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Morphological investigation of polymer solar cell layers using atomic force microscopy and Raman spectroscopy

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Abstract.

In the present work, the photoactive layer of blended of poly (3- hexylthiophene) (P3HT) and [6,6]-phenyl C61-butyric acid methylester (PCBM) based on BHJ concept was used to produce PCS. The configuration of Ag/MoO_3/ P3HT:PCBM/ZnO/ITO/Glass was used. Confocal Raman measurements and Atomic Force Microscope (AFM) were carried out at room temperature to figure out the morphology of PSC layers. Raman spectra shown that the strongest peak for ZnO thin film was at 437 cm^{-1} and the most intensive Raman peak of P3HT:PCBM photoactive layer was observed at 1442 cm^{-1}. Moreover, other Raman peaks for both ZnO and P3HT were clearly observed in the Raman spectroscopy results. The photovoltaic (PV) performance of PCS was evaluated by using the current density-voltage (J-V) measurement under AM 1.5 illumination. The power conversion efficiencies (PCE) of PSC was measured as 3.74 %. Additionally, the device exhibited a short-circuit current (J_{SC})) of 9.95 mA/cm^2, open-circuit voltage (V_{OC}) of 0.57 V and fill factor (FF) of 66%.

Keywords: Polymer Solar Cells, P3HT:PCBM, Sol-gel method, Raman Spectroscopy, Atomic Force Microscope (AFM).

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Recently, polymer solar cells (PSC) have attracted considerable attention due to the need to develop a clean, cheap, flexible and sustainable renewable energy source. Polymer based bulk heterojunction (BHJ) PV solar cells consist of electron-donating polymers and electron-accepting fullerene derivatives[1]. One of the promising photoactive materials in PSC is a mixture of P3HT as the donor and PCBM as the acceptor. The photoactive layer of a PSC absorbs the light and leads to the generation of excitons, which can separated into free charges at donor/acceptor interfaces by transferring the electron from donor to the acceptor and the hole from acceptor to the donor[2]. The power conversion efficiencies (PCE) of a PSC based on BHJ is therefore largely dependent on the local nanoscale organization of the photoactive layer in all three dimensions. Therefore, the morphology of the photoactive layer affects the efficiency of the PSC, as it strongly affects the order of the crystal and phase separation. The PCE of devices with blended P3HT:PCBM layer has been reported in between 2 and 5%[3–5].

In the study, the inverted configuration of Ag/ MoO_3/P3HT:PCBM/ZnO/ITO/Glass was used to produce PCS. The metal oxide layer of ZnO as an electron transport layer was spin-coated on top of the ITO coated glass substrate via sol-gel method. Commercially purchased P3HT and PCBM (1:1 wt-ratio) were diluted in dichlorobenzene solvent to obtain the polymer mixture. Then, polymer mixture was deposited on top of the ZnO via spin coating technique. MoO_3 as a hole-collecting layer and Ag as a top metal electrode layer were thermaly deposited on the P3HT:PCBM layer. In order to understand morphology of PSC layers, confocal Raman (Nd:Yag laser with 532 nm wavelength) and AFM measurements at room temperature were performed. Raman spectra shown that the strongest Raman peak of ZnO thin film was at 437 cm^{-1} which was assigned to the E_2 (LO-high) mode and the most intensive Raman peak of P3HT:PCBM photoactive layer was observed at 1442 cm^{-1} which was assigned to the symmetric C=C stretching. Moreover, other Raman peaks for both ZnO and P3HT were clearly observed in the Raman spectroscopy results. The J-V measurement under AM 1.5 illumination was carried out to measure photovoltaic device performance of solar cell. The PSC device exhibited PCE of 3.74 %, a short-circuit current (J_{SC})) of 9.95 mA/cm^2, open-circuit voltage (V_{OC}) of 0.57 V and fill factor (FF) of 66%.

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