JCSE International Journal of Computer Sciences and Engineering Open Access
Research Paper **Vol.-6, Issue-12, Dec 2018** **E-ISSN: 2347-2693**

A Study on Optical Parameters of Ge-Se-Te Thin Film for Optical Storage Devices

Manuj Kumar Agarwal[1*], Manish Saxena[2], Shilpa Gupta[3]

[1,2,3]Moradabad Institute of Technology, Moradabad – 244001, India

Corresponding Author: manuj6july@gmail.com, Tel: 91-8909288878

Available online at: www.ijcseonline.org

Accepted: 27/Dec/2018, Published: 31/Dec/2018

***Abstract* –** The chalcogenide glasses have recently been investigated intensively because of their promising technological applications in reversible phase change optical recording. Recently, there is a trend of using amorphous materials, rather than carefully prepared crystalline semiconductors, in much needed investigation of such chalcogenide based materials. The present study examines the impact of germanium (Ge) content variation on the optical properties of $Ge_xSe_{50}Te_{50-x}$ (x = 10, 20, 30, 40 at %) based thin films. The optical absorption estimations were performed at room temperature with the change in wavelength. Numerous optical constants were also studied for the concentrated thin films using the optical absorption information in transmission spectra. It was observed that the optical absorption mechanism follow the rule of the allowed direct transition. The theoretical band gap was found to decrease as the Ge content (%) increases from 10 to 40 at %. This outcome was clarified regarding the compound bond approach and hence shows usefulness for optical recording devices.

***Keywords* –** Absorption coefficient, extinction coefficient, theoretical energy band gap, refractive index

I. INTRODUCTION

Chalcogenide based glasses have been attracting much attention in the field of optical recording devices as well as in infrared optics, since they exhibit several peculiar phenomena useful for devices such as electrical switches, memories, image storage, photo resistors etc. The common feature of these glasses is the presence of localized states in the mobility gap, as the result of the absence of long-range order as well as various inherent defects. Optical data storage based on laser induced amorphous to crystalline (a-c) phase transformation of various chalcogenide glasses has been an interesting area with on-going activities of several researchers [1–4]. The recent trend of using amorphous materials, rather than carefully prepared crystalline semiconductors, in useful electronic devices necessitates much needed investigation of such chalcogenide based materials. These glasses have been known to exhibit a particular single glass transition temperature and a single crystallization temperature, which is the most important condition for rewritable devices. Several chalcogenide alloys have been developed as sophisticated recording layer and their vast practical performance has also been reported [5–7].

Erasable recording technique is usually considered to be a potential replacement for conventional recording only techniques due to its high storage density and long archival stability. The chalcogenide materials, used for recording medium, must be easy to amorphize and crystallize, and there should be a high optical contrast between the amorphous and crystalline states. In phase change optical recording technology, a laser pulse of several hundred nanoseconds duration is used to erase a written spot. For the amorphous to crystalline phase transformation in phase change recording, the layer material must be very fast so as to enable erasing in such a short time. Hence, the study of amorphous to crystalline phase transformation is of utmost importance for the development of some new chalcogenide glasses as better phase change optical recording materials [8].

The addition of Germanium to the Se-Te system is expected to modify the material properties to make it more suitable for reversible optical recording with an erase time less than 1 μsec. Ge-Se-Te framework has a special place with chalcogenide glasses and has gotten the immense consideration because of mechanical significance, for example, memory switches, optical recording, reversible phase change and fiber optics [9, 10]. This framework can be delivered by alloying Ge, Se, Te components in proportionate ratio. Se has already established its importance as one of the critical components because of its vital commercial applications [11]. Be that as it may, it has a short lifetime and low sensitivity, that's why several researchers have utilized distinctive added substances, for example, Bi, Ga, Pb, As, Sn and Ge for alloying Se to some degree [12-14]. The expansion of third chalcogen component could make a chemical and topological issue in Ge-Se composite.

