Optical properties of Ternary $Se_{80-x}Te_{20}Ge_x$ Thin Films

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Abstract

The present paper deals with prepared of ternary $Se_{80-x}Te_{20}Ge_x$ system alloys and thin films. The XRD analysis improved that the amorphous structure of alloys and thin films for ternary $Se_{80-x}Te_{20}Ge_x$ (at x=10and 20at.%Ge) which prepared by thermal evaporation techniques with thickness 250 nm. The optical energy gap measurements show that the optical energy gap decreases with increasing of (Ge) content from (1.7 to 1.47 eV)

It is found that the optical constants, such as refractive index ,extinction coefficient, real and imaginary dielectric constant are non systematic with increasing of Ge contents and annealing temperatures.

Keywords

$Se_{80-x}Te_{20}Ge_x$ Thin Films
Optical properties

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الخصائص البصريةلأغشية المركب الثلاثي $Se_{80-x}Te_{20}Ge_x$

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خلاصة

في البحث الحالي تم تحضيرسبائك واغشية من المركب الثلاثي $Se_{80-x}Te_{20}Ge_x$. اثبتت نتائج فحوصات الاشعة السينية ان السبائك المحضرة والاغشية المحضرة منها بطريقة التبخير الحراري كانت عشوائية التركيب عند نسب (x=10 and20 at.%Ge) $Se_{80-x}Te_{20}Ge_x$.
اظهرت الفحوصات البصرية للعينات المحضرة ان قيم فجوة الطاقة تتروراح بين (1.7 to 1.47 eV)
وان قيمتها تقل بزيادة نسبة الجرمانيوم. اما حسابات الثوابت البصرية (معامل الانكسار ,معامل الخمود وثابت العزل الحقيقي والخيالي) فانها اظهرت عدم انتظام في قيمها بزيادة التلدين وزيادة نسبة الجرمانيوم.

Introduction

Amorphous thin films based on chalcogenides of Ge , Sb and another elements are widely applied in optics, electronics and optoelectronics(optical memories, gratings, waveguide, optical sensors,……etc.).The chalcogenide glasses have recently attracted the attention because of their use in various solid state devices. The structural studies of these materials are very important for better understanding of the transport mechanisms in them. The studies of chalcogenide glasses are also attractive due to their importance in preparing corrosion resistive and electronic memories materials [1]. The optical constants fully describe the optical behavior of materials. They are different for different materials, temperatures and pressures [2].

The optical constants are properties of the bulk phase, not properties of individual molecules in the phase.Moreover, they are interesting as core materials for optical fibers for light transmission, especially when short wavelength transmission and good flexibility are required [3,4].

The selenium has wide commercial applications and its device applications like switching memory, xerography, X-ray imaging, photonic and non-linear applications etc. made it attractive. it also exhibits unique properties of reversible transformation[5,6],however, pure selenium has disadvantages because of its short life time, low sensitivity and thermal instability.Binary Se-Te alloys are found to be useful in practical applications from the technological point of view, these glasses being stable with time and temperature. The addition of Ge,Sb and Bi as a third element in Se-Te alloys improves the stability of these alloys. [7,8]

Experimental work

Glassy alloys of Se-Te-Ge are prepared by well known quenching technique. Materials (5N purity) are weighted to their atomic percentages and sealed in quartz ampoule in vacuum ~$2x10^{-2}$ torr.the sealed ampoules are kept inside a furnace where the temperature is increased up to $1000C^0$ at a heating rate of 5-8 C^0/min.The ampoules are frequently rocked for 6 hours at the highest temperature to make the melt homogenous to avoid phase separation. The quenching is done in cold water. Thin films are deposited on glass substrates which are first cleaned with soap solution then ultrasonically cleaned by trichloroethylene, followed by methyl alcohol. on the cleaned substrate thin films of glassy alloys are deposited by vacuum evaporation technique at room temperature and base pressure of ~10^{-5} torr using a molybdenum boat . By using the x-ray diffractometer (Philips PW 1410/20), the structure analysis for all prepared samples (bulk and films) has been carried out.

The optical absorbance spectra of the $Se_{80-x}Te_{20}Ge_x$ films are measured using UV/Visible (centera 5) spectrophotometer over the wavelength range (280-1100 nm).

Results and discussion

The X-ray diffraction of $Se_{80-x}Te_{20}Ge_x$ at x=10 and 20 at.%Ge showed amorphous structure for alloys and all prepared samples. The optical absorption coefficient (α) could be calculated from the values of (A) (absorbtance) using the following relation[9]:

$$\alpha=2.303A/t \quad ....(1)$$

where t is the thickness of the sample.

