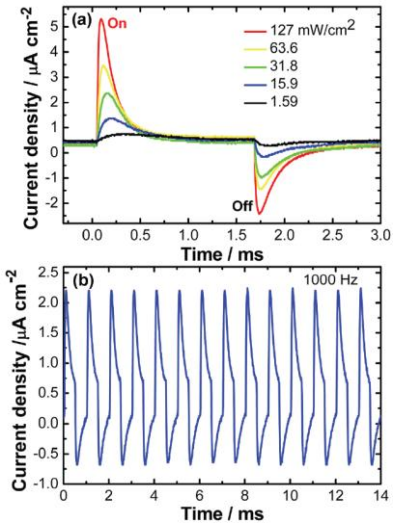

Figure 2. The photoresponse of an ITO/PVDF/ZnPc:C_{60}/Al photocell under illumination from a modulated 532-nm laser (300 Hz) with different intensities. The sample was illuminated from the ITO side. (b) Photoresponses with a light modulation of 1 kHz.

Conclusion

We have successfully proposed a novel organic optoelectronic conversion. This is a mechanism to harvest pulsed light, in which the space charges of the organic materials are regarded as a merit. We also found that TPC was dramatically increased by increasing the dielectric constant of the insulating layer. These results suggest a new light harvest principle for various fields, including communications, remote control and image sensors.

References

(1) Iwasaki, A *et al. Angew. Chem. Int. Ed*., **2009**, *48*, 4022.
(2) Hu, L. *et al. Chem. Phys. Lett.* **2010**, *484*, 177.
(3) Hu, L. *et al. Appl. Phys. Lett.* **2010**, *96*, 243303.