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# Electrical and Switching Properties of Ge $Se_{1.5}$ $Tl_{0.1}$ thin Films

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## ABSTRACT

Ge $Se_{1.5}Tl_{0.1}$ were prepared as a bulk material by direct fusion of stiochoimetric proportions of constituent elements. Then , Ge $Se_{1.5}Tl_{0,}$ thin films were deposited under vacuum on highly polished pyrographite substrates by thermal evaporation. The obtained results for the temperature dependence of Ge $Se_{1.5}$ $Tl_{0.1}$ Thin film resistance were taken at different film thicknesses (220,401,and 506 nm). The obtained value of the calculated conduction activation energy is (0.72 eV) Static (I-V) characterstic curves were also obtained at room temperature for Ge $Se_{1.5}Tl_{0.1}$ amorphous thin films .The behavior of the obtained curves formed of low and high conduction branches following the load line of typical (I-V ) characterstic curve for a memory switch. The dynamic (I-V) characterstic for Ge $Se_{1.5}$ $Tl_{0.1}$ films were obtained by using an a.c source. The obtained dynamic (I-V) curve is also typical for a memory switch .

**Key words:** Electrical and Switching Properties , Ge $Se_{1.5}$ $Tl_{0.1}$ Thin Films.

## INTRODUCTION

Amorphous semiconductrs are disordered materials . Its structure is characterized by the complete absence of the long range order and the existence of short – range order. In recnt years , considerable attention has been focused on amorphous semiconductors especially those knownas chalcogenide glasses due to their numerous industrieal applications . chalcogenide glasses are amorphous semiconductors synthesized on the basis of elements of VI group of the periodic table ( S , Se , and Te , That so called chalcogen).

The addition of thallium to chalcogenide glasses is generally accompanied by a marked change in their structural and physical properties and attracted much attention because of their potential applications in acousto – optical devices On the other hand the discovery of nondestructive switching in thin films of interest on the physics of non – crystalline semiconductors generally. Cetain amorphous semiconducters have shown interesting electrical effects involving sudden change in resistance . These are generally grouped as switching propertjes. Typical materials which show those properties are those properties are the chalcogenide glasses. lts is now more than two decades sincs the first demonstration of switching and memory devices based on chalcogenide glasses have been reported by ovshinsky.

In chalcogenide glass memory devices , the memory action is the result of a reversible structure change between an amorphous state , which is of high – resistance , and a small grain crystalline state, which is of low – resistance This structure change takes place in the region of the ON – state filament . The transformation to the microcrystalline state occurs during the lock – on period after the device has switched to the ON – state and the current filament has formed The joule – heating, the high field and the excess .carrier concentration in the current path are believed to bring about the crystallization. Boer and ovshinsky (…) have shown that phenomenon is inintiated by joule – heating of current channel causing thermal stabilized high electric field effects close to the electrodes which is sufficient for staringe the switching transition. The proposed switching models have been classified into thermal, electronic and electronic modified thermal However the switching mechanism is still controversial.

The aim of this work can be summarized as studying of the switching phenomenon. This study includes determinaion of the electrical conduction activation energy of the as –deposited $GeSl_{1.5}Tl_{o.1}$ thin films deposited on pyrographitc substated, (I-V) characteristic curve of the as –deposited $Ge\ Se_{1.5}\ Tl_{o.1}$ thin films of different thicknesses ,and Thickness dependence of the threshold voltage.

## MATERIALS AND METHODS

### 1-preparation of samples for study.

### 1.1. Synthesis of $Ge_1Se_{1.5}Tl_{o.1}$

Synthesis of $GeSe_{1.5}Tl_{o.1}$ was accomplished in evacuated silica ampoule.The proper amounts for preparing 10 gm of the composition were weighted and introduced into the cleaned silica ampoule which was then evacuated to $10^{-5}$ torr and sealed.

Synthesis was accomplished in an oscillatory furnace The synthesis of the sample was carried out at the following sequence, the temperature was raised to $250^0$c for 1 hr, and then $400^0$c further 2 hrs, and the finally the furnace temperature was gradually raised to $950^0$ and kept at this temperature for about 6 hrs.

Long duration of the synthesis and the mechanical shaking of the melt in the oscillatory furnace ensures the homogeneity of the composition .The ampoule was then rapidly quenched in an icy water to obtain the sample in the glassy state .

### 1.2. Thin Films preparation .

Pyiographite substrates of dimension 1x0.5 x 0.2 $cm^3$ were polished and used.

