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Spray Pyrolysis Deposition and Effect of Annealing Temperature on Optical Properties of Cu:NiO Film

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ABSTRACT

Spray pyrolysis method that used to prepare Cu:NiO thin films onto glass substrate with various annealing temperature. Spectral transmittance of prepared thin films determined by UV-Visible spectrophotometer in the range of (380-900) nm. The transmittance decreased with increasing annealing temperature. While the absorption coefficient and extinction coefficient increased with increasing annealing temperature. Energy gap decreased from 2.9 eV before annealing to 2.78 eV after 500 ºC annealing temperature.

Keywords: Cu; NiO; thin film; optical properties; Energy gap

1. INTRODUCTION

Transparent conducting oxides (TCO) thin films are attracting more and more attention due to their widely applications such as liquid crystal displays, light-emitting diodes, solar cells and detector[1-2]. In the literature, the optical band gaps of bulk NiO is 4 eV [3-5]. Due to the wide band gap 3.6-4 eV, it has a wide range of applications in optoelectronics as well as in thermal applications [6]. Metal oxides like nickel oxides have found wide application in materials applications such sensors [7], transparent electrode [8], efficient control of energy inflow-outflow of buildings or automobiles and aerospace [8-9], large scale optical switching glazing and electronic information display [10]. Several physical and chemical methods, such as sputtering [11], pulsed laser deposition [12], chemical bath deposition [11-13] and sol-gel [14] have been used to obtain nickel oxide films. All the NiO thin film prepared methods offer different advantages depending on the application of interest and many efforts have been conducted to obtain films with the desirable physical and/or chemical properties [15].

In the present work, the effect of annealing temperature on the optical properties of Cu-doped NiO films deposited by chemical spray pyrolysis is considered.

2. EXPERIMENTAL DETAILS

Thin films of NiO doped by Cu were prepared using chemical spray pyrolysis method. The coating solution was made by dissolving nickel chloride hexahydrate (NiCl2.6H2O) (from sigma-Aldrich company), into 100 ml of redistilled water to make 0.1 M solution. The volumetric ratio of Cu was 4% and substrate temperature was 380 ºC. The layers have been deposited onto glass substrates that are cleaned in distilled water and then dried using air blower. After that they were cleaned again with acetone in order to remove any strains on it. In order to optimize the depositionarrivingat the following conditions; spraying rate 0.2 ml /spray, substrate to nozzle 30 cm, spraying time during each cycle 7 sec, time interval between successive sprays1.5 min, and the carrier gas (filtered compressed air) was maintained at a pressure of 105 Nm-2.

Thicknesses of the films were measured gravimetrically and the measured thickness is about 300 nm. The prepared films were annealed at 450 and 500 ºC, the noptical transmittance and absorbance were recorded in the wavelength range (380-900nm) using UV-Visible spectrophotometer (Shimadzu Company Japan) double beam spectrophotometer.

3. RESULTS AND DISCUSSION

The transmittance spectra of Cu-doped NiO thin film for various annealing temperature have been recorded by UV-Visible spectrophotometer as in Fig.1. From this figure, it can notice that the transmittance decreases with increasing annealing temperature for all deposited thin films.

