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# Growth and characterization of semiconducting cadmium selenide thin films

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Semiconducting thin films of cadmium selenide have been grown by conventional thermal evaporation technique. The effect of various growth parameters like rate of deposition and deposition temperature has been studied in detail. Films deposited at room temperature are cadmium rich with segregated selenium globules. A deposition temperature of 453K has been found to yield stoichiometric, homogeneous films. The films have been analysed for optical band gap and thermal activation energies. Films of low electrical resistivity have been obtained for possible applications.

## 1 Introduction

In recent years much attention has been shown in semiconducting II-VI compounds because of their opto-electronic properties and applications. Cadmium selenide is an important member of this group of binary compounds. It has a direct intrinsic band gap of 1.74 eV which makes it an interesting material for various applications. The material has been grown in bulk single crystalline form and has been used as an efficient photodetector. Cadmium selenide and cadmium sulphide films grown by evaporation technique have been used as gas sensors for the detection of oxygen [1]. Sabastian [2] has studied the transport and optical properties of CdSe-CdTe pseudobinary thin films. Properties of CdSe thin films as a function of lateral distance from chromium contacts have been studied by Waechter et al. [3]. Cadmium selenide thin films have been grown by vacuum deposition technique by Mahmoud and Eid [4]. However, no detailed study is reported of the growth, characterisation and properties of the material in its thin films form. The evaluation of any material for applications is complete and meaningful only when its structure and composition are precisely known and related to its electronic properties.

The present paper reports detailed studies carried out on the structural and compositional analysis of cadmium selenide thin films.

## 2 Experimental

Cadmium selenide thin films were prepared by thermal evaporation of a stoichiometric powder of the compound (Chemical purity 99.999% from M/S Research Organic/ Inorganic chemical corporation U.S.A.) in a residual air pressure of $10^{-5}$ torr. Molybdenum boat sources were used for the evaporation. Freshly cleaved sodium chloride single crystals preheated to the required temperature served as substrates for structural studies where as glass slides were used for optical and electrical characterisation. The thickness of the film used for structural characterisation was of the order of 50 to 80nm and that of the films used for electrical and optical

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characterisation was in the range 250 – 300nm. Structural observation were made on a transmission electron microscope, Philips EM-400, operating at 100 kV. Compositional information was obtained by EDAX system attached to it. Optical studies were carried out on Shimadzu UV-365 spectrophotometer.

## 3 Results and Discussion

Thin films deposits were prepared at different rates of deposition in the range 5 to 30nm $min^{-1}$ and at different substrate temperature from 300 to 453 K. When deposited at a low rate of deposition of 5nm $min^{-1}$ on substrates maintained at room temperature (300 K), the films were observed to have randomly arranged selenium spots (fig 1). Similar results have been reported by Chase et al. [5]. Selected area electron diffraction patterns taken from these spots match well with the reported x-ray data for hexagonal selenium. The number density of these selenium inclusions is found to decrease as the substrate temperature is increased. The films become homogeneous as these selenium spots disappear when the films were deposited at 453 K. However, when the films were deposited at higher rates of deposition, the selenium inclusions were absent (fig 2). The room temperature deposits were rich in cadmium content and n-type. With increase in substrate temperature, the cadmium concentration reduced and a stoichiometric composition was obtained at 453 K. The associated changes in the crystallinity and grain size was only marginal (fig 1 and 2).

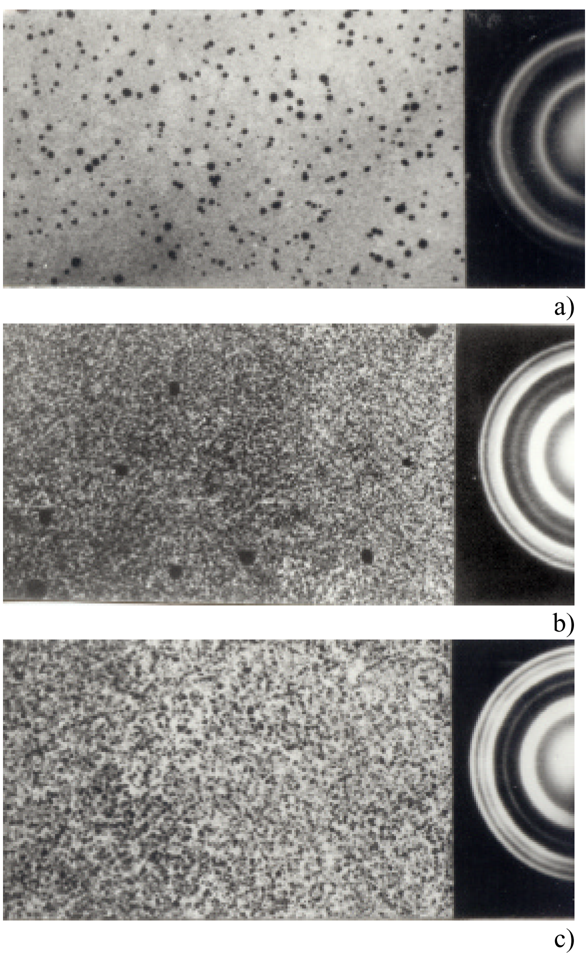


**Fig. 1** Electron Micrographs (x33,000) and selected area electron diffraction pattens of CdSe thin films deposited at a rate of 5 nm $min^{-1}$, Substrate temperatures are (a) 300 K, (b) 275 K, (c) 453 K.

