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AFFECTS DEPOSITION TIME AND SUBSTRATE TEMPERATURE ON OPTICAL PROPERTIES OF ZnO THIN FILM

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ZnO thin films have been prepared with different processes such as pulsed-laser deposition, chemical vapor deposition spray pyrolysis and sol-gel process etc. Among them, chemical vapor deposition (CVD), in this paper we will study the effect of, deposition time and temperature of the substrates. The temperatures of substrate was varied as was the deposition time of ZnO in order to determine the best substrate temperature and deposition time to produce the best physical properties of deposition. using pure zinc acetate hydrous $Zn(Ch_3COO)_2{\cdot}2H_20$ with 98% purity. The best deposition time was found to be (20 min) while the best temperature degree was (500 °C).

Keywords: thin film, chemical vaporous deposition, ZnO, pulsed-laser deposition.

ZnO тонких плівок були підготовлені з різними процесами, такими як імпульсного лазерного осадження, хімічного осадження парів ПІРОЛІЗ і золь-гель процесу і т.д. Серед них, хімічне осадження парів (CVD), в цій статті ми будемо вивчати вплив, час осадження і температури підкладки. Температура підкладки варіювалася як було часу осадження з ZnO з метою визначення кращих температур підкладки та осадження час, щоб зробити найкращі фізичні властивості осадження, з використанням чистого цинку ацетат водний $Zn(CH3COO)_2{\cdot}2H_2$ з 98% чистоти. Кращий час осадження виявиться (20 хв), а найкраща температура мірою була (500 °C).

Ключові слова: тонкі плівки, хімічні пароподібні осадження, ZnO, імпульсно-лазерне напилення.

ZnO тонких пленок были подготовлены с различными процессами, такими как импульсного лазерного осаждения, химического осаждения паров ПИРОЛИЗОМ и золь-гель процесса и т.д. Среди них, химическое осаждение паров (CVD), в этой статье мы будем изучать влияние, время осаждения и температуры подложки. Температура подложки варьировалась как было времени осаждения из ZnO с целью определения лучших температуры подложки и осаждения время, чтобы произвести самые лучшие физические свойства осаждения. с использованием чистого цинка ацетат водный $Zn(CH3COO)_2{\cdot}2H_2$ с 98% чистоты. Лучшее время осаждения оказалось (20 мин), а лучшая температура степени была
(500 °C).

Ключевые слова: тонкие пленки, химические парообразные осаждения, ZnO, импульсно-лазерное напыления.

INTRODUCTION

Zinc oxide (ZnO) films have been investigated in recent years as transparent conducting oxide (TCO) because of their good electrical and optical properties in combination with large band gap, abundance in nature, and absence of toxicity [1]. This material is an II – VI compound semiconductor with a wide variety of applications as electrodes, window materials in display, solar cells, and various optoelectronic devices [2 – 5]. Besides, ZnO have attracted intense attention in the searching for high temperature de Curie (Tc) ferromagnetic diluted magnetic semiconductors (DMS) materials since Dietl et. al.

ZnO films can be deposited by a variety of techniques such as:

– Chemical Vapor Deposition (CVD) [3];
– Molecular Beam Epitaxy (MBE) [4];
– Pulsed Laser Deposition (PLD) [1];
– Spray Pyrolysis Deposition (SPD) [4 – 6];
– Magnetron Sputtering (MS) [3 – 4].

Some of the most important factors that affect the properties of the films prepared using chemical vapor deposition (CVD) techniques are as follows:

– Location of the sample;
– Deposition time;
– Temperature of the substrates;

– Rate of gas flow.

Thin deposited ZnO films on glass or silicon substrates were prepared in groups each in different deposition conditions .The procedure was to fix three of the four factors and changing one in order to investigate the effect of this factor on the physical properties of the produced films, in this paper we will study the effect of, deposition time and temperature of the substrates.

The temperatures of substrate was varied as was the deposition time of ZnO in order to determine the best substrate temperature and deposition time to produce the best physical properties of deposition. The best deposition time was found to be (20 min) while the best temperature degree was (500 °C).

