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A photoelectrochemical electrode of electrodeposited cuprous oxide on ITO/glass with deposition time adjustment

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Summary:
Electrodeposition of Cu_2O on ITO glass at 50°C was carried out at various time with studies on their morphological and photoelectrochemical properties. AFM analysis exhibits a clear correlation between electrodeposition time and the average surface roughness. The electrochemical performance evaluated by cyclic voltammetry (CV) demonstrates the excellent conductivity of Cu_2O fabricated at 120s for photocurrent generation. A proper Cu_2O film exhibits a high photocurrent generation, highlighting the significance of controlled film thickness in optimizing device performance, which can be applied in photoelectrochemical applications.

Keywords: cyclic voltammetry, Electrodeposition, Photoelectrochemical, photoelectron conduction

INTRODUCTION

With the continuous advancement in technology, health and environmental protection gain attention. Therefore, green energy production and highly selective detection methods have attracted great interest. Photoelectrochemical (PEC) methods are involved in a photo-enhancement to drive electrochemical reactions at the interface of a photoactive material and an electrolyte [1]. Furthermore, the design of PEC devices can be optimized by illumination management, ensure electrochemical stability, and be compatible with mass production for widespread deployment [2]. The most important component of PEC device is the photoactive material which determine performances including photo-electron transfer efficiency and stability. Among Several metal-oxide based materials, Cu_2O has been obtained significant interests for PEC systems, as its advantages of proper band gap (2.3 eV) matched to visible light adsorption, low cost, easy availability and eco-friendliness. Electrodeposition does not require specialized vacuum system and can be conveniently implemented under standard laboratory conditions. Operational flexibility make electrodeposition an attractive method to generate Cu_2O films. Therefore, photoelectrochemical characterization of Cu_2O prepared by temperature-dependent electrodeposition is proposed in this study.

MATERIALS AND METHODS

The fabrication flow and setup of electrodeposited Cu_2O layer on indium tin oxide (ITO)/glass (RLO35SD, Ruilong, Taiwan) is shown in Fig. 1(a). ITO/glass was cleaned by acetone, methanol and distill water sequentially for 10 min in each step. 0.4 M copper sulfate and 3 M lactic acid (Sigma, U.S.) solution were prepared for electrodeposition. A constant bias voltage at -0.4 V was provided by a potentiostat (PalmSens4, PalmSens BV, Netherlands) via 3-electrode setup with working electrode, counter electrode made of ITO/glass and a commercial Ag/AgCl as reference electrode, respectively. The deposition temperature was controlled for 50°C at different time from 600 to 30s as various experimental groups. 4-well encapsulation with Polydimethylsiloxane (PDMS) was attached on the surface of fabricated Cu_2O samples with a fixed area of 3x3 mm^2 of each well used as working electrode. Cyclic voltammetry (CV) measurement was performed using the potentiostat with the 3-electrode setup. The measurement setup with a counter and reference electrode are platinum plate and commercial Ag/AgCl reference electrode (RE-1B, ALS Co. LTD., Japan) as shown in Fig. 2, respectively. To evaluate the photoelectrochemical response, an LED illumination system with multiwavelength (pE-4000, CoolLED, UK) was used to provide the fixed

power intensity of 1 mW/cm^2 of a LED with wavelength of 525 nm through an optical fiber to fabricated Cu_2O samples.

RESULTS AND DISCUSSION

Morphology of all Cu_2O layers were investigated by atomic force spectroscopy (AFM) (NanoView1000, FSM-Precision, China) as shown in Fig. 3(a)-(e) for Cu_2O deposition time from 600s to 30s, respectively. These images show unique surface features with orientated crystalline resulting that the increase in deposition time is directly proportional to the average surface roughness. Cross-sectional SEM images of different groups present the thickness reduction with deposition time. To know their basic electrochemical response, a standard cyclic voltammetry (CV) measurement is performed to Cu_2O films with and without illumination of 525 nm LED as shown in Fig. 4(a)-(e). Highest enhancement was observed in both (cathodic and anodic) for the Cu_2O electrodeposited for 120s. Excellent electrical conductivity and greater photoactivity, supporting its suitability for photocurrent generation [3]. The enhancement rate of the 50°C-120s sample is higher than that of the 50°C-600s, 240s, 120s and 60s sample. This supports the idea that thinner Cu_2O films can efficiently amplify electrical signals in response to illumination.

