Journal of the Nigerian Association of Mathematical Physics
Volume 29, (*March, 2015*), **pp 331 – 338**
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Characterization of Zinc Sulphide/Cadmium Sulphide (ZnS/CdS) Superlattice by Electrodeposition Technique

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Abstract

Zinc sulphide/Cadmium sulphide (ZnS/CdS) superlattices have been successfully deposited on a glass substrate (Indium Tin oxide) by electrodeposition technique (ED) or electrochemical deposition technique (ECD). The absorbance was measured using M501 UV-visible spectrophotometer in the wavelength range of 300-900nm. Observation show that the absorbance of Zinc sulphide/Cadmium sulphide (ZnS/CdS) superlattice films is in the range of 0.04-0.35. Cadmium sulphide/Zinc sulphide (ZnS/CdS)) superlattice was investigated at room temperature. XRD analysis showed that the Zinc sulphide/Cadmium sulphide ZnS/CdS superlattice, so deposited, exhibit Hexagonal structure with a preferred orientation along (100) plane.

Keywords: ZnS, CdS thin films, electrodeposition, structural and optical properties

1.0 Introduction

II–VI compound semiconductor materials are commercially used in solar cells [1], infrared windows [2], and phosphor materials by doping with transition or rare-earth metals [3, 4]. There has been growing interest in developing techniques to prepare semiconductor ZnS/CdS superlattice. ZnS/CdS superlattice are produced using various techniques, including radio frequency (RF) magnetron sputtering [5], chemical vapour deposition (CVD) [6], solvothermal [7] and chemical bath deposition [8], spray pyrolysis (SP) [9, 10], electrodeposition [11, 12] etc. have been used to obtain superlattice thin films. All these experimental techniques either demand stringent reaction conditions such as high temperature and pressure, and hazardous chemicals or both. Among the different methods for film deposition, the relative simplicity of the successive ionic layer adsorption and reaction, electrodeposition technique and its potential application for large area deposition make it very attractive. Easy control on film thickness by adjusting number of deposition cycles is the beauty of this method. In electrodeposition technique, to prepare thin films substrates are immersed into separately placed cationic and anionic precursors and precipitate formation in the solution, i.e. wastage of the material was thus avoided. Also, electrodeposition can be used to deposit compound materials on a variety of substrates such as insulators, semiconductors, metals. In this research exploration, we have reported electrodeposition of ZnS/CdSsuperlattice thin films onto substrates (ITO) at room temperature

2.0 Material and Method

Zinc sulphide/Cadmium sulphide (ZnS/CdS) superlattices were deposited by electrodeposition technique using 17cm^3 of 0.25m of $Na_2S_2O_3$ mixed 17cm^3 of 0.25m of cadmium (Cd) and 5cm^3 of potassium tetraoxosulphate VI (K_2SO_4) solution with0.25m solution of$ZnSO_4.7H_2O$. Then, 5cm^3 of 0.4m of tetraoxosulphate VI acid (H_2SO_4) was used to acidify the solution and added into the mixture and stirred well. The indium doped tin oxide (ITO) glass was used as substrate. The ultrasonically cleaned glass substrate was immersed vertically into the solution for electrodeposition process. The films growth was carried out at 300k. During deposition process, the deposited films were tested for adhesion by subjecting it to a steady stream of distilled water. Optical absorbance study was carried out using M501 UV-Visible spectrophotometer. The films coated indium thin oxide glass was placed across the sample radiation pathway while the uncoated (ITO) was placed on the reference path. X- Ray diffractometer (XRD) analysis was carried out using DM-10 diffractometer for the 2θ ranging from 15- 55^0 with cuka (λ = 1.5406Å) radiation.

