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A Study of the Effectiveness of Tin on the Thermal Conductivity Coefficient and Electrical Resistance of Se60Te40-xSnx Chalcogenide Glass

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Abstract

This research calculated the effect of partial replacement of Trillium with tin by weight ratios x=0, 5, 10, 15, and 20 of the weight of manufactured samples on the thermal conductivity coefficient of Se60Te40-xSnx chalcogenide glasses. The thermal conductivity coefficient of the samples was calculated using a disk- Lee. The results showed that increasing the concentration of tin improves the thermal insulation ability by decreasing the thermal conductivity value and then determining the optimal weight ratios at which a large thermal insulation is obtained.

The electrical resistivity as a function of temperature was studied. The electrical resistivity ($\rho_{d.c}$) was calculated as a function of temperature for all samples, using two-point probe techniques in the dark electrical resistivity measurements of $Se_{60}Te_{40-x}Sn_x$ glasses for all values made in the temperature range 303-455 K. The electrical resistivity was found that it depends on the change in Tin addition, the temperature is clearly affected by the increase in the concentration of tin in the alloy. The electrical resistance increases when the concentration of Tin increase of $Se_{60}Te_{40-x}Sn_x$

Keywords: Partial replacement, Thermal conductivity coefficient, thermal insulation ability, chalcogenide glasses, concentration of tin.

1.Introduction

The electrical and thermal properties are among the essential basic properties that must be considered when choosing semiconductor materials. Improving one of these two properties may lead to a deterioration of the other property. Therefore, these two characteristics must be considered together when selecting certain materials. The decision is left to the manufacturers of these materials to choose in their practical applications. The study of amorphous materials has received significant attention in the recent past due to their interesting electrical, optical, and magnetic properties in many electronic works and industries [1]. Amorphous semiconductor materials have conduction and valence bands with edges extending within the energy gap, resulting in localized states. These states are very dense and may overlap or leave tails within the energy gap depending on the type and composition of the material [2]. Amorphous semiconductors can be classified into different groups of tetrahedrons, such as silicon glass and Chalcogenide [3]. Chalcogenide glasses consist of chalcogen elements from the sixth group of elements of the periodic table [4]. Chalcogenide glasses are considered one of the most promising materials in the modern era due to their live technological applications [5] and commercial importance [6]. The present work is based on a tin-containing (Se-Te) glass system as a third alternative. Se-Te-Sn shows a narrow glass-forming region but has higher transmittance in the infrared region [7].The addition of the third element tin (Sn) in the Se-Te system significantly changes its electrical and optical properties [8]. The present work is based on (Se-Te) a -chalcogenide glassy system containing tin as the third substitute. Se-Te-Sn shows a narrow glass-forming region but has the advantage of higher transmittance in the IR region [9]. The addition of the third elements tin (Sn) in the Se-Te system changes its electrical and optical properties significantly [10]. Replacing the proportions of some chemical elements in the chemical compound may improve some physical properties at the expense of other properties [11-12]. Many researchers have found that partial replacement of different proportions of chemical elements such as aluminum, chromium, nickel, and lanthanum affects the thermal, electrical, and structural properties. The partial replacement of chalcogenide glass was found to be significantly affected [14]. The type and method of preparing the compound and controlling the preparation conditions play a significant role in the electrical and structural properties [13].

In this paper, we study the changes in thermal conductivity by partial substitution of tellurium (Te) with Tin in $Se_{60}Te_{40-x}Sn_x$ alloy with different concentrations of Tin (0, 5, 10, 15, and 20) and the mechanisms of thermal conductivity in chalcogenides are reviewed. Extraction of the thermal conductivity coefficient for each Tin substituted value for $Se_{60}Te_{40-x}Sn_x$ glasses with different Tin concentrations. We also study the change in the electrical resistance.

2.Materials and Methods

The study aims at conducting the process of preparing the alloy with the chemical formula $Se_{60}Te_{40-x}Sn_x$ with different concentrations of Sn (0, 5, 10, 15, 20) by melting point method. The chemical elements Se, Te, and Sn were taken at high purity (99.999%). The alloy elements were weighted according to the atomic weight ratio and the addition ratios x = 0, 5, 10, 15 and 20. The above chemical elements were mixed using an alcohol solution, and then the elements were ground using an electric grinder for half an hour. The mixture was placed in an oven at 100 °C for drying. Samples collected in the form of pellets (1.5 cm in diameter and 0.25 cm in thickness) are obtained by compressing the fine powder of glass ingots under a load of about 7 tons using hydraulic pressure.

