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Temperature Dependent Electrical Study of $Ge_{17}Se_{74}Sb_9$ Thin Film

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Abstract: Bulk sample of $Ge_{17}Se_{74}Sb_9$ alloy was prepared using melt-quench technique. Thin film of the alloy was deposited using thermal evaporation. Thin film was characterized by x-ray diffraction and current-voltage measurements were obtained at different temperatures ranging from 298K to 348K at a step of 5K using an electrometer and were found to be ohmic in nature. The temperature and voltage dependence of resistivity of thin film has been studied.

Keywords: Chalcogenide glasses; Resistivity; Activation energy.

1 Introduction

Continuous progress in chalcogenide glasses has imposed either new or an improvement in their properties. Chalcogenide glasses have the major advantage that these can be synthesized in any batch or compositions using the traditional melt quench technique. These glasses are finding applications in infrared optical elements, infrared optical fibres, switching and memory devices, solar cells, phase change optical recording media [1,2,3,4,5,6,7]. Among various chalcogenide glass compositions $Ge-Se-Sb$ system is of quite interest due to its high transparency in 2 m to 14 m region and high nonlinear optical properties [8,9,10]. Although $Ge-Se-As$ system shows very good properties in III-IV-VI chalcogenide glasses but working with As is health hazardous [11]. The replacement of As with Sb also shows nearly similar properties [12,13]. Moreover, $Ge-Se-Sb$ system has relatively lower vapour pressure in comparison to $Ge-As-Se$ system [14].

Among various $Ge-Se-Sb$ glassy compositions we have taken $Ge_{17}Se_{83}$, as it is the bearer of short range order of initial components and also exhibit compound short range order formed from both the initial components [15]; then Se is replaced with Sb. The usefulness of these glassy systems lies on the ability to engineer their properties to meet the particular demands. The tailoring of these glasses for their particular properties is possible but we are not having enough data of these glassy systems so as to choose them according to compositions. Authors have already reported the physical, optical and structural bonding arrangements for the above said system [16,17,18].

In the present communication, our aim is to develop a basic understanding on the temperature dependent electrical properties. We have investigated the $Ge_{17}Se_{74}Sb_9$ thin films for their intrinsic dark dc resistivity and other electrical parameters using the temperature dependent current-voltage studies.

2 Experimental details

Glassy composition of $Ge_{17}Se_{74}Sb_9$ alloy has been prepared by using the well-known melt quench technique. The details of experimental procedure may be seen elsewhere [16,17,18]. The thin film of this glassy composition has been deposited using the thermal evaporation at a base pressure of $\sim 10^{-5}$ mbar (Hindhivac Model No. 12A4D). The thickness of the deposited solid film was monitored during depositions by using a thickness monitor (DTM-101) and it was kept at 600 nm. The composition of the deposited thin film has been checked by an electron microprobe analyzer (JEOL 8600 MX) on different spots (size $\sim 2\mu$m) and was uniform within the measurement accuracy of about $\pm$1.5-2.0%. The bulk as well as the thin films of the samples prepared were characterized by the x-ray diffraction (XRD) technique (Philips PW 1710 x-ray diffractometer, Cu Kα

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radiation, λ = 1.540 598 $\AA$, 40 kV and 35 mA, 2θ range from 5° to 100°, step size = 0.017°). The XRD spectrum has been given elsewhere for $Ge_{17}Se_{74}Sb_9$ thin film [16].

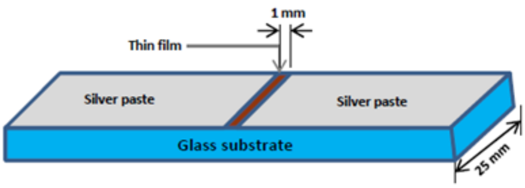

Fig. 1: Schematic of thin film used for electrical characterization.

A schematic of thin film used for the electrical measurements is shown in figure (1). Keithley's electrometer (model 6487) has been used to record the current-voltage measurements of thin film. The thin film has been put into a specially designed sample holder, in which a vacuum of 10-3 *mbar* was maintained throughout the measurements. The experiments were performed at different ambient temperatures (298K to 348K at a step of 5K) using a PID temperature controller. At least five minutes stabilization time was put into action at each temperature before performing the I-V measurements.

