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Synthesis and Characterization of Zinc Selenide Thin Films by Vacuum Deposition Technique

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***Abstract:** Materials of Group II-VI of the periodic table are very suitable for electronics and optoelectrical applications. Zinc Selenide (ZnSe) is one of them. The thin film of ZnSe has been grown on a cleaned glass substrate by vacuum deposition technique under a vacuum 10^{-6} Torr. The zinc selenide powder is heated in a molybdenum boat at 600°C. The substrates temperatures were maintained constant during deposition. The Zinc Selenide (ZnSe) thin films prepared by vacuum evaporation method were investigated. The crystal structure and lattice parameter ZnSe thin films are determined by X-ray diffractograms. X-rays diffraction measurement confirms the cubic structure of ZnSe thin film. The lattice parameters of deposited ZnSe thin films are almost matching with the JCPDS standard data of zinc selenide. The surface morphology of ZnSe thin film was investigated by SEM analysis.*
***Keywords:** Thin film, ZnSe, a vacuum deposition technique, crystal structure, XRD, surface morphology, SEM*

I. INTRODUCTION

The Zinc selenide (ZnSe) is a light yellow binary compound semiconductor having a wide bandgap of 2.7 eV [1]. The ZnSe compound exists in wurtzite (hexagonal) and zinc blende (cubic) crystalline forms, of which the cubic phase is believed to be stable than others. ZnSe is generally produced as an n-type semiconductor like most of the other II-VI compounds.The II-VI group semiconductor compounds are mostly used for optoelectronic devices[2-3]. Zinc Selenide (ZnSe) is one of the most attractive binary wide band gap semiconducting material amongst II-VI group materials. Currently, nanotechnology and nanomaterials have attracted a number of researchers across the world from different fields due to their unique properties and potential applications in diverse areas such as photocatalysis, display panels, solar cells, light-emitting diodes, and color-converted solid-state lighting devices [4-6].Thin films of ZnSe material can be deposited by using a variety of methods, including electrodeposition technique, Chemical Vapour Deposition, Inert Gas Condensation method , evaporation method, Thermal Evaporation , Vacuum Evaporation , Chemical Bath Deposition (CBD), Molecular Beam Epitaxy , Successive Ionic Layer Adsorption and Reaction, Cyclic Voltammetry method [4 , 7] etc. To deposit the thin films of ZnSe we used vacuum deposition technique which is one of the fast synthesis methods to produce high-quality thin films of large scale. The vacuum evaporation technique is the best method for preparation of thin solid films for scientific studies and many other technological applications This technique offers many advantages compared to the other sophisticated techniques, like simple mechanism, reproducibility, high deposition rate, and economically viability[8]. ZnSe thin films of a thickness of 1000 Å, 1500 Å, 2000 Å, and 2500 Å were deposited on cleaned glass substrate by vacuum deposition technique at a different substrate temperature ranging from room temperature to 200 ºC, under a vacuum of 10^{-6} Torr [12]. In this paper, we have studied ZnSe thin film of a thickness of 2000 Å.The Crystal structure and lattice parameters of zinc selenide thin film of thickness 2000 Å were obtained by XRD and surface morphology of film studied by SEM characteristics [14].

II. EXPERIMENTAL

A. Thin Film Deposition

The glass slides were well cleaned in a detergent solution, distilled water and acetone to remove the impurities from the surface of slides. The dried and cleaned glass slides were used for thin film deposition in a vacuum unit[8, 12]. Thin films of ZnSe were deposited by vacuum deposition technique at the vacuum of ~10-6 Torr using an oil diffusion evaporation unit. In this vacuum deposition unit, there were two pressure gauges, Pirani Gauge which measures low vacuum up to 10^{-3} Tor and a very sensitive Penning Ionization Gauge which measures relatively high vacuum from 10^{-2} to 10^{-6} Torr[7]. The source material ZnSe is in ingot form, a compound of ZnSe is obtained by mixing granule of pure zinc material with pure selenium powder in an equal ratio of their atomic weight at a very high temperature in a quartz glass tube. here the materials i.e. pure zinc and selenium are from Sigma Aldrich chemical company of purity 99.999 %[7-9]. The uniformly mixed compound of ZnSe was grounded in powdered form and it was evaporated from a molybdenum boat. The low tension (LT) supply for evaporation source is obtained from a 230V input transformer by means of parallel connections in the secondary side of the transformer[17]. The glass substrate was placed above the source. The deposition rate was maintained (02 - 06 Å/sec) constant throughout the sample preparations[15-16]. substrates were kept at constant temperature by a constant flow of cold water from a tap. The films of thicknesses 1000 Å, 1500 Å, 2000 Å, and 2500 Å were deposited under the almost same environment. The thickness monitor model no. DTM - 101 provided by Hind-High Vac using which the different thickness of ZnSe thin films was monitored. Deposited samples were kept under vacuum overnight[9].

