CHAPTER - I

1.1 Introduction:

The present thesis concerns with the photoconductivity (PC) and photoluminescence (PL) studies of some II-VI compounds in the mixed form. PC phenomenon is concerned with the increase of the electrical conductivity of matter produced by the motion of charge-carriers created by absorbed radiations, under conditions of thermal equilibrium. II-VI binary semi-conducting compounds, belonging to the cadmium chalcogenide family (CdS, CdSe, CdTe, etc.), are considered to be very important materials for a wide spectrum of opto-electronic applications as having specific physical properties such as direct band-gap width and infra-red part of solar spectrum, good electrical properties (e.g. carrier mobility and life-time) and increased capability in obtaining adjustable n- or p-type conductivity by doping. In spite of the photoconductance process, it provides valuable information about the physical properties of materials and is used in photo-detection and radiation measurements. The thin film technology has further enhanced the development of low dimensional photo-detectors. The rapid development of this field is due to its applications in industry and defence. Highly sensitive photo-detectors in the infra-red region are generally photo-conducting type. The use of p-n junction photovoltaic devices is important because of their high speed, high response and small dimensions. Moreover, with the development of optical communication and optical computers, a need of integrated electro-optical circuitry [Hudson 1987] is there and so high-speed photodiodes, photonic devices, laser diodes etc. [Mourou and Bloom 1985; Mattera et al 1986; Temkin et al 1986] are being developed. Because of the important applications mentioned above, the material was
prepared in the form of thin film for the present study. Thin films are generally confined to a limited range of thickness between a few Å to 5000 Å [Goswami 1996]. The thin film technology has also become more advanced with the industrial application of microelectronics for the development of synthetic materials of tailored properties for VLSI / GSI, communication, informatics, solar energy conversion, optical coatings, integrated optics and surface science. Moreover, this technology has enabled the designing of smaller active electronic devices with a high packing density, higher speed performance and lower cost. The thin films can be termed as two-dimensional micro materials. These low dimensional materials exhibit quantization, non-equilibrium electron, photon and phonon transport processes and surface dominated diffusion and chemical processes. The tailoring of the properties of these films is possible via various physical phenomena occurring during the growth of the films. By varying deposition parameters, one can obtain a whole range of structural disorder, microstructures, topographic and geometrical features, growth anisotropies, frozen-in point and line defects and compositional profiles. These tailored materials find their application in obtaining optical interference filters, wave-guides and optical components like thin films, gratings and polarizers [Chopra K. L. 1969]. The properties to be tailored to create micro materials with desired reflectance / transmittance / emittance are:

1. Optical band gap
2. Appropriate reflectance / transmittance / emittance spectra
3. Stoichiometric deviations
4. Alloys of variable composition and multi-component compounds
5. Electron transport parameters and surface activation and passivation behaviour.
Although a number of preparational techniques are used to produce thin films as discussed in chapter - III, the chemical bath deposition (CBD) techniques has been found to be particularly useful in the tailoring of the above mentioned properties. CBD normally takes place through the adsorption of metal hydroxide ions on the surface of the substrate which provides a nucleation layer and the chemical conversion of this layer to the metal chalcogenide layer through reaction with chalcogenide ions. Once this happens, the metal chalcogenide layer acts as a catalytic surface for the ion-by-ion condensation of the metal and chalcogen ions leading to the growth of the film [Pavaskar et al. 1977]. The pH of the solution is adjusted so that the hydroxide phase of the metal is present only during the initial phase of the deposition. The ion-by-ion condensation is promoted through: (i) the use of appropriate complexing agents for the initial ions so that the availability of free metal ions is controlled through chemical equilibrium, and (ii) the slow hydrolysis of chalcogen-bearing species in the presence of hydroxo ions [Nair and Nair 1987] in the solution. Film thickness of ~ 0.05-1 μm are usually attainable by this technique.

