International Journal of Advance Interdisciplinary Research
Vol. 01(01), June 2025, pp. 10-17

Glassy Chalcogenide doped with cadmium and rich in selenium: an optical study

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Abstract:

In my most recent study, I examined the effects of adding cadmium (Cd) to the optical examinations of the Se90-xTe10Cdx (x = 0, 10, 20 at. %) chalcogenide alloys while maintaining a constant atomic weight percentage of tellurium (Te) and reducing the atomic weight percentage of selenium (Se). UV/VIS/NIR spectroscopy demonstrates the spectral dependency of the absorption spectra (200–1800 nm) and thermally annealed materials in normal wavelength. As photon energy increases, the optical band gap (Eg) of the As-formed sample rises whereas that of the thermally annealed sample falls. As the percentage of Cd in the synthesised materials increases, the absorption constant and coefficient of the As-formed and annealed samples S_1, S_2, and S_3 reduced.

Keywords: $Se_{90-x}Te_{10}Cd_x$ (x = 0, 10, 20 at. %) powder; UV/VIS/NIR;

1. Introduction

The optical investigations of chalcogenide alloys are the main topic of this study since glass is a wonderful material for light propagation because it is devoid of flaws like bubbles and blemishes [1]. Inorganic glasses devoid of oxygen that include more than one types of chalcogen elements (Se and Te) are known as chalcogenide glasses [2]. While Se-rich alloys have a semiconducting character, Te-rich alloys limit the capacity to create glass because of their high degree of crystallinity and semi-metallic nature [3]. The type of bonding that gives the interchain cohesion is the primary distinction between Se and Te. Compared to oxide glasses, chalcogenide glasses are often weaker and less bound. Assuming that Te atoms function as an impurity centre in the mobility gap might help to explain the shift in the composition's optical characteristics [4–7]. Increased hardness, higher photosensitivity, improved thermal stability, and reduced ageing effects are all displayed by the Se-Te alloys [9]. Se-Te-based glasses have been used as phase-change materials for optical storage in Digital Versatile Disc (DVD) technology because of their strong crystallisation propensity [10, 11]. In this respect the creation of devices like nonlinear components and laser fibre amplifiers, these glasses are researched on priority because of passive devices (windows, lenses, and fibres) [12]. Chalcogenide glasses are used in memory, photocells, switching devices, rectifiers and because of their special thermal, electrical, and optical characteristics [13].

The structure of binary chalcogenide systems is known to alter when metallic additions are added, and these alloys are predicted to acquire new characteristics. The impact of adding Cd metal on the optical characteristics of the Se-Te binary system has been examined from this perspective.

2. Experimental Setup

In this study, Se90-xTe10Cdx(x = 0, 10, 20 at. %) chalcogenide alloys are prepared using the melt quenching process, which yields 99.999% pure amorphous structure made by elements like Se, Cd, and Te. Using an electronic scale with a minimum count of 10-4 grammes, the precise quantity of alloying elements were involved accordance to their atomic weight before being placed into ultra-cleaned quartz ampoules (length = 5 cm and internal diameter ≈ 8 mm). To prevent alloying elements from reacting with oxygen at a higher temperature, the ampoules were evacuated and sealed using rotary pumps and an oxygen-hydrocarbon flame torch at a vacuum of 10-3 Torr. In a furnace, the sealed ampoules were heated at a rate of 40 degrees Celsius per minute. The temperature was maintained for ten hours after being elevated to 1000 0C. To guarantee the uniformity of the alloying ingredients, a ceramic rod continuously shook the ampoules while they were heating. To prevent crystallisation and promote glass formation, the ampoules containing the molten ingredients were quickly quenched in the ice-cooled water. The ampoules were broken open to remove the chalcogenide material ingots. To create uniform alloys, the resulting melt was crushed into a powder and filtered. To reduce internal stress and make the material less brittle, the resulting sample is further annealed for four hours at a fixed temperature of 150 °C. Following that, a hydraulic press machine was used to compress the As-formed and thermally annealed bulk samples into pellets with 13 mm diameter and 1-2 mm thickness at 5 tonnes of constant pressure. The S1 (Se90Te10), S2 (Se80Te10Cd10), and S3 (Se70Te10Cd20) bulk/pellets were manufactured from Se90-xTe10Cdx (x = 0, 10, 20 at. %) alloys. Each pellet's physical dimensions were measured using a digital screw gauge (BAKER-Type J02, 7301) with a minimum count of 0.01 mm. For all materials dissolved in ethyl alcohol at normal incidence, optical studies were recorded using a quartz cuvette with an optical path of

1 cm and a JASCO V670 UV/VIS/NIR spectrophotometer in the spectral range of 200 to 1000 nm.