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3.0 Theoretical Background

From the law of conservation of energy we obtained,

$$A+T+R=1 \quad (1)$$

Where A is the absorbance, R is the Reflectance, and T is the transmittance, by

$$T = 10^{-A} \quad (2)$$

Refractive index n and the 0ptical thickness t are given in [12]

$$n = \frac{1+R}{1-R} + \sqrt{\frac{4R}{(1-R)^2}} - K^2 \quad (3)$$

$$t = \frac{r\left(\frac{1-R^2}{T}\right)}{\alpha} \quad (4)$$

Coefficient of absorption α and photon energy E are given by

$$\alpha = \frac{A}{\lambda} \quad (5)$$

$$E = \frac{hc}{\lambda} \quad (6)$$

Extinction coefficient k and Optical conductivity σ are given by

$$K = \frac{\alpha}{4\pi} \quad (7)$$

$$\sigma = \frac{\alpha}{4\pi} \quad (8)$$

Real dielectric constant ε_r and Imaginary dielectric constant ε_i[13] are

$$\varepsilon_r = n^2 - k^2 \quad (9)$$

$$\varepsilon_i = 2nk \quad (10)$$

4.0 Optical Properties of ZnS/CdS Superlattice

The optical properties of ZnS/CdS superlattice were studied using a M501 UV-Visible spectrophotometer in a wavelength range of 300-900nm. Observation show that the absorbance of Zinc sulphide /Cadmium sulphide (ZnS/CdS) superlattice films is in the range of 0.04-0.35. The transmission spectra show in Figure 1. The transmittance spectra show very high transmittance in the VIS-NIR regions of the electromagnetic spectrum. It is observed that the transmittance of the films is high in visible & infrared regions. ZnS/CdSsuperlattice has peak transmittance in infrared region. The wide transmission revealed in the figure makes the materials useful in manufacturing optical components, windows, mirrors, lenses for high power infra red laser. Absorbance of ZnS/CdS films is high UV region and in visible and IR regions as shown in Figures 1-3. The reflectance of the deposited films in Figure 3 shows that the films reflect much at UV region and decays in the visible and IR region. The high absorbance in UV region makes the material useful in formation of p-n junction solar cells with other suitable thin film materials for photovoltaic application. These optical properties make ZnS/CdSsuperlattice nice glazing material for maintaining cool interior in buildings in warm climate regions while still keeping the rooms well illuminated. To ensure that the thermal radiation from the warm glazing to the interior is inhibited and the thermal energy dissipated in the glazing due to absorption is predominantly transferred to the exterior by enhanced convective heat transfer of the glazing to the exterior. It was suggested in [14] that reflectance in the spectral region should be strengthened while encouraging low thermal emittance.