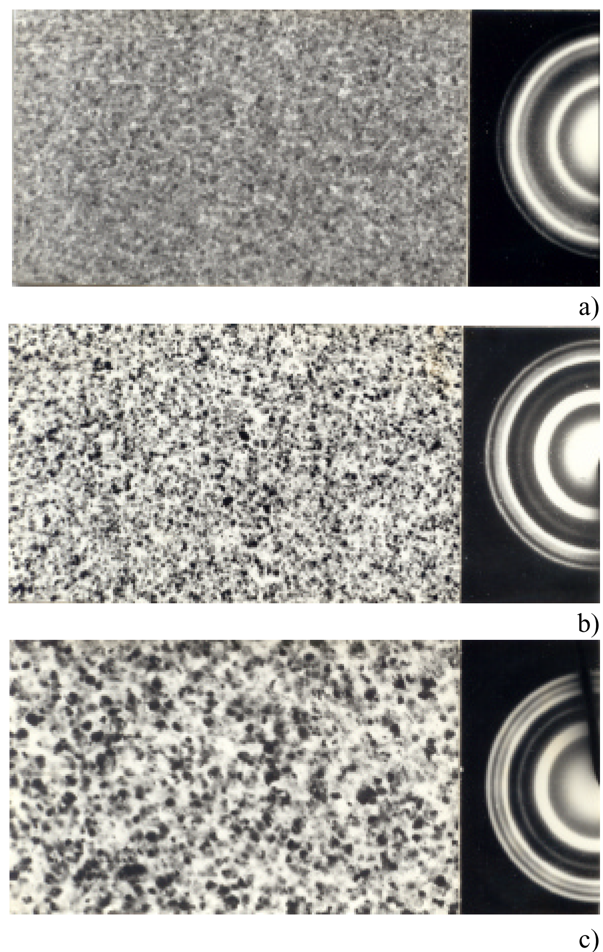


**Fig. 2** Electron micrographs (x33,000) and selected area electron diffraction patterns of CdSe thin films deposited at a rate of 30 nm $min^{-1}$. Substrate temperatures are (a) 300 K, (b) 275 K, (c) 453 K.

Cadmium selenide films were n-type over the entire range of deposition temperature studied. This is attributed to the presence of excess cadmium content in the deposited films [6-11]. Indium metal is found to make a low ohmic contact with n-CdSe films. The films deposited at 453 K are found to be stoichiometric with a resistivity value of the order of $10^{-2}$ ohm.m. The films deposited at 453 K were cooled to room temperature and the variation of resistance with temperature was studied. The plot of ln R versus ($10^3$/T) consists of two regions (fig 3) a low temperature region with a thermal activation energy of 0.34 eV and a high temperature region of activation energy 01.86 eV. These regions are associated with extrinsic conduction due to the presence of donor states produced by excess cadmium and an intrinsic region setting in at a temperature of 330 K. These observations are in agreement with the values of activation energies in cadmium selenide.

Homogeneous films of cadmium selenide deposits at a rate of 30 nm $min^{-1}$ were used to study the effect of deposition temperature on the fundamental optical absorption edge. The films were found to have an allowed direct transition with characteristic energies 1.89 and 1.88 eV when deposited at temperatures 300 K and 375 K. As the substrate temperature is increased to 453 K, the absorption edge shifted to the bulk value of 1.74 eV. (fig 4).

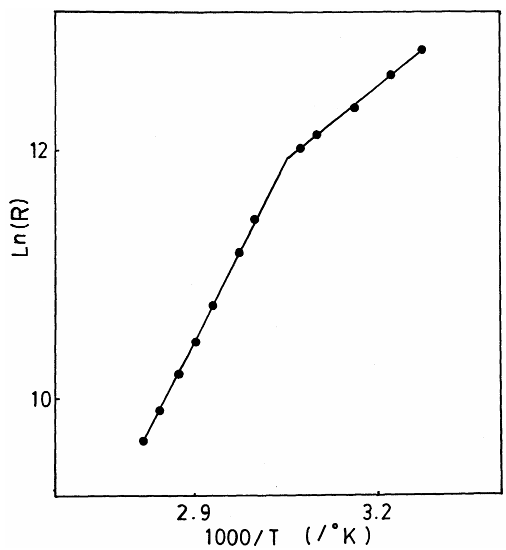


**Fig. 3** Plot of ln R vs (1000/T) for CdSe films deposited at 453 K.

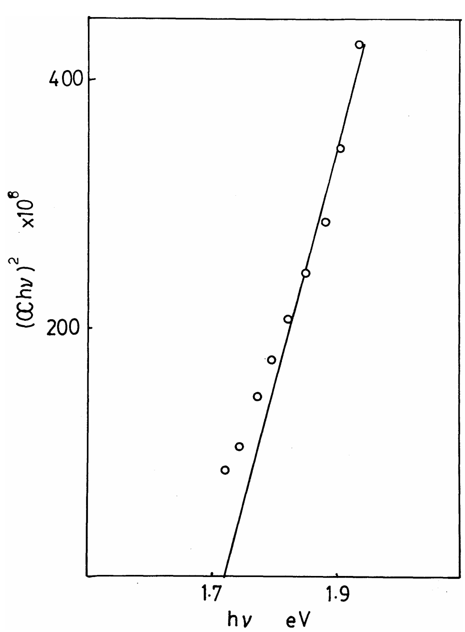


**Fig. 4** Plot of $(\alpha h\nu)^2$ vs hν for CdSe films deposited at 453 K.

## 4 Conclusion

Homogeneous, stoichiometric thin films of cadmium selenide have been obtained at a deposition temperature of 453 K. The films are found to be n-type with a typical low resistivity of the order of $10^{-2}$ ohm.m.

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