The tablets were placed in quartz ampoules, deflated, and sealed under a 10-4 swelling vacuum to prevent any reaction of the alloy elements with oxygen at higher temperatures. The ampoules were heated to 1000 °C at a furnace rate of 4-5 K/min. The temperature was heated up and kept for 2½ hours. After the above period, the prepared vitreous material was removed from the ampoules by crushing it. The molten material was extracted and ground with a slurry for half an hour, after which it was pressed using a hydraulic press of less than 5 tons.

After this process, disc-shaped samples were obtained, with the chemical formula as follows when x=0 (Se_{60} Te_{40}), x=5(Se_{60} Te_{35} Sn_5), x=10 (Se_{60} Te_{30} Sn_{10}), x=15 (Se_{60} Te_{25} Sn_{15}) and x=20(Se_{60} Te_{20} Sn_{20}).

Thermal conductivity was checked using a Lee disk, and samples were placed in the apparatus shown in Figure 1. Each sample was placed between two copper disks, and each copper disk was connected to a thermocouple. The reading of each thermocouple and the application of Equation 1 were recorded and

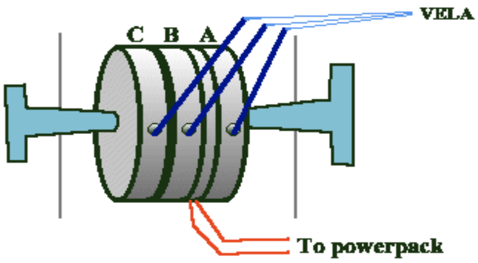

Figure 1. diagram of Lee's disk.

A value of thermal conductivity coefficient of the specimens (K) of a thickness (ds) and radius (r) is calculated by using the equation (1) [13].

$$K\left(\frac{TB-TA}{ds}\right)= e\left[TA+\frac{2}{r}\left(dA+\frac{1}{4}ds\right)TA+\frac{dsTB}{2r}\right] \qquad (1)$$

Where ds, dA, dB,dC: are thickness of the sample, disks A, B, C (mm), TA, TB,TC: are temperature of the disks A, B, C (°C) and e: heat loss in (sec/cm2), the results were recorded.

Electrical resistance was examined as a function of temperature, samples were placed in a mold, and each sample was connected to a wire without resistance. Each sample was connected through two electrodes and connected these wires to the voltmeter, ammeter, and thermocouple placed on the sample. The sample was placed in the oven, and its temperature was raised from 303-455 K. The voltage and current were read as a function of temperature, and the results were recorded. Then the electrical resistance was found as a function of temperature through the relationship (ρ = RA / t), where R = v / I [15, 16].

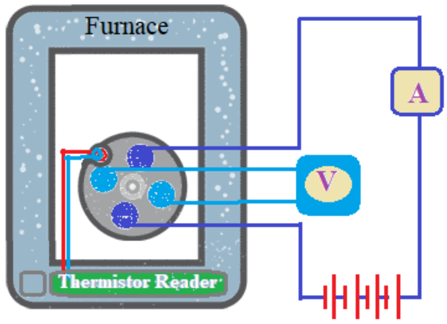

Figure 2. diagram of electrical circuit

3. Results and Discussion

A Lee disc was used to calculate the thermal conductivity by placing each of the five samples under experiment between the three discs in **Figure 1**. The temperature of the disc contacting the electric heater and the two discs in contact with the sample sandwiched between them were calculated by three thermocouples TA, TB, TC, respectively. Through these readings, the thermal conductivity was calculated, after it was calculated in Equation 1.

The thermal conductivity was plotted as a function of temperature for all samples of alloys Se60Te40-x and for all values of x, as shown in **Figure 2. Figure 2** shows the thermal conductivity temperature dependence of the Se_{60} $Te_{40-x}Sn_x$ glass system (withx = 0, 5, 10, 15, 20) as a function of temperature. The reading obtained indicates that the Se_{60} $Te_{40-x}Sn_x$ samples are semiconductors with thermal conductivity behavior that changes with temperature. It was found that the behavior of the samples takes the behavior of a straight line, but the increase in the concentration of Tin Sn led to a change in the thermal conductivity. This behavior is expected because the tin element is a good conductor of heat. When the chemical elements constituting the alloy have equivalent bonds, the thermal conductivity increases. But, if there is an unevenness, it generates drooping bonds that reduce the thermal conductivity and this is what is observed through the results listed in **Table 1**. and **Figure 1.** [17-18].

