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The Optical parameters of $Se_{85}Ge_{15-x}Bi_x$ amorphous thin films

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Abstract:*Thin amorphous films of $Se_{85}Ge_{15}$-xBi_x system, where (x = 0, 5, 10, 15, at %) were prepared by alloying the spec. pure raw materials using the common melt quenching technique, then using the thermal evaporation technique to form the required thin films These films where checked by XRD and EDX to ensure the amorphous structure and composition of each sample. The optical parameters, (Transmittance T, Reflectance R) and the optical constants (Refractive index n, Extinction coefficient k, Absorption coefficient α , were studied at the wave length range from 400 – 2500 nm.*
The optical constants (n, k, and α, of these films were calculated, using the measured experimental values of the transmittance (T) and the reflectance (R) for each Bi concentration in the same wavelength range. The results showed that the increase of Bi content in the sample from (0 to 15 at%) tends to reduce the optical band gap of the sample from (1.82 eV to 1.21 eV), which may be attributed to the presence of localized states near the conduction band edge so that the electrical conduction in this thin film system is due to the hopping of electrons which have been excited and got sufficient energy to reach the localized states leading to the reduction of the optical energy band gap of the samples

I. Introduction

Chalcogenide materials are subject to extensiveresearch work because their physicaland chemical properties change according to the change in the preparation conditions (1, 2) .

The thin films of chalcogenide materials have many applications and they are used as wide band gap high power devices, and sensitiveinfrared detectors. They behave as semiconductors with band gap energy ranging from 1 eV to 3eV(3-5).

Thin film materials with high optical transparency, could be used as flat panel displays, lightsensors, optical limiters, and a variety of other devices that depend on the nonlinear optical responseof their components(6-8).The studies of the optical constant of such materials showed that these materials could be useful if they were used in the optical fibers and reflecting coating, which may be related to their molecular structure and their electronic band structure(9-11).

The amorphous chalcogenide materials, in particular, Germanium containing chalcogenides have manyapplications. The Bismuth addition induced structure modifications in the Germanium-seleniummatrix. This is very clear in the study of Bismuth effect on the optical energy gap(12, 13).

The aim of the present work, is to study the effect of Bismuth addition to the Ge-Se parentalloy on the optical parameters of the system,$Se_{85}Ge_{15-x}Bi_x$where, x = 0, 5, 10, 15 at%.

II. Experimental technique

2. 1. Sample preparation:

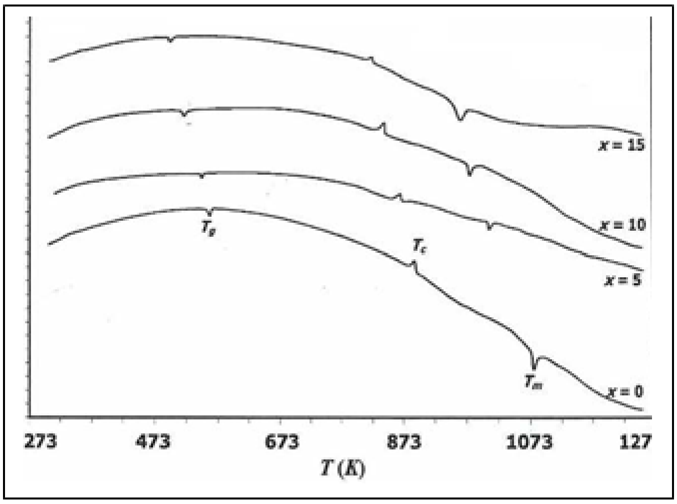
Preparation of the $S_{85}Ge_{15-x}Bi_x$ thin amorphous films system where(x = 0, 5, 10, 15, at%) was Performedon two step.preparation of the bulk ingot alloys, then preparation of the thin films.

a. Preparation of the bulk ingot alloys

Preparation of the bulk alloys ingots started by preparing the system of powder samples to beinvestigated, having the composition Se85Ge15-xBix, where (x = 0, 5, 10, 15 at%) from spectrallypure powder materials with 5n purityfrom Aldrich.The preparation of the bulk samples was performed using the well-known melt quenchtechnique.The differential thermal analysis DTA was performed to detect the glass formingtemperature T_g, the crystallization temperature T_c, and the melting temperature Tm for eachcomposition. (Fig.1)and (table. 1) show the DTA data for each sample.

