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EFFECT OF CRYO SUBSTRATE ON THERMALLY EVAPORATED PbSe MULTILAYER THIN FILMS

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Lead Selenide multilayer thin films were prepared by thermal evaporation technique at Cryo substrate temperature (0^{o}C) by successive coatings of Lead and Selenium metals. The effect of substrate temperature is studied by varying it to the ambient and also to high temperature (80^{o}C).The crystallinity improves as the deposition temperature increase and the Grains also grow in size as it is evident from the XRD patterns. The crystalline size varies from 5 to 6nm and 11 to 13 nm for the films prepared at low substrate temperature for two and five layers respectively. The result of the absorption shift towards blue clearly indicates the presence of nano particles trapped at interface of the successive Lead and Selenium layers. The films deposited at the low temperature have lower absorption edge and the calculated value of the radius of the particles is much smaller than the Bohr radius of the particle.

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Keywords: Cryo substrate, Multilayer, Thermal evaporation, PbSe

1. 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], Solar cells [4] and so on. Among the group IV-VI compounds, Lead Selenide (PbSe) thin films used as a target material in infrared sensor grating, lenses and various optoelectronic devices [1]. It has cubic crystal structure and a direct band gap of 0.27 eV at room temperature. It does not require cooling but performs better at low temperature. 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 effect of substrate temperature (say high, room and low temperature) on the formation of Quantum Dots of PbSe multi layers thin films which deals with the structural studies and electrical resistivity of PbSe thin films prepared by thermal evaporation technique.

2. Experimental technique

Lead selenide thin films are prepared by thermal evaporation technique at various substrate temperatures onto a glass substrate at vacuum pressure of 10^{-6} torr. The successive coating of Lead and Selenium were deposited on the glass plate alternatively. The Pb and Se material were placed in the molybdenum boat (200 amps) and were heated with current by energizing transformer. The thickness of the films is maintained Pb≈200A^0 and Se≈200A^0 and was monitored by the Quartz Crystal thickness monitor. The constant rate of evaporation ranging 1-3A^0/sec is maintained throughout the experiment. For depositing the source material at low temperature on the substrate, an exclusively designed substrate holder is used. The substrate is fixed at the bottom of the holder and is filled with ice cubes. Now, the bottom of the substrate holder undergoes low temperature and the source material is evaporated and deposited on the substrate. Samples with two layers (Pb and Se with 200 A^0) and five layers of (3 layers of Pb and 2 layers are Se alternatively) were prepared. The structural analysis of the prepared films was carried out by using X-ray diffractometer and optical studies were carried out by UV-vis spectro photometer.

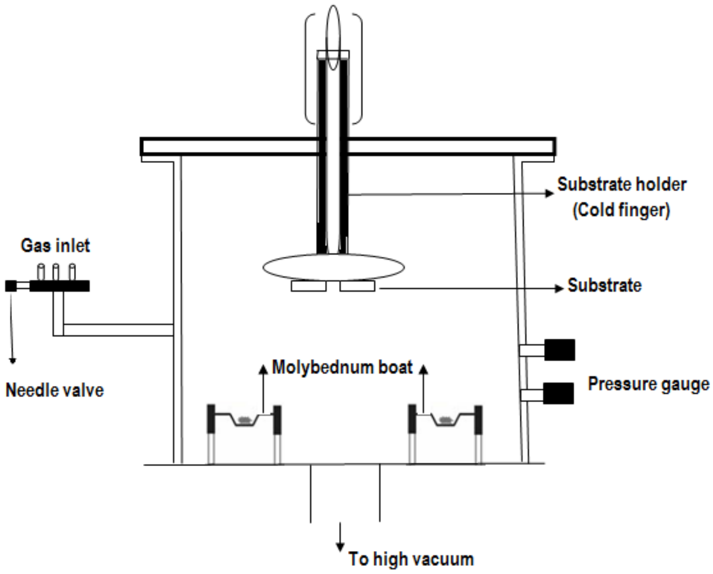

Fig.1. Schematic of vacuum chamber with cold finger

3. Result and discussion

3.1. Optical studies on PbSe multilayer films

The as deposited multilayer PbSe films were analysed under (Jasco-570 UV/VIS/ NIR Spectrophotometer) optical studies (UV-Vis to IR region) to see the absorption edge, absorption coefficient and finally to find the energy band gap. The successive layer deposition with two layer and 5 layer PbSe films under different temperature conditions were shown below.

