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Spectroscopic study of vacuum evaporated crystalline Zinc Selenide thin films

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Vacuum evaporated crystalline films of Zinc Selenide (ZnSe) have been characterized by using optical spectroscopy (especially absorption and transmission spectroscopy). Crystalline ZnSe films have been deposited by vacuum evaporation technique on highly clean glass substrates and their optical properties (energy band gap, refractive index and extinction coefficient) have been studied. The energy band gap (E_g) of the films has been calculated from absorption spectra by using Tauc relation. The transmission spectra in the spectral range 400-850 nm has been used to calculate the refractive index (n), extinction coefficient (k) and wavelength dependence of n and k of the films have been studied. Optical spectroscopy of the films have been done with the help of the Hitachi spectrophotometer model U-3400.

1 Introduction

The II-VI group compound semiconductor, zinc-selenide (ZnSe) having a wide band gap is a promising material for use in photo-voltaic devices, blue light emitting diodes and laser diodes[1-3]. For high efficiency

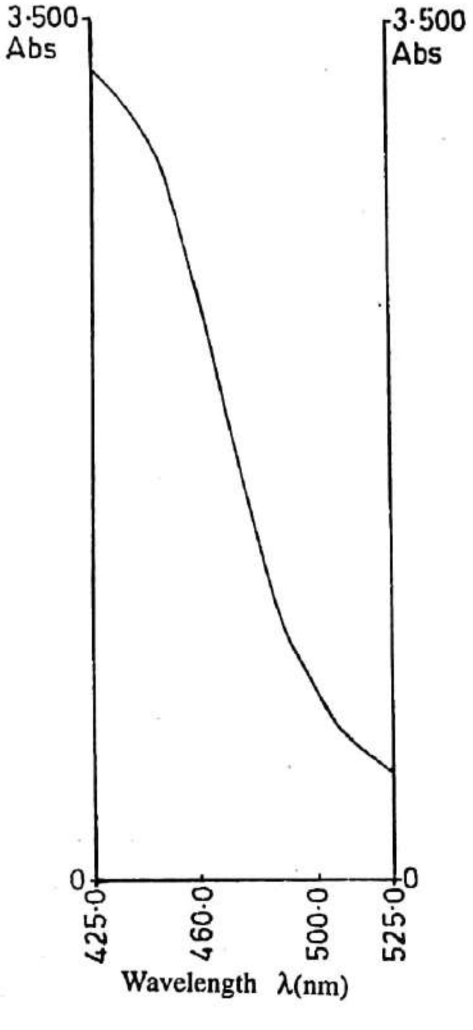

Fig 1. Absorption spectra of vacuum evaporated ZnSe thin film.

solar cells, a high band gap material is required for maximum transmission of solar spectrum to the low band gap material, which increases the V_{oc} of the solar cell. Cadmium and zinc selenide are now -a-days attracting a great deal of attention owing to their fundamental, experimental and applied interests in thin film devices, like laser screen materials in projection color TV's, nuclear radiation detectors, light emitting diodes, laser diodes[4–8], photovoltaic and photoelectrochemical (PEC) devices[9,10].

