Bulgarian Journal of Physics vol. **XX** (20XX) 1–17

Optical Absorption and Electrical Resistivity of Tertiary Amorphous $Se_{70}Te_{30-x}Sn_x$ ($x = 0$, 5, 10 & 15) Chalcogenides Glasses

Anis Ahmad[1], **Imran Khan**[2]

[1]School of Basic Sciences (Physics) Galgotias University,
Greater Noida -203201, India
[2]Department of Physics, G.F. College Shahjahanpur,
MJP Rohilkhand University Bareilly -242001, India

Received *25 August 2025*

Abstract. In this study of the Se-Te-Sn ternary systems of chalcogenide glasses, the electrical and optical properties (absorption and energy band gap), with various Sn concentrations reported. The composition $Se_{70}Te_{30-x}Sn_x$ ($x = 0$, 5, 10, and 15) has been chosen for the investigation of the electrical and optical characteristics of glassy semiconductors. The research involves creating chalcogenide glasses in the Se-Te binary system with various tin (Sn) compositions by quenching technique. The four selected compositions ($x = 0$, 5, 10, and 15) allow for a systematic evaluation of the effect of tin (Sn) content on the electrical and optical properties of the glasses. The distinctive electrical and optical characteristics of chalcogenide glasses make them interesting materials for use in various applications, such as optoelectronics & photonics. We use the melt-quenching method to create chalcogenide glasses. High-purity (99.999%) elemental Se, Te, and Sn were used for the formation of the samples, which were then heated and quenched. The prepared glasses will next go through a comprehensive characterization for their XRD, electrical conductivity and optical energy band gap. A controlled variation in Sn concentration was performed to investigate its influence on the electrical and optical band gaps of Se-Te-Sn chalcogenide glasses. The outcomes will advance knowledge of amorphous nature and offer ideas into their potential and technical uses. In general, this study of the electrical and optical characteristics of $Se_{70}Te_{30-x}Sn_x$ ($x = 0$, 5, 10, and 15) chalcogenide glasses will strengthen the knowledge of glassy chalcogenide-semiconductor research and open the door for their utilization in the field of optoelectronic and photonic devices.

KEY WORDS: Amorphous Semiconductors, Chalcogenides, Glassy materials, XRD and Absorption, Conductivity.

1 Introduction

Any material with electrical conductivity that falls between that of an insulator and a conductor is referred to as a semiconductor. The basis of contemporary electronics, semiconductors have completely changed how we work, live, and exchange information. Semiconductors are used in a wide range variety of devices, including, smart-watches, computers, printing, smart-phones, and solar cells, lasers, LEDs etc. Semiconductors are unique in that their electrical properties can be easily controlled by adding impurities, a process called doping. This allows them to be engineered to have specific electronic properties, such as different energy band gaps, and makes them incredibly versatile materials [1–3]. One of the most important characteristics of semiconductors is their ability to form p-n junction diodes, which are the foundation of many electronic devices. Semiconductors materials mainly categorized into two kinds, intrinsic & extrinsic types. The intrinsic semiconductors are pure semiconducting substance, such as silicon and germanium, and have limited conductivity due to their valence electrons being fully utilized in covalent bonds. Extrinsic semiconductors, on the other hand, have impurities intentionally introduced to modify their electronic properties. These impurities, also known as dopant, introduce either free electrons or holes into the material which increases its conductivity [4]. The electronic properties of semiconductors are further classified based on their energy band structure. In an atom, electrons occupy specific energy levels, or orbital, and when they come together to form a crystal lattice, these energy levels combine to form energy bands. The band gap, defined as the energy difference between the conduction and valence bands, plays a crucial role in determining a semiconductor's electrical conductivity [5]. Semiconductors are a crucial component of modern electronics, and their unique properties make them incredibly versatile materials. Their conductivity is controlled by their energy band structure and their capacity to form p-n junctions, which enables the fabrication of electronic devices with certain features. Semiconductors will become more and more important as technology advances.

2 Chalcogenide Glassy Semiconductors

In crystalline semiconductors, all chemical bonds are saturated, whereas in amorphous semiconductors, some bonds remain unsaturated. These chemically unsaturated bonds are referred to as 'dangling bonds'. The amorphous materials are either conducting, semiconducting, or insulating when examining their electrical performance, semiconducting characteristics have been noted in compounds, single elements, and alloys with several components. The crystalline alloys in molten form of chalcogenide glasses are quickly cooled to prepare them. Some of the bonds break because of the quick cooling; these fractured bonds are referred toas "Dangling Bonds." In general, amorphous materials have a higher

