Enhancing Photocurrent of p-Cu_2O by Synthesis of p-Cu_2O/ rGO Composite Films

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Abstract

The composites of p type Cuprous Oxide and reduced Graphene Oxide (p-Cu_2O/rGO) were prepared by depositing a rGO layer on top of nano sized Cu_2O particles prepared on a Cu substrate as a thin film. These Cu_2O nano-particles emerge through the rGO surface forming p-Cu_2O/rGO composites. These synthesized composites help to enhance the photocurrent than that of bare Cu_2O, which means rGO acts as an excellent electron acceptor to separate electrons from Cu_2O particles. To fabricate p-Cu_2O, well cleaned Cu plate was inserted into the muffle furnace providing a temperature rate of 100 $^0C\ min^{-1}$ starting from room temperature. After reaching 300 ^0C, it was at that temperature for 30 minutes and then cooled down to room temperature. Finally, brownish red colored nano sized Cu_2O layer was appeared on the Cu surface.

Here rGO layer was fabricated using Electrophoretic Deposition (EPD) technique. For that Graphene Oxide (GO) was used. GO was synthesized from purified natural graphite by the modified Hummers method. Then GO was dispersed in distilled water and a solution of pH of 4 was made using a NaOH solution. Then the Cu/p-Cu_2O electrode and a Pt plate were immersed in that solution about 2 cm apart and a 10 V direct current (DC) potential was applied between the sample electrode and the Pt electrode for 5 seconds time intervals. The GO platelets migrated towards the positive electrode when the DC voltage was applied. After deposition, samples were air dried. The deposition time controls the rGO layer thickness. To find the best rGO deposition time, the photocurrent of p-Cu_2O/ rGO composites was measured using the three electrode system. Here, a Pt plate was used as the counter electrode, an Ag/AgCl electrode was used as the reference electrode. A (10^{-2} M) Fe^{2+} / Fe^{3+} (10^{-4} M) solution of pH 5 was used as the electrolyte. Under visible light irradiation (100 W tungsten filament lamp), a photocurrent of 0.2 mA was observed in p-Cu_2O/ rGO (25 sec.), which is higher than that of the p-Cu_2O electrode (0.15 mA). The enhancement of photocurrent is clearly indicate that rGO acts as a good electron acceptor that helps to enhance the charge separation within the p-Cu_2O semiconductor.

Fabricated samples were characterized using diffuse reflectance spectra, Fourier Transmission Infrared (FTIR) spectra and development of the photocurrent with time in photoelectrochemical cells.

Optical absorption of the p-Cu_2O/ rGO and bare p-Cu_2O were tested using UV-visible diffuse reflectance spectroscopy. p-Cu_2O/ rGO composites show higher absorption in visible range compared that with bare Cu_2O due to the additional absorption by rGO. The wavelengths of p-Cu_2O and p-Cu_2O/rGO are 625 nm and 635 nm respectively. With compared to bare Cu_2O, a slight shift in light absorption edge can be observed in Cu_2O/ rGO film, which could be due to hybridization of the carbon material. As a result, the calculated bandgap of Cu_2O is 1.98 eV and the bandgap of Cu_2O/ rGO composites is 1.95 eV.

In order to find the functional groups in fabricated samples, FTIR analysis was done. The presence of oxygen-containing groups illustrates that graphite has been oxidized to GO. But in Cu_2O/ rGO IR spectrum, peaks of OH group and epoxy group become weak and some of C-O bonds disappear. Furthermore a new peak appears around in 630 cm^{-1} due to the stretching vibration of Cu-O bond in Cu_2O. It confirms the formation of rGO and Cu_2O.

Furthermore, the photocurrent stability of p-Cu_2O and p-Cu_2O/rGO photoelectrodes were measured for 1 hour under visible light illumination. It was clear that Cu_2O/rGO electrode has remarkable photocurrent stability in an electrochemical medium than with the bare Cu_2O. The photocurrent decay of the bare Cu_2O may occur due to the self-photoreduction of Cu_2O into Cu. But in the Cu_2O/rGO electrode, the photo-generated electrons accumulate on rGO layer before transferring to the electrolyte species enhance the steady photocurrent of p-Cu_2O/rGO electrolyte interface which means that rGO minimize the possibility of contacting with H^+ ions presence in the electrolyte with Cu_2O particles and reduce the photoreduction of Cu_2O into Cu.

In conclusion, a significant photocurrent development than p-Cu_2O nano particles with a remarkable stability can be achieved by synthesizing p-Cu_2O/ rGO composites, since rGO acts as an excellent electron acceptor.

Keywords: rGO; Cu_2O; Composite; Photoelectrochemical cell