With a specific end goal to comprehend the physical properties of this material the estimation of optical parameters is imperative. Thus the estimation of optical parameters with the shifting structure is essentially vital. The aim of the present work is to examine the impact of arrangement minor departure from optical parameters of $Ge_xSe_{50}Te_{50-x}$(x = 10%, 20%, 30% and 40%).

II. METHODOLOGY

Right off the bat, the utilization of the material in optical applications, like, interference filters, optical fiber, and reflecting covering requires precise information of their optical constants over an extensive variety of wavelengths. Furthermore, the optical properties of all materials might be identified with their nuclear structure and electric properties. Thirdly high refractive record and low optical losses allow their improvement as infrared optical material [15].

The optical parameters of chalcogenide thin films such as absorption coefficient, extinction coefficient, and optical band gap can be resolved by studying the transmittance and reflectance information estimated by using a spectrophotometer.

The major absorption is identified with band-to-band change, which is subjected to certain determination rules [16]. The changes are grouped into a few sorts, as indicated by the band structure of a material. At room temperature, optical absorption spectra of $Ge_xSe_{50}Te_{50-x}$(x = 10%, 20%, 30% and 40%) thin films have been studied to determine the absorption coefficient. The connection between absorption coefficient and optic band gap for coordinate progress is given by

$$\boldsymbol{\alpha h v = B\left(h v - E_g\right)^n} \qquad \textbf{(1)}$$

Where E_g is the optical band gap in ev, α is the absorption coefficient and n is the parameter depend upon the transition type of the absorption edge. the parameter n can have any value which is equal to 1/2, 2, 3/2, and 3 for direct allowed, indirect allowed, direct forbidden, and indirect forbidden transitions. n is a power factor which depend upon the nature of the material whether the material is crystalline or non-crystalline. For the amorphous material, indirect transitions are valid. According to Tauc's law [17] for indirect transition n=2.

$$\boldsymbol{(\alpha h v)^{1/2} = B\,(h v - E_g)} \qquad \textbf{(2)}$$

In the greater part of the cases, a little portion of scattering of light is overlooked which is specifically identified with the extinction coefficient of the complex material. The extinction coefficient is identified with the decay, or damping of the oscillation amplitude of the occurrence light. Along these lines, we can state that the extinction coefficient in optics is the consolidated impact of scattering of light and absorption coefficient. A huge extinction coefficient implies that the beam is immediately "attenuated" (weakened) as it goes through the medium, and a little extinction coefficient implies that the medium is moderately transparent to the beam [18]. Attenuation coefficient describes the extent up to which the radiant flux of a beam is reduced after passing through a specific material. it is given by

$$\boldsymbol{k = \frac{\alpha\lambda}{4\pi}} \qquad \textbf{(3)}$$

The theoretical band gap as the minimum energy required for optical excitation of the material. Theoretical energy gap has been calculated using Shimakawa's relation [19]

$$\boldsymbol{E_g = xE_g(Ge) + yE_g(Se) + zE_g(Te)} \qquad \textbf{(4)}$$

where x,y,z are the volume fractions of Ge, Se and Te and E_g(Ge) = 0.95eV, E_g(Se) = 1.95 eV and E_g(Te) = 0.65 eV are energy gaps of Ge, Se and Te respectively. Optical band gap and refractive index are two most important properties of semiconductor. Optical transmission range of the thin film is seen to be moved towards higher wavelength with the expansion of Ge content.

Refractive index is the key optical property of a substance which defines the working performance of a material. Refractive index of a material reflects the relative permittivity and the relation is given by $\varepsilon_{opt} = \eta^2$. The relative change distribution of atoms in microscopic complex causes is altered due to the incident light. The refractive index of the sample increase with increase of Ge which is due to the increase in the polarizability associated with the larger Ge atom. Larger atomic radius results in the larger polarizability and also increases in refractive index according to Lorentz- Lorentz relation given as [20]

$$\boldsymbol{\left[\frac{\eta^2-1}{\eta^2+2}\right]\frac{M}{d} = 2.53\ \alpha\ 10^{24}} \qquad \textbf{(5)}$$

Where M, d and α are the molecular weight, density and electronic polarizability respectively.

