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Deposition and Characterization of ZnO Thin Film using Sol-Gel Spin Coating Approach

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Abstract

ZnO is the semiconductor material used in many applications under the opto-electrical properties. ZnO is a wide band gap metal oxide semiconductor material which is used in gas sensors, solar cells, light emitting diode and surface acoustic wave devices. This paper reports the sol gel preparation and characterization of ZnO thin film. ZnO thin film was prepared by solgel process using zinc acetate dehydrate as a precursor, ethanol as a solvent and monoethanolamine (MEA) as a stabilizer. The solution was deposited on n-type silicon (111) substrate by spin coating at 3000 rpm. Hydrolysis and condensation process produced a complex solution. After drying at 100°C, samples were annealed at 575°C by post heating. Precise control of concentration of precursor, solvent used, spinning speed of the substrate and heat treatment conditions, are the factors which strongly affect the crystallographic orientation and morphology of the resultant ZnO films. The crystalinity of the film as found from X-ray diffraction (XRD) had different orientations at different temperatures.. Morphology is determined by scanning electron microscopy (SEM) and transparency and optical properties are determined by UV-visible.

Keywords: *ZnO, Sol-gel, Spin coating, Anealing.*

Introduction

ZnO is been focused by different researchers as the effective semiconductor materials because of multi-functionalities due to novel nonlinear optical properties. The application area of ZnO includes the nanostructure and micro-structure analysis with inclusion of non-toxicity under low cost and quantum size effect. ZnO is more effective in different functional areas with larger free exciton binding energy up to room temperature. The application areas of ZnO include the ultraviolet detectors, thin film transistors, gas sensors, varistors, thin film solar cells etc. There are different fabrication methods under which the analysis of the thin film is under different temperature values for different property based changes. ZnO films can be prepared by various methods, including vapor deposition, pulsed laser deposition, molecular beam epitaxy, metal organic chemical vapor deposition , sputtering, electron beam evaporation and spray pyrolysis. But all of them, Sol-Gel process is very attractive because of its efficiency, easily implanted in the laboratory and the non-alkoxide route make the sol gel thin films very interesting in the semi-conductor oxide thin films field. The deposition process of the ZnO thin film is defined by different researchers under the nano-structured substances so that the device performance is been improved. Another parameters that effects of the surface under different substrates includes the optical loss minimization as well as the enhancement of the material under the active region analysis. The objectives of these solution process is to reduce the cost of the surface generation under the property setup along with doping process with specific substances.

In this paper, the exploration of the properties and the ZnO thin film is defined in this section. This section includes the description of ZnO, its application and its deposition and basic characterization in section II, the deposition process using sol-gel spin coating is described and the work description includes the contribution of different authors. In section III, the experimentation work is defined using sol-gel approach. In section IV, the results obtained from the work are discussed. In section V, the conclusion of the work is described.

ZnO Using Sol-Gel

There are number of researchers that defined the work on ZnO deposition and characterization. Some of the work done by the researchers is defined in this section. In year 2011, Peter A. Hersh has defined the characterization on Zinc Oxide with effect of structural analysis with CIGS PV devices. Author defined the work on device structure analysis for undoped ZnO as well as ZTO(Zinc-Tin Oxide alloys). Author defined the tuning and optimization process under the composition of ZTO with the definition of Fermi Level and alignment. The obtained results from the system shows the efficiency and optimization has been improved[1]. Another work on Zinc Oxide to suppress the negative bias illumination was defined by Chang-Kyu in year 2013. Author defined the work on photo-bias instability for ZTO using thin film transistors. Author defined attribute analysis for valance band offset between TiOx and ZTO[2]. Another work on the characterization and synthesisized of mechanochemical processing was defined by Sharipah Nadzirah in year 2012. Author defined the work on ZnO under the mechnochemical process. Author defined the investigation for the under the concentration of Zn dopoant for properties analysis of SnO2. An optimality is also considered for the crystalline size and the effective generation so that the visibility of the system will be estimated effectively. The results shows that the volume samples are decreased so that the energy gap will improved with the increasing Zn concentration[3]. Another work on properties exploration of ZnO was defined by Kyungsoo Jan in year 2013. Author defined the work on the crystallinity of the electrical properties for Indium-Tin-Zinc Oxide. Author defined the analysis on the effects analysis for carrier concentration. Author presented the field-effect mobility under ratio analysis so that effective frame rate for the display will be obtained with ultra high resolution[4].