3. Results and Discussion

1. Absorption coefficient

The feature of a substance that determines how much light it absorbs is called the absorption coefficient (α), which is dependent on the material's composition and photon energy [22]. The Beer-Lambert rule ($\alpha = 2.303A/t$) has been used to calculate the absorption coefficient (α), where A is optical absorption that is dependent on wavelength and point defect density and (t) is the length of the light path (10 mm) [23]. The As-formed and annealed bulk sample of S_1, S_2, and S_3 for Se90-xTe10Cdx(x = 0, 10, 20 at. %) with incoming photon energy range is shown in Figure 1 (a, b). The absorption coefficient of As-formed samples is observed in UV regions and decreases gradually with greater frequency for Cd-doped samples S2, S3, and undoped sample S1, in compared to heat processed samples, where the absorption coefficient is noticed in NIR regions and constantly reduces with enhancing frequency [24, 25]. This is caused by impurities and defects, the magnitude and shape of which depend on the thermal history, preparation conditions, and transparency.

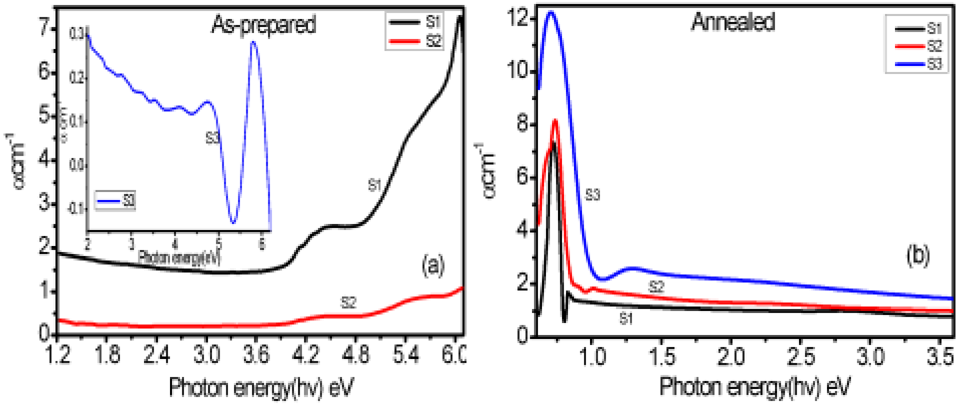

Figure 1 (a, b) shows the absorbance coefficient for the As-formed and annealed samples S1, S2, and S3 of the Se90-xTe10Cdx(x=0, 10, 20 at.%) alloys.

2. Optical Bandgap

Optical band gap energy is the energy at which a pair of electrons and holes is created. The optical band gap energy is determined by the high absorption area. The intercept of the plot of (αhν) 1/2 against hν is known as the optical energy gap. The optical band gap of samples S1, S2, and S3 as prepared and thermally annealed for Se90-xTe10Cdx (x = 0, 10, 20 at.%) via the direct transition is displayed in Figure 2 (a,b).

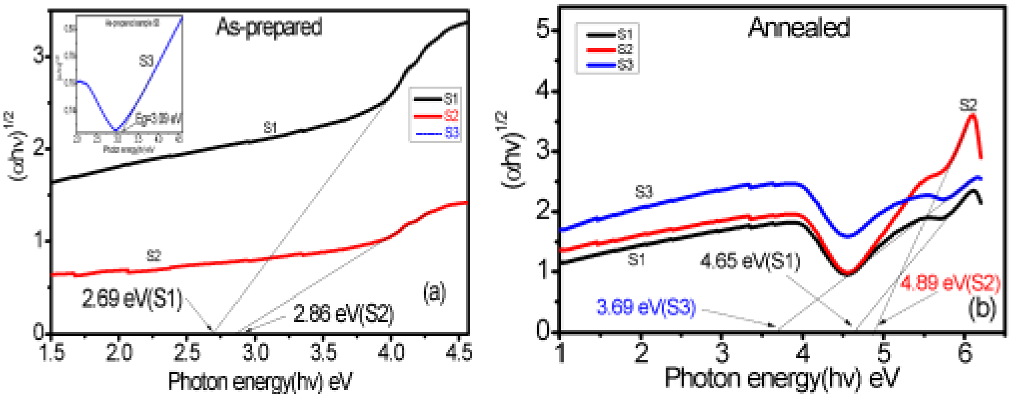

Figure 2(a, b) shows the optical band gap for Se90-xTe10Cdx samples S1, S2, and S3 as prepared and annealed (x = 0, 10, 20 at. %)

The rise in the optical band gap with increased Cd concentration may be due to the reduction in instability and density of states of defect in the as-prepared samples S1, S2, and S3 [26]. When comparing thermally annealed sample S3 to undoped sample S1, the measured optical band gap decreases due to the development of charged defects in the band tail regions [27]. Table 1 lists the anticipated optical band gap values for samples S1, S2, and S3 as prepared and after thermal annealing.