defect density. As a result, preparation methods and outcomes have a significant impact on the characteristics of amorphous materials. In amorphous systems, the carriers rely heavily on the atomic arrangement's unpredictability. The atoms are arranged regularly even at large atomic distances in crystalline solids, whereas in chalcogenide glasses, the atoms are arranged irregularly and mostly in short-range order. This indicates that the minimum distance between neighbouring crystals is essentially the same as in a crystal when the crystal transitions from its crystalline to its amorphous form. However, in the process, long-range order (LRO) is lost. Understanding the impact of disorder on material properties is one of the main continuing issues in solid-state physics. Comparing disordered materials to their crystalline equivalent, novel characteristics are frequently observed. Because they are simple to produce, disordered or amorphous materials are appealing for usage. As a result, research on these materials is extremely important because it provides the basis for both academic and practical applications. Various types of unique glassy materials are widely used in IR fibers, acousto-optic devices, infrared optics, and optoelectronics. Their advantages include the ability to produce coatings over large areas and varying thicknesses, low cost, minimal sensitivity to contaminants, and simple synthesis procedures–making disordered materials especially attractive for such applications. To achieve this, various deposition techniques can be employed, including vacuum evaporation, magnetron sputtering, flash evaporation, and sol–gel or spin-coating methods. The refractive index of glassy materials can be tailored, as demonstrated by the photo-induced effects observed in chalcogenide glasses. These glasses possess a random atomic arrangement, characteristic of their amorphous nature. Thus, they lack long-range atomic periodicity completely, but they do have short-range order of a few atomic lengths. Because non-crystalline solids are a well-established and rapidly developing field in science and technology, their research problems are both fascinating and significant. Across the world, scientists, engineers, and technicians have expressed interest in the research being conducted on Chalcogenides glasses more specifically [6]. The chalcogens are elements that are represented in the periodic table as sulphur (S), selenium (Se), tellurium (Te), Given that these elements are frequently found in minerals connected to copper ore, the term "chalcogen" is derived from the Greek word "chalkos," which means "ore" or "copper."Chalcogens have similar properties, as they all have six valence electrons in their outermost shell. This gives them the ability to form stable compounds with other elements, including metals, non-metals, and other chalcogen [7].

Chalcogenide glass is a type of glass composed of one or more elements from the chalcogen group, such as sulphur, selenium, and tellurium. These glasses are typically non-crystalline and exhibit a range of desirable properties, including a high refractive index, good infrared transparency, and low phonon energy. Chalcogenide glasses are unique in that they are able to switch between amorphous and crystalline phases when subjected to heat, making them useful in

applications such as phase-change memory and rewritable optical storage [8]. They are also used in infrared optics, fibre optic communication systems, and as a material for solar cells. Chalcogenide glasses has a number of benefits, one of which is their versatility in terms of shape and size, which enables them to be used in a wide range of applications. They can be formed into thin films, fibers, and bulk materials, and their properties can be tailored by adjusting their composition and processing conditions. Chalcogenide glassy semiconductors constitute a class of amorphous materials incorporating chalcogen elements, including sulphur (S), selenium (Se), and tellurium (Te) These materials are widely used in the development of electronic and optoelectronic devices, including photovoltaic cells, memory devices, and sensors. Chalcogenide glasses have seized a significant position for the uses of non-crystalline materials because of their unique electrical and optical characteristics. One of the most well-known chalcogenide-based semiconductors is cadmium telluride (CdTe), which is commonly used in the production of photovoltaic cells for solar energy [9]. Other chalcogenide-based semiconductors include copper indium gallium selenide (CIGS) [10], lead sulphide (PbS) and lead selenide (PbSe) [11, 12]. Chalcogenide-based semiconductors are also being investigated for their potential use in memory devices, due to their ability to switch between different states of electrical conductivity. In addition, these materials are being studied for use in sensors, as they are highly sensitive to changes in temperature, pressure, and light. In the field of materials science, chalcogenide-based semiconductors are a promising area of study with possible applications in a broad range of electronic and optoelectronic devices. Binary, ternary, and quaternary chalcogenide systems refer to the different combinations of chalcogen elements that can be used to create semiconducting materials. Binary chalcogenide systems contain two elements, one from the chalcogen group and one from another group, typically a metal. Examples of binary chalcogenides include cadmium sulphide (CdS) and zinc selenide (ZnSe). These materials are often used as photo-catalysts, as they can be excited by light to produce a chemical reaction. Ternary chalcogenide systems contain three elements, typically two chalcogen and one metal. Examples of ternary chalcogenides include copper indium gallium selenide (CIGS) and cadmium telluride (CdTe). These materials are often used in solar cells due to their high efficiency at converting sunlight into electricity. Quaternary chalcogenide systems contain four elements, typically three chalcogens and one metal. Examples of quaternary chalcogenides include copper indium gallium selenium sulphide (CIGSSe) and cadmium zinc telluride (CdZnTe) [13]. These materials are used in a variety of applications, including photo-detectors, light-emitting diodes (LEDs), and thermo-electric devices. The properties of these chalcogenide systems can vary depending on the specific combination of elements used. By carefully selecting the elements and tuning their properties, researchers can create materials with specific properties that are tailored to a particular application.

3 Application of Chalcogenides

Chalcogenide-based semiconductors have a wide range of applications in electronic and optoelectronic devices due to their unique properties. Some of the most important applications of chalcogenide-based semiconductors include:

3.1 Solar cells

Thin-film solar cells, a type of photovoltaic device, use a thin coating of semiconducting material to convert sunlight into electrical energy. Due to their unique properties, chalcogenide-based semiconductors such as copper indium gallium selenide (CIGS) and cadmium telluride (CdTe) are widely used in the fabrication of thin-film solar cells [14]. Chalcogenide-based materials' high absorption coefficient of sunlight is one of their main advantages for solar cell applications. This means that they can efficiently capture a large fraction of the solar energy that falls on them, which translates into higher conversion efficiencies. In respect to other types of solar cells, CdTe-based solar cells have reached conversion efficiencies of over 22% [15]. Another advantage of chalcogenide-based materials for solar cells is their ability to be deposited as thin films. This allows for the creation of light weight and flexible solar cells that can be used in a wide range of applications. In addition, the use of thin films reduces the amount of material needed for the solar cell, which can help to reduce the cost of production [16]. The use of chalcogenide-based materials also offers potential environmental benefits. For example, CdTe-based solar cells have a much lower carbon footprint than silicon-based solar cells, due to the lower energy required to produce them. In addition, CdTe is a non-toxic material that can be recycled, which makes it a more sustainable option for solar cell production.

