Accepted Manuscript

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PII: S0925-8388(17)30697-7

DOI: 10.1016/j.jallcom.2017.02.249

Reference: JALCOM 40977

To appear in: *Journal of Alloys and Compounds*

Received Date: 12 January 2017

Revised Date: 18 February 2017

Accepted Date: 23 February 2017

Please cite this article as: X.G. Mbuyise, E.A.A. Arbab, K. Kaviyarasu, G. Pellicane, M. Maaza, G.T. Mola, Zinc oxide doped single wall carbon nanotubes in hole transport buffer layer, *Journal of Alloys and Compounds* (2017), doi: 10.1016/j.jallcom.2017.02.249.

Zinc oxide doped single wall carbon nanotubes in hole transport buffer layer

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(Dated: February 23, 2017)

Zinc oxide doped single wall carbon nanotubes (ZnO:CNT) are incorporated in PEDOT:PSS aqueous solution to serve as a hole transport buffer layer in the preparation of thin film organic solar cells (TFOSC). The solar cells were fabricated according to bulkheterojunction design whose photoactive layer is composed of poly (3 hexythiophene) (P3HT) and [6,6]-phenyl-C61-butyric acid methyl ester (PCBM) blend. Significant improvement in harvesting photo-generated currents and low series resistances were observed which lead to higher power conversion efficiencies compared to the devices without ZnO:CNT. The optical properties and surface morphologies of ZnO:CNT/PEDOT:PSS hole transport layers are investigated and compared with the changes in the measured parameters of the solar cells. The power conversion efficiency of the devices increased by nearly 116%, 63% and 42% for ZnO:CNT loading at 2.5 %, 5 % and 10 % by weight, respectively, from the devices that uses only PEDOT:PSS as a hole transport layer. Furthermore, a complete recovery of device performance was found by storing the device in warm nitrogen atmosphere.

PACS numbers: 73.61.ph; 73.61 Wp

Keywords: Organic solar cell; Hole transport layer; post-annealing; optical properties; morphology; OSCs stability.

I. INTRODUCTION

Solar energy is the most abundant source of energy on Earth which is pouring on our planet at the rate received every minute suffices to cover the world's energy demand for a year [1–4]. Of all the energy produced, on a daily bases today, solar energy constitute about 1 % while substantial fraction comes from the use of nonrenewable energy sources which are not sustainable, environmental unfriendly and could even endanger the mere existence of life on Earth [5–7]. The conventional solar panels produced using inorganic materials are relatively expensive and can only be assembled on rigid surfaces. However, the introduction of conjugated polymers in organic electronics opens up a new dimension of materials as a solar absorber. The advantages of thin film organic solar cells over the inorganic one are low device manufacturing cost, light weight, flexibility and compatibility with roll-to-roll manufacturing techniques [8–11]. However, TFOSCs are also suffer from low power conversion efficiencies and environmental instability in the presence of oxygen and moisture [12].

Water soluble poly(3,4-ethylene dioxythiophene):poly (styrene sulfonate), known as PEDOT:PSS, is the most common hole transport layer (HTL) used in the preparation of thin film organic solar cells. Neverthless, the ITO/PEDOT:PSS interface is highly unstable due to the corrosive (acidic) and hygroscopic nature of PEDOT:PSS which contribute to poor device performance and instability under ambient environment [13]. On the other hand, the fevorable optoelectronic properties of carbon nanotubes (CNTs) have attracted more research interest for photonic applications. CNTs are known for their high electrical conduction, carrier mobility and a wide optical transmittance which can be tunable by the process of doping. Moreover, CNTs posses mechanical flexibililty suitable for roll to roll device manufacturing techniques [14–16]. Such attractive features of CNTs often regarded as a solution for the challenges in the charge transport process in bulk-heterojunction (BHJ) organic solar cell. This is due to the fact that well dispersed carbon nanotubes in BHJ photoactive medium can create a highly conductive charge percolation pathways and improve charge collection [17]. However, there is very little progress made so far in the effective utilization of CNTs in photonic devices.

In this investigation, we employed zinc-oxide (ZnO) doped single wall carbon nanotubes in PEDOT:PSS hole transport buffer layer with the view to improve surface contacts and assist charge collection in organic solar cell. Zinc oxide is one of the most popular functional metal oxides in the preparation of thin film organic solar cells due to its outstanding optical and electrical properties. It has a wide direct band gap, large exciton binding energy, excellent chemical and thermal stability fevorable for optoelectronic applications [5, 18, 19]. Pure ZnO is not suitable as a hole transport buffer layer in standard TFOSC structure because of the low valance band edge, but, it has been extensively used as an electron transport buffer layer in an inverted organic solar cell structure [20]. Meanwhile, ZnO has been used as a dopant molecule to tune the optoelectronic properties of several functional materials including carbon nan-

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