### Evaporation technique:

The preparation of thin film samples for electrical and optical measurements was carried our using the coating unit type (Edwards E306 A) .
The vacuum chamber was pumped down and when vacuum level reached 2 x $10^{-5}$ Torr , the boat was heated gradually by increasing the heating current until the evaporation process started. The thickness of films were measured by quartz crystal thickness monitor thecnique.

### 2. Conduction and swiching phenomena in $Ge_1\ se_{1.5}\ Tl_{0.1}$ Thin Films.

### 2.1. Static I – V characteristic curve.

Static I-V characteristic curve was studied for thin film samples of different thicknesses of $\mathbf{Ge_1\ Se_{1.5}Tl_{0.1}}$ films . Highly cleaned and polished pyrographite substrates were . used for the preparation of these samples as mentioned above. Figure (1) illustrates a schematic representation of the cell used for I-V measurements. The thin film sample was sandwitched between two electrodes of the cell, where the upper is movable and its lower part is made of platinum needle having a circular end of diameter 0.2 mm. The lower electrode is a circular brass disc. A small spring (Fig. 1) to keep the electrode pressure on the surface of the sample constant during measurements. The measurements were carried out using the electric circuit shown in Figure (2). To study I – V characteristic curves at elevated temperatures, the measuring cell with the sample is plased coaxially in cylindrical vertical furnace whose temperature is controlled using a thermostat as will be explained later.

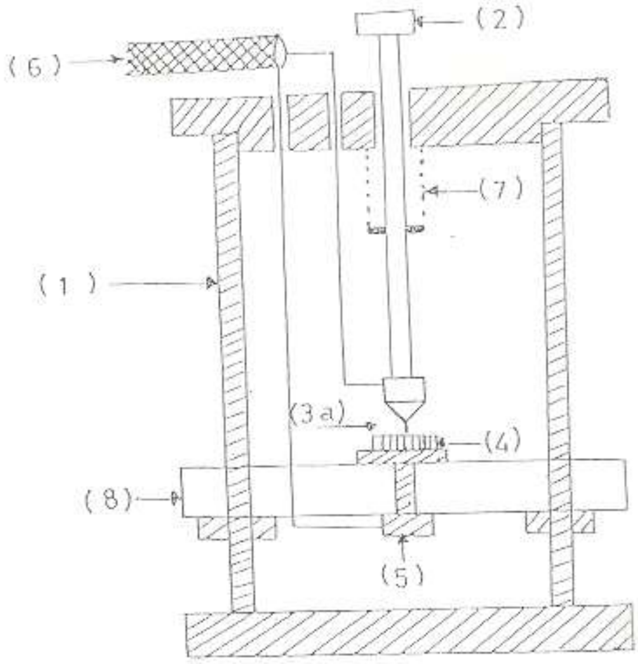


Fig . (1). The holder of switching measurements

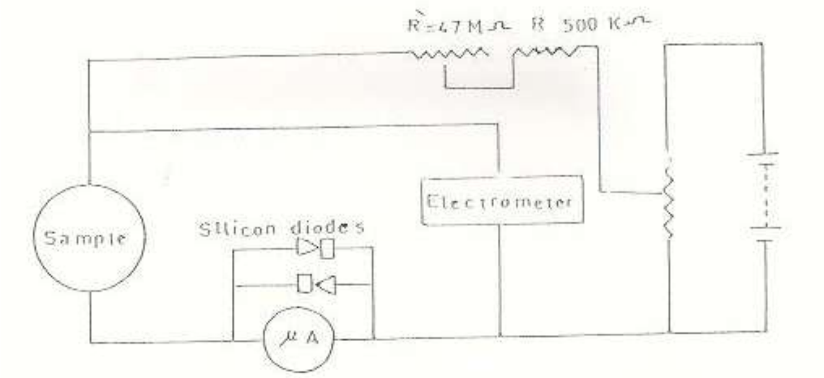


**Fig. (2). The circuit for measuring the static switching**

Increasing the voltage applied to the sample the current passing through it increases slowly at first. At a certain value of the applied voltage (switching voltage v ) The current suddenly increases while the voltage across the sample decreases. During the experiment the readings of the voltmeter and micrometer are recorded and then plotted for each sample, The same procedure is repeated for every sample at room temperature, as well as, at elevated temperatures. These measurements are checked for reproducible date by repeating I-V reading at different times under the same condition. a adigital electrometer (keithly type E616 A) was used for the potential drop measurements and microdigit multimeter (Te 924) was used for current measurements.