3.2 Memory devices

Phase-change memory (PCM) is a kind of non-volatile memory that stores information using materials based on chalcogenides. In PCM, information is stored by changing the phase of a chalcogenide material from amorphous to crystalline or vice versa, which corresponds to two different states of electrical conductivity. This process can be reversed, allowing the device to switch between the two states and read or write information [17]. The key advantage of PCM over other types of non-volatile memory such as flash memory is its high speed and low power consumption. PCM can operate much faster than flash memory because it does not require the same erase and write cycles, and it can also consume less power because it uses a lower voltage to switch between states. Chalcogenide-based materials are used in PCM because they have unique properties that allow for the reversible phase-change process [18]. Specifically, chalcogenide materials have a high melting point, which means that they can be heated to a temperature where they melt and become amorphous [19]. They also have a low thermal

conductivity, which allows the material to cool rapidly and become crystalline. The process of changing the phase of a chalcogenide material in PCM is typically achieved by passing a current through a small area of the material, which heats it up and causes it to melt. The material is then rapidly cooled to form the amorphous phase. To switch back to the crystalline phase, a current is passed through the material again, heating it up and causing it to crystallize. Overall, the unique properties of chalcogenide-based materials make them ideal for use in PCM, which offers high-speed, low-power, and non-volatile memory storage. PCM is currently being explored for a range of applications, including in computer memory and storage, as well as in embedded systems and Internet of Things (IoT) devices.

3.3 Sensors

Chalcogenide-based materials have unique properties that make them highly sensitive to changes in temperature, pressure, and light, making them useful in a variety of sensor applications. Temperature sensors based on chalcogenide materials are able to detect changes in temperature by measuring the changes in electrical resistance of the material as the temperature changes. Due to their high temperature coefficient of resistance (TCR), chalcogenide materials' resistance varies significantly with temperature. This makes them useful for temperature sensing applications, such as in thermostats, industrial process control, and automotive applications. Gas sensors based on chalcogenide materials [20] are able to detect changes in the concentration of gases in the environment by measuring changes in electrical conductivity or resistance of the material. Chalcogenide materials have a high sensitivity to changes in the concentration of gases, making them useful for gas sensing applications, such as in environmental monitoring, industrial process control, and healthcare. Photoconductive sensors based on chalcogenide materials [21] are able to detect changes in light by measuring the changes in electrical conductivity of the material as it absorbs photons. Chalcogenide materials have a high absorption coefficient for light, which makes them useful for light sensing applications, such as in cameras, optical communication systems, and photo-detectors. In addition, chalcogenide-based materials are also being investigated for other sensing applications, such as pressure sensing and bio-sensing. In pressure sensing, the material is able to detect changes in pressure by measuring changes in electrical conductivity or resistance. In bio-sensing, chalcogenide materials are being explored for their ability to detect biological molecules, such as proteins and DNA, by measuring changes in electrical conductivity or optical properties.

3.4 Infrared detectors

Chalcogenide-based semiconductors such as lead sulfide (PbS) and lead selenide (PbSe) are highly sensitive to infrared radiation, making them suitable for a variety of uses that require detection of infrared radiation, such as in night vision

devices, thermal imaging cameras, and remote sensing systems. The high sensitivity of PbS and PbSe to infrared radiation is due to their narrow band gap, which allows them to absorb infrared radiation with wavelengths in the mid-infrared (MIR) region. The chalcogenide-based semiconductor absorbs infrared light, which excites electrons from the valence band to the conduction band. This produces a photocurrent that can be measured and is used to recognize infrared radiation. The sensitivity of PbS and PbSe to infrared radiation can be further enhanced by controlling the composition and structure of the chalcogenide-based material [22]. For example, by introducing impurities or doping the material with other elements, it is possible to tune the band gap and absorption properties of the material, allowing it to detect infrared radiation with different wavelengths and levels of sensitivity. Infrared detectors based on PbS and PbSe are commonly fabricated using thin-film deposition techniques such as thermal evaporation, sputtering, or chemical vapour deposition. The resulting thin film is then patterned and processed to form the detector device, which typically comprises two or more electrodes and a chalcogenide-based semiconductor layer.

3.5 Optical communication

Chalcogenide-based materials are commonly used in optical communication systems, including optical fibers and other devices, because of their unique optical properties, including a high refractive index and low dispersion. In optical communication systems, information is transmitted using light signals that are sent through optical fibers or other waveguides. The chalcogenide-based materials are used as the core material in the optical fibers due to their suitable high refractive-index. The suitable high refractive-index of chalcogenide-based materials causes light to be confined within the core of the optical fiber, reducing the amount of light that is lost through the fiber cladding and allowing for efficient transmission of the light signal over long distances. Chalcogenide-based materials also exhibit low dispersion [23], which is the tendency of different wavelengths of light to travel at different speeds through the material. In optical communication systems, dispersion can cause distortion of the light signal and limit the amount of information that can be transmitted. The low dispersion of chalcogenide-based materials allows for efficient transmission of light signals with minimal distortion, allowing for high-speed data transmission over long distances. In addition to optical fibers, chalcogenide-based materials are also used in other optical communication devices, such as planar waveguides and optical amplifiers. Planar waveguides are used to guide and manipulate light signals in integrated optical circuits, while optical amplifiers are used to amplify weak optical signals.