Photoconductivity phenomenon is concerned with the enhancement of the electrical conductivity due to irradiation of light photons on the surface of the film [Bube 1974]. In the absence of irradiation, the thermally generated carriers are distributed among the available states according to Fermi-Dirac statistics. These electrons and holes occupying conduction states determine the dark conductivity of the material. Under constant illumination, a steady state photocurrent is reached in which the rate of photogeneration is balanced by the various recombination processes through which the carriers tend to relax to normally equilibrium distribution. The phenomenon of
photoconductivity thus involves processes like absorption, photogeneration, recombination and transport [Mort and Pai 1976] in an intimate relationship. Concurrent with the basic studies, this phenomenon has been important because of the emergence and successful exploitation of a wide range of technologies and devices e.g. electrophotography, light meters, image intensifiers and energy converters etc. Both these disciplines need development of better and better characterized materials with controlled properties.

This phenomenon has been observed in a variety of materials like crystalline covalent solids, molecular solids, the amorphous state and liquids. II-VI compounds present very important class of materials as these are direct band gap materials with band gaps ranging throughout the visible spectrum. The choice of obtaining maximum response in the visible region can be easily achieved by mixing the different materials. With this in view, Cd(S-Se) mixed base was selected for the present work. The materials were prepared in the form of films, since thin film studies have been rewarded in the form of variety of active and passive microminiaturized components and devices such as solar cells, radiation sources and detectors magnetic memory devices, cryotrons, bolometers, interference filters, reflection and antireflection coatings [Chopra 1969].

Phenomenon of photoconductivity can be obtained in pure form of the materials known as intrinsic photoconductivity or in presence of impurities or crystal imperfections called impurity or imperfection photoconductivity [Bube 1967]. Group III and group VII impurities in II-VI compounds act as donors, whereas group I and group V impurities in these compounds act as acceptors. Role of imperfections can be regarded in changing the dark conductivity, the photosensitivity and the spectral response. The II-VI
compounds are normally characterized by having deep acceptor levels. High photosensitivity in most of such compounds is associated with the presence of compensated acceptors which are negatively charged and thus have a much larger cross-section for the capture of free holes than they have subsequently for the capture of free electrons. In order to provide these compensated acceptors, it is common to incorporate both donor and acceptor impurities in II-VI compounds. It is found that with increasing proportion of halide donors incorporated, both the dark and photo-conductivity increase. The ratio of photo to dark conductivity is found to be maximum at a certain proportion of incorporated donors. Copper acceptors may reverse the effect of donors and thus cause a decrease in photo and dark conductivities. The increase in photosensitivity due to incorporation of halide impurity is normally related to (1) compensation of cation vacancy acceptors due to halide donors; (2) partly causing deviation from stoichiometry in the form of cation vacancies, which in turn are compensated by the donors.

Evaporated layers of CdS have frequently been prepared to have an excess of cadmium. The photosensitivity of such layers is found to be decreased by heating in sulphur, after heating, it is restored by heating in cadmium. In such layers without added impurity anion vacancies can act as donor and the cation vacancies as acceptor. Bhushan and Sharma (1988) reported that in CdS:Yb crystals, annealing in air produced less photocurrent. That in sulphur made the crystal very conducting and annealing in presence of Cd metal made the photoresponse quite fast. Bube (1974) reported that annealing in oxygen decreased the photo and dark conductivities of CdS. Bargale (1980) found that in CdS:Na, photocurrent was maximum at a particular annealing time. Bhushan and
Sharma (1990) also found similar observations for CdS films. Studies on annealing effect of undoped and doped Cd(S-Se) films form a subject of present thesis also.

The thickness of the photoconducting layer/film is also an important criterion to find the maximum photocurrent. Maximum photocurrent may appear at a particular thickness, as was observed by Bhushan and Diwan (1986) in powder layers. At comparatively higher thickness, the photocurrent may reduce due to absorption of the light photons in the first few layers. Bhushan and co-workers (1990, 1992) found that in films of CdS the maximum saturated photocurrents appear for a particular deposition time, which means a particular thickness. Such studies also form part of present studies.

