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Optical Properties of $Ge_{12}Bi_xSe_{88-x}$ Thin Films

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ABSTRACT

The optical properties of $Ge_{12}Bi_xSe_{88-x}$ deposited by the pulsed laser deposition [PLD] technique using Nd:YAG laser were studied. The optical transmittance, T (λ), and reflectance, R (λ), determined at normal incidence in the wavelength range 190-2500 nm have been analyzed. Optical parameters such as refractive index, "n", absorption coefficient, "α", extinction coefficient, "k", and optical band gap, "E_g", have been evaluated. Dispersion energy, "E_d", single oscillator energy, "E_0", and static refractive index, "n_0", have been calculated on the basis of Wemple–DiDomenico model. Also other parameters have been calculated such as the real and imaginary parts of complex dielectric constants, "ε_r" and "ε_i", volume energy loss function, "VELF", and surface energy loss function, "SELF".

Key words: Thin film, PLD technique, $Ge_{12}Bi_xSe_{88-x}$, optical properties

Introduction

Studying the optical properties of the chalcogenide semiconducting thin film of materials plays an essential role in understanding the optoelectronic nature of the deposited films (Sharma *et al*., 2013; Zakery and Elliott, 2003). This is due to the interaction between the incident photons and the semiconducting thin film materials. Also, the characteristic of the light incident spectrum passing through the deposited films can be changed or affected by the optical properties of these films. Where the light spectrum gives a general view about the characteristic of samples under investigation, otherwise the intensity of the incident waves or the propagation vector can be modified by the optical properties. Generally optical absorption study constitutes an easy way for getting the optical band gap energy and other related parameters and interpreting the band structure of the semiconductor film materials.

The effect of addition of some metals such as "Cd", "Zn" and "Bi" to $Se_{0.62}Ge_{0.35}X_{0.03}$ (Fayek and Ibrahim, 2013) and "In", "Sb" and "Bi" to $Ge_{20}Se_{80}$ (Aly *et al*., 2010) on the optical properties are studied. The obtained data reveal that, the values of optical gap "E_g" and oscillator energy "E_0" are minimum values for "Bi" metal, while values of dispersion energy "E_d", static refractive index "n_0" and the carrier concentration to the effective mass ratio " N/ m*" recorded the high values for "Bi" addition.

Some efforts are exerted to calculate some of optical constants for Ge-Bi-Se system. Some authors (El-Korashy *et al*., 2005; El-Zahed and El-Korashy, 2000) calculated the optical band gap and reported that the increase of "Bi" into $Ge_{20}Bi_xSe_{80-x}$ leads to red shift and hence a reduction in optical band gap for $x \geq 10$.

The optical dispersion parameters "E_0", "E_d" and high frequency dielectric constant "ε_∞" were determined for $Ge_{20}Bi_xSe_{80-x}$ (Hafiz *et al*., 2007) which recorded a decrease in both values of "E_0" and "E_d" by increasing "Bi" content whilst the values of "ε_∞" increase. A decrease in the indirect optical gap "E_g" is also observed due to annealing near the crystallization temperature. This manner is referring to surface dangling bonds production around the crystallites which formed during the crystallization process. Analysis of accurate refractive index for $Ge_{15}Se_{60}Bi_{25}$ gives the values of "ε_∞", "E_d" and "E_0" (Atyia and Hegab, 2014).

Experimental details:

Bulk $Ge_{12}Bi_xSe_{88-x}$ [x = 3.5, 7, 10.5, 14, 17.5] samples were prepared by the conventional melt quenching technique. An appropriate mixture of 99.999% purity of "Ge", "Se", and "Bi" was taken in

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chemically cleaned quartz ampoules. The ampoules were sealed under vacuum and held at 1000°C for 24 h in a furnace in order to insure a homogeneous melt and the melt is then quenched in ice water. Thin film samples were deposited on ultrasonically cleaned glass substrate using the pulse laser deposition [PLD] technique using Nd:YAG laser operated at the wavelength of 532 nm. The targets were ablated in a vacuum chamber at a background pressure of 5×10^{-4} torr with the laser power of 1.4 J. $Ge_{12}Bi_xSe_{88-x}$ films were deposited at room temperature. The pulse repetition rate was set at 10 Hz and the incidence angle was 45◦.

The optical transmittance, T (λ), and reflectance, R (λ), of the deposited thin films on a transparent glass substrates were measured with a double beam spectrophotometer, with automatic computer data acquisition [Type Jasco, v-570, UV–VIS–NIR], and photometric accuracy of ±0.002 to ±0.004 absorbance and ±0.3% transmittance at normal incidence of light in the wavelength range from 190 nm to 2500 nm. The data of T (λ) and R (λ) are used to determine the optical constants: the refractive index "n", the extinction coefficient "k", the absorption coefficient "α" and optical band gap "E_g" of the material and other parameters.

Results and Discussion

Transmission, reflection spectra and refractive index:

Fig. 1 shows T (λ) and R (λ) spectra of the $Ge_{12}Bi_xSe_{88-x}$ thin film samples of thickness [~100] nm. It is clearly seen that, the transmittance spectra could be divided into three main special regions: [i] very high absorption region, which observed at the wavelength of 250-380 nm. [ii] Fundamental absorption region in the wavelength range 380-1000 nm, at which both R+T ≠ 1; and [iii] The transparent region, beyond 1000 nm where the sum of the transmittance and reflectance was found to be in the order of the unity i.e. R+T ≈ 1, indicates that almost no scattering or absorption occurs in this region.