A work on the improvement with photo-bias stability for Zinc oxide based Thin film transistor for the carrier blocking layer. Author defined the analysis on different property types including the morphological, electrical and structural property analysis. Author defined the work on ZTO with gate-stack of silicon nitrate. Author defined the physical property analysis so that the enhancement in the stability will be obtained under the valence band-off structure under the amorphous nature of thermal films[5]. Another work on the study of different kind of properties for ZnO was performed by Amit Kumar Srivastava in year 2011. Author defined the work under high temperature and low resistivity with subsequent annealing in air and vacuum. Author defined the work in annealing environment under the filling process of cation site for Zinc solution stage[6]. Another work on structural and optical property exploration and analysis was proposed by P. Muthukumar. The obtained fibers are defined under the uniform free and strong adherent analysis under different substrate XRD, EDAX, SEM with optical properties analysis[7]. In year 2010, Sharul Ashikin Kumarunddin has defined the sol-gel technique for the deposition and the characterization. In this paper, spin coating and its fabrication for ZnO film on glass substrates is defined. The fabrication of the ZnO films was investigated for the structural a analysis so that the examination on the properties will be done effectively. Author defined the characterization of ZnO for ultraoiolet visible spectroscopy. The experimentation has explored the effects of exploration[8].

Experimentation

A) Material Composition

ZnO thin films were deposited by sol-gel spin coating method onto silica substrates. The sol was prepared using Zinc acetate dehydrates; ethanol and mono-ethanolamine (MEA) were used as a starting material, solvent and stabilizer, respectively. The glass substrates were precleaned detergent, and then cleaned in methanol and acetone for 10 min each by using a cole-parmer ultrasonic cleaner and then cleaned with deionized water and dried. A solution (molarity1M) of zinc acetate dehydrate is first prepared in ethanol. The molar ratio of MEA to zinc acetate was maintained at 1.0 MEA is added thereafter and the mixture heated at 80°C for 1h under constant stirring to obtain a clear sol and then aged at room temperature (RT) for 24 hrs to yield a homogeneous solution. ZnO thin films were prepared by spin coating the stored solution on a glass substrate at rotation speeds ranging from 4000 rpm for 60 sec. The ZnO thin films were then dried on a hot plate at100°C for 1h.This procedure was repeated 5 to 8 times to reach the desired thickness. Finally the film was post-heated at 300°C for 1 h. An X-ray diffractometer was used to investigate the crystallinity and the structural properties of the ZnO thin films. The surface morphology of the films was analyzed using a scanning electron microscope (SEM). While the optical properties were examined using ultraviolet–visible spectroscopy

B) Sol-Gel Technique

The sol-gel process is a wet-chemical technique widely used in the fields of materials science and ceramic engineering. Such methods are used primarily for the fabrication of materials for thin films. Solgel is the process in which formation of an oxide network through polycondensation reactions of a molecular precursor in a liquid. A sol is a stable dispersion of colloidal particles or polymers in a solvent. The particles may be amorphous or crystalline. An aerosol is particles in a gas phase, while a sol is particles in a liquid. A gel consists of a three dimensional continuous network, which encloses a liquid phase, In a colloidal gel, the network is built from agglomeration of colloidal particles. In a polymer gel the particles have a polymeric sub-structure made by aggregates of sub-colloidal particles. Generally, the sol particles may interact by van der Waals forces or hydrogen bonds. A gel may also be formed from linking polymer chains. In most gel systems used for materials synthesis, the interactions are of a covalent nature and the gel process is irreversible. The gelation process may be reversible if other interactions are involved.

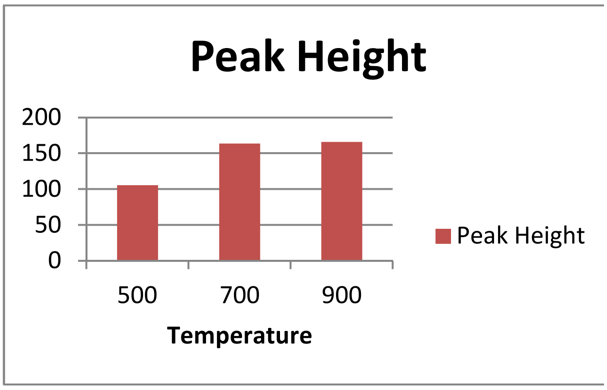
Sol-gel synthesis may be used to prepare materials with a variety of shapes, such as porous structures, thin fibers, dense powders and thin films. If the gel is dried by evaporation, then the capillary forces will result in shrinkage, the gel network will collapse, and a xerogel is formed. If drying is performed under supercritical conditions, the network structure may be retained and a gel with large pores may be formed. This is called an aerogel, and the density will be very low. A record is < 0.005 g/cm3.