Woods (1958) showed that the photosensitivity of CdS can be increased through the control of crystal defects either by passage of a limited breakdown current, the characteristics of which are similar to those obtainable by incorporating a halide, or a trivalent cation or by heating in vacuum at temperatures up to 700°C which forms excess cadmium. Many-fold increase in photosensitivity was also reported due to trivalent rare-earths by Bhushan et al. (1988, 1992). Thin film deposition at elevated temperatures or by annealing subsequent to deposition gives rise to increased grain size and resistivity along with weak photoconductivity [Chopra 1969]. However, when sensitized in presence of impurities, these films become efficient photoconductors. The electrical properties are also found to depend upon the atmosphere in which the preparation is carried out [Kröger and Dikhoff 1950] e.g. when Ga$^{3+}$ is incorporated in sulphurizing atmosphere, it does not increase the conductivity. However, when Ga$^{3+}$ is incorporated in a reducing atmosphere the conductivity is increased because of the freed extra electrons. So far as CdSe is concerned, most of the investigations depending upon defects in CdSe
have been concerned with luminescent properties. However, this shows photoconduction particularly when mixed with CdS. In the present work, effect of rare-earth impurities has been investigated in films of Cd(S-Se). It should be noted that both these crystals show fractional ionic or covalent character [Kittel 1983]. It is found that compounds with ionic binding have largest band gaps and those with covalent binding have the smallest ones. In general, decrease in mobility is expected for increased ionic character of the binding, because of greater electrostatic interaction between the free charge carriers and the charged ions of the crystal.

Two types of photocurrents have normally been obtained: (1) primary photocurrent, which is considered to be the direct result of the absorption of energy and (2) secondary photocurrent which is due to the result of passage of primary photocurrent. Quantum efficiency or gain is defined as the ratio of number of charges passing between the electrodes to the number of photons absorbed in a given time interval. While primary photocurrents are characterized by a maximum gain of unity, secondary photocurrents, which are more prominent at high electric fields and high light intensities, are characterized by gains greater than unity.

Trapping is a fundamental process for energy storage in almost all electronically active solids. This energy storage is accomplished by spatial localization of an excited electron or hole in such a way that electron or hole is prohibited from moving freely throughout the crystal unless supplied with proper thermal / optical energy. When the captured carrier has a greater probability of being thermally re-excited to a free state than of recombining with a carrier of opposite sign at the imperfection, the corresponding centres are called trapping centres. On the other hand; in the opposite case, the centre is
called recombination centre. Thus, when the trapped electron or hole is released, it is free to move until captured by a recombination centre or a trap. Those regions of the crystal which are able to capture electrons and holes and detain them in a restricted volume are called traps.

Generally a demarcation level is specified separating trapping and recombination levels. A demarcation level is an energy level from which transition to higher as well as lower levels are equally probable. The location of demarcation level depends upon the specific values of capture coefficients for a particular type of imperfection and each kind of imperfection is associated with one set of demarcation levels. The sensitization of PC by a given impurity depends totally on the location of the demarcation level.

The observed photoconductivity growth and decay are described in terms of monomolecular or bimolecular recombination processes [Gurevich and Tolstoi 1950; Ryovkin 1964]. Decay curves are bound to depend upon temperature and light intensity and their shape is modified by trap filling and emptying. If one type of trap is involved, the decay is of exponential type and if traps of different depths are involved, the resulting decay can be observed as a combination of many exponentials. From the exponential decay curves, the trap depths can be easily determined. In the present work results of such calculations are presented for different systems. The PC rise and decay curves are also used to determine the important parameters like the instantaneous lifetime (τ), mobility (μ) and the ratio of saturation photo to dark current (I_{PC}/I_{DC}) defined as PC gain (G).

