



PHYSICS

# PHOTOCONDUCTIVITY AND PHOTOLUMINESCENCE STUDIES OF SOME CHEMICALLY DEPOSITED Cd(S-Se):CdCl<sub>2</sub>, Gd FILMS

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## Abstract

Chemical deposition on appropriate substrate involves precipitation followed by condensation. Films of Cd(S-Se) were prepared by the chemical deposition method using sodium seleno sulphate as Se<sup>2-</sup> ion source. Results of scanning electron microscopic (SEM) & X-ray diffraction (XRD) studies, optical absorption spectra, photoluminescence (PL) emission spectra and photoconductivity (PC) rise & decay are presented for some Cd (S-Se) films, prepared at 60°C and room temperature (RT) on glass substrate, in presence of CdCl<sub>2</sub> as flux and Gd as impurity. SEM studies show presence of grains, cluster type and leafy structures along with voids which are related to layered growth. XRD studies show prominent diffraction lines of CdS, CdSe along with that of Gd. The values of strain ( $\epsilon$ ), grain size (D) and dislocation density ( $\delta$ ) are evaluated from XRD studies and the nature of crystallinity of the films are discussed. From the results of optical absorption spectra, the band gaps are determined. The effect of flux, impurities on the saturated photo to dark current ratio  $I_{pc}/I_{dc}$  is observed in the PC rise and decay studies. The maximum value of  $I_{pc}/I_{dc} \sim 10^7$  is obtained for the impurity doped films. The high photo sensitization is related to increase in mobility and lifetime of carriers due to photoexcitation. PL is found to be stronger in films prepared at RT. In PL two peaks are observed which are related to transitions between excitonic levels and levels due to Gd.

**Keywords:** Cd(S-Se), chemical bath deposition, photo conductivity, photoluminescence

## Introduction

CdS/CdSe is a binary semiconductor and amongst the  $\Pi$ -VI group of semiconductor compounds, it is considered as an important material for the development of different opto – electronic devices [1-3] because of its high photosensitive nature and suitable intrinsic band gap. However, in recent years, the effect of alloying of CdS, CdSe and other II-VI group compounds for the PC and PL studies has become a field of much interest. Gupta et al [4] employed the PC studies to determine the barrier height at the inter-crystalline boundary in CdS<sub>x</sub>Se<sub>1-x</sub> evaporated layers. Similarly, studies on the application of high speed CdS<sub>0.20</sub>Se<sub>0.80</sub> photoconductor as a line image sensor [5] and photoelectrochemical cells made up of chemically deposited coupled films of CdS and CdSe exhibiting higher sensitizations, superior stability and smaller recombination rates [6] were also reported. The PL spectral studies of Cd(S-Se) semiconductors showed interesting results. Shevel et al [7] studied the localized electronic states created by compositional disorder in Cd(S-Se) by employing the pico-second luminescence spectroscopy. Further the disorder effects in CdS<sub>x</sub>Se<sub>1-x</sub> films were correlated with

excitation of localized states observed in PL spectra [8]. Encouraged with these results Cd(S-Se) was selected as the base material for the present study. The role of CdCl<sub>2</sub> in recrystallisation and sensitization of PC in CdS and CdSe is well known so it was taken as a flux. Further, impurities particularly the rare earth ions play a great role in this phenomenon. These ions when incorporated into a solid show distinct spectral lines of absorption and emission as a result of electronic transitions within the 4f<sup>n</sup> shell configuration [9]. The rare earth ions have partially filled 4f shell that is well shielded by 5S<sup>2</sup> and 5P<sup>6</sup> orbitals. The emission transitions, therefore, yield sharp lines in the optical spectra. The rare earth elements based phosphors, therefore, show narrow emission in the visible region with high efficiency [10]. Thus, in present work one of the lanthanides Gd was selected as impurity. A variety of deposition techniques like thermal and electron beam evaporations, sintering technique and spray pyrolysis method were used by earlier workers [11-13] to grow CdS/CdSe type films. However, Bhushan and co-workers [14-19] used simple chemical deposition method to prepare (Cd-Pb)S and (Cd-Zn)S films and observed photo current to dark current ratios of the order of 10<sup>7</sup> in such films under visible excitations using incandescent bulb. They also observed PL and a.c

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electroluminescence in such films. The utility of chemical deposition method in metal chalcogenide films was reviewed earlier by Kale and Lokhande [20]. Cd(S-Se) has advantage over CdS, in changing the band gap of this material depending on concentration of two ingredients and hence emission wavelength can be obtained as per required application. In present work Cd(S-Se) films have been prepared by chemical bath deposition method.

