Effect of Reduced Graphene Oxide Depositing on n-Cu_2O for Solid State Photovoltaic Cell

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Abstract— *A low cost solid state photovoltaic cell made with a simple preparation method of Cu2O and deposition of reduce graphene oxide (rGO) on Cu2O. The graphene oxide was prepared by modified Hummer's method and deposition of rGO was done by the electrophoretic deposition (EPD) technique on a well cleaned copper substrate. There after Cu/ rGO substrate was boiled in a CuSO4 (0.05M) for 60 minutes to fabricate Cu/ rGO/ n-Cu2O. Finally the Cu/ rGO/ n-Cu2O was sealed with a conductive glass plate (ITO) to fabricate the solar cell. Photocurrent enhancement was observed in Cu/ rGO/ n-Cu2O/ ITO when comparing the Cu/ n-Cu2O/ ITO photoelectrode. Diffuse reflectance spectra, FT-IR, I-V curves were used to explain the photocurrent enhancement of the solar cell. The maximum power efficiency was observed as 1.4% was observed after introducing rGO for the Cu/ n-Cu2O and remarkable stability was observed in the solar cell.*

Keywords— *n-Cu2O, Graphene, Solid State Photovoltaic Cell*

I. INTRODUCTION

There has been a great interest on the carbonaceous material in many research areas including in renewable energy devices due it low cost, environmental friendliness, high abundance. Graphene is the revolutionary carbonaceous materials in electronic devices. It has one atomic layer of carbon atoms in a 2D lattice structure with excellent in electrical, thermal and mechanical. Hummer's method is widely used in synthesizing graphene (GO). There are several methods to produce reduced graphene oxide (rGO) from GO and electrophoretic deposition (EPD), is a well-developed technique and an economical method (An , et. al. 1990).

Another interesting research area is fabricating copper based photovoltaic cells due to high natural abundancy of Cu, low cost and nontoxicity. Among the Cu based materials Cu_2O have been attract tremendous attention. The band gap is $\approx$ 2.0 eV of Cu_2O with a higher absorption coefficient. There are various types to deposit Cu_2O on different substrates like n-type and p-type semiconductors (Fernando, et. al., 2010).

In this study a solid state thin film solar cell was fabricated in Cu/ n-Cu_2O/ rGO/ ITO configuration. n-Cu_2O fabricated by boiling well cleaned copper plate in $CuSO_4$. rGO was deposited on n-Cu_2O by EPD technique. UV visible spectroscopy, FT-IR, I-V characteristics were used for characterization purposes.

II. EXPERIMENTAL

A. Preparation Cu/ n-Cu_2O junction photoelectrode

According to the Fernando et al. (Fernando, C.A.N., 2000) a well cleaned copper plate (1 cm x 3 cm) was immersed in a 0.05M $CuSO_4$ solution and boiled for 60 minutes until a layer of Cu_2O appeared of the surface.

B. Preparation of GO

Modified Hummer's method was used to prepared graphene oxide (GO) (Kovtyukhove. et. al., 1999). 2 g of graphite powder was mixed with 46 ml conc. H_2SO_4 and 1 g $NaNO_3$ solution at 0 ^{0}C. 6 g of $KMnO_4$ was added slowly to the flask while the temperature kept below 15 ^{0}C with vigorous stirring for 30 minutes. The suspension was mixed until the temperature exceed 35 ^{0}C then it became a browinish in colour. 92 ml of de-ionized water was added slowly while stirring for further 15 min. Finally 10 ml of H_2O_2 (30 wt.%) solution was added slowly to the mixture and the colour of the mixture change into yellow in colour.

The mixture was centrifuged and washed with water and HCl based on a volume ratio 10:1 for several times to remove the residual ions. The powder was dried at room temperature in a vacuum desiccator for an overnight.

C. Deposition of rGO by EPD

As mention above the EPD technique was used to deposit rGO on a well cleaned Copper palete. 2 mg of GO dispersed in 40 ml of de-ionized water. A setup which consists two electrodes was used for EPD. Where, anode was the substrate and the cathode was the Pt plate. The distance, 30 mm was maintained in between the electrodes all the time. The depositions take places on the anode. EPD of the rGO was carried out under constant 10 V DC voltage supply (GPC-1850D) for 30s. After deposition, the substrate was removed from the solution and dried with an air flow at room temperature.

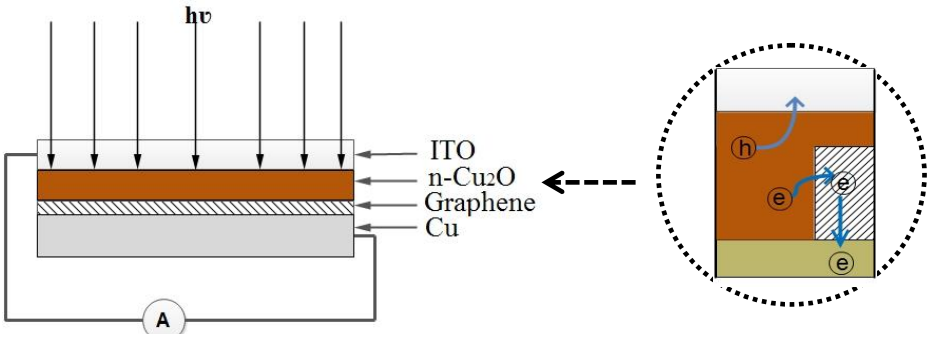


Figure 2. Schematic Structure of the Cu/ rGO/ n-Cu_2O Solar cell

D. Deposition of n-Cu_2O on Cu/rGO Substrate

After deposition rGO on top of the Cu, The substrate was immerse in a 0.05M $CuSO_4$ solution and boiled for 60 minutes until a layer of Cu_2O appeared of the surface. Finally the Cu /rGO/n-Cu_2O /ITO solid state photovoltaic cell fabricated by placing an ITO coated glass plate on top of the rGO layer. The schematic structure of the solar cell shown in the Figure 1.