Life time of photo excited carriers is the key parameter for understanding of phenomenon of photoconductivity. There are different kinds of life time:
(1) **Free life time** : The free life time is the time that the charge carrier is free to contribute to conductivity. It is the time that an excited electron spends in the conduction band or the time that an excited hole spends in the valence band. The free life time of a charge carrier can be: (a) terminated by recombination, or if the carrier is extracted from the crystal by the electric field without being replenished from the opposite electrode, (b) interrupted if the carrier is trapped, and (c) undistributed if the carrier is extracted from the crystal by the field at the same time as an identical carrier is injected into the crystal from the opposite electrode.

(2) **Excited life time** : The excited life time is the total time that the carrier is excited between the act of excitation and the act of recombination or extraction without replenishment. The excited life time includes any time that the carrier may spend in traps. It is therefore usually longer than the free life time.

(3) **Pair life time** : This is the free life time of an electron-hole pair. If either electron or hole is captured or extracted without replenishment, the pair life time is terminated.

(4) **Minority carrier life time** : This is the free life time of a minority carrier. Usually the pair life time is equal to the minority carrier life time.

(5) **Majority carrier life time** : The majority carrier life time is the free life time of the majority carrier. If the density of free carriers in a material is very much greater than the density of recombination centres, the majority carrier life time will be equal to the minority carrier life time.

There are three simple processes by which the minority carriers can be a function of photoexcitation [Bube 1974]. The first of these is for photoexcitation to remove the
charges on charged impurity centres dominating the scattering of free carriers. Mobility changes by a factor of 2 or less are common under photoexcitation intensities which change the free carrier density by many orders of magnitude in high resistivity semiconductors or insulators. A second process might involve the excitation of carriers from a low mobility band to a high mobility band, thus producing photoconductivity even though there is no change in carrier density. Finally, a change in mobility may be considered to result from a photoexcitation reduction of barrier heights to free carrier flow in an inhomogeneous material. In the present work, results of life time and mobility are also obtained for certain systems.

Photosensitivity is one of the very important factors of photoconduction phenomenon and is defined in a number of ways:

1. One way is to describe it as a material's property in terms of product of life time and mobility. In this case photosensitivity is related to the change in conductivity per photon absorbed.

2. A second way is to describe photosensitivity in terms of detectivity which is a measure of radiation power needed to give a signal equal to the noise. So photoconductivity can be related to the ratio of the photoconductivity to darkconductivity.

3. A third way is to define photosensitivity as gain which is defined as the number of charge carriers passing between the electrodes per photon absorbed.

A major effect of trapping is to make the experimentally observed decay time of photocurrent longer than the carrier life time. In absence of trapping, the observed photocurrent will decay in the same way as the density of free carriers, and thus the
observed decay time will be equal to the carrier life time. In presence of trapping, if the free carrier density is much greater than the density of trapped carriers, again the observed decay time of photocurrent will be equal to the carrier life time. But if the density of free carriers is comparable to or less than the density of trapped carriers, the thermal freeing of trapped carriers during the course of decay can prolong the decay. In the extreme case, when the density of carriers is much greater than the density of free carriers, the entire decay of photocurrent is dominated by rate of trap emptying. The recombination process also determines the life time of free carriers and hence the sensitivity of photoconductor. Recombination may occur both by the direct recombination of free electrons and holes without one of the carriers being first captured at an imperfection and by the recombination of free carrier of one type with a bound carrier of opposite type, previously captured at an imperfection in this system. In most cases, recombination through an imperfection dominates for low carrier density and direct recombination becomes important only for high current densities.

