Influence of active layer processing on electrical properties and efficiency of polymer-fulleren organic solar cells

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Polymer-fullerene organic solar cells are inexpensive source of renewable electrical energy with efficiency (PCE) increasing systematically every year (PCE=8.4 % in 2018 [1]). Their active layer is typically in form of bulk heterojunction (BHJ) - a nanoscale blend of polymer (donor) and fullerene (acceptor) materials. Constituents of organic cells are solution-processable in contrast to sophisticated semiconductor technology, and the whole structure can be flexible and semi-transparent, which opens possibilities of application in new fields. However, the serious disadvantage of organic solar cells on the way to their commercialization is relatively low efficiency and low stability. For this reason, attempts to improve these parameters are carried out on a large scale.

In the presented paper we studied polymer-fullerene organic solar cells, in particular the influence of active layer processing methods on their efficiency. Although the tested techniques are known to some extend from literature [2], the comprehensive comparative studies are lacking. The studied BHJ layers consisted of a commercially available conjugated polymer: P3HT or PTB7, and fullerene derivative $PC_{60}BM$. We used mostly the standard glass/ITO/PEDOT:PSS/active layer/Al structure, so photocurrent generated in the active layer led to collection of electrons by Al cathode and holes by ITO anode. Additionally, inverted cells with glass/ITO/TiO_2/active layer/Au structure were also prepared and characterized. Main steps of photocurrent generation: absorption of photons leading to electron-hole pair generation, dissociation of electron-hole pairs and transport of free carriers to electrodes, take place in BHJ active layer. Therefore, it is obvious that the method of active layer processing influencing its molecular structure, and as a consequence its carrier mobility, has a decisive influence on the obtained solar cell efficiency.

The polymer-fullerene blend dissolved in chlorobenzene was spincoated on substrates, and the obtained layers were then processed as spincoated or annealed in argon or in vapors of the organic solvent prior to the electrode deposition. Pure active layers were characterized by optical absorption spectroscopy and electrical resistivity measurements. I-V characteristics under illumination of AM 1.5G solar light simulator were measured for the respective cells to determine their electrical parameters and efficiency. Photocurrent spectra allowed to compare spectral response of the cells. Exciton dissociation and time of carrier transfer to the acceptor were observed by time resolved photoluminescence spectroscopy. TEM, AFM studies, and measurements of hole and electron concentration are in progress. The main result of the studied processing methods and consequently their improving is decrease of resistivity of active layer and increase of the respective cell efficiency. It seems that organic materials perform better in solar cell structures when they are covered with Al soon after deposition. The important question is what kind of molecular modification (most probably related to presence of solvent and/or inherence of reactive carbon double bonds in BHJ components) takes place during drying and crystallization. This is a subject of our current research.

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