

## Photoluminescence analysis on vacuum deposited PbSe multilayer thin films

V. Arivazhagan, M. Manonmani Parvathi and S. Rajesh\*

*Thin film laboratory, Department of Physics, Karunya University, Coimbatore, India*

### ABSTRACT

*Lead Selenide multilayer thin films were prepared by thermal evaporation technique by successive coatings of lead and Selenium metals. Polycrystalline nature of as deposited films observed from X-Ray diffraction method with the crystalline size of 17 nm. The absorption edge towards blue wavelength clearly indicates the presence of nano particles trapped at interface of the successive Lead and Selenium layers. The room temperature photoluminescence analysis of the films with different excitation wavelengths ranges from 300-450 nm shows the green and red emission bands. The Stokes shift varies from 1.57-1.62 eV observed at exciting energy of 4.14 eV and the results were discussed in this paper.*

### INTRODUCTION

Thin films of semiconducting Nanocrystals are emerging as an important class of materials for electronic and optoelectronic devices such as field emission transistor [3], Photo detector [2], Thermal images [1], Light emitting diodes [2] and Solar cells [4]. Among the group IV-VI compounds, Lead Selenide (PbSe) thin films are used as a target material in infrared sensor grating, lenses and various optoelectronic devices [1]. It has cubic crystal structure and a direct narrow band gap of 0.27 eV at room temperature. Semiconductors like PbSe quantum dot produce as many as seven Excitons from one high energy photon of sunlight (7.8 times the band gap energy). In electronic applications they have proven to operate like single electron transistor (SET) and show the Coulomb blockade effect [9]. Various methods are employed for depositing PbSe thin films such as Chemical vapour Deposition (CVD), Physical Vapour Deposition (PVD), Molecular Beam Epitaxial growth method etc. Among these methods Thermal evaporation is the most widely used technique for the deposition of metals, alloys and also for many compounds. In this present work, we report the photoluminescence analysis of Lead Selenide multilayer films with various excitation wavelengths and also discuss the structural and optical studies on as deposited films prepared by thermal evaporation technique.

### MATERIALS AND METHODS

Lead selenide thin films were prepared by thermal evaporation technique onto ultrasonically cleaned glass substrate at vacuum pressure of  $10^{-6}$  torr. The successive coating of Lead and

Selenium were deposited on the glass plates alternatively. The Pb and Se metals were placed in the molybdenum boat (200 amps) and were heated with current by energizing

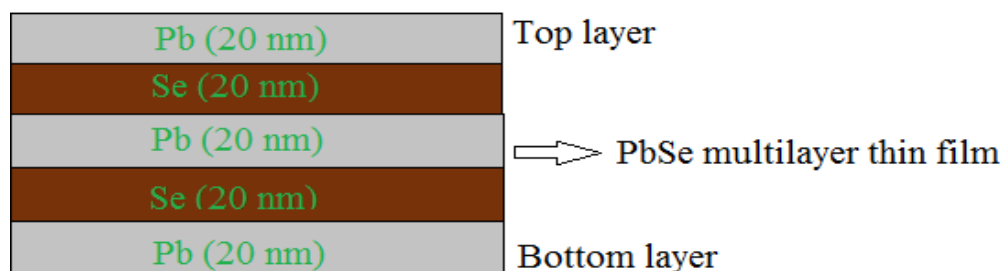


Fig.1. Schematic of PbSe multilayer thin films grown on glass substrate

transformer one by one till achieve the required thickness. The thickness of the films is maintained at  $\approx 200\text{\AA}$  for Pb and  $\approx 200\text{\AA}$  for Se and was monitored by the Quartz Crystal thickness monitor. The constant rate of evaporation ranging  $1-3\text{\AA}/\text{sec}$  is maintained throughout the experiment. Samples with five layers of (3 layers of Pb and 2 layers are Se alternatively) were prepared at glass substrate without any temperature. Photoluminescence characterization was carried out by Fluoromax-4 spectrometer in which Xenon is used as source. . The optical and structural characterization of the prepared films carried out by UV-Vis (Jasco-570 UV/VIS/NIR) spectrometer and Shimadzu XRD-6000 diffractometer and the result were explained in this paper.