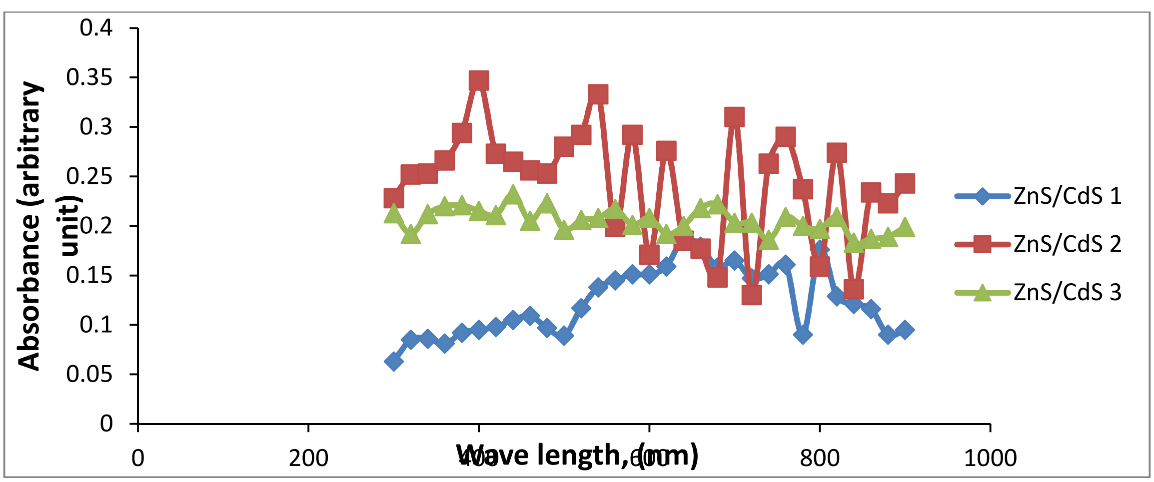

Figure.1. Plot of absorbance as a function of Wavelength

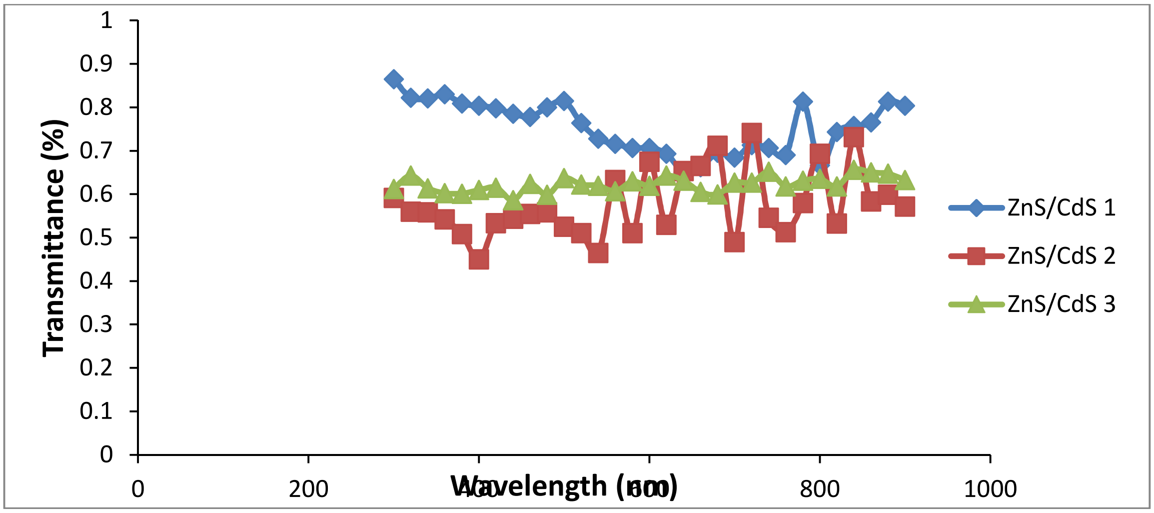

Figure.2. Plot of Transmittance as a function of Wavelength

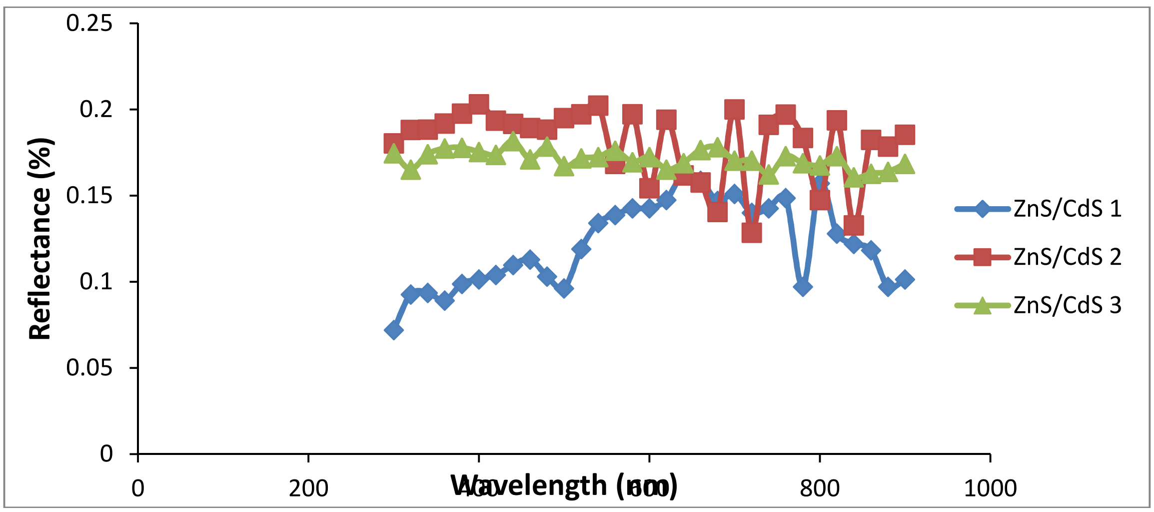

Figure.3. Plot of Reflectance as a function of Wavelength

The refractive index decays with decreases in the photon energy. ZnS/CdS superlattice shows a high refractive index. The high refractive index