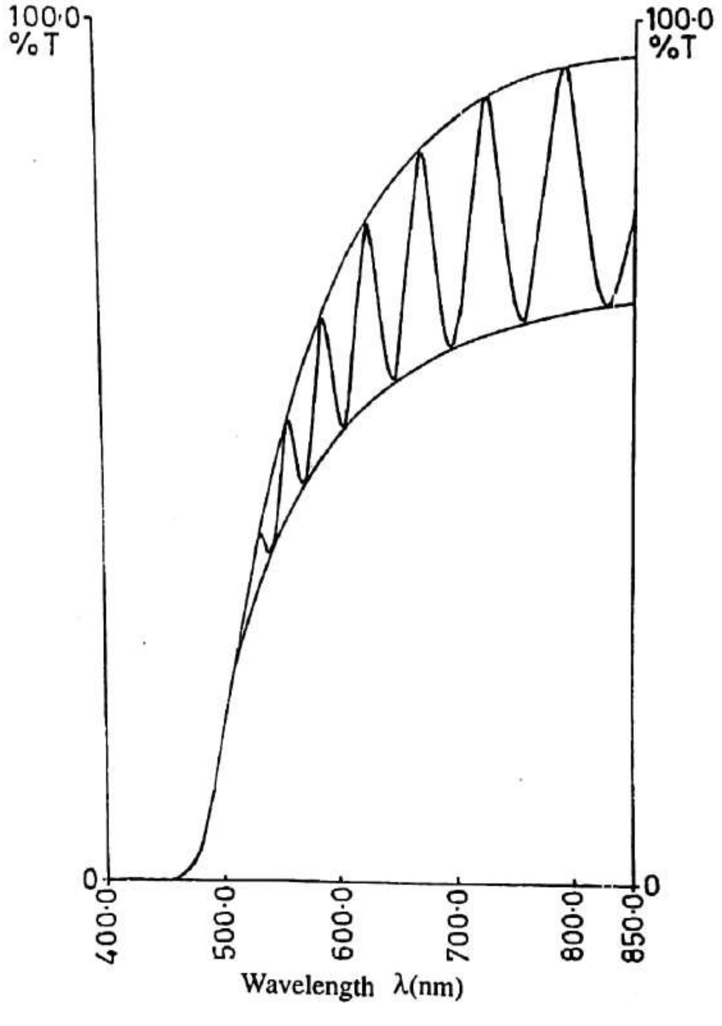

Fig 2. Transmission spectra of vacuum evaporated ZnSe thin film.

Investigation of optical properties of semiconducting films are essential for proper application in semiconductor devices. In the present work we have studied the optical properties of crystalline ZnSe films deposited on highly clean glass substrates.

2 Experimental details

Zinc-selenide powder (99.99 % pure) was evaporated at about 950°C from a narrow mouthed molybdenum boat. Deposition was made onto glass substrates held at 150°C in vacuum of the order of 10^{-5} Torr. The substrates were cleaned in aquaregia, washed in distilled water and iso-propyl alcohal (IPA). Absorption and transmission spectra of vacuum evaporated ZnSe films were taken at room temperature with the help of Hitachi Spectrophotometer Model U-3400. In this model all the lenses have been replaced with mirrors. So the image deviation due to chromatic aberration is eliminated in the wavelength range 187-2600 nm.The PbS detector is used for the detection of infrared rays. The visible wavelength light source was a long life WL lamp.

3 Results and Discussion

The absorption spectra of ZnSe films in the wavelength range 425-525 nm is used to determine the optical band gap (E_g) as shown in Fig 1. The transmission spectra of the ZnSe films in the wavelength range 400-850 nm (Fig 2) was used to determine the optical constants (refractive index and extinction coefficient).

To measure the energy band gap from absorption spectra the Tauc relation[11] is used.

$$\alpha h\nu = A(h\nu - E_g)^n$$

where the symbols have their usual meanings.