This paper consists of the results of optical absorption spectra, PC rise and decay and PL emission spectra along with those of SEM and XRD studies of some chemically deposited films of Cd(S-Se):CdCl<sub>2</sub>, Gd. The changes observed with respect to the variations in the compositions of different ingredients used are discussed.

## Experimental

### Film preparation

The films were prepared on substrates of microscopic glass slides of dimension 24mm×75mm. The substrates were first cleaned with acetone and double distilled water. Then they were dipped vertically into a mixture of solutions of 1M cadmium acetate, thiourea, triethanolamine, sodium selenosulphate [Na<sub>2</sub>SeSO<sub>3</sub>] solution (prepared by heating elemental selenium [99.9% pure] in aqueous solution of sodium sulphite [Na<sub>2</sub>SO<sub>3</sub>] at 90°C for 5 hrs.) and 30% aqueous ammonia (all AR grade 99.9% pure). The solutions were prepared in double distilled water, and the pH value of the mixture was found to be about 11. Doped films were prepared by adding to the original mixture 0.01M solutions of 99.9% CdCl<sub>2</sub> and Gd<sub>2</sub>O<sub>3</sub> which since being insoluble in distilled water was dissolved in H<sub>2</sub>SO<sub>4</sub>. The depositions were made at a temperature of 60°C in a WB or at RT. After deposition the films were cleaned with distilled water and then dried by keeping in the open air at RT. The thickness of the films was measured by interferometry method and was found to lie between 0.303 μm to 0.339 μm for films deposited in WB at 60°C and in range of 0.5987 μm to 0.6231 μm for RT deposition.

### PC and PL cells

For photoconductivity studies coplanar electrodes (1.5mm wide and 24mm long at a separation of 1mm) were formed by applying colloidal silver paint to the surface of the film. The photocurrents were measured by exposing the total area of the films. The PL cell consisted of the films deposited on the glass substrates.

### Measuring instruments

The excitation source for photoconductivity rise-decay studies was 100W incandescent bulb. The corresponding measurements of the photocurrents were made using a nanometer (DNM-121), and for

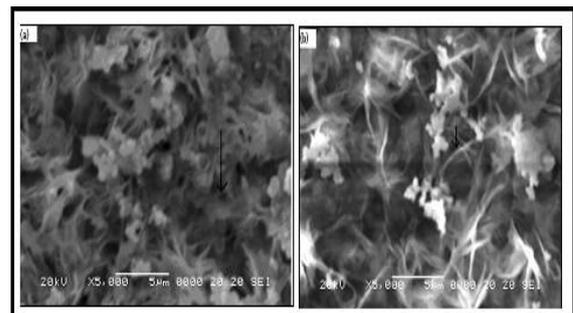
measurement of voltages, a digital multimeter (Scientific HM 5011-3) was used. The PL excitation was made by 365 nm line of Hg which was obtained from a high pressure mercury vapour lamp using a Carl Zeiss interference filter. Light output was detected by an RCA 6217 photomultiplier tube which was operated by a highly regulated power supply (EHT-11 Scientific Equipment, Roorkee). The integrated light output in the form of current was recorded by a sensitive polyflex galvanometer. For spectral studies a prism monochromator was used. XRD and SEM studies were performed at IUC-DAE, Indore using Rigaku RU: H2R Horizontal Rotaflex X-ray machine and JEOL JSM 5600 scanning electron microscope respectively. The optical absorption spectra were recorded by using a 1700 Pharmaspec Shimadzu Spectrophotometer over the wavelength range 300-700 nm.

