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Synthesis and X-ray Diffraction Study of Se_{79} Te_{20} Pb_{1} Chalcogen Glass

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ABSTRACT

Chalcogenide glasses have received much attention from researchers during the last few years because of their interesting optical, electrical, dielectric, thermal, and physical properties by changing the composition such as wide transmission range, high refractive index, good chemical durability, optical switching, and from amorphous to crystalline phase transition. In this paper, $Se, Te,$ and Pb are taken in appropriate atomic weight percentages. Ternary $Se_{79}Te_{2}$ Pb_{1} chalcogenide glass is prepared by conventional melt quenching technique. XRD method is used for the identification of crystalline materials. Thus, the absence of any sharp and prominent peak in the XRD pattern confirmed the amorphous nature of chalcogenide glass.

Keywords- Chalcogenide Glass, Melt Quenching, Solids, X-ray Diffraction.

I. INTRODUCTION

Objects with definite sizes and shapes are known as solids. They generally exhibit certain characteristics that set them apart from liquids and gases. For instance, they can resist any force that is applied to their surfaces. Because they are generally held together by ionic or strong covalent bonding and the attractive forces between the atoms, ions, or molecules in solids are very strong. However, the solid state of compounds largely depends on the properties of atoms such as their arrangement and the forces acting between them. Solids are incompressible, meaning the constituent particle is arranged close to each other and because of that, there is negligible space between the constituent particles. Solids are rigid. This is due to the lack of space between the constituent particles which makes it rigid or fixed. Solids have definite mass, volume, and shape due to which it has a compact arrangement of constituent particles. The intermolecular distance between molecules is short. Due to this, the force between the constituent particles (atoms, molecules, or ions) is very strong. The constituent's particles can only oscillate about their mean positions. Solids are classified into two-state types according to the arrangement of constituent particles: Crystalline Solids and Amorphous Solids (J. Schottmiller et al.,1990).

Crystalline solids are the most common type of solids. They have a typical geometry. In Crystalline solids, there are definite arrangements of particles (atoms, molecules, or ions) throughout the 3D network of a crystal in a long-range order. Examples include Sodium Chloride, Quartz, Diamond, ice, sugar, etc.

Amorphous solids are those which have the property of rigidity and incompressibility to a certain extent. Amorphous, or non – crystalline solids lack the long–range order characteristics of a crystalline solid. Examples include glass, rubber, plastic, thin film lubricants, etc. The structure of crystalline solids and amorphous solids is shown in Fig. 1.

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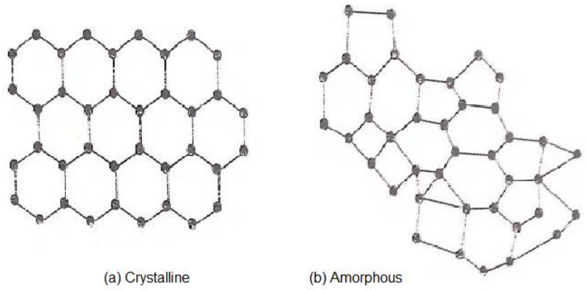

Fig. 1: (a) Structure of crystalline (b) structure of amorphous solids

The term glass was developed in the late Roman Empire. It was the Roman glassmaking center at Trier, now in modern Germany, that the Latin term 'glum' originated, probably from a Germanic word for a 'transparent' & 'lustrous' substance. Glass is an amorphous solid material that lacks long-range periodic crystalline structure and usually produced when a suitably viscous molten material cools very rapidly (as shown in Fig. 2). This type includes the chalcogenide glasses.

