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TEMPERATURE EFFECT ON THE TURN OVER POINTS OF THE I-V CHARACTERISTICS OF Se_{100-x} - Sb_x

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ABSTRACT

The I-V characteristics of the amorphous material Se_{100-x} - Sb_x, where x=5, 10, 15 and 20, were measured at different ambient temperatures. The increase of the ambient temperature from 299°K to 338°K leads to the rise of the conduction path temperature to be in the range 335-384°K. This in turn leads to the shift of the turn over points to up left direction.

INTRODUCTION:

The marked decrease in the resistivity on heat treatment, of the memory type glass, is an indication on the phase transformation[1]. This fact supports the view that switching to a permanent low resistance state in the bulk glass is associated with formation of more ordered filament between electrodes[1]. The electrical properties of the glassy system Ge-Sb-Se were found to be composition dependent[2]. Increasing antimony content in glasses lead to a gradual increase in the electrical conductivity and a decrease in the thermal activation energy, which suggest a change in the mobility gap. Two different mechanisms were found to be responsible for the reduction of the mobility gap. According, to Kastner[3], the appearance of the As-As bonds in the glassy As_2 Se_3 leads to the broading of the conduction band. On the other hand, the presence of antimony near selenium tends to broaden the valence band. Both of these mchansims could be effective in the reduction of the thermal activation energy. The change of the temperature of the amorphous Semiconductors causes the change in the mobility gap as well as the number of charge carriers[4-6]. In non-crystalline semiconductors the presence of localized states in the forbdden energy gap affect greatly the electrical properties[7].

The aim of the present work is to investigate, the effect of the ambient temperature on the turn over points (T.O.P) of the I-V characteristic of the system Se_{100-x}-Sb_x, where x = 5, 10, 15 and 20. The effect of the ambient temperature on the temperature of the conduction path, as well as on the forbeddin energy gap will be reported.

EXPERIMENTAL TECHNIQUE:

Appropriate mixture of 99.99% pure Se and Sb were sealed in quartz tubes under vacum. The tubes were kept at 550°C for 8 hours. During the course of heating, the tubes were shaken several times to maintain their uniformity. Finally, the tubes were quenshed in water coolded, the absence of the x-ray diffraction lines, confirm the glassy state of the ingots.

The I-V characteristics of the system Se_{100-x}-Sb_x, where x = 5,10,15 and 20, were recorded, using perviously published technique[8-9], under the effect of different ambient temperatures.

RESULTS AND DISCUSSION:

The I-V characteristic curves of the amorphous Se_{100-x}-Sb_x, where x = 5, 10, 15 and 20, were recorded at different ambient temperatures, Fig. ($1_{a,b,c}$ & $_d$). These compositions will be named 5, 10, 15 and 20. The I-V characteristics of composition 5, was linear and unaffected by increasing the ambient temperature upt to 60°C (Just below the glass transition temperature[10]). The I-V characteristics of the other compositions (10, 15 and 20) could be divided into three states. The turn over point (T.o.p) separate the off state (first state) from the current controlled negative resistance state (C.C.N.R). The third state, starts at the crystallization point (I_c, V_c), where I_c is the crystallization current and V_c is the crystallization voltage. The retracing of the I-V relation at the same ambient temperature is possible if the current passing through the sample is less than twice the current at the turn over point (2 $I_{T.o.p}$). This means that there is no possibility of phase transformation below 2 $I_{t.o.p}$. At current values greater than 2 $I_{T.o.p}$ and below I_c the process of nucleation starts and a hysteresis would be expected on retracing the I-V relation. At point (I_c, V_c) the nucleated conduction path will be transformed into a highely conductive crystalline state and that is why the third state is called the "ON" state.

Fig. ($1_{b,c\ \&\ d}$) shows that the turn over point shifts up to the left direction as ambient temperature increases i.e $V_{T.o.p}$ dcreases. This behaviour is normal for most of the amorphous materials, but we wish to add here that the real temperature of the conduction path is the summation of the ambient temperature (T) plus the rise in temperature (ΔT_J) due to Joule heating. The rise in temperature due to Joule heating is given by[9].,

$$(\Delta T_J) = \frac{KT^2}{E-KT} = \frac{KTT^{*}}{E}$$

where T is the ambient tmperature, T^{*} is the corrected temperature of the conduction path, k is the Boltzmann's constant and E is the activation energy of conduction.