## RESULT AND DISCUSSION

### *Structural analysis on PbSe multilayer films*

X-Ray diffractogram of PbSe multilayer thin films (5 layers) on unheated glass substrate is shown in figure 1. The XRD pattern reveals that the polycrystalline nature of the films with intense peak at  $[1\ 1\ 0]$ ,  $[2\ 0\ 0]$  and  $[2\ 2\ 0]$  planes corresponding to cubic structure. The orientation of the plane and crystal structure of as deposited films are well agreed with JCPDS (PDF 89-7105) values.

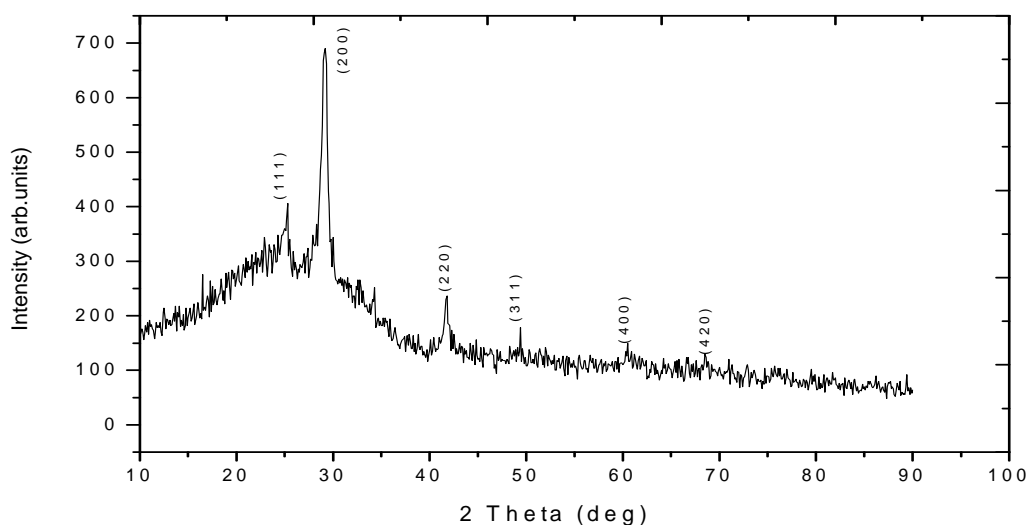


Fig.1. XRD pattern of PbSe multilayer thin films on Si glass substrate

Table 1. Structural Parameters on PbSe multilayer thin films.

Multilayer film	h k l	d (Å <sup>o</sup> )	2θ (deg)	FWHM (β)	D (Å <sup>o</sup> )	a (Å <sup>o</sup> )	ρ (10 <sup>15</sup> ) lines/m <sup>2</sup>	ε (10 <sup>-3</sup> )
PbSe	1 1 1	3.63289	24.4833	0.56670	140	6.29	3.6	2.41
	2 0 0	3.12224	28.5663	0.47480	170	6.24	2.8	2.01
	2 2 0	2.19279	41.1322	0.48440	170	6.20	2.8	1.97

The prominent growth of crystallite to perpendicular to [2 0 0] plane, gives rise to the rock salt cubic structure of PbSe multilayer films. The multilayer PbSe with alternate Lead and Selenium of 200Å each shows that there is possible nano particles presence at the interface of these Pb and Se successive layers which will lead to a Quantum confinement. The various structural parameters such as dislocation density ( $\rho$ ), lattice constant ( $a$ ), crystalline size ( $D$ ) and micro strain ( $\epsilon$ ) were calculated and are tabulated in table 1.