**(2.2.) Dynamic (I-V)characteristic curves).**

Figure (3) shows the circuit used for measuring the dynamic I-V characteristic curves where the AC voltage was taken from an autotransformer and the obtained I-V curve was displayed on the screen of the cathode ray oscilloscope (CRO).

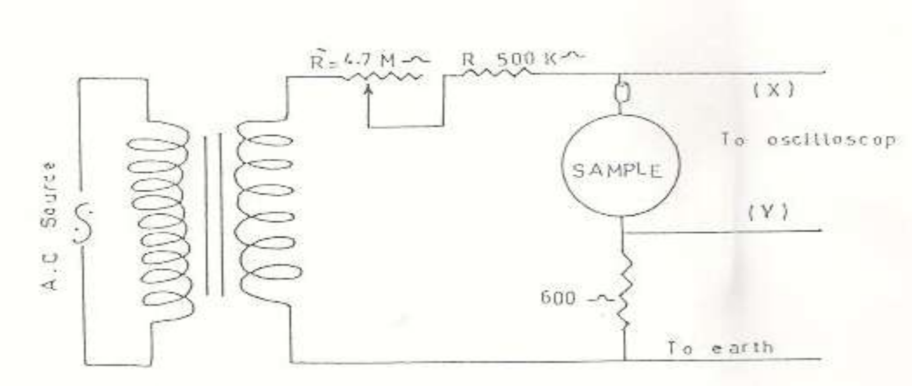


**Fig. (3). The circuit for measuring the dynamic switching**

**(2.3.) The Vertical Furnace**

The furnace used in the switching measurements is show in Figure (4). The main part of the furnace is an iron cylinder whose length is 15 cm , outer diameter is 16 cm and the inner diameter is 16cm. A mica sheet is wound around this cylinder for electrical insulations and a nickel chrome wire is doubly wound to avoid magnetic induction effects . The iron cylinder is placed coaxially inside a cylindrical metallic container, whose diameter and height are 24 and 27 cm respectively . The space between the two cylinders is filled by asbestos powder for thermal insulation The stable zone inside the furnace was determined by measuring the temperature of the composition during synthesis was carried out using a thermocouple placed inside the furnace in contact with the silica tube. .

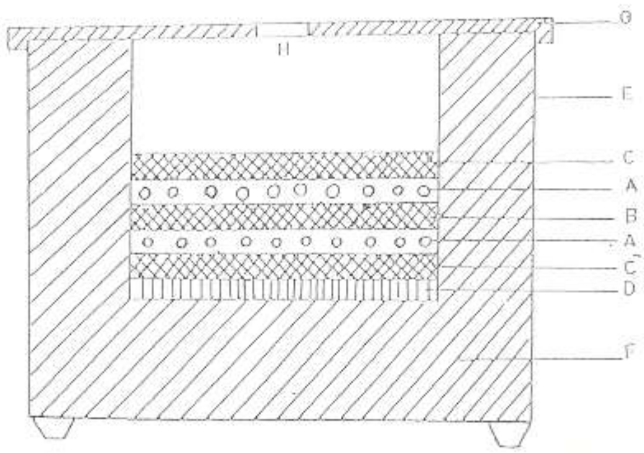


**Fig. (4). The oven used for thin film resistivity measurements at temperatures**

## RESULTS AND DISCUSSION

**Temperature dependence of electrical Resistivity and actvation energy measurements of the as–deposited $Ge_1Se_{1.5}Tl_{0.1}$ thin filme**

The resistance of thin film samples of the investigated compound was measured as a function of temperature in the range (298-373 k) using the circuit given in fig(2-2a)from the static I-V curves. This was performed by simply dividing the value of potential difference across the sample dy the corresponding value of the current passing through it Values of the voltage used in this case must be in the linear part of the corresponding I-V curve. This procedure was repeated at different several points uniformly distributed throughout the whole surface of the film and hence the mean values of sample resistance R was obtained at each temperature value.

Measuring of R at elevated temperature was performed using the vertical furnace The obtained results for the temperature dependence of the film resistance are shown in Figure (5) as in R versus 1000/T for samples of thicknesses 220 nm, 401 nm and 506 nm .

