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Push Coating Technique Applied for a Bulk-heterojunction Solar Cell

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Abstract

The push coating technique was applied to fabricate a bulk heterojunction PTB7:$PC_{71}BM$ organic solar cell. A PTB7:$PC_{71}BM$ dichlorobenzene solution was dropped and push-coated on the PEDOT:PSS deposited ITO glass surface with a dimension of 13 x 19 mm^2, and only 5 µl of the solution was enough to cover the entire surface of the substrate. The thickness variation of the active layer ranged between 25 and 55 nm. The acceptable performance of the fabricated solar cell indicates that the push coating technique will be applicable to polymer solar cell fabrication processes with the minimum loss of the organic semiconductor materials.

1. Introduction

Flexible and printed electronics is an attractive technology that can provide various new electronic devices with cost effective and environmentally friendly processes technologies [1]. Organic bulk heterojunction (BHJ) solar cells have attracted much attention due to their advantages, such as light weight, low-cost fabrication, and flexibility [2-4]. However, there still remain several dilemmas such as loss of materials during spin coating and difficulty in controlling thicknesses of active layers. Ikawa et al. recently reported a simple way to deposit organic semiconductor solutions onto hydrophobic surfaces by push coating processes [5]. This push coating technique utilizes a layer of poly(dimethylsiloxane) (PDMS)-based stamp, and semiconductor solution materials are sandwitched by a PDMS stamp and a substrate. This method can further reduce amount of organic semiconductor materials in the solution processes.

In this research, BHJ solar cells were fabricated using push coating of a solution composed of poly[[4,8-bis[(2-ethylhexyl)oxy]benzo [1,2-b:4,5-b'] dithiophene-2,6-diyl] [3-fluoro-2-[(2-ethylhexyl)carbonyl] thieno[3,4-b]-thiophenediyl] (PTB7) and [6,6]-phenyl C71 butyric acid methyl ester ($PC_{71}BM$) after a layer of poly(3,4-ethylenedioxythiophene):poly(styrene sulfonate) (PEDOT:PSS) was deposited on an indium tin oxide (ITO)-coated glass substrate.

2. Experimental

The device structure investigated in this research was glass/ITO/PEDOT:PSS/PTB7: $PC_{71}BM$/LiF/Al. The active layer was deposited by push coating a solution in which 10 mg of PTB7 and 15 mg of $PC_{71}BM$ were dissolved in 1,2-dichlolobenzene. The solar cells were evaluated using a solar simulator under AM1.5 illumination.

Figure 1 shows the deposition processes of PTB7:$PC_{71}BM$ active layer by push coating. Only 5 µl of the PTB7:$PC_{71}BM$ dichlorobenzene solution was dropped on the PEDOT:PSS deposited ITO glass surface with a dimension of 13 x 19 mm^2. Then, the surface was covered by a PDMS stamp layer that was glued on a glass substrate using a double sided Kapton (polyimide) sticking tape [(see Fig. 2(a)].

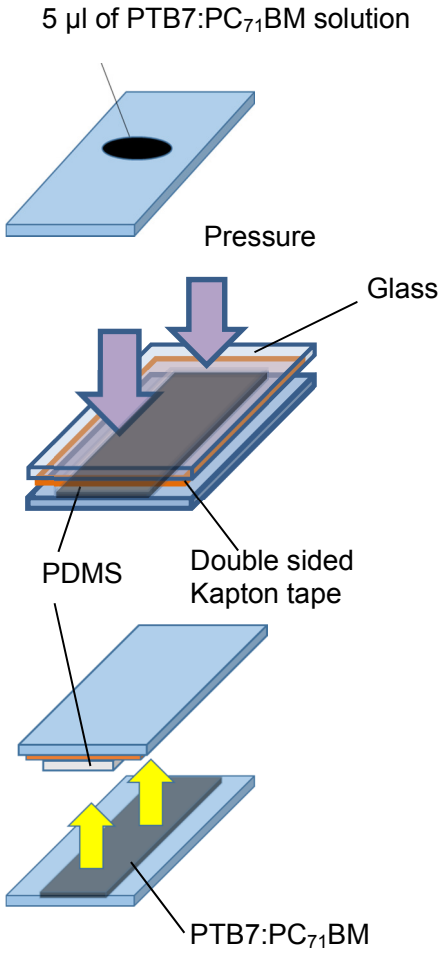
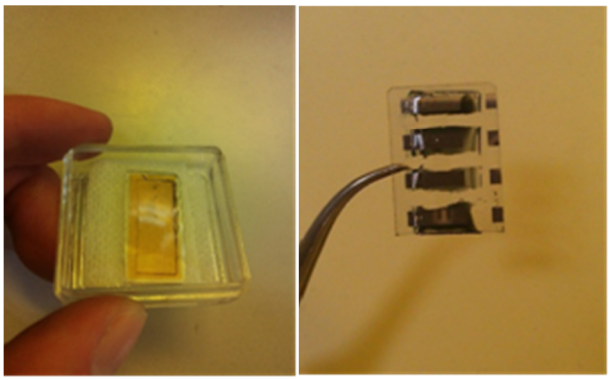


Fig. 1 Deposition processes of the PTB7:$PC_{71}BM$ active layer by push coating.