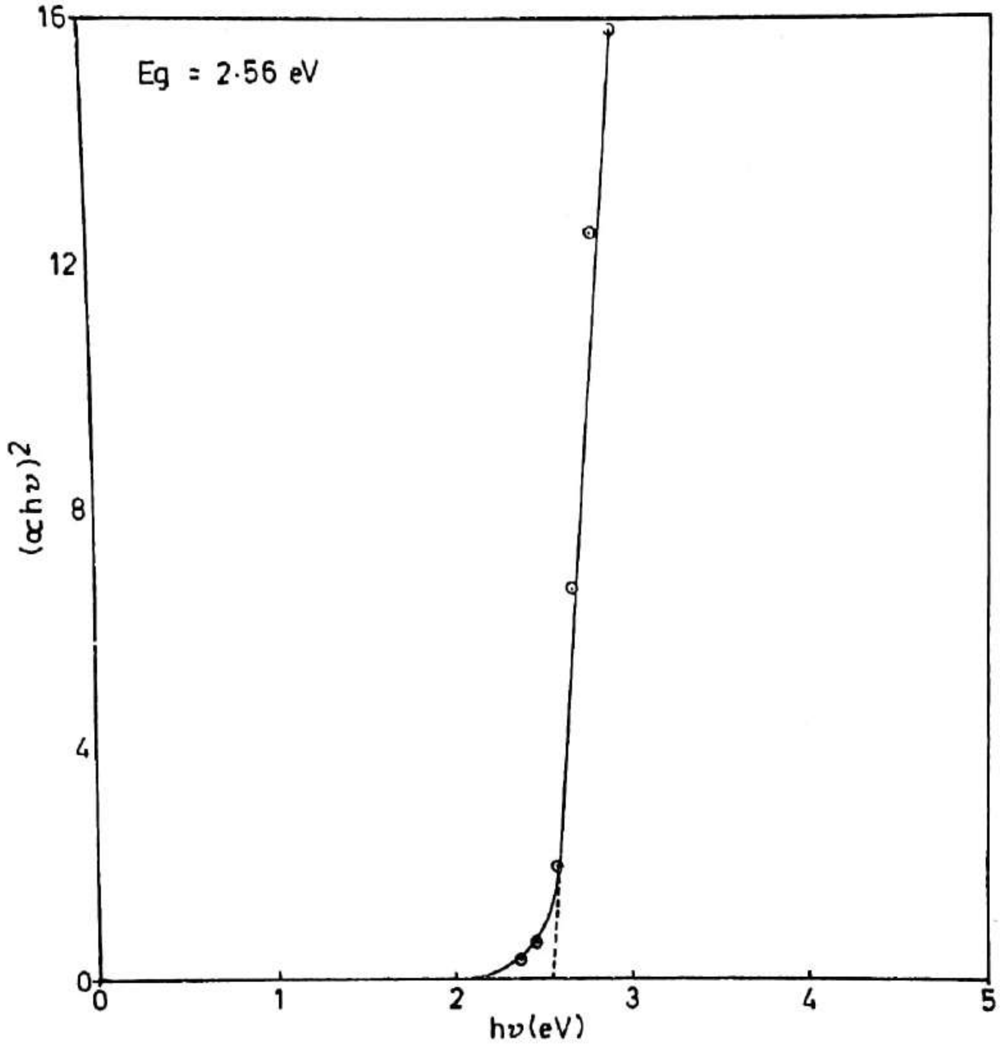

Fig 3. Plot of $(\alpha h\nu)^2$ versus hν for vacuum evaporated ZnSe thin film.

To measure the energy band gap from absorption spectra a graph of $(\alpha h\nu)^2$ vs hν is plotted. The extrapolation of the straight line to $(\alpha h\nu)^2 = 0$ axis gives the value of the energy band gap (Fig 3). From this graph, the value of energy band gap of ZnSe comes out to be 2.56 eV.

The optical constants (refractive index and extinction coefficient) of these films have been determined from transmission spectra by using Manifcier's envelope method. These films showed , in general good transparency (T >75%), exhibiting interference patterns.

The refractive index (n) of the films deposited is given by

$$n = [N + (N^2 + n_0^2 n_1^2)^{1/2}]^{1/2}$$

where the number

$$N = (n_0^2 + n_1^2)/2 + 2n_0 n_1 (T_{max} - T_{min})/(T_{max} \cdot T_{min})$$

where T_{max} is the upper extreme transmission point and T_{min} is the lower extreme transmission point for particular wavelength.

