INVESTIGATION ON OPTICAL PROPERTIES AND APPLICATION OF ZnO THIN FILM

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ABSTRACT

ZnO thin film was investigated on the optical properties and application. Thin films preparation, ZnO thin film was deposited on glass substrate by a direct current (dc) magnetron sputtering system using a ZnO target as in-house-make. The deposition process was conducted at ambient temperature for 30 min under argon atmosphere of 50 mT and dc power applied at 30 W. Phase identification, morphology, thickness and composition of the thin film were investigated by X-ray diffraction (XRD), scanning electron microscope (SEM) and energy dispersive X-ray spectroscopy (EDS), respectively. Optical properties of the thin film were measured by UV-visible spectroscopy. It was found that, the crystal structure of thin film was ZnO single phases within atomic composition of Zn : O to be 48.80% : 52.20%. Film morphology showed the more roughness within the distribution of gains around 20 nm to 50 nm. Cross-sectional SEM views indicated that the film thickness was about 200 nm. Optical properties showed the percent transparent increase and absorption decrease with the wavelength increasing 350 nm to 400 nm (UV radiation). This result has been induced to be UV radiation protection in sunglasses.

KEYWORDS: *ZnO thin film, optical properties, UV radiation, sunglasses*

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INTRODUCTION

Zinc oxide (ZnO) is key materials for researchers because it leading provider of market, technology research and industry analysis services for the thin film, organic and printable electronics businesses [1-7]. It is versatile for numerous commercial applications, for example, as an additive in various industrial products ranging from plastics, ceramics, glass, cement, rubber, lubricants, paints, ointments, adhesives, sealants, pigments, foods, batteries,…, to first aid tapes [8-9]. In addition, ZnO is alternative window material for solar cells [10], thermoelectric element for electric and cooling generations [11] and suitable for short wavelength optoelectronic applications with the wide direct band gap semiconductors (3.3 eV) [12-14]. Moreover, the disordered nanoparticles and thin films can be find high excitant binding energy (60 meV) in ZnO crystal to be ensured efficient excitonic emission at room temperature and room temperature ultraviolet (UV) luminescence, including has transparent to visible light and can be made highly conductive by doping [1].

In this work, we are investigating on the crystallography, morphology, composition and optical properties ZnO thin film on glass substrate into the application such sunglasses.

MATERIALS AND METHODS

ZnO Thin film was deposited by an in-house-built dc magnetron sputtering system using the ZnO target as obtained by simple preparation. The preparation of the target was pressed ZnO powder (99.99 % purity, QRëC, New Zealand) onto copper supporting cap to obtain the target of 60 mm in diameter and 3.0 mm thick. The substrate was soda-lime glass plates of 2.0×2.0 cm^2

area and was cleaned with acetone in ultrasonic washer for 10 min followed by drying in air, before loading in sputtering chamber for deposition of thin films. The process conditions for the deposition were as base pressure 3.2 mT, working pressure 42 mT, dc power 30 W, substrate temperature 300 K and deposition time 30 min. After the deposition process, phase identification, morphology, thickness and composition of thin films were observed by X-ray diffractometer (XRD-6100, Shimadzu), scanning electron microscope (SEM) and energy dispersive X-ray spectroscopy (EDS) using SEM&EDS instrument (JSM-5410, JEOL). Optical properties of thin film were measured by UV-visible (UV5200, Shanghai Metash Instruments Co. Ltd). In addition, based on the thin film deposition condition could be coated the ZnO thin film on sunglasses.

RESULTS AND DISCUSSION

Figure 1 shows the XRD patterns of the glass substrate and ZnO thin film to be clearly difference of amorphous and crystalline phase of ZnO on hexagonal wurtzite structure as confirmed with PDFWIN#89-1397. The crystallite size (*D*) and lattice strains (ε) were evaluated from the (002) peak by using Debye–Scherrer's formula as followed;

