

Optical analysis of Cadmium doped Selenium-rich Glassy Chalcogenide

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Abstract:

In my recent work, investigating the influence of addition of cadmium (Cd) with decreasing atomic wt. % of Selenium (Se) at constant atomic wt. % of Tellurium (Te) on the optical studies of the $\text{Se}_{90-x}\text{Te}_{10}\text{Cd}_x$ ($x = 0, 10, 20$ at. %) chalcogenide alloys. Spectral dependence of the absorption spectra recorded in the range of 200-1800 nm for as-prepared and thermally annealed samples in normal wavelength scanning mode is shown by UV/VIS/NIR spectroscopy. Optical band gap (E_g) of the as-prepared sample increases and thermally annealed sample decreases with increasing photon energy. Absorption coefficient and absorption constant of the as-prepared and annealed samples S1, S2, S3 decrease with increasing Cd% in the synthesized materials.

Keywords: $\text{Se}_{90-x}\text{Te}_{10}\text{Cd}_x$ ($x = 0, 10, 20$ at. %) powder; UV/VIS/NIR;

1. Introduction

This work is focussed on discussing the optical studies of chalcogenide alloys because any glass is free from defects like bubbles or imperfections; it can be considered as a perfect material for propagation of light [1]. Chalcogenide glasses are oxygen-free inorganic glasses containing one or more kinds of chalcogen elements (Te, Se) [2]. Due to semi-metallic nature and a high degree of crystallinity, Te-rich alloys limits, the glass forming ability whereas Se-rich alloys show a semiconducting nature [3]. The main difference between Se and Te is the nature of the bonding responsible for the interchain cohesion. Chalcogenide glasses are generally less strong more weakly bonded materials than oxide glasses. The change in the optical properties of the composition may be explained by assuming that Te atoms act as an impurity centre in the mobility gap [4-7]. The Se-Te alloys exhibit higher photosensitivity, greater hardness, better thermal stability, and lower ageing effects [9]. Se-Te based glasses, due to their extreme tendency to crystallise, have found applications as phase change materials for optical storage in the Digital Versatile Disk (DVD) technology [10, 11]. These glasses are being studied mostly for applications as passive devices (lenses, windows, fibres) and also attractive for the preparation of active devices such as Laser fibre amplifiers and nonlinear components [12]. Photocells,

rectifiers, memory, and switching devices due to their unique electrical, thermal, and optical properties are the technological applications of the chalcogenide glasses [13].

It is well-known that the addition of metallic additives to binary chalcogenide system changes their structure and new properties are expected for these alloys. From this point of view, the effect of the addition of Cd metal on the optical properties of the Se-Te binary system has been studied.

2. Experimental Setup

In the present work, Melt quenching method has been adopted to prepare $\text{Se}_{90-x}\text{Te}_{10}\text{Cd}_x$ ($x = 0, 10, 20$ at. %) chalcogenide alloys to obtain an amorphous structure from 99.999% pure Se, Te and Cd elements. The exact amount of alloying elements were weighed according to their atomic weight percentages using an electronic balance with the least count of a 10^{-4} gram and then placing into ultra-cleaned quartz ampoules (length ≈ 5 cm and internal diameter ≈ 8 mm). The ampoules were evacuated and sealed in a vacuum of 10^{-3} Torr with an oxygen-hydrocarbon flame torch using rotary pumps to avoid reaction of alloying elements with oxygen at a higher temperature. The sealed ampoules were heated in a furnace at the rate of $4^\circ\text{C}/\text{min}$. The temperature was raised up to 1000°C and was maintained for 10 hours. During the heating process, the ampoules were constantly rocked by a ceramic rod to ensure the homogeneity of the alloying materials. The ampoules with molten materials were rapidly quenched into the ice-cooled water to allow glass formation and to avoid crystallisation. The ingots of chalcogenide materials were taken out from ampoules by breaking them. The obtained melt was ground into powder form and filtered to obtain homogeneous alloys. The obtained as-prepared sample is further annealed for 4 hours at a 150°C fixed temperature to remove internal stress to make the material less brittle. After that bulk samples of as-prepared and thermally annealed was compressed into pellets form having a diameter of 13 mm and thickness of about 1-2 mm under a uniform pressure of 5 tons using a hydraulic press machine. Bulk/pellets made from $\text{Se}_{90-x}\text{Te}_{10}\text{Cd}_x$ ($x = 0, 10, 20$ at. %) alloys were named as S1 ($\text{Se}_{90}\text{Te}_{10}$), S2 ($\text{Se}_{80}\text{Te}_{10}\text{Cd}_{10}$), and S3 ($\text{Se}_{70}\text{Te}_{10}\text{Cd}_{20}$). Physical dimensions of each pellet were measured with the help of digital screw-gauge (BAKER-Type J02, 7301) having least count 0.01 mm. Optical studies were recorded using JASCO V670 UV/VIS/NIR spectrophotometer in the spectral range of 200 to 1000 nm using a quartz cuvette with an optical path of 1 cm for all samples dissolved in ethyl alcohol at normal incidence.

