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Fabrication of homojunction Cu_2O solar cells by electrochemical deposition

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ABSTRACT

Homostructural Cu_2O solar cells were fabricated with consecutive electrochemical depositions of a *p*-Cu_2O thin film and a *n*-Cu_2O layer on a transparent conductive substrate. The parameters of growth Coulomb number for *n*-type and *p*-type Cu_2O films, which determine the film thickness of Cu_2O, were fine-tuned to investigate their effects on the performance of homojunction solar cells. According to XRD and SEM analyses, the crystalline structure and the optimum thickness of Cu_2O films were accomplished at growth Coulomb numbers 0.135 C for *n*-Cu_2O and 0.208 C for *p*-Cu_2O. Significantly, the best performance of the homojunction Cu_2O cell achieved conversion efficiency 0.42% with V_{oc} = 0.42 V, J_{sc} = 2.68 mA cm^{-2} and *FF* = 0.38. This work hence demonstrates that the proposed strategy to improve the performance of solar cells realized by electrochemical deposition has the potential to produce cheap and environmental friendly solar cells.

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1. Introduction

Over the past decade, the development of photovoltaic solar cells has exhibited important progress in the efficiency of solar-to-electron conversion, but the fabrication of highly efficient devices is costly and tedious because of the required expensive facilities and high-vacuum process. The establishment of a cheap device based on simple and facile synthesis hence attracts increasing attention. According to these criteria, there has been a renewal of interest in solar cells based on copper(I) oxide (Cu_2O) as the active layer because this metal-oxide semiconductor shows many important characteristics useful for the production of solar cells [1–4]. These characteristics of Cu_2O include *p*-type conducting nature, cheap raw material, direct energy gap 2.1 eV, nontoxicity, enduring stability and amenability to cheap scalable fabrication [5–8]. Although the theoretical limit of the efficiency of energy conversion of a Cu_2O solar cell is about 20% (based on radiative recombination), the greatest efficiency obtained on this substrate is 5.38% [3], which reflects the limited work devoted to this semiconductor. The optimization of Cu_2O solar cells is slowed by a lack of clear understanding of the electronic and thermodynamic properties of its intrinsic point defects and by the difficult doping processes. Cu_2O is spontaneously a *p*-type semiconductor as it contains negatively charged copper vacancies and probably interstitial oxygen. Most investigations of solar cells based on Cu_2O hence focused on a heterojunction, which consists of *n*-ZnO and *p*-Cu_2O because of difficult formation of *n*-Cu_2O [9–11].

Many elements have been tested as doping impurities [12,13], but only few demonstrated *n*-type conductivity; a possible explanation for this negative result is based on the self-compensation mechanism or the small solubility of the tested doping impurities. Electrochemical deposition offers a reliable route to synthesize *n*-Cu_2O in an acidic electrolyte [14]. There are few reports on the homojunction Cu_2O by means of electrodeposition [15,16], but the conversion efficiencies of devices are still small. Increased effort is required to investigate systematically homojunction Cu_2O as photovoltaic solar cells. In this work, *p*-type and *n*-type Cu_2O thin films were fabricated with an electrochemical method in basic and acidic electrolytes, respectively; the various parameters of growth for thin film were carefully tuned to understand the structural and opto-electric properties of Cu_2O homojunction solar cells.

2. Experiments

In a typical electrodeposition, a piece of platinum foil serves as counter electrode and a standard silver/silver chloride electrode (Ag/AgCl electrode) as reference electrode. A glass substrate