possessed by ZnS/CdS superlattice made it suitable as anti reflection coatings. Figure 4

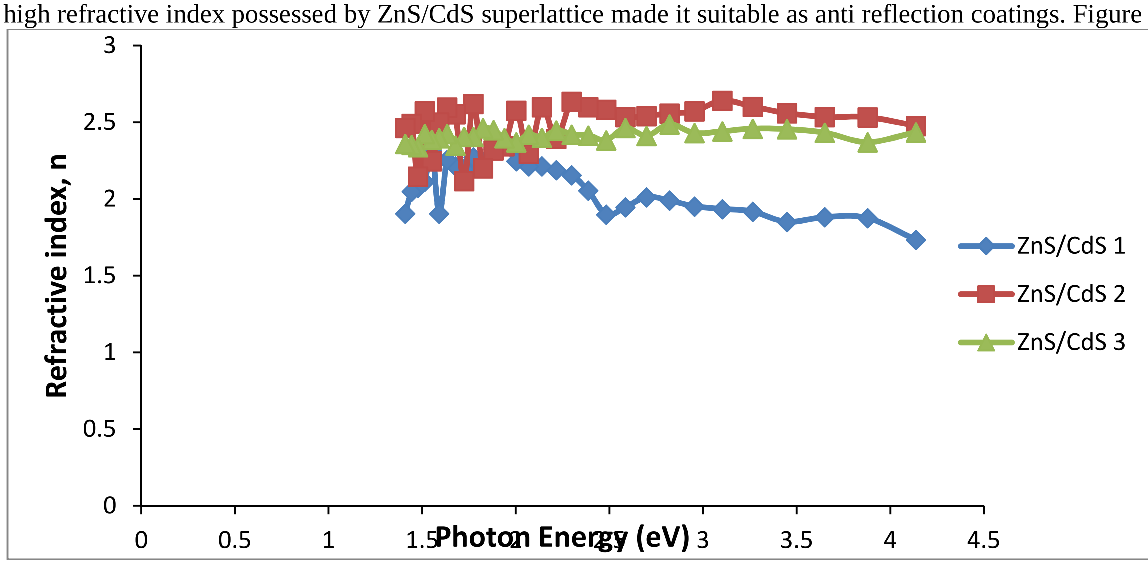

Figure.4. Plot of refractive index as a function of photon energy

The extinction coefficient with photon energy of ZnS/CdS superlattice shows that the extinction coefficient increases and later decreases as photon energy increases. The optical conductive increases and decays as photon energy increases. Figure 5-6