EXPERIMENTAL PROCEDURE

In order to prepare pure ZnO films using chemical vapor deposition (CVD) techniques on glass substrates the deposition material used was pure zinc acetate hydrous $Zn(Ch_3COO)_2{\cdot}2H_20$ with 98% purity. After preparing the substrates, they were placed and adjusted in the deposition unit while the temperature degrees were varied between (400 – 500 °C) in order to ensure optimum film properties. The pressurized air flow was also adjusted to the best flow rate which was found to be 2 L/min to produce the best samples as the rate of airflow is related to the uniformity of the deposited film and it must be adjusted to prevent the formation of colored strips on the glass substrates that can interfere with visional and microscopic inspection. We choose deferent time for doping ZnO (20, 25, 30 min) to study the effect of deposition time and substrate temperature for the optical properties.

Various temperature degrees were tested when heating the deposition material and it was found that the temperature of (340 – 360 °C) is the appropriate temperature degree to vapor zinc acetate and then to produces the best results of zinc oxide deposition and then, samples were left afterwards to cool.

The following equations show, how ZnO is produced.

$$Zn(Ch_3COO)_2{\cdot}2H_2O \rightarrow ZnO+CO_2+CH_3+ + \text{Steam}. \quad (1)$$

The thickness of the films is an important consideration in manufacturing any type of devices because of its effect of the properties of the films. The study relayed on the weight as a measurement method by using a sensitive electrical balance with a sensitivity of 10^{-4} gm. The sample is weighed before and after the deposition process and the thickness of the film is determined from the difference between the two weights and the density of the material through the formula:

$$T = (m_2 - m_1)/A{\cdot}\rho, \quad (2)$$

T – the average thickness of the film, $m_2 - m_1$ – the weight of samples before and after the deposition process respectively; A the surface are of the sample, ρ – the density of the film material. The transmission spectra and absorbance spectra were measured for all pure ZnO films in various deposition conditions as a function of wavelength within the (320 – 1000 nm) range using UV-visible range spectrophotometer mode Ce 1021 at room temperature. The optical parameters of ZnO films included the investigated effect of deposition temperature on the transmission spectra and absorbance spectra with the UV-visible region. Calculating absorption coefficient and the effect of deposition temperature on this coefficient. The photon energy was calculated as a function of the wavelength from the equation

$$hv(ev) = 1.24/\lambda. \quad (3)$$

The optical energy gap was calculated from the intersect of $(\alpha hy)^2$ with the photon energy axis (hy).

RESULTS AND DISCUSSION

The process of deposition and producing homogeneous films is not a simple process but requires a number of tests including the selection of the precursor material, the temperature of substrates, the evaporation temperature and the flow rate of the carrier gasses in addition to the location of the sample in the deposition chamber. All these factors have a direct effect on the type of the required prepared film that and on its physical properties.

In this study we observed a number of observations concerning the films. In some instance the films did not grow over the substrates or they only partly covered them. In other instances we observed that the films were formed as stripes. These cases took place at temperatures less than 400 °C. While at this temperature and above, we found that the films status was enhanced significantly concerning the rate of growth and homogeneity while the optimal temperature degree in this study was found to be 500 °C to obtain the best optical, and electrical properties. In order to determine the effect of deposition time on the optical and electrical properties of ZnO films deposited on glass substrates, the transmission was measured as a function of the wavelength and the absorption coefficient was determined as a function of the photon energy, absorption edge, and the optical energy gap.

Fig. 1 shows the transmission spectrum as a function of the wavelength for ZnO samples deposited at various deposition times (20, 25, and 30 minutes) and it is evident from the figure that the films are not transmission for wavelength that are within the UV region and transmission starts at the visual spectrum and ranging between (70 – 80%) with this spectrum and reaches a maximum transmission in the wavelengths at the end of the visible range and near to the IR region.

