Swift Journals

Swift Journal of Physical Sciences
Vol 2(1) pp. 001-004 May, 2016.
http://www.swiftjournals.org/sjps


*Original Research Article*

# Structural Properties of Zno Thin Films Prepared Using Different Techniques

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Accepted 29th March, 2016.

**In this work, zinc oxide (ZnO) thin film has been fabricated using sol-gel and thermal spray methods on glass substrate. To fabricate a ZnO solution which dipped on substrate and spin coating treatment, zinc acetate and triethanolamine (TEA) with NaOH were used as solvents and stabilizer materials, respectively. Structural properties of ZnO films have been studied, using X-ray diffraction (XRD) and scanning electron microscopy (SEM). XRD results show that the prepared films have a polycrystalline in nature. The referred orientation ZnO (002) has the lower grain size to be 9.9 and 8.3 nm for zinc acetate, triethanolamine (TEA) with NaOH of concentration ratio of 1:4 using spin coating and thermal spray respectively, which calculated using Debye Scherer's formula. SEM images are in agreement with the XRD results that films with zinc acetate and triethanolamine (TEA) with NaOH using spin coating have a rough surface, that make ZnO thin film a promising material to solar cells and optoelectronic devices in UV range.**

**Keywords:** optoelectronic devices, ZnO, triethanolamine (TEA) and NaOH, menoethanolamine (MEA)

## INTRODUCTION

Semiconductor devices are attracting considerable attention because of their functions in our daily life. Semiconductors are integrated in most modern electronic appliances such as computers, TV displays, etc. These commercial applications of semiconductors started in 1947. The invention of an integrated circuit (IC) that is capable of sending silicon (Si) chips possible after the creation of a bipolar transistor. Semiconductors such as Si, Ge, III-V, II-IV, etc. have many advantages. They can be used in many optoelectronic devices because of their low cost, good physical properties, and small size, which also explain why various industries highly invest in them [1 – 5].

Zinc oxide (ZnO) is a semiconductor that attracts researchers given its wide band gap energy, large exaction binding, and ability to grow a single crystal substrate. The properties of ZnO make it an ideal candidate in a variety of applications such as laser diodes, gas sensors, photodetectors, etc. To grow small layer size, a well-oriented and a uniform ZnO can be subjected to different techniques such as sol-gel, and thermal spray. Each technique has its own advantages and disadvantages. Researchers have achieved a well-known minimum size of these materials, called nanostructure materials [6 – 8]. It recently has interesting development of the ZnO based on the possibility to grow the compound by epitaxial layers, quantum wells, nanorods, quantum dots and related objects, where research was focused on the applications of the ZnO as. Blue/UV optoelectronics, including light emitting diodes, laser diodes instead of using the GaN and SiC based structures [9 – 12]. In addition, a ferromagnetic material by doping it with cobalt (Co), manganese (Mn), Iron (Fe), vanadium (V), etc. and for semiconductor spintronics highly transparent conducting oxides by doping with aluminium (Al), gallium (Ga), indium (In), etc. as an alternative to In-SnO (indium tin oxide ITO). ZnO has been used commercially as Varistors that constitute hundreds of millions of dollars business a year. ZnO based surface wave acoustic devices are also regularly used in mobile phones [13].

For the above applications, many published works deal with the preparation of undoped and doped ZnO that has led to the research being focused on the nanostructures (structures with a reduced dimension) emphasizing on the electrical and optical properties. In this work, ZnO films grown on glass substrates using the sol-gel method were fabricated and intensively investigated, in order to fabricate films with high quality for solar cell applications.

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## EXPERIMENTAL DETAILS

To prepare zinc, 1.1 grams of zinc acetate, which is a solid substance as a white powder has been used as a solvent and mixture with 50 ml of ethanol alcohol solution. Then the mixture placed on a magnetic starrier and the hot plate device, at a temperature of 60 Celsius, and with rotating one thousand cycles for a period of half an hour. In addition, 5 grams sodium hydroxide, which is also a solid substance in the form of white crystals, used with Triethanol amine (TEA) as a stabilizer. ZnO films were prepared using aqueous solutions of Zn (CH3COO)2•2H2O, triethanolamine (TEA) and NaOH [weighed amounts] in de-ionized water to the volume of 50 ml [14]:

$$Zn(CH_3COO)_2.2H_2O + TEA \longrightarrow [Zn(TEA)]^{2+} + 2CH_3COO^-$$

$$[Zn(TEA)]^{2+} \longrightarrow Zn^{2+} + TEA$$

$$2NaOH \longrightarrow 2Na^+ + 2OH^-$$

$$Zn^{2+} + 2OH^- \longrightarrow Zn(OH)_2 \downarrow$$

$$Zn(OH)_2 \longrightarrow ZnO + H_2O \uparrow$$

The solution dropped on glass substrate located on spin coating with different ratio. In order to the composition of the film we use a spin coating device, where we paste the slides on the device, and then Zinc oxide placed on the slides - with the different proportions of zinc oxide. The device has been set up to 1000 cycles for 10 seconds, and then increase speed to 4500 cycles for 30 seconds. After that, put slides in an electric oven at a temperature of 100 Celsius for a period of 10 minutes in order to be drying slides and in this way a thin film action has been done.