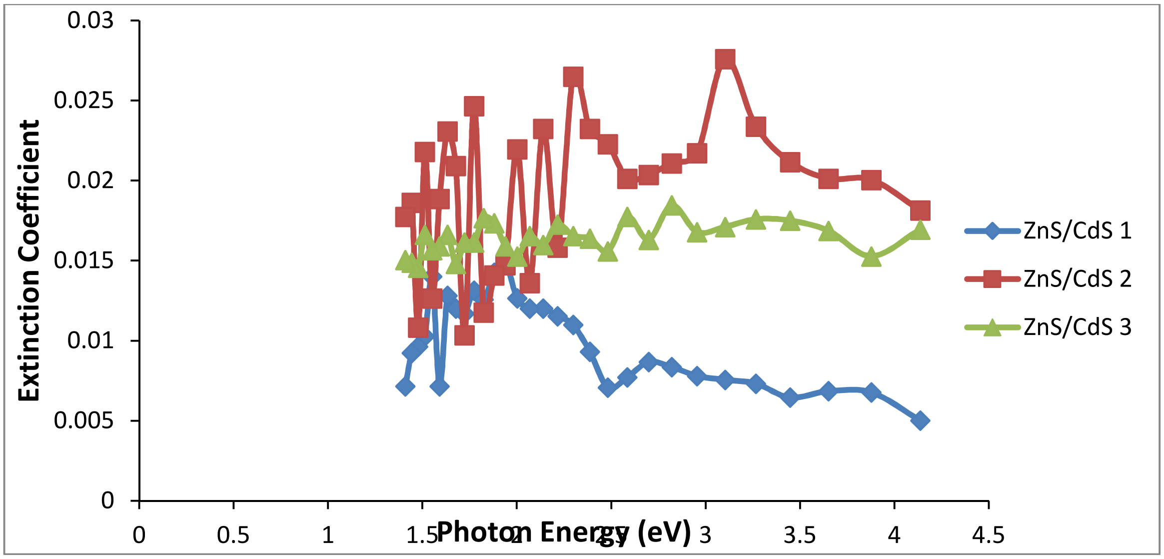

Figure.5. Plot of Extinction coefficient as a function of photon energy

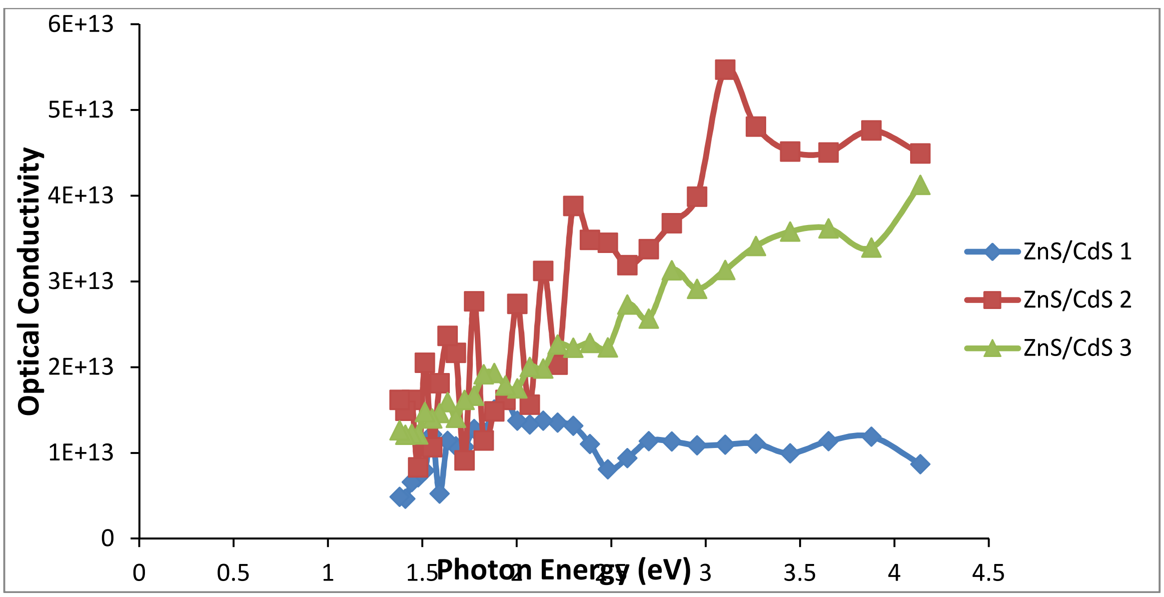

Figure.6. Plot of optical conductivity as a function of photon energy

The real dielectric constant ε_r can be calculated with the help of refractive index and of the extinction coefficient. It is associated with the term that describes how much it will slow down the speed of light in the material, and may be calculated with the equation