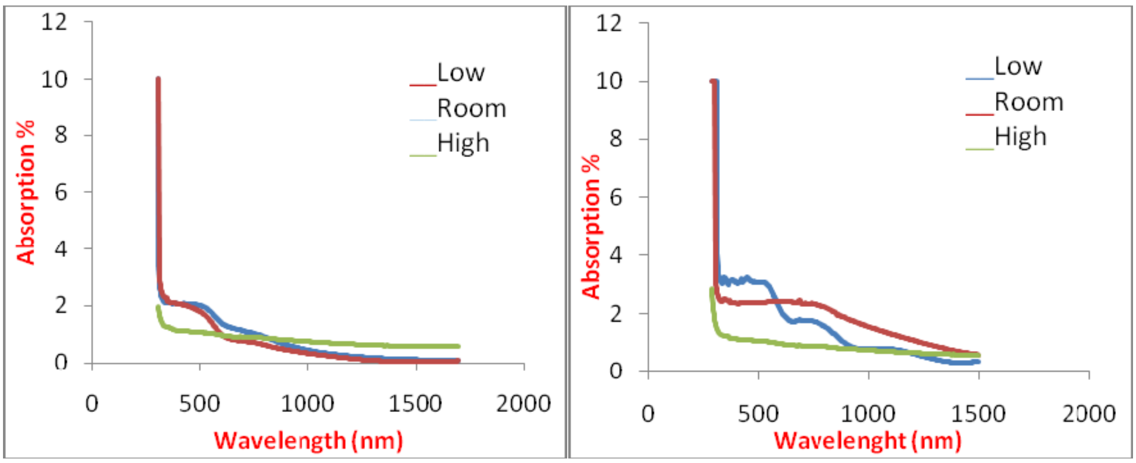

Fig. 2. Absorption spectra of 2 layer and 5 layer PbSe films at various substrate temperature.

The absorption edge starts with the wavelength of (316 nm) for the PbSe films deposited at high temperature (80^0c). The absorption edge for room (28^0c) and low temperature (0^0c) are (310 nm) and (306 nm) respectively. The result of this absorption shift towards blue clearly indicates the presence of nano particles trapped at interface of the successive Lead and Selenium.

As it is evident that the temperature influences in growing the crystallites and the bulk characteristics of PbSe films. The films deposited at the low temperature have lower absorption edge. The PbSe Quantum confinement can possibly incorporated at this low temperature and in addition of a matrix of five layers.

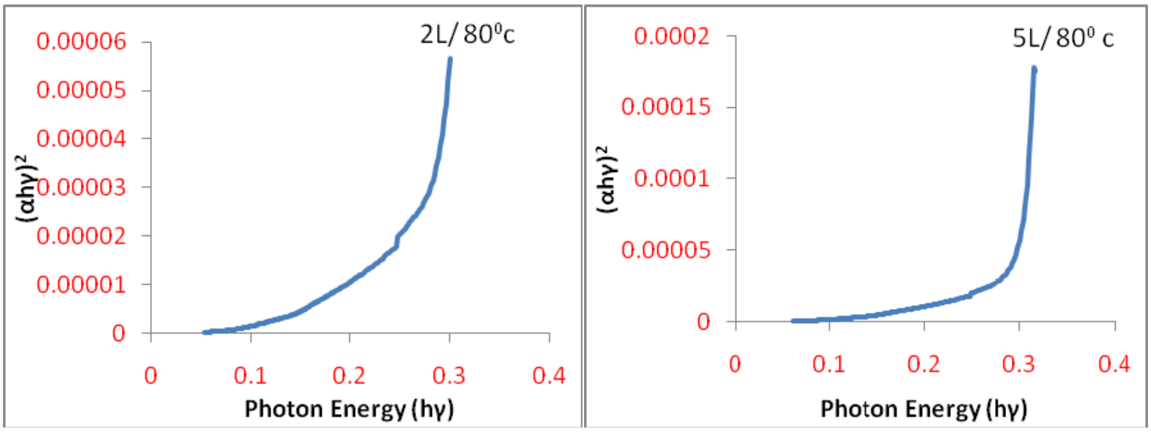

Fig.3. Optical band gap of 2 layer and 5 layer PbSe films at 80°C.