CONCLUSION

The photoelectrochemical characteristics of the Cu_2O thin films revealed the influence of deposition time on their electrochemical performance. The surface roughness and thickness of Cu_2O crystals is directly affected by the process time. Electrochemical studies prove the excellent electrical conductivity and photoactivity of an electrodeposition time of 120s. A thinner film benefits to enhance photoelectron conduction, demonstrating a direct relationship between film thickness and photoelectrochemical signal strength. A high efficiency achieved for the Cu_2O deposited at 50°C for 120 sec, which can be applied in PEC relative applications. Altogether, these findings highlight the critical role of controlled electrodeposition in tailoring the properties of Cu_2O/ITO thin films, providing valuable insights for optimizing their performance in different applications.

References

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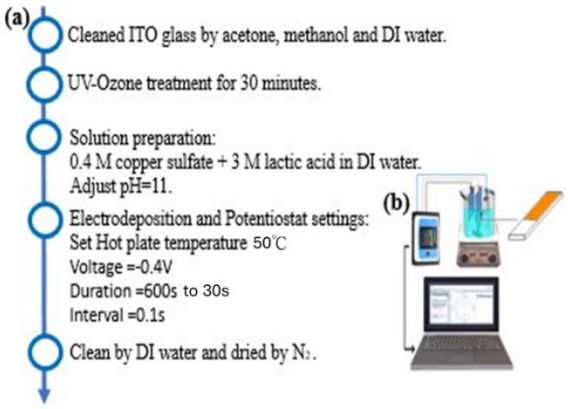

Fig. 1. (a) Process flow and (b) experimental setup of electrochemical deposition of Cu_2O.

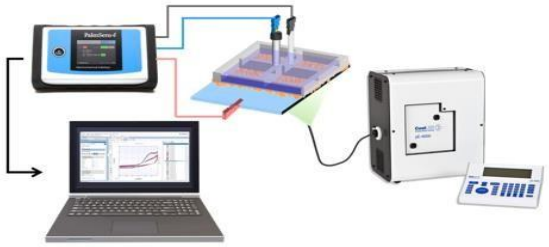

Fig. 2. CV measurement setup with illumination setup.

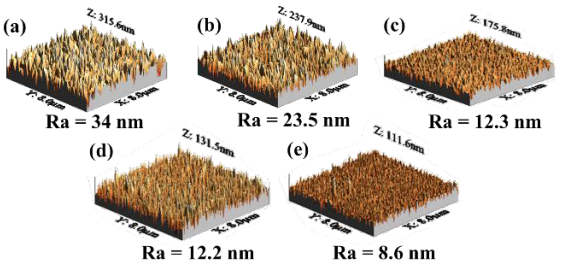

Fig. 3. Surface morphology of Cu_2O samples electrodeposited at different process time: (a) 600s, (b) 240s, (c) 120s, (d) 60s and (e) 30s collected by AFM with its average roughness (Ra).

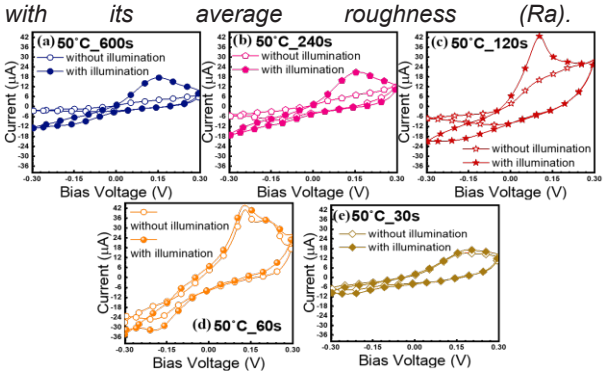

Fig. 4. CV curves of Cu_2O samples electrodeposited at different process time: (a) 600s, (b) 240s, (c) 120s, (d) 60s and (e) 30s measured in 0.1X PBS solution with and without illumination.

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