B) *Characteristics*

The X-ray diffraction (XRD) was used to investigate the structure of ZnSe thin films of thickness 2000 Å. The interplanar spacing '*d*' in the crystal has been determined By using the X-rays of known wavelength and measuring the angle of diffraction 2ө of the most intense peak[7]. formula is given as,

$$\lambda n = 2d \sin \theta$$

where '*d*' is lattice spacing, '*θ*' is the angle between the incident beam and the planes (hkl), '*λ*' is a wavelength of monochromatic X-rays, '*n*' is the order of reflection (n = 1, 2, 3,…..)[10, 14].

The lattice parameter (a) for the cubic structure is determined by using the following expression[13]

$$\frac{1}{d^2} = \frac{h^2 + k^2 + l^2}{a^2}$$

The particle size (D) is calculated using the Scherer's formula from the full width at half maximum β (FWHM)[12].

$D = 0.94\lambda / \beta \cos \Theta$

Where D is the mean dimension of the crystallites, λ the wavelength of X-ray and Ө is the Bragg's angle

SEM is a best suitable technique for the topography study of samples. Surface morphology of the ZnSe thin film was studied by scanning electron microscope (SEM). SEM gives valuable information regarding the growth mechanism, shape and size of the particles and/or grains [13].

III. RESULTS AND DISCUSSIONS

For the structural analysis of the ZnSe thin films X-ray diffraction (XRD) technique is the most promising analytical tool [5]. 'd' value calculated using Bragg's equation for the known value of θ, λ, and n. The hkl indices are obtained by comparing the x-ray diffraction data of deposited zinc selenide thin films with the Joint Committee on Powder Diffraction Standard (JCPDS) data cards [10]. This data of x-ray diffraction can also be used to determine the particle size, structural factors, residual stresses, etc [11]. The structural properties of the ZnSe thin film of 2000 Å thickness were studied by the X-ray diffractometer (XRD) using Cu Kα radiation (l =1.54060 ´) [20]. Scan angle with angular range 20° ≤ 2θ ≤ 80° at 40 kV voltage and 40 mA current. The particle size (D) is calculated using the Scherer's formula from the full width at half maximum β (FWHM). Where β is equal to 0.452 [12].