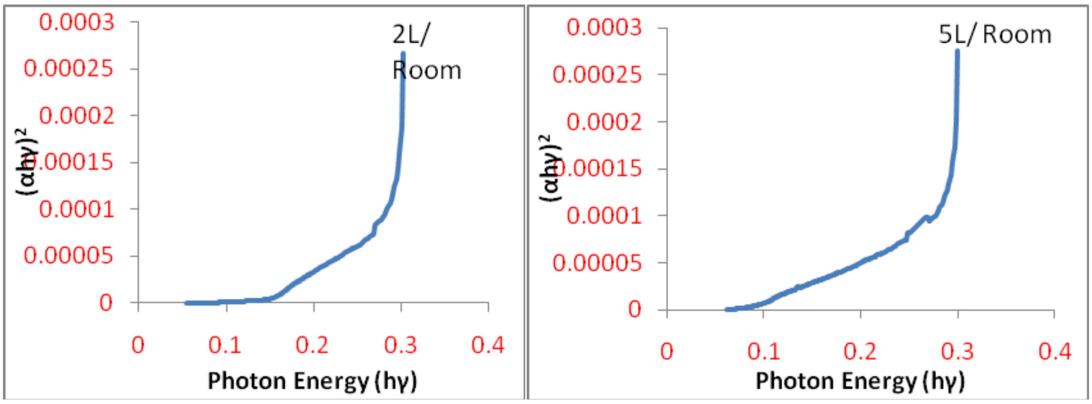

Fig.4. Optical Band gap of 2layer and 5 layer PbSe films at ambient temperature.

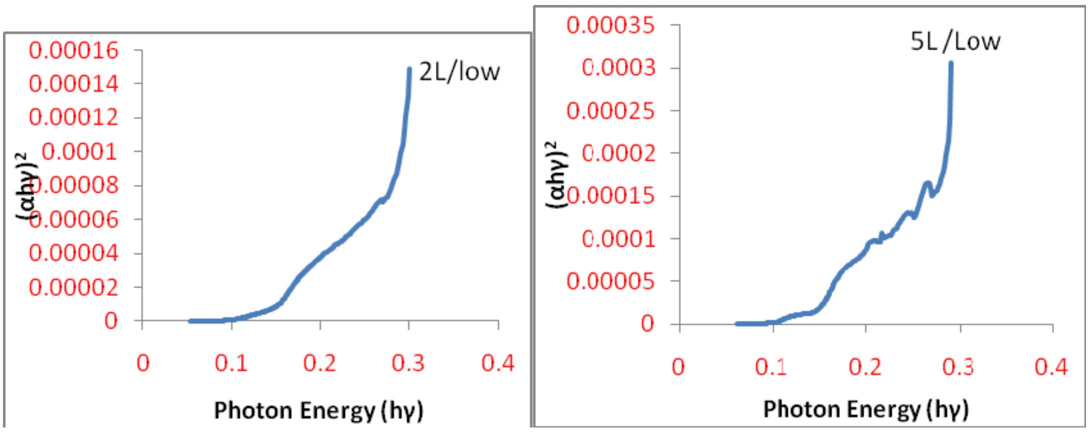

Fig.5. Optical Band gap of 2layer and 5 layers PbSe films at Low temperature.

To find the suitability of the device formation with silicon substrate was studied by calculating its band gap of PbSe at various temperatures and numbers of layers were shown below.

Table.1.Optical band gap of 2 layer and 5 layer PbSe films at various substrate temperature.