Results and Discussion

The XRD based diffraction pattern for high temperature analysis. The temperature considered in this work is 500°C, 700°C and 900°C. The process is performed on the ZnO phase hexagonal structure under the pattern analysis with cell structure analysis with the lattice parametric formation and the exploration. It includes the deviation of the parameters under the presence of various defect points such as zinc antisties, oxygen vacancies and the extended defect analysis. The XRD shows the crystal quality is improved along with stronger and sharper. It performs the crystal quality analysis under the improved and the variation of peak height wand the FWHM with different annealing temperature.

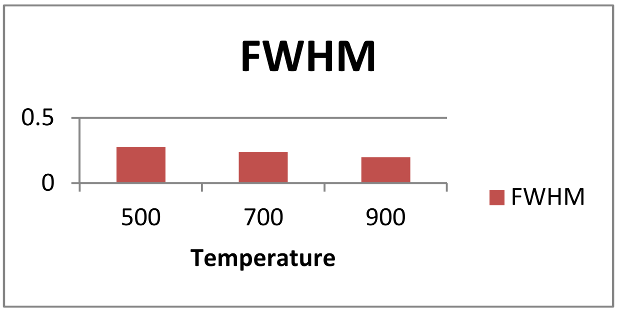
Peak height obtained at 500°C is 105 and the FWHM obtained is 0.2755. The height based analysis under the temperature effect is shown in figure 1.

Figure 1 : Peak Height Vs. Tempeature



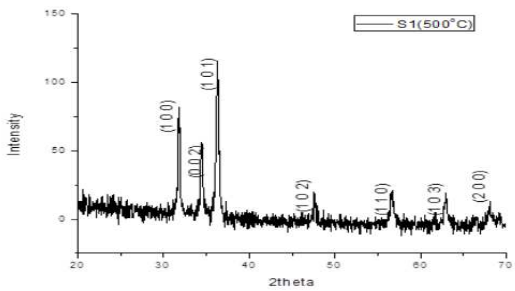
The obtained results in terms of FWHM under different annealing temperature is shown in figure 2. The XRD on the ZnO were broadened and the dependent on the Miller indices so that the crystal planes are defined. The temperature crystalline of the particles is increased under the particle becomes bigger.

Figure 2 : FWHM Vs. Temperature



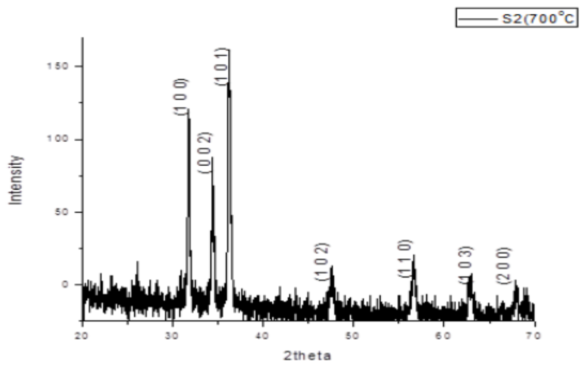
The smaller particles based lower temperature is favorable. It also includes the samples calcined at high temperature of 900°C where the fine peaks are obtained. The characterization results at different temperature are shown in figure 3,4, 5

Figure 3: ZnO characterization XRD Pattern analysis at 500°C



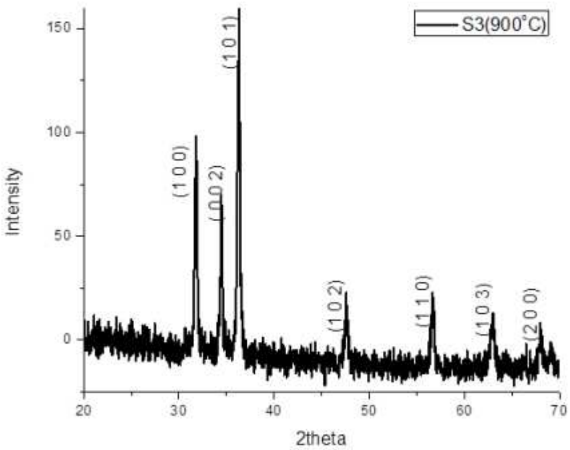
As we can see, in figure 3, the XRD pattern based ZnO characterization results at 500°C are shown. Here the X axis represents the theta value to define the rotational vector and y axis represents the intensity value.

