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Optimizing phthalocyanine based dye-sensitized solar cells: The role of reduced graphene oxide

Francis Chindeka, Philani Mashazi, Jonathan Britton, Gertrude Fomo, David O. Oluwole, Azole Sindelo, Tebello Nyokong*

Department of Chemistry, Rhodes University, Grahamstown 6140, South Africa

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ABSTRACT

Dye-sensitized solar cells (DSSC) were fabricated by incorporating graphene materials as catalysts at the counter electrode. Platinum was also used as a catalyst for comparison purposes. Different phthalocyanines: hydroxyl indium tetracarboxyphenoxy phthalocyanine (**1**), chloro indium octacarboxy phthalocyanine (**2**) and dibenzoic acid silicon phthalocyanine (**3**) were used as dyes. Complex **3** gave the highest power conversion efficiency (η) of 3.19% when using nitrogen doped reduced graphene oxide nanosheets (NrGONS) as a catalyst at the counter electrode, and TiO_2 containing rGONS at the anode. The value is close to 3.8% obtained when using Pt catalyst instead of NrGONS at the cathode, thus confirming that NrGONS is a promising candidate to replace the more expensive Pt. The study also shows that placing rGONS on both the anode and cathode improves efficiency.

1. Introduction

Dye sensitised solar cells (DSSCs) belong to a group of thin film solar cells. DSSCs utilize nanocrystalline wide bandgap nanoporous semiconductor metal oxide electrodes such as ZnO [1] or TiO_2 [2] in the presence of a dye sensitizer [3]. Indium tin oxide (ITO) and fluorine tin oxide (FTO) coated glass have been widely used as window electrodes in DSSCs [4]. Graphene materials, with their exceptional electrical, optical, and mechanical properties, have been incorporated into each aspect of a DSSC [4–12].

DSSCs contain two interdependent electrodes, the counter electrode (CE) and the photoanode. At the counter electrode (cathode), the reduction of the electrolyte occurs and at the photoanode the oxidation of the same electrolyte occurs. The ideal counter electrode material should possess a low sheet resistance, high reduction catalytic activity, good chemical stability, and have low production costs [13,14]. Counter electrodes are commonly composed of ~15–20 nm thick Pt layer, deposited onto FTO or ITO. However, Pt has several setbacks. First of all, it has limited reserves on earth and it is costly. Furthermore, from the technical point of view, Pt suffers degradation over time, especially when in contact with the I_3^-/I^- liquid electrolyte, and it tends to induce formation of polyiodides, strongly reducing the efficiency of DSSCs. The aforementioned problems have boosted efforts towards the replacement of Pt with cheaper and/or more stable materials [5]. In this work DSSCs were fabricated using ITO coated glass and graphene based materials as electrode material. In 2010, Roy-Mayhew et al. [15] discovered that functionalizing graphene contributes to the high catalytic activity of graphene towards I^-/I_3^- redox reaction, showing comparable performance to the Pt catalyst. Hence doped (with nitrogen) graphene is employed in this work.

Metallophthalocyanines (MPc) have been successfully employed as sensitizers for dye-sensitized solar cells [16–18], as a result of their light-harvesting properties in the red and near-infrared (near-IR) spectral regions. A successful phthalocyanine sensitizer for DSSCs should show stable adsorption to the semiconductor surface, preferably by covalent bonds. Such stable adsorption is typically realized by carboxylate or sulfonate anchoring groups or, in some cases, by ligation of surface metal atoms using metal-free phthalocyanines [16,19,20]. There are limited reports on the use of MPcs with graphene for construction of DSSCs. There is one report using an unsubstituted ZnPc - CdS/CdSe quantum dots and Au nanoparticles /graphene oxide composite in DSSCs [21]. The current work reports on the use of carboxylated phthalocyanines (Fig. 1). As stated above, carboxy groups on the Pcs allow for formation of covalent bonds to the hydroxide groups on the surface of the TiO_2. Reduced graphene oxide nanosheets (rGONS) and nitrogen doped graphene oxide (NrGONS) on ITO are used as counter electrodes for DSSC in this work. rGONS modified TiO_2 photoanodes were also used to fabricate DSSCs. Graphene improves suppression of charge recombination at the photoanode/dye/electrolyte interface and also enhances electron transport in the photoanode [22].

* Corresponding author.
E-mail address: t.nyokong@ru.ac.za (T. Nyokong).

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