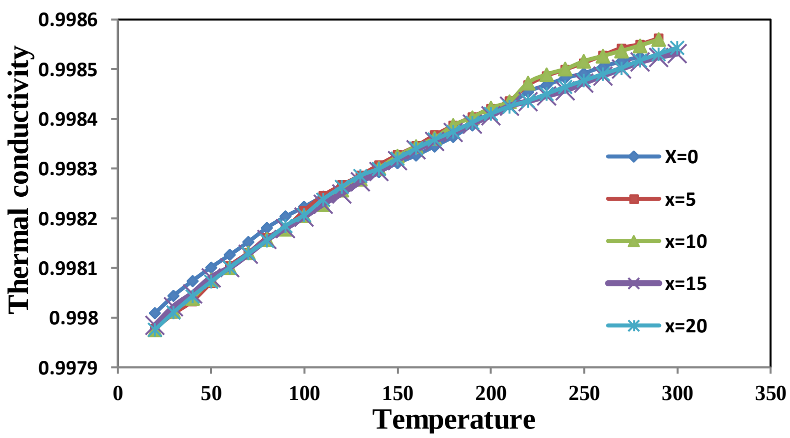

Figure 3. thermal conductivity is represented as a function of temperature of the $Se_{60}Te_{40-x}Sn_x$glass system (x = 0, 5, 10, 15, 20)

The thermal conductivity K of the glass alloy Se60Te40-xSnx was calculated at temperatures of 50, 100, 150, 200, 250, 300, and 350 °C for each tin concentration value (x = 0, 5, 10, 15, 20) and included in **Table 1.** The results show that the values of thermal conductivity K at different temperatures change when the concentration of Sn increases. These results agree with the reference because increasing any metal element in the alloy changes the thermal conductivity. After all, metals have a high thermal conductivity [19].

Table 1. Represents thermal conductivity K and the concentration of Sn of the $Se_{60}Te_{40-x}Sn_x$glass system (x = 0, 5, 10, 15, 20)

X	K(W/m.K)at 50	K(W/m.K)at 100	K(W/m.K)at 150	K(W/m.K)at 200	K(W/m.K)at 250	K(W/m.K)at 300
0	0.22073	0.09811	0.04906	0.63212	0.0211	0.01785
5	0.0097	0.0028	0.0016	0.001	0.008	0.007
10	0.009	0.0029	0.0017	0.0013	0.001	0.009
15	0.2078	0.0803	0.0471	0.0346	0.0276	0.0236
20	0.1682	0.0706	0.0364	0.0276	0.0217	0.0186

Figure 3 represents the thermal conductivity K as a function of the concentration of Sn, which can be seen from the figure. When the concentration of Sn is 0 in the sample, the value of K is the largest possible as it is equal to 0.09811 (W / m.K). When the concentration becomes 5 and 10, we notice that the values of K fall as low as possible as they take the values 0.0028 and 0.029 (W / m.K). When adding a concentration of Sn by 15, we notice changes in the value of K equal to 0.0803 (W / m.K). When the concentration of Sn is 20, the K value is 0.0706 (W / m.K). This is due to the formation of equivalent bonds that lead to an increase in thermal conductivity or unevenness, which generates hanging bonds that reduce thermal conductivity, which depends on the values of tin added to the alloy, as noted in **Figure 3.** [19]

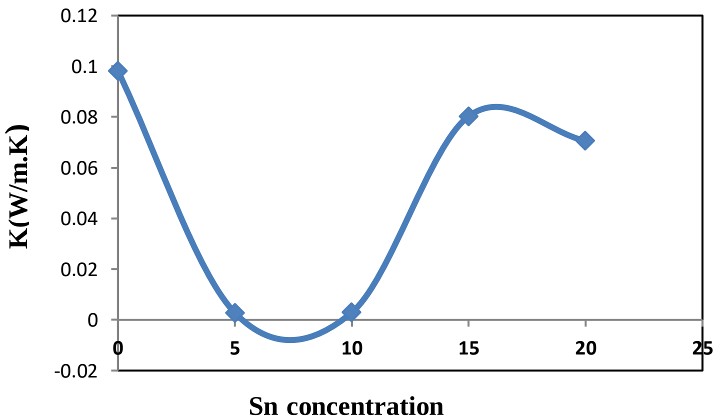

Figure 4. thermal conductivity K as a function of Tin concentration for $Se_{60}Te_{40-x}Sn_x$ alloy

The electrical resistivity (rd.c) was calculated as a function of temperature for all samples. Using two-point probe techniques in the dark electrical resistivity measurements of Se60Te40-xSnx glasses for all values made in the temperature range 303-455 K. as shown in **Figures (5-9)**[20].