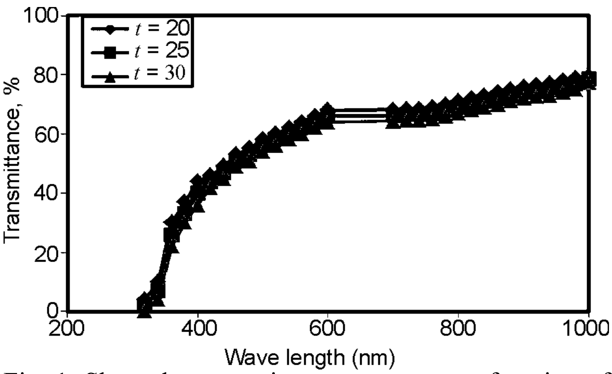

Fig. 1. Show the transmittance spectra as a function of the wavelength for ZnO samples deposited at various deposition times (20, 25, and 30 mins).

From the fig. 1 we can see that the transmission in general decreases with the increase in the deposition time as the transmission depends on the thickness of the deposited film as shown on the following formula.

$$T = 1/e^{\alpha d}, \quad (4)$$

α – the absorption coefficient and d – the thickness of the film.

The thickness of the film is directly related to the deposition time as we have previously stated and this conforms to the researches and through calculating the absorption coefficient as a function of the energy of the incident photon.

From fig. 2 the absorption edge that ranges between (3.1 – 3.24) eV was found for the depositions times ranging between (20 – 30) min res-

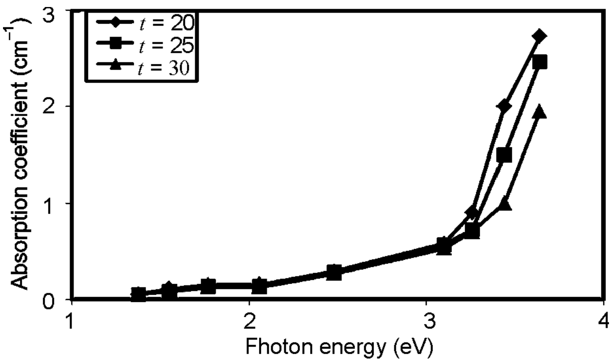

Fig. 2. Optical absorption coefficient (α) of ZnO samples deposited at various deposition times (20, 25, and 30 mins).

pectively. We see that the absorption edge shifts towards the lower energies with the increase in deposition because of the increase in the charge carriers with the increase in the deposition time and thickness. The figure also shows that the absorption coefficient decreases with the increase in the deposition time as the absorption edge and as:

$$A = \log 1/T = 2.303 \ln 1/T = 2.303 \ln(e^{\alpha d}), \quad (5)$$

$$A = 2.303 \alpha d, \quad (6)$$

$$\alpha = A/2.303 d, \quad (7)$$

This supports the practical results that is obtained besides.

Fig. 3 shows the relationship between $(\alpha hy)^2$ and the photon energy, the incident photon on ZnO films from which the optical energy gap (E_{opt}) for these films deposited at various deposition times are obtained. E_{opt} is determined form the intersection of the straight lines of the curve with the energy axis at photon energy and in our case E_{opt} was found to be 3.2 eV. The effect of substrate temperature on the crystal structure of ZnO films deposited on glass substrates was investigated using samples deposited at different substrate temperatures (400, 450, and 500 °C)

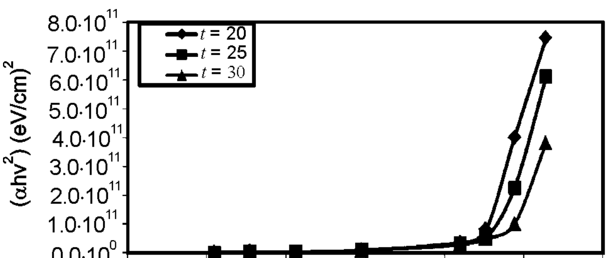

Fig. 3. Measurement of energy band gap for ZnO samples deposited at various deposition times (20, 25, and 30 mins).

were tested while the deposition time and flow rate were kept at (20 min) and (2 L/m) respectively as follows.

