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The electrical properties of the$Se_{85}Ge_{15-x}In_x$ amorphous thin film system before and after thermal annealing

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Abstract:
The electrical properties of theas prepared amorphous thin film system having the composition, $Se_{85}Ge_{15-x}In_x$, where (x = 0, 5, 10, 15 at%), werestudied, then the same study was performed on the same system of samples after being thermally annealed at 380 K, and 490 K, for one hour each. The results showed that the activation energy of the annealed samples decreases as the In content and the annealing temperature increase, and consequently the electrical Conductivity increases.

I. Introduction

Any material containing S, Se, or Te, is called chalcogenide material.These materialshave many applications in the scientific and technological fields. [1].In the recent days the chalcogenide materials'researchesfocus on photonics and x-ray imaging, [2]. amorphous Se chalcogenide shows unique semiconducting properties, [3–5].It was found that the addition of some elements like Ge, In, and Sb, improve the Se optical sensitivity and its electrical conduction. [6-11]. As example (Se-Ge), (Se-In), and (Se-Ge-In) alloys confirm this idea. [12-19]. the structure of such alloys were studied using XRD, IR absorption, and other techniques [20-29],while DTA and DSCare good suitable tool to specify the fixed temperatures which affect the structure, [30]. Davis and Mott gave a model, which gives a good explanation for the DC conductivity of the amorphous semiconductors. [30-34].

The aim of this work is to study the effect of the thermal annealing temperature onthe electrical properties of the thin film system having the composition, $Se_{85}Ge_{15-x}In_x$, where (x = 0, 5, 10, 15 at %).

II. Experimental technique:

The amorphous thin films of the system$Se_{85}Ge_{15-x}In_x$,as(x = 0, 5, 10, 15 at%), were prepared on two steps using two different techniques of preparations.First preparing the samples in solid bulk glassy ingots,and then preparing the amorphous thinfilms.

a- Preparation of the system $Se_{85}Ge_{15-x}In_x$, samples in glassy ingots.

The alloys of the system ingots were prepared using the well-known melt quenching technique, [4, 45].This was done using the adequate molar amounts and ratios of each element contributing in the composition of the alloys of this system in a powder form having 5n purity from Aldrich. The powdersof each sample were thoroughly mixed to ensure its stoichiometric composition, then were contained in an evacuated silica tube, sealed and then well shacked for half an hour using an electric shaker. Before starting the melting process, differential scanning calorimetry tests (DSC), were performed for the different samples composition powder,Fig.[1]. The data obtained from these testswereused to design the melting plan. After melting, the molten were quenched in ice water, the solid ingot samples,were grinded into fine powders and checked for amorphous structure using XRD Fig. [2].