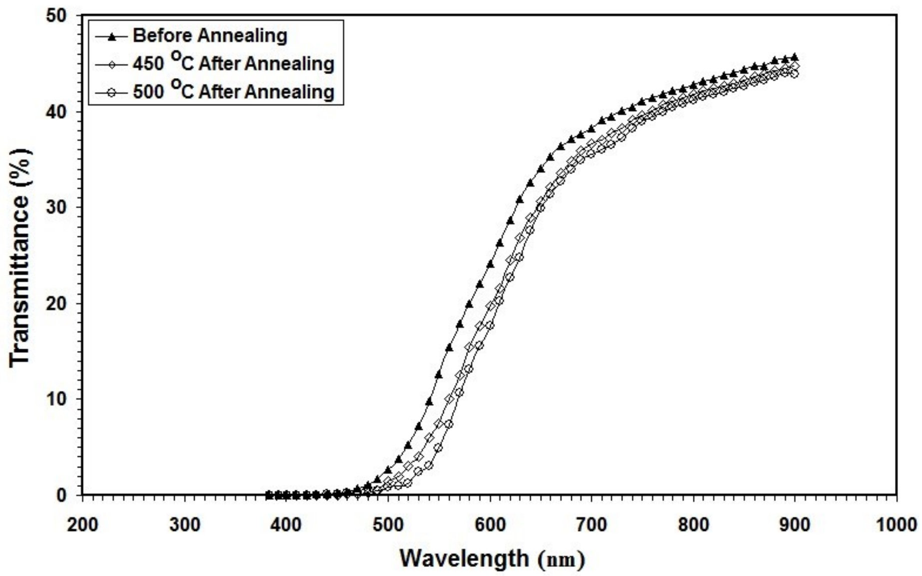

Fig. 1. The transmittance spectra versus wavelength of Cu:NiO thin film.

The absorption coefficient (α)is defined as the ability of a material to absorb the light of a given wavelength, and is measured from the following relation [16]:

$$\alpha = \frac{2.303A}{d} \quad (1)$$

where A is the absorbance and d is the thickness of the film. The relationship between α and wavelength (λ) shown in Fig.2. From this figure, it can notice that the absorption coefficient increases with increasing annealing temperature for all deposited Cu:NiO thin films.

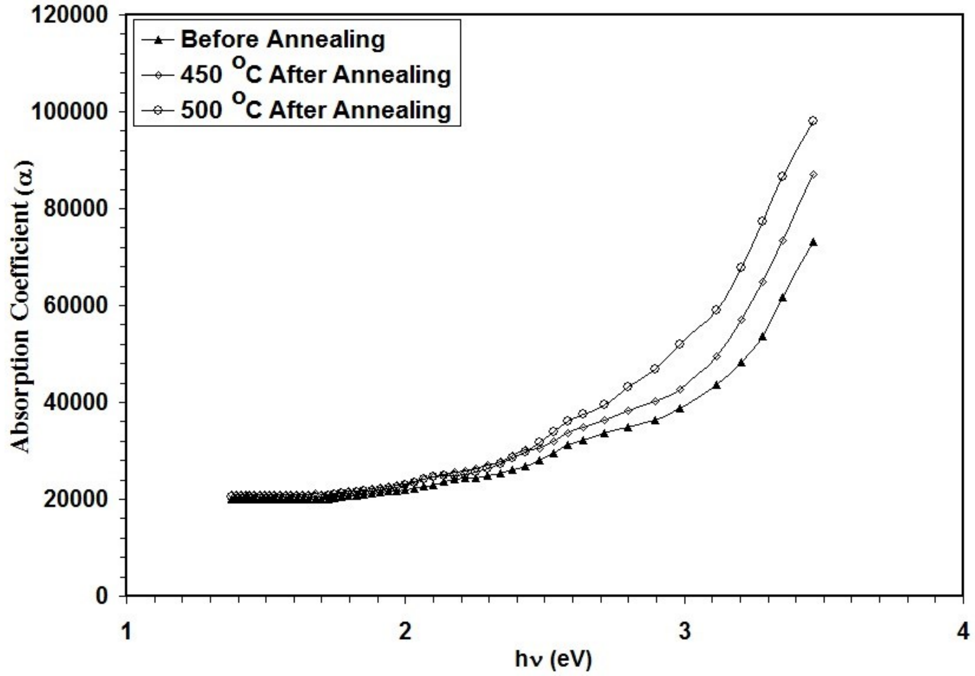

Fig. 2. The absorption coefficient versus photon energy of Cu:NiO thin film.

