스핀코팅으로 제작된 Cu_2O 필름의 광전기적 특성

논 문
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Optoelectronic Characteristics of Transparent Cu_2O Films Spin-coated on Glass Substrates

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(Kiyeol Kwak · Kyoungah Cho · Sangsig Kim)

Abstract – Cu_2O nanoparticles-based films are fabricated by spin-coating on glass substrates and their optoelectronic characteristics are investigated in this study. The Cu_2O films are nearly all-transparent as high as 98% in a wavelength range from 400 nm to 900 nm and three exciton peaks associated with the sublevels in the conduction band are observed at the wavelengths shorter than 400 nm in the absorption spectrum. Under the illumination of the 325 nm wavelength light, the photocurrent efficiency of the Cu_2O film is 1.8×10^5 μA/W at a voltage of 2.5 V in air.

Key Words : Oxides, Thin films, Optoelectrical, Transparent device, Spin-coating

1. Introduction

Cuprous oxide (Cu_2O) has been one of attractive metal-oxide semiconducting materials in a variety of applications such as solar cells, humidity and gas sensors, and thin-film transistors [1-3]. Especially, Cu_2O has attracted considerable interests in the field of optoelectronics since it is p-type metal-oxide semiconductor with direct band gap energies of 2.0-2.2 eV [4-8]. In addition, Cu_2O is one of promising materials for low-cost optoelectronic devices because Cu_2O films are easily formed via relatively low cost processes including electrodeposition and thermal oxidation of copper surfaces [9-10]. Nevertheless, there is some cumbersome post-processing to obtain desirable optoelectronic characteristics of Cu_2O films formed by electrodeposition or thermal oxidation. The above-mentioned methods can be applied to only substrates having conductivity and thermostability to form Cu_2O films. As a result, the formation of Cu_2O films is restricted by the types of substrates, and then it is difficult to form Cu_2O films on plastic or glass substrates by the above-mentioned methods. Among several methods of forming thin films, spin-coating technology is one of very useful methods because it is applied to any substrate and a simple fabrication technique with low-cost and large-area coverage. Recently, the fabrication of transparent devices has been a hot issue in optoelectronics since transparent photoconductive devices are available for aesthetically pleasing solar cells [11]. In this study, therefore, we attempt to fabricate a Cu_2O thin film on a transparent glass substrate using spin-coating method and examine its optoelectronic characteristics in air at room temperature.

2. Experimental

Cu_2O nanoparticles (NPs) were synthesized by using copper nitrate hydrate and glucose in alkaline solution as follows. $Cu(NO_3)_2 \cdot 3H_2O$ of 0.966 g and glucose of 0.36 g were dissolved in 10 mL of deionized water and the mixture solution was heated to 90 ℃. Then 1 M NaOH was added to the mixture solution until the color of solution turned into reddish brown from light blue indicating synthesis of Cu_2O. The Cu_2O NPs solution passed through a membrane filter with a pore size of 0.25 μm was spin-coated on a glass substrate. Then Cu_2O films were patterned with gold finger electrodes by thermal evaporation. The absorption and transmittance of the Cu_2O films were taken with a Shimadzu UV-3101PC spectrophotometer. The excitation source for photoluminescence (PL) and photoresponses was the 325 nm wavelength light from a He-Cd laser with an optical power of 11 mW. The optoelectronic properties of the Cu_2O films were characterized with an Agilent 4155C semiconductor parameter analyzer in air at room temperature.

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3. Results and discussions

Figure 1a shows the transmission spectrum obtained from a Cu_2O film on a glass substrate in the wavelength range from 400 to 900 nm, which exhibits high transmittance about 98% in the visible region. The PL and absorption spectra of the Cu_2O film are depicted in Fig. 1b. Three peaks seen in the UV region of the absorption spectrum are attributed to the transition from the copper d-shells to higher sublevels of the conduction band [12]. The shape of the PL bands in the PL spectrum resembles that of the Cu_2O film made by electrodeposition, although their peak positions are blue-shifted, compared with our case [13].

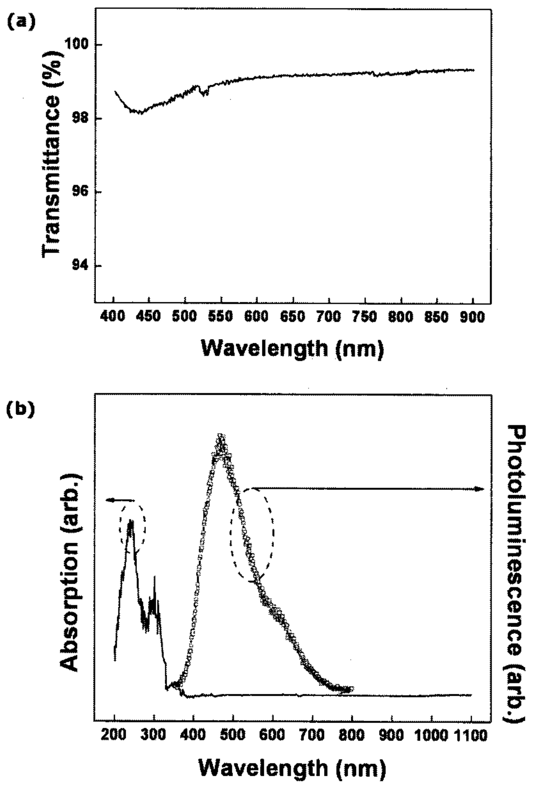

Fig. 1 (a) Transmittance spectrum obtained from a Cu_2O film on a glass substrate as a function of wavelength from 400 nm to 900 nm, and (b) the absorption and PL spectra obtained from the Cu_2O film.