Substrate temperature	2 Layer: Band gap (E_g) eV	5 Layer: Band gap (E_g) eV
High temperature	0.25	0.26
Ambient temperature	0.27	0.28
Low temperature	0.28	0.29

The band gap is found to decrease due to an increase of the cluster size or grain size(R); this is known as the quantum size effect. In the quantum size effect, both strong and weak confinements are possible, when $R << a_e$ the confinement is strong and it is weak for $R >> a_e$ where a_e is the effective Bohr radius and is 46 nm for PbSe (large Bohr radii)[11] . The strong and weak confinements occur due to the small and large grains in the sample. In general, a nanocrystalline sample is a combination of small and large grains. The expression for weak (E_w) and strong (E_s) confinement energies can be written as

$$E_s = E_g + \frac{h^2\pi^2}{2\mu R^2} - \frac{1.8e^2}{\varepsilon R}$$

Where, Eg is the bulk band gap, μ reduced mass of exciton, the second term represents the kinetic energy of the confined exciton and the third term indicates the Coulomb interaction of the electron with the hole. Here coulomb interaction is negligible. Using above equation the radius of the particle has been calculated which is much smaller than Bohr radius. This clearly indicates that there is a strong quantum confinement on the multilayer PbSe films.

3.2. Structural studies on PbSe multilayer films

The X-ray diffraction (XRD 6000) studies are carried out for these samples to find the effect of deposition temperature on structure PbSe multilayer films. The PbSe films were exposed to Cu Kα source and the scattering angles were shown in the graph.

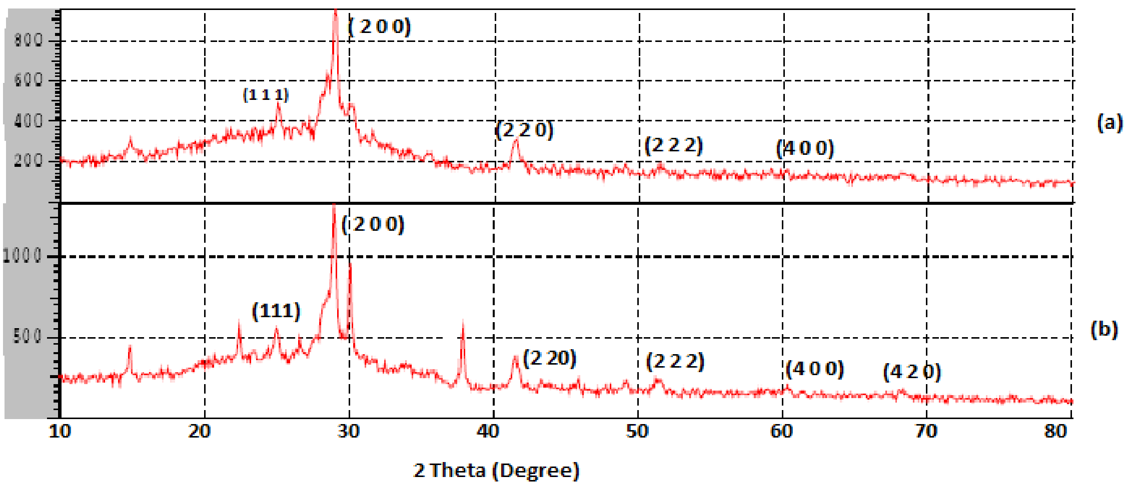

Fig.6. XRD patterns of 2 layer PbSe fimls prepared at low temperature (a) and room temperature (b)

Table.2. Crystalline size of the 2 layer PbSe films prepared at various substrate temperature.