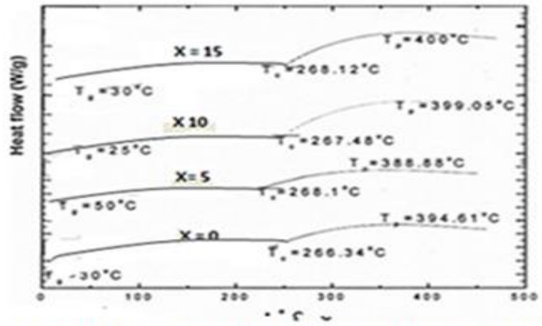

Fig. [1] DSC patterns of $Se_{85}Ge_{15-x}In_x$ powders

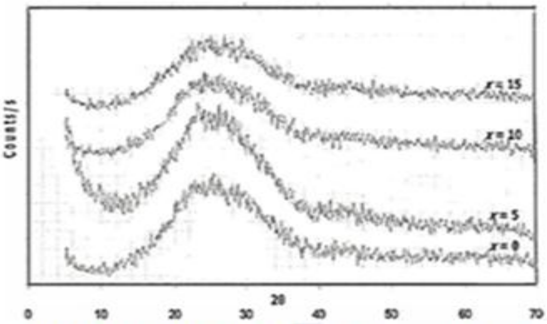

Fig.[2] XRD patterns of the $Se_{85}Ge_{15-x}In_x$ ingots

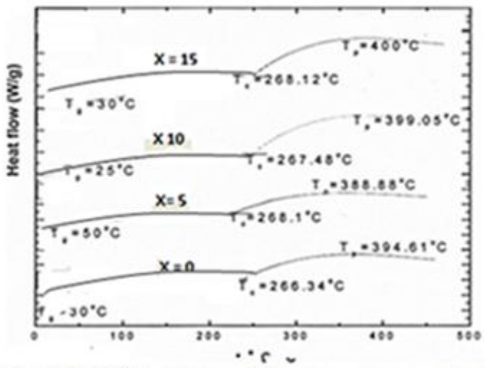

Fig. [1] DSC patterns of $Se_{85}Ge_{15-x}In_x$ powders

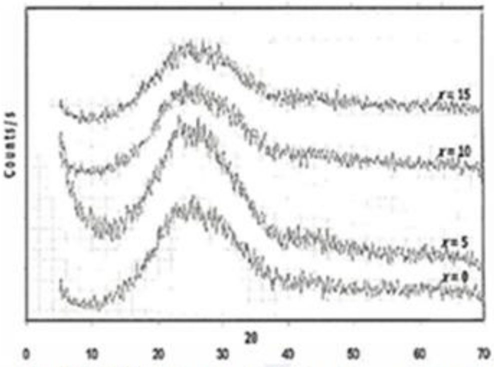

Fig.[2] XRD patterns of the $Se_{85}Ge_{15-x}In_x$ ingots

B- Preparation of the system, $Se_{85}Ge_{15-x}In_x$ thin films, where, (x = 0, 5, 10, 15 at %),

The thin filmsamplesof the$Se_{85}Ge_{15-x}In_x$systemwere prepared using the well-known CVD technique, under vacuum condition of 10^{-5} Torr. The vapor of the materials powder were deposited on clean quartz glass substrates, the films thickness were controlled using a quartz thickness monitor, and confirmed by an interferometric technique.Then were checked for amorphous structure using XRD, Fig. [3].

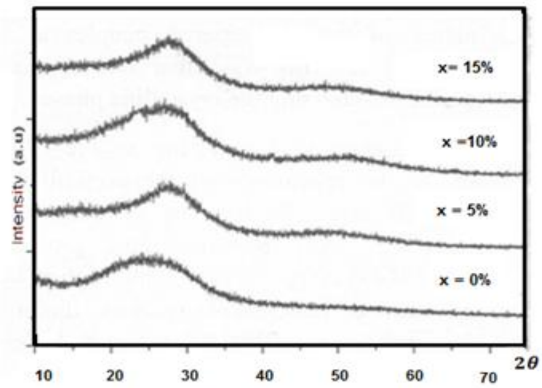

Fig. [3] XRD for the thin film system $Se_{85}Ge_{15-x}In_x$

c- Measurement of the $Se_{85}Ge_{15-x}In_x$ system DC conductivity.

The system $Se_{85}Ge_{15-x}In_x$, thin films DC conductivity was measured using a two probe method through the evaporation of gold probe electrodes**.**

III. Results and discussion

The I-V characteristics for the as prepared samples and for the thermally annealed samples at 380 K and 490 K,for one hour each, were performed, and the collected data was plotted as illustrated in Figures, [4, 5, 6]..