## Results and Discussion

### SEM studies

Fig 1(a) and 1(b) represents the SEM micrographs of Cd(S<sub>0.95</sub>-Se<sub>0.05</sub>):CdCl<sub>2</sub>(3ml), Gd(2ml) and Cd(S<sub>0.7</sub>-Se<sub>0.3</sub>):CdCl<sub>2</sub>(2ml), Gd(4ml), films prepared on glass substrate (at 60°C), at a magnification of 5000X respectively. These compositions correspond to the maximum PC and PL response respectively. In both the diagrams, presence of grains, voids, some cluster type and leafy type structures are observed. Earlier workers [21] in this laboratory found well developed cabbage structure which they interpreted in terms of layered growth structure forming cabbage due to overlap of different layers formed under continued growth. The cluster type structure in the present case also shows overlap of such structures. The leafy structure may result from not well developed cabbage structure. Thus the leafy structure results from layered growth. Presence of voids are also seen in such growth. The thickness of the layers determined from the scale shown on the micrograph is found to be approximately 300nm [fig 1a] and 280nm [fig 1b] respectively (marked by an arrow).

Fig1. SEM micrograph of (a) Cd (S<sub>0.95</sub>-Se<sub>0.05</sub>):CdCl<sub>2</sub> (3ml), Gd (2ml) (b) Cd(S<sub>0.7</sub>-Se<sub>0.3</sub>):CdCl<sub>2</sub> (2ml), Gd (4ml) film prepared on glass substrate at 60°C



**Optical absorption spectra**

The optical absorption spectra of different Cd(S-Se) films prepared on glass substrate at room temperature by placing an uncoated identical glass substrate in the reference beam are shown in fig 2. The optical absorption spectra of the films were recorded in the wavelength range 300–700 nm. From their Tauc’s plots (extrapolation of plots between absorbance and energy) show direct band gap nature of the material. As expected the band gaps reduce due to increasing concentration of Se (table1), as band gap of CdS is 2.4eV and that of CdSe 1.7 eV [22].On mixing a common lattice of Cd(S-Se) is formed whose band gap lies in between these two values. On addition of CdCl<sub>2</sub> and Gd slight changes in the band gap are observed. The overall absorption in presence of Se and Gd decreases which shows that the films become more transparent in their presence. Spikes in absorption curves of fig.2 in lower wavelength side may be probably due to nanocrystalline effect according to which the continuum of states in conduction & valence bands are broken down into discrete states [23]

Fig 2: Optical absorption spectra of different Cd (S-Se) films [1- Cd (S<sub>0.95</sub>-Se<sub>0.05</sub>) 2- Cd (S<sub>0.9</sub>-Se<sub>0.01</sub>) 3- Cd (S<sub>0.8</sub>-Se<sub>0.2</sub>) 4- Cd (S<sub>0.7</sub>-Se<sub>0.3</sub>) 5- Cd (S<sub>0.95</sub>-Se<sub>0.05</sub>) :CdCl<sub>2</sub> (3ml) 6-- Cd (S<sub>0.95</sub>-Se<sub>0.05</sub>) :CdCl<sub>2</sub>(3ml),Gd(2ml)]

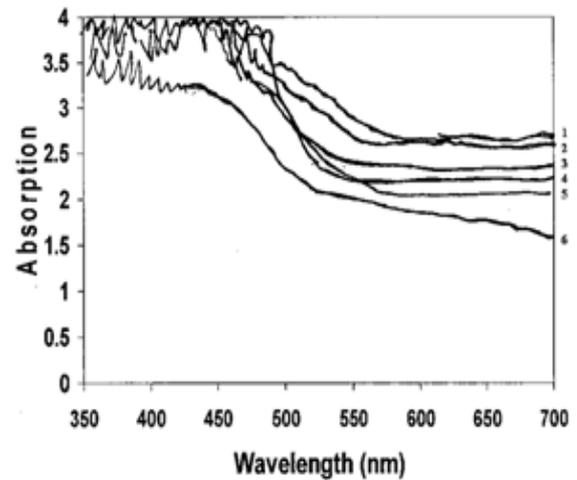


Table 1: Values of band gap energy for different Cd(S-Se) films [Deposition temp = 600C, time of deposition = 1hour]

System	Band gap energy(eV)
Cd (S <sub>0.95</sub> -Se <sub>0.05</sub> )	2.37
Cd (S <sub>0.9</sub> -Se <sub>0.01</sub> )	2.34
Cd (S <sub>0.8</sub> -Se <sub>0.2</sub> )	2.24
Cd (S <sub>0.7</sub> -Se <sub>0.3</sub> )	2.17
Cd (S <sub>0.95</sub> -Se <sub>0.05</sub> ) :CdCl <sub>2</sub> (3ml)	2.36
Cd (S <sub>0.95</sub> -Se <sub>0.05</sub> ) :CdCl <sub>2</sub> (3ml), Gd(2ml)	2.35

