Astudy the electrical properties of a- Se:2.5%As thin films prepared by Thermal evaporation in Vacuum

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Abstract

Thin films of Se:2.5%As were deposited on a glass substrates by thermal co-evaporation technique under high vacuum at different thickness (950,2400,3500,4300)A within the range temperature (293-373)K and studied the electrical properties before and after annealing. The result shown that the D.C conductivity increases and decreases in activation energy. There were two activation energies indicating different conductivity mechanisms in the gap. From the Hall effect experiment, the charge carriers are electrons and there concentration (n) were observed to decrease with increasing the thickness. The thermopower results confirmed the sign of Hall effect measurements.

Introduction

In amorphous films, it is known that there is no long-range periodicity of the atomic arrangements, and the local environment surrounding the atoms is ordinarily different from that in the case of crystalline material [1]. The chalcogenides , such as selenium and tellurium exhibit divalent bonding and the structural stability is one dimensional in nature. Selenium has often been taken as being a mixture of Sen chain and Se8 rings[2]. Selenium is a typical chalcogenide glassy semiconductor and is contain two kinds of molecule, polymeric chain and monomeric rings and inherent defect states called valence-alternation pairs (VAP).The creation of VAP is described by reaction:

$$2Se_2^{\circ}=Se_1^{-}+Se_3^{+}$$

where the subscripts denote the covalent coordination and the superscripts- the charge states.

Structural ,electrical and optical properties of V-VI compounds have been studied in various publication [3-6]. Still the properties of the prepared materials are highly dependent on the preparation condition , leading to difference in the values of the parameter connected with electrical properties , optical properties, glass transition temperature, crystallization ....etc. Doping of selenium with some additives produces a strong effect on the physical properties of pure a-Se. The introduction of (In, As, Sb) into a-Se was expected to increase the electrical conductivity by one order of magnitude [illegible] because of the presence of a high density of [illegible] defects which act as acceptors [5].

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This research presents the results of studying the electrical properties of a-Se+2.5%As thin films with different thickness(950,2400,3500,4300)A with a temperature range (293-373)K.

Experimental:

Thin films of a pure (99.99%) Se doped with 2.5% As deposited on transparent glass slides at room temperature by thermal co-evaporation from two molybdenum boats in a vacuum of 10^{-5} Torr in an Edwards coating unit .The thickness of the films are (950,2400,3500,4300)A, which has been measured by Tolonsky method. X-ray diffraction studies carried out on the samples using Cu-Kα:(λ=0.15404nm) in a Siemens D-500 diffractometer. The electrical measurements were carried out using Kiethely 616 digital electrometer,PE 15400 DC power supply, electronic thermometer Comark type(Ni-Al).

Results and Discussion:

1- The structure of the films:

X-ray analysis at room temperature for all prepared films showed the absence of any peak ,which indicated that the films were amorphous.

2- The electrical conductivity:

Figs.(1),(2),(3)and (4) showed the relation between the current and the voltage with different temperature and with voltage range (2-20)V .We founded the current increased with increasing the temperature , that mean the resistivity decreased with increasing temperature[9].

The dc conductivity (σ) [which is found from Ohm's low] of doped selenium, were determined over a temperature range ,293K to 373K.

Fig. (5) shows the effects of , thickness on the electrical conductivity of a-Se:2.5%As thin films. It can be noted that the electrical conductivity increases with increasing thickness. The increasing of conductivity can be interpreted on bases of increasing carrier concentration and forming impurity levels near the band edges and that will lead to decrease the activation energy in accordance with the equation [10]:

$$\sigma=\sigma o \exp(-Ea/k_B T) \quad \text{.......................(1)}$$

where σo is a constant (the value of σo is known to vary from 10^2 to10^4 $\Omega^{-1}cm^{-}$ depending on the composition[9],&T is the absolute temperature, Ea is the electrical activation energy and K_B is the Boltzman constant.

Table (I) shows the value of activation energy Ea [which is found from the slope of figure (5)] with thickness.