3. Absorption constant

When electromagnetic waves go through a sample, the absorption constant shows how much absorption is lost. It is possible to connect changes in optical transmittance to changes in the absorption constant.

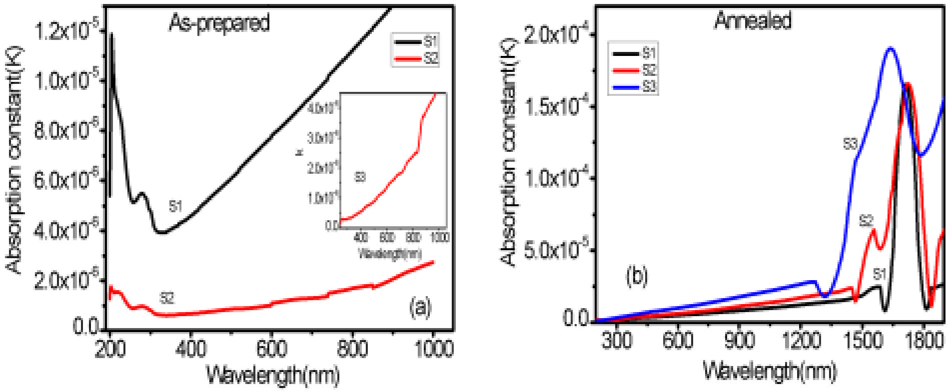

Figure 3 (a, b): Absorption constant for Se90-xTe10Cdx(x = 0, 10, 20 at.%) alloys as produced and annealed samples

The absorption constant for S1, S2, and S3 at increasing wavelengths is displayed in Figure 3 (a, b) for the as-prepared and thermally annealed sample of Se90-xTe10Cdx(x = 0, 10, 20 at. %). As wavelength increases, the absorption constant decreases, indicating a rise in transmittance. This kind of behaviour results from the absorption coefficient decreasing as the incoming photons' wavelength increases. The NIR areas show differences in the absorbance loss of samples S1, S2, and S3 as prepared and after thermal annealing. The formula K=λα/4π has been used to calculate the absorption constant [28, 29].

Table.1: Crystal size by XRD and Optical parameters of as-prepared and annealed $Te_{90-x}Se_{10}Cd_x$ (x = 0, 10, 20 at. %) chalcogenide

Sample	Absorption coefficient (α) in cm^{-1}		Absorption constant (K)		Optical band gap (Eg) 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($Se_{90}Te_{10}$)	1.566	1.131	3.95×10^{-6}	8.45×10^{-}	2.69	4.65

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S2($Se_{80}Te_{10}Cd_{10}$)	0.247	1.466	6.54×10^{-7}	1.14×10^{-5}	2.86	4.89
S3($Se_{70}Te_{10}Cd_{20}$)	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 in all As-formed and thermally annealed samples of Se-rich Se90-xTe10Cdx(x = 0, 10, 20 at. %) chalcogenide alloys indicates that the charge carriers absorb more energy, leading to a small absorption coefficient that may not be suitable for optical data storage.shift in the optical gap caused by the raw and annealed samples' increased Cd doping concentration. As the wavelength increases, the amount of absorption lost in both samples reduces. Because of surface imperfections in the synthesised materials, the annealed sample only showed the lowest intensity of luminescence in the visible (green) area with increasing wavelength, whereas the as-prepared sample showed luminescence between the UV and visible (red) regions.