**XRD studies**

The X-ray diffractogram of Cd (S<sub>0.95</sub>-Se<sub>0.05</sub>) :CdCl<sub>2</sub>(3ml),Gd(2ml). (composition showing max. PC) and Cd(S<sub>0.7</sub>- Se<sub>0.3</sub>):CdCl<sub>2</sub>(2ml), Gd(4ml) film (composition showing max.PL) are presented in fig 3(a) and 3(b) respectively. The corresponding data are presented in table 2. The assignments of peaks have been made from the comparison of ASTM data & calculation of lattice constants and their comparison with the reported values. The different assigned peaks are also mentioned in the figure. Thus, prominent peaks of CdS, CdSe and Gd<sub>2</sub>O<sub>3</sub> [fig3 (a)] and peaks of CdS, CdSe along with that of Cd [fig3 (b)] are observed. It is also observed that CdS is found in cubic as well as hexagonal phases. Such phases arise due to difference in arrangement of atomic layers. The cubic and hexagonal phases arise due to atomic

arrangements as ABCABC.....and ABAB....[24]. It is also possible to find mixed forms with random stacking of very long period repeats as is found in polytypes of SiC [25]. The total crystal consists of different atomic layers of CdS in cubic as well as hexagonal phases along with some atomic layers of CdSe in hexagonal phases. According to Langer et al [26] one might think of solid solutions as mixtures of microcrystalline regions of the pure CdSe and CdS, where each micro region might consist of a number of unit cells of each material with the lattice-constant of CdS stressed by surrounding CdSe and that of CdSe compressed by its CdS neighbours. Such a model can explain uniform shift of absorption edge with variation in composition. A possibility of solid solution consisting of statistical distribution of CdSe and CdS with respect to their overall concentration was also mentioned by these workers. It should be noted that shift of

absorption edge has already been observed in the present case. The particle size  $D$  [27], strain value  $\epsilon$  [28] and dislocation density  $\delta$  [29] were obtained for (111)c peak of CdS by using the well known formulae and such values are presented in table 3. It is observed that with decreasing FWHM the particle size increases and the corresponding strain value and dislocation density decrease. The decrease in dislocation density suggests that films become more crystalline.

Fig. 3(a): XRD pattern for Cd (S<sub>0.95</sub>-Se<sub>0.05</sub>):CdCl<sub>2</sub> (3ml), Gd (2ml) film (b):Cd (S<sub>0.7</sub>-Se<sub>0.3</sub>) CdCl<sub>2</sub> (2ml),Gd (4ml) film

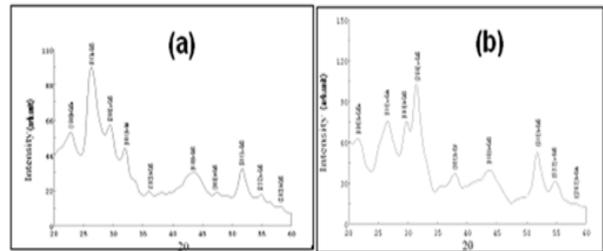


Table 2: XRD data of Cd (S<sub>0.95</sub>-Se<sub>0.05</sub>):CdCl<sub>2</sub> (3ml), Gd (2ml) Film (Preparation time =60 min; Preparation temperature =60°C)

