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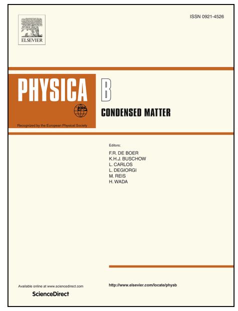

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Near-field enhanced performance of organic photovoltaic cells

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Metal nano-particles (NPs) have been successfully synthesized by the reduction of $Ag@Cu_2O$ with the aid of surfactant PVP and excessive reducer ascorbic acid in ambient conditions. The composition and structures of the NPs were characterized by scanning and tunnelling microscopies (SEM and TEM). The synthesized nano-particles were employed as solar absorber in thin film organic photovoltaic (OPV) with the view to exploit the effect of local surface plasmon resonance (LSPR) of the metals. As a consequence, substantial improvement on the major solar cell parameters were measured by the incorporation of Ag@Cu NPs in the P3HT:PCBM based photo-active medium. The power conversion efficiency of the solar cell increased by 103 % compared to those devices fabricated without metal nano-particles. The observed balanced charge transport, in the current experiment, is attributed to presence of metal nano-particles in OPV devices which are responsible for near field enhanced photons scattering in the medium.

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Keywords: nano-particles; plasmon resonance; photovoltaic; core-shell; charge transport

I. INTRODUCTION

Solution processed bulk heterojunction (BHJ) organic solar cells have received significant scientific interest due to their low cost device fabrication, light weight and flexibility [1–4]. However, improving the overall device performance, without compromising the low cost of device fabrication and sufficient life time, is one of the major challenges facing OPVs today [5]. Several mechanisums have been tested to improve photons harvesting in OPV by way of enhanced optical absorption and efficient mechanisms to collect photogenerated currents. These include but not limited to the use of suitable solvents, thermal annealing, solvent additives and incorporation of metal nanoparticles. The effeicent harvesting of solar radiation is one of the fundamental requirements to realize high power conversion in a solar cells [6]. Ideally, an increasing the thickness of the photoactive layer would have been the easiest route to enhance absorption through increased optical path length to harvest more photons. However, the exciton diffusion length in polymer medium is very short ($\sim$ 10 nm) that limits the size of the solar absorber film thickness to the range of (120 - 250) nm [6–9]. As a consequence, most of the incident photon in OPV cell remain undetedcted. On the otherhand, the incorporation of metallic nanoparticles in the photoactive medium of OPV serves as a mechanism to trap electromagnetic radiation by way of light scattering that resulted in enhanced optical absorption and overall device performances [7, 10]. This would then assist in the realization of an efficient and thin film solar absorber in OPV.

Furthermore, the metal NPs in conjugated polymer medium are not only improve the conductivity of the composite layer but also expected to cause local surface plasmon resonance (LSPR) which would assist in the harvesting of photons. LSPR is the result of a collective oscillation of charges on the surface of metal nanoparticles due to the interaction with the incident electromagnetic fields [10]. The plasmon excitation is doubly beneficial for the solar cells which on one hand serve as strong scattering center of the incident photons, on the other, create strong local electric field in the vicinity of the particle that can assist in exciton dissociations [11]. In an effort to maximize the contribution of LSPR in OPV; a number of investigators employed the metal nanocomposites in the various layers of the device configurations, such as photoacive medium or/and in charge transport buffer layers between the active layer and electrodes [12–14]. In most cases, it was reported that metal nano-particles have positively contributed to improve device performance in thin film organic solar cells. Similar observations have been reported on the use of metal nanoparticles in the preparation of dye synthesised solar cell (DSSC) [13–15]. The optical absorptions of the nano-composites resulted from LSPR effect are dependent on the size, shapes, concentration and uniformity [16–19]. The most investigated metals that exhibit plasmonic resonance modes are gold, silver and copper which have optical absorbance in the visible or near infra-red region of the electromagnetic spectrum [10, 20]. For effective use of LSPR in OPV, the optical absorbance of the nanoparticles preferably be in region of visible and near infrared part of the spectrum where the emission intensity is high. Nontheless, it is reported that the incorporation of plasmonic Au and Ag nanoparticles into OPVs has significantly increased optical absorption which yields enhanced power conversion efficiencies (PCE) of the solar cell[20–23]. However,

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