References

1. M. Barsoum, Mc Graw-Hill, New York, 543 (**1977**).
2. B.T.Kolomieto, Phys. Status Solidi. 7 (**1964**) 713.
3. S.O.Nelson, J. Microwave Power and Electromagnetic Energy, 44 (2) (2010) 98-113.
4. A.N.R. Long, Adv. Phys, 31 (1981) 553-637.
5. V.K. Bhatnagar**,** K.L**.** Bhatia, J. Non-Cryst. Solids, 119(2) (1990) 214-231.
6. AN.I.Gubanov, Quantum Electron theory of amorphous conductors, New York, (1965).
7. S.K. Shinde, D.P.Dubal, G.S.Ghodake, V.J.Fulari, Synthesis and characterization of chemically deposited flower-like $CdSe_{0.6}Te_{0.4}$ thin films for solar cell application, Materials Letters,126 (2014) 17-19.
8. C. Conseil, J.C Bastien, C. B.Pledel, Optical Materials Express. 2(11) (2012) 1470.
9. J.Bartak, R.Svoboda, J. Malek, J.Applied Physics, 111094908 (2012).
10. J.Feinlei, Deneufville, J.Moss, S.C.Ovshinsky, Appl. Phys. Lett, 18 (1971) 254.
11. N.O.Yamada, E.Nishiuchi, E. Akahira, N.Takao, J. Appl. Phys, 69 (1991) 2849-2856.

12. D.Lezal, J. Pedlikova, J.Zavadila, Chalcogenide Glasses for Optical and Photonics Applications, Optoelectronics and Advanced Materials. 6 (2004) 133-137.
13. V Modgil, V.S, Rngra, J.Non-Oxide Glasses, 6(4) (2014) 69-78.
14. Y.Haoyong, X. Zhude, B. Jingyi, B.Huahui, Z. Yifan, Ethylenediamine assisted the growth of single crystal tellurium channels, Materials Letters. 59 (2005) 3779.
15. M.Brian, X.Younan, One-dimensional nanostructures of trigonal tellurium with various morphologies can be synthesized using a solution-phase approach. J. Mater. Chem. 12 (2002) 1875.
16. C.Bhattacharya, J.Datta, J. Solid State Electrochem, 11(2007) 215.
17. Md.Nasir, M. Zulfiqar, Open J. of Inorganic Nonmetallic Mat., 2 (2012) 11-17.
18. P.K.Mishra, V.Dave, R.Chandra, J.N.Prasad, A.K.Choudhary, Effect of processing parameter on structural, optical, and electrical properties of Photovoltaic chalcogenide nanostructures RF magnetron sputtered thin absorbing films, Mat. Sci. at Semiconductor Processing. 25 (2014) 307-319.
19. E-Abd El-Wahab, Vacuum, 57(2000) 339.
20. J.Pankove, J. I, Optical process in semiconducting thin films, Thin Solid Films, 90 (1982)172.
21. J. Tauk, R. Grigorovici, A. Vancu, Phy. Sta. Solidi. 15 (1966) 627.
22. A.A. Al-Ghamdi, Vacuum, 80(2006) 400-405.
23. A. Ashour, N. El-Kdry, S.A. Mahmoud, Thin Solid Films, 269 (1995) 117.
24. P. Petkov, M. Wuttig, P. Ilchev, T. Petkova, J. Opt. Adv. Materials, 5 (2003) 1101.
25. M. Devika, N.K. Reddy, K. Ramesh, H.R. Sumana, K.R.Gunasekhar, E.S.R. Gopal, K.T. Ramakrishna Reddy, Semicond. Sci.Technol, 21, (2006) 1495.
26. N.Mott, E.A.Davis, Electronic Processes in Non-crystalline Materials, Clarendon Press, (1970).
27. K.Shimakawa, A. Kondo, K. Hayashi, S. Akahori, T. Kato, S. R. Elliot, Photoinduced metastable defects in amorphous semiconductors: commonality between hydrogenated amorphous silicon and chalcogenides, J.Non-Cryst. Solids, 387 (1993) 164-166.
28. A.A.Mulama1, J. M. Mwabora, A. O. Oduor, C.C. Muiva, Optical Properties, and Raman Studies of Amorphous Se- Bi Thin Films, The African Review of Physics. 9 (2014) 33.

29. V.Pandey, S.K.Tripathi, A.Kumar, J.Optoelectronics and Advanced Materials 8(2006) 789-793.
30. R.A.Taylor, J.F.Ryan, Time-resolved exciton photoluminescence in GaSe and GaTe., J. Phys. C, 20(1987) 6175.
31. H.S.Guder, B. Abay, H. Efeoglu, Y.K. Yogurtu, J.Lumin, 93 (2001) 243.
32. A.V.Kolobov, J.Tominaga, Properties of Amorphous Chalcogenides.DOI: 10.1007/978-3-642-28705-3_2, Chalcogenides, Springer Series in Materials Science, (2012) 164.