Novel Platinum-Free Counter-Electrode with PEDOT: PSS-Treated Graphite/Activated Carbon for Efficient Dye-Sensitized Solar Cells

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Abstract

Developing an efficient material as a counter electrode (CE) with excellent catalytic activity, intrinsic stability, and low cost is essential for the commercial application of dye-sensitized solar cells (DSSCs). Photovoltaic properties DSSCs fabricated with low-cost and platinum-free CEs based on different mixtures of carbon allotropes graphite (GR), activated carbon (AC) and PEDOT: PSS films. The DSSCs assembled with PEDOT: PSS/GR/AC showed an impressive photovoltaic conversion efficiency of 4.60%, compared to 4.06% for DSSCs with GR/AC CE or 1.66% for PEDOT: PSS alone or 6.56 % for Pt under the illumination 100 mW cm^{-2} (AM 1.5 G) due to the superior electrocatalytic activity and the conductivity of AC and PEDOT: PSS. The fabricated carbon counter electrodes were extensively characterized by using scanning electron microscopy (SEM), X-ray diffraction (XRD), Raman spectroscopy, cyclic voltammetry (CV), Tafel measurements and electrochemical impedance spectroscopy (EIS). The CV, EIS and Tafel measurements indicated that the PEDOT: PSS/Graphite/AC composite film has low charge-transfer resistance on the electrolyte/CE interface and high catalytic activity for the reduction of triiodide to iodide than the GR/AC CEs. It is potentially feasible that such a carbon configuration can be used as a counter electrode, replacing the more expensive Pt in DSSCs.

Highlights

- Proposing a novel PEDOT: PSS/Graphite/Activated Carbon composite counter electrode with better performances.
- Achieving better interaction between the electrolyte and the counter electrode.
- Power conversion efficiency of 4.60 % has been found by using the PEDOT: PSS/GR/AC counter electrode

1. Introduction

Among the third-generation photovoltaic devices dye-sensitized solar cells (DSSCs) are the most promising photovoltaic devices due to their desired properties such as straight forward fabrication process, environmental friendliness, and adequate efficiency [1]. A typical sandwich-structured DSSC consists of three primary components: a dye-adsorbed TiO_2 layer on a conductive glass substrate serving as the photoanode, an iodide/triiodide (I_3^-/I^-) redox couple as the electrolyte, and a platinized counter electrode (CE) [2]. The CE plays a crucial role in DSSCs by collecting electrons from the external circuit and catalyzing the reduction of I_3^- to I^-. This process demands both excellent catalytic activity and high conductivity from the CE materials [3]. Although platinum (Pt) and Pt-based materials are currently the standard catalysts for CEs in DSSCs due to their superior electron conductivity and catalytic efficiency. Their limited availability, high cost, and instability in iodine-based electrolytes pose significant challenges for large-scale commercial applications. Therefore, the development CEs of non-noble metal catalysts with competitive electrochemical performance and exceptional stability are essential for advancing sustainable energy technologies and facilitating their broader commercialization [4]. In recent