Table [1]

Composition	Tg(K^o)	Tc(K^o)	Tm (K^o)
Se85 Ge15	548.60	889.65	1074.25
Se85 Ge10Bi5	542.92	866.71	1005.91
Se85 Ge5 Bi10	511.99	841.44	977.12
Se85Bi15	491.88	821.08	903.12



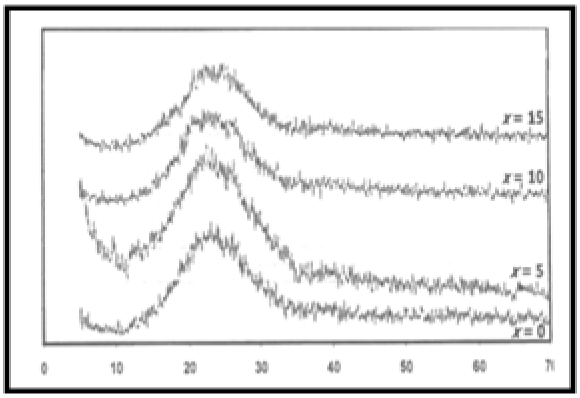


Fig. [2] XRD pattern for the bulk system $Se_{85}Ge_{15-x}Bi_x$where, x = 0, 5, 10, 15 at%.

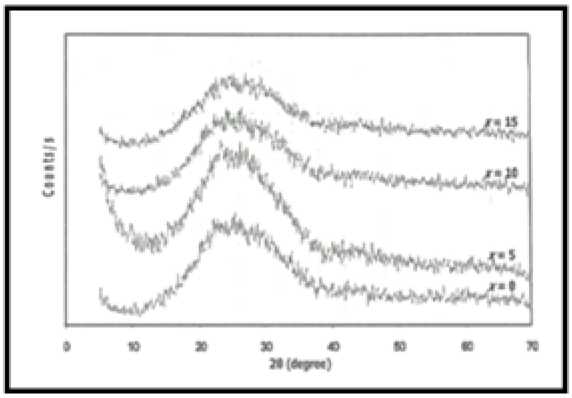


Fig. [3] XRD pattern for the thin film system $Se_{85}Ge_{15-x}Bi_x$where, x = 0, 5, 10, 15 at%.

The samples synthesis was performedin silica tubes undervacuum,(10^{-5}Torr.). The tubes

Werewellshacked me time to ensure good powder mixing and consequentlyhomogenous alloys composition, then they were placed ina programmable furnace for 2 hours at500 K^o, temperature was raised to 550 $K^o$for another 2 h. The temperature was increased to 1225K^o

K^o,andkept at this temperature for 2h, then again was raised in steps each of 50 degrees up to 1373K^o, for 10 hours. During the cooking process the tubes were frequently rockedto ensurethehomogeneity of the samples, and thenthe meltof each composition was quenched in ice water.

b. Preparation of the thin films

Thermal vapor deposition technique was used to form the required films by evaporating the alloyson clean quartz substrates. The films thicknesswere obtained usinga thickness monitor,Theamorphous structure of the obtained bulkmaterialsfigure (2), and the prepared thinfilms figure (3), were confirmed by XRD

c. Measuring the Optical properties of the samples

a. Measuring Transmittance (T) and Reflectance (R)

The transmittance (T) and the reflectance (R) data were recorded at room temperature and normalincidence in the wave length range (400 – 2500 nm) using a double beam spectrophotometer type(Jasco V- 570).

The valueof T was calculated from the experimental data using the formula(1)

$$T = T_{exp} \ (1 - R_g) \ (1)$$

Where T is the absolute value of transmittance, T_{exp} the experimental value, and $R_g$is the reflectance of the glass substrate.