$$D = \frac{K\lambda}{\beta \cos\theta} \quad (1)$$

and

$$\varepsilon = \frac{\beta}{4\tan\theta} \quad (2)$$

where K, λ, θ and β were the shape factor (equal to 0.89), wavelength of X-ray radiation, the Bragg diffraction angle of the (002) plane and the full width at half-maximum (FWHM) of the (002) diffraction peak [15, 16], respectively. The result showed that the crystallite size of ZnO thin film was approximately 22 nm while the lattice strains equal to 0.54 %. Which, the lattice strains and the crystallite size of ZnO thin films have been affected of the transparent and conductive. These results indicated that ZnO thin films were successfully deposited on the substrates, as can be seen in the SEM images in Fig. 2. From Fig. 2 (a), the morphology of thin film displayed the more roughness within the distribution of gains around 20 nm to 50 nm agreeing with the crystallite size as evaluated by using Debye–Scherrer's formula from the XRD result. Figure 2 (b) shows the cross-sectional SEM image to be indicating the film thickness about 200 nm. Moreover, the film thickness could be predicting the deposition rate of ZnO thin film about 6 nm/min. Also, the EDS result confirmed ZnO thin film deposit on the substrate as shown in Fig. 3.

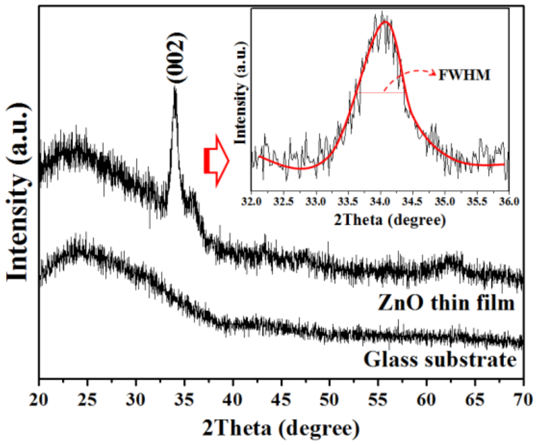


Fig. 1. The XRD patterns of the glass substrate and ZnO thin film

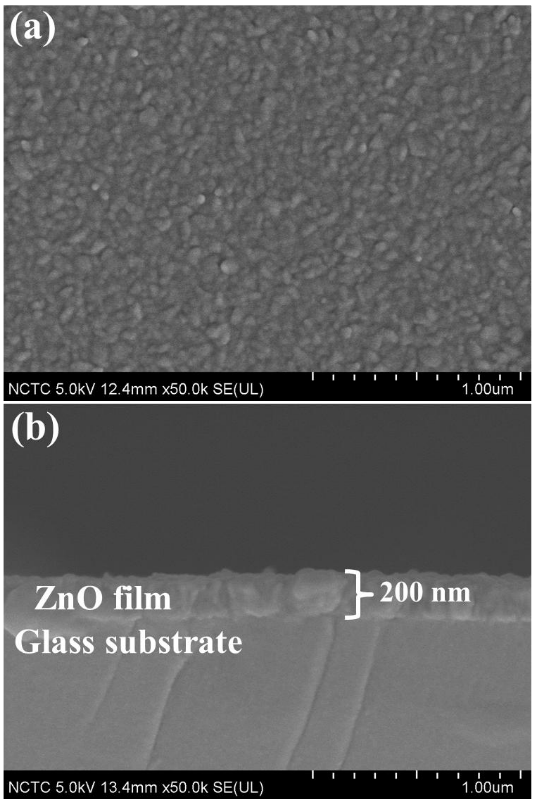


Fig. 2. SEM images for (a) morphology and (b) thickness of ZnO thin film

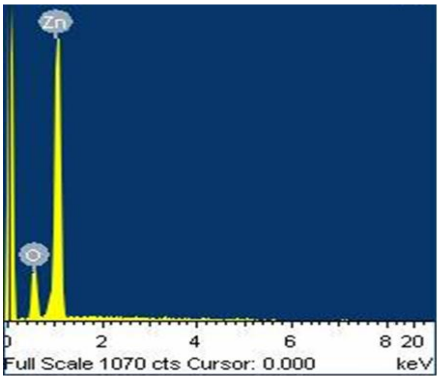
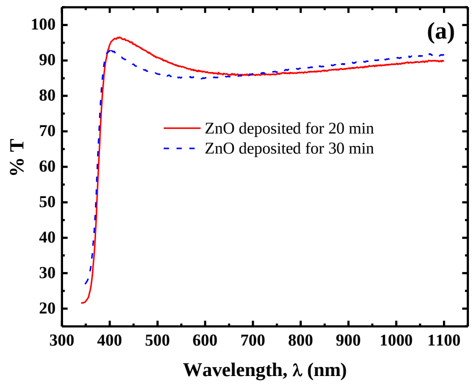