d value		Intensity		h k l	Lattice constant	
Obs.	Rep.	Obs.	Rep.		Obs.	Rep.
<b>(a) Cd (S<sub>0.95</sub>-Se<sub>0.05</sub>):CdCl<sub>2</sub>(3ml),Gd(2ml)</b>						
3.89	3.72	58.3	100	(100)h-CdSe	a=4.49	a=4.30
3.39	3.36	100	100	(111)c-CdS	a=5.871	a=5.818
3.02	2.90	62.9	40	(200)c-CdS	a=6.01	a=5.818
2.794	2.759	48.6	100	(101)h-Gd	-----	-----
2.49	2.45	21.3	25	(102)h-CdS	a=4.137, c=6.87	a=4.135, c=6.71
2.07	2.06	33.3	57	(110)h-CdS	a=4.137, c=6.82	a=4.135, c=6.71
1.914	1.899	20.7	42	(103)h-CdS	a=4.137, c=6.79	a=4.135, c=6.71
1.766	1.753	35.7	60	(311)c-CdS	a=5.848	a=5.818
1.67	1.680	19.7	10	(222)c-CdS	a=5.775	a=5.818
1.584	1.581	14	7	(202)h-CdS	a=4.137, c=6.78	a=4.135, c=6.71
<b>(b) Cd(S<sub>0.7</sub>-Se<sub>0.3</sub>):CdCl<sub>2</sub>(2ml),Gd(4ml)</b>						
4.11	3.72	62.4	100	(100)h-CdS	a=4.745	a=4.30
3.35	3.36	75	100	(111)c-CdS	a=5.802	a=5.818
2.99	3.16	74	100	(101)h-CdS	a=4.135 c=6.38	a=4.135 c=6.71
2.84	2.90	100	40	(200)c-CdS	a=5.68	a=5.818
2.37	2.34	37	100	(101)h-Cd	-----	-----
2.06	2.06	39	57	(110)h-CdS	a=4.135, c=6.79	a=4.135, c=6.71
1.76	1.753	52	60	(311)c-CdS	a=5.837	a=5.818
1.67	1.68	30	10	(222)c-CdS	a=5.785	a=5.818
1.580	1.581	14	7	(202)h-CdS	a=4.135 c=6.69	a=4.135 c=6.71

Table 3: Values of Particle size, Strain and Dislocation density for Cd (S<sub>0.7</sub>-Se<sub>0.3</sub>): CdCl<sub>2</sub>, Gd (4ml) and Cd (S<sub>0.95</sub>-Se<sub>0.05</sub>):CdCl<sub>2</sub> (3ml), Gd (2ml) films

Sample	Particle size D(nm)	Strain $\epsilon$ (lin <sup>-2</sup> m <sup>-4</sup> )	Dislocation density( $\times 10^{15}$ lin/m <sup>2</sup> )
Cd(S <sub>0.95</sub> -Se <sub>0.05</sub> ):CdCl <sub>2</sub> (3ml),Gd(2ml) film	5.23	0.00695	36.91
Cd(S <sub>0.7</sub> -Se <sub>0.3</sub> ):CdCl <sub>2</sub> (2ml),Gd(4ml) film	3.90	0.0092	65.74

**PL emission spectra**

The PL emission peak of CdS is found to be at 516 nm corresponding to its band gap 2.43 eV, calculated by the absorption studies. Thomas and Hopfield [30] reported that at lower temperatures the edge emission in CdS appears due to transitions associated with the defect-exciton complexes ,however,

at room temperature only free excitons have sufficient binding energy ( $\approx 0.029$ meV) to sustain the thermal dissociation ( $KT \approx 0.0258$  meV). Jeong and Yu [31]found that PL in CdS crystal grown by sublimation method consists of a broad and intense excitonic emission peak at 2.44 eV at 298°K related to free exciton and their LO-phonon replica. Thus in present case also emission of CdS can be attributed to the

excitonic transition involving free excitons. Change in band gap due to addition of CdSe has already been reported in the absorption spectra. Corresponding changes were also observed in PL emission spectra. Two peaks appear in undoped Cd(S-Se). Maximum emission intensity of these peaks appears in Cd(S<sub>0.7</sub>-Se<sub>0.3</sub>) at 500 nm and 570 nm, and hence this combination was used for PL studies. In the presence of flux, at its different concentrations, the highest emission appears at a volume of 2ml of CdCl<sub>2</sub>. Therefore, for further study this combination was used. The PL emission spectra of different Cd(S-Se), Cd(S-Se):CdCl<sub>2</sub> films prepared on glass substrate at different concentrations are shown in fig4 (a). The corresponding peak positions of PL intensities are mentioned in table 4. Owing to similar excitonic nature of edge emission in both CdS and CdSe, the emission observed at 500 nm can be associated with the annihilation of free excitons [32]. The second peak observed at 570nm can be associated with the donor – acceptor transitions. In CdS type material incorporation of cations (excess Cd) introduces shallow donor levels like S vacancies with ionization energies ≈0.03eV, where as that of anions like S or Se, in the present case introduces deep acceptor levels (Cd vacancies with ionization energy ≈ 1.1 eV for sulfides and ≈ 0.6 eV for selenides) for the charge compensation of the system. Improvement in intensities of emission peaks in presence of CdCl<sub>2</sub> may be due to better crystallization in its presence [22]. PL emission spectra of different Cd(S-Se): CdCl<sub>2</sub>, Gd films at different molar concentrations of Gd<sub>2</sub>O<sub>3</sub> were also taken. It is observed that maximum emission spectra at 0.01 concentration and hence this molar concentration was used for different preparations in the presence of Gd. At this molar concentration the emission spectra were studied at different volumes, and are shown in fig 4 (b). It is seen that in presence of CdCl<sub>2</sub> and Gd slight shift is observed along with improvement in intensity. The highest emission appears at a volume of 4ml of Gd. Origin of emission peaks in presence of Gd may be related to transitions between these excitonic levels & the levels due to Gd which produce a slight shift. Improvement in peaks intensities may be due to energy transfer from levels of Gd. The PL emission spectra were studied for films prepared in WB at 60°C and at RT. The maximum PL intensity appears in films prepared at RT, as shown in fig 4(c). This may be due