The XRD patterns of crystalline ZnSe thin film is shown in Figure 1

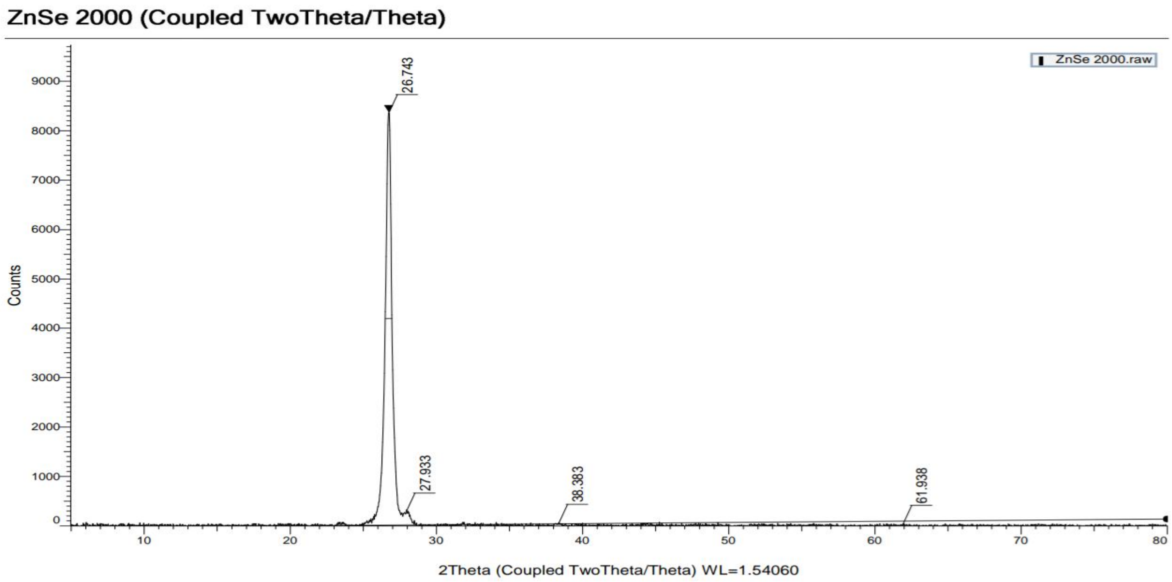

Figure 1: XRD spectrum obtained for ZnSe films of thickness 2000 Å

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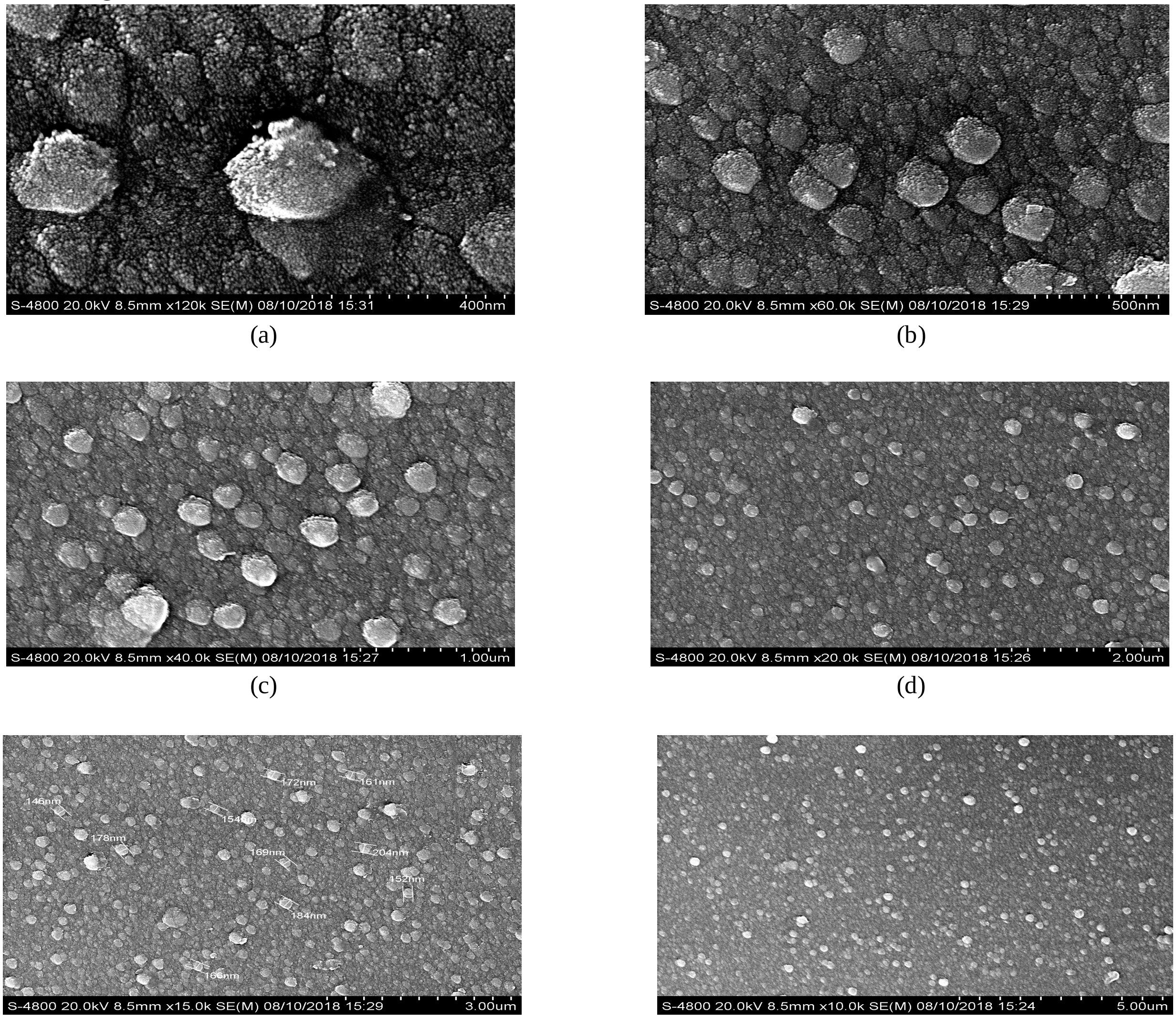
[hkl] values from JCPDS data	d(Å) values from JCPDS data	Observed values of d(Å)	Observed (2θ)° values of peaks	intensity	Lattice parameter a(Å)	Particle size D (Å)
111	3.273	3.273	27.230	1577	5.669	3.2965
220	2.004	2.005	45.200	286	5.670	3.4703
311	1.707	1.708	53.600	196	5.664	3.5894
400	1.417	1.417	65.840	170	5.668	3.8167
331	1.300	1.300	72.650	160	5.666	3.9780
242	1.157	1.198	80.000	125	5.868	4.1823

Table 1. X-ray diffractogram (XRD) data of bulk Zinc Selenide sample of thickness 2000 A^0

The SEM pictures of ZnSe thin films of thickness 2000 Å on glass substrates are shown in Figure 2. The oval-like shape of the particles can be observed easily in high magnification micrographs[18]. SEM observations show the crystalline growth for the deposited ZnSe film [19]. The present work, SEM investigations are done by using a LEICA S440 SEM instrument at K.B.C.N.M.U., Jalgaon.



(a) (b) (c) (d) (e) (f)

Figure 2 : SEM pictures taken for ZnSe films with different x content (a) 400 nm, x = 120k (b) 500 nm, x = 60k (c) 1.0 µm, x = 40k (d) 2.0 µm, x = 20k (e) 3.0 µm, x = 15k (f) 5.0 µm, x = 10k

IV. CONCLUSION

It is found that the deposited ZnSe films of thickness 2000 Å are highly oriented with cubic zinc blende structure and the preferred crystal orientation is (111), (220) and (311) planes. The lattice parameters are almost matching with the JCPDS data of ZnSe. The value of lattice constant is nearly 'a' = 5.66 Å and the average particle size D = 3.722 Å were determined in the XRD pattern.

The SEM shows uniform growth of ZnSe on a glass substrate. The particles are spherical in shape with size in the submicron range. The results of SEM shows that the sizes of grain were from 146 nm to 5 µm.

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