Electrodeposited nano-crystalline cuprous oxide thin films for solar energy applications

K.M.D.C. Jayathileka[1]*, W. Siripala*[1] *and J.K.D.S. Jayanetti*[2]
[1]*Department of Physics, University of Kelaniya, Kelaniya*
[2]*Department of Physics, University of Colombo, Colombo*

Abstract

Cuprous oxide thin films were electrodeposited in a cupric acetate bath and resulting films were investigated in a photo-electrochemical cell to determine the intrinsic defects density variations. It was observed that by controlling the pH value of the deposition bath, density of both Cu and O vacancies which are responsible for acceptor and donor levels respectively, can be controlled and thereby it is possible to electrodeposit either n-type or p-type cuprous oxide thin films. The study reveals that not only the pH value but also the cupric ion concentration of the acetate bath determines the nature of conductivity of the films. Structural and morphological studies revealed that nano-crystalline films of size, 100 nm, can be electrodeposited by controlling the deposition parameters. These films will be very useful in applications of solar energy converting devices.

1. Introduction

Cuprous oxide (Cu_2O) is an attractive cheaper material for solar energy device applications because it is non toxic and, has a direct band gap of 2 eV [1]. Among the various methods available for growing Cu_2O films, electrodeposition is suitable due to its economic nature and the ability to control both conductivity type (n- or p-type) and the surface morphology of the films [2].

However Cu_2O has not been commonly used because of its low energy conversion efficiency (<1%) which results due to the fact that light generated charge carries in micron sized Cu_2O grains are not efficiently transferred to the surface and are lost due to the recombination. If the grain radius is reduced from micron to nano scale, the opportunity for recombination can be dramatically reduced. Resulting films also increase the effective surface area by orders of magnitudes giving rise to the improved efficiency of related devices. Thus the preparation of nanocrystalline Cu_2O thin films is a key to improve the performance of devices such as solar cells [3].

In this work, morphology of the electrodeposited films was investigated with Scanning Electron Microscopy (SEM) and Atomic Force Microscopy (AFM). Conduction type of the films was studied with photocurrent spectral response measurements. It was found that good quality Cu_2O films with different morphological properties and conductivity could be obtained while maintaining the same stoicheometry by changing the deposition parameters in electrodeposition.

2. Experimental

Cu_2O thin films were deposited on Ti substrates by the electrodeposition. The electrodeposition was accomplished in a three-electrode electrochemical cell containing aqueous solutions of 0.1M sodium acetate and 0.01 M cupric acetate. The temperature of the electrolyte was maintained at 60 ^{o}C during the deposition that was carried out under a potentiostatic condition of -200 mV vs. SCE for 45 minutes. pH of the electrolyte was adjusted by adding a dilute sodium hydroxide solution to the bath.

Spectral responses of the electrodes were measured using a phase sensitive detection method to monitor the photocurrent signal produced by a chopped monochromatic light beam. The chopping frequency was 63 Hz. A monochromator (Sciencetech - 9010), a potentiostat (Hukoto Donko HAB-151), a lock-in amplifier (Stanford Research- SR 830 DSP), and a chopper (Stanford-SR 540) were used with a personal computer for the spectral response measurements. The surface Morphology of the films and devices was determined by a scanning electron microscope (Philips XL40) and an atomic force microscope (Nanosurf Mobile S).

3. Results and Discussion

Fig.1(a) shows the photocurrent spectral responses of the Cu_2O thin films deposited on Ti substrates prepared by potentiostatic electrodepositon at pH (a) 5.4, (b) 6.3, (c) 6.6, (d) 6.9 and (e) 7.9 in a deposition bath containing 0.1 M sodium acetate and 0.01 M cupric acetate. It is very clearly seen that slightly acidic conditions resulted in n-type (positive) photosignals in the entire spectral range. When the pH value of the bath was higher, the photoresponse of the films became p-type (negative). This sensitivity of the pH value of the depositing bath on the conduction type of the film may be the reason why previously reported Cu_2O films deposited using different acetate baths produced n- type as well as p-type films [3].

Fig.1(b) shows the spectral response of Cu_2O films prepared in a bath of pH 6.0 containing 0.1 M sodium acetate and cupric acetate concentrations of (a) 0.0005 M, (b) 0.001 M (c) 0.002M, (d) 0.005 M, (e) 0.008 M, and (f) 0.01 M. It is clearly seen in Fig.1(b) that the films produced at lower concentrations of cupric ions, curves (a), (b) and (c), result in p-type films whereas those prepared at higher concentrations, curves (d), (e) and (f), result in n-type films. This suggests that the conductivity of the electrodeposited Cu_2O films depends not only on the pH but also on the cupric ion concentration of the deposition bath.