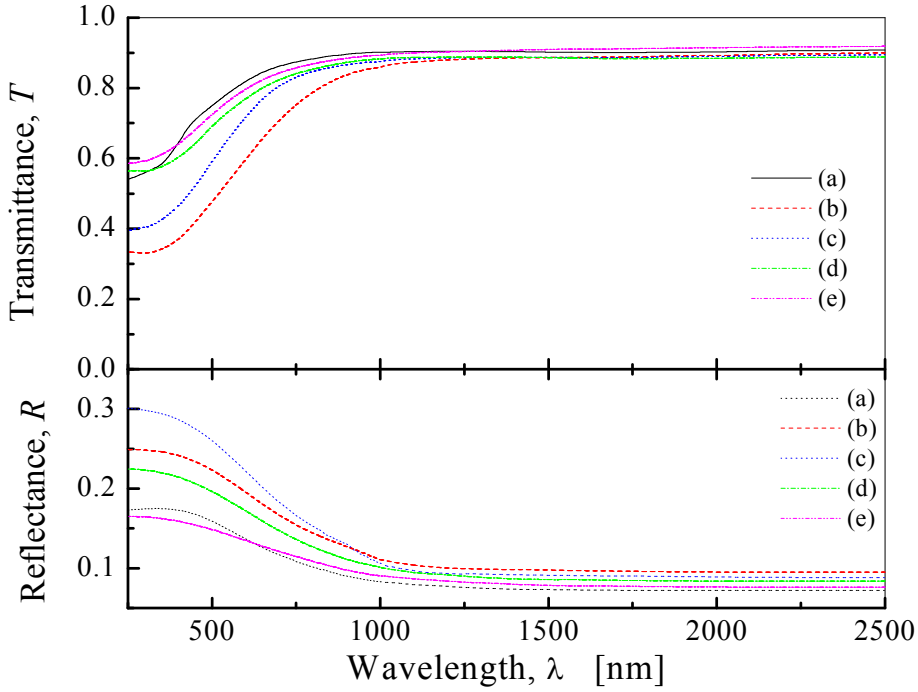


Fig. 1: The transmittance and reflectance spectra of $Ge_{12}Bi_xSe_{88-x}$ thin films ternary system
(a) $Ge_1Bi_{3.5}Se_{84.5}$ (b) $Ge_{12}Bi_7Se_{81}$ (c) $Ge_{12}Bi_{10.5}Se_{77.5}$ (d) $Ge_{12}Bi_{14}Se_{74}$ (e) $Ge_{12}Bi_{17.5}Se_{70.5}$

From the theory of reflectivity of light, the values of refractive index, "n" can be calculated by using the relation (El-Nahass *et al*., 2015):

$$n = \frac{(1+R)}{(1-R)} + \left[\frac{4R}{(1-R)^2} - k^2\right]^{1/2} \quad (1)$$

Fig. 2 shows the spectral variation of the refractive index, "n" for the investigated $Ge_{12}Bi_xSe_{88-x}$ thin films system. It has been observed that at the lower wavelength region 250 ≤ λ ≤1000 nm, the refractive index, "n", has a high value. In the wavelength range 250-450 nm the refractive index "n" shows shoulder and exhibits anomalous dispersion behavior. The anomalous dispersion behavior of the refractive index can be attributing to the effect of resonance between the incident electromagnetic radiation and the electron polarization (Hassanien and Akl, 2015).

Beyond this shoulder the refractive index is sharply decreases for all the investigated films, till become almost constant at higher wavelengths values, exhibits normal dispersion behavior.

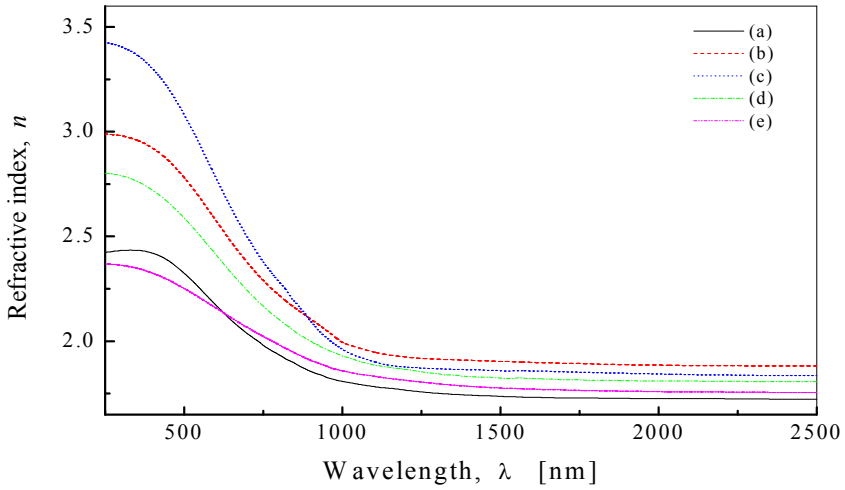


Fig. 2: Spectral variation of the refractive index, n vs. wavelength for $Ge_{12}Bi_xSe_{88-x}$ samples

Dispersion energy, "E_d", single oscillator energy, "E_0", and static refractive index, "ε_s", of Wemple–DiDomenico model:

The refractive index dispersion data in semiconductor materials can be analyzed using the idea of the effective single-oscillator model proposed by Wemple-DiDomenico (Wemple, 1973; Wemple and Didomenico, 1971).

This model attaches between three various types of energies, they are: [i] the single oscillator energy, "E_o" or average band gap energy, which provides quantitative information on the general band structure of the material, [ii] the dispersion energy, "E_d", which measures the average strength of inter-band optical transitions and [iii] the incident photon energy, "hυ". The importance of using the single effective oscillator model for fitting the experimental data of the refractive index is that it gives an intuitive physical analysis of the measured quantities. Also, this model is successfully applied to the experimental data of different binaries and ternary chalcogenide systems (Kotb and Abdel-Rahim, 2015; Salim *et al*., 2015; Sharma *et al*., 2007; Sharma *et al*., 2012; Štrbac *et al*., 2007). In the frame of this model the relationship between the refractive index "n", and the single-oscillator strength below the band gap is given by the expression (Selim *et al*., 2013):

$$n^2 = 1 + \frac{E_0 E_d}{E_0^2 - (h\upsilon)^2} \tag{2}$$

where "E_d" and "E_o" are the single-oscillator constants. "E_o" is the energy of the effective dispersion oscillator [an average of the optical band gap]. Experimental verification of Eq. 2 can be obtained by plotting $[n^2\_1]^{-1}$ *vs.* $(h\upsilon)^2$, as shown in Fig. 3 for $Ge_{12}Bi_xSe_{88-x}$ thin film ternary system, which yields a straight line for the normal behavior. From the slope of straight line which is $[E_d\ E_o]^{-1}$ and intercept of the vertical axis $[E_o/E_d]$, "E_d" and "E_o" can be calculated. The observed curvature deviation at shorter wavelength is occasionally attributed to the closeness of the band edge or excitonic absorption (Wemple and Didomenico, 1971).

