A roll-to-roll process to flexible polymer solar cells: model studies, manufacture and operational stability studies

An inverted polymer solar cell geometry comprising a total of five layers was optimized using laboratory scale cells and the operational stability was studied under model atmospheres. The device geometry was substrate-ITO-ZnO-(active layer)-PEDOT:PSS-silver with P3HT-PCBM as the active layer. The inverted devices were compared to model devices with a normal geometry where the order of the layers was substrate-ITO-PEDOT:PSS-(active layer)-aluminium. In both cases illumination was through the substrate which requires that it is transparent. Both device types were optimized to a power conversion efficiency of 2.7% (1000 W m$^{-2}$, AM1.5G, 72 ± 2 °C). The devices were operated under illumination while being subjected to different atmospheres to identify the dominant modes of degradation. Dry nitrogen (99.999%), dry oxygen (99.5%), humid nitrogen (90 ± 5% relative humidity) and ambient atmosphere (20% oxygen, 20 ± 5% relative humidity) were employed and both device types were found to be stable in a nitrogen atmosphere during the test period of

200 hours. The devices with a normal geometry where an aluminium electrode is employed gave stable operation in dry oxygen but did not give stable device operation in the presence of humidity. The inverted devices behaved oppositely where the less reactive silver electrode gave stable operation in the presence of humidity but poor stability in the presence of oxygen. The inverted model device was then used to develop a new process giving access to fully roll-to-roll (R2R) processed polymer solar cells entirely by solution processing starting from a polyethyleneterephthalate (PET) substrate with a layer of indium-tin-oxide (ITO). All processing was performed in air without vacuum coating steps and modules comprising eight serially connected cells gave power conversion efficiencies as high as 2.1% for the full module with 120 cm$^2$ active area (AM1.5G, 393 W m$^{-2}$) and up to 2.3% for modules with 4.8 cm$^2$ active area (AM1.5G, 1000 W m$^{-2}$).
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