Figure 5 represents electrical resistance as a function of temperature. It also represents the pure state of the Se60Te40-xSnx alloy when x is equal to zero without additives. It can be seen that with increasing temperature, the electrical resistivity increase.

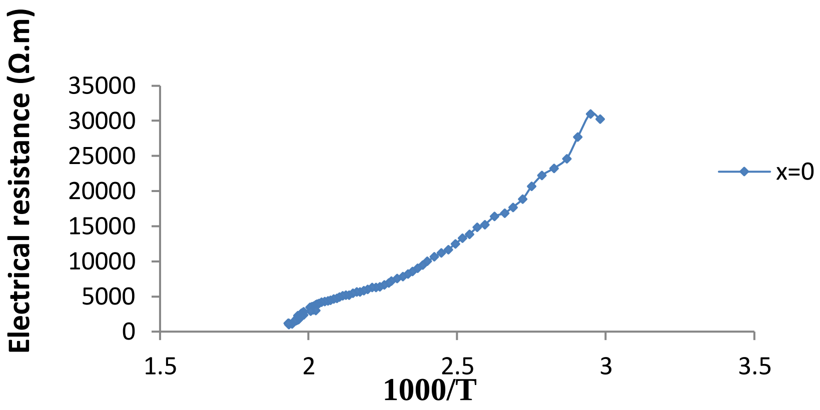

Figure 5. electrical resistance as a function of temperature of of the $Se_{60}Te_{40-x}Sn_x$ glass system (x = 0, 5, 10, 15, 20)

Figure 6 represents electrical resistance as a function of temperature of the $Se_{60}Te_{40-x}Sn_x$ alloy. This figure shows the electrical resistance dependence of the Se_{60} $Te_{40-x}Sn_x$ glass system when x equal to 5, and it can be seen that with increasing temperature, the electrical resistance increase.

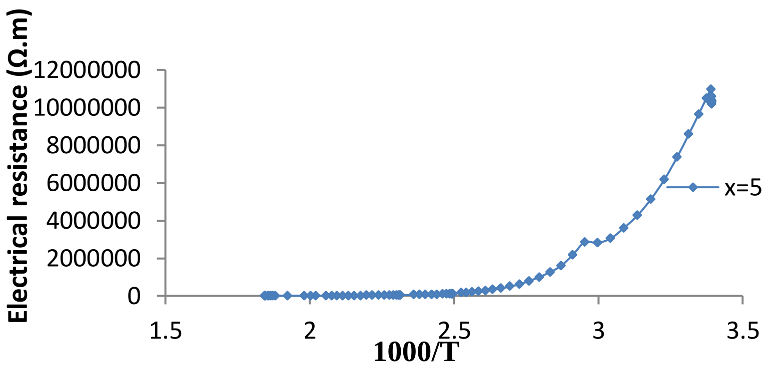

Figure 6. Electrical resistance as a function of temperature of of the $Se_{60}Te_{40-x}Sn_x$ glass system (x = 0, 5, 10, 15, 20)

Figure (7) represents electrical resistance as a function of the temperature of the Se60Te40-xSnx alloy when x is equal to 10. From this figure, it found that with increasing temperature, the electrical resistance increase.

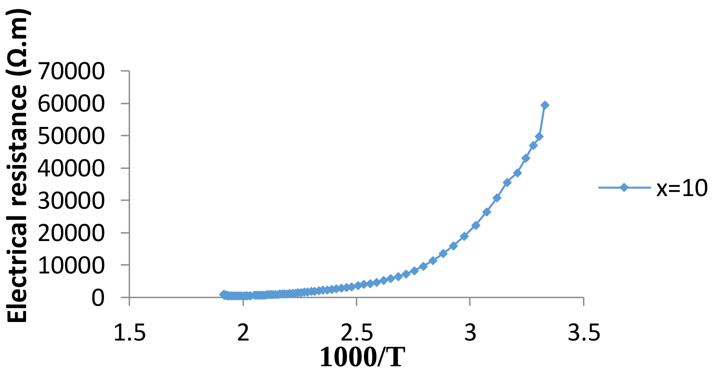

Figure 7.electrical resistance as a function of temperature of of the $Se_{60}Te_{40-x}Sn_x$ glass system (x = 0, 5, 10, 15, 20)

Figure 8 represents electrical resistance as a function of the temperature of the Se60Te40-xSnx alloy. This figure shows the electrical resistance dependence of the Se60 Te40-xSnx glass system when x is equal to 15, and it can be seen that with increasing temperature, the electrical resistance increase.