The correlation between absorption coefficient and optical band gap Eg, as expressed by the following relation [17]:

$$\alpha h\upsilon = (h\upsilon - Eg)n \quad (2)$$

Where hυ is the photon energy and n is 1/2 for direct inter band transitions or 2 for indirect inter band transitions. Portion of the graph of (αhυ)n against hυ is extrapolated to α= 0 the intercept gives the transition band gaps as in Figs 3-5. From these figures, it can notice that the energy gap decreases with increasing annealing temperature from 2.9 eV before annealing to 2.78 eV after 500 ºC annealing temperature.

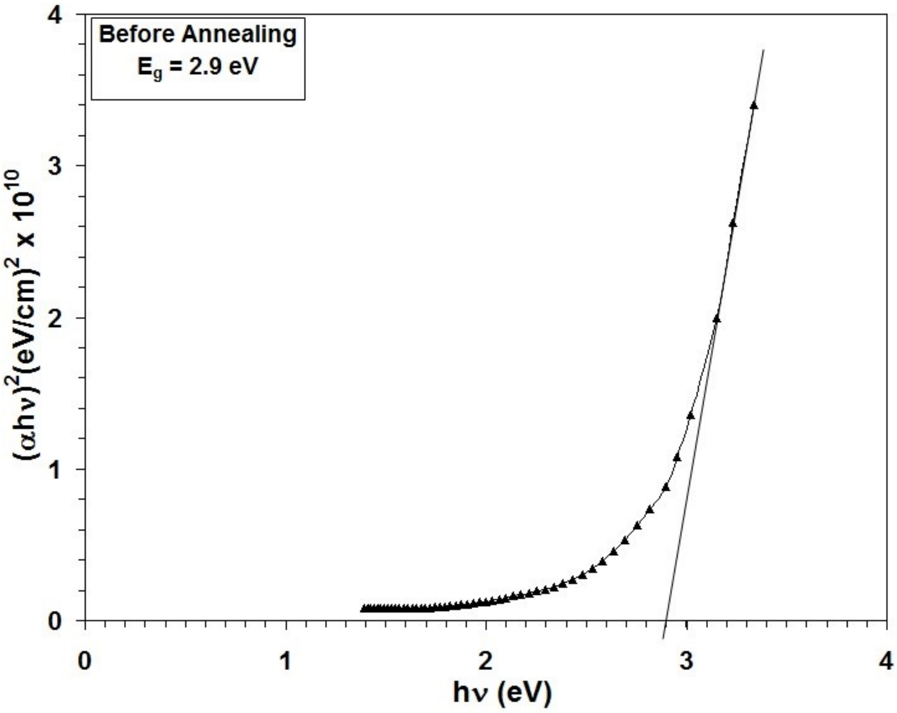

Fig. 3. Variation of (αhυ)2 with photon energy of Cu:NiO thin film before annealing.