3.Results and Discussion

1.Absorption coefficient

Absorption coefficient (α) is the property of a material which defines the amount of light absorbed by it and depends upon photons energy as well as the nature of the material [22]. The absorption coefficient (α) has been evaluated by Beer-Lambert law ($\alpha = 2.303A/t$), where A is optical absorption which depends on wavelength and density of point defects and (t) is light path length (10 mm) [23]. Figure 1 (a, b) shows the absorption coefficient of as-prepared and annealed bulk sample of S1, S2, S3 for $\text{Se}_{90-x}\text{Te}_{10}\text{Cd}_x$ ($x = 0, 10, 20$ at. %) with incident photon energy range. The absorption coefficient of the as-prepared samples observed in UV regions and gradually decrease with increasing frequency for Cd-doped sample S2, S3 with respect to undoped sample S1, whereas in thermally annealed samples absorption coefficient observed in NIR regions and continuously decrease with increasing frequency, originates due to defects and impurities whose shape and magnitude depends on the purity, thermal history and preparation conditions [24, 25].

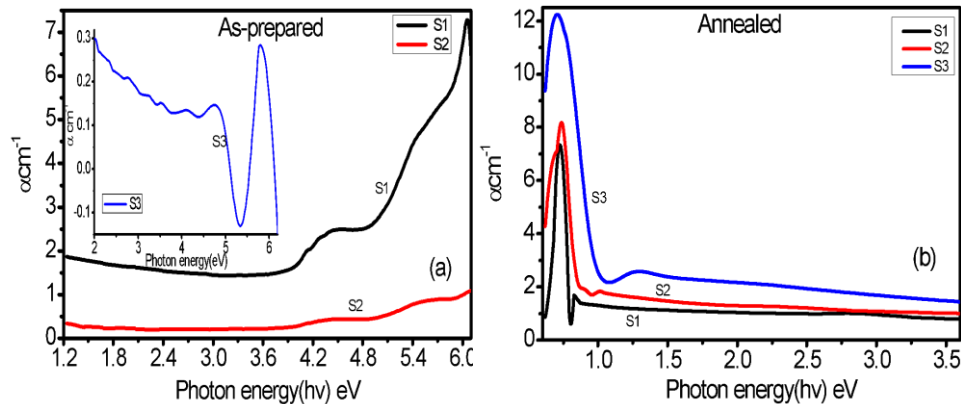


Fig. 1 (a, b) Absorption coefficient for as-prepared and annealed samples S1, S2, S3 of $\text{Se}_{90-x}\text{Te}_{10}\text{Cd}_x$ ($x=0, 10, 20$ at. %) alloys

2.Optical Bandgap

The energy at which electron and hole pair is generated is called optical band gap energy. The high absorption region determines the optical band gap energy. The optical energy gap is defined as the intercept of the plot of $(\alpha h\nu)^{1/2}$ against $h\nu$. Figure 2 (a,b) shows the optical band gap of as-prepared and thermally annealed sample S1, S2, S3 for $\text{Se}_{90-x}\text{Te}_{10}\text{Cd}_x$ ($x = 0, 10, 20$ at.%) by the direct transition.

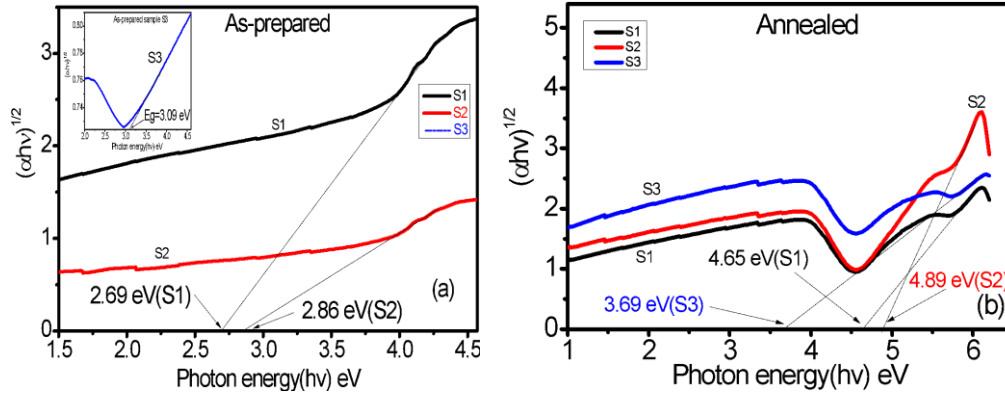


Fig. 2(a, b) Optical band gap for as-prepared and annealed samples S1, S2, S3 of $\text{Se}_{90-x}\text{Te}_{10}\text{Cd}_x$ ($x = 0, 10, 20$ at. %)

The increment in the optical band gap with increasing Cd concentration in the as-prepared sample S1, S2 and S3 may be due to the reduction in the disorder and decrease in density of defect states [26]. Reduction in the value of measured optical band gap for thermally annealed sample S3 with respect to undoped sample S1 due to the increment of charged defects in the band tail regions, which leads to reducing the optical band gap [27]. The expected value of optical band gap for as-prepared and thermally annealed sample S1, S2, S3, are given in Table 1.