Figure 4: ZnO characterization XRD Pattern analysis at 700°C



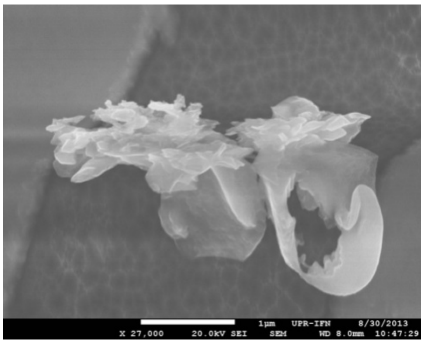
As we can see, in figure 4, the XRD pattern based ZnO characterization results at 700°C are shown. Here the X axis represents the theta value to define the rotational vector and y axis represents the intensity value.

Figure 5: ZnO characterization XRD Pattern analysis at 900°C



As we can see, in figure 5, the XRD pattern based ZnO characterization results at 900°C are shown.

Figure 6: SEM image for ZnO



Here figure 6 is showing the SEM morphology result of the synthesized nano ZnO particles. Figure is showing the formation of spherical ZnO nanoparticles and the change in morphology under defined temperature.

The UV-Visible is defined to determine the band-gap energy under the absorption coefficient. It includes the transition to the photon energies along with standard relation specification. The UV report of the sample at 700°C and 900°C is shown in the figure 7

Figure 7: UV Report of sample taken under different Temperatures.

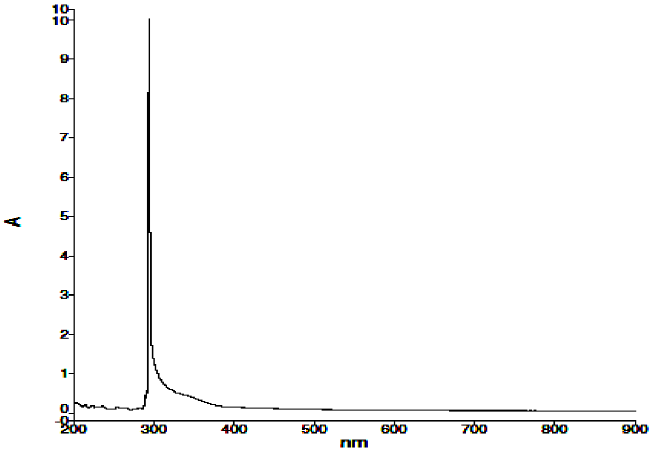


Figure 7(a): Optical absorption coefficient spectra of ZnO thin films.

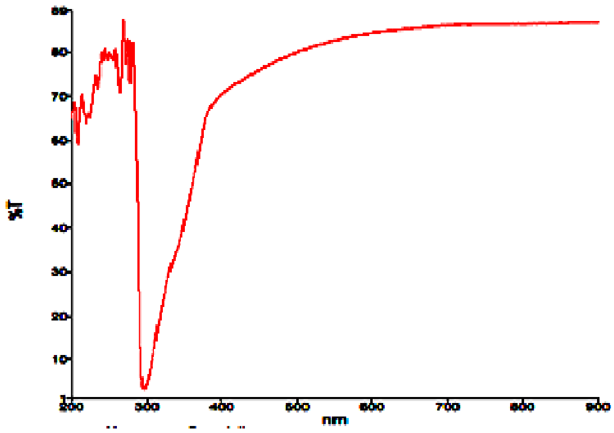


Figure 7(b): Optical transmittance coefficient spectra of ZnO thin films.

Conclusion

In this paper, Deposition of ZnO is performed using sol-gel approach and characterization are performed by XRD, SEM and UV-visible.. The analysis of the work is done under the XRD pattern analysis. In this paper, the experimentation of the work is defined as well as the results obtained from the solution are described. In our research, transparent and conductive ZnO thin films for transparent conducting oxide applications on silica substrates were prepared by using a sol-gel spin coating process and ZnO thin film depended on the coating speed of the spin coater and on the viscosity of the sol. The effects of various post-heating temperature on the optical, structural and electrical properties of the ZnO films were studied. All the films were polycrystalline with a hexagonal wurtzite crystal structure. The grain size was increased with temperature. We obtained a high transmittance in the visible range and an increase of post-heating temperature caused the optical band gap to increase.

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