It can be observed from figure ((5) and table (I) that it is characterized by two different stages of conductivity regions. Two different mechanisms of conduction are not unfamiliar in amorphous materials and have been discussed in details by Mott and Davis [11], at higher temperature the conduction mechanism of this stage is due to carriers excited into the extended states beyond the mobility edge and at intermediate temperature the conduction mechanism due to carriers excited into the localized states at the edge of the band . In addition the activation energies increase with increasing the thickness . The variation in the result can be related to the increase in thickness of the films (from 950A to 3500A)but for thickness films(3500A to 4300A)the activation energy remained constant as shown in table (I).These results can be interpreted by assuming the presence of defects in amorphous thin films. It is known that during the deposition of amorphous film unsaturated bonds are produced as a result of deposition defects. The unsaturated bonds are responsible for formation of dangling bond and vacancies .Such defects produce localized states in the amorphous solid. In the case of thicker films ,i.e. greater deposition builds up more homogeneous network thus lowering the dangling bonds and there by minimizing the number of defects. As a result, the concentration of localized states are reduced ,to approach nearly ideal amorphous sample .Nikam and Aher [10] have studied the conduction mechanism in co-deposited Bi-Se and Sb-Se thin films. The value of Ea are found to increase with increase of thickness of the films .The same dependence of Ea on thickness [1] of the films have been observed in the case of amorphous Selenium films. Our results are disagreement with Hassen [12], which they found that the activation energy for ZnSe thin

films is decrease with increasing the thickness.

The value of carrier concentration of the film obtained from Hall coefficient R_H $[R_H=1/e.n]$ versus thickness as shown in table (I). The sign of Hall coefficient for the films is negative.

The Seebeck coefficient(S) was measured as a function of temperature for amorphous film with t=((950A,2400A,3500A,4300A)as shown in Fig.(7). The sign of S is also negative that means electrons are the dominate carriers. Inverse temperature dependence of S(Fig.(2)) was observed to follow the relation:

$$S=(K_B/e)[E_s/K_BT+A] \quad ....(3)$$

Here A is related to the carriers scattering mechanism and Es is the activation energy of thermopower. The thickness dependence of Ea and Es and n are shown in table(I).Our result are in agreement with the result that found by Al-Ani et,al.[3] which they studied the electrical properties of a-Se thin films doped with As,In and Sb,they found there were two activation energies for Se:As thin films and the sigen of Seebeck coefficient was negative. Makadsi et.al.[13] studied the dependence of Ea,Es and n on thickness for Ge-Se they found that the value of Ea, Es, and n increase with thickness .

Table (I):Thickness and activation energies determined for Se:2.5%As

Thickness (A)	Ea_1(eV)	Ea_2(eV)	Es(eV)	n*10^{14} (cm^{-3})
950	0.786	0.155	0.08	8.4
2400	0.865	0.210	0.106	5.2
3500	0.943	0.224	0.120	2.86
4300	0.949	0.237	0.130	2.3

Conclusion:

1- Thin films samples are amorphous as related by x-ray diffraction.

2- Electrical conductivity measured for a-Se:2.5%As films with thickness and over temperature range (293-373)K.

3- The electrical conductivity has been observed to decrease with increasing the thickness , while the activation energy was increase with increasing the thickness.

4- The type of carriers are electrons which found from thermoelectric measurement.

5- The concentration of electrons which found from Hall effect were found to decrease with increasing the film thickness.

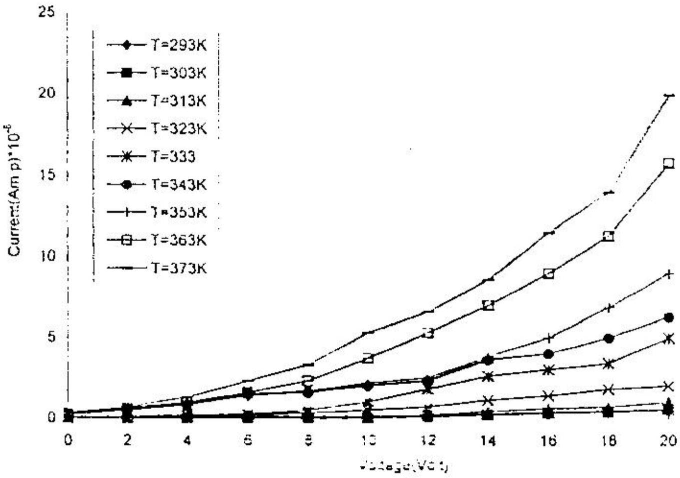

Fig.(1) The variation of current with voltage at different temperatures for a-Se:2.5%As thin films at t=950A.

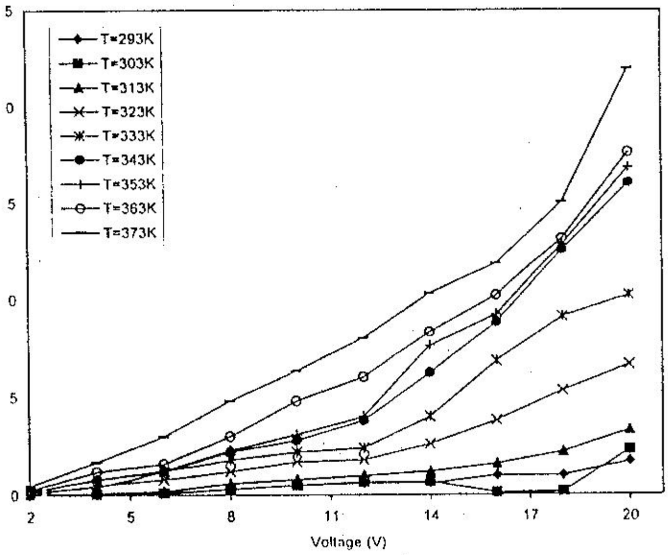

Fig.(2):The variation of current with a voltage at differente temperature for Se.2.5%As at t=2400A.

