Annealing effect on the performance of PTB1: PCBM bulk heterojunction solar cells

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Organic photovoltaic solar cells based on photonics technology have been widely investigated as they show the promise of solar energy conversion efficiencies at low cost and ease of fabrication [1-3]. In the past decades, much research has focused on device structure optimization and new materials synthesis to improve the efficiency of the device. In organic solar cells structure optimization, annealing of the polymer blend layer is an effective method to induce the crystallization, increase the phase separation and improve the transport across the interface between the active layer and electrode. Many efforts have been made to investigate the effect of temperature and scale on the thermal annealing in P3HT: PCBM hybrid system [4, 5]. Recently, a new series of the width spectral response polymer PTB1 have attracted much attention because of 6% high power conversion efficiency [6, 7]. In this work, we focus on the structure optimization of the PTB1: PCBM BHJ solar cell and discuss the influence of thermal annealing on the performance.

Photovoltaic (PV) devices were fabricated on pre-cleaned patterned ITO glass substrates. The ITOcoated glass substrate was cleaned stepwise in acetone, methanol, isopropanol, distilled water for 20min each. And then it was dried in an oven for 10 h at 60°C. A 30 nm hole extraction layer PEDOT:PSS was applied onto the substrates by spin coating. After being baked at 120°C for 20 min, the PTB1:PCBM film with 1:1 weigh ratio and the PTB1 concentration of 10 mg/ml dissolved in 1, 2-dichlorobenzene was cast on the PEDOT: PSS layer at 1000 rpm for 30 s without further treatment inside a glove box. Subsequently, 100 nm Ag layer on top of 25 nm Ca layer were thermally deposited on the organic activity film under the vacuum of $1x\,10^{-6}$ using a thermal evaporator. The thermal annealing process was conducted at 100°C for 20 min in the same glove box after cathode evaporation. The device efficient area was measured to be 0.09 cm^2. The current-voltage curves were measured using a Keithley 2400 source measure unit under AM1.5G illumination at 100 mW/cm^2. The light density was determined by a monosilicon detector to reduce spectral mismatch.

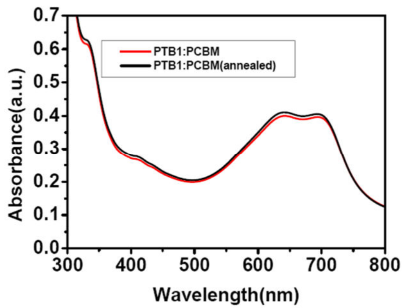

Figure 1: UV-vis absorption spectra of PTB1: PCBM 1:1pristine and annealed film at 100°C for 20min.

Annealing is an indispensable step for the complete solar cell device fabrication in light absorption, phase separation and final efficiency. Figure 1 shows UV- Vis absorption spectra of PTB1: PCBM blend layer before and after the annealing at 100°C for 20min. A broad peak in the 626-705 nm region is the characteristic π-π* transition of the PTB1. And the 325 nm peak comes from the absorption of PCBM. The results are in agreement with previous report [5]. In our experiment, light absorption of the PTB1:PCBM film is not significantly shifted after annealing at 100°C for 20min compared with the results that Yu *et al.* has reported [6]. The different spectral response suggests that the rigid backbone of PTB1 is not changed after annealing as in P3HT system. Although the light absorption is not increased by annealing, the thermal annealing of the activity layer changes the photovoltaic properties. Current density-voltage characteristic result shows that the Jsc of the device made from an annealed film dropped dramatically from 12.8 to 12.2 mA/cm^2 compared to the pristine PTB1: PCBM film. FF and PCE were calculated to decrease after annealing from 60.8% to 55.7% and from 4.44% to 3.9%, respectively (Figure.2). It is concluded that the Jsc and FF decreasing were a result of the improved phase separation and the reduced interfacial area between the donor PTB1 and the acceptor PCBM after annealing. This resulted in charge recombination and low transportation efficiency in the organic blends. In contrast, the Voc increased from 0.57 V to 0.58 V after annealing. Typically, the Voc is governed by the energetic relationship between the donor and acceptor as well as the contact form of polymer/electrode interface. And the energy level change is closely correlated to interchain interaction between the donor and the acceptor. However, the UV-Vis spectroscopy results (Figure 1) showed no absorption shift, which suggests that this interchain interaction between polymers does not altered. Therefore, the Voc increase can be explained due to an improvement of the ohmic contact of polymer/electrode interface in the PTB1: PCBM blend system.

This work was supported by the Spanish Ministry of Science and Innovation (MICINN) under grant number tec2009-09951, TEC2012-34937, CONSOLIDER HOPE project CSD2007-00007, by Catalan authority under project 2009 SGR 549.

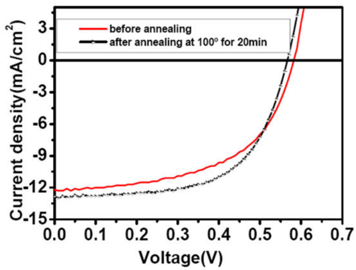

Figure 2: The typical current-voltage characteristic solar cell Device (ITO/PEDOT:PSS/PTB1:PCBM/Ca/Ag) made by PTB1: PCBM 1 : 1 pristine and annealed film under the AM 1.5 condition.

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