3.6 Thermoelectric devices

The thermoelectric effect, which turns heat into electricity, can be exploited to fabricate thermoelectric devices using materials based on chalcogenides. The

thermoelectric effect occurs when a temperature difference is applied across a material, which causes an electric current to flow through the material [24]. Chalcogenide-based materials are ideal for thermoelectric devices because they exhibit a high thermoelectric efficiency, which is a measure of the amount of electrical energy that can be generated from a given temperature difference. The high thermoelectric efficiency of chalcogenide-based materials is due to their unique electronic structure, which allows them to efficiently convert thermal energy into electrical energy. Thermoelectric devices based on chalcogenide-based materials have many potential applications, including waste heat recovery in industrial processes, automotive and aerospace systems, and microelectronics [25]. Waste heat recovery involves converting the waste heat generated by various industrial processes into useful electrical energy, which can help to reduce energy costs and increase efficiency.

Chalcogenide-based thermoelectric devices can also be used in automotive and aerospace systems to generate electricity from the heat generated by the engine or other sources. The effectiveness and reliability of microelectronic systems can be increased by using chalcogenide-based thermoelectric devices. The development of chalcogenide-based thermoelectric devices is an active area of research, and ongoing efforts are focused on improving the efficiency and performance of these devices for a range of applications.

4 Melt Quenching Technique

Melt Quenching is a process used to produce glassy materials and alloys. It involves heating the material to its melting point, followed by rapid cooling to prevent crystallization, resulting in a non-crystalline or amorphous structure. This technique has been used to create a variety of materials with unique properties, such as high strength, corrosion resistance, and electrical conductivity. This process is widely used to produce metallic glasses, as well as glass-ceramics and other non-crystalline materials. Advances in melt quenching technology, such as the development of rapid solidification techniques and the use of high-pressure systems, have further expanded the range of materials that can be produced using this technique. Ongoing research in this field is focused on developing new materials with unique properties and improving the efficiency and scalability of the melt quenching process. The melt quenching process involves several steps:

(a) **Material selection:** The first step in melt quenching is to select a suitable material. The material should have a high melting point and a large undercooling range, which is the difference between the melting temperature and the glass transition temperature.

(b) **Melting:** The material is heated to its melting point using a furnace or other heating method. The temperature and duration of the melting process depend on the material and its desired properties.

(c) **Quenching:** After melting, the material is rapidly cooled using a quenching method, such as plunging into a liquid or gas, spraying, or using a high-speed air jet. The cooling rate must be fast enough to prevent crystallization and maintain an amorphous structure.

(d) **Annealing:** In some cases, the material is annealed after quenching to relieve residual stresses and improve its properties. Annealing involves heating the material to a lower temperature for a period of time and then slowly cooling it down.

The properties of the resulting amorphous material depend on the cooling rate and the starting material Faster cooling rates generally lead to higher strength and increased glass transition temperatures. The structure of the resulting material can be analyzed using techniques such as X-ray diffraction (XRD), transmission electron microscopy (TEM), and differential scanning calorimetry (DSC). Melt quenching is widely used in the production of metallic glasses, semiconductors, and biomaterials. It offers a way to create materials with unique properties and tailored for specific applications.

5 Experimental

In order to further investigate the properties of these materials, it is essential to prepare high-quality samples for characterization and analysis. In this study we present a detailed description of the sample preparation process for tertiary $Se_{70}Te_{30-x}Sn_x$ ($x = 0$, 5, 10 & 15) chalcogenide glasses. Glassy Chalcogenide materials were made using conventional melt quenching technique. The purity of Selenium (Se) 99.999%, Tellurium (Te) 99.999% & Tin (Sn) 99.999%, used for the preparation of $Se_{70}Te_{30-x}Sn_x$ ($x = 0$, 5, 10 & 15) samples. We utilized quartz ampoule in this experiment, firstly, we washed the quartz ampoules with acetone then weighed all the components as per required ratio using weighing machine. Evacuated the ampoules through rotatory pump in the order of 10^{-6} torr. These required amount of each element are enclosed in 10^{-6} Torr vacuum in the quartz ampoules. All the four ampoules were tied to a ceramic iron rod and placed inside a Muffle-furnace with a temperature setting of 500°C. The furnace was then turned on, and heating began at a rate of five degrees per minute until the temperature reached 500°C, we heat the samples at constant temperature at 500°C for 14 hours for better homogenization. During these 14 hours we constantly rotated the rod at time interval of (20–30) minutes so that sample can properly melt for better homogenization. The ampoule was placed in a rocking furnace and quickly cooled in ice water to ensure the liquid was properly mixed and homogeneous. After 14 hours' samples were quenched in a bucket of ice-water (4°C). After that the ampoules were broken and open to extract the samples. The samples were subsequently pound into fine-powder using a pestle and mortar and put into highly cleaned boxes. Thus, we have prepared four samples based on different amount of Sn doping in the tertiary

compound $Se_{70}Te_{30-x}Sn_x$ ($x = 0$, 5, 10 &15) which is given in Table 1. With the composition the amorphous nature of the prepared bulk chalcogenide glassy materials was studied using an X-ray Diffraction technique and also developed thin film by coating unit through vapour deposition technique and measure the thickness of the film by thickness monitor unit, it was measured as 300 nm, by using UV visible spectrophotometer measure the absorbance and transmittance of the samples. we determine the conductivity of material using pellets.