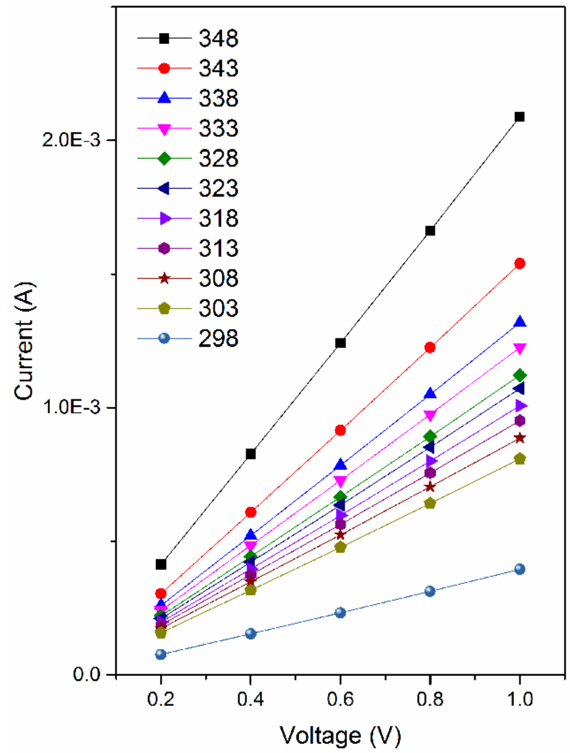

Fig. 2: Variation of current with applied voltage for the $Ge_{17}Se_{74}Sb_9$ thin film at different temperatures.

3 Results and Discussion

The X-ray diffraction pattern for the $Ge_{17}Se_{74}Sb_9$ thin film shows no prominent peak which indicates the amorphous nature of the thin film deposited on the glass substrate [16].

The I-V curves at different temperatures have been plotted in Figure (4). The electric field across the thin film sample is assumed to be uniform. The plots of the I-V curves have been observed to be straight lines for all temperatures, which clearly indicate the ohmic nature of conduction. The slope of the I-V curves varies with temperature. The increase in the slope is less for lower temperatures (298K - 338K), but increment in slope gets enhanced for high temperatures i.e. 343K - 348K. The slope at 338 K has been observed to be almost three times that at room temperature i.e. 298K. This is due to the reason that the density of charge carriers goes on increasing as the density of the thermally generated charge carriers increases with increase in temperature[19]. The current due to the charge carriers remain ohmic despite of increase in temperature. This may be due to the narrow range of voltage applied across the thin film sample. The slopes of the I-V curves at different temperatures have been used to calculate the resistivity of the sample. The resistivity across the thin film sample decreases with temperature for the investigated range of applied potential difference. The resistance of the sample at the given voltage (say 1 volt) drops by more than five times with increase in temperature.

The figure (3) shows the variation of resistivity with increasing temperatures across the thin film under study. The resistivity of the film goes on decreasing with an increase in applied voltage at all the temperatures. The voltage dependence of resistivity decreases with an increase in temperature. The d.c. resistance (R) is calculated from the slopes of I-V curves in figure (3) and using the formula ($R = \rho l/A$), the d.c.resistivity (ρ), is calculated and has been plotted in figure (4).

There are predominantly three basic mechanisms for conduction in chalcogenide glasses. Firstly, the band conduction of the electrons excited above the conduction band and the holes below the valence band which is predominant when the density of states and the mobility of carriers is having lesser dependence on the temperature [20,21]. The conductivity curve may have two slopes with carrier being predominant at lower temperature and the other at higher temperature. Secondly, the conduction takes place by thermally assisted conduction through the tunneling in the localized gap states near the mobility edges in the donor and acceptor bands. This thermally assisted tunneling is aided by hopping in addition to the activation energy required to excite the electron to the localized states [20,21].The slope of the conductivity curve decreases as the temperature decreases. Lastly, the conduction takes place through tunneling near the Fermi level defined by the

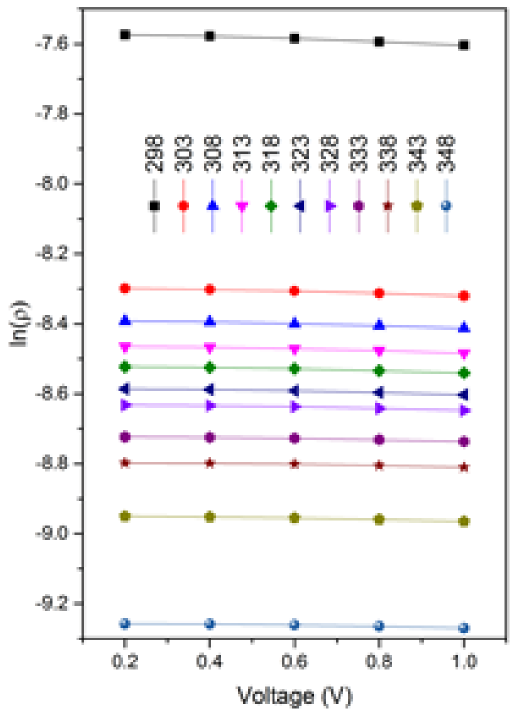

Fig. 3: Variation of resistivity with voltage at different temperatures for the $Ge_{17}Se_{74}Sb_9$ thin film.