$$\varepsilon_r = n^2 - k^2 \quad (11)$$

While the imaginary coefficient of the dielectric constant ε_i which describes how a dielectric absorbs energy from electric field due to dipole motion, is given by the following relation

$$\varepsilon_i = 2nk \quad (12)$$

The spectral distribution of both real and imaginary parts of the dielectric constant are shown in Figure 7-8

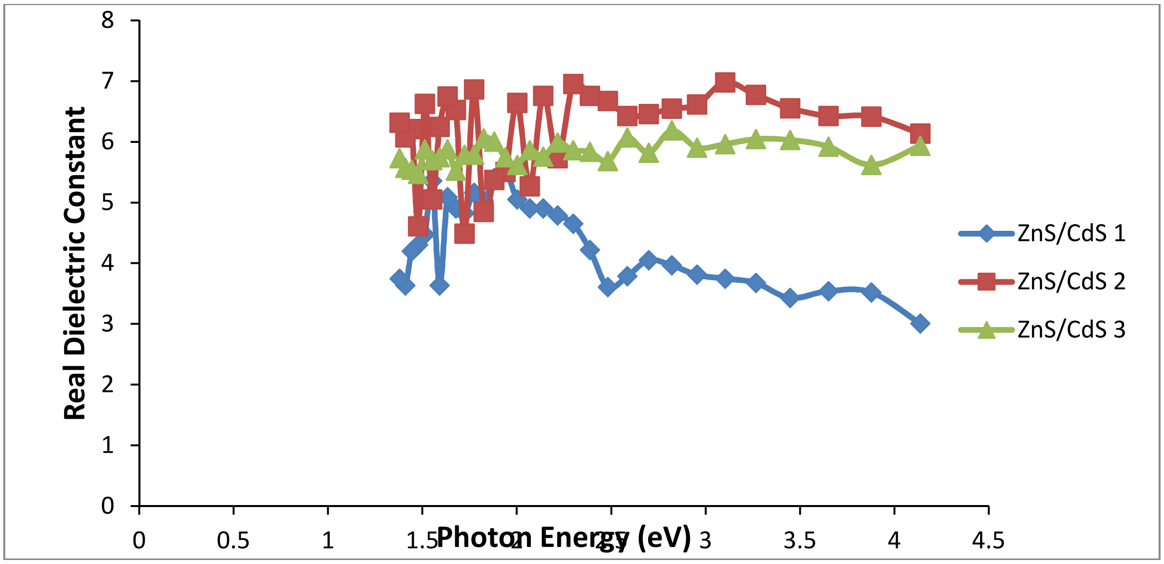

Figure.7. Plot of real dielectric constant as a function of photon energy

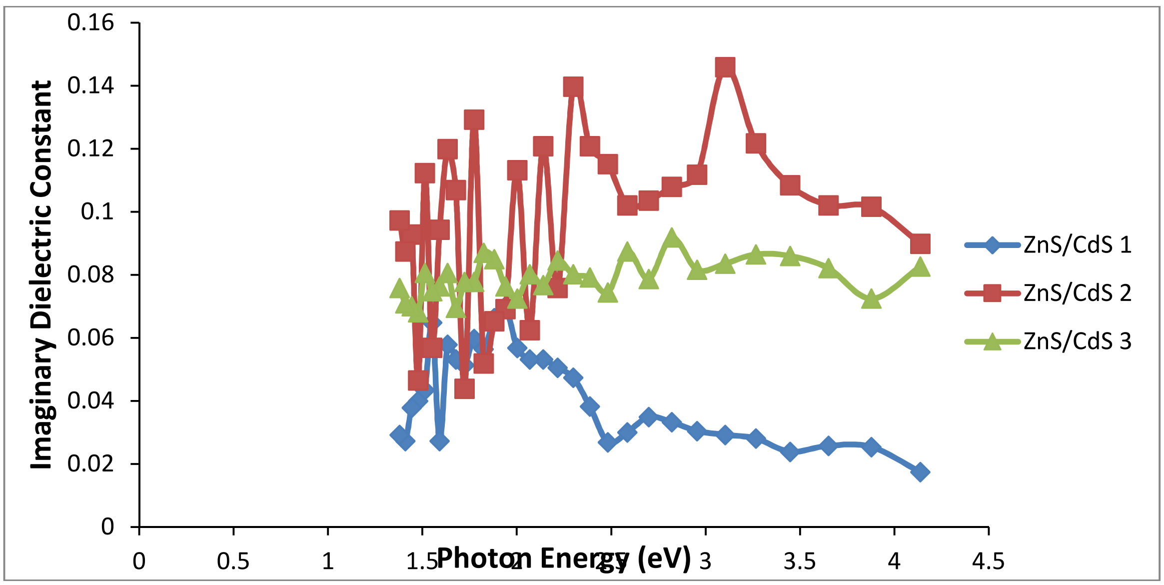

Figure 8. Plot of imaginary dielectric constant as a function of photon energy

5.0 Structural Properties of ZnS/CdS Superlattice

X-ray diffractometer using CuKa radiation (λ = 1.5406Ǻ). The X-ray diffraction patterns of ZnS/CdS superlattice are presented in Figure.9-11. The X-ray diffraction pattern showshexagonal structure which correspond to (100-102) planes. The diffraction angle 2ϴ value is 16.46˚and 16.97^0 with d = 5.383Å and d = 5.224Ǻ. The preferred orientation lies along the (100) plane. The lattice