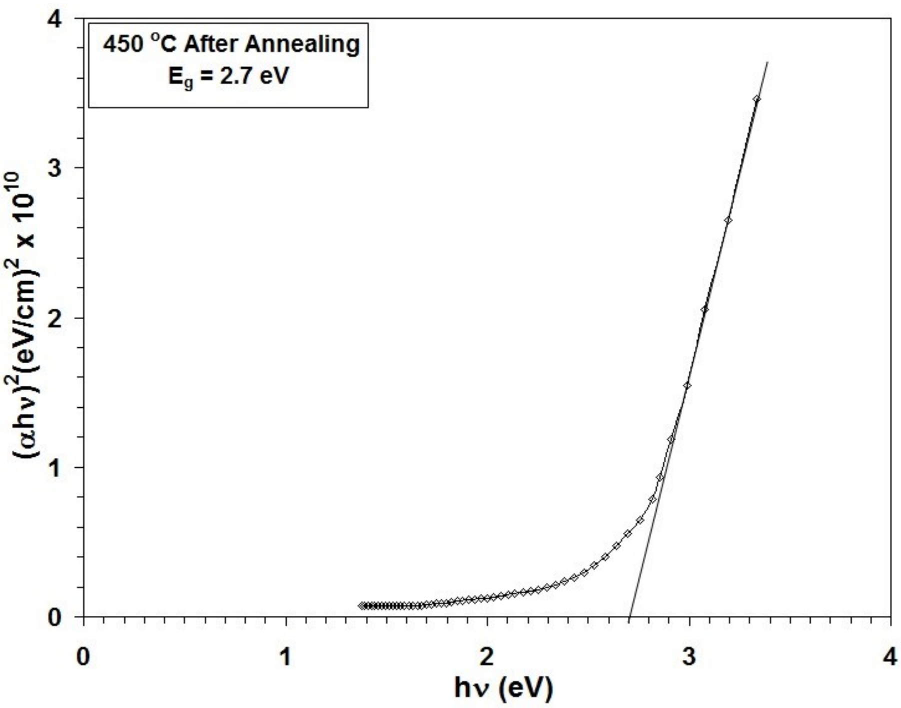

Fig. 4. Variation of (αhυ)2 with photon energy of Cu:NiO thin film after 450 ºC annealing temperature.

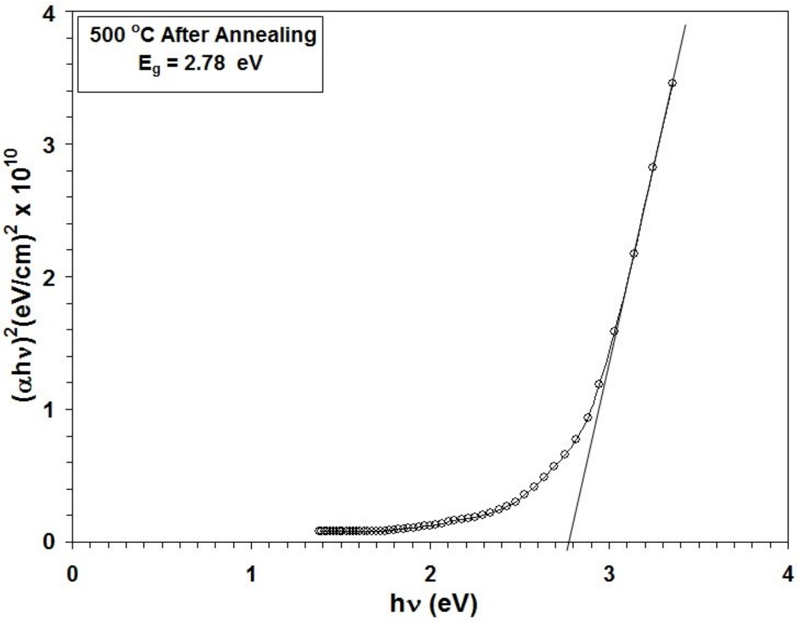

Fig. 5. Variation of (αhυ)2 with photon energy of Cu:NiO thin film after 500 ºC annealing temperature.