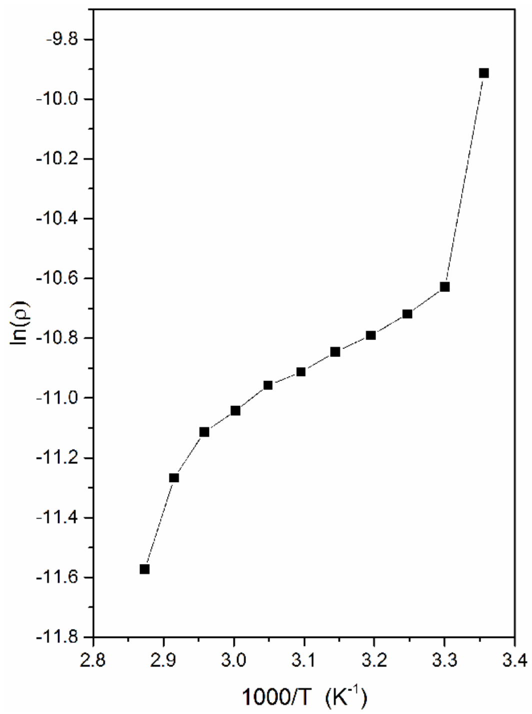

Fig. 4: Variation of resistivity of the $Ge_{17}Se_{74}Sb_9$ thin film sample with temperature at an applied potential difference of 1 volt.

variable range hopping mechanism to the energy states which are having energy close to the thermal energy [20, 21, 22, 23].

The plot of $\ln(\rho)$ vs $1000/T$ in figure (4) clearly indicates the semiconducting nature of the samples. The resistivity decreases with increase in temperature for the thin film sample. The slope of the linear variation of resistivity in figure 3 has been used to calculate activation energy (E_a). The activation energy for carrier excitation and the pre-exponential factor ρ_0 have been evaluated using the relation [24], where Δ is the activation energy required for the charge carriers to move from the valence band. The variation of activation energy with applied voltage has been plotted in figure (5). The figure clearly indicates that the activation energy for conduction goes on decreasing with increase in the potential difference applied across the thin film from 0.2V to 1.0 V.

4 Conclusion

The I-V characteristics of the $Ge_{17}Se_{74}Sb_9$ thin film have been studied. The linear nature of the I-V curves in the narrow range of applied potential difference across the $Ge_{17}Se_{74}Sb_9$ thin film essentially indicate the ohmic nature of the conduction. The resistivity of the studied film decreases with increase in temperature indicating the semiconducting nature of the thin film. The activation energy decreases with an increase in the voltage applied across the thin film.

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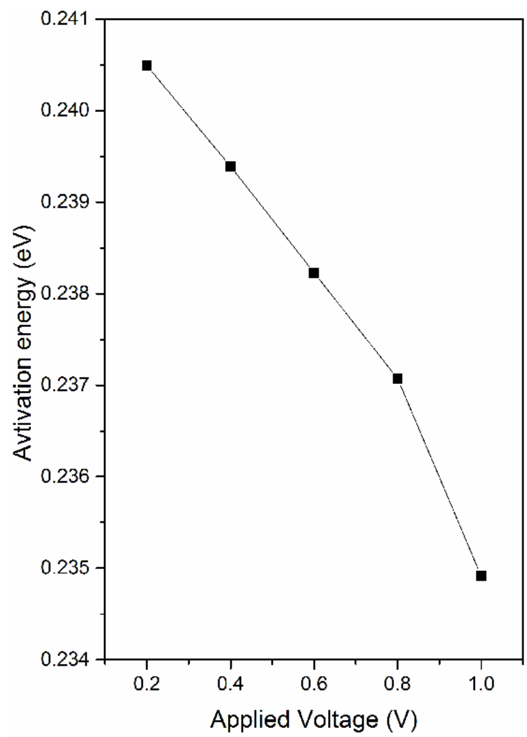

Fig. 5: Variation of activation energy with the applied potential difference across the $Ge_{17}Se_{74}Sb_9$ thin film.

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