The absolute value of reflectance R, wasdetermined using the formula(2)

$$R = \left(\frac{I_{rf}}{I_r}\right) \qquad (2)$$

WhereI_{rf} isthe reflectance of the thin film, Ir is the reflectance of the reference.

III. Result And Discussion

The Transmittance (T) and Reflectance (R), of the amorphous system, $Se_{85}Ge_{15-x}Bi_x$, were recorded, in the wavelength range 400 – 2500lec

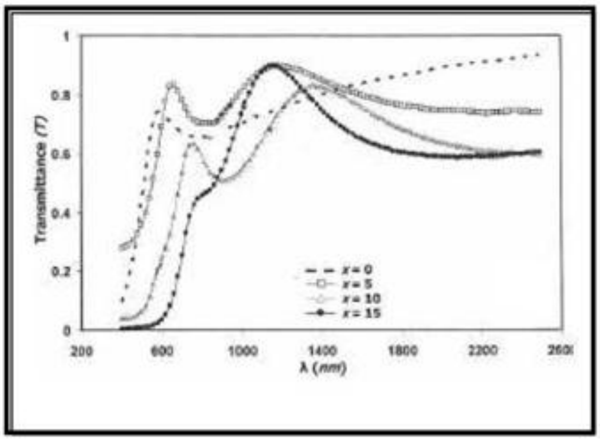


Fig. [4] The Transmittance vs. the wave length for the thin film system $Se_{85}Ge_{15-x}Bi_x$

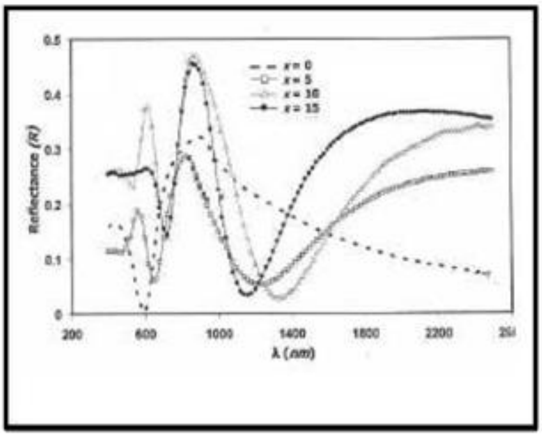


Fig. [5] The reflectance vs. the wave length for the thin film system $Se_{85}Ge_{15-x}Bi_x$

These figures illustrate that T and R, are nonlinear functions at the measured wavelength range.

Thespectral distribution of T and R revealed that the transmitted light through these materials is very low and almost undetectable in the UV region, while the reflectance is 25, which means that the absorption of UV region is very high which may make the materials of this system materials couldbe considered a good one as a UV radiation protector, a suitable window for near infrared, andfor night vision imaging devices.

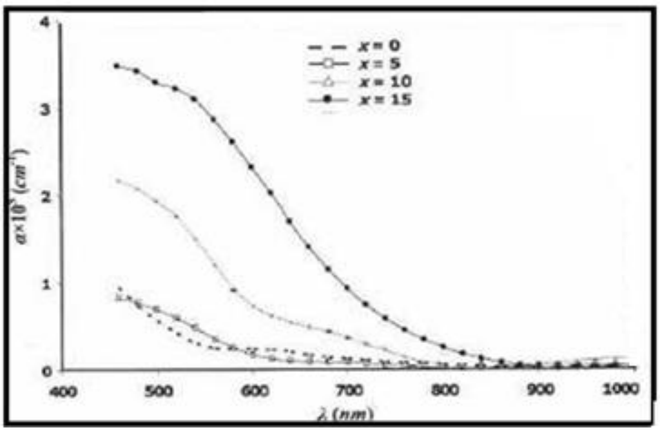
The values of The transmittance T and the reflectance R all over the rest of the spectral distribution nearly satisfy the relation R + T = 1.

This means that the absorption during the visible and near Infrared regions is low reaching about 10%.

The values of T &R, were employed to calculate the optical parameters (α, k, n). The obtained values of these parameters were plotted as functions of the given spectral wavelength range.