Table 1. Samples based on different Sn concentration. Weight of components of samples for a fixed weight of 4 g

No.	Sample	Sample weight [g]	Component	Weight [g]
1	$Se_{70}Te_{30}$ Sn_0	4 g	Se	2.363
			Te	1.637
			Sn	0
2	$Se_{70}Te_{25}Sn_5$	4 g	Se	2.397
			Te	1.370
			Sn	0.255
3	$Se_{70}Te_{20}Sn_{10}$	4 g	Se	2.386
			Te	1.101
			Sn	0.512
4	$Se_{70}Te_{15}Sn_{15}$	4 g	Se	2.397
			Te	0.847
			Sn	0.772

Table 2. General information about Sn, Te & Sn

Sample number	Element	Atomic number	Atomic weight	Melting point (degree Celsius)	Boiling point (degree Celsius)
1	Selenium (Se)	34	78.97	220.80°C	685°C
2	Tellurium (Te)	52	127.6	449.51°C	988°C
3	Tin (Sn)	50	118.71	231.97°C	2270°C

6 X-Ray Diffraction (XRD) Techniques

A powerful analytical method used in many scientific fields to examine the atomic and molecular structures of crystalline materials is X-Ray Diffraction (XRD). This technique has since become an indispensable tool in fields such as material science, mineralogy, chemistry, geology, and even art conservation. This article aims to shed light on the principles, applications, and significance of XRD in modern scientific research. X-ray diffraction (XRD) is primarily based

on the interaction of X-rays with the ordered atomic structure of a crystalline substance. When a monochromatic X-ray beam strikes a crystalline sample at a specific angle, it gets scattered by the atoms' periodic arrangement. The scattered X-rays then interfere constructively or destructively, creating a diffraction pattern that carries crucial information about the sample's crystal structure. The experiments in X-ray diffraction can be explained using Bragg's law as given below:

$$n\lambda = 2d\sin(\theta) \tag{1}$$

where n is an integer, λ is the incident X-rays' wave-length, d is the interplanar spacing, and θ is the glancing angle. When the assumptions of this equation are satisfied, the constructive interference that results from the X-rays diffracting off the material results in high-intensity peaks on the spectrum. In essence, semi-crystalline materials are composed of two phases, one of which is crystalline and the other amorphous. The distribution of interatomic distances within the disordered structure determines the general characteristics of the amorphous phases. The term "halo hump" or "amorphous halo" refers to these wide characteristics.

7 Results and Discussion

7.1 X-Ray diffraction pattern

Prepared samples are characterized through XRD techniques and analyzed in the prepared amorphous materials high intensity peaks are absent which are seen in Figures 1–4.

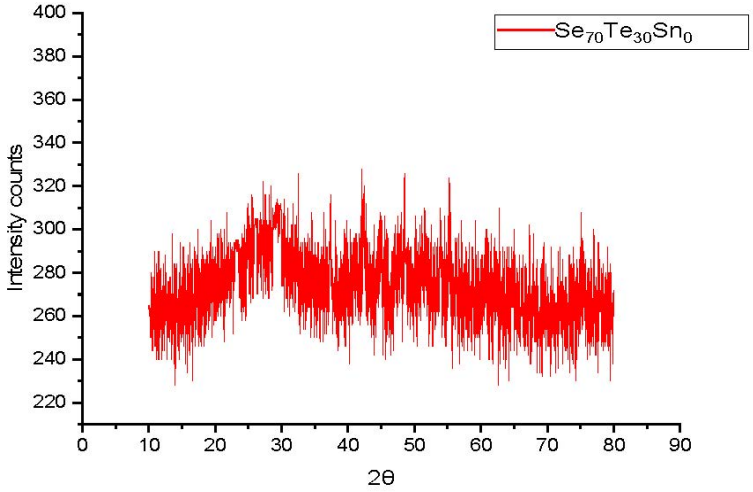

Figure 1. X-ray diffraction pattern of $Se_{70}Te_{30}Sn_0$.

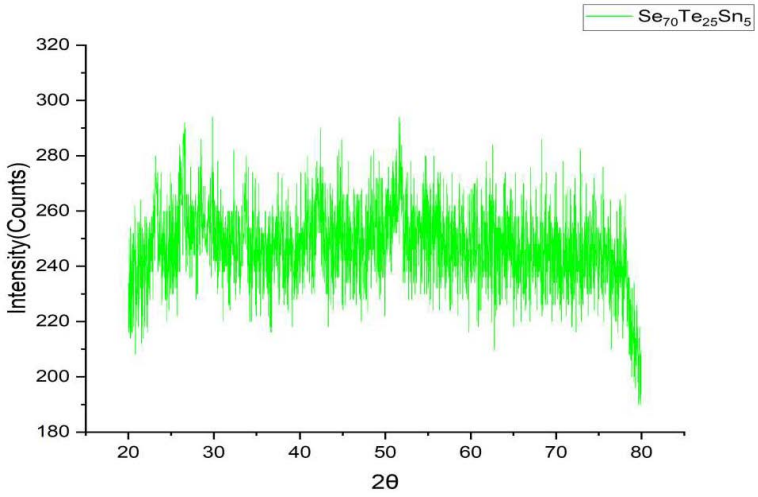

Figure 2. X-ray diffraction pattern of $Se_{70}Te_{25}Sn_5$.