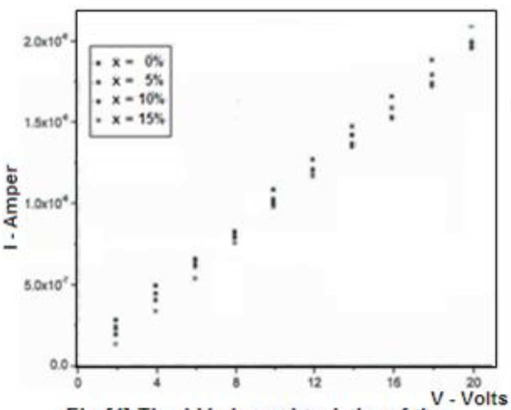

Fig.[4] The I-V charachteristics of the as prepared system of samples

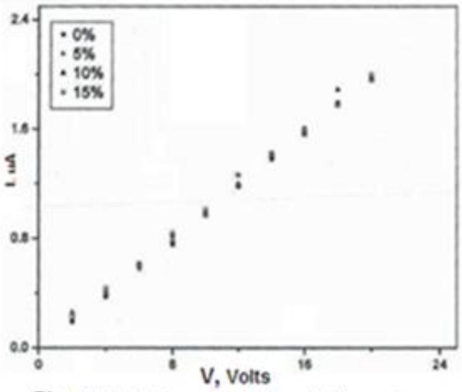

Fig. [5] I-V characteristics of the system $Se_{85}Ge_{15-x}In_x$ thin films annealed at 380K

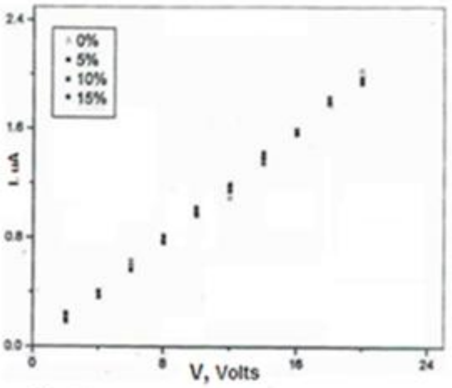

Fig.[6] I-V characteristics of the system $Se_{85}Ge_{15-x}In_x$ thin films annealed at 490K

The linear behavior of these, relations reveal ohmic contact and no diffusion from the gold electrode atoms into the samples' core. This probable zero diffusion length, proves that the thin layers of such material keep themselves pure with respect to the electrode material. Also as the purity of this system is still unaffected by the gold electrode atoms, this confirms that the contact resistance could be neglected in the electrical measurements.

Also it is noticed that the increase of In content on the expenses of Ge in this system from 0% up to 15%, leads to very slight variation in the I-V characteristic curves.

This behavior was detected for both the as prepared and the thermally annealed samples, as per the previously mentioned Figures.The temperature dependence of the DCconductivity fits with the well-known Arrhenius formula, $\sigma = \sigma_0 e^{\frac{-\Delta E}{KT}}$.

The relation $\left(\ln\sigma \text{ vs } \frac{1000}{T}\right)$ displayed two straight lines with different slopes for both the as prepared, and the thermally annealed samples, as shown in figure [7] for the as prepared samples, and figures [8, 9] for the thermally annealed ones.

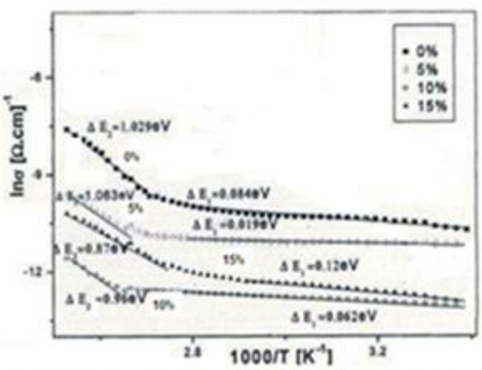

Fig. [8] DC.Conductivity of the system $Se_{85}Ge_{15-x}In_x$ thinfilms annealed at 380 K

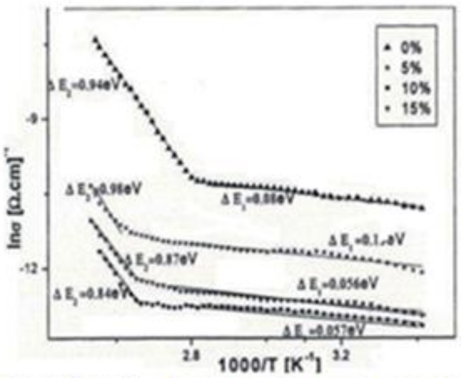

Fig. [9] DC.Conductivity of the system $Se_{85}Ge_{15-x}In_x$ thinfilms annealed at 490 K

From these figures we notice that the slope of the relation $\ln\sigma \text{ vs } \frac{1000}{T}$ in the low temperature range issmall, while the slope becomes high in the high temperature range.