The calculated values of the dispersion parameters [E_o and E_d], the static refractive index, n_o (0) = [E_d/ E_o +1]$^{1/2}$ (Hassanien and Akl, 2015). ; as well as the static dielectric constant, "ε_s" at high frequency [hυ → ∞], of the investigated thin films $Ge_{12}Bi_xSe_{88-x}$ ternary system are listed in Table 1.

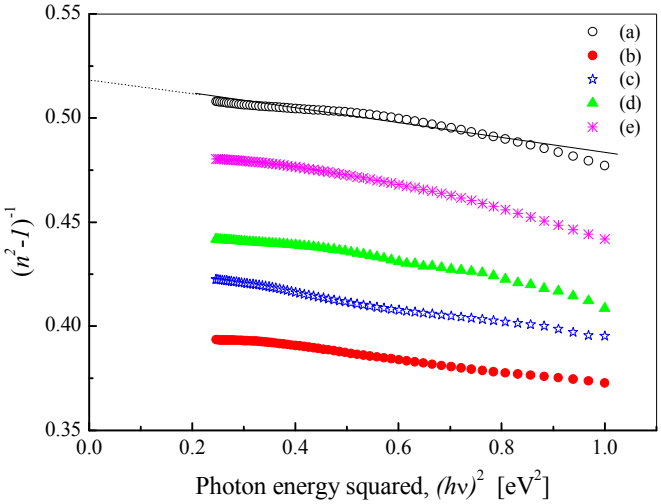


Fig. 3: Plots of $(n^2-1)^{-1}$ as a function of photon energy squared for $Ge_{12}Bi_xSe_{88-x}$ thin films ternary system.

Table 1: Calculated values of E_d, E_o, static dielectric constant, ε_s at high frequency (hυ → ∞), static refractive index, n_o (0).

Exact Sample compositions	Bi at%	E_d [eV]	E_o [eV]	$n_o(0)$	ε_s	E_g^{WD} [eV]	N_e	N_c	β [eV]
$Ge_{17.85}Bi_{6.06}Se_{76.09}$ (a)	6.06	7.41	3.84	1.71	2.93	1.92	7.34	2.42	0.21
$Ge_{12.44}Bi_{7.57}Se_{79.99}$(b)	7.57	9.13	3.67	1.87	3.49	1.84	7.1	2.32	0.28
$Ge_{10.41}Bi_{10.49}Se_{79.11}$(c)	10.49	8.04	3.46	1.82	3.32	1.73	7.19	2.31	0.24
$Ge_{13.52}Bi_{13.57}Se_{72.91}$(d)	13.57	7.57	3.44	1.79	3.2	1.72	7.67	2.41	0.21
$Ge_{11.55}Bi_{18.71}Se_{69.74}$(e)	18.71	6.53	3.23	1.74	3.02	1.61	8.00	2.42	0.17

It has been observed from the data summarized in Table 1 and Fig. 4 that the determined "E_d", values increases at a peculiarity "Bi" content of 7.57 at % thereafter goes to decrease with further increasing of "Bi" content. While the "E_o" values decrease with increasing of "Bi" content in the investigated ternary system. The determined "E_d" and "E_o" values are comparable with the corresponding values calculate for $Bi_5Ge_xSe_{95-x}$ ($30 \leq x \leq 45$) (F. M. Abdel-Rahim *et al*., 2011).

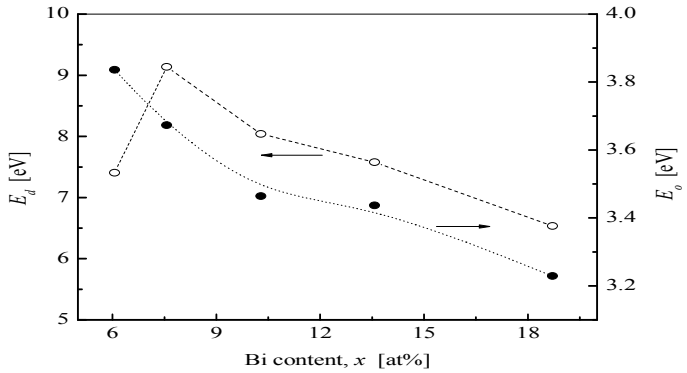


Fig. 4: variation of the dispersion parameters E_d and E_o as a function of the exact Bi content at%, for $Ge_{12}Bi_xSe_{88-x}$ thin films ternary system

The oscillator energy, "E_o", is an average energy gap called Wemple-DiDomenico band gap energy [E_g^{WD}] (Wemple, 1973; Wemple and Didomenico, 1971) and to a good approximation. It alters in proportion to the optical band gap, as was found by Tanaka (Tanaka, 1980) to an empirical relation; [$E_0 \approx 2E_g^{WD}$]. The variation of the [E_g^{WD}] with "Bi" content follow the trend of the oscillator energy "E_o". It must be mentioned here that, the information obtained from "E_o" i.e [E_g^{WD}] is completely different from the optical energy gap "E_g" that determined from the fundamental absorption edge. Where, the optical energy gap explores the optical properties near the band edges of the material, in particular localized states near the conduction or the valence band. Here the variation in the values of the oscillator energy, "E_o" with "Bi" content at % gives us an initial impression on the behavior of the optical band gap energy evaluated latter from the fundamental absorption region as a function of the "Bi" content.

A significant accomplishment of the Wemple-DiDomenico model is that it connects the dispersion energy, "E_d" to other physical parameters of the material through an empirical formula (Wemple, 1973; Wemple and Didomenico, 1971):

$$E_d = \beta N_c Z_a N_e \tag{3}$$

where "β" has a two constant values with either ''ionic'' or ''covalent''

[$\beta_i = 0.26 \pm 0.03$eV and $\beta_c = 0.37 \pm 0.04$ eV for ionic and covalent, respectively], "N_c" is the coordination of the cation nearest neighbor to the anion, "Z_a" is the formal chemical valency of the anion [Z =2] and "N_e" is the total number of valence electrons [cores excluded] per anion (Wemple and Didomenico, 1971). Using the calculated values of the total number of valence electrons [cores excluded] per anion; N_e= [4×Ge atomic % + 3×Bi atomic %+ 6×Se atomic %] / anion,

where 4, 3, and 6 are the valence electrons of "Ge","Bi" and "Se", respectively, and from the value of "N_c", one can obtain the constant β, [$\beta = E_d/(N_c Z_a N_e)$] for the investigating $Ge_{12}Bi_xSe_{88-x}$ thin films ternary system. The calculated values of "N_e", "N_c" and "β " are listed also in Table 1. It has been observed that the calculated "β" values for the studied system are found to be in the range [0.26 eV] indicating that the ionic bonds are dominant in the investigated system.