Substrate temperature	h k l	d (A)	2θ	FWHM (β)	Crystalline size (D)nm
Low temperature	1 1 1 2 0 0 2 2 0	3.10546 2.95695 2.13011	28.7239 30.2000 42.4000	1.42280 1.05000 1.04000	5 7 8
Room temperature	1 1 1 2 0 0 2 2 0	3.10146 2.97439 3.18409	28.7618 30.0188 28.0000	1.19260 0.78260 1.29420	6 10 6

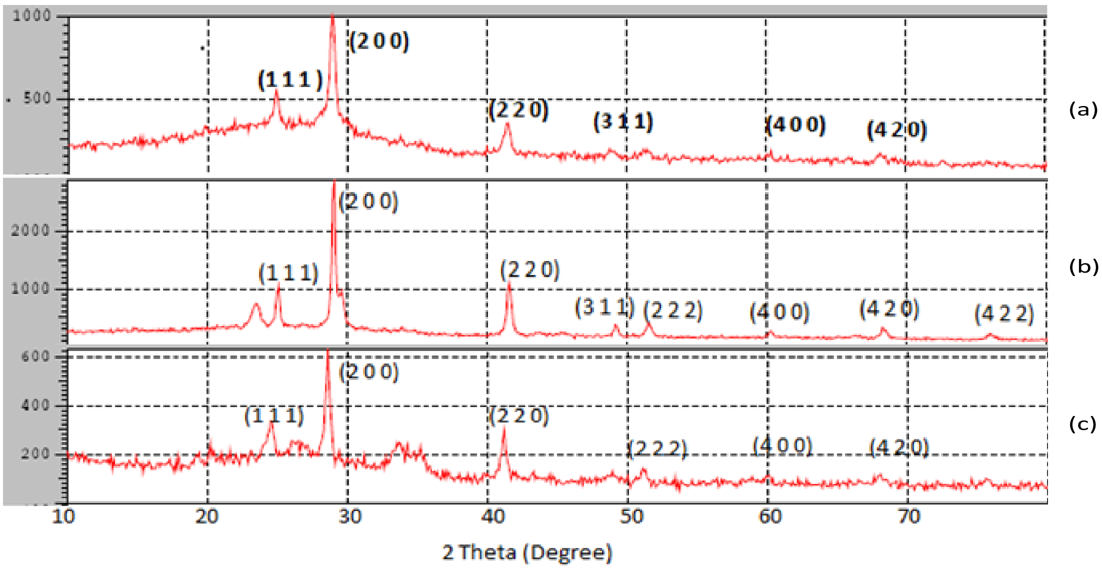

Fig.7. XRD pattern of 5 layer PbSe prepared at low temperature (a)Ambient temperature(b) and high temperature(c).

Table. 3.Crystalline size of the 5 layer PbSe films prepared at various substrate temperature.

Substrate temperature	h k l	d (A)	2θ	FWHM (β)	Crystalline size (D)nm
Low temperature	1 1 1 2 0 0 2 2 0	3.58010 3.08661 2,17847	24.8500 28.9032 41.4150	0.70000 0.61970 0.65110	11 13 13
Room temperature	1 1 1 2 0 0 2 2 0	3.63289 3.12224 2.19279	24.4833 28.5663 41.1322	0.56670 0.47480 0.48440	14 17 17
High Temperature(80^0c)	1 1 1 2 0 0 2 2 0	3.55334 3.07344 2.17076	25.0402 29.027 41.5688	0.34990 0.32030 0.32030	23 25 21

The PbSe two layer XRD pattern is shown in the fig(6) depicts that the crystalline nature of the films having grain size of 5 to 8 nm. The two layer PbSe with alternate Lead and Selenium of $200A^0$ 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 crystallinity improves as the deposition temperature increase and the grains also grow in size as it is evident from the XRD patterns. To confirm the temperature dependence on the size the 5 layer PbSe films (fig.7) are also analysed under XRD and the result is tabulated in (Table 3).

4. Conclusions

Multilayer thin films with different substrate temperatures (Cryo, High, and Ambient) of PbSe were prepared by thermal evaporation technique by successive coatings of Lead and Selenium. From the observed and bulk energy band gap of the as deposited PbSe multilayers , the radius of the particles has been calculated. This calculated value for cryo substrate is found to be much smaller (12 nm) than Bohr radius (46 nm) and revealed that there is a strong Quantum confinement effect on the prepared multilayer thin film. The X-ray diffraction studies revealed the formation of small grains having a size of 5 to 10 nm (two layers) and 11 to 25 nm (five layers) for the cryo substrate resulting in the formation of PbSe quantum dots.

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