Improvement of inverted OPV performance by enhancement of ZnO layer properties as an electron transfer layer

Abstract

In order to achieve the cost-efficient scalability of flexible organic photovoltaics (OPVs), the optimization of the materials and printing processes is necessary. A normal OPV architecture is undesirable for a large-scale production due to the vacuum processing steps. Also, the use of high work-function anode materials (e.g. Ag ink) in inverted architectures enhances device stability. In order to print inverted OPVs of high functionality and stability, several parameters have to be optimized such as the surface morphology, thickness, roughness, surface energy and the electrical characteristics of the printed layers. The present study aims to optimize several parameters that enhance the layer quality and electrical characteristics of a fully gravure-printed OPV on a laboratory scale. To be more specific, the experimental methodology includes, at first, the investigatory printing of ZnO nanoparticle suspensions with differentiated concentrations on top of Polyethylene-Terephthalate (PET) and Indium Tin Oxide (ITO) substrate. A very cheap and commercially available ZnO suspension was chosen to be under study. The investigation of printed ZnO layers quality results in a decrease on nanoscale surface roughness and a rise on thickness and surface wettability with nanoparticle concentration. As next step for this work, the effect of nanoparticle concentration's variation on the electrical characteristics of an inverted OPV is studied. Diversified concentration is the only parameter that does not remain constant during the printing steps, so that its effects can be better discerned and understood. Every different nanoparticle concentration results in different J-V curves that, additionally, allow the extraction of the electrical parameters of the Photovoltaic Device. After assessing the respective results, it is concluded that OPV performance gets enhanced when nanoparticle concentration rises up to a certain critical percentage, above which, ZnO layer thickness get too high values to allow high performances. During this step, the impact of ZnO layer and surface properties on OPV performance gets under investigation. On top of that, the optimum concentration that maximizes OPV efficiency results in a ZnO layer thickness that needs to be compared with the according literature values. Subsequently, next goal of this study is to achieve optimum electrical OPV characteristics with lower ZnO layer thicknesses. Filtering ZnO suspensions prior to printing is a simple solution to that direction, since it successfully reduces ZnO layer roughness and slightly reduces layer thickness. Similar OPV devices were gravure-printed, yet at lower, filtered concentrations in order to track the correlation of OPV performance to modified ZnO layer thickness and roughness, as well as to find the optimum ZnO concentration. From corresponding J-V curves it is checked whether the optimized filtered concentrations yield low layer thickness and maximize OPV efficiency, hence fulfilling literature criteria. As a final step, since suitability of ZnO dispersion for Roll-to-Roll production is the long-term goal of this study, the impact of material cost and consumption with regard to gravure printing is under discussion. Thus, differences in J-V curves and the corresponding OPV characteristics per each ZnO concentration, either filtered or non-filtered are spotted and the two distinct cases that maximize OPV efficiency are selected. On the other hand, optimized ZnO concentrations with this suspension are compared with other two cases of another commercially available suspension which yields even lower thicknesses and also repeatedly high OPV performances.