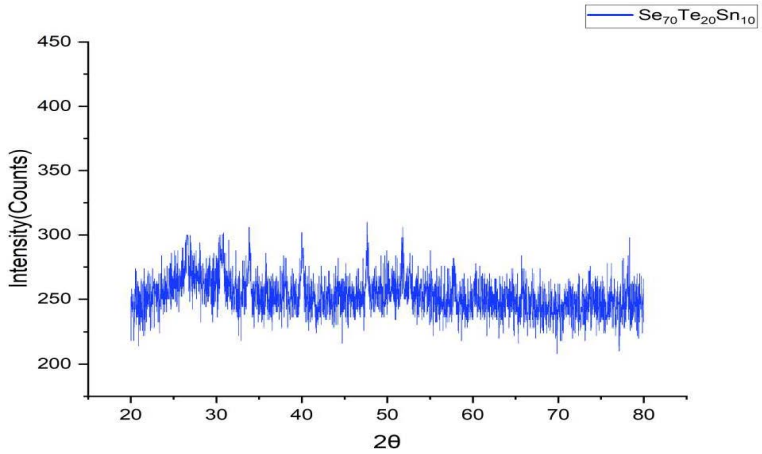

Figure 3. X-ray diffraction pattern of $Se_{70}Te_{20}Sn_{10}$.

The broadness of the XRD pattern for glass is due to the short-range order of atoms within a few angstroms. This short-range order arises from the tendency of atoms to arrange themselves in a local, more structured manner, but this order does not extend over long distances as it does in crystalline materials. As a consequence, the X-ray diffraction signals from neighboring atoms overlap, leading to the broad, diffuse scattering pattern. The lack of sharp peaks and the presence of this broad hump in the XRD pattern are characteristic of amorphous materials like glass. This distinct feature of the XRD pattern is one of the ways to

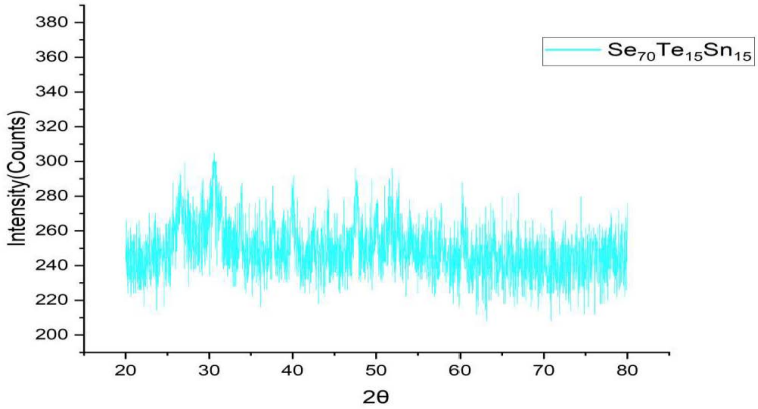

Figure 4. X-ray diffraction pattern of $Se_{70}Te_{15}Sn_{15}$.

distinguish between crystalline and amorphous materials. Thus, XRD patterns from Figure1 to Figure 4, It has been confirmed that all the samples prepared are amorphous in nature.

7.2 Optical absorption of $Se_{70}Te_{30}Sn_{30-x}$ (x = 0, 5, 10 & 15) thin films

The different combinations of chalcogen elements used in binary, ternary, and quaternary chalcogenide systems allow for the creation of materials with specific properties tailored to particular applications. On keeping the potential application of chalcogenide glassy semiconductor, we have decided to investigate the optical energy band gap and electrical conductivity of tertiary $Se_{70}Te_{30-x}$ Sn_x (x = 0, 5, 10 & 15) chalcogenide glasses. The most crucial method for figuring out the band structures of semiconductors is optical measurement. The refractive index (n) and extinction coefficient (k), which are the material's optical constants, are often determined using the material's optical behavior. The films are excellent test subjects for measurements of transmittance and reflectance. Making k requires determining n separately and measuring the specimen's reflectance and transmittance. demonstrates how the optical absorption coefficient (α) varies for thin films of $Se_{70}Te_{30}Sn_{(30-x)}$ (x = 0, 5, 10 & 15), as a function of incident photon energy (hv). Using the relation [26–28] provided by

$$\alpha = OD/t\,, \tag{2}$$

where OD is the optical density measured at a layer thickness (t).

By analyzing the absorbance against wavelength curves, we may easily determine the absorption coefficient (α). The value of the absorption coefficient (α) has been shown to rise with the increase in photon energy for all samples of the $Se_{70}Te_{30}Sn_{(30-x)}$ system. In the absorption process, a photon of known energy

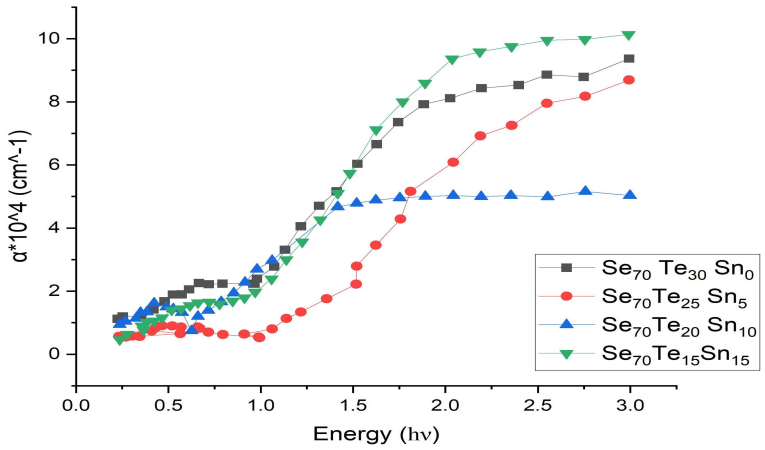

Figure 5. Absorption coefficient (α) against photon energy in $Se_{70}Te_{30}Sn_{30-x}$ thin films.

excites an electron from a lower to a higher energy state, corresponding to an absorption edge [29–32].