The sol-gel technique is becoming more popular because of its cost effectiveness and simplicity. Moreover, in this technique, doping is easily incorporated, and large-area substrates are readily coated. In the spin-coating method, the seed layer was first coated by the spin-on sol-gel method. The molar ratio of monoethanolamine (MEA) to Zn(CH3COO)2•2H2O are 1:1, 1:2, 1:3 and 1:4, and the Zn(CH3COO)2 concentration is 0.5 mol/L [14]. The sol-gel layers were heat-treated to optimize the seed layer properties and increase the uniformity of the grain structure.

As well as, the ZnO thin film was deposited by spray technique on glass. Then, the structural and optical properties of fabricating ZnO films have been characterized. There are many parameter effects on prepared homogenous thin film as:

1-Substrate temperature
2-Spraying time
3-Nozzle distance from the substrate
4-Gas pressure
5-Deposition rate

## RESULTS AND DISCUSSIONS

The structural properties of ZnO/glass thin films prepared using sol-gel and thermal spray methods with zinc acetate and triethanolamine (TEA) with NaOH and with a concentration ratio of 1:4 are analyzed using XRD, and SEM measurements have been stated. Fig. (1) a and b show the XRD spectrum of ZnO thin films grown on glass substrate using sol-gel and themal spray, respectively. It reveals that the diffraction peaks of the ZnO thin films prepared using sol gel and thermally spray methods with zinc acetate: TEA 1:4 are of the sample prepared using sol-gel show that the diffraction peaks of 34.5°, 56.48° and 69.49 correspond to ZnO (002), (102), and (103), respectively as shown in Figure 1-a (red curve). The XRD pattern of the ZnO thin film deposited on glass substrate using thermal spray method is shown in Figure 1-b (blue curve). In this Figure, the XRD spectrum of the ZnO film reveals that the diffraction peaks of the film are (002), (101), (102), and (103) at 2q of 34.42°, 36.24°, 47.54°, and 62.82°, respectively. These diffraction peaks indicate that the films are polycrystalline in nature. The XRD results also signify that the film preferentially grow along a c-axis orientation perpendicular to the substrate.

The FWHM value, grain size, calculated lattice constant c, and corresponding values of the ZnO thin film strain are listed in Table 1. The preferred orientation (0002) of ZnO thin films prepared using a sol-gel method with Zinc acetate and triethanolamine (TEA) with NaOH with a concentration ratio of 1:4 are compared in this table. The sample prepared using thermal spray methods have a broad FWHM value of 0.634 degrees and small grain size of 8.3 nm compared with the sample prepared using spin coating method. This is attributed to the nano-sized atom inside the film prepared thermal spray with the (002) ZnO thin films.

SEM was used to study the surface morphology of deposit ZnO thin films on glass substrate by sol-gel and thermal spray methods using zinc acetate and both triethanolamine (TEA) with NaOH) with concentration ratio of 1:4 as shown in Figure 2 (a and b) respectively in which the ZnO structure was obtained. The images reveal that this result is in line with XRD results in term of grain size. This reveals that the standard method provides ZnO nanostructures compared with the highly sophisticated and other methods. Figure 2: SEM images of ZnO thin film fabricated using different methods, with Zinc acetate a) triethanolamine (TEA) with NaOH and b) menoethanolamine (MEA) with a concentration ratio of 1:4

