Structural behavior of DC sputtered zinc oxide (ZnO) Thin films

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ABSTRACT

In this paper ZnO thin film, has been deposited using DC sputtering technique, then the thin film has been characterized by XRD, the results showed that the strongest peak was at 36.4137 degree, FWHM was at 0.1779 degree, lattice constant was 2.46537 Å and the average grain size was 49.10 nm. AFM analysis showed that the increasing of pressure sputtering to increase of roughness average from (6.53 to 8.32) nm, root mean square from (7.67 to 9.63) nm but ten points height decreased from (28.6 to 16.6) at 3*10⁻³, 6*10⁻³ and 9*10⁻³ mbar respectively

Keywords: Thin films, zinc Oxide, DC Sputtering

1- Introduction

study of optical properties of semiconductors as a thin films is very important for many applications, including interference devices, such as antireflection coatings, laser mirrors and monochromatic filters, as well as optoelectronics, integrated optics, solar power engineering, microelectronics and optical sensor technology depending on the reflectance and transmittance properties of the films during their preparation. The determination optical parameters of the semiconductor materials are very important, both from a fundamental and a technological viewpoint[1-4]. Furthermore, the changes in refractive index are important for controlling optical properties of semiconductors, because optical properties are directly related to their structural and electronic properties. ZnO is a
technologically one of important materials. It have been investigated because of their interesting optical, piezoelectric and electrical properties. ZnO is an II–VI semiconductor with a stable wurtzite structure at room temperature. It has a wide direct band gap (3.37 eV) at 300 K and a large exciton binding energy (60 meV)[5]. ZnO can be obtained by various techniques such as spray pyrolysis [5,6], chemical vapor deposition [7], pulsed laser deposition [8], sol-gel process [9] and sputtering [10-11] . Among these methods, sputtering has advantages such as good uniformity, high process controllability, and large-area deposition and has been widely used. Ellmer investigated the effect sputtering parameters on the properties of ZnO films [12]. The aim of this study is to investigate the optical properties and determine optical constants of the semiconductor ZnO by optical characterization method.

2- Materials and Methods

ZnO thin film has been deposited as explained below: cleaned the pure Zinc target 99.95% (5cm dia.) with soft sanding and ethanol, then placed cleaned substrate with deionized water and ethanol using ultrasonic on sample stage (9cm dia.) at the center of chamber (27*30)cm, closed the cover of the chamber and engaged the doorknob clock wise until tightened firmly, started the rotary vacuum, then turned on the pressure gauge, after reaching pressure to value of 1.5 *10^-3 mbar, the sputtering system (13.56Hz) has been turned on, The precipitation of the zinc oxide compound was performed on a group of vitreous samples for the purpose of studying the effect of increasing the atomization pressure on the thickness of the samples with time and current used. My agency:

Three samples were deposited using a continuous current of 300 mA, and the sedimentation time was 30 minutes under different pressures. One of the deposited thin film has been characterized with XRD to study structural behavior. The same process has been repeated with different pressure sputtering as three more thin films has been deposited at 3*10^-3, 6*10^-3, 9*10^-3 mbar. Finally deposited thin films has been analyzed with AFM to study morphology of thin films surfaces.

3- Results and Discuss

Structural Properties: thin film has been characterized by XRD(SHIMADZU Japan XRD 6000) , the results showed in Table (1) below

| Compound | θ (deg) | FWHM (deg) | Lattice Const.(Å) | G.S (nm) |
|----------|--------|------------|------------------|--------|
| Zno      | 36.4137| 0.1779     | 2.46537          | 49.10  |
Also the XRD test results (Card 36-1451) has stated that ZnO which is polycrystalline (Hexagonal), the strongest peaks were (2θ= 36.4137), that is similar to [hkl= 101] respectively, as shown in Fig. (1).

![XRD Patterns of ZnO thin film](image)

**Fig. (1): XRD Patterns of ZnO thin film**

Average of Grain Size has be calculated by Scherer's Crystallite Size Formula.

\[
G. S = \frac{k\lambda}{\beta\cos\theta}
\]

(1)

where \(k\) is called shape factor which have value of 0.94, \(\lambda\) is the wavelength, \(\beta\) is FWHM (full-width at half- maximum value) and \(\theta\) is Bragg's diffraction angle.

**Morphology:** in order to study the effect of pressure change on structural behavior, three ZnO thin films have been deposited on glass substrates with following parameters (working current 300 mA, deposition Time: 30 min., those films were deposited in different pressure, \((3*10^{-3}, 6*10^{-3})\) and \(9*10^{-3}\) mbar, then the samples have been analyzed with AFM (SPM AA3000) to analyze surface morphology of the films as shown in Table (2).

| Pressure (mbar) | AFM Results |
|----------------|-------------|
| 3              |             |
| 6              |             |
| 9              |             |

Table (2) AFM results of ZnO thin films prepared under different pressure
| Sample # | pressure mbar | Roughness Average nm | Root Mean Square nm | Ten Points Height nm |
|----------|---------------|-----------------------|---------------------|----------------------|
| 1        | $3\times10^{-3}$ | 6.53                  | 7.67                | 28.6                 |
| 2        | $6\times10^{-3}$ | 6.66                  | 7.68                | 26.6                 |
| 3        | $9\times10^{-3}$ | 8.32                  | 9.63                | 16.6                 |

Also AFM images shows ZnO films at different pressures fig(2).

![AFM images of ZnO films at different pressures](image)

Fig.( 2) AFM images of ZnO prepared film at (a. $3\times10^{-3}$, b. $6\times10^{-3}$, c.$9\times10^{-3}$ ) mbar

4-Conclusion

Firstly, ZnO thin film, has been deposited on glass substrates using DC sputtering technique at applied power 300mA, working pressure 4.5*10-2mbar, substrate temperature 150ºC for 40 minutes, then the thin film has been characterized by XRD, the results showed that strongest peak was at 36.4137degree, and FWHM was 0.1779degree, lattice constant was 2.4653Å, and the average grain size was 49.10nm, then another three samples have been deposited with the same previous parameters.. Then
those samples have been analyzed with AFM to study the effect of increasing the atomization pressure on the thickness of the samples with time and current used. My agency three samples were deposited using a continuous current of 300 mA, and the sedimentation time was 30 minutes under different pressures. Results showed that the increasing of pressure sputtering to increase of roughness average from (6.53 to 8.32) nm, root mean square from (7.67 to 9.63) nm and ten points height from (28.6 to 16.6) at $3\times10^{-3}$, $6\times10^{-3}$ and $9\times10^{-3}$ mbar respectively. Which means at higher pressure roughness of thin film surface will increase due to increasing while the thickness will be decreased of grains size.

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