7.3 Resistivity of glassy materials

Temperature of the glass transition and resistance of Several glasses' temperature-dependent, resistivity in the experimental range are depicted in Figure 6. As the temperature rises, the resistivity decreases, according to the following relationship:

$$\rho = \rho_0 \exp(\Delta E/KT)\,, \tag{3}$$

where ΔE is the activation energy and k the Boltzmann constant. The behavior is similar to the experimental results reported for other chalcogenide glasses.

The absorption coefficient (α) of the $Se_{70}Te_{30}Sn_{(30-x)}$ thin films increases linearly with the increase in incident photon energy ($h\nu$).

This indicates that as the energy of the incident photons rises, the material exhibits a proportional increase in its ability to absorb light. This behavior is commonly observed in semiconductors and is linked to the excitation of electrons from lower to higher energy states, corresponding to absorption edges. The observed linear increase in the absorption coefficient with photon energy points to the presence of distinct absorption edges in the material's band structure. These edges signify the energy levels at which electrons can be excited to higher states by absorbing photons with specific energies. The analysis of these absorption edges provides essential information about the electronic properties of the semiconductor [33–35]. The temperature-dependent resistivity measurements reveal a clear trend in the behavior of chalcogenide glasses. As the temperature increases, the resistivity of the glasses decreases. This indicates that the glasses

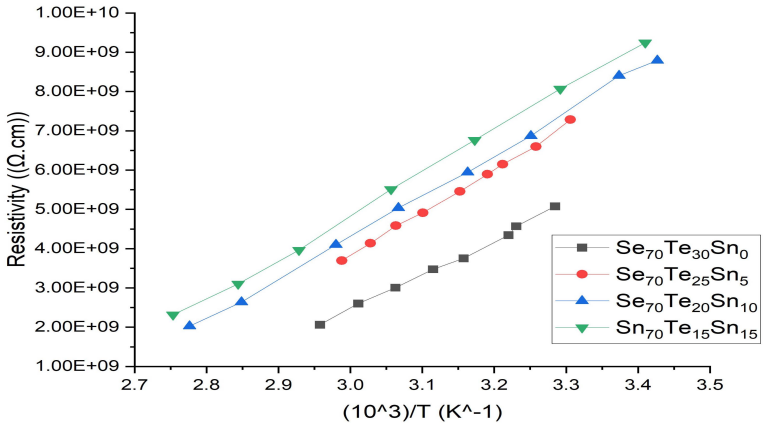

Figure 6. Temperature dependence of resistivity.

undergo a transition, known as the glass transition, where their resistive properties change with temperature. The observed decrease in resistivity with increasing temperature. As the temperature rises, more charge carriers are activated, leading to increased electrical conductivity and decreased resistivity [36–38].

8 Conclusion

With potential applications in a broad range of electrical and optoelectronic devices, chalcogenide materials are excellent for use in memory devices, sensors, solar cells, and other applications because of their special electrical and optical features. The investigations on the $Se_{70}Te_{30}Sn_{(30-x)}$ thin films of chalcogenide glasses have provided valuable insights into the optical and electrical behaviors of these materials. For the amorphous $Se_{70}Te_{30}Sn_{(30-x)}$ thin films, the linear increase in the absorption coefficient (α) with incident photon energy ($h\nu$) indicates the presence of distinct absorption edges in the material's band structure. This behavior is a common characteristic of semiconductors, where the excitation of electrons from lower to higher energy states leads to increased light absorption. The analysis of these absorption edges offers crucial information about the electronic properties of the semiconductor, which is essential for designing and optimizing optoelectronic devices. On the other hand, the temperature-dependent resistivity measurements of chalcogenide glasses reveal a clear trend as temperature rises, the resistivity of the glasses decreases. This phenomenon is attributed to the glass transition, where the resistive properties of the material change with temperature. As temperature increases, more charge carriers are activated, enhancing electrical conductivity and resulting in decreased resistivity. This behavior has significant implications for developing advanced memory devices, infrared sensors, and other electronics that operate

across varying temperature ranges. Both sets of findings highlight the importance of understanding the optical and electrical properties of semiconductors and chalcogenide glasses. These materials play critical roles in various technological applications, ranging from optoelectronics to data storage and sensing technologies. Overall, the knowledge gained from these studies contributes to the broader fields of materials science and solid-state physics, paving the way for innovative technologies that can shape the future of electronics, communication, and energy-related applications. Continued research and exploration in these areas hold promise for transformative advancements that will drive progress and improve our daily lives. The investigations on the optical and electrical behaviors of $Se_{70}Te_{30}Sn_{(30-x)}$ thin films and chalcogenide glasses offer promising future prospects for technological advancements and scientific discoveries. Researchers can tailor the band structures of these materials to achieve specific optical and electronic properties, thereby enabling the development of more efficient and versatile optoelectronic devices. combining the unique properties of chalcogenide glasses and semiconductors, researchers can develop devices with enhanced capabilities for sensing, data storage, and energy harvesting. The understanding of optical and electrical behaviors in $Se_{70}Te_{30}Sn_{(30-x)}$ thin films of chalcogenide glasses paves the way for exciting future prospects in materials science, electronics, and photonics which improve the quality of life. therefore, tertiary $Se_{70}Te_{30-x}Sn_x$ ($x = 0$, 5, 10 & 15) chalcogenide glasses have emerged as a promising material system in the field of optoelectronics due to their unique optical and electrical properties.