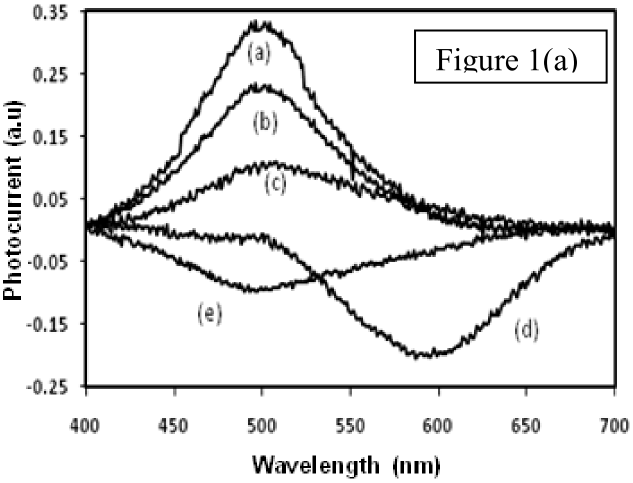


Figure 1(a)

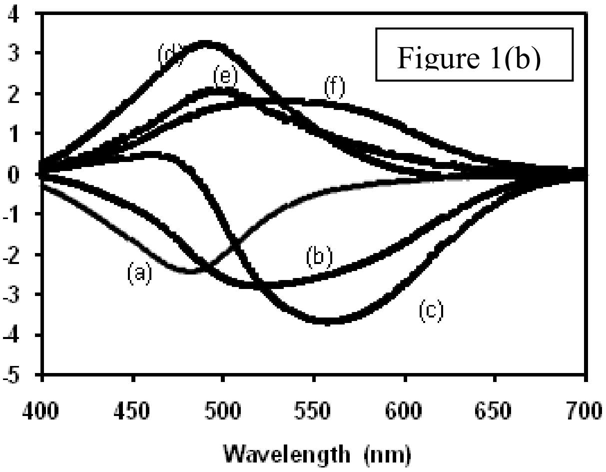
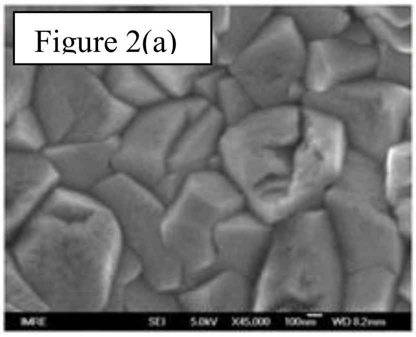