to higher thickness of the films prepared at RT. Changing thickness affects the emission itself.

Fig 4(a): PL emission spectra of different Cd (S-Se) films 1.CdS 2. Cd (S<sub>0.95</sub>-Se<sub>0.05</sub>) 3. Cd (S<sub>0.9</sub>-Se<sub>0.1</sub>) 4. Cd (S<sub>0.8</sub>-Se<sub>0.2</sub>) 5. Cd (S<sub>0.7</sub>-Se<sub>0.3</sub>) 6.Cd (S<sub>0.6</sub>-Se<sub>0.4</sub>) 7. Cd (S<sub>0.7</sub>-Se<sub>0.3</sub>) CdCl<sub>2</sub> (2ml)

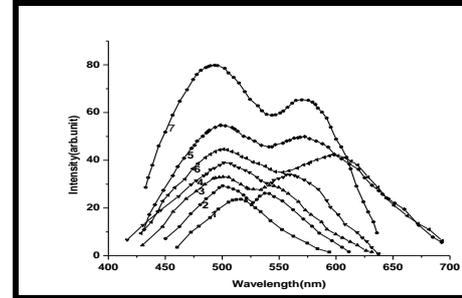


Fig 4(b): PL emission spectra of different Cd (S<sub>0.7</sub>-Se<sub>0.3</sub>):CdCl<sub>2</sub> (2ml), Gd films at different volumes of Gd<sub>2</sub>O<sub>3</sub> [0.01M] 1- (3ml) 2-- (4ml) 3-- (5ml) 4-- (6ml) 5-- (7ml)

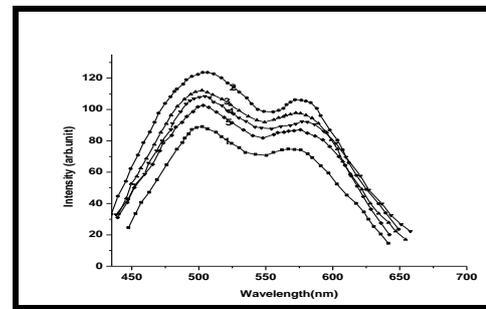


Fig 4(c): PL emission spectra of different Cd (S<sub>0.7</sub>-Se<sub>0.3</sub>)CdCl<sub>2</sub> (2ml) Gd (4ml) films 1. in water bath at 60°C 2. at RT

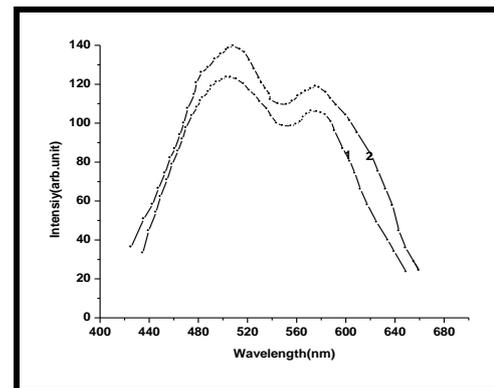


Table 4. Values of peak positions and PL intensities of different Cd(S-Se) films prepared on glass substrate at 60°C in WB and at RT

