Effect of Donor/Acceptor Blend Ratio and Molecular Weight of Polymer Acceptor on Fracture Behavior of All-Polymer Solar Cells

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1. Introduction

All-polymer solar cells have been actively studied due to their advantages such as lightweight, low-cost, and high throughput compared to conventional silicon solar cells [1]. Nevertheless, there are many problems to commercialize the polymer solar cells due to the poor stability and low mechanical reliability [2]. In particular, it is well known that the blend ratio of polymer donor and acceptor is highly correlated to the efficiency of the polymer solar cells [3]. However, most of the previous studies have mainly focused on the photoelectric performances depending on the blend ratio without consideration of the mechanical characteristics of the polymer solar cells.

In this study, we examined the fracture energy of polymer solar cells according to the donor/acceptor blend ratio by double cantilever beam (DCB) test. As a result, the high fracture resistance of the polymer solar cell above 3.0 J/m^2 could be obtained over the broad donor/acceptor ratio by using high molecular weight polymer acceptor. (M_n = 115 kg mol^{-1}) In addition, the surface morphology of the fractured polymer solar cells was analyzed to reveal the change of the fracture behavior according to the donor/acceptor blend ratio. This study demonstrates the importance of the donor/acceptor blend ratio for the mechanically robust polymer solar cells.

2. Result and discussion

In order to measure the fracture energy of polymer solar cells, we performed DCB tests by the Delaminator Adhesion Test System. (DTS Company, Menlo Park, USA) (Fig. 1 (a)) The DCB test has been extensively used to measure the quantitative fracture energy of organic solar cells [4-5]. The structure of the DCB test specimens was shown in Fig.1 (b). The active layer films were spin-coated on the ITO glass substrate by using PBDB-T:P(NDI(2OD)-T2) blend solutions, and then the Au film was coated by evaporation to protect the active layer against the epoxy. Dummy ITO glass was attached to the Au-active layer-ITO glass by using the epoxy. The cracks were propagated cohesively through the active layer by repetitive loading, which is acting on the tip of the specimen.

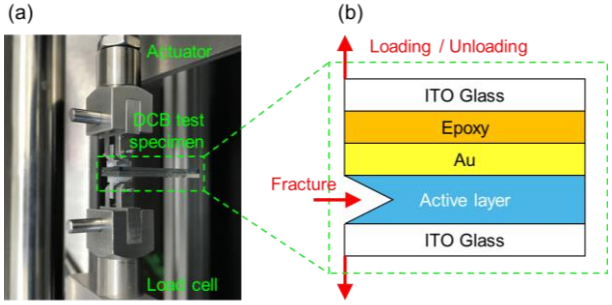

Fig.1 (a) Schematic of the DCB test system and (b) the structure of the DCB test specimen

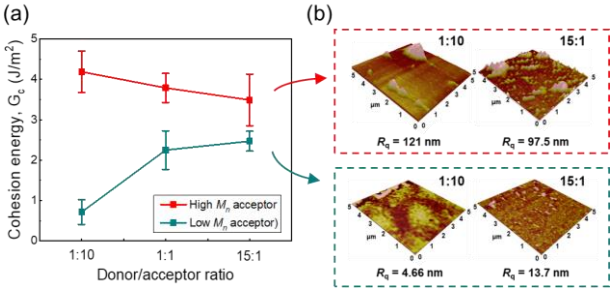

Fig.2 (a) Cohesive fracture energy of the active layer versus donor/acceptor ratio and (b) AFM height images of the fractured active layer

By the DCB tests, we measured cohesive fracture energies of the active layer as a function of the blend ratio of polymer donor and acceptor. (Fig. 2 (a)) For the low M_n (9 kg mol^{-1}) of polymer acceptor (P(NDI(2OD)-T2)) cases, the cohesion energy increased as the donor content increased. When the M_n of polymer acceptor increased from 9 to 115 kg mol^{-1}, higher cohesion energies were measured than the low M_n of polymer acceptor cases, despite the cohesion energy decreased as the donor content increased.

To analyze the change in cohesion energies of the active layer, the fractured surfaces of the active layer were observed by using atomic force microscopy (AFM). (Park Systems, XE-100) The fractured surfaces of the low M_n of polymer acceptor cases were very flat even the donor content increased. (Fig. 2 (b)) When the M_n of polymer acceptor increased from 9 to 115 kg mol^{-1},

surface roughness (R_q) increased significantly compared to the low M_n of polymer acceptor cases. These rough surfaces were caused by the large plastic deformation due to the entanglement of the polymer chains with high molecular weight [5]. Therefore, it is assumed that the cohesion energy increased due to the large deformation by the entanglement of the polymer chain.

3. Conclusions

In this study, we investigate the fracture behavior of all-polymer solar cells as a function of the donor/acceptor blend ratio by conducting DCB test. The relationship between the cohesion energy and the blend ratio varied with the molecular weight of the polymer acceptor (P(NDI(2OD)-T2). Particularly, high cohesion energy of the polymer solar cell was observed over the broad donor/acceptor ratio when the molecular weight of polymer acceptor increased. This increase in the cohesion energy was considered to be due to large plastic deformation by entanglement of the polymer chains.

Acknowledgment

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