III. RESULTS AND DISCUSSION

Optical Parameters of Thin Film

The transmittance spectra of $Ge_{10}Se_{50}Te_{40}$ thin films were appeared to be increased, while reflectance as a result was found to be decreased with the increase in Ge content. This means the expansion of Ge focus in the compositions leads to a diminishing of the deformities inside the chalcogenide materials. This shows that the film is transparent and does not bear much scattering loss. This also confirms the excellent surface quality and homogeneity.

Figure1 shows the transmittance and reflectance curve with varying wavelength. From the figure it is clear that the transmittance is increasing with the wavelength while the reflectance is decreasing. It revealed that the film is transparent and does not bear much scattering loss. It all confirms the excellent surface quality and homogeneity. The variation of transmission with wavelength for $Ge_{10}Se_{50}Te_{40}$ thin film is shown in the figure 1.

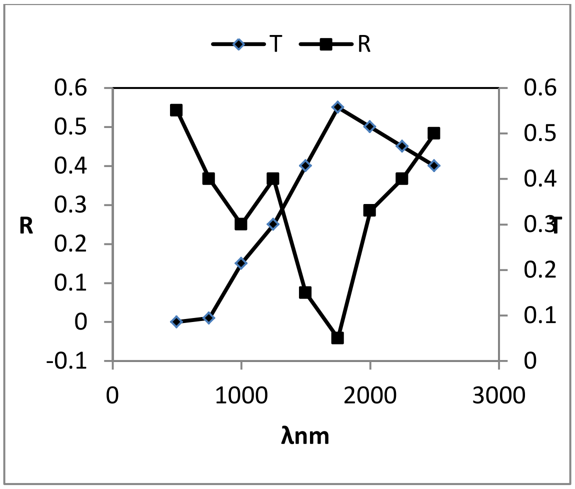

Figure 1: Variation of Transmittance (T) and reflection (R) with wavelength (λ) for $Ge10Se_{50}Te_{40}$ thin films.

Optical Absorption

Figure 2 shows the variation of photon energy $h\nu$ with the energy axis $(\alpha h\nu)^2$ which shows the increase of $(\alpha h\nu)^2$ with the photon energy and favoring the glass forming ability.

Extinction Coefficient

In the figure 3 shows the variation of extinction with the wavelength which shows that it is decreasing with the increase wavelength. This helps in the formation of the glass.

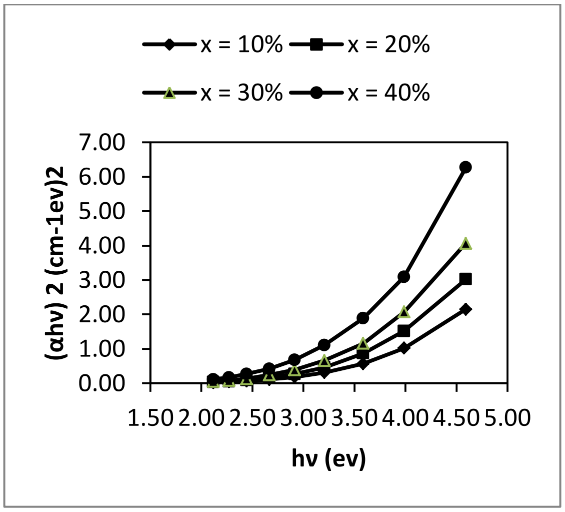

Figure 2: Dependency of $(\alpha h\nu)^2$ on photon energy (hν) for amorphous$Ge_xSe_{50}Te_{50-x}$ (x =10,20,30,40%) thin films.

