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Research Article

Optimization and characterization of doped photoactive layer P3HT: ICBA for organic optoelectronic applications

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ABSTRACT

A doped bulk heterojunction P3HT: ICBA active layer was studied, aiming at the effects of chromium chloride ($CrCl_2$) and Cobalt chloride ($CoCl_2$) doping. The study involved linear optical and electrical characterization to analyze the impact of these additives on the photoactive layer's performance. The electrical properties of doped P3HT: ICBA revealed enhancements with $CrCl_2$(5%wt), $CrCl_2$(10%wt), $CoCl_2$(5%wt), and $CoCl_2$(5%wt) (5%wt) by 8.5x, 11x, 10x, and 14x respectively, compared to pure P3HT:ICBA under dark/light conditions. This improvement is attributed to enhanced internal charge generation. The study also examined the effect of thermal treatment on the active layer from 20 °C to 65 °C under dark/light conditions. Additionally, the doped photoactive layer samples were tested as optical sensors under white, green, and red light, with a slightly higher optical response under white light. The findings confirm that doping P3HT: ICBA with $CoCl_2$ and $CrCl_2$ improves optical and electrical responses due to better charge transfer and generation.

1. Introduction

Due to the growth in achieving sustainability in all life sectors, intense studies are performed to conserve the environment and one of them is focusing on renewable energy systems [1,2]. A renewable energy field of research has developed in the last decades due to the necessity of reducing greenhouse gas emissions and the impacts of climate change [3,4]. Using solar energy compared to other sources can achieve many benefits as it offers a cost effective, non-contaminating, noiseless system and capability to support large-scale solar energy [5]. Over the last two decades, organic photovoltaic cells (OPVs) gained enormous attention from scientific researchers worldwide due to their semi-transparency properties and advantages in harvesting energy, roll-to-roll device fabrication, and being lightweight [6,7]. In general, OPVs consist of a sandwich contains a light absorber layer has donor/-acceptor material in between two bilayers (hole transfer and electron transfer layers), then for collecting holes comes an anode layer, and for electrons the cathode evaporated on top of all previous layers. A bulk heterojunction active layer structure generates a high-performance record [8]. The active layer blend (donor: acceptor) is dissolved in a common organic solvent such as chloroform (CF) or chlorobenzene (CB) to form a bulk-heterojunction (BHJ) morphology with a small exciton diffusion length of ~10 nm of organic materials and thus organized the maximize the D–An interface to get the highest charge separation performance with efficiency ~ 18 % [9–11]. A common BHJ active layer solar cell is P3HT: PCBM and it has a power conversion efficiency (PCE) of around 4 % [12,13] which achieved this performance by vapor annealing [14] and solvent [13]. However, the relatively small offsite between the lowest unoccupied molecular orbital (LUMO) of the acceptor (PCBM) and the highest occupied molecular orbital (HOMO) of a donor (P3HT) led to reducing open circuit voltage (V_{oc} ≈ 0.6 V) and creates a limitation on device improvement [13]. The next improvement step was introducing a new acceptor (a novel indene-C_{60} bisadduct (ICBA) to use with a donor material (P3HT) as it has a high LUMO energy level of 3.74 eV in comparison to PCBM leads to generate a relatively high V_{oc} ~0.8 V. In contrast to PCBM, ICBA has more facile preparation, higher solubility in many organic solvents such as Chloroform, Chlorobenzene, and Dichlorobenzene and it exhibits a high light absorption at a UV–visible region for improving the light-harvesting in OPVs devices [15,16]. In previous reports, P3HT: ICBA OPVs devices achieved around 7 % efficiency and after several optimization steps the device PCE has exceeded 7 % [17,18].

In this report, the P3HT: ICBA BHJ active layer has been prepared and then doped with (Cobalt chloride ($CoCl_2$) and chromium chloride ($CrCl_2$)) according to the following percentage (P3HT: ICBA blend, P3HT:ICBA: $CoCl_2$(5%wt), P3HT:ICBA: $CoCl_2$(5%wt), P3HT:ICBA:

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