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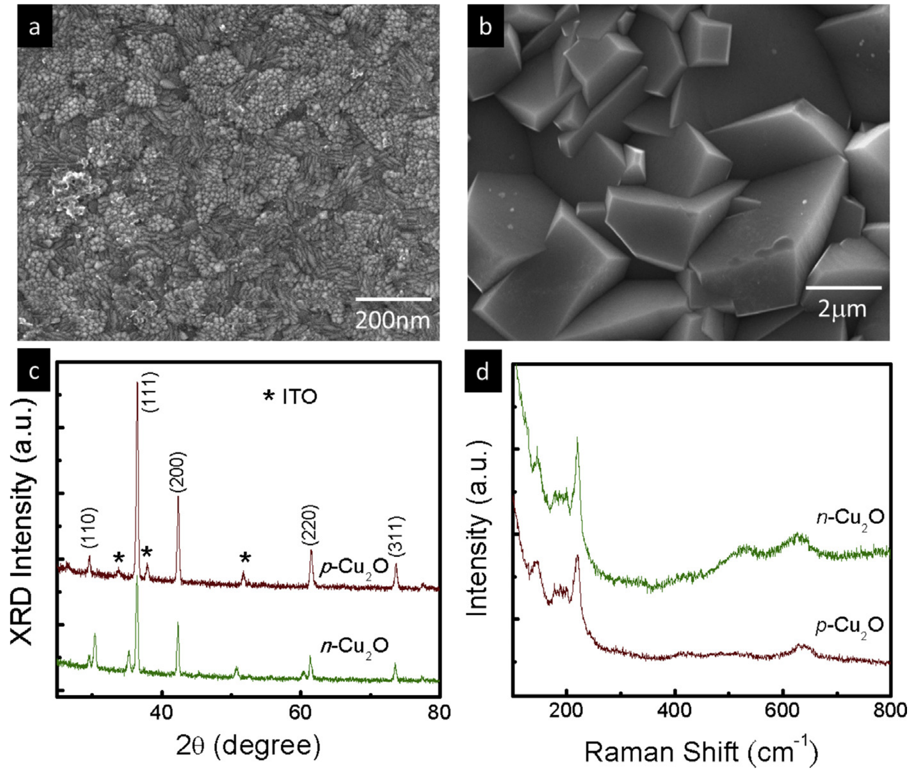

Fig. 1. SEM images of an electrodeposited Cu_2O thin film in (a) acidic and (b) basic solutions. (c) X-ray diffraction patterns and (d) Raman spectra of Cu_2O thin films as grown in acidic and basic electrolytes.

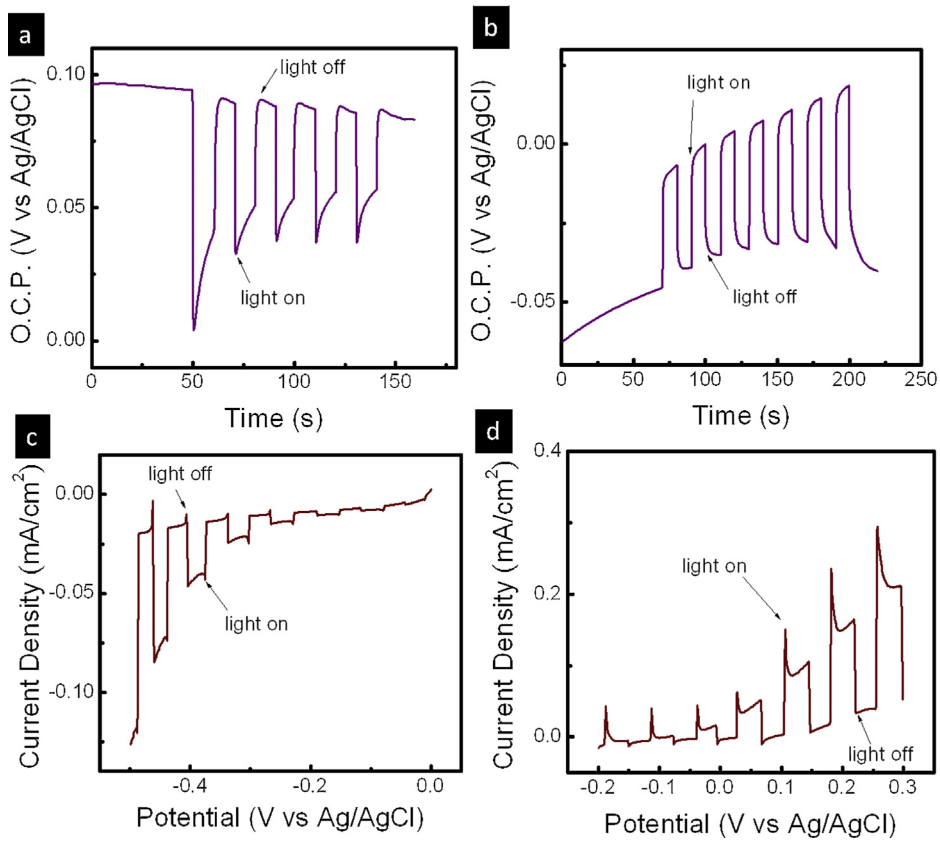

Fig. 2. OCP versus time of Cu_2O thin films as grown in the (a) acidic and (b) basic electrolytes. Photocurrent–voltage responses of (c) *p*-type Cu_2O thin film, and (d) *n*-type Cu_2O thin film.

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