Under suitable conditions, photocurrent may overshoot the equilibrium value during growth and undershoot the equilibrium value after the cessation of excitation [Bube 1967]. Plateaus and infection points are also found in the rise curves, which are explained in terms of distinct groups of traps being filled with electrons successively and after each filling, the photocurrent again rises [Görlich 1961]. Undershoot is normally explained by considering a material with electron traps and large cross-section centres containing captured photo excited holes. It may be possible that the free and very shallow trapped electrons are drained off very rapidly by recombination, the rate of which falling below the rate of ejection of electrons from traps [Bube 1957].
The microscopic or conductivity mobility is the mobility of free carriers defined through the relation $\mu = \sigma / ne$. However, there are different types of mobility defined for different processes. The Hall mobility is defined as the product of Hall constant and the conductivity. The drift mobility of the charge carriers is defined as the drift velocity per unit electric field acquired by the charge carrier [Sze 2002] and is an important factor in the study of photoconductivity. The drift mobility can be obtained from measurement of photoconductivity gain and decay time in a material in which conductivity is predominant by one type of carriers e.g. electrons in n-type semiconductors like CdS or Cd(S-Se). The mobility is significantly affected by the presence of phonons and impurities through scattering. The instantaneous values of lifetime and the mobility can be calculated with the help of standard relation of PC gain.

The PC gain can be measured by a number of methods like by measuring the change in conductivity per photon absorbed, by obtaining the ratio of photoconductivity to dark conductivity or by obtaining the number of charge carriers passing between the electrodes per photon absorbed. However, in the present work PC gain (G) is taken as the ratio of saturated photo current to dark current ($I_{pc} / I_{dc}$). The instantaneous lifetime and mobility has been calculated by using the values of PC gain. Such results for different samples are presented and discussed in this thesis.

In order to measure PC of a material the electrical contacts are made with the help of electrodes. The nature of electrode also affects the dark and photocurrents. Ideally, the electrode should not introduce any resistance to the flow of current. The contact can be ohmic or non-ohmic depending upon the work functions of the metal and semiconductors. Fassbender (1956) formed ohmic contact to CdS by subjecting the
contact area to ionic bombardment by electric discharge. Bhushan and co-workers (1988, 1990, 1992, 2002, 2006) found that the colloidal silver gives ohmic contact at comparatively lower applied voltages. In the present work also colloidal silver has been used to form electrodes in PC studies.

Because of the complex mechanisms involved in the photoconduction process, complementary information from other experimental techniques such as PL, optical absorption etc. is always needed for interpretation purposes. The optical behaviour of thin films can be studied through the PC and PL excitation, PL emission, optical reflectance and transmission spectral studies. The optical techniques are widely used for thin film characterization, because they are fast, non-destructive and can be applied in any system. The ternary and quaternary alloys are used in photo-detection technology with a precise knowledge of variation in the band structure as a function of the structure of the material [Bottka et al 1981]. In the present work, optical absorption studies are used to determine the band structure properties including the magnitude and nature of the band gap. From the optical absorption spectra band gaps are determined using Tauc’s plots. PL emission spectra are used to determine the transitions involving energy levels of the base as well as the impurities. PL presents emission of radiation from materials due to excitation of light photons and has been classified as fluorescence and phosphorescence. Luminescence is a comprehensive term in which all radiation processes in crystals are included. Garlick (1949) defined fluorescence as the luminescent emission during excitation ($<10^{-8}$ s) and phosphorescence as emission after ($>10^{-8}$ s). The substances emitting light after an excitation are called phosphors. The property of luminescence is attributed to the presence of imperfections in crystals. The phenomenon of PL is associated with
impurities (foreign elements) or defects in the crystal structure [Bube 1967]. The localized imperfection levels involved in luminescent emission are named as activators [close to upper edge $E_v$ of the valence band {VB} and absorbers (near the lower edge $E_c$ of the conduction band {CB}] [Haug 1972]. Under favourable conditions the excitation energy of electrons are transferred from VB to CB. Consequently, electrons from activator levels recombine with holes in the VB and the electrons from CB fall into the absorber level. At activator centres the probability of radiative transitions is greater than that of non-radiative one. If the probability of non-radiative transition is greater than that of radiative transition, then the centres are called killer-centres.