III. RESULTS AND DISCUSSION

A. Diffuse reflectance spectra

Figure.2(a)-(b)shows the diffuse reflectance spectra of Cu/ n-Cu_2O, Cu/ n-Cu_2O/ rGO respectively. The shapes of the curve were resembled with each other. So it shows that there is no transformation has been made by introducing rGO on to the Cu/ n-Cu_2O layer. The evaluated band gap is $\approx$ 1.9 eV ($\lambda \approx$ 650 nm) for n-Cu_2O.

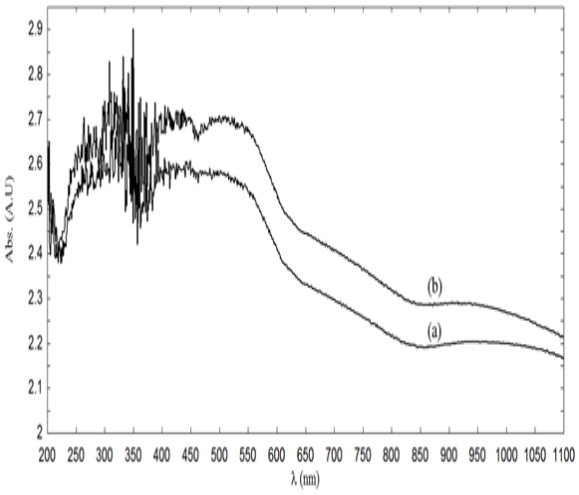
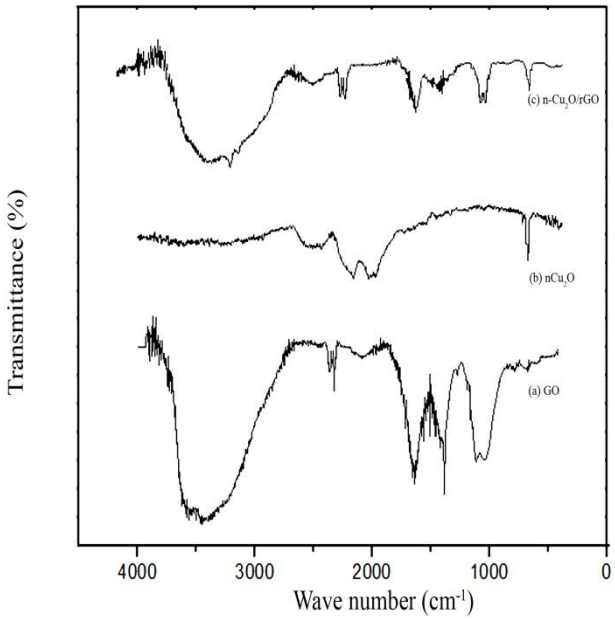


Figure 2. Diffuse reflectance spectra of (a) Cu/n-Cu_2O, (b) Cu / rGO/ n-Cu_2O

B. FT-IR

Figure.3(a)-(c) shows the FT-IR pattern of the GO, Cu/ n-Cu_2O, and Cu/ rGO/ n-Cu_2O respectively. The absorption peaks of GO situated nearly at 3400, 2365, 1700, 1633, 1380, 1200, 1080, 1050 cm^{-1}, corresponding to O-H, CO_2, C=O, C=C, C-O, C-O-C, C-OH, C-O respectively. Figure.2(b) shows the FT-IR pattern of the Cu_2O and the Cu-O stretching vibration was observed at 657 cm^{-1}. The FT-IR of Cu/ rGO/ n-Cu_2O represent in Figure.2(c) and it clearly indicate the successful deposition of rGO of the Cu/ n-Cu_2O substrate.



Cu/ rGO

C. V- I characteristics and the time development of the photocurrent

For Cu/ n-Cu_2O cell, the short-circuit photocurrent (Isc) $\approx$ 1.4 mA cm^{-2}, open-circuit voltage is (Voc) $\approx$ 499 mV and power conversion efficiency $\approx$ 0.4%. Enhancements of short-circuit photocurrent (Isc) $\approx$ 3.8 mA cm^{-2}, open-circuit voltage (Voc) $\approx$ 640 mV and power conversion efficiency $\approx$ 1.4% was observed in Cu / rGO/ n-Cu_2O cell. So it is clear that the efficiency of the solid state photovoltaic cell made by Cu/ n-Cu_2O has been enhanced by introducing rGO on top of the Cu/ n-Cu_2O.

IV. RESULTS AND DISCUSSION

A solid state thin film photovoltaic cell produced with Cu / rGO/ n-Cu_2O/ ITO for the 1st time. FT-IR confirms the successful deposition of rGO on Cu_2O. The power conversion efficiency enhancement was observed in Cu/ n-Cu_2O/ rGO compared with Cu/ n-Cu_2O photoelectrodes by I-V characteristics. The photocurrent increases when introducing rGO and it act as an electron acceptor. The observed power conversion efficiency was 1.4%. Remarkable stability was observed in the Cu/ rGO/ n-Cu_2O / ITO solid state photovoltaic cell.

ACKNOWLEDGMENT

National Research Council of Sri Lanka (NRC) is acknowledged for providing the equipment grant No-26 for this research program. National Science Foundation (NSF) of Sri Lanka is also acknowledged partly providing a research grant nano-01. Mr. B M G Dharmasiri and Mr. S A D Wijayasinghe Nano-Technology Lab, Wayamba University of Sri Lanka is appreciated for providing technical assistance.

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