The obtained graphs were also nonlinear, as shown in figures [6, 7, 8], respectively.

Fig. [6] relation between α and λ for the thin film system Se85Ge15-xBix



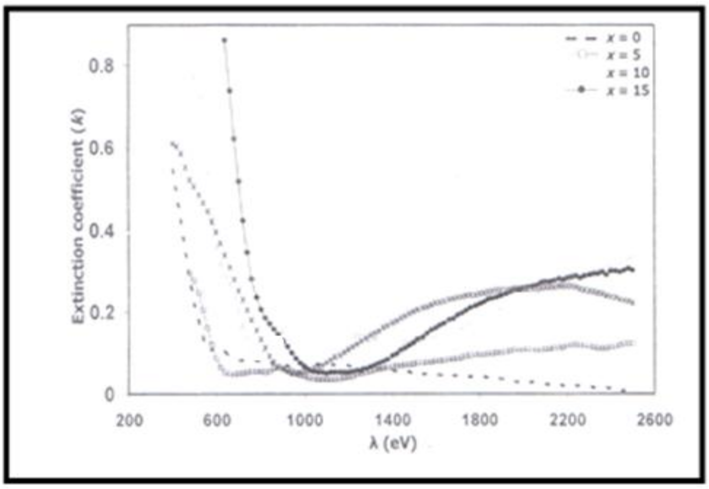


Fig.[7] (k) vs. (λ) of the thin film systemSe85Ge15-xBix

Fig. [6], shows the relation between α, and. From this graph one can observe that α at 900 nm reaches a saturation minimum value as λ increas. On the other hand α at that location increases gradually, as the absorbed photon energy increases. This graph also shows that the increase of Bi content leads to a corresponding increase in the absorption coefficient all the recorded wave lengthrange.

From fig. [7] it is clear that the highest values of k are in the visible region , which indicates that the thin film surface is rough. The values of k over the rest of the recorded ranges ranges between 0 and 2.5. this reveals that the topology of the thin films surfaces turns intosmooth ones at the low photon energies.

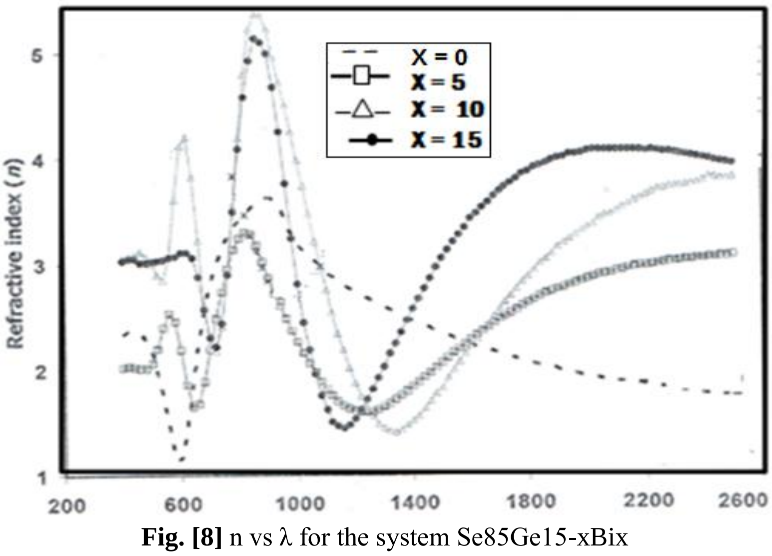


Fig. [8] n vs λ for the system Se85Ge15-xBix

Fig. [8], shows that the refactive index (n) changes with the wave length λ in a nonlinear behavior.This means that this system material can be used to produce a graded refractive indices optical fibers used in communication system.

IV. Conclusion

The main obtained results of this work are:

1. The recorded values of T, R, k, and n, were nonlinear functions with wavelength.
2. Data of T, R, and α confirm the possibility of using these materials as UV radiation protector and as windows for visible light, and near infrared.
3. The nonlinear relation of (n-λ), shows an opportunity to use this material as a graded refractive indices material to produce multimode optical fibers used in communication systems.

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