Absorption coefficient, "α", extinction coefficient, "k", and optical band gap, "E_g"

The optical absorption coefficient, "α" could be determined from the measurements of T (λ) using the following equations (El Mandouh and Selim, 2000; Zhou *et al*., 1996):

$$\alpha = (1/t)\log(1/T) \tag{4}$$

where "t" is the film thickness. The extinction coefficient, "k" [imaginary part of the refractive index] can be computed from the absorption coefficient, "α" using the equation

$$k = \alpha\lambda / 4\pi \tag{5}$$

where "λ", is the wavelength of the incident photon.

The absorption coefficient extracted from transmittance data on the basis of Eq.4 are shown in Fig. 5. The figure reveals that, the absorption coefficiecnt, "α" for $Ge_{12}Bi_xSe_{88-x}$ thin films increases with increasing photon energy and has high values reach to 10^4 cm^{-1} in the photon energy range 1.24-5.0 eV.

Fig. 6 shows the spectral variation of the extinction coefficient, "k" [imaginary part of the refractive index] of the investigated $Ge_{12}Bi_xSe_{88-x}$ films as a function of the wavelength. It has been observed that the "k" curve shows a single broad peak appears in the wavelength range 300-500 nm, beyond this peak the values of "k" decreases with increasing the wavelength of incident photons corresponding to strong electronic absorption between valence and conduction band. Similar behavior for the "k" curves has been also observed for $Ge_{20}Se_{80-X}Bi_X$ [*x* =6, 8, 10 and 12] (Sharma *et al*., 2005).

In the fundmental absorption region, "α" can be denoted by the relation (Sharma *et al*., 2013; Ahmad *et al*., 2014):

$$\alpha = C(E - E_g)^p / h\nu \tag{6}$$

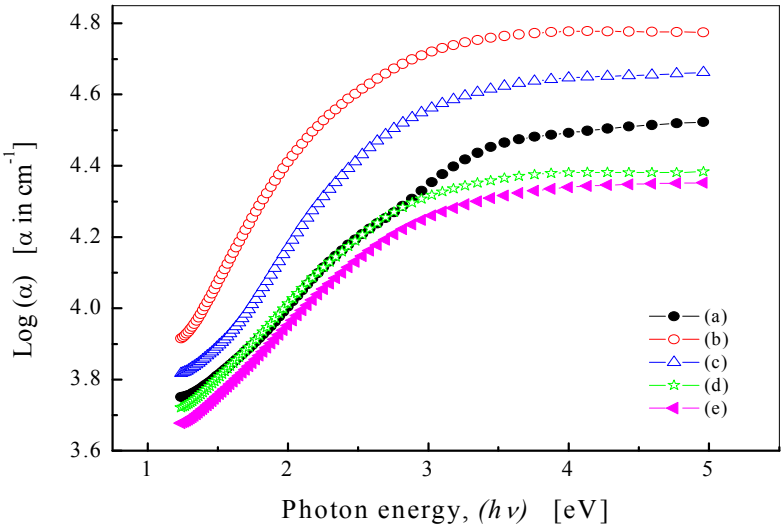


Fig. 5: Plots of log α vs. photon energy, (hν) for $Ge_{12}Bi_xSe_{88-x}$ thin films

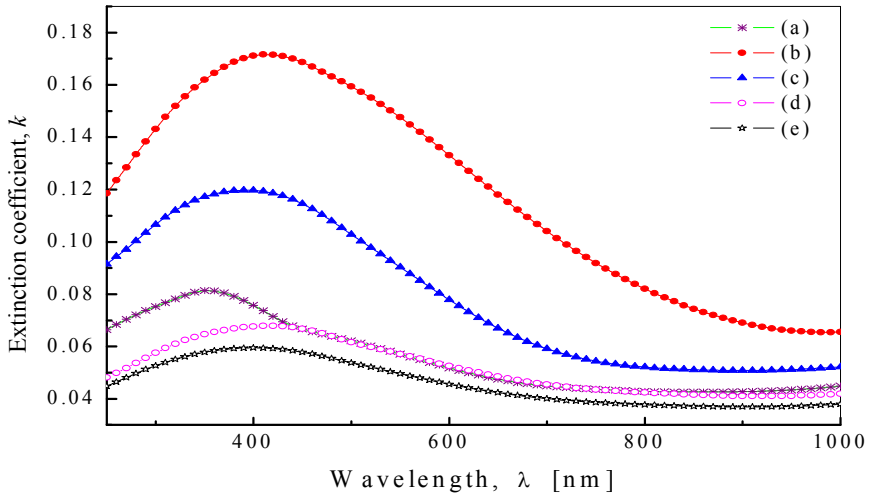
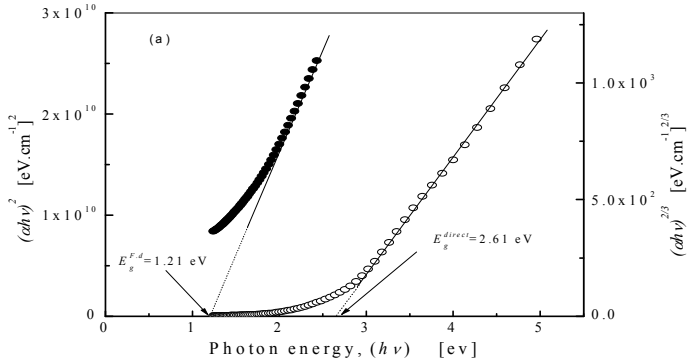
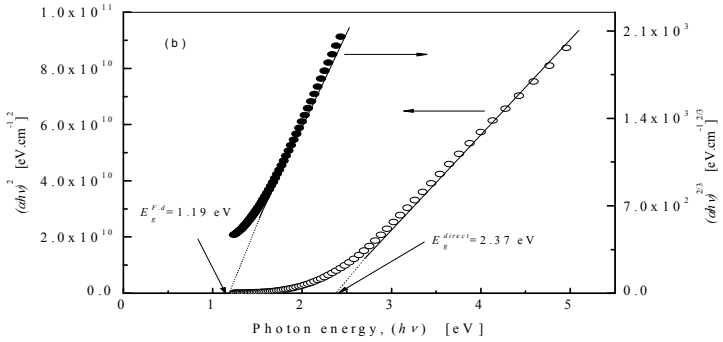