The solubility of the activators are enhanced in presence of some other element known as co-activator, e.g. a trivalent ion III B or a halide ion VII B usually acts as co-activator in the lattice of II B – VI B compounds. The luminescent emission is normally attributed to interaction between emission centre and host-crystal lattice [Vlam and Brit 1954] and luminescent emission depends on the activator and its concentration in a particular host lattice. If the activator concentration is high, the activator atoms destroy the matrix resulting in quenching of photoluminescence emission [Kröger and Helingman 1948]. The potential fluctuations in ternary compounds due to alloying of different components of the compounds create additional traps related to the disordering in the lattice in the form of potential wells [Shevel et al 1987]. These traps are able to hold the excitons even at room temperature. The excitonic effects observed at room temperature in the emission spectra of different Cd(S-Se) films are also discussed in the present work.
The as-prepared thin films can be characterized by scanning electron microscopy (SEM) and X-ray diffraction (XRD) techniques. SEM reveals the topographical feature of the films. In this technique, a finely focused beam is scanned over the surface of the specimen and the secondary electrons emanating from the specimen are used for the Z-modulation in a corresponding raster on a TV or oscilloscope screen. For topographical feature determination, the secondary electron mode (emissive mode) is preferred since these electrons emanate from the surface and hence the picture obtained is a faithful reproduction of the surface feature. The sample preparation is also easy for this study. The magnification obtained is \( \sim 3 \) to \( 10^5 \). The highest resolution is \( \sim 30 \) Å and a depth of focus is a few hundred times that of a light microscope. Additional information like thickness of the film, grain size, columnar structure etc. can be obtained by studying the cross-section of the film. The crystal structure, lattice constants, grain size, lattice defects etc. can be analyzed through the XRD studies. In the present work, results of SEM and XRD studies are included.
Problem undertaken

The present thesis is concerned with PC and PL phenomena along with optical absorption of II-VI ternary compound Cd(S-Se). The main object of the thesis is to present a comprehensive study of the growth parameters, doping of impurities and post-deposition thermal treatment (annealing) of the chemically deposited films and their effect on the fundamental electronic transitions and the optical response through PC rise and decay, optical absorption and PL emission spectral studies. Suitable growth condition for the preparation of highly photosensitive and PL films are developed and are optimized for these studies.

(i) Base material:

The base material chosen for the present study is the II-VI group ternary compound Cd(S-Se). These semiconductors are highly photosensitive materials. Their band gaps can be tuned in the visible region by changing the sulphur to selenium ratio in the source solution. The Cd(S-Se) alloy forms an important semiconductor and has a range of technological applications based on its larger non-linear susceptibility, good photoconduction and fast response time [Meit 1992; Nagomi et al 1993; Perna et al 1999; Pan et al 2005]. CdS type materials have wide technological applications as sensitive photoconductors, IR detectors, solar cells, lamp phosphors and display devices. Boudreau and Rauh (1983) and Mandal and Savadago (1992) studied chemically deposited films of Cd(S-Se) and found encouraging results. Rincon et al (1998) studied changes in the surface structure and composition as a function of operational time for the coupled films coated with or without a thin ZnO layer. Pan et al (2005) reported the
colour tunable PL covering the visible spectrum by shear like nano-belts fabricated by one step thermal evaporation process recently. These results prepared the ground for choosing Cd(S-Se) as base material.

