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Enhanced Photovoltaic Performance via Co-sensitization of Ruthenium (II)-Based Complex Sensitizers with Metal-Free Indoline Dye in Dye-Sensitized Solar Cells

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Abstract: Co-sensitization is shown to be an effective method to improve the efficiency of dye-sensitized solar cells wherein ruthenium (ii)-based complex sensitizers (N749, N719) is co-sensitized with the metal-free indoline dye (D149), where photovoltaic efficiency of 5.40% is achieved by co-sensitized N749+D149 and efficiency of 4.94% is achieved by co-sensitized N719+D149. The assembled dye-sensitized solar cells were studied by UV-vis absorption measurements of dye solutions, the absorption spectra of the dye-sensitized TiO_2 film along with co-sensitized TiO_2 film and current–voltage characteristics. The co-sensitized based device exhibits better photovoltaic performance compared to the devices fabricated from individual sensitizers. Upon optimization, the device made of co-sensitized N749+D149 yielded J_{sc} = 13.6 mA/cm^2, V_{oc} = 690 mV, FF = 0.576 and η = 5.40% and the device made of co-sensitized N719+D149 yielded J_{sc} = 13.3 mA/cm^2, V_{oc} = 660 mV, FF = 0.563 and η = 4.94%. This demonstrated that the performance of co-sensitized devices is improved from that of the devices sensitized with either N749 (4.56%), N719 (4.24%) or D149 (4.06%) under the same fabrication conditions.

Keywords: Dye-sensitized solar cell; Co-sensitization; Ruthenium (II)-Based Complex Sensitizers; Metal-Free Indoline Dye; Enhanced Efficiency

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1 Introduction

Solar energy is considered one of the most positive ways to decrease the climate change resulting from the use of fossil resources for energy generation [1–4]. The low-cost as well as environmentally friendly properties of dye-sensitized solar cells (DSSC) make the DSSCs one of the most promising classes of photovoltaic cells for the conversion of photon energy to electricity [5]. DSSCs were first reported by O'Regan and Grätzel in 1991 [6]. A DSSC is composed of a working electrode in which mesoporous nanocrystalline TiO_2 is deposited on the surface and enclosed with a monolayer of dye molecules, a redox-couple electrolyte and platinized coated fluorine-doped tin oxide (FTO) glass substrate as counter electrode. When a photon strikes the surface of the photoanode, the incident photon energy is absorbed by a sensitizer on the nanoporous TiO_2 layer that ensures charge separation and the transfer of electrons from the excited dye molecule to the photoanode [7, 8]. The sensitizer is then regenerated by an electrolyte containing a redox-couple. The photosensitizer is one of the key components of DSSCs for achieving good efficiency. Photosensitizers work as solar light harvesters of Photovoltaic (PV) cells. In addition their electronic properties are recognized to affect light harvesting efficiency along with power conversion efficiency (PCE) [9, 10]. In DSSCs, the majority of low efficiencies are based on traditional photosensitizers undergoing low absorption, narrow absorption spectra, along with the loss of energy absorbed by the electrolyte [5]. For this reason, an approach using co-sensitization was demonstrated and implemented to recover the performance of the DSSC [11, 12].

Much of the research has targeted the improvement of new and efficient photosensitizers, including sensitizers like ruthenium complexes [13–15], zinc porphyrins [16–18] as well as metal-free organic dyes [19–22]. Ruthenium-based sensitizers such as the N3 dye/ N719 dye [9, 10, 23] and black dye [24] were rigorously tested as light har-