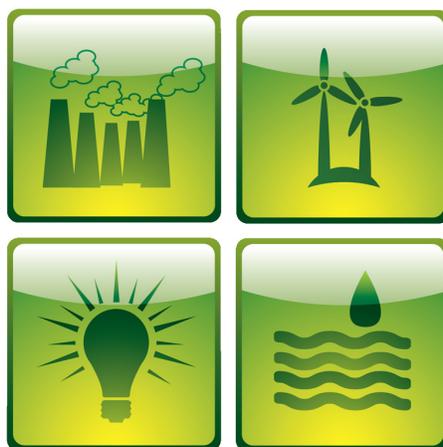




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Potential Fabrication Processes for Inverted Organic Solar Cells



E-Futures

Mini-project Report 1

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1.0 Introduction

It is generally found in organic solar cells (OSCs) that conjugated polymers having differing surface energies vertically phase separate, with the lower surface energy component tending to segregate at the air interface thus causing a concentration gradient of the high surface energy component adjacent to the substrate [8]. Due to the respective surface energies of P3HT and PCBM, a common polymer-fullerene derivative blend, being 27 mN/m² and 38 mN/m² the standard fabrication procedure for OSCs produces the inverse of what is ideal for device performance, owing to P3HT inhibiting selective electron collection. Therefore fabricated devices have to be thermally annealed in order to correct this imperfection which is shown to increase the concentration of PCBM at the cathode interface from approximately 31% to 72% which thus enhances photovoltaic performance [8] [9].

With the onus regarding OSCs on mass production and reel to reel processing, ease of production is paramount, and in order to maximise efficiency in terms of both device production and mass manufacture, potentially huge energy savings could be gained from the removal of the thermal annealing stage in device fabrication [10]. In this report the inverse of what is currently deemed the norm in OSC production will be explored, by starting with a low work function metal cathode substrate and spin coating polymer layers building up to a functioning OSC.

2.0 Experimental: Device fabrication

In order to assess the comparative performance of such inverted devices, standard devices were fabricated in conditions alike in order to promote a true comparison.

For standard devices a layer of 0.45 µm filtered PEDOT:PSS was spin coated at 5000 rpm onto ITO coated glass substrates which were then annealed on a hot plate at a temperature of 125 °C for 1 minute. A layer of 0.45 µm filtered 1:0.8 P3HT:PCBM was then spin coated at 2000 rpm forming the active layer of the devices and following that the devices were solvent annealed for 5 minutes in an atmosphere of chlorobenzene. The device cathode taking the form of silver nanoparticle coated plastic sheeting was cut into two 3 mm by 15 mm strips which were both applied with pressure to the active layer coating before being encapsulated using a glass coverslip and a UV cured epoxy to protect the active layer from degradation.

The fabrication process for the inverted devices differed slightly in relation to the spin coating of the P3HT:PCBM active layer. The P3HT:PCBM active layer was spin coated onto the 3

mm by 15 mm silver nanocoated cathode strips rather than on top of the PEDOT:PSS layer coating the ITO glass substrates. The cathode strips were then applied with pressure to the PEDOT:PSS and ITO coated glass before being encapsulated.

3.0 Results and discussion

Prior to device fabrication initial tests were conducted on the interaction between polymer layers when orientated in the inverted structure. This was carried out by bar spreading a 4 μm layer of P3HT:PCBM onto a sheet of aluminium foil using a wired bar of wire diameter 50 μm , on top of which was spread a PEDOT:PSS layer of the same thickness.

The interaction between the P3HT:PCBM and aluminium was seen to be favourable, the P3HT:PCBM layer showing to sufficiently wet the aluminium foil, forming an apparent uniform structure. However, the PEDOT:PSS layer was not shown to sufficiently wet the spread P3HT:PCBM layer, forming noticeable beads on the surface of the P3HT:PCBM coated aluminium and in turn highlighting an unfavourable interaction.

This is likely to be due to the hydrophilic nature of PEDOT:PSS and respective hydrophobic nature of the organic P3HT:PCBM layer and therefore proves the surface tension of PEDOT:PSS to lie outside the wetting envelope of the spread P3HT:PCBM. In order to counter this issue further treatment to the P3HT:PCBM active layer needs to be carried out in order to allow the two layers to interact successfully [14]. The general principle of this process can take two different forms; either by increasing the surface energy of the active P3HT:PCBM layer, or by reducing the surface energy of the PEDOT:PSS layer. Commonly it is found that a composite of the two brings about a favourable result, both increasing the surface energy of the P3HT:PCBM active layer and reducing the surface energy of PEDOT:PSS. The PEDOT:PSS layer can be doped with non-ionic surfactant Zonyl FS 300 in concentrations between 0.0001 – 1 wt% and also with IPA in the range of 0.1 and 50 wt%. Treatment with the non-ionic surfactant Zonyl FS 300 avoids the degradation of the electrical properties PEDOT:PSS holds and the IPA reduces the overall surface energy. However, in order to promote the PEDOT:PSS to lie within the wetting envelope of the spread P3HT:PCBM active layer, the surface of the active layer also needs to be treated with a pulse of oxygen plasma; typically a 30 W pulse for 10 seconds proving to facilitate the wetting process [13].

Due to the added difficulty and respective treatment needed of the P3HT:PCBM active layer, this treatment was not carried out and further avenues were explored; specifically the

possibility of producing two separate layered substrates and combining the two as a dual substrate to produce a functioning inverted OSC. The two layers in question were an ITO coated glass substrate supporting a thin film of spun PEDOT:PSS (5000 rpm), and a transparent conductive sheet of silver nanoparticle coated plastic holding a thin film of spun P3HT:PCBM (2000 rpm).

The P3HT:PCBM was shown to interact favourably with the silver coated plastic but was not easily cleaned of the spun P3HT:PCBM layer using IPA as standard ITO glass substrates are shown to be. The IPA was shown to be detrimental to both the spun P3HT:PCBM and the silver nanoparticles, leaving a bare plastic sheet freed of both materials. However, an alternative method using adhesive tape as a cathode mask was proven successful, leaving a defined interface between the spun P3HT:PCBM and the silver nanoparticle framework.

The fabrication procedure outlined in section 2.0 was successfully carried out but failed to produce any substantial results when tested of their I-V characteristics; both for the standard and inverted devices fabricated. Due to the ITO / PEDOT:PSS interface and the PEDOT:PSS / P3HT:PCBM interface both being favourable when dealing with the standard devices, it is thought that the P3HT:PCBM / Silver interface was the failing issue. Similarly in the case of the inverted devices, the ITO / PEDOT:PSS interface and the P3HT:PCBM / Silver interface were both shown to be favourable, so it is suggested that the PEDOT:PSS / P3HT:PCBM interface was the failing issue when discussing the inverted devices.

4.0 Conclusion

It is the high intimacy of the evaporated aluminium cathode with the spun P3HT:PCBM active layer that ensures good electrical qualities in standard fabricated OSCs and in turn the production process taking place as a single substrate. In order to successfully produce an inverted structure it is imperative that the device is fabricated in a like manner using a single substrate, starting with a low work function cathode building up as a true inversion. However, the unfavourable interaction between P3HT:PCBM and PEDOT:PSS layers proves this to be a difficult process to undertake unless further treatment to the P3HT:PCBM layer is carried out as detailed in section 3.0. Further to this there is an added complication in the form of the application of both an ITO layer and a transparent protective glass coating, which regrettably proves the feasibility of the process as a whole to be low.

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