Fig. 4 illustrate the spectrum of transmittance as a function of wave length, the decrease of wave length, as its value very high at the wave length which is located with in optical spectrum and infra – red radiation, which indicates that these films have large energy gap to allow most of the visible light to pass as shown in fig. 3, the transmittance value increases by increasing substrate heat degree, which leads to improve the crystal structure.

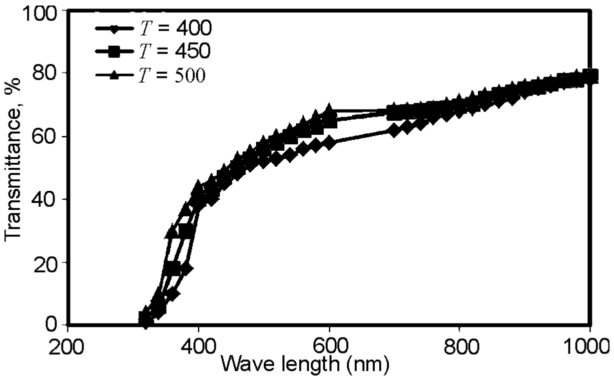

Fig. 4. Show the transmittance spectra as a function of the wavelength for ZnO samples deposited at various temperatures (400, 450, 500 °C).

Fig. 5 elucidates the relation between the absorption coefficient and the energy of the incident photon for ZnO films and shows that the absorption coefficient slightly increases with the temperature of substrates and also with the increase in the energy of the incident photon within the low energy range. The absorption coefficient largely increases as it approaches the absorption edge.

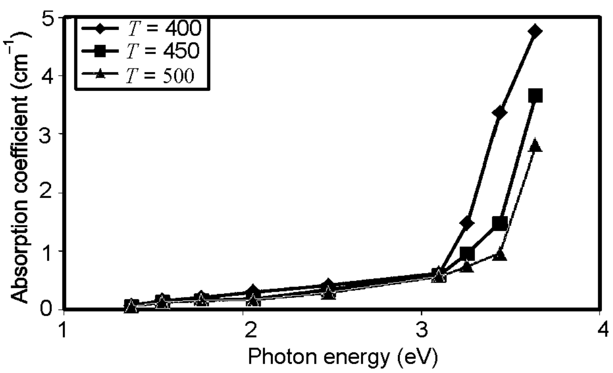

Fig. 5. optical absorption coefficient (α)) of ZnO samples deposited at various temperature (400, 450, 500 °C).

Fig. 6 elucidates the relation between $(\alpha hy)^2$ and the energy of the incident photon for ZnO as it shows optical energy gap increase with increasing substrate temperature for these films, E_{opt} is determined from the intersection of the straight lines of the curve with the energy axis at (hv),and Eopt was found to be (3.2 – 3.3) eV.

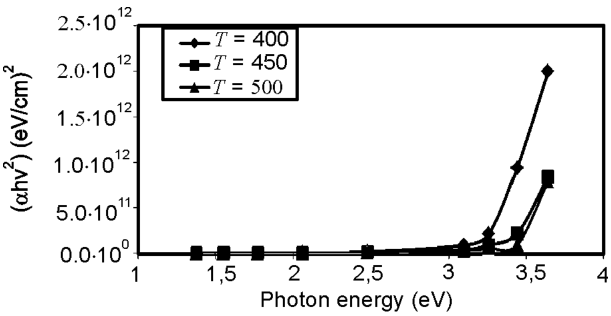

Fig. 6. Measurement of energy band gap for ZnO samples deposited at various temperature (400 , 450, 500 °C).

CONCLUSION

1. The transmission in general decreases with the increase deposition time.
2. The absorption coefficient decreases with the increase deposition time.
3. The transmission in general increases with the increase in deposition temperature.
4. Optical energy gap increase with increasing substrate temperature.
5. The best deposition time was found to be (20 min) while the best temperature degree was 500 °C.

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