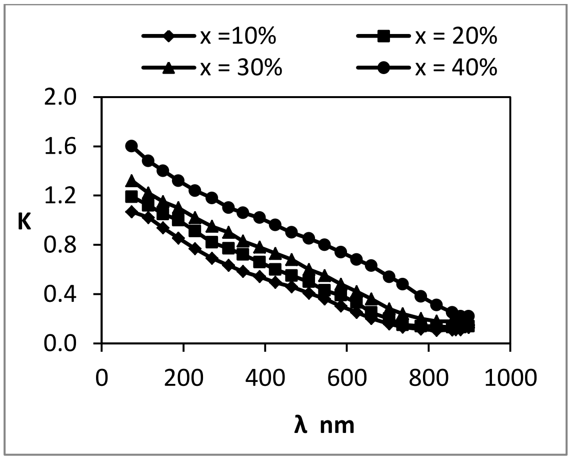

Figure 3: Variation of extinction coefficient with wavelength for GexSe50Te50-x (x = 10%, 20%, 30%, 40%).

Energy Band Gap

Energy band gap for the sample decreases from 1.274 eV to 1.268 eV with increasing Ge contents. Figure 4 shows the variation of theoretical band gap with germanium.

According to Kastner [21, 22] there is a correlation between electronegativity and energy gap. Se is electronegative because its electronegativity is high. With the addition of electropositive element like Ge energy of lone pair state increases and causes the broadening of valance band.

In conclusion, the optical gap E_g for $Ge_xSe_{50}Te_{50-x}$ (x = 10%, 20%, 30% and 40%) controlled by volume fraction and the optical gap Eg ascertained utilizing the trial information; prompt the guess that a changed virtual crystal approach for blended crystals is adequate for an amorphous framework.

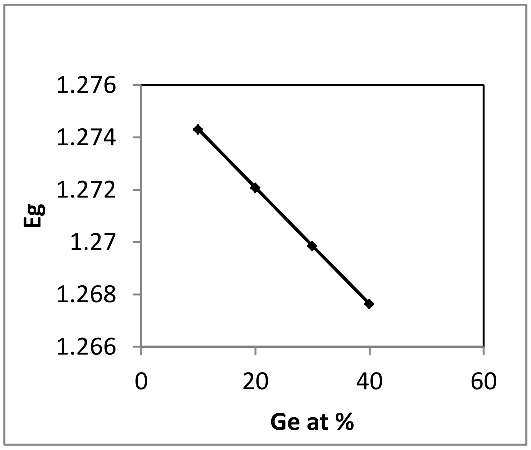

Figure 4: Variation of theoretical band gap with Ge at % for $Ge_xSe_{50}Te_{50-x}$ (x = 10%, 20%, 30%, 40%) thin film.

Refractive Index

The nonattendance of long-run arranges in these glasses permits the alteration of their optical properties to a particular mechanical application by consistently changing creation. The variation of refractive index for $Ge_{10}Se_{50}Te_{40}$ thin films as a function of energy (hv) is shown in figure 5. The refractive index is found to increase with increase in energy.

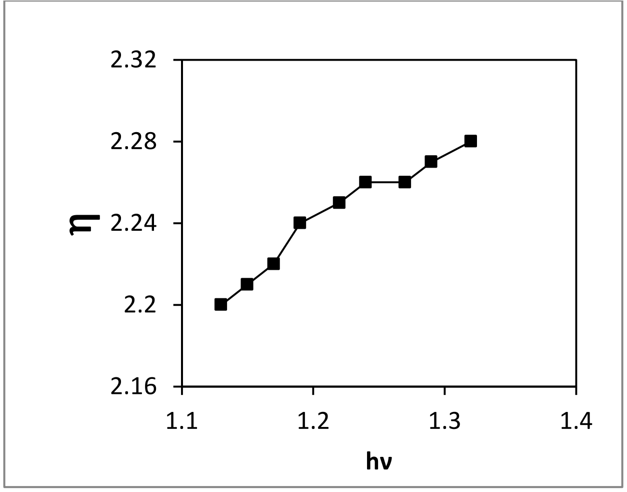

Figure 5 Variation of refractive index with energy for $Ge_xSe_{50}Te_{50-x}$ (x= 10%, 20%, 30%,40%) thin film.