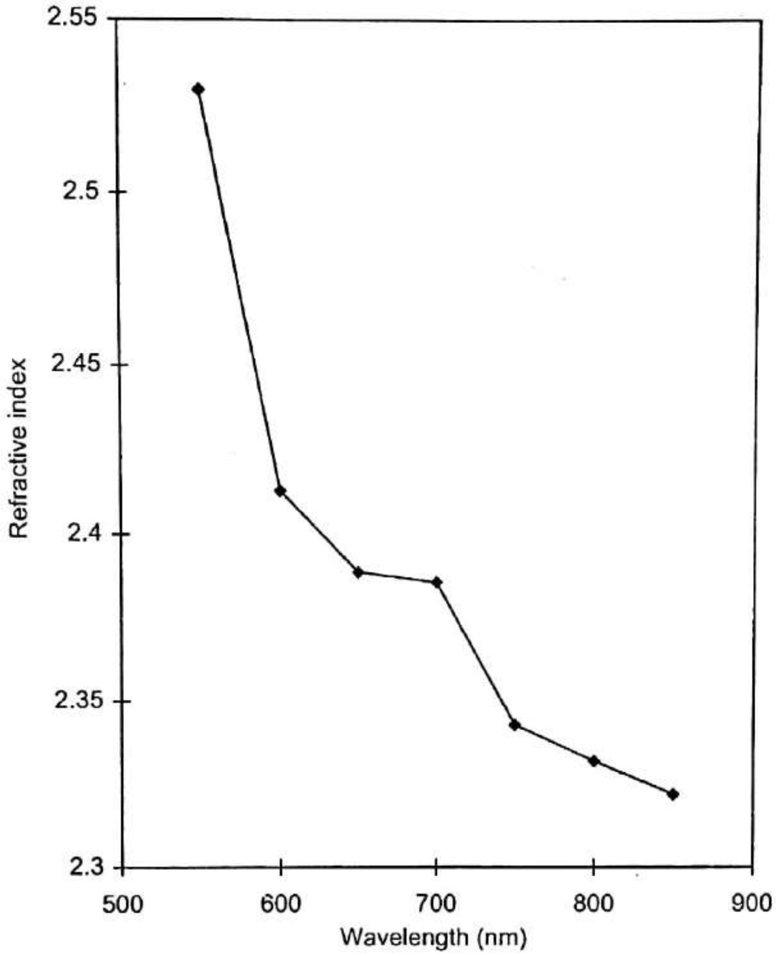

Fig 4. Variation of refractive index (n) with wavelength (λ) of vacuum evaporated ZnSe thin film.

The extinction coefficient k is given by

$$k = (-\lambda\lambda/4\pi t)\ln(P)$$

where t is the thickness of the film deposited,

and $$P = C_1[1 - T_{max}/T_{min}]/C_2\,[1 + T_{max}/T_{min}]$$

with $$C_1 = (n + n_0)(n + n_1) \text{ and } C_2 = (n - n_0)(n_1 - n)$$

Where n is the refractive index of the film at particular wavelength, n_1 is the refractive index of the substrates (glass) and n_0 is the refractive index of the air.

The thickness of the film has been measured and it comes out to be 0.72 μm. The plots of n(λ) and k (λ) for the films are shown in Figs (4) and (5) respectively and it has been observed that the refractive index (n) decreases, while the extinction coefficient (k) increase with increase in wavelength (λ).

By this study we conclude that the absorption and transmission spectroscopic techniques are important techniques for measuring the eenergy band gap (E_g) and optical constants (n, k) of a semiconducting thin film.

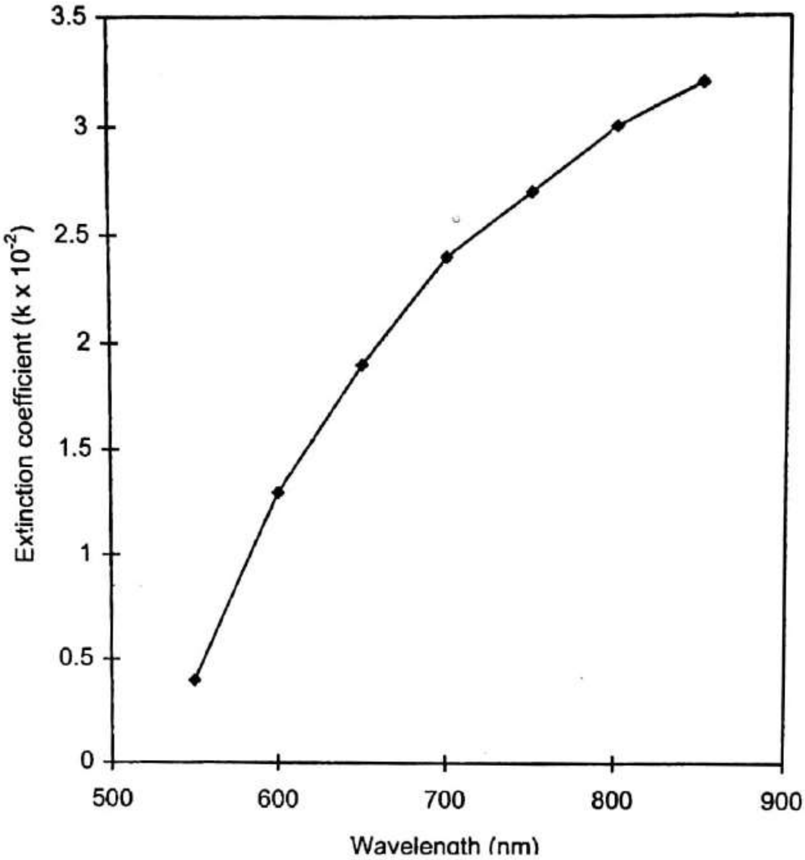

Fig 5. Variation of extinction coefficient (k) with wavelength (λ) of vacuum evaporated ZnSe thin film.

These techniques have been verified for various thin films like CdSe, ZnTe etc.

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