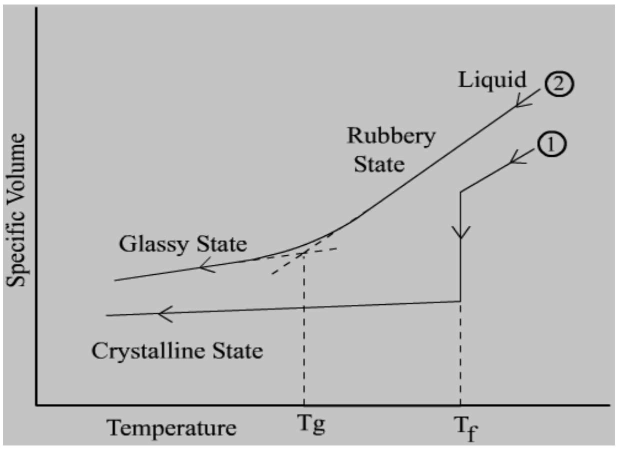

Fig. 2: Volume – Temperature dependence for a material

Chalcogens are the elements in group 16 of the periodic table. This group consists of O, S, Se, Te, and Po. Only S, Se & Te compounds are known as chalcogenides. Oxygen is treated separately from other chalcogens due to its very different chemical behavior. Polonium is also a chalcogen but is not used in glasses because of its strong radioactivity. A chalcogenide glass consists of one or more chalcogen elements belonging to group 16 in the periodic table i.e. S, Se, and Te. Such glasses are covalently bonded. The chalcogenide glasses are band gap semiconductors and are infrared transmitting (Mehta N. et al. 2011).

Chalcogenide glasses have captivated much attention of researchers during the last few years because of their interesting optical, electrical, dielectric, thermal, and physical properties by changing the composition. They have a wide transmission range, high refractive index, good chemical durability, optical switching, and from amorphous to crystalline phase transition (Patial B. S. et al. 2019).

The absence of rigidity of the structure in chalcogenide glasses makes them appropriate for several applications. Especially, Se-based chalcogenide glasses are preferred due to their wide range of properties such as high transparency in broad middle and far infrared regions, reversible transformations, and strong non-linear properties (Afify N et al. 2008). But pure Se has a short lifetime and lower sensitivity even though it is characterized by higher viscosity (Thakur A. et al. 2017). The doping of tellurium helps to overcome these problems which give high sensitivity, greater hardness, high crystallization temperature (Tp), and small aging effects as compared to pure Se glass (Lucovsky G. et al. 1967). The Se-Te alloys are found to be useful if these alloys are thermally stable with time and temperature during use (S. O. Kasap and C. Juhaz 1986). However, thermal instability leading to crystallization is found to be one of the problems of these alloys. Hence, attempts have been made to improve the stability of the Se-Te glassy system by the addition of a third element which creates compositional and configurational disorder concerning the binary system (Priyanka V. et al. 2020, Patial B. S. et al. 2019). The insertion of an impurity in Se-Te binary alloy at the cost of Se is of interest owing to the advantages like higher glass transition temperature (Tg) and Tp and thermally more stable effects as compared to host Se- Te alloy (Tacke M. et al. 1995). The addition of metallic impurities like Pb affects the basic bonding. It is observed that the addition of Pb helps in getting a cross-linked structure thus increasing Tg and Tp of the binary alloy, improving the thermal stability, and glass-forming ability, and reducing aging effects (A. N. Kumar et al. 2018). It is also observed that the addition of Pb not only increases the conductivity and thermal stability of the system but also leads to a transition in conduction from p-type to n-type which makes them ideal materials for replacing the conventional p-n junction (Suri N. et al. 2007). Pb-doped chalcogenide materials are being considered to be used for high-resolution spectroscopy, optical fiber analysis, optical communication, detecting atmospheric pollutants such as hydrocarbons, and fast automotive exhaust analysis which makes them an important issue for researchers (Agne M. et al. 1994).

The intermediate phases have been identified in chalcogenide glasses. These phases represent glass composition where the glass-forming tendency is optimized and ideal stress-free networks exist (Ahmad M. et al. 2009). The dielectric parameters viz dielectric constant, dielectric loss, and AC conductivity in the frequency range 10 Hz to 500 kHz and temperature 300-320 K have been studied. It is found that for dielectric constant, dielectric loss, and AC conductivity the glassy system shows unique trends at x=1 at % for the same temperature and same frequency. Hence, it has been

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concluded that $Se_{79}Te_{20}Pb_1$ is critical composition (Wuttig M. et al. 2017). $Se_{79}Te_{20}Pb_1$ is a critical component at which maxima occurs and the system becomes a chemically ordered alloy containing comparatively higher energy hetero-polar bonds Zeinab S. et al. 2017).

