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Organic photovoltaic effects using CuPc and C_{60} depending on layer thickness

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Abstract

We have studied photovoltaic effects in ITO/CuPc/Al and ITO/CuPc/C_{60}/BCP/Al devices to investigate the effect of layer thickness of CuPc, C_{60}, and BCP exciton blocking layer. The thickness of CuPc single layer was varied from 10 nm to 50 nm using thermal vapor deposition, and we obtained optimum current density-voltage characteristics of ITO/CuPc/Al for 40 nm thick CuPc layer. From the thickness-dependent photovoltaic effects in CuPc/C_{60} heterojunction devices, higher power conversion efficiency was obtained for ITO/20 nm CuPc/40 nm C_{60}/Al, which has a thickness ratio (CuPc:C_{60}) of 1:2. The BCP layer was introduced as an exciton blocking layer, and there was a pronounced improvement of conversion efficiency with the use of BCP layer.

Keywords : Solar cell, photovoltaic effect, exciton blocking layer

1. Introduction

Nowadays, more than seventy percent of the energy consumed on earth comes from a fossil fuel. Since this energy is getting exhausted, there is a need to develop new energy sources. Solar energy is one of the possibilities for a replacement. In 1839, French physicist Becquerel discovered photovoltaic effect from a device consisting of metal electrodes in electrolyte [1]. When the device was exposed to the light, he found a very small amount of current flowing through the device. In 1954, Chapin et al. in Bell laboratory developed applicable photovoltaic cells having an efficiency of 4.5% using crystalline silicon. Since then, lots of inorganic photovoltaic cells were developed. However, even though an efficiency of organic photovoltaic cell is low compared to that of silicon solar cell [2], there is a growing concern on organic photovoltaic cell these days. It is considered to be one of the possible applications because organic materials are attractive in thin-film fabrication and cost [3-4].

In 1986, Tang developed a photovoltaic cell using CuPc/PV organic materials and obtained a solar power efficiency of about 1% with corresponding external quantum efficiency of about 30% [5]. In 2001, Peumans et al. reported a photovoltaic cell having a power conversion efficiency of 3.6% [6]. These photovoltaic devices have been intensively studied to improve the conversion efficiency for the last ten years [7-10].

In this paper, we report photovoltaic effects in ITO/CuPc/Al and ITO/CuPc/C_{60}/BCP/Al devices to see an effect of layer thickness of CuPc and C_{60}, and BCP exciton blocking layer.

2. Experimental

The indium-tin-oxide (ITO) glass, having a sheet resistance of 15 Ω/□ and 170 nm thick, was received from Samsung Corning Co. A 5 mm wide ITO strip line was formed by selective etching in vapor of solution made with hydrochloric acid (HCl) and nitric acid (HNO_3) with a volume ratio of 3:1 for 10 ~ 20 minutes at room temperature. The patterned ITO glass was cleaned by sonicating it in chloroform for 20 minutes at 50°C. And then the ITO glass was heated at 80°C for 1 hour in solution made with second distilled deionized water, ammonia water and hydrogen peroxide with a volume ratio of 5:1:1. We sonicated the substrate again with chloroform for 20 minutes at 50°C and in deionized water for 20 minutes at 50°C. After sonicating the substrate, it was dried with N_2 gas stream and stored under vacuum.

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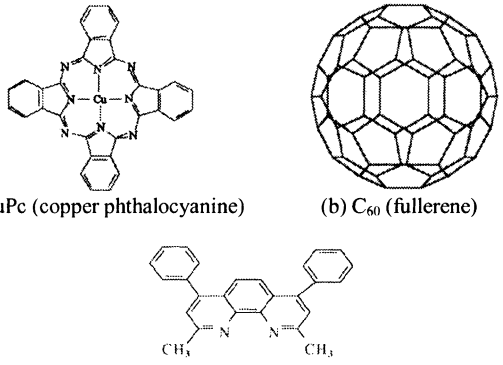

Fig. 1. Molecular structures of (a) CuPc, (b) C_{60}, and (c) BCP

Molecular structures of (a) CuPc, (b) C_{60}, and (c) BCP are shown in Fig. 1. Reported values of exciton diffusion length of CuPc, ZnPc and C_{60} are about 10 nm, 30 nm, and 40 nm, respectively.[11]