According to Tauc law the relation between $(\alpha h\upsilon)^{1/r}$ and photon energy ($h\upsilon$) was examined for different value of (r=1/2,3/2,2 and 3) to determine the type of the optical transition. Using computer program the straight line portion in the strong absorption region is extrapolated to zero and the values obtained represented the optical energy gap. Figure (1) shows the relation between $(\alpha h\upsilon)^{1/2}$ and $h\upsilon$ where the transition of $Se_{80-x}Te_{20}Ge_x$ system is a direct transition for the value of (x=10and 20at.%Ge).

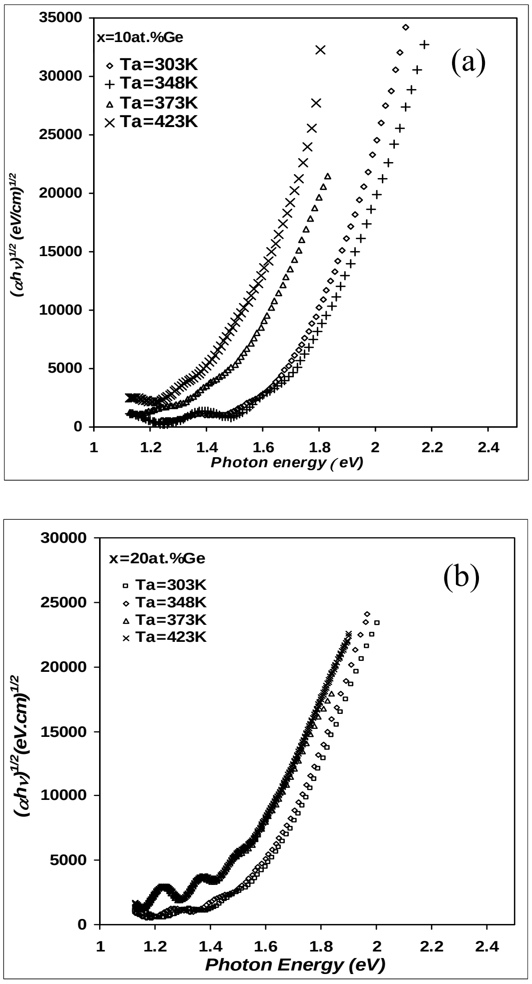


Figure (1a & b) the relation between $(\alpha h\upsilon)^{1/2}$ with photon energy for $Se_{80-x}Te_{20}Ge_x$ thin films at various T_a and both x (a)=10 at.%,(b) 20at.% Ge.

Table (1) shows the values of energy gap for system thin films, it is clear from this Table the value of energy gap decreases with increase of the value of Ge content .

It is clear that the energy gap not systematic with increasing annealing temperatures, this is attributed to the germanium films contain voids and a large number of dangling (weak) bonds, which made lead to a number of states within the gap that can be assumed to be distributed uniformly in energy. It is possible that the weak bonds (the states within the gap) are not eliminated. Rather they become strongly localized, so that they cannot participate in energy gap [12].

Investigation of refractive index (n) and extinction coefficient (k) for an absorbing film deposited onto a transparent substrate within the range (400-1100 nm) for as deposited films and annealing samples was carried out.

The equation (1) was used to calculate the refractive index [9,10]:

$$n = [(4R/(R-1)^2)-k^2]-(R+1)/(R-1) \quad ...(2)$$

where n is the refractive index, R is the reflectance.

The extinction coefficient (k) is related to the exponent decay of the wave as it passes through the medium and is defined to be[11]

$$k=\alpha\lambda/4\pi \quad ....(3)$$

where λ is the wave length of the incident radiation.

An absorbing medium is characterized by a complex dielectric constant

$$\varepsilon = \varepsilon_r - i\varepsilon_i = 1+4\pi\phi \quad ....(4)$$

where ε_r is the real part of dielectric constant, ε_i is the imaginary part of dielectric constant and ϕ is the sum of polarizabilities resulting from free carriers, so that [11]

$$\varepsilon_r=n^2-k^2 \quad ....(5)$$

$$\varepsilon_i=2nk \quad ....(6)$$

It is clear from Fig.(2) that the refractive index decreases with increasing wavelength and shifted toward long wave length. Fig. (3) shows the variations of extinction coefficient with wavelength for $Se_{80-x}Te_{20}Ge_x$ thin films at both values of Ge content and annealing temperature.

From Table (1) it can be deduce that the extinction coefficient depends mainly on the absorption coefficient according to relation (2).from this reason we notice that the extinction coefficient is increased [13].