IV. CONCLUSION

The impact of arrangement on the optical absorption behavior of $Ge_xSe_{50}Te_{50-x}$ (x = 10%, 20%, 30% and 40%) thin film has been researched. It has been discovered that the optical energy gap decreases with the change of Ge content. This is due to the decrease in the electro negativity of the system because optical band gap is bond sensitive property. Then again, the optical properties of amorphous Ge-Se-Te based have been investigated utilizing a generally basic and clear strategy using the transmission spectra. The point of the present work is to examine the impact of organization on the structure and optical parameters of present thin films using the optical transmittance and reflectance spectra. The optical absorption results showed that the allowed direct electronic transition is mainly responsible for the photon absorption inside the studied thin films.

REFERENCES

[1]. T. Phatak, S.D. Sawarkar, "Detection of Faulty Sensor Node within Wireless Sensor Network for improving Network Performance", Int. J. Sc. Res. in Network Security and Communication, Vol. 5, Issue 3, pp. 117 – 122, 2017.

[2]. R. V. Dharmadhikari, S. S. Turambekar, S. C. Dolli, P K Akulwar, "Cloud Computing: Data Storage Protocols and Security Techniques", International Journal of Scientific Research in Computer Science and Engineering Vol.6, Issue.2, pp.113-118, 2018.

[3]. M. Ilyas, M. Zulfequar, M. Husain, "Optical properties of a-(Se70Te30)100-x(Se98 Bi2)x Thin Films", Optical Materials, Vol. 13, Issue 4, pp. 397-404, 2000.

[4]. J. C. Phillips, M. F. Thorpe, "Constraint Theory, Vector Percolation and Glass Formation", Solid State Comm., Vol. 53, Issue 8, pp. 699-702, 1985.

[5]. M. Saxena and S. Gupta, "Effect of Compositional Dependence on Physical Properties of Ge16Se84-xBix Glass System for Phase Change Optical Recording", MIT Int. J. Electronics & Communication Engg., Vol. 2, Issue 2, pp. 63, 2012.

[6]. K. M. Al Mokhtar and B.O. Alsobhi, "Structural, Morphology and Some Optical Properties of Chalcogenide Ga80−xSexTe20 (Where x = 10%, 15% and 20%) Glassy Material," New Journal of Glass and Ceramics, Vol. 7, pp. 91-99, 2017.

[7]. M. Saxena, and S. Gupta, "A Comparison on Physical Properties of Ge–Se–Bi Based Chalcogenide Glasses," Material Focus, Vol. 6, Issue 4, pp. 474–479, 2017.

[8]. S. Tiwari, A.K. Saxena, D. Saxena, "Optical characterization of Ge0.15Se0.85-xAgx (0<x>0.20) Glasses", Advances in Appl. Sci. Research, Vol. 2, Issue 5, pp. 77-83, 2011.

[9]. P. Nermec, M. Frumar ,J. Jedelsky , M. Jelinek, J. Lancok, I. Gregora, "Optical Properties of As36Te42Ge10Si12 Thin Films", J. Non-Cryst.Solids, Vol.1013, pp. 299–302, 2002.

[10].M. S. Kamboj, G. Kaur, R. Thangaraj "Dark and photoconductivity of amorphous Se–Te–Pb thin films", Thin Solid Films, Vol. 420, pp. 350 – 353,2002.

[11].J.A. Savage, "Infrared Optical Materials and their Antireflection Coatings", Adam Hilger, Bristol, 1985.

[12].K. A. Aly, "Optical properties of Ge–Se–Te wedge-shaped films by using only transmission spectra", J.Non-Cryst.Solids, Vol. 355, pp. 1489-1495, 2009.

[13].A. El-korashy, Bakry A, M.A. Abdel-Rahim and M. Abdel-Sattar, "Annealing effects on some physical properties of Ge5Se25Te70 chalcogenide glasses", Physica B, Vol. 391, pp. 266-273, 2007.