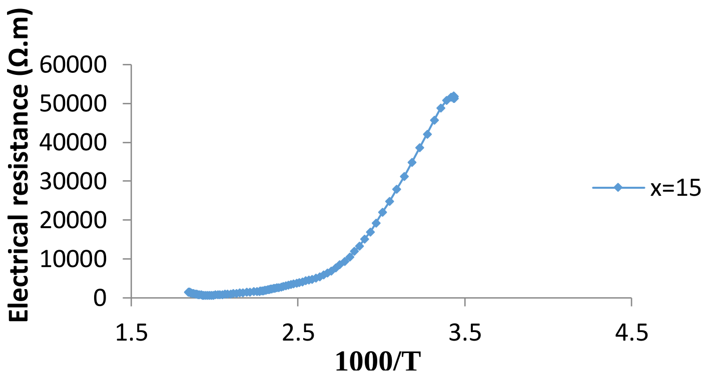

Figure 8. electrical resistance as a function of temperature of of the $Se_{60}Te_{40-x}Sn_x$ glass system (x = 0, 5, 10, 15, 20)

Figure 9 represents electrical resistance as a function of the temperature of the $Se_{60}Te_{40-x}Sn_x$ alloy. This figure shows the electrical resistance dependence of the Se_{60} $Te_{40-x}Sn_x$ glass system when x is equal to 20, and it can be seen that with increasing temperature and the electrical resistance increase.

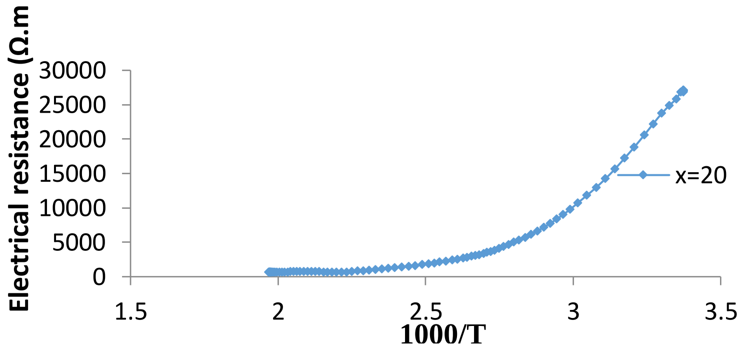

Figure 9. electrical resistance as a function of temperature of of the $Se_{60}Te_{40-x}Sn_x$ glass system (x = 0, 5, 10, 15, 20)

For all samples above, the electrical resistance was found as a function of temperature through the relationship ($\rho = RA / t$), where $R = v / I$, electrical resistivity depended on the change in Tin addition. This was because all samples, despite the partial replacement of trillium with tin, did not change the behavior of the alloy as it maintained its behavior as a semiconductor material. The temperature is clearly affected by the increase in the concentration of tin in the alloy. Also, the electrical resistance increased when the concentration of Tin increases of $Se_{60}Te_{40-x}Sn_x$.This decrease in the electrical resistance was due to the rise in the concentration of Tin and the fact that the Tin is a metallic element with a high conductivity like other metals. It has a low resistance, causing an increase in its concentration in the alloy to a decrease in electrical resistance. The best samples that gave the best results were the Se_{60} $Te_{40-x}Sn_x$ glass system when x was equal to 10 and 20

4. Conclusions

In this paper, the effect of partial substitution of tellurium with tin in the alloy $Se_{60}Te_{40-x}Sn_x$(where x= 0, 5, 10, 15 and 20) was prepared and studied by the melting point method. The thermal conductivity was calculated as a function of temperature. It was found that the thermal conductivity increased with the increase in the concentration of Sn and the value of K at a different temperature increased and decreased when the concentration of Sn increased of Se_{60} $Te_{40-x}Sn_x$.This behavior occurred because the tin element was a good conductor of heat. When specific values increased, it had equivalent bonds with the chemical elements that made up the alloy. The thermal conductivity increased, but if values exceeded the required limit, this disparity generated dangling bonds that reduced thermal conductivity. The electrical resistivity ($\rho_{d.c}$) was calculated as a function of temperature for all samples. The electrical resistance increased when the concentration of Tin increased of $Se_{60}Te_{40-x}Sn_x$ with different x.

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