constant was given in the X-ray diffraction analysis is found to be a = 4.112Å. The crystallite size was determined by means of the X-ray line broadening method using Scherer equation [15]

$$D = \frac{0.9\ \lambda}{\beta} \quad (13)$$

Where λ is the wavelength of CuKa radiation (λ = 1.5406Ǻ), is the full width of half β maximum FWHM of the (hkl) peak of the diffracting angle hkl 2θ. The average grain size D, the dislocation density δ is calculated using the following relation [16]

$$\delta = \frac{1}{D^2} \text{ lines/m}^2 \quad (14)$$

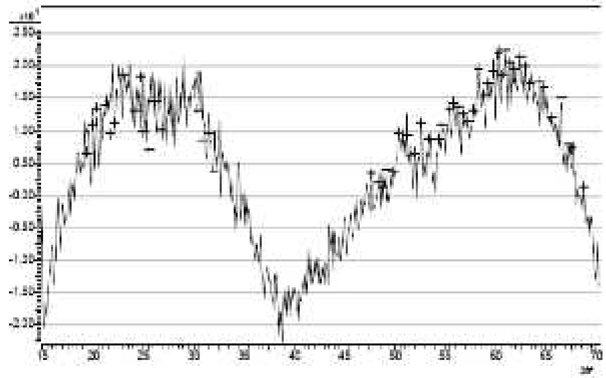

Figure 9. X-ray diffraction pattern of ZnS/CdS 1 superlattice

Table 1. Structural parameters of ZnS/CdS 1 superlattice

H k l	2θ		d(	d(	Lattice constant (	FWHM (rad.)	Grain size,(D)(	Dislocation density,	Micro strain ε
	Deg.	Rad.							
100	16.46	0.258	5.383	5.384	4.112	0.76234	1.837	1.317	0.575
002	16.97	0.266	5.224	5.225		0.76234	1.838	1.280	0.609
101	17.30	0.271	5.124	5.125		0.76234	1.839	1.252	0.637
102	17.65	0.277	5.023	5.024		0.76234	1.839	1.227	0.663

