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The effect of substrate temperature on the active layer for spray-deposition process in organic solar cells

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Abstract. In this paper, we fabricated organic solar cells using spray-coating with substrate heated method. We heated substrate temperature to 50 °C, 100 °C, and 150 °C respectively, during spray-coating process and observed different morphologies of the active layer. The difference of morphologies affected the performance of the organic solar cell. One of these samples, substrate heated as 150 °C, showed an open voltage of 0.61 V, short current density of 20 mA/cm^2 and power conversion efficiency of 3.84%.

Key words

Spray-coating, substrate heating, organic solar cell

1. Introduction

Shortage of energy by the exhaustion of the earth's natural resources made people look for new energy which can supply the demands for modern society. Solar energy which is sufficient to supply, harmless, free from pollution and having endless capacity is emerging alternative suggestion and regarded as an essential source of energy by many developed nations - use huge sum of investment via research facility – and try to make the material at a stage of practical use. So several kinds of solar cells are being developed[1]-[7]. Among them, there is a solar cell, which is processed via silicon, available as commercialized item with some advantages; considerable amount of efficiency of 20%, long life expectancy[1],[2]. Nevertheless, many research facilities strive to make a step further in developing 'organic solar cell'. Organic solar cell is regarded as an energy source that will replace the silicon based solar cell becouse it could be processed by solution process[1], [9]-[13]. The solution prcess is implementable to fabricate low cost and large-area structure by easy manufacture process like spin coating, ink-jet printing, knife-over-edge coating, slot-die coating and screen printing process[14]-[18]. One of those fabrication methodes, spray-coating method, compared with spin coating, consumes less solution and has no restriction to select substrate that have possibility to be flexible device and fabricated by roll-to-roll process[18]-[20].

In this study, we fabricated organic solar cells using spray-coating method in different substrate heating temperature of 50 °C, 100 °C, and 150 °C, and then we investigated the morphology of the active layers in each condition and measured performance of OSCs.

2. Experimental

In this study, the organic solar cells were fabricated through this process. The active solution to be formed photoactive layer by spray-coating method have conjugate polymer-fullerene derivative compounds, which is known as bulk heterojunction(BHJ) structure. As donor, regioregular(rr) poly(3-hexylthiophene) (P3HT; Sigma-Aldrich, St. Louis, MO) was used and phenyl-C71-butyric-acid-methylester (PCBM; ADS, Quebec, Canada) was used as acceptor, 30 mg/ml at weight ratio 1:1 in Dichlorobenzene(DCBZ), which was prepared in room temperature and stirred for 24 h. Indium tin oxide(ITO) patterned glasses(sheet resistance of below 20 ohm/square) of 30 mm by 30 mm were cleaned in acetone, methanol and deionized water, in that order. The cleaned glasses were blown with N_2 gas and dried at 150 °C for 10 min, after that modified Poly (3,4-ethylenedioxythiophene)–polystyrene sulfonate (PEDOT:PSS; Clevios PH500) was spin-coated at 3000 rpm for 30 sec for form thickness of 24 nm on the cleaned ITO glass. Active layer was sprayed for 20 sec onto PEDOT:PSS layer annealed in 150 °C for 10 min, in conditions of the distance from spray nozzle to substrate was 20 cm and the sprayed pressure of N_2 was 0.1 MPa, when the substrate was heated to 50 °C, 100 °C, and 150 °C by hotplate respectively. Finally, Al was evaporated 150 nm as cathode on the active layer and post-annealed at 150 °C for 10 min. The active area of the fabricated organic solar cell was 0.09 cm^2.

The morphology roughness of active layer could be showed by using confocal laser scanning microscope (CLSM; Olympus, Tokyo, Japan), because it can display surface depending on the focus distance, and optical microscope also used. To measure the performance of the fabricated OSC, solar simulator was prepared in condition of AM 1.5 G, 100 mW/Cm^2 of xenon arc lamp which is calibrated by reference cell and filter, when I-V