3.Absorption constant

Absorption constant indicates the amount of absorption loss when electromagnetic wave propagates through the sample. The variations of absorption constant can be related to the variation of optical transmittance.

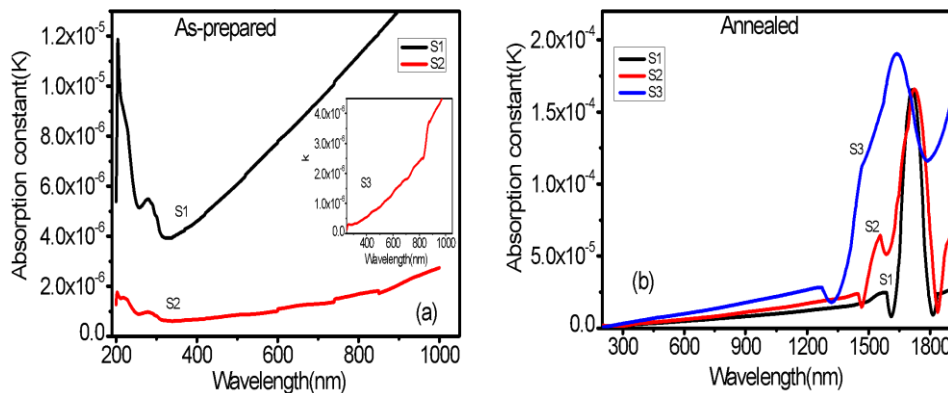


Fig. 3 (a, b): Absorption constant for as-prepared and annealed sample of $\text{Se}_{90-x}\text{Te}_{10}\text{Cd}_x$ ($x = 0, 10, 20$ at. %) alloys

Figure 3 (a, b) shows the absorption constant of the as-prepared and thermally annealed sample of $\text{Se}_{90-x}\text{Te}_{10}\text{Cd}_x$ ($x = 0, 10, 20$ at. %) for S1, S2, S3 with increasing wavelength. The decrease in absorption constant with increasing wavelength shows that the transmittance is increased. This type of behaviour is due to decrease in absorption coefficient with increasing wavelength of the incident photons. Variations of absorption loss of as-prepared and thermally annealed sample S1, S2 and S3 are observed in NIR regions. The absorption constant has been evaluated using formula $K = \lambda\alpha/4\pi$ [28, 29].

Table.1: Crystal size by XRD and Optical parameters of as-prepared and annealed $\text{Te}_{90-x}\text{Se}_{10}\text{Cd}_x$ ($x = 0, 10, 20$ at. %) chalcogenide

Sample	Absorption coefficient (α) in cm^{-1}		Absorption constant (K)		Optical band gap (E_g) in eV	
	As-prepared at 3.90 eV in UV regions	Annealed at 1.50 eV in NIR regions	As-prepared at 329 nm	Annealed at 900 nm	As-prepared	Annealed
S1($\text{Se}_{90}\text{Te}_{10}$)	1.566	1.131	3.95×10^{-6}	8.45×10^{-6}	2.69	4.65
S2($\text{Se}_{80}\text{Te}_{10}\text{Cd}_{10}$)	0.247	1.466	6.54×10^{-7}	1.14×10^{-5}	2.86	4.89
S3($\text{Se}_{70}\text{Te}_{10}\text{Cd}_{20}$)	0.131	2.388	3.50×10^{-7}	1.80×10^{-5}	3.09	3.69

Conclusion

The decrease in energy loss with an increase in Cd concentration of all as-prepared and thermally annealed samples of Se-rich $\text{Se}_{90-x}\text{Te}_{10}\text{Cd}_x$ ($x = 0, 10, 20$ at. %) chalcogenide alloys indicates that the charge carriers absorb more energy giving small absorption coefficient which may not be suitable for optical data storage. Variation in the optical gap due to the increment of the doping concentration of Cd in as-prepared and annealed samples. Amount of absorption loss in both samples decreases with increasing wavelength. Luminescence of as-prepared sample observed

between UV and visible (red) regions while annealed sample observed only in visible (green) region with the lowest intensity due to surface defects in the synthesized materials with increasing wavelength.

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