### Optical Studies on PbSe multilayer films

The as deposited multilayer PbSe films were analysed under UV-Vis to NIR region to see the absorption edge, absorption coefficient and finally to find the energy band gap. The absorption spectra of successive layer deposition with five layers PbSe films are shown in figure 2. The absorption edge starts with 315 nm and the result of this absorption shift towards shorter wavelength (blue shift) clearly indicates the presence of nano particles trapped at interface of the successive Lead and Selenium. The rise in absorption peak around at 684 nm may be due to nanocrystalline effect of the films. The optical band gap of the as

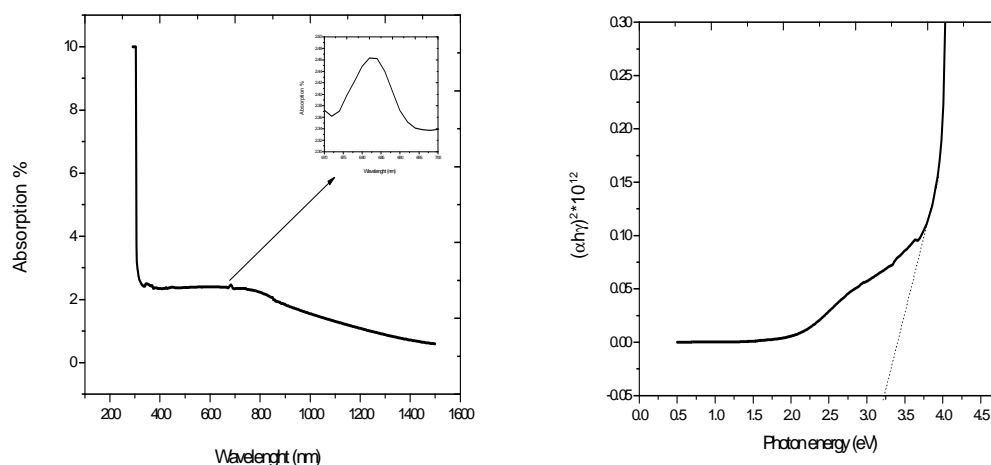


Fig.2. Absorption and optical band gap spectra of PbSe thin films

deposited films has the value of 3.25 eV which is much larger than the band gap value of PbSe in room temperature. It may due to the quantum confinement be able to possibly incorporate at the interfaces.

### Photoluminescence Studies on PbSe multilayer thin films

The photoluminescence spectra of as deposited Lead Selenide multilayer thin films under various excitation energy varies from 2.76-4.14 eV are shown in figure (3,4 and 5). The as deposited films excited under the wavelength of 300 nm (fig.3) have the emission peak at 2.52 eV (482 nm) and 2.57 eV (493 nm). The strongest peak is comparatively broad than short wavelength peak and gives near green emission bands. The emission band of this peak is due to band to band transition and this toward shorter wavelength reveals that there is a presence of nano particle in the interfaces of successive lead and selenium layers.

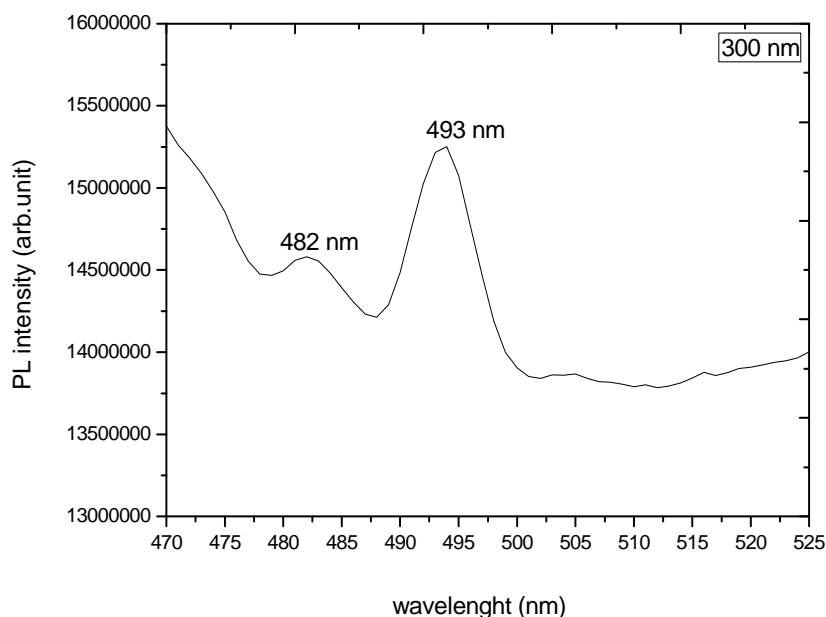


Fig.3. Room temperature PL spectra of PbSe multilayer thin films ( $E_w = 300$  nm)