The electrical conduction activation energy ($\Delta E_\sigma$) is calculated from the slopes of the linear part of the curve of Figure (5) and using the following equation :

$R=C \exp (\Delta E_\sigma /KT)$

$R=C \exp (-\Delta E_\sigma /KT)$…………………………….(1)

Where $\Delta E_\sigma$ is the electrical conduction activation energy,C,a constant ,K b oltzmann constant and T temperature of sample .The obtained value for $\Delta E_\sigma$ is (0.72eV)

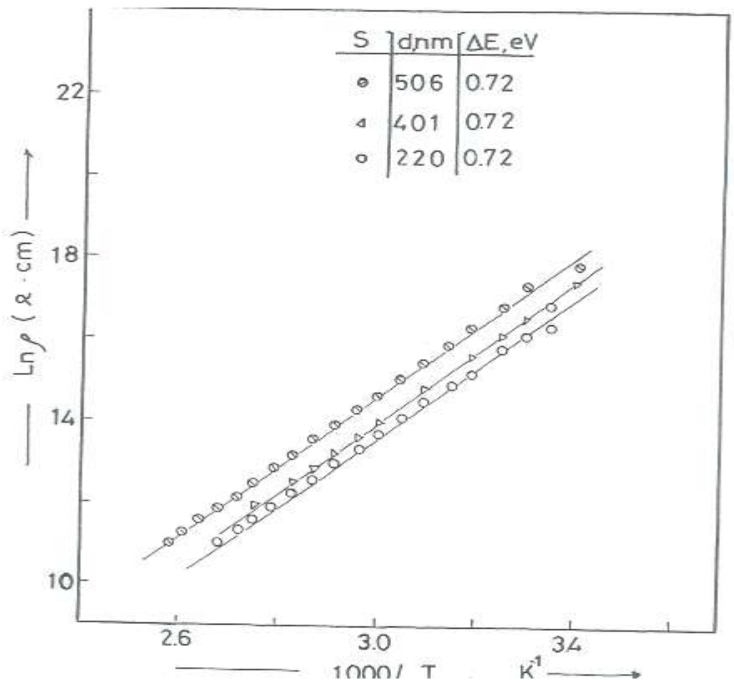


**Fig. (5). The temperature (T) dependence of the conductiviy for $Ge_1Se_{1.5}$ $Tl_{0.1}$ thin fhin at different thicknesses.**

**Static I-V characteristic curve of $Ge_1$ $Se_{1.5}$ $Te_{o.1}$ Thin Films .**

Static I-V characteristic curves were obtained at room temperature for **$Ge_1Se_{1.5}Tl_{o.1}$** amorphous thin film samples deposited on clean highly polished substrates of pyrographite using the circuit shown in Figure (2) and D.C Source. As a representative cxample the obtained static I-V curve of film of thickness 506nm is illustrated in Figure (6).

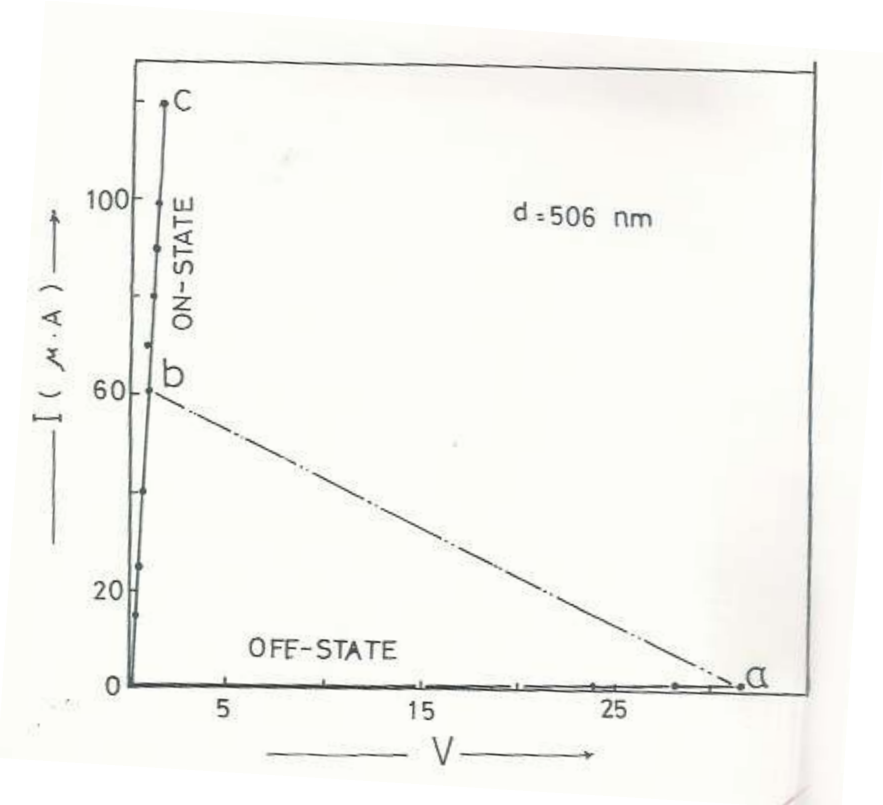


**Fig. (6). The I-Vcharacteristics curve for $Ge_1Se_{1.5}$ $Tl_{0.1}$ thin film before and after switching process of thickness 506.1nm**