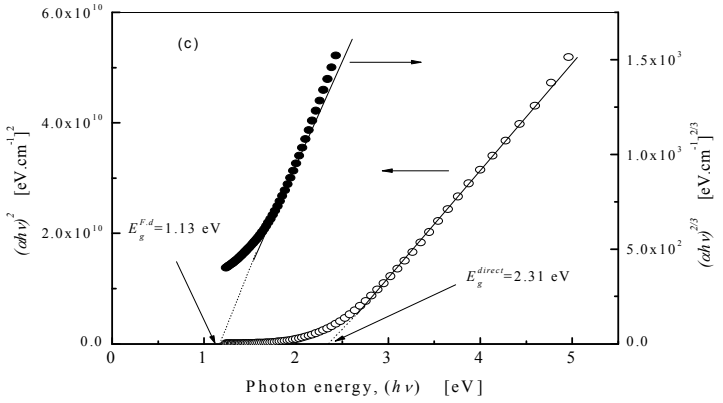
Fig. 6: Shows the spectral variation of the extinction coefficient, k vs. wavelength for $Ge_{12}Bi_xSe_{88-x}$ thin film ternary system.

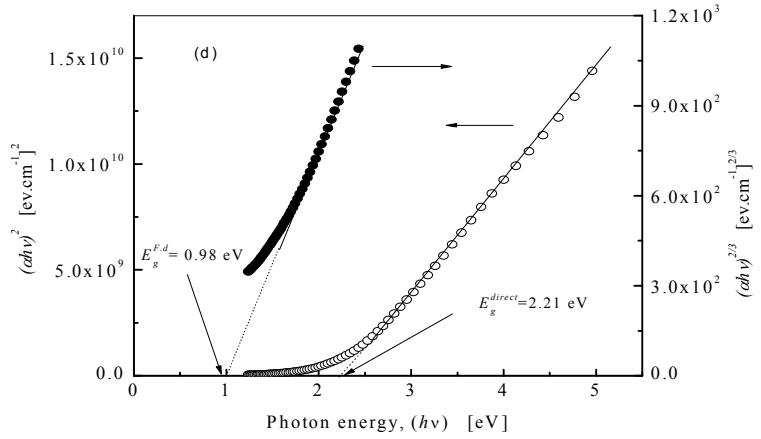
where "C" is constant depending on the transition probability, "E_g" is the band gap, "hυ" is photon energy and "p" is an index which illustrate the type of the optical absorption transition and is theoretically equal to 2, 1/2, 3 or 3/2 for indirect allowed, direct allowed, indirect forbidden and forbidden direct transitions, respectively. The value of the band gap, "E_g" at specific temperature is determined by plotting a graph of $(\alpha h\upsilon)^{1/p}$ versus photon energy, "hυ " according to Eq. 6. If a suitable value of "p" is utilized to get linear plot, the value of "E_g" will be yielded by the intercept with the axis. To apply this relation for the investigated sample, $(\alpha h\upsilon)^{1/2}$, $(\alpha h\upsilon)^2$, $(\alpha h\upsilon)^{1/3}$ and $(\alpha h\upsilon)^{2/3}$ as function of "hυ " were plotted.

The analysis of the absorption coefficiecnt , "α" in the photon energy range 1.24 - 4.96 eV, reveals that in the photon energy range 2.48 - 4.96 eV, the dependence of "α" on "hυ" could be illustrated by the Equ. 6 with p=1/2, which corresponding to direct optical transition. While, in the photon energy range 1.24-2.48 eV, the dependence of "α" on the photon energy, "hυ"could be described by the relation 6 with p =3/2, which corresponding forbidden direct optical transition. Fig. 7. illustrats the plots of both $(\alpha h\nu)^2$ and $(\alpha h\nu)^{2/3}$ as a function of "hυ" for the investigated $Ge_{12}Bi_xSe_{88-x}$ thin films. The extrapolation of the linear parts of the curves to the photon energy axis as shown, would give the optical band gap energy for both direct and forbidden direct optical transitions. The determined values of the corresponding energies are listed in Table 2 in comparison with the corresponding reported values.


(a)
$E_g^{F.d}$=1.21 eV
E_g^{direct}=2.61 eV
$(\alpha h\nu)^2$ [eV.cm^{-1}]^2
$(\alpha h\nu)^{2/3}$ [eV.cm^{-1}]$^{2/3}$
Photon energy, ($h\nu$) [ev]


(b)
$E_g^{F.d}$=1.19 eV
E_g^{direct}=2.37 eV
$(\alpha h\nu)^2$ [eV.cm^{-1}]^2
$(\alpha h\nu)^{2/3}$ [eV.cm^{-1}]$^{2/3}$
Photon energy, ($h\nu$) [eV]


(c)
$E_g^{F.d}$=1.13 eV
E_g^{direct}=2.31 eV
$(\alpha h\nu)^2$ [eV.cm^{-1}]^2
$(\alpha h\nu)^{2/3}$ [eV.cm^{-1}]$^{2/3}$
Photon energy, ($h\nu$) [eV]


(d)
$E_g^{F.d}$= 0.98 eV
E_g^{direct}=2.21 eV
$(\alpha h\nu)^2$ [ev.cm^{-1}]^2
$(\alpha h\nu)^{2/3}$ [ev.cm^{-1}]$^{2/3}$
Photon energy, ($h\nu$) [eV]

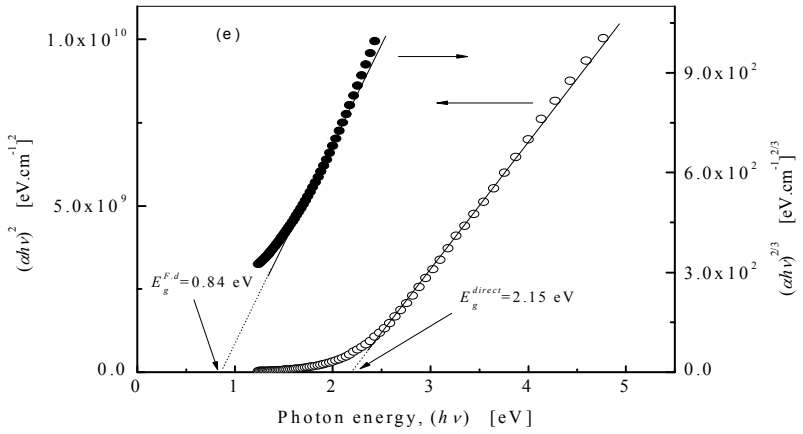


Fig. 7: Illustrates the plots of $(\alpha h\nu)^2$ and $(\alpha h\nu)^{2/3}$ as a function of the photon energy, hν for the $Ge_{12}Bi_xSe_{88-x}$ thin films

Table 2: the determined direct and indirect band gap energies of $Ge_{12}Bi_xSe_{88-x}$ thin films in comparison with the corresponding reported values.