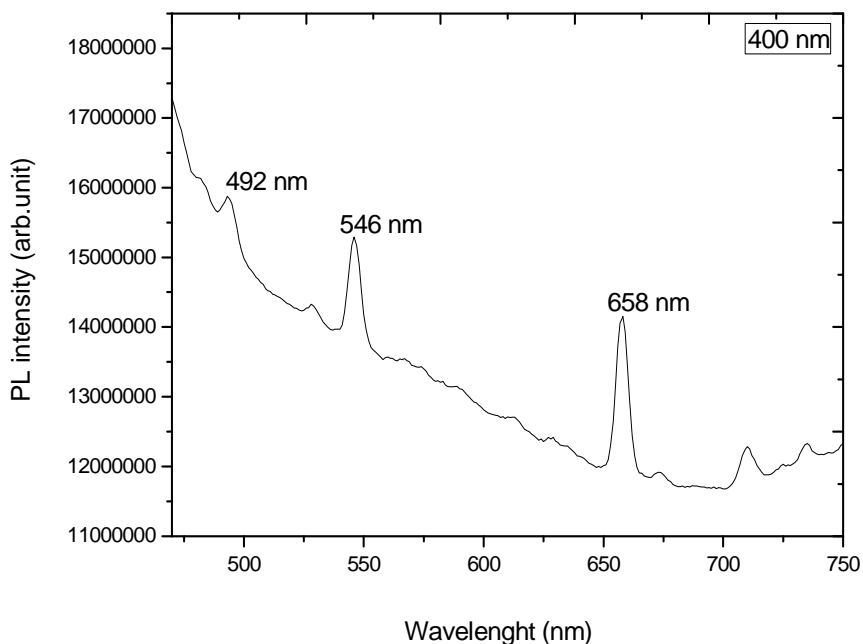


Fig.4. Room temperature PL spectra of PbSe multilayer thin films ( $E_w = 400$  nm)

The Stokes shift of 1.57-1.62 eV is calculated which is the difference of energy between emission and absorbed peaks. There are two absorption narrow peaks observed at the films excited at 3.1 eV and shown in figure 4. The green shifted peak at 2.27 eV has more intensity than the red shifted peak at 1.88 eV. Variation in intensity plays a vital role in multilayer thin films for surfaces and interfaces. The observed Stokes shift of 0.84-0.96 eV is less than the film excited at 4.14 eV. Maximum of three strongest peaks observed on the films excited at 4.14 eV and shown in figure 5. The orange shifted peak at 2.02 eV (613 nm) has the larger intensity and the red shifted peaks at 1.83 eV (676 nm) and the near infrared shifted peak at 1.67 eV (740 nm) have not major changes in PL intensity.