System	PL peak position (nm)	Intensities (arb. Unit)
CdS	516	24
Cd (S <sub>0.95</sub> -Se <sub>0.05</sub> )	500, 531	30, 27
Cd (S <sub>0.9</sub> -Se <sub>0.01</sub> )	500, 538	35, 33
Cd (S <sub>0.8</sub> -Se <sub>0.2</sub> )	500, 553	41, 37
Cd (S <sub>0.7</sub> -Se <sub>0.3</sub> )	500, 570	55, 49
Cd (S <sub>0.6</sub> -Se <sub>0.4</sub> )	500, 598	45, 42
Cd (S <sub>0.7</sub> -Se <sub>0.3</sub> ):CdCl <sub>2</sub> (2ml)	500, 570	80, 65
Cd(S <sub>0.7</sub> -Se <sub>0.3</sub> ):CdCl <sub>2</sub> (2ml),Gd(4ml) [WB ]	507, 571	123, 106
Cd(S <sub>0.7</sub> -Se <sub>0.3</sub> ):CdCl <sub>2</sub> (2ml),Gd(4ml)[RT]	508, 575	140, 118

## PC studies

Fig 5 shows the rise and decay curves of different Cd(S-Se) films using CdCl<sub>2</sub> as flux and Gd as impurity. All these curves show a rapid rise of photocurrent in the early part, which is followed by a slower rise, finally leading to a saturation of photocurrent. The PC in CdS is sensitized with incorporation of CdSe in Cd(S-Se) films. According to Bube [22] the initial rapid rise of photocurrent in such semiconductors occurs as the hole demarcation level moves down near to the sensitizing levels in Cd(S-Se) due to generation of carriers under irradiation. The slow rise corresponds to the time required for readjustment of empty and filled bands in the forbidden gap, hole becoming located at sensitization centres with small recombination cross-section and electrons becoming located at centres with large recombination centres. A saturated photocurrent occurs due to balancing of the generation and recombination effects. Similarly decay curves consist of fast decrease followed by a very low decrease. Fast decrease is related to direct recombination effects, whereas the slow variation is related to a slow release of the trapped electrons from deep traps formed in CdS/CdSe system. The high photosensitivity in II-VI compounds is associated with the presence of compensated acceptors. In the CdS/CdSe films deposited by CBD method an excess of Cd (equivalent to a sulfur/selenium vacancy) is naturally incorporated as interstitial atoms, which act as donors. These donors compensate the cation vacancies (acceptors) either already present in the material or created by the nonstoichiometry. The halide ions in CdCl<sub>2</sub> incorporated as flux also act as donors, which further sensitize the films through the same mechanism. The trivalent rare earth ion donates an extra electron introduced for each RE<sup>3+</sup> incorporated, which becomes free at room temperature and above. This explains the high photosensitivity in the presence of Gd. Due to the variation in Se content, maximum photocurrent was observed for 0.95:0.05 combination of CdS to

CdSe under visible radiation. With this combination the volume of CdCl<sub>2</sub> was varied, and the maximum current was observed for 3ml volume. Similarly the volume of Gd<sub>2</sub>O<sub>3</sub> was also varied. The maximum photocurrent was observed for a volume of 2ml. PC response was studied for the film prepared at RT and in water bath at 60°C. PL in films prepared at RT show better (PL) emission, and hence lower PC is expected in such films. The corresponding data of the dark current ( $I_{dc}$ ), the photocurrent ( $I_{pc}$ ) and their ratio ( $I_{pc}/I_{dc}$ ) are summarized in table 4. The values of life time; mobility and life time are also obtained by methods described elsewhere [33]. It is observed that the values of lifetime and mobility both increase in the presence of impurities, which accounts for the better photo-response.