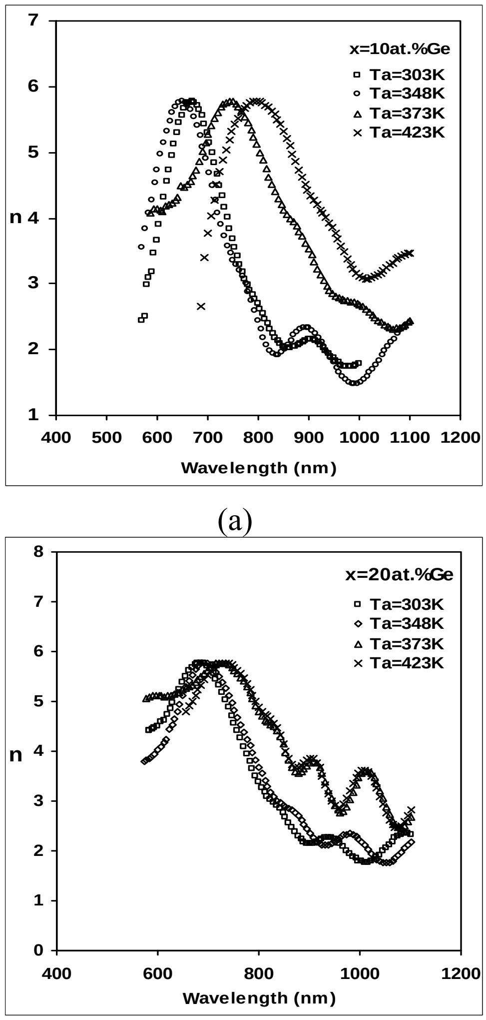
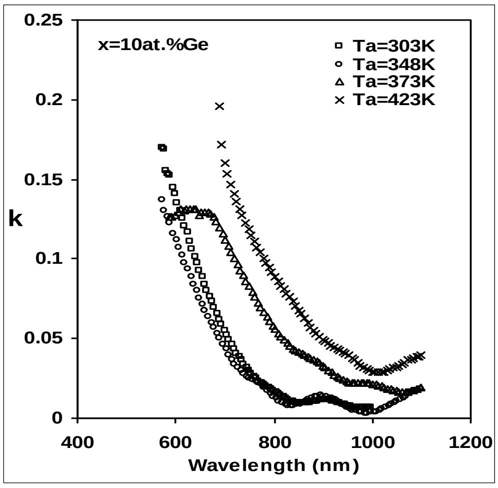
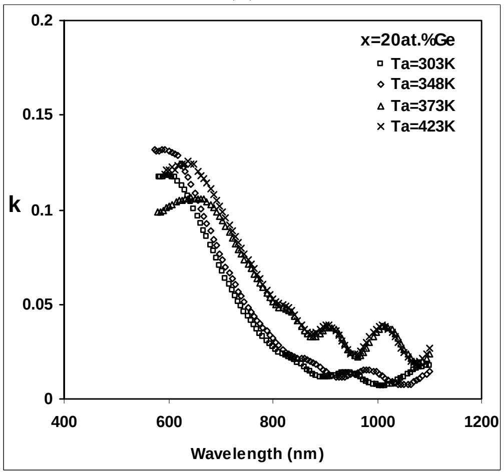


Fig. (2a&b) The relation between refractive index and wavelength for $Se_{80-x}Te_{20}Ge_x$ thin films at various T_a and at x (a)=10 at.%,(b) 20at.% Ge.



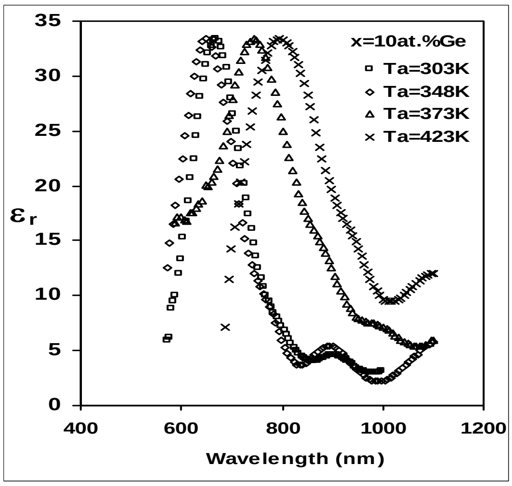
(a)