Exact Sample compositions	Bi at%	E_g^{direct} [eV]	$E_g^{F.d}$ [eV]	$E_g^{indirect}$ [eV]	Refrences
$Ge_{17.85}Bi_{6.06}Se_{76.09}$ (a)	6.06	2.61	1.21	----	p.w*
$Ge_{20}Bi_5Se_{75}$		2.55	----	----	(El-Korashy *et al*., 2005)
$Ge_{20}Bi_6Se_{74}$		1.94	-----	1.45	(Sharma *et al*., 2005)
$Ge_{12.44}Bi_{7.57}Se_{79.99}$(b)	7.57	2.37	1.19	-----	p.w
$Ge_{20}Bi_8Se_{72}$		1.95	----	1.29	(Sharma *et al*., 2005)
$Ge_{10.41}Bi_{10.49}Se_{79.11}$(c)	10.49	2.31	1.13	-----	p.w
$Ge_{20}Bi_{10}Se_{70}$		2.41	----	-----	(El-Korashy *et al*., 2005)
$Ge_{20}Bi_{10}Se_{70}$		1.42	----	1.25	(Sharma *et al*., 2005)
$Ge_{13.52}Bi_{13.57}Se_{72.91}$(d)	13.57	2.21	0.98	----	p.w
$Ge_{20}Bi_{12}Se_{68}$		1.69	----	1.17	(Sharma *et al*., 2005)
$Ge_{11.55}Bi_{18.71}Se_{69.74}$(e)	18.71	2.15	0.84	-----	p.w

*P.W (present work)

It has been observed that from the data summarized in Table 2 that the determined direct and forbidden direct band gap energies were found to decrease with increasing "Bi" content. Fig. 8 illustrates the direct and forbidden direct band gaps as a function of the "Bi" content for the investigated $Ge_{12}Bi_xSe_{88-x}$ thin films.

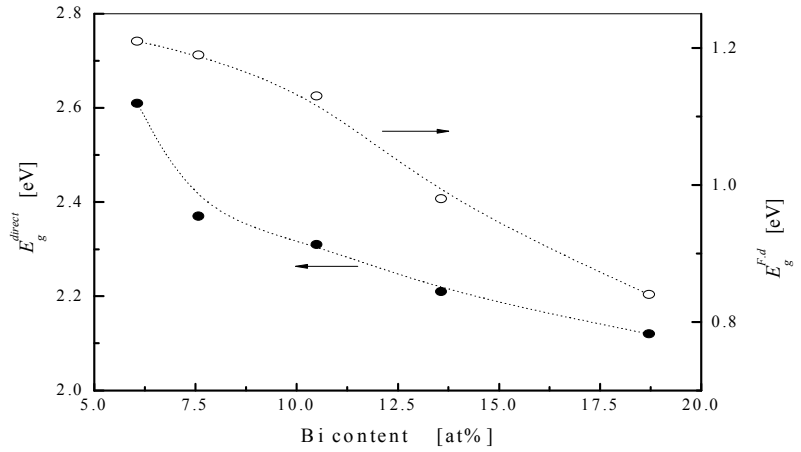


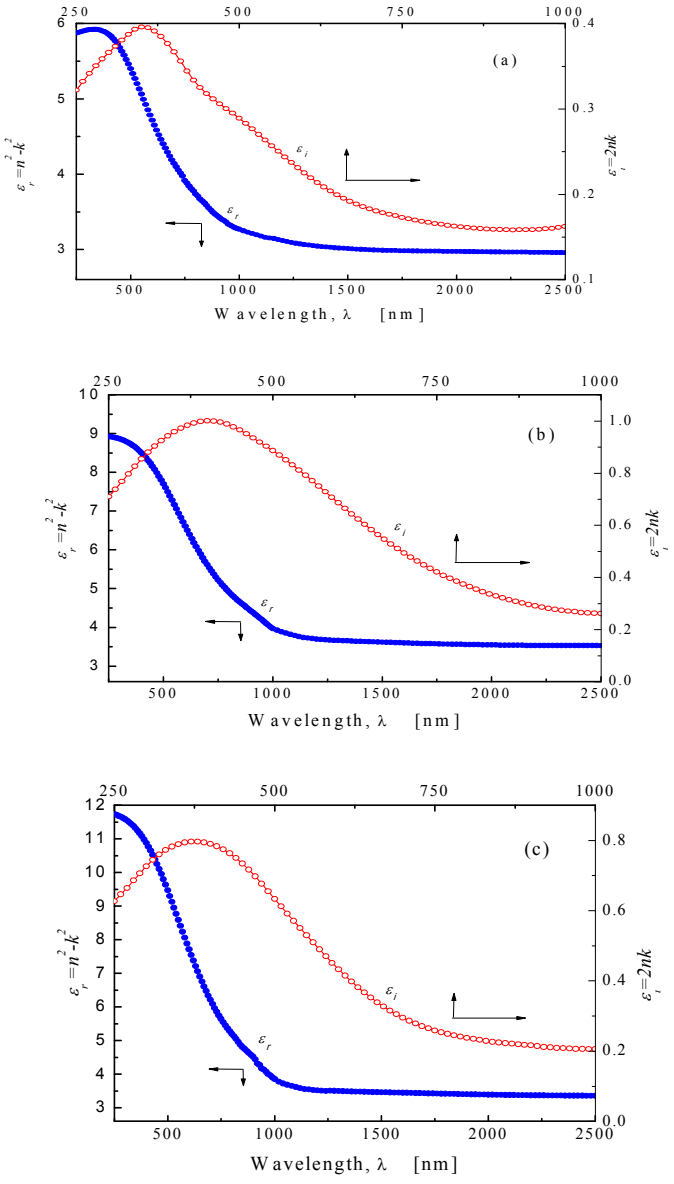
Fig. 8: Variation of the direct and forbidden direct band gaps with the exact Bi content .

