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Optical Properties Of the system Se_{80} Ge_{20-x} In_x Before and After Thermal Annealing

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Abstract: *The transmittance (T), Reflectance(R), and optical parameters of the system $Se_{80}Ge_{20-x}In_x$ show nonlinear behavior during the wavelength range250-2500nm.This was attributed to the dependence of the obtained physical quantities on the light energy intensity. The obtained values of the optical parameters, refractive index (n), extinction coefficient (k) and the absorption coefficient, (α) dcrease as the photon energy decreases. The characteristic peaks of T, R, n, k, and (α) were shifted towards low photon energy values as the thin film samples were thermally annealed at 383k for one hour. This shift slightly increased as the annealing temperature increased to 493k for one hour. The optical energy gap has been decreased as the Indium content and the annealing temperature increased. The nonlinearity of n, k and (α) of this system will give a chance to produce optical elements (lenses& gratings) with graded values to be components for the future optical computers. The decrease of n, k and (α) shift towards low photon energies is a key to use this material as a human eye protector against the UV high photon energy. In the same time this material can be used as smart windows for heating buildings in cold weather. The narrowing of the optical energy gap of this material recommends it as a raw material for photovoltaic solar cells.*

I. Introduction:

Chalcogenide glasses have drawn the attention of many scientists and engineers because of their extensive use in many solid state devices(1,2). Optical memory effects in amorphous Chalcogenide glasses are a subject of systematic research due to the changes in their Physical and chemical properties(3,4). Chalcogenide materials have been found to exhibit a change in the optical parameters under the influence of light(5-7). One of the most interesting optical properties of the chalcogenide glasses is their photosensitivity, Which is only observed in its amorphous state(8). This was detected by photo- darkening of the sample under test(9). The interaction of chalcogenide materials with strong enough light filed can lead to nonlinear optical behavior(10,11). Chalcogenid glasses have transparent windows extend to the infrared region of the spectrum. This recommends it as a candidate material for Infrared fiber optics and other optical elements(12). The optical parameters of the Se, Ge, In system thin films did not have enough intensive research work(13,14). In the present work the optical properties of Se_{80} Ge_{20-x} In_x will be investigated for green and thermally treated samples. The optical parameters of this system will be deduced and the effect of replacing In atoms on the expense of Ge atoms also will be studied.

II. Experimental Technique:

The $Se_{80}Ge_{20-x}In_x$ bulk material was prepared using melt-quenching technique. The used elements Se, Ge and In were with purity of 5N. The mixture of these elements was introduced into fused silica tubes and sealed under vacuum 10^{-5} Torr. The tubes were heated in an electric programmable furnace at 950 c for 15h. After complete melting and ensured good mixing of the mixture the tubes were quenched in ice water. The amorphous structure of the obtained samples was confirmed by XRD. The amorphous thin films of the system $Se_{80}Ge_{20-x}In_x$were prepared using thermal evaporation technique under vacuum. The films thickness were determined and found to be in the range of 150 -400 nm. To ensure the stoichiometry of the mixture ratios in each sample the energy dispersive x-ray analysis (RDX) was performed. The transmittance (T) and reflectance (R) of the system $Se_{80}Ge_{20-x}In_x$were recorded using UV-VIS-NIR (Jaco750) within the spectral range 200-2500nm double beam spectrophotometer.

III. Results:

1-Transmittance (T) and Reflectance (R) of the system $Se_{80}Ge_{20-x}In_x$

The samples of the system $Se_{80}Ge_{20-x}In_x$ were thermally annealed at 383k and 493k separately, for one hour each. The transmittance (T) and Reflectance (R) of this system were recorded in the wavelength range 250 – 2500nm, before and after thermal annealing, figures (1-5). These figures depict a nonlinear behavior for all tested samples before and after thermal annealing (15).

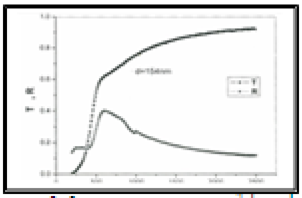

Fig. [1] λ [nm]
T & R of $Se_{80}Ge_{20}$

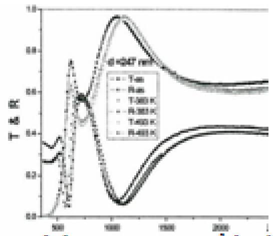

Fig. [2] λ [nm]
T&R of $Se_{80}Ge_{15}In_5$

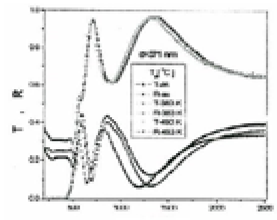

Fig. [3] λ [nm]
T&R of $Se_{80}Ge_{10}In_{10}$

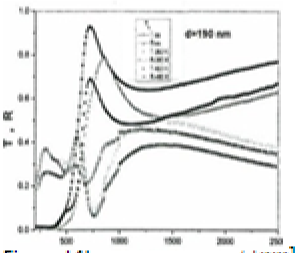

Figure [4] λ [nm]
T & R of $Se_{80}Ge_5In_{15}$

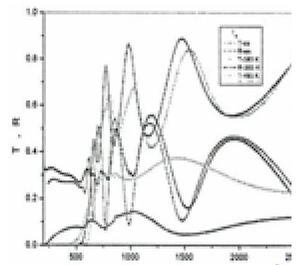

Figure [5] T & R of $Se_{80}In_{20}$ λ (nm)

The characteristic peaks of (T) and (R) shifted towards longer wavelength with some changes in the peaks intensities as the thin samples were annealed at 383k. These changes in both intensities and peak locations increased slightly as the annealing temperature raised from 383k to 493k.

2-The optical parameters of the system $Se_{80}Ge_{20-x}In_x$.

The refractive index(n), extinction coefficient (k) and absorption coefficient(α) and optical energy gap E_g^o of the system $Se_{80}Ge_{20-x}In_x$ were drown out from the wavelength spectral distribution of (T) and (R) using the

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

$$k = \frac{\alpha\lambda}{4\pi}$$

$$\alpha = \frac{ln}{d}\left\{\frac{(1-R)^2}{2T} + \left(\frac{(1-R)^4}{4T^2} + R^2\right)^{\frac{1}{2}}\right\}$$

$$z\alpha h\upsilon = A\left(h\upsilon - E_g^o\right)^m$$

relations(16-21)

Where, d is the thin film thickness, λ is the wavelength, υ is the frequency, k is Blank's constant and m is an exponent depends on the transition mechanism. The obtained results were illustrated in figures(6-9).

λ [nm]