## CONCLUSIONS

ZnO thin films have been deposited on glass substrate using spin coating and thermal spray methods, treatment using zinc acetate and both triethanolamine (TEA) with NaOH as solvents and stabilizer materials, respectively. XRD results show that the prepared films have a polycrystalline in nature and the referred orientation ZnO is (002) have the low grain size to be 8.3 nm for samples prepared using thermal spray which calculated using Debye Scherer's formula. SEM images are in agreement with the XRD results that films prepared using thermal spray have a rough surface, which make a ZnO thin film a promising material to solar cells and optoelectronic devices
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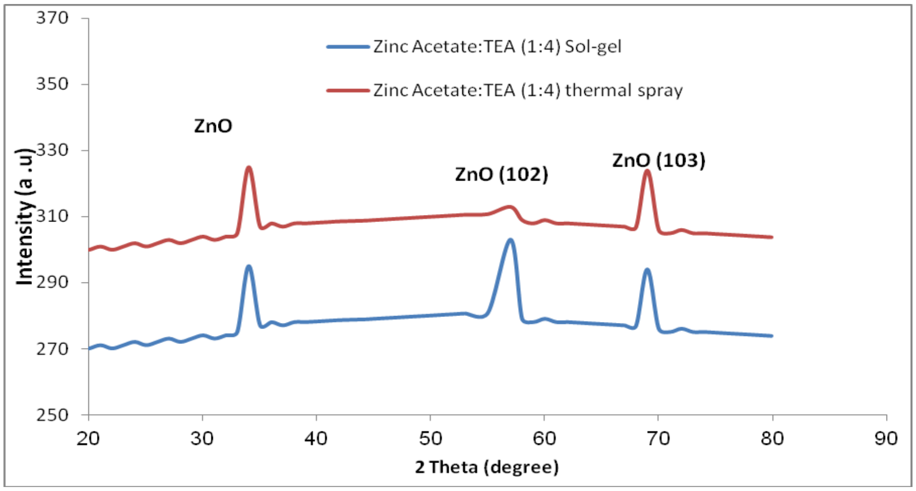
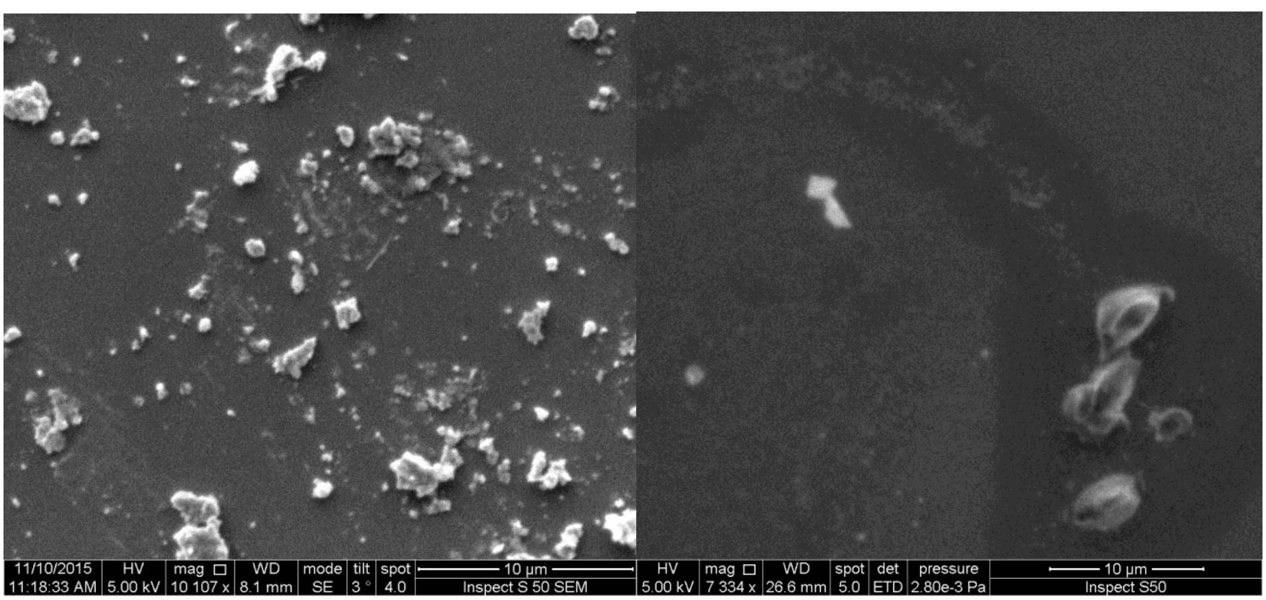



Figure 1: XRD diffraction peaks of ZnO thin films on glass substrate using spin coating and thermal spray methods

Table 1: The FWHM, grain size and the calculated lattice constant c of ZnO (002)/glass thin films prepared by sol-gel methods with zinc acetate and both triethanolamine (TEA) with NaOH and menoethanolamine (MEA) with a concentration ratio of 1:4.

| Method | Solution | $2\theta$ (Degree) | FWHM $(2\theta^{0})$ | Grain size (d) nm | Lattice constant (c) |
|---|---|---|---|---|---|
| **Sol-gel** | Zinc acetate:TEA 1:4 | 34.05 | 0. 532 | 9.96 | 2.6309 |
| **Spray** | Zinc acetate: TEA 1:4 | 34.05 | 0.634 | 8.35 | 2.0498 |




**(a)** **(b)**

**Figure 2:** SEM images of ZnO thin film fabricated using different methods, with Zinc acetate a) triethanolamine (TEA) with NaOH and b) menoethanolamine (MEA) with a concentration ratio of 1:4

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