Then, a weight of 50 or 100 g was placed on the PDMS stamp. After removal of the stamp layer, the structure was placed in a Petri dish to solidify the PTB7:$PC_{71}BM$ layer for nearly 30 min (solvent annealing) before it was transferred to a vacuum chamber to deposit a LiF layer and an Al layer to form the cathode layer. Figure 2(b) shows the fabricated four sets of solar cells. It should be noted that the amount of the PTB7:$PC_{71}BM$ solution was only 10% of the volume needed for spin coating of PTB7:$PC_{71}BM$ (typically 50 µl) and that the PTB7:$PC_{71}BM$ layer extended on the total ITO surface area.

Note that the active layer and PEDOT:PSS extended on the total substrate area, and the unnecessary areas of the active layer were wiped out to isolate the devices.



(a) (b)

Fig. 2 Photographs of (a) PDMS stamp placed on a patterned ITO glass substrate with an area of 13 x 19 mm^2, and (b) fabricated 4 sets of solar cells.

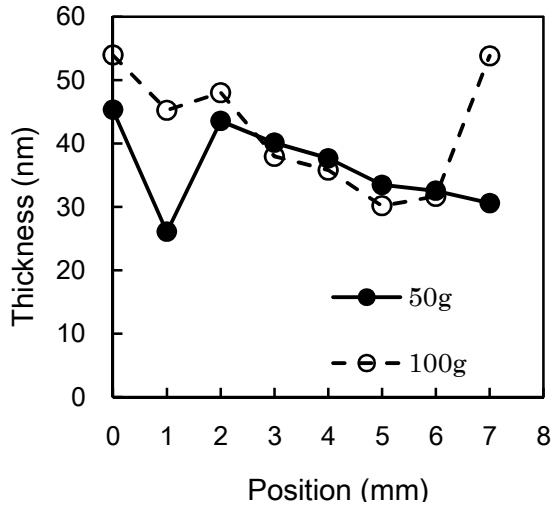


Fig. 3 Thickness variation of PTB7:$PC_{71}BM$ active layers deposited on PEDOT:PSS coated silicon substrate as measured by ellipsometry. The weight of 50 or 100 g was used.

3. Results and Discussion

Figure 3 shows the variation of the active layer thickness with the position on a PTB7:$PC_{71}BM$ coated silicon substrate as measured by ellipsometry. The thickness variation ranges between 25 and 55 nm, and it seems almost independent of the pressing pressure. The Thickness variation may be related to the surface roughness of the PDMS stamp.

Figure 4 shows the current density vs voltage (*J-V*) characteristics of the PTB7:$PC_{71}BM$ solar cell measured in the dark and under 100 mW/cm^2 illumination. The short circuit current density J_{sc} was 8.05 mA/cm^2, and the open circuit voltage V_{oc} was 0.803 V. The fill factor (FF) was 0.41. The power conversion efficiency (PCE) was 2.65%.

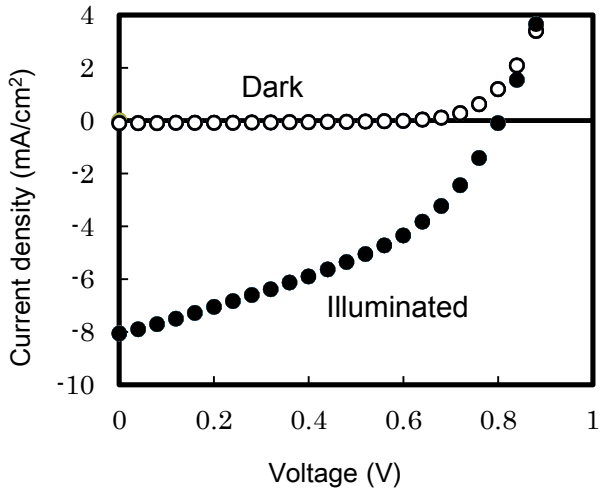


Fig. 4 Current density vs voltage characteristics of the PTB7:$PC_{71}BM$ solar cell in the dark and under illumination.

3. Conclusions

A bulk heterojunction solar cell based on PTB7:$PC_{71}BM$ was fabricated utilizing the push coating technique. The fabricated solar cell exhibited the short circuit current of 8.05 mA/cm^2, open circuit voltage of 0.803 V, fill factor of 0.41, power conversion efficiency of 2.65 %.

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