It is clear that on increasing the applied voltage, a very small current passes through the film which increases along the region (oa) of the curve. At a certain value of the applied voItage corresponding to point a on the curve, a sudden increase in the current and consequent decrease in voltage takes place i.e. sample switches on. This critical value of the applied voltage is called the threshold voltage and the region (oa)on the curve is called the Off – state of the switch . Since switching process takes place in a very short time (~$10^{-9}$ s), it was impossible to record any reading during this time corresponding to the part (ab) on the curve. Thus, current and voltage values could be recorded only at the beginning and at the end of the switching process (point a , b on the curve). Further increase in the applied voltage increases the current passing through the sample without any significant observed increase in the potential drop across the sample (the part bc) . This part is called ON state of the switch . When the the voltage applied in the sample in the ON state at point C decreases the current decreases following the load line along the part co. The behaviour of this obtained curve being formed of a low and high conducting branches (oa and bc) connected by two branches (ab and co) following the load line makes it typical I-V characteristic curve for a memory switch .

**Dynamic I-V Characteristic curve of $Ge_1$ $Se_{1.5}$ $Tl_{0.1}$ thin films.**

The dynamic I-V characteristic curves for **$Ge_1$ $Se_{1.5}$ $Tl_{0.1}$** films were obtained using a.c. source and the electrie circuit given above in Figure (3) . As a representative example the obtained dypamic I-V curve for film of thickness 506 nm is given in Figure (7) . The lower photo of Figure (7) represents the high resistive OFF- state and the upper photo represents the high conductive ON – state. As clear, the obtained dynamic I-V curve is also typical for a memory switch .