From the figures too, it could be noticed that the kink temperature between the two straight lines for each sample in both the as prepared and the thermally annealed films was afunction in the indium content.

The values of the activation energy of each straight line, for each sample was calculated and found to be different.The smaller ones characterized the low temperature range, while the higher ones characterized the high temperature range, and are denoted as ΔE_1 and ΔE_2 for each sample and tabulated in tables [1], [2], [3].

Table [1] The Activation Eneravies of the as prepared samples of the system $Se_{85}Ge_{15-x}In_x$ thin films

X%	T_{ex} [K]	ΔE_1[eV]	ΔE_2 [eV]
0	361	1.023	0.075
5	368	0.956	0.068
10	352	0.900	0.089
15	342	0.845	0.087

Table [2]TheActivation Energyies of the thermally annealed samples at 380 K

X%	T_{ex} [K]	ΔE_1[eV]	ΔE_2 [eV]
0	370	1.029	0.084
5	376	1.063	0.019
10	380	0.96	0.062
15	366	0.87	0.12

Table [3] The Activation Energyies of the thermally annealed samples at 490 K

X%	T_{ex} [K]	ΔE_1 eV	ΔE_2 eV
0	357	0.94	0.08
5	377	0.98	0.13
10	373	0.84	0.057
15	368	0.87	0.056

From these tables we may notice that the values of ΔE_1 and ΔE_2 for the thermally annealed samples at 380 k for one hour, table[2], were, less than those of the green thin film samples table [1]. As the samples were thermally treated again at higher temperature (490 k), the values of ΔE_1 andΔE_2, table [3], were decreased more.These data fits well with previous work. [35].

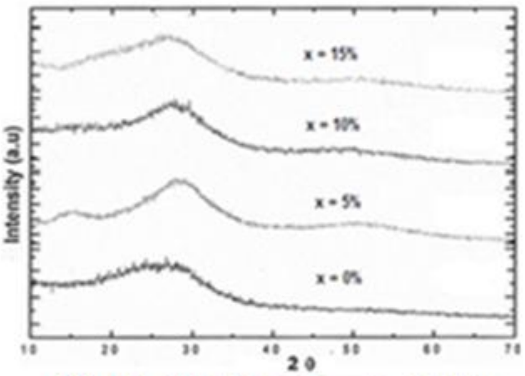

Fig. [10] XRD OF $Se_{85}Ge_{15-x}In_x$ thin films annealed at380K

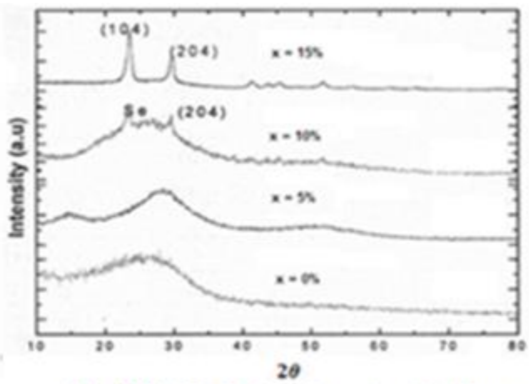

Fig. [11] XRD OF $Se_{85}Ge_{15-x}In_x$ thin films annealed at 490 K

Figures [10, 11] show the XRD patterns of the system thermally annealed films at 380 K, and 490 K, from which one can notice distinct peaks in the samples thermally annealed at 490 K, this may be attributed to the transition from a disordered state into an ordered one. This is revealed from the detected crystalline phase which is In_2Se_3in the hexagonal structure.

IV. Conclusion

The study of the electrical conductivity of the as prepared, and the thermally annealed amorphous chalcogenide thin film system $Se_{85}Ge_{15-x}In_{x,}$ where (x = 0, 5, 10, 15 at%) at different annealingtemperatures showed that this system of material could be recommended as a good candidaterawmaterial for the manufacturing of solar cells with high efficiency.

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