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# OPTO-ELECTRICAL CHARACTERISATION OF CARBON-BASED THIN FILM SOLAR CELLS OF EXCITONIC DESCENT IN BULK HETEROJUNCTION ARCHITECTURE

**Lordwell Jhamba (589986) – Thesis Abstract**

Organic photovoltaic cells (OPVCs) continue to be intensively investigated due to their low cost and high utility potential. However, their low power conversion efficiency (PCE) has limited their full commercialization. The efficiency of the OPVCs is dependent on charge injection mechanisms, morphology and their underlying kinetics and energetics. Understanding the mechanisms that influence the efficiency of conjugated polymer solar cells is therefore pivotal to the enhancement of the devices' performance and the implementation of low priced fabrication technologies. In this regard, we investigated the dependence of the efficiency of organic solar cells on light intensity (*I*) using thin films of P3HT:PCBM blends, sandwiched between ITO/PEDOT:PSS and Al electrodes, the assembly of which was subjected to differing illumination intensities. Since charge transport through interfaces of such devices depends on charge carrier injection mechanisms, charge injection mechanisms at metal-organic active layer (here-in referred to as 'metal-active layer') interfaces in the devices were studied under changing external voltage bias. Use was made of the Richardson-Schottky (R-S) thermionic emission currents and those due to Fowler-Nordheim (FN) tunneling in generating complete J(V) curves which were compared with those obtained through combined graphical representations of the variation of open circuit voltage ($V_{oc}$) and efficiency ($\eta$) with light intensity. This led to the findings that under forward bias, the metal- active layer junction of an organic solar cell becomes ohmic after a certain threshold electrical field ($E_{thresh\ tunn}$) associated with quantum mechanical tunneling of charge carriers through the device's respective interfaces. Furthermore, we found that the open circuit voltage at which efficiency starts to decrease ($V_{oc\ thresh\ eff.\ decay}$) approximates in magnitude the internal threshold open circuit voltage ($V_{oc\ thresh\ tunn}$) at which FN quantum mechanical tunneling starts within the device at the electrode (a metal)- active layer interface.

Explanatory findings were that for photoactive P3HT:PCBM composite devices, increasing white light intensity incident on them increases the photogenerated open circuit voltages that increasingly bias them with voltages, which with effect from the thresholds due to opto-electrical mechanisms at the devices' metal-active layer interfaces, are sufficient to greatly increase the dark currents. The increased dark current reduces the short circuit current density significantly, which in turn inflicts a likewise decrease in the power conversion efficiency of the devices.

The theme of the next set of investigations was on the characteristic changes in the opto-electrical properties of the 1:1 blend of P3HT:PCBM with thickness of the active layer in ITO/PEDOT:PSS/P3HT:PCBM/Al solar cells, with intentions of finding out their effect on the threshold voltage at which efficiency starts to decrease ($V_{threshold\ eff\ decay}$) and also for purposes of optimizing the thickness of the active layer. To obtain different active layer thicknesses (ALTs), each sample was cast at different spin-coat speeds. The thicknesses determined by surface profilometer through variation of spin-coating speeds were 61.5, 69.4, 77.1 and 84.5 nm. Whilst this study's empirical results demonstrated optimal performance at approximately 77.1 nm active layer thickness, the overall findings have been that the existence of a static universal optimum active layer thickness is not practical. Such an optimum rather exhibits contextual dependence.

Annealing investigations revolved around attempts to empirically broaden and deepen the presently scarce understanding of the fundamental mechanisms defining thermal annealing process in conjugated polymers. To achieve this, we studied the opto-electrical effects of post-fabrication thermal annealing of bulk heterojunction ITO/PEDOT:PSS/P3HT:PCBM/AL solar cells at different heat treatment temperatures in the range 65 – 180 °C. The photoactive P3HT:PCBM layer was cast in air. The effect of air exposure has been found to chemically dope the polymer. Dedoping brought in by thermal annealing has been demonstrated to be responsible for the aggravated drop of efficiency. Summary findings lead to the generalisation that annealing of polymers is a two-step process, the first of which causes a decrease in conductivity, followed by its increase. Although impurity dedoping decreases 'under dark' current density in certain regions of the active P3HT:PCBM composite layer during annealing, it has beneficial aftermaths, some of which surface upon illumination of the P3HT:PCBM-based solar cell. When illuminated, photogenerated current density in the illuminated device immediately increases. This happens so, because of less electron capture and immobilization during illumination of the annealed device. Morphologically, thermal annealing has been found to enhance the formation of the deeply quenched bicontinuous network at the nanoscale between P3HT and PCBM, leading to high efficiency devices. We propose that the beneficial structure formation in P3HT:PCBM blends, is initiated by the crystallization of P3HT as it segregates PCBM, possibly to the amorphous P3HT. Thermal annealing renders significant enhancement in Jsc, Voc and FF of the annealed device. The optical absorbance was found to increase with increase in annealing temperature.