Current-voltage (I-V) curves for the photocurrent excited by the 325nm wavelength light and for the dark current are plotted in Fig. 2. The I-V curves in both cases show ohmic contact behaviors, originating from the work function difference between Au and Cu_2O. In the cases of p-type metal-oxide semiconductor materials, the vacancies of metal ions are most responsible for the dark current. We confirm the type of our Cu_2O films to be p-type through the experiment of a back-gate field-effect thin film transistor with the Cu_2O film used as a channel (not shown here). Thus the vacancies of Cu^{+1} contribute mainly to the dark current in this study. The photocurrent efficiency is estimated to be about 1.8×10^5 μA/W at 2.5 V and the ratio of the photocurrent to the dark current (on/off ratio) is about 2×10^2.

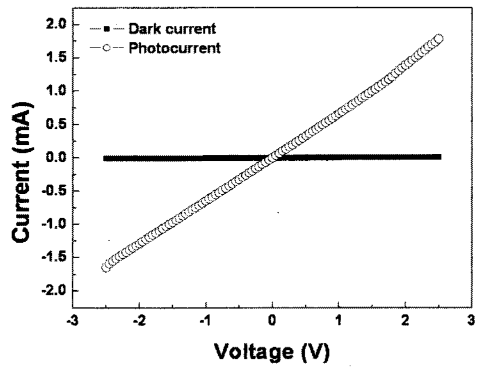

Fig. 2 Current-voltage (I-V) curves for the Cu_2O film in the dark and under the illumination of the 325 nm wavelength light with a power of 11 mW at room temperature in air.

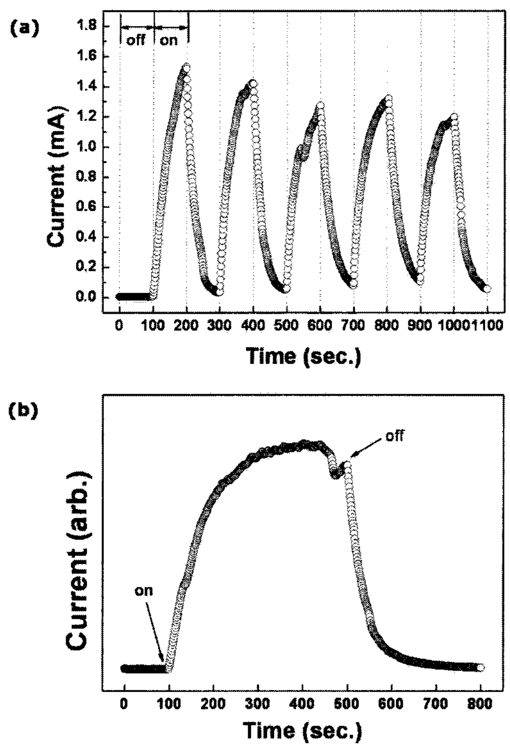

Fig. 3 (a) The photocurrent transients of the Cu_2O film measured at a bias voltage of 2.5 V under the periodical illumination of light with a wavelength of 325 nm, and (b) the photocurrent transient measured during one cycle.

Figure 3a demonstrates the photocurrent transients of the Cu_2O film measured at a bias voltage of 2.5 V under the illumination of light with a wavelength of 325 nm periodically for 100 s. The slow photoresponse observed in Fig. 3a indicates the hopping transport of photo-generated charge carriers responsible for photocurrent. The photocurrent decreases in magnitude with successive irradiation, while the magnitude of dark current increases. A possible origin of this phenomenon is that the timescale (100 s) applied in this study is shorter than rise and decay time of photocurrent of the Cu_2O film. As shown in Fig. 3b, it takes 300 seconds to reach the maximum photocurrent under the illumination, and the decaying time is longer than 200 seconds. Therefore, the phenomenon observed in Fig. 3a can be explained as follows. When another light is irradiated before traps are completely emptied (after the light is turned off), the probability that the photo-generated holes and trapped electron meet and recombine radiatively or nonradiatively is increased. Consequently, the decrease in the number of holes contributing to the photocurrent brings about the stepwise decrease in the magnitude of the photocurrent in successive illumination. In addition, the dark current is slightly larger in magnitude than the initial value, which may be owing to the filling of deep traps on the timescale of 100 s.

4. Summary

The Cu_2O film-based photodetector is successfully fabricated on a glass substrate by a spin-coating process. Under the illumination of the 325nm wavelength light, the photocurrent efficiency of the Cu_2O film in air at room temperature is estimated to be about 1.8×10^5 μA/W at a bias voltage of 2.5 V. The transparent Cu_2O film easily formed by a spin-coating technique is a promising material in application of UV photodetectors.

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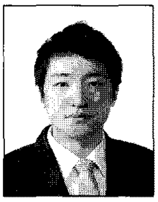
BIOGRAPHY



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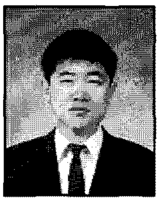

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