Figure 1(b)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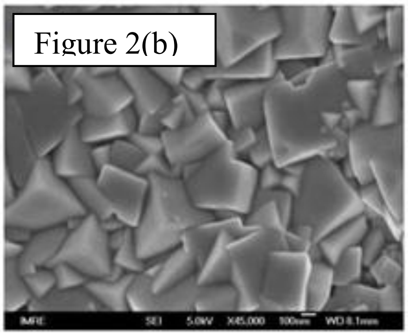
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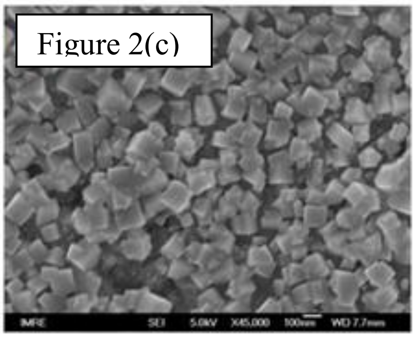
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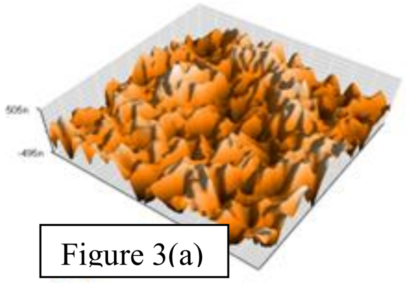
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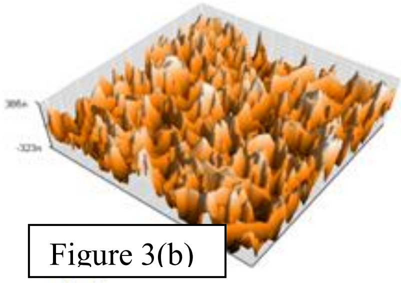
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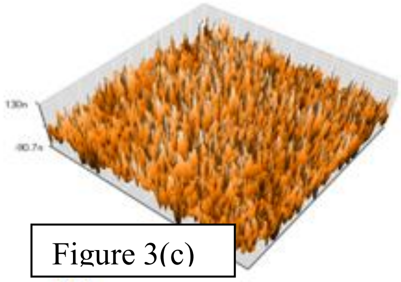
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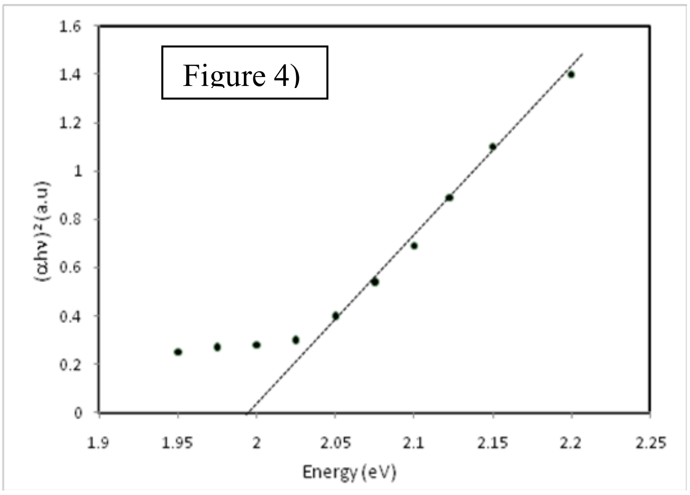

Results show that the morphology of the electrodeposited Cu_2O thin films strongly depends on the pH value of the deposition bath. For example, Fig. 2 shows the SEM pictures of the films deposited in acetate baths containing 0.1M sodium acetate and 0.01M cupric acetate at pH values (a) 6.2 (b) 6.9 and (c) 7.5 respectively. Similar results of dependence of morphology of the Cu_2O films on the pH of the deposition bath have been reported earlier [4]. It is important to note here that a pH value of 7.5, crystalline grain size is of the order of 100 nm.

Fig. 3 shows the AFM images of the films deposited in acetate baths containing 0.1M sodium acetate and 0.01M cupric acetate at pH values (a) 6.2 (b) 6.9 and (c) 7.5 respectively. They indicate that the surface morphology and surface roughness of the films are affected by an increase in the pH of the bath. The grain size can be decreased by increasing the pH. Films of smaller grains have a higher roughness showing consistency with the SEM images.The band gap (Eg) obtained by extrapolation of the plot of $(\alpha E)^2$ vs. E (Fig (4)) was found to be 1.99 eV for nanocrystalline films showing a good agreement with the values reported earlier [2].

4. Conclusions

Results show that, for the first time, that the conductivity type of electrodeposited cuprous oxide thin films is determined not only by the pH of the deposition bath but also by the cupric ion concentration. The general trend is that for high cupric ion concentrations, the films produced at low pH are n-type and at high pH are p-type. However, at very low cupric ions concentrations p-type films could also be obtained at low pH values. This investigation demonstrated that polycrystalline cuprous oxide thin films having small crystals of the size of 100 nm could be electrodeposited.

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Development of an Automated Weather Station with Remote Data Transmission Capability

R. Weerasinghe[1], M.S.M. Aroos[1], A.S. Pannila[1], M.K. Jayananda[2] and D.U.J. Sonnadara[2]
[1] Electro Technology Laboratory, Industrial Technology Institute
[2] Department of Physics, University of Colombo

Abstract

The development of an automated weather station with remote data transmission capability is presented. The complete system consists of three separate modules for data collection, data storage and data communication. The modules communicate serially and are controlled by three separate PIC18F452 microcontrollers. The data collection module is interfaced to a set of sensors to collect weather parameters such as temperature, humidity, wind speed, wind direction, pressure and rainfall. The data storage module saves the captured data in real-time to a micro secure digital (SD) card. The data transmission module transmits data to a central station through a global system for mobile communication (GSM) or a general packet radio service (GPRS) network. The weather data can be viewed in real-time through a graphical user interface (GUI). The modular