Fig. 3. EDS spectra of ZnO thin film

Figure 4 shows the transmittance and absorbance spectra of ZnO thin film in the wavelength range from 350 to 1100 nm comparison between the deposited films at 20 min and 30 min. The films showed the electromagnetic spectrum of highly transmittance to 95% and 93% and low absorbance to 0.01 and 0.03 for thin film deposited at 20 and 30 min, respectively, within a sharp ultraviolet cut-off at approximately 400 nm. In addition, the as-deposited thin films of 30 min can be showed absorption in the visible (400–700 nm) due to transmittance decreased and absorbance increased. In this case has effected to the minor reduced transparency of thin film in the visible rang. These results indicated that the ZnO thin film has been good transmittance and also has absorbance which interesting to be application into the UV radiation protection in sunglasses as shown in Fig. 5. The transmittance and absorbance of sunglasses before and after coating ZnO thin film for 30 min in the wavelength range from 350 to 1100 nm as shown in Fig. 6. This result shows that the sunglasses after coating ZnO thin film can be absorption UV-visible about 3.15 % and the good transparency in the visible rang.



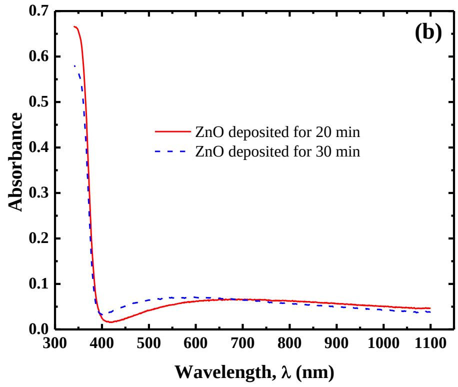


Fig. 4. (a) transmittance and (b) absorbance spectra of ZnO thin film

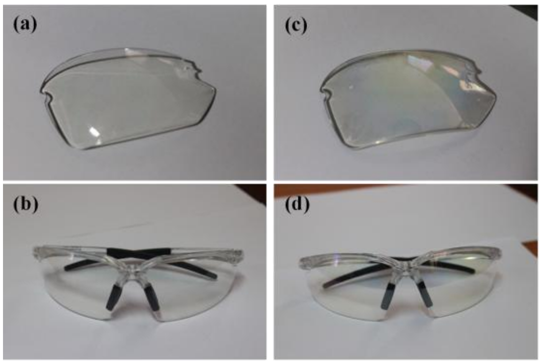
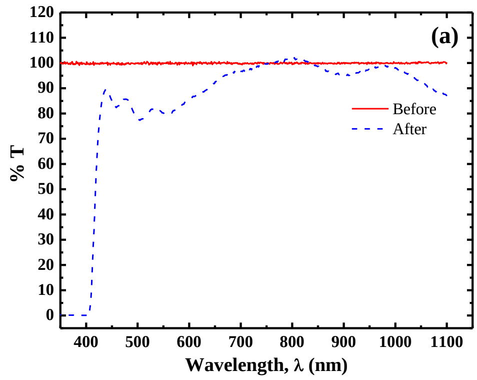


Fig. 5. Application of the ZnO thin film coating on sunglasses (a) and (b) before coating and (c) and (d) after coating



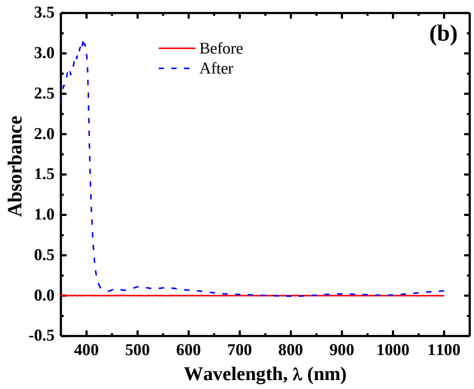


Fig. 6. (a) Transmittance and (b) absorbance of sunglasses before and after coating ZnO thin film for 30 min

CONCLUSION

ZnO thin film could be deposited on glass substrate by a dc magnetron sputtering system. Crystal structure of the thin film was hexagonal wurtzite structure ZnO single phases within the crystallite size approximately 22 nm, the lattice strains of 0.54 %, morphology of the gains distribution around 20 nm to 50 nm and thickness about 200 nm. The ZnO thin film was highly transparent and lowly absorption in the visible range of the electromagnetic spectrum within a sharp ultraviolet cut-off at approximately 400 nm. Optical properties ZnO thin film could be induced to be UV radiation protection in sunglasses about 3.15 %.

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