The increase in (ΔT_J) with ambient temperature, table (1), may be due to the increase in the vibrational amplitude of atoms as the ambient temperature increases. This in turn causes an increase in the number of collisions between charge carriers and network atoms. As a result the forbidden energy gap decreases due to the rise in the temperature of the conduction path. This may lead to the observed shift of the turn over point to the up left direction on the I-V curves as the ambient temperature increases.

Another-veiw can be used to Explain the behaviour of the turn over point: It is necessary to remember that any amorphous ingot may contain dipoles scattered at random through the amorphous matrix. The dipoles present in the conduction path will be oriented gradually along the direction of the applied electric field. The degree of the allingment depends on the viscosity of the amorphous matrix as well as the strength of the electric field. As the voltage increases during the off state, the temperature of the conduction path rises due to Joule heating. This cause a decrease in the viscosity of the material of the conduction path. Consequently, the prefered oriention of the dipoles will increases gradually along the off state, till it reach a maximum value at the turn over point. At the turn over point, the force from the electric field will be equale to the restoring force due to viscosity at the given ambient temperature. As the ambient temperature increases the Joule heating will increases and the viscosity will decreases and the field required to cause a maximum prefered orientation will decreases. This explain why the turn over voltage shift to lower values as the ambient temperature increases. In other words the turn over point will be defined as the point on the I-V curve at which the restoring force due to viscosity (η) balances the force strength from the electric field. Consequently, the $V_{T.O.P}$-T curve resembles to some extent the η-T curve. Fig. (2), shows the two relations.

As, the ambient temperature increases the cross-sectional area of the conduction path increases and one expect too many dipoles to make contribution in the conduction path. This may explain why the $I_{T.O.P.}$ increases as the ambient temperature increases.

The above arguments were suggested to explain why the turn over curve shifts to up left direction as the ambient temperature increases and more informations are required to confirm this view.

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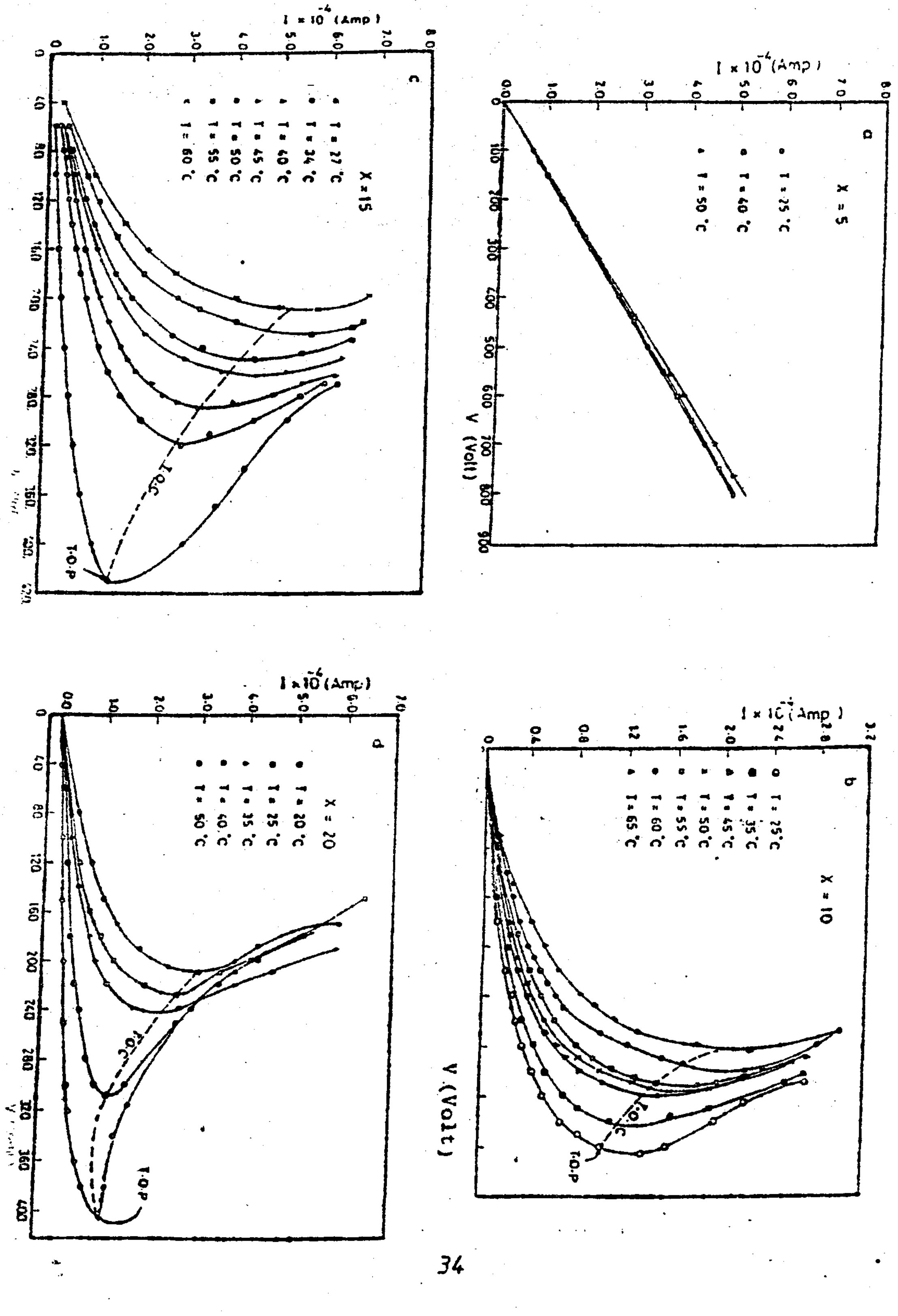
I × 10^-4 (Amp)
V (Volt)
a
X = 5
T = 25 °C
T = 40 °C
T = 50 °C
b
X = 10
T = 25 °C
T = 35 °C
T = 45 °C
T = 50 °C
T = 55 °C
T = 60 °C
T = 65 °C
T.O.C
T.O.P
c
X = 15
T = 27 °C
T = 34 °C
T = 40 °C
T = 45 °C
T = 50 °C
T = 55 °C
T = 60 °C
T.O.C
T.O.P
d
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T = 50 °C
T.O.C
T.O.P