The real, "ε_r", and imaginary, "ε_i", parts of complex dielectric constants:

The real and imaginary parts of the dielectric constant of as-deposited $Ge_{12}Bi_xSe_{88-x}$ thin films can be evaluated using refractive index "n" and extinction coefficient "k". *via* the well-known Equs. (El-Nahass *et al*., 2003; Salem *et al*., 2008):

$$\varepsilon_r = n^2 - k^2, \qquad \varepsilon_i = 2nk \tag{7}$$

The variation of both "ε_r" and "ε_i" as a function of wavelength for the films under consideration are shown in Fig. 9. From Fig. 9 it has been observed that for such of the investigated film composition, the real, "ε_r", and imaginary, "ε_i", parts of the dielectric constant decreases intensify by increasing wavelength in range 250-770 nm, where, the imaginary part of the dielectric constant reach a minimum value at the end of this range, while the real dielectric constant decrease slowlly after that. This behaviour can be understood due to the fact that "ε_r" is associated with the term that how much it will delay the speed of light in the material, while "ε_i" gives that how a dielectric absorb energy from electric field because of dipole motion.



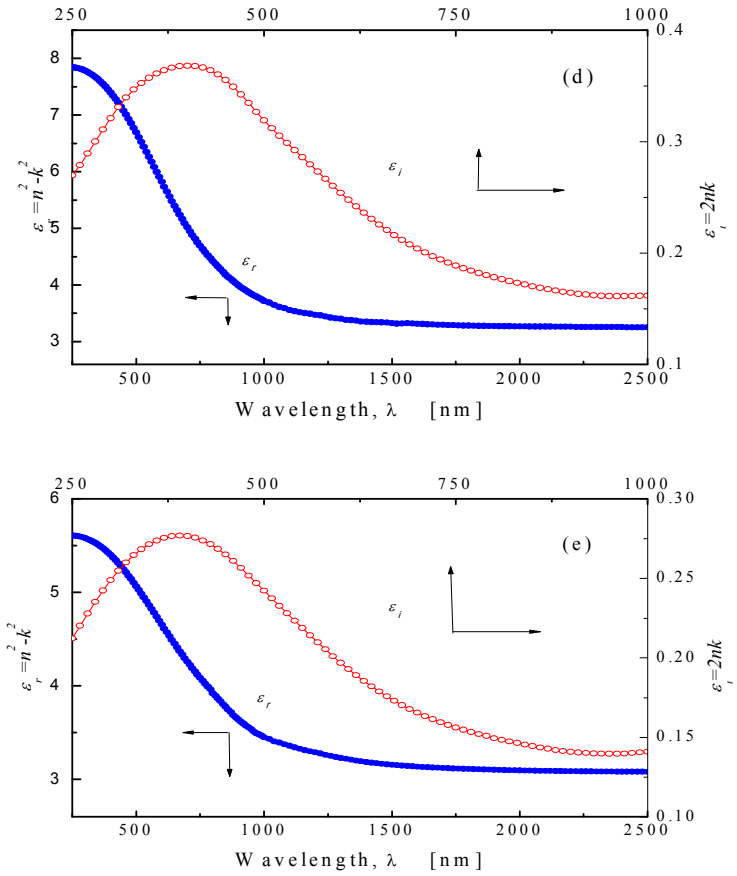


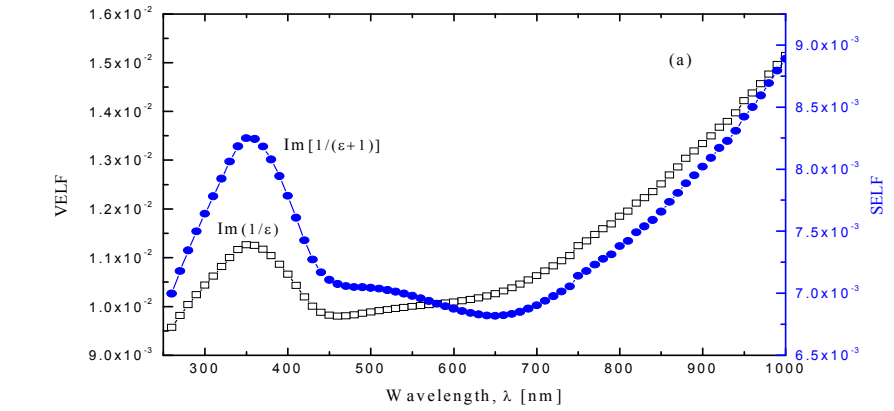
Fig. 9: variations of ε_r and ε_i as a function of wavelength for $Ge_{12}Bi_xSe_{88-x}$ thin films ternary system.

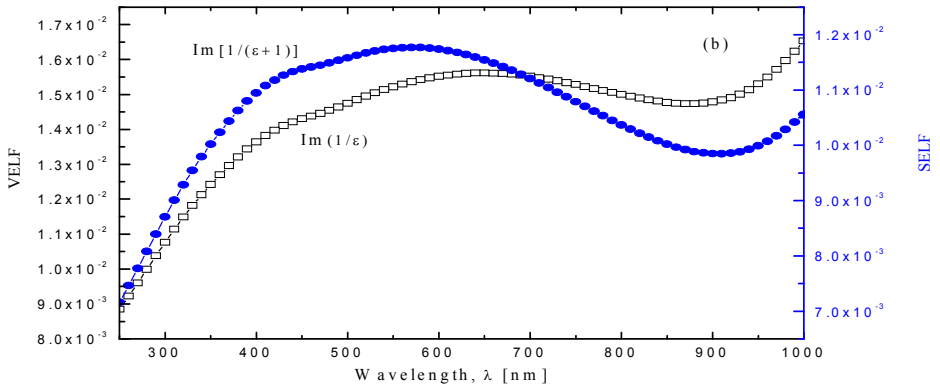
Volume energy loss, "VELF", and surface energy loss, "SELF", of thin films:

