Ain Shams University

Faculty of Engineering

Electronics and Communications Engineering Department

Amorphous Semiconductors Characteristics and Their Modern Application

A Thesis Submitted for the award of

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Abstract

Chalcogenide glasses are a recognized group of inorganic glassy materials which always contain one or more of the chalcogenide elements S, Se or Te but not O, in conjuction with more electro positive elements as As, Sb, etc.

Chalcogenide glasses are generally less robust, more weakly bonded materials than oxide glasses. Glasses were prepared from Sb, Se, Bi and In elements with purity 99.999%. These glasses are reactive at high temperature with oxygen. Therefore, synthesis was accomplished in evacuated clean silica tubes. The tubes were washed by distilled water, and then dried in a furnace whose temperature was about 100°C.

The weighted materials were introduced into the cleaned silica tubes and then evacuated to about 10^{-4} torr and sealed. The sealed tubes were placed inside the furnace and the temperature of the furnace was raised gradually up to 900°C within 1 hour and kept constant for 10 hours. Moreover, shaking of the constituent materials inside the tube in the furnace was necessary for realizing the homogeneity of the composition. After synthesis, the tube was quenched into ice water. The glassy ingots could be obtained by drastic quenching. Then materials were removed from the tubes and kept in dry atmosphere. The proper ingot was confirmed to be completely amorphous using

x-ray diffraction and differential thermal analysis. Thin films of the selected compositions were prepared by thermal evaporation technique under vacuum 10^{-4} torr with constant thickness 100 nm. The effect of radiation, optical and some other effects on composition were studied.

The structural properties of $Sb_{20}Bi_{20}Se_{(60-x)}In_x$ amorphous semiconductor in the powder and thermally evaporated thin films have been investigated. Differential Thermal Analysis, DTA, for $Sb_{20}Bi_{20}Se_{(60-x)}In_x$ in the powder form showed that an endothermic peak in the DTA curve results from an increase in specific heat at the glass transition temperature T_g. The absence of any sharp exothermic peak in the DTA curve is good indicator for absence of the structural changes. The analysis of X-Rays Diffraction Patterns (XRD) of $Sb_{20}Bi_{20}Se_{(60-x)}In_x$ in the powder form confirmed amorphous state. Scanning electron microscope SEM micrographs were made for Se-Bi-Sb films deposited at room temperature. The film consisted of individual grains, which are irregular in size and shape and separated by well-defined inter-grain boundaries. By adding In, further separation of the surrounding media gives rise to large grains in size at x=10 at%. Then large grains can be seen for partially crystalline at x=20 at% the grain sizes become smaller for x=30 at% and the number of grains become larger.

The density of the as prepared glasses of the system $Sb_{20}Bi_{20}Se_{(60-x)}In_x$ films has been determined by the hydrostatic method with an accuracy of ± 0.05 %. It has been noticed that the density increases by increasing In from 5.691 gm/cm^3 for the composition $Sb_{20}Bi_{20}Se_{(60-x)}In_x$ at x=0% to 5.786 gm/cm^3 for composition $Sb_{20}Bi_{20}Se_{(60-x)}In_x$ at x=30%.

The optical properties of $Sb_{20}Bi_{20}Se_{(60-x)}In_x$ have been characterized by the measurements of the transmittance and reflectance in the wave length 200 – 1100 nm for the deposited films. The type of the electronic transition responsible for optical properties is indirect allowed transition with transport and onset energy gap in the range $1.89x10^{-3}$ – 1.79 $x10^{-3}$ eV. The values of the optical energy gap E_{opt} were found to decrease with increasing In content which could be due to the fact that In has a metallic behaviour.

The absorption spectra of $Sb_{20}Bi_{20}Se_{(60-x)}In_x$ is recorded in the UV region. Some important parameters such as coordination number N_{co} , the number of constraints (N_S), the parameter (r) determined the deviation of Stoichiometry. If there is a linear dependence between the bond strength and the average band gap, and if one allows their superposition to describe the compounds, then the addition of In will affect the average band gap. By increasing the In content, the average bond strength of the compound decreases, and hence E_g will decrease. In order to emphasize the relationship between E_g and the average bond strength more clearly, E_g is compared with H_S/N_{co} which is the average single-bond energy in the alloy.

The electrical properties of $Sb_{20}Bi_{20}Se_{(60-x)}In_x$ alloys include the measurements of DC conductivity for $Sb_{20}Bi_{20}Se_{(60-x)}In_x$ films and the measurements of switching. The DC conductivity of $Sb_{20}Bi_{20}Se_{(60-x)}In_x$ thin films has been measured as function of temperature. The dependence of the electrical DC conductivity on the temperature showed the existence of two distinct linear regions with two activation energies ΔE_1 and ΔE_2.

The switching measurements have been made for $Sb_{20}Bi_{20}Se_{(60-x)}In_x$ thin films and the addition of In has led to an increase in both the threshold voltage (V_s) and threshold current (I_s) from 1.6 volt and 1.2 μA respectively at x=0 up to 5.8 volt and 2.5 μA respectively at x=30 for constant film thickness d=100 nm. As for the holding voltage (V_h), it was found to increase with the increase of In content from 0.3 volt at x=0 to 4.8 volt at x=30. On the contrary, the increase of In content has caused a decrease in the holding current (I_h) from 48 μA at x=0 to 18 μA at x=30 for a constant thickness 100 nm. It was proved that the threshold power increased by increasing In content. This means that the quality of switching is reduced by increasing the In content. The addition of In content decreases the cohesive energy and consequently affects the switching properties. Raising the film temperature improved the switching characteristics where the threshold voltage decreased and the threshold current increases. Also, the addition of In reduced the filament temperature, thus reducing the switching ability. Increasing the In content from x=0 to 10, 20 and 30 led to an increase in the switching rise time from t_r = 25 to 40, 100 and 200 nano second respectively and a decrease in the cohesive energy from C.E. = 3.884 to 3.6o7, 3.329 and 3.053 eV respectively. These results indicate that composition $Sb_{20}Bi_{20}Se_{(60-x)}In_x$ shows good electrical threshold switching results and promises a useful threshold switching device in computer applications and memory.

Finally, the study of effect of gamma rays on the $Sb_{20}Bi_{20}Se_{(60-x)}In_x$ showed that the gamma radiation did not have a noticeable effect, for a dose of 15MRad showed a constant value in the transmittance upon the addition of In.

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