ACKNOWLEDGEMENT:

We are heartfelt thankful to Prof. M. Zulfequar and Dr. Javid Ali for providing research facilities at Department of Physics, Jamia Millia Islamia (central university), New Delhi-110025.

References

[1] A. Ahmad, S.A. Khan, K. Sinha, L. Kumar, Z.H. Khan, M. Zulfequar, M. Husain (2008) *Vacuum* **82** 608-61.

[2] C.S. Ray, S.T. Reis, R.K. Brow (2005) *J. Non-Cryst. Solids* **351** 1350.

[3] B.G. Streetman, S.K. Banerjee (2015) *Solid State Electronic Devices* (7th ed.) Prentice Hall.

[4] S.M. Sze, K.K. Ng (2006) *Physics of Semiconductor Devices* (3rd ed.) Wiley-Interscience.

[5] S.O. Kasap (2006) *Principles of Electronic Materials and Devices* (2nd ed.) McGraw-Hill.

[6] P.H. Gaskell (1995). *J. Non-Cryst. Solids* **192-193** 9-22.

[7] V.G. Orlov, G.S. Sergeev (2022) *Phys. Solid State* **64** 1864.

[8] T. Gille, K.D. Meyer, D.J. Wouters (2008) *Phase Transit.* **81** 773-790.

[9] S.C. Ray, K. Mallick (2013) *Int. J. Chem. Eng. Appl.* **4** 183-186.

[10] S. Lastella, S. Aksu, A. Kleiman-Shwarsctein, M. Pinarbasi (2011) *ECS Meeting Abstracts* **02** 198-198.
[11] K. Udofia, I. Lucky (2018) *Asian J. Phys. Chem. Sci.* **5** 1-7.
[12] H. Moreno-García, M.T.S. Nair, P.K. Nair (2011) *Thin Solid Films* **519** 2287-2295.
[13] J.K. Tripathi, S.SA. Harilal, A. Hassanein (2014) *Mater. Res. Express* **1** 035904.
[14] J. Zhou, C. Li (2021) *E3S Web of Conferences* **267** 02031.
[15] C. Ferekides, J. Britt (1994) *Sol. Energy Mater. Sol. Cells* **35** 255-262.
[16] P.K. Nair, M.T.S. Nair (1987) *Solar Cells* **22**(2) 103-112.
[17] C. Das, G. Mohan Rao, S. Asokan S. (2010) *Adv. Mater. Res.* **123** 1207-1210.
[18] Y. Yin, S. Hosaka (2016) *Key Eng. Mater.* **698** 149-153.
[19] V. Kishore, R. Sharma, V. Saraswat, N. Saxena, K. Sharma, T.P. Sharma (2007) *Appl. Therm. Eng.* **27** 1552-1554.
[20] R.K. Jha, N. Bhat (2020) *Adv. Mater. Interfaces* **7** 2070038.
[21] F. Dong, V. Chu, J.P. Conde (2011) *Sens. Actuators A: Phys.* **170** 32-35.
[22] N.M. Ravindra, V.K. Srivastava (1980) *Infrared Phys.* **20** 399-418.
[23] H. Mushahid, R. Swati (2013) *Adv. Mater. Res.* **679** 41-45.
[24] M. Spurny, L. O'Faolain, D.A.P. Bulla, B. Luther-Davies, T.F. Krauss (2011) *Opt. Express* **19** 1991.
[25] B. Jariwala, N.M. Ravindra (2014) *Nanomater. Energy* **3** 68-81.
[26] Z. Li, W. Li, Z. Chen (2017) *Energies* **10** 1489.
[27] D.P. Gosain, T. Shimizu, M. Ohmura, M. Suzuki, T. Bando, S. Okano (1991) *J. Mater. Sci.* **26** 3271-3274.
[28] E.K. Shokr, M.M Wakkad (1992) *J. Non-Cryst. Solids* **23** 1197.
[29] H. Keller, J. Stuke (1965) *Phys. Status Solidi* **8** 831.
[30] J. Tauc (1979) *Amorphous and liquid semiconductors*. New York: Plenum Press, p. 159.
[31] M. Ilyas, M. Zulfequar, Zishan H. Khan, M. Husain (1998) *Opt. Mater.* **11** 67-77.
[32] M. Ilyas, M. Zulfequar, M. Husain (2000) *Opt. Mater.* **13** 397.
[33] Shobhit Saraswat, V.K. Tomar, V.K. Deolia, N. Mehta (2023) *Mater. Today Proc.* doi: https://doi.org/10.1016/j.matpr.2023.03.455.
[34] R. Gadhwal, H. Singh, A. Devi (2023) *Mater. Today Proc.* **74** 354-357.
[35] S. Kuntze, D. Ban, E.H. Sargent, St.J. Dixon-Warren, J.K. White, Ka. Hinzer (2005) *Crit. Rev. Solid State Mater. Sci.* **30**(2) 71-124.
[36] A.A. Ebnalwaled, A. Thabet (2016) *Synth. Met.* **220** 374-383,
[37] A. Serpenguzel, A. Kurt, U.K. Ayaz (2008) *Photonics Nanostructures - Fundam. Appl.* **6**(3-4) 179-182.
[38] Z. Amara, M. Khadraoui, R. Miloua, A. Boukhachem, A. Ziouche, A. Nakrela, A. Bouzidi (2020) *Phys. B: Condens. Matter* **585** 412121.