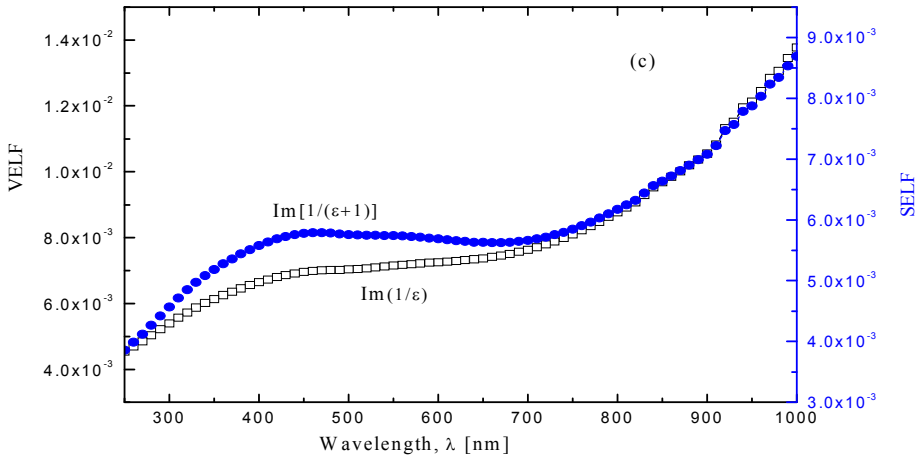
Sequentially, in electron energy-loss spectroscopy, when the energetic electron beams passes through a thin film, they loss energy with the amount related to the free-electron density in the material. The volume $-\mathrm{Im}(1/\varepsilon)$ and surface $-\mathrm{Im}\,1/(\varepsilon+1)$ energy-loss functions are related to the material optical properties *via* the real, " $\boldsymbol{\varepsilon_r}$" and imaginary, " $\boldsymbol{\varepsilon_i}$" parts of the dielectric functions as (El-Nahass *et al*., 2003; Salem *et al*., 2008)

$$-\mathrm{Im}\left(\frac{1}{\varepsilon}\right)=\frac{\varepsilon_i}{\varepsilon_r^2+\varepsilon_i^2};$$
$$-\mathrm{Im}\left(\frac{1}{(\varepsilon+1)}\right)=\frac{\varepsilon_i}{[(\varepsilon_r+1)^2+\varepsilon_i^2)} \quad (8)$$

Fig. 10 shows the graphical representation of the spectral variation of the volume and surface energy loss functions as a function of the wavelength for different values of "Bi" content. It was observed that for all the investigated and at any of certain value of wavelength the magnitude of the surface energy loss is lower than that of the volume energy loss.


(a)
Im[1/(ε+1)]
Im(1/ε)
VELF
SELF
Wavelength, λ [nm]


(b)
Im[1/(ε+1)]
Im(1/ε)
VELF
SELF
Wavelength, λ [nm]


(c)
Im[1/(ε+1)]
Im(1/ε)
VELF
SELF
Wavelength, λ [nm]

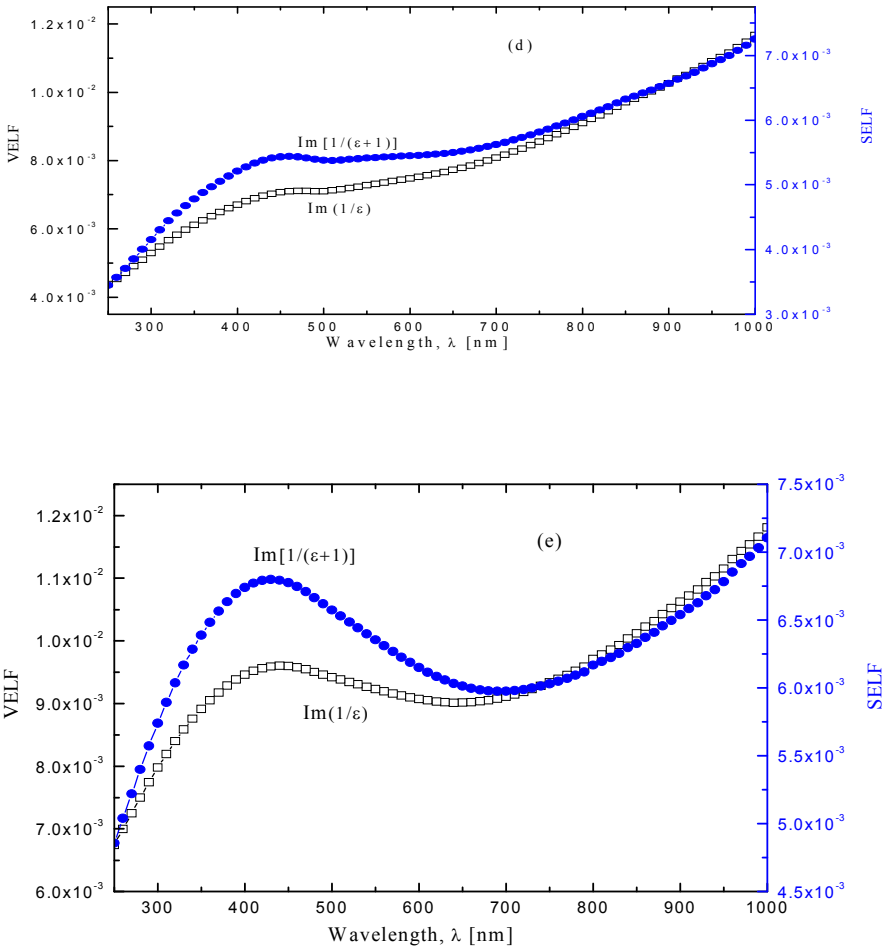


Fig. 10: Variation of VELF and SELF as a function of wavelength for $Ge_{12}Bi_xSe_{88-x}$ thin films

Conclusion

The optical properties of $Ge_{12}BixSe_{88-x}$ are studied. It is found that, each of the refractive index and extinction coefficient reduces for all the investigated films with increasing the wavelength of incident photons after wavelength 500 nm.

The determined direct and forbidden direct band gap energies were found to decrease with increasing "Bi" content at %, science the value of E_g decreases from 2.61 to 2.15 for direct transition and E_g decreases from 1.21 to 0.84 for forbidden direct transition.

The determined "E_d"**,** values increases at a peculiarity "Bi" content of 7.57 at % thereafter goes to decrease with further increasing of "Bi" content, while the "E_o" values decrease with increasing of "Bi" content in the investigated ternary system.

Each of the real and imaginary parts of the dielectric constant decreases intensify with increasing wavelength in range 250-770 nm. The graphical representations of surface and volume energy loss functions were also showed.

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