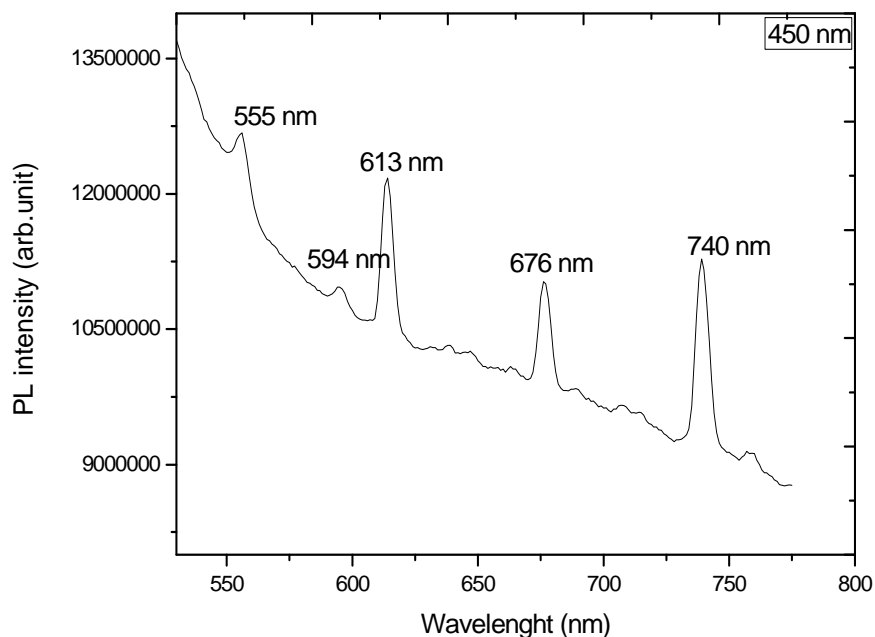


Fig.5. Room temperature PL spectra of PbSe multilayer thin films ( $E_w = 450$  nm)

The Stokes shift of 0.23-0.58 eV observed at 2.7 eV excited films and is comparatively very less than other two cases. From three cases, the broad peak observed at emission energy of 4.41 eV which has comparatively larger Stokes shift than others. Also PL spectra are observed to be broad and emission occurred at a lower energy value than that corresponding to the excitonic emission band. This could be attributed to that the recombination of the charge carriers trapped in the surface state.

## CONCLUSION

Lead Selenide multilayer thin films were prepared by successive coatings of Lead and selenium. The polycrystalline nature of the films with 17 nm as crystalline size observed from XRD. The absorption edge toward blue wavelength reveals that there is a presence of nano particle trapped at the interface of Pb and Se layers. The room temperature photoluminescence analysis of as deposited films shifted from shorter (green) to longer (red) wavelength reveals that the interface nature of the films. The films excited at 4.14 eV have the broader peak (493nm) and larger Stokes shift and have higher PL intensity. The calculated value of particle size from blue shift is smaller than the Bohr radius of the material. This reveals that the quantum size effect is present in thermally prepared PbSe multilayer thin films. The calculated band gap value is fall on visible region and this leads to future potential applications.

## REFERENCES

- [1]. A.Munoz,J.Melendez ,M.C.Torquemada et al.*Thin Solid Films* 317(1998) 425-428
- [2]. Dmitri V,Talapin,Christopher B.Murray. *Science* 310,86(2005)
- [3]. Seiki kitada, Einosuke Ki Kuchi et al. *Solid State Communication* 149(2009) 1853-1855
- [4]. Sestro Kumar et al, *Current appl Phys.*5156(2005)
- [5]. Myung-Hyun Lee, Woon Jin Chung,*Nanotechnology*16 (2005) 1148-1152
- [6]. Jieun Chang, Chao Liu, Jong Heo, *J.of Non-crystalline solids* 355 (2009)

- [7]. Z.Hens, D.Vanmacekelbegh, *Phy.rev.letters*, vol.92 (2004)
- [8]. Joshua J.Chol, Yee-Fun Lim, *Nano letters*, vol 9 (2009),3749-3755
- [9]. Joshua J.Chol, Yee-Fun Lim, *Nano letters*, vol 9 (2009),3749-3755
- [10]. N.C.Greenham, XiaogangPeng, *Physical review*, Vol 54, (1996)
- [11]. Joseph M. Luther, Matt Law, Qing Song, *ACS NANO*, 2008
- [12]. S.Prabakar,N.Suryanarayanan,K.Rajeshkumar,S.Srikanth,*Chalco. letters*, 6(2009)
- [13]. Dmitri V.Talapin and Christofer B.Murray, *Science AAAS*, 2005.
- [14]. R.D. Schaller and V.I. Klimov, *Physical review letters*, may 2004.
- [15]. Ram Thapa, Kaushik Roy choudhury, *Applied Physics letters*, 2007.
- [16]. K.Roy Choudhury, y. Sahoo, T.Y.Ohulchansky, *Applied Physics letters*, 2005.
- [17].Dehu Cui, Jian Xu, Ting Zhu, Gary, *Applied Physics letters*, 2006.
- [18].N.C.Greenham, Xiaogang Peng, *Physical review*, vol.541996.
- [19]. Matthew C.Beard, Kelly P. Knutsen et al , *Nano letters*, vol.7 ,8,2007.
- [20].E.I. Rogacheva, T.V. Tavrina, O.N. Nashchekina, *Applied Physics letters*, 2008.