Thin indium tin oxide nanoparticle films as hole transport layer in inverted organic solar cells

Tina Wahl, Sabrina Zellmer, Jonas Hanisch, Georg Garnweitner, Erik Ahlswede

PII: S0040-6090(16)30520-X
DOI: doi: 10.1016/j.tsf.2016.09.012
Reference: TSF 35461

To appear in: *Thin Solid Films*

Received date: 2 February 2016
Revised date: 5 September 2016
Accepted date: 5 September 2016

Thin indium tin oxide nanoparticle films as hole transport layer in inverted organic solar cells

Tina Wahl [a*], Sabrina Zellmer [b], Jonas Hanisch [a], Georg Garnweitner [b], Erik Ahlswede [a]

[a] Zentrum für Sonnenenergie- und Wasserstoff-Forschung (ZSW) Baden-Württemberg Industriestr. 6, 70565 Stuttgart, Germany

[b] Institute for Particle Technology and Laboratory for Emerging Nanometrology, Technische Universität Braunschweig, Volkmaroder Str. 5, 38104 Braunschweig, Germany

[*]electronic mail: tina.wahl@zsw-bw.de

Abstract

Indium tin oxide nanoparticles (ITO-NPs) were used as hole transport layer (HTL) in doctor-bladed inverted bulk-heterojunction organic solar cells. After the non-aqueous synthesis of ITO nanoparticles, a customized stabilization strategy was established. As result, ethylenediamine, a stabilizer with a low boiling point was used for an easy removal of the remaining organic compounds in the ITO-NP layer by a short annealing step at 120 °C. Furthermore, different post-processing treatments (thermal annealing and plasma treatment) on the ITO-NP layer were investigated to improve the electrical parameters of the solar cell. Using poly(3-hexylthiophen) as photoactive polymer, power conversion efficiencies of 3% were achieved with the incorporation of ITO-NPs as HTL, being almost as good as the efficiencies of the reference system where poly(3,4-ethylenedioxythiophene) was used as HTL.

Keywords: organic photovoltaics, hole transport layer, doctor blading, ITO nanoparticles, thin films, non-aqueous synthesis

1 Introduction

Solution processed organic solar cells have attracted great attention in the last years because of their potential of a large-scale and low-cost production as well as their fast increase in power conversion efficiencies (PCE) with almost 10% [1-6] and over 10% for single [7] and tandem cells [4, 8] and over 11% for tandem [9] and for triple cells [10, 11]. These organic solar cells are mostly built in the bulk-heterojunction (BHJ) structure, which consists of an interpenetrating network of a donor material, usually a conjugated polymer and an acceptor material, commonly a fullerene derivative.

There are mainly two types of device structures of BHJ polymer solar cells, the standard and the inverted structure. In the standard device architecture often indium tin oxide (ITO)/poly(3,4-ethylenedioxythiophene (PEDOT:PSS)/absorber/LiF/Al or Ca/Al is used. Unfortunately, these solar cells show a strong degradation under ambient conditions, mainly due to the acidic nature of PEDOT:PSS on top of the ITO electrode [12] and the highly oxidative LiF/Al or Ca/Al cathode. These problems can be overcome by the use of the inverted structure [13-15], where air-stable high-work-function metals (such as Ag) are integrated and the ITO/PEDOT:PSS-interface is avoided. As a result, a much better stability can be achieved [16]. For hole transport layers (HTL) normally thermally evaporated molybdenum oxide (MoO_3) [17-19] is used, but there are also reports about the application of solution-processed MoO_3 [20], PEDOT:PSS [21, 22], solution-processed MoO_3:PEDOT:PSS [23], tungsten oxide (WoO_3) [17, 18, 24], nickel oxide (NiO) [25], graphene oxide [19, 26], Nafion [27] and phosphomolybdic acid [28].

In this work we investigated the usage of indium tin oxide nanoparticles (ITO-NPs) as HTL, especially in inverted organic solar cells. Metal oxides are known to have better stability compared to organic materials and the ITO-NPs can be adjusted (for example in particle size) for different applications. ITO-NPs were mostly used to fabricate solution processed transparent ITO electrodes [29, 30], also