Fig 5: PC rise and decay curve of different Cd(S-Se) films prepared on glass substrate 1. Cd (S<sub>0.95</sub>-Se<sub>0.05</sub>) 2. Cd (S<sub>0.95</sub>-Se<sub>0.05</sub>) CdCl<sub>2</sub> (3ml) 3. Cd (S<sub>0.95</sub>-Se<sub>0.05</sub>) CdCl<sub>2</sub> (3ml) Gd (1ml) 4. Cd (S<sub>0.95</sub>-Se<sub>0.05</sub>) CdCl<sub>2</sub> (3ml) Gd (2ml) 5. Cd (S<sub>0.95</sub>-Se<sub>0.05</sub>) CdCl<sub>2</sub> (3ml) Gd (3ml) 6. Cd (S<sub>0.95</sub>-Se<sub>0.05</sub>) CdCl<sub>2</sub> (3ml) Gd (4ml)

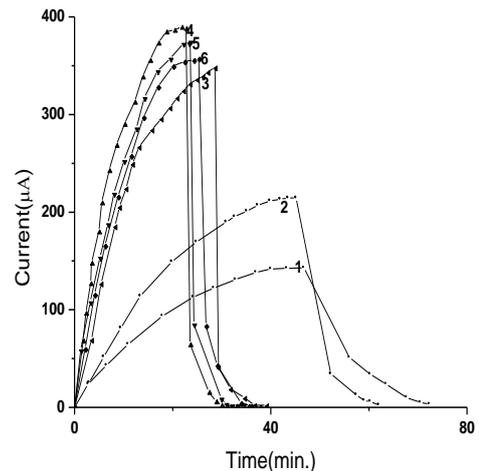


Table 5 – Values of  $I_{dc}$ ,  $I_{pc}$ ,  $I_{pc}/I_{dc}$ , life time, mobility & trap depths for different films

System	$I_{pc}$ ( $\mu$ A)	$I_{dc}$ (nA)	$I_{pc}/I_{dc}$	Life Time ( $\tau$ ) Sec	Mobility $Cm^2/Vs$	Trap Depth(eV)	
						E1	E2
Cd (S <sub>0.95</sub> -Se <sub>0.05</sub> )	143	0.17	$0.84 \times 10^6$	20.2	30.1	0.709	0.711
Cd(S <sub>0.95</sub> -Se <sub>0.05</sub> ) :CdCl <sub>2</sub> (3ml)	214	0.1	$2.14 \times 10^6$	35.1	44.4	0.727	0.737
Cd(S <sub>0.95</sub> -Se <sub>0.05</sub> ) :CdCl <sub>2</sub> (3ml),Gd(1ml)	345	0.07	$0.49 \times 10^7$	53.2	61.4	0.812	0.823
Cd(S <sub>0.95</sub> -Se <sub>0.05</sub> )CdCl <sub>2</sub> (3ml)Gd(2ml)	389	0.04	$0.97 \times 10^7$	67.5	96	0.815	0.853
Cd(S <sub>0.95</sub> -Se <sub>0.05</sub> )CdCl <sub>2</sub> (3ml)Gd(3ml)	375	0.08	$0.46 \times 10^7$	42.7	71.8	0.813	0.821
Cd(S <sub>0.95</sub> -Se <sub>0.05</sub> )CdCl <sub>2</sub> (3ml)Gd(4ml)	358	0.05	$0.71 \times 10^7$	52.7	89.8	0.823	0.813

## Conclusions

Highly photosensitive materials can be prepared by chemical deposition of Cd(S-Se) films doped with rare earths. SEM studies show layered growth of films. XRD patterns of Cd (S<sub>0.95</sub>-Se<sub>0.05</sub>):CdCl<sub>2</sub> (3ml), Gd (2ml) and Cd (S<sub>0.7</sub>-Se<sub>0.3</sub>): CdCl<sub>2</sub> (2ml), Gd (4ml), films prepared on glass substrate at 60°C show diffraction lines due to CdS, CdSe and Gd. PL emission spectra of chemically deposited Cd (S<sub>0.7</sub>-Se<sub>0.3</sub>), Cd (S<sub>0.7</sub>-Se<sub>0.3</sub>): CdCl<sub>2</sub>, Gd (2ml) films consist of two peaks which are related to the transition between excitonic levels and levels due to Gd. PL emission is found to be stronger in films prepared at RT. Highly photosensitive films having I<sub>pc</sub>/I<sub>dc</sub> ratio of the order of 10<sup>7</sup> can be prepared by using Cd(S-Se) films by a chemical deposition technique. The life time and mobility determined from the decay curves and the I<sub>pc</sub>/I<sub>dc</sub> ratio are found to increase under doping condition. From absorption spectra direct band gap nature is found along with band gap value equal to 2.35eV to 2.15 eV corresponding to increasing proportion of Se in Cd(S-Se) films.

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