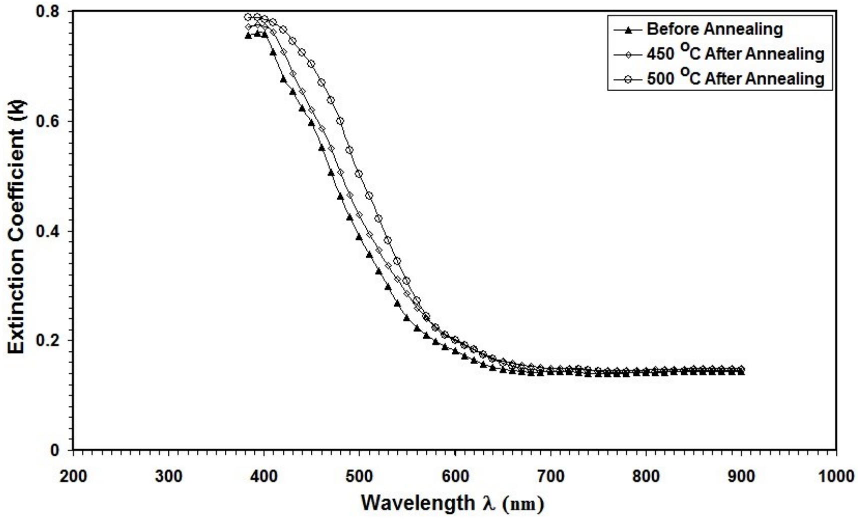

Fig. 6. The extinction coefficient versus wavelength of Cu:NiO thin film.

The refractive index (n) depend on the reflectance (R) and extinction coefficient as in the following relation [20]:

$$n = \left[\left(\frac{4R}{(R-1)^2}\right) - K_0^2\right]^{1/2} - \frac{R+1}{R-1} \tag{4}$$

Fig.7 represent the relationship between refractive index and wavelength for Cu-doped NiO thin film for various annealing temperature. From this figure, it can notice that the refractive index decreases with increasing annealing temperature until 550 nm, and then the refractive index change slightly at wavelength greater than 550 nm.

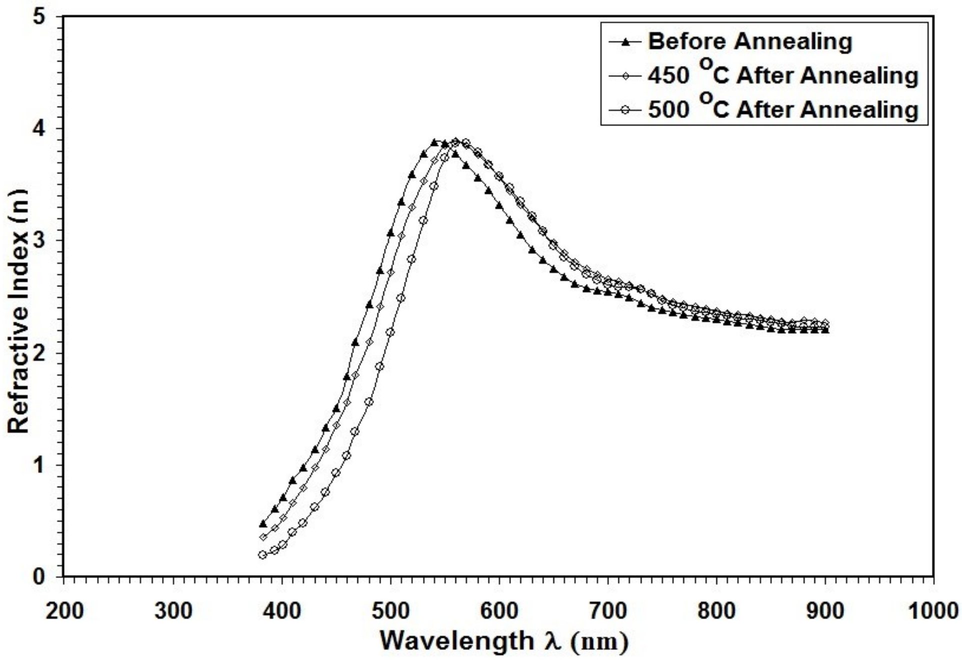

Fig. 7. The refractive index versus wavelength of Cu:NiO thin film.

4. CONCLUSION

Spray pyrolysis method that used to prepare Cu:NiO thin films onto glass substrate with various annealing temperature. The transmittance decreased with increasing annealing temperature. While the absorption coefficient and extinction coefficient increased with increasing annealing temperature. The refractive index takes various behaviors with wavelength. Energy gap decreased from 2.9 eV before annealing to 2.78 eV after 500 ºC annealing temperature.

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