II. EXPERIMENTAL

A sample of $Se_{79}Te_{20}Pb_1$ alloy is prepared using the melt quenching technique. Se, Te and Pb are taken in appropriate atomic weight percentage. Quarts ampoule is cleaned thoroughly with acetone and soap solution. Pour the elements into the quartz ampoule. A vacuum $\sim 2 \times 10^{-5}$ mbar is created and then the ampoule is sealed. Ampoule is heated inside the Muffle furnace up to 700°C. Quenching in ice-cooled water. Ampoule broken, Ingot is obtained. The ingot is crushed into powdered form. The stoichiometric weight of various constituents of sample $Se_{79}Te_{20}Pb_1$ is shown in table 1.

Table 1: Stoichiometric weight of various constituents of sample $Se_{79}Te_{20}Pb_1$

Composition	Elements	Percentage (%) (a)	Atomic mass (b)	$a * b$	Actual weight is taken for $3g$ (g)
$Se_{79}Te_{20}Pb_1$	Se	79	78.96	6237.84	2.080
	Te	20	127.6	2552.00	0.851
	Pb	1	207.2	207.20	0.069

The X-ray Diffraction (XRD) method is used for the identification of crystalline materials. For amorphous materials, XRD provides very little information. XRD is based on constructive interference of monochromatic X-rays generated by CRT. The interaction of the incident rays with the sample produces constructive interference when Bragg's condition is satisfied i.e. nλ= 2dsinθ as shown in Fig. 3.

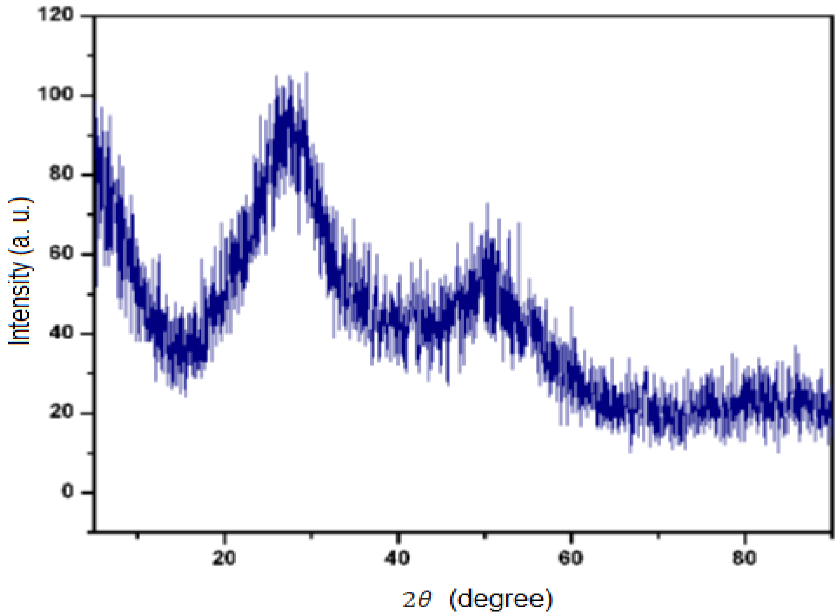

Fig. 3: The relation of the intensity of incident rays with sample vs angle.

III. CONCLUSIONS

In this research paper structural features have been analyzed for Ternary $Se_{79}Te_{20}Pb_1$ chalcogenide glass prepared by conventional melt quenching technique. The samples are analyzed through the XRD technique and the nλ= 2dsinθ is used. The absence of any sharp and prominent peak in the XRD pattern confirmed the amorphous nature of chalcogenide glass.

IV. DISCUSSIONS

Amorphous chalcogenide semiconductors have commercial worth and have many applications such as image formation, including x-rays, and high-definition TV pick-up tubes. They have widespread uses in the microelectronics industry and amorphous metallic alloys also have useful magnetic properties. Here, Se, Te and Pb are taken in appropriate atomic weight

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percentage. The sample of $Se_{79}\,Te_{20}\,Pb_1$ alloy is prepared using the melt quenching technique. The glass transition phenomenon, amorphous crystallization transformation, and the ease of glass formation of chalcogenide $Se_{79}\,Te_{20}\,Pb_1$ alloy have been studied. Hence, the absence of any sharp and prominent peak in the XRD pattern confirmed the amorphous nature of chalcogenide glass.

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