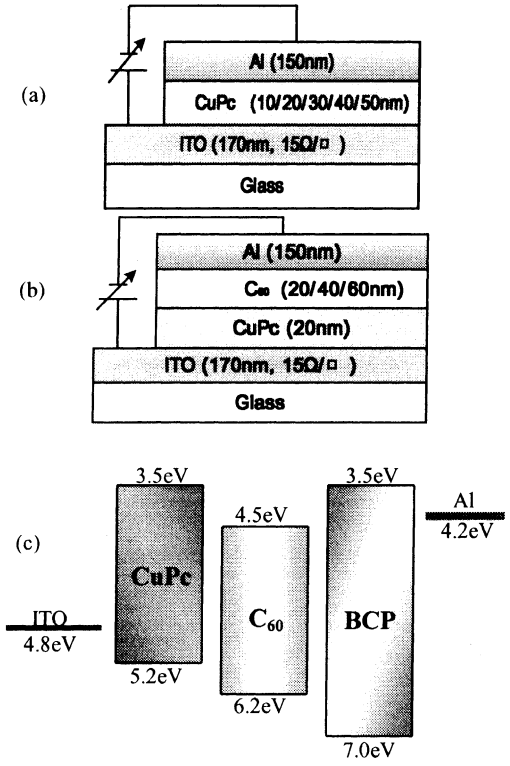

Fig. 2. Device structures of (a) CuPc single layer, and (b) CuPc/C_{60} heterojunction layer, and (c) energy-level diagram.

Photovoltaic device was made using a donor-like CuPc and acceptor-like C_{60}. Figure 2 shows a schematic structure and energy-level diagram of photovoltaic cells used in our experiment. Single-layered organic photovoltaic cells of ITO/CuPc/Al were fabricated with a variation of CuPc layer thickness from 10 nm to 50 nm. To compare a performance with multi-layered photovoltaic cells, a device structure of ITO/CuPc/C_{60}/BCP/Al was also fabricated using thermal evaporation. Al cathode (150nm) was deposited at 1.0×10^{-5} torr using thermal evaporation as well. An active cell area of device was made using a shadow mask to be 3 mm × 5 mm.

Current density-voltage characteristics of organic photovoltaic cells were measured using Keithley 236 source-measure unit and a 500 W xenon lamp (ORIEL 66021). Light intensity on the device was measured by radiometer/photometer of International Light Inc (IL14004). All measurements were carried out at room temperature.

3. Results and Discussion

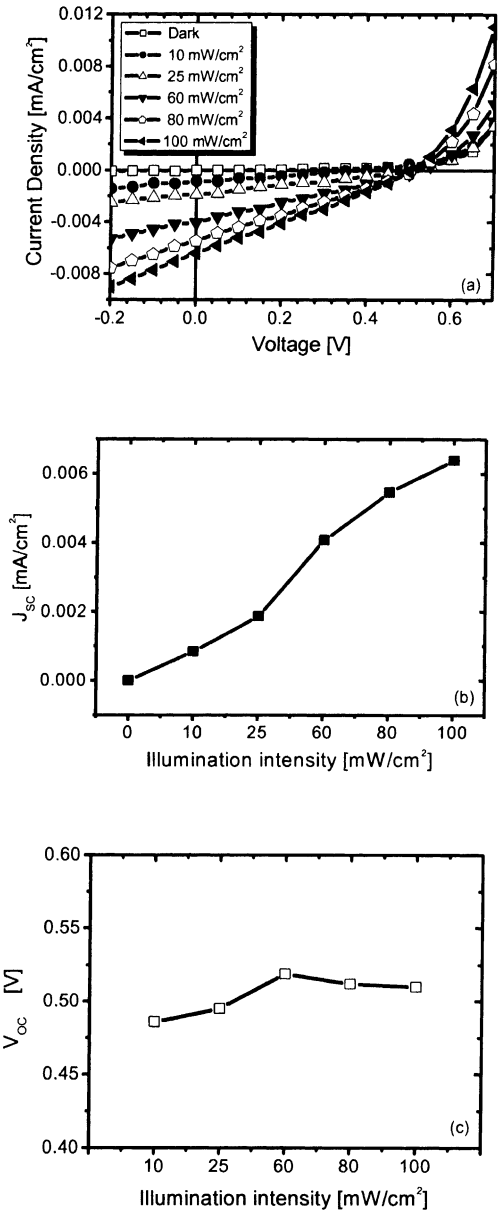

Fig. 3. (a) Current density-voltage, (b) short-circuit current density, (c) open-circuit voltage characteristics depending on illumination intensity of ITO/40nm CuPc/Al device.