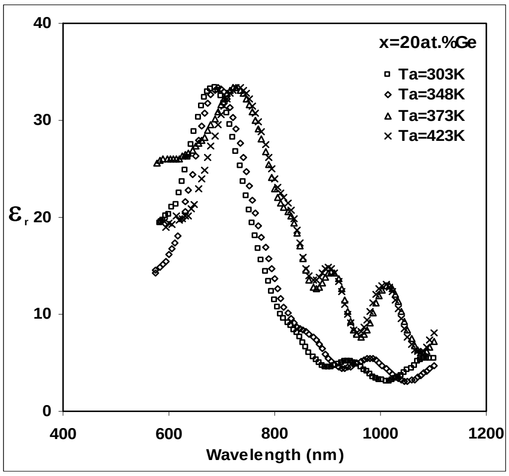
(b)

Figure (3a&b) The relation between extinction coefficient and wavelength for $Se_{80-x}Te_{20}Ge_x$ thin films at various T_a and at x (a)=10 at.%,(b) 20at.% Ge.

Figs. (3 and 4) show the variation of ε_r and ε_i versus the wave-length in the range (600-1100 nm) at different Ge content and annealing temperatures. The variation of ε_r and ε_i with increase of the wavelength of the incident radiation is due to the change of reflectance and absorbtance. The behavior of (ε_r) is similar to that of the refractive index because of the smaller value of (k^2) as compared with (n^2), while (ε_i) mainly depends on the (k) value which are related to the variation of absorption coefficient.

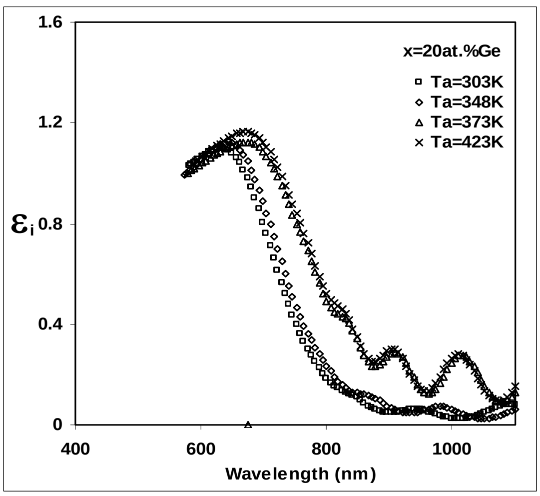


(a)

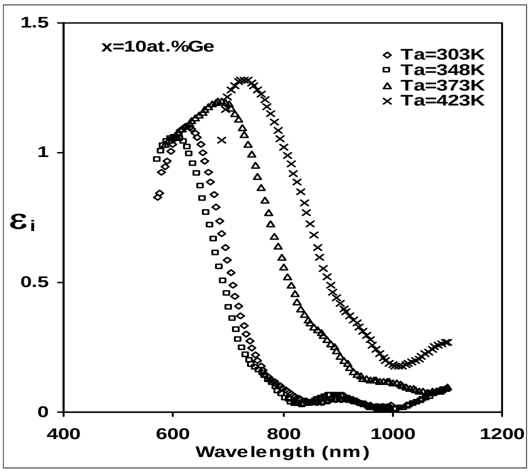


(b)

Figure (4a&b) The relation between real dielectric constant and wavelength for $Se_{80-x}Te_{20}Ge_x$ thin films at various T_a and at x (a)=10 at.%,(b) 20at.% Ge.



(a)



(b)

Figure (5a&b) the relation between imaginary dielectric constant and wavelength for $Se_{80-x}Te_{20}Ge_x$ thin films at various T_a and at x (a)=10 at.%,(b) 20at.% Ge.

Table (1) The value of E_g and optical constants of $Se_{80-x}Te_{20}Ge_x$ thin films for both values of x and different T_a

Ge concn.	T_a (K)	E_g (eV)	n	k	ε_r	ε_i
10	303	1.70	1.77	0.007	3.150	0.025
	348	1.75	1.49	0.003	2.245	0.010
	373	1.45	2.68	0.021	7.199	0.115
	423	1.68	3.11	0.021	9.704	0.181
20	303	1.58	1.79	0.007	3.224	0.026
	348	1.60	2.22	0.013	4.939	0.061
	373	1.43	3.48	0.035	12.175	0.251
	423	1.47	3.57	0.037	12.790	0.269

Conclusion

Ternary compound of $Se_{80-x}Te_{20}Ge_x$ are prepared with both values of Ge(x=10and 20 at.%) and their films are prepared successfully by thermal evaporation technique. Amorphous structure has been observed for alloys and prepared films. Thin films have a direct energy gap which decreases with increasing annealing temperature. The optical constants appeared non systematic behavior for all prepared films.

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