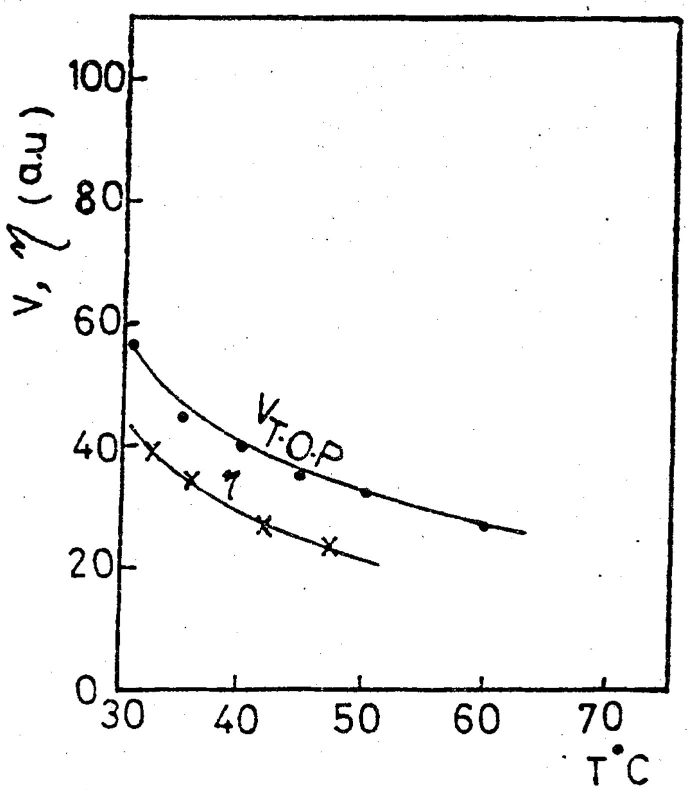

Fig.(2)

Table (1)

X	TK°	(ΔT_J)	T" K°
10	299	36.04	335.04
	308	38.38	346.38
	318	41.07	359.07
	323	42.46	365.46
	328	43.88	371.88
	333	45.32	378.32
	338	46.78	384.32
15	307	19.18	326.18
	313	19.96	332.96
	318	20.63	338.63
	323	21.99	349.99
	333	22.60	355.69
20	293	14.66	307.66
	298	15.18	313.18
	303	15.71	318.71
	308	16.24	324.24
	313	16.79	329.79
	318	17.34	335.34
	323	17.91	340.91