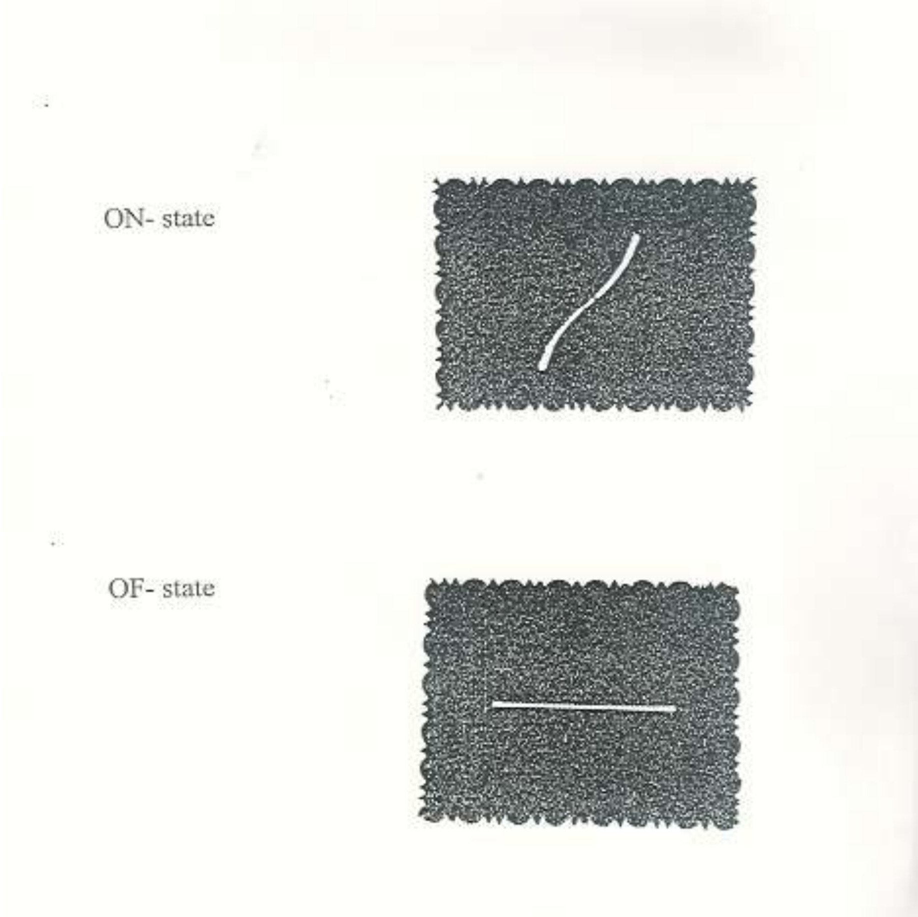


**Fig. (7). Dynamic I-V characteristic curve of $Ge_1$ $Se_{1.5}$ $Tl_{0.1}$ thin film of thickness 506 nm .**

The thickness dependence of threshold voltage for $Ge_1Se_{1.5}$ $Tl_{0.1}$ thin films of different thicknesses in the range (200-506nm ) was investigated from the current –voltage measurements obtained at room temperature. The mean value of the threshold voltage $V_{th}$ for each sample was calculated .As a representative example of the obtained I-V curve for each sample, we choose that for which the threshold voltage is equal to $V_{th}$ . The obtained such I-V curves for $Ge_1Se_{1.5}$ $Tl_{0.1}$ films of different thicknesses are illustrated in Figure (8). Also, the mean value of the threshold voltage $V_{th}$ increases linearly with thickness in the investigated range . The observed relation of thickness dependence of $V_{th}$ agrees with the previous observations for different amorphous systems .

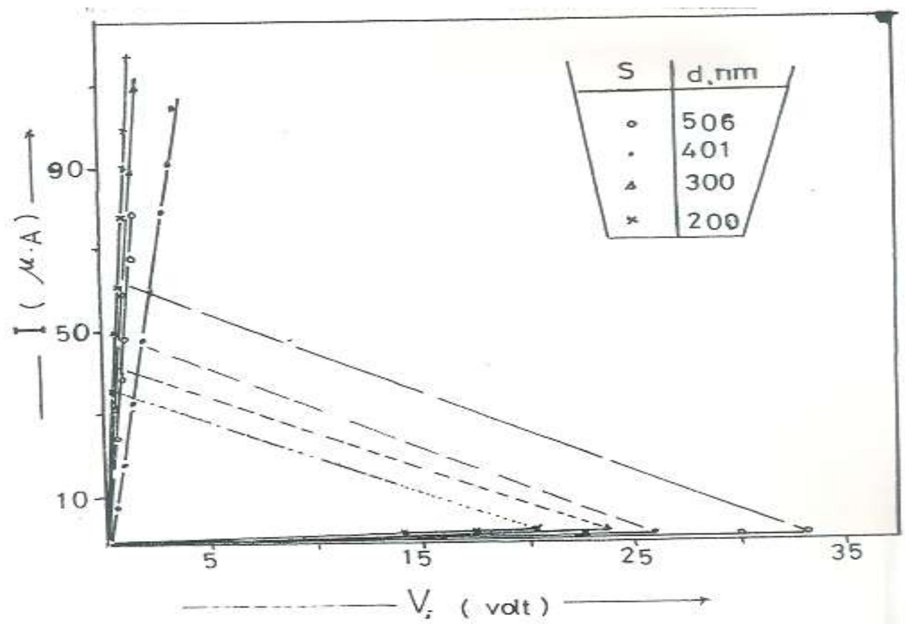


**Fig (8). The I-V characteristic curves for $Ge_1Se_{1.5}$ $Tl_{0.1}$ thin film at differcnt thicknesses at room temperature.**

**Conclusion**

The films were deposited onto polished pyrographite substrate by thermal evaporation technique. $Ge_1Se_{1.5}$ $Tl_{0.1}$ in got material is to be prepared by direct fusion of stiochiometric proportions of constituent elements. The film thickness were cantrolled during the evaporation by a quartz thickness monitor. The obtained value of the calculated electrical conduction activation energy ($\Delta E\sigma$) is (0.72eV).

The dynamic I-V characterstic curves for $Ge_1$ $Se_{1.5}$ $Tl_{0.1}$ thin films were obtained by using an a.c. source . a high resistive (OFF – state) and a high conductive (ON – State) was found. As clear the obtained dynamic I-V curves is also typical for a memory switch. Static I-V charaecteristic curves were obtained at room temperature for Ge $Se_{1.5}$ $Te_{0.1}$ amorphous thin films deposited on clean highly polished substrates of pyro graphite. The behavior of the obtained curves formed of low and high conduction branches following the load line typical I-V characteristic curve for a memory switch .

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