(ii) Impurities / Activators:

In the present case, CdCl₂ was used as flux and samarium (Sm) and dysprosium (Dy) were selected separately as impurities for doping. The reason for selecting Sm has been the energy levels of its emitting state \( ^4\)\(G\)\(_{5/2}\) lying below the energy level of the trap states in Cd(S-Se) base, hence energy transfer from host defects to rare earth activator Sm\(^{3+}\) could occur [Frindel et al. 2003] and hence presented interesting activator. According to Pang et al. (2003), when Dy\(^{3+}\) is located at a low symmetry local site without inversion centre, the forced-electric dipole transitions are often dominated in their emission spectra. This fact about Dy\(^{3+}\) has made it an interesting dopant. A method developed in our laboratory is found to be quite effective for doping of impurities at quite low temperatures (30° C - 80° C). The electro-optical studies of the base material were done under different preparative conditions. CdCl₂ was taken as flux, because it also helps in re-crystallization of CdS and CdSe, apart from increasing the solubility of the activators [Bube 1974]. Further, Lanthanide doped (Cd-Zn)S and (Cd-Pb)S films were found to show enhancement in photosensitive properties of these films as studied by Bhushan et al (2001, 2002, 2006). Bhushan et al (1990, 1992, 2006) have also reported a manifold increase in the photosensitivity of II-VI compounds due to doping of trivalent rare earths and alkali halides. So, the enhancement of both PC and PL of Cd(S-Se) films in presence of CdCl₂ and trivalent rare earths (Sm and Dy) are studied in the present work.
Preparation of the material:

The materials were prepared in the form of films having thickness in the range of 0.1 μm to 0.49 μm. So, they can be put in the category of thin films [Goswami 1996]. Thin films are generally confined to a limited range of thickness between a few Å to 5000 Å depending on the properties to be investigated. However, for technological applications the films as thick as 5-10 μm are also being used, as the reliability of performance is the most important criterion there. The method of preparation of these films is the CBD method. The thin films can be grown by any of the established techniques like physical vapour deposition, chemical vapour deposition, electrochemical deposition or a combination of these techniques, but the advantage of CBD method over them is that it is simple and cost effective method, which can be used for large area deposition. The flexibility of this thin film growth process allows the fabrication of desired geometrical, topographical, physical, crystallographic and metallurgical structures, thus enabling to tailor-made structure sensitive chemical, physical or electro-optical properties of micro materials. So, the films are deposited at different temperatures with different compositions and the corresponding changes are observed in different studies.

Photoconductivity Studies:

The PC rise and decay studies were performed at room temperature for different doped and undoped films of Cd(S-Se). The effects of flux and impurities on PC gain, lifetime and mobility of the carriers were studied. The effect of alloying of CdS and CdSe like the trapping of charge carriers, the slow decay of photocurrent and increase in lifetime of excited carriers due to it has also been observed in the present study. By using the
PC rise and decay curves, the ratio of saturated photo-current to dark current \( \frac{I_{pc}}{I_{dc}} \), defined as PC gain \( G \), lifetime \( \tau \), mobility \( \mu \) and trap depths \( E \) are calculated.

(v) Spectral studies:

Apart from the above mentioned studies, spectral response provides quite useful information about the material. The optical absorption spectra are studied in the visible region (300 - 700 nm). The effect of impurities, deposition temperature and compositional changes on the optical absorption of the material prepared, have also been included in the present study. The band gap of the materials have been determined by Tauc’s plot [Tauc 1970].

PL emission spectral studies constitute an important part of the present thesis. The exact nature of the transitions involved in the PL emission reveals the fundamental energy levels present in a system. Apart from this, the formation of donor-acceptor pairs [Thomas et al 1964], presence of excitons and their complexes [Dexter and Knox 1961; Reynolds et al 1981, 1982; Knox 1963; Reynolds et al 1982] etc. are also associated with the electronic transitions observed in the PL spectra of the doped and undoped Cd(S-Se) films. The PL emission corresponding to the transitions between different energy levels of the rare earth impurities Sm and Dy have been observed in the impurity doped films.

(vi) Characterization of samples:

For the characterization of the samples, XRD and SEM are used. The crystal structure, lattice constants, grain size, lattice defects etc. were analyzed through the XRD studies. The observed inter-planar distances and intensities of the diffraction peaks were compared with the JCPDS values and the peak values were assigned accordingly. SEM
shows the topographical features of the films. Nature of observed SEM micrographs has been discussed.