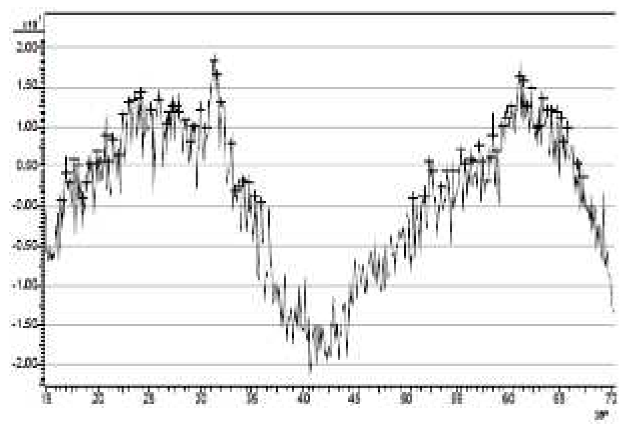

Figure 10. X-ray diffraction pattern of ZnS/CdS 2 superlattice

Table 2. Structural parameters of ZnS/CdS 2 superlattice

H k l	2θ		d(	d(	Lattice constant (	FWHM (rad.)	Grain size,(D)(	Dislocation density,	Micro strain ε
	Deg.	Rad.							
100	19.42	0.305	4.570	4.571	4.112	0.19466	7.223	0.165	3.673
002	19.93	0.313	4.454	4.455		0.81278	1.731	0.338	8.753
101	20.40	0.320	4.351	4.352		1.30660	1.485	0.333	9.001
102	21.17	0.332	4.194	4.195		0.23691	1.465	0.025	1.600

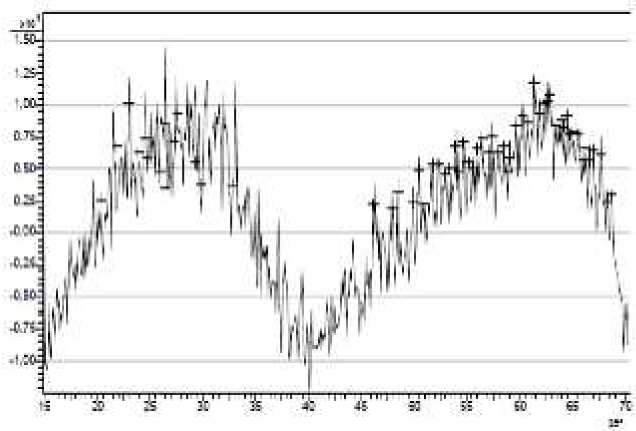

Figure 11: X-ray diffraction pattern of ZnS/CdS 3 superlattice

Table 3: Structural parameters of ZnS/CdS 3 superlattice

H k l	2θ Deg.	2θ Rad.	d(	d(	Lattice constant (	FWHM (rad.)	Grain size,(D)(	Dislocation density,	Micro strain ε
100	20.32	0.319	4.368	4.369	4.112	0.58448	3.197	0.161	3.857
002	21.86	0.343	4.064	4.065		0.32077	6.593	0.005	4.000
101	22.97	0.360	3.871	43.872		0.19039	1.548	0.025	1.600
102	23.96	0.376	3.712	3.713		0.30339	5.454	0.106	8.899

6.0 Conclusion

Zinc sulphide/Cadmium sulphide (ZnS/CdS) superlattice has been successfully studied using the electrodeposition technique. High-quality films of ZnS/CdS superlattice with hexagonal structure were deposited. The films were found to have moderate absorbance in the visible region. They have generally high transmittance which increases as the photo energy increases. The film can be used as a window glaze and in formation of p-n junction solar cells with other suitable thin film materials for photovoltaic application.

7.0 Reference

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