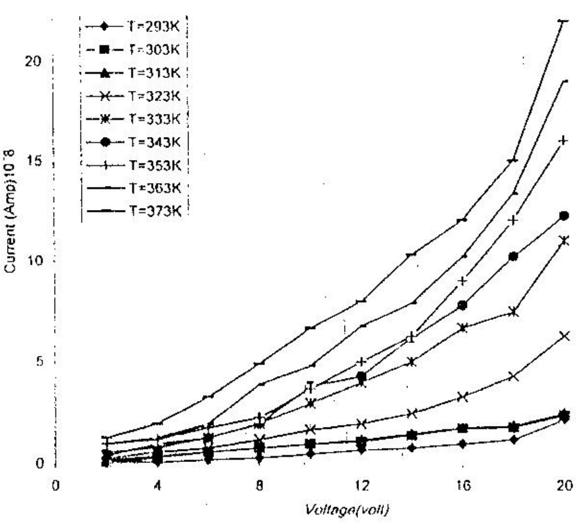

Fig.(3):The variation of current with a voltage at differente temperatures for a-Se:2.5%As thin films at t=3500A.

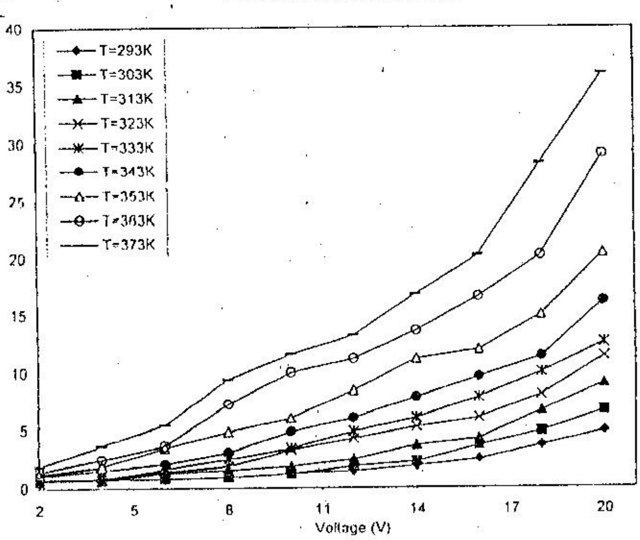

Fig.(4). The variation of current with voltage at differente temperature for Se.2.5%As at t=4300A

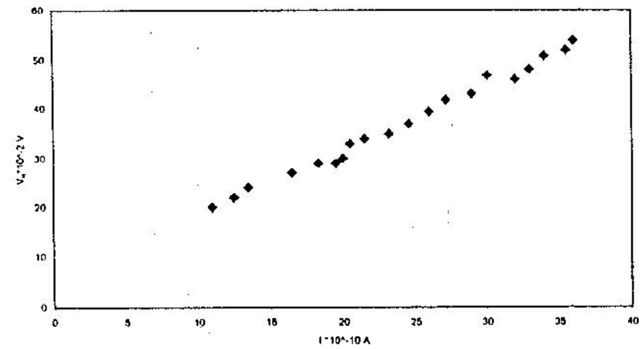

Fig.(6):The variation of Hall voltage with current for a-Se:2.5%As thin film

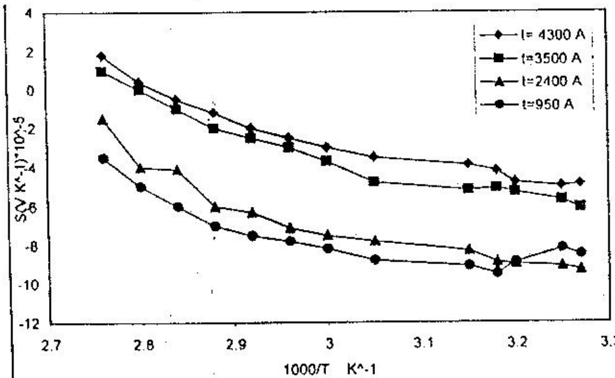

Fig.(7):Seebeck coefficient versus reciprocal absolute temmperature for a-Se:2.5%As thin films at different thicknesses.

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