[14].M. K. Agarwal, M. Saxena and N. Rastogi, "Study Of Influence Of Ge Content On Physical Parameter Of Ge-Se-Te System", Vol. 8, Issue, 10, pp. 20914-20917,2017,

[15].M. Kubliha, P. Kostka, V. Trnovcová, J. Zavadil, J. Bednarcik, V. Labaš , J. Pedlíková, A. Ch-Dippel, H.-P. Liermann and J. Psota, "Lanthanides in Non-oxide Glasses", J. Alloys Compd. Vol. 586, pp. 308-313, 2014.

[16].J. Collway, Book on "The theory of energy bands Structure," Moscow Mir, 1969.

[17].M. Naser Ahmed , Zaliman Sauli, Uda Hashim and Yarub Al-Douri, "Investigation of the absorption coefficient, refractive index, energy band gap, and film thickness for Al0.11Ga0.89N, Al0.03Ga0.97N, and GaN by optical transmission method", Int. J. Nanoelectronics and Materials, Vol. 2, pp. 189-195, 2009.

[18].A. Shamshad Khan, M. Zulfquar and M. Husain, "Effects of annealing on crystallization process in amorphous Ge5Se95− xTex thin films", Physica B, Vol. 324, Issue 1-4, pp. 336-343, 2002.

[19].K. Morigaki, "Physics of Amorphous emiconductors",World Scientific, Singapore, 1999.

[20].S. R. Elliott, "The Physics and Chemistry of Solids", Wiley, Chichester, 2000.

[21].M. Kastner, "Bonding Bands, Lone-Pair Bands, and Impurity States in Chalcogenide Semiconductors," Physics Review Lett., Vol. 28, Issue 6, pp. 355-357, 1972.

[22].M. Kastner, "Compositional Trends in the Optical Properties of Amorphous Lone-Pair Semiconductors", Physics: Review B, Vol. 7, Issue 12, pp. 5237-5252, 1973.

Authors Profile:-

Manuj Kumar Agarwal pursed Bachelor of Science from Rohilkhand University ,Bariely, India in 1996 and Master of Science from Rohilkhand University, Bariely, India in 1998. He is currently pursuing Ph.D. and currently working as Assistant Professor in Moradabad Institute of Technology, University of Taiwan, Moradabad, India, since 2006. He has published more than 10 research papers in reputed international journals including Thomson Reuters and conferences. His main research work focuses on Chalcogenide Glasses and Optical Storage Media. He has 15^+ years of teaching experience and 7 years of Research Experience.

Dr. Manish Saxena secured his Graduation and Post Graduation degrees in 1985 and 1987 He was awarded Ph.D. in 1995 from University of Delhi, New Delhi. He also secured DIM, PGDBM, PGDFM, MBA (Finance) from IGNOU, New Delhi. Dr. Manish Saxena has been working in Moradabad Institute of Technology, Moradabad since its inception in 1996. Dr. Saxena had also taught to M.Sc. (Electronics) and M. Tech. (Microwave Electronics) students in Delhi University from 1991-1993. Apart from regular teaching assignment, Dr. Manish Saxena is also continuously involved in Research activities. He is life member of various scientific societies like ISCA, MRSI, SSI and ISTE. He has more than 75 quality publications to his credit in various National/International Journals and Conferences. Five of his research scholars have been awarded Ph.D. degrees under his supervision and at present five research scholars are pursuing for Ph.D. degree. Dr. Manish Saxena has also reviewed research papers as referee for reputed International Journals associated with Springer.

Dr. S. Gupta pursued her Bachelor degree from Himachal Pradesh University, Shimla, in 2003 and Master of Science from Gurukul kangri Vishvidayala, Haridwar, in 2006. She pursed her Ph.D. degree from Singhania University Rajasthan in 2014. She is currently working as Assistant Professor in Department of Applied Sciences. She is currently working as Assistant Professor in Department of applied Science in Moradabad Institute of Technology, Uttar Pradesh, India. She has published more than 30 research papers in reputed International & National Journals & Conferences.