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Electrochemical pulsed deposition of platinum nanoparticles on indium tin oxide/polyethylene terephthalate as a flexible counter electrode for dye-sensitized solar cells

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ABSTRACT

In this study, a pulsed-mode electrochemical deposition (Pulse-ECD) technique was employed to deposit platinum nanoparticles (PtNPs) on the indium tin oxide/polyethylene terephthalate (ITO/PET) substrate as a flexible counter electrode for dye-sensitized solar cells (DSSCs). The characteristic properties of the Pulse-ECD PtNPs were prepared and compared to the traditional (electron beam) Pt film. The surface morphologies of the PtNPs were examined by field emission scanning electron microscopy (FE-SEM) and the atomic force microscope (AFM). The FE-SEM results showed that our PtNPs were deposited uniformly on the ITO/PET flexible substrates via the Pulse-ECD technique. The AFM results indicated that the surface roughness of the pulsed PtNPs influenced the power conversion efficiency (PCE) of DSSCs, due to the high specific surface area of PtNPs which enhanced the catalytic activities for the reduction (I_3^- to I^-) of redox electrolyte. In combination with a N719 dye-sensitized TiO_2 working electrode and an iodine-based electrolyte, the DSSCs with the PtNPs flexible counter electrode showed a PCE of 4.3% under the illumination of AM 1.5 (100 mW cm^{-2}). The results demonstrated that the Pulse-ECD PtNPs are good candidate for flexible DSSCs.

1. Introduction

Dye-sensitized solar cells (DSSCs) have greatly attracted the attention of many research workers since it is the potential candidates to be the next generation solar cells due to their low cost, easy fabrication, and high photoconversion efficiency [1]. A typical DSSCs is composed of a wide band semiconductor (Ex: TiO_2) adsorbed with dye molecule on a conductive glass as a working electrode, an electrolyte containing redox couples between electrodes, a catalytic activation layer deposited on conductive glass is often utilized as the counter electrode [2]. The counter electrode plays an important role in DSSCs, the function of counter electrode in DSSCs is used to regenerate the iodide/triiodide redox couples (I^-/I_3^-) in the electrolyte and make the cell to be a complete circuit [3]. Fluorine-doped tin oxide (FTO) glass, a transparent conductive oxide glass, is commonly used as a conductive substrate for photoelectrochemical solar cells [4]. FTO glass coated with a thermal or sputtered platinum (Pt) film is widely used as the counter electrode for DSSCs. However, because of the important development trends in flexible DSSCs, conductive plastic substrates have become an important research topic [5–8]. Recently, electrochemical deposition was found to be an efficient method for room-temperature deposition of Pt nanoparticles (PtNPs) as a counter electrode for the efficiency improvement of DSSCs [9–13]. In this work, we herein describe our investigation of the properties of the PtNPs deposited on indium tin oxide/polyethylene terephthalate (ITO/PET) by a Pulse electrochemical deposition (Pulse-ECD) method. The Pulse-ECD PtNPs were examined by field emission scanning electron microscopy (FE-SEM), ultraviolet–visible (UV–Vis) spectrometry and atomic force microscopy (AFM). The electrochemical catalytic performances of the activity of reduction I_3^- ions were studied by the cyclic voltammetry (CV). The power conversion efficiency (PCE) of the DSSCs with the Pulse-ECD PtNPs on ITO/PET as a flexible counter electrode was examined under the illumination of AM 1.5 (100 mW cm^{-2}).

2. Experimental methods

2.1. Preparation of the TiO_2 working electrodes

The working electrode utilized the FTO glass (TEC-7, 2.2 mm, Hartford), which was coated with nanocrystalline TiO_2 (the coating was performed using print-screen technology); the area and thickness of the TiO_2 film were approximately 0.28 cm^2 and 10 μm, respectively.

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After print-screen, the working electrodes were dried at 120 °C, then sintered in air at 550 °C for 30 min. Prior to the fabrication of the DSSCs, the sintered working electrodes were immersed in a N719 (Solaronix) solution (0.3 mM in a mixture of acetonitrile and tert-butylalcohol) at room temperature for 24 h. The dye-adsorbed working electrode was then washed with acetonitrile and dried at room temperature for few seconds [14–19].

2.2. Preparation of the Pt counter electrodes

Two different methods of Pt counter electrode preparation were studied: (1). Electron beam evaporation Pt film on FTO glass (TEC-7, 2.2 mm, Hartford), and (2). Pulse-ECD PtNPs on ITO/PET (PETITO175-14, 175 μm, Solaronix). A counter electrode coated with a Pt film was prepared by electron beam evaporation

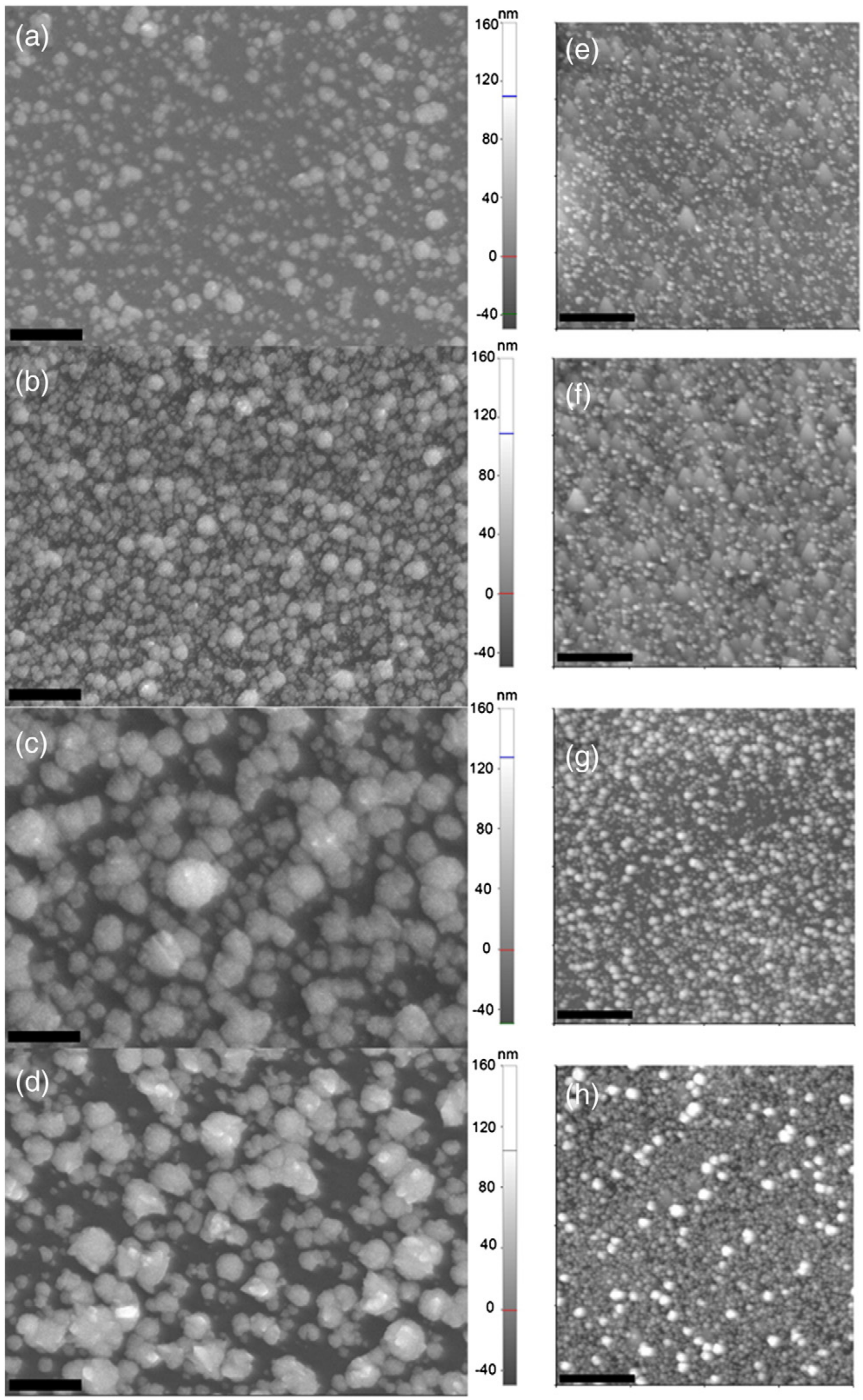

Fig. 1. FE-SEM surface morphology of Pulse-ECD PtNPs on ITO/PET (a) 50 cycles, (b) 100 cycles, (c) 150 cycles, and (d) 200 cycles, respectively. And AFM 2D roughness images of Pulse-ECD PtNPs on ITO/PET (e) 50 cycles, (f) 100 cycles, (g) 150 cycles, and (h) 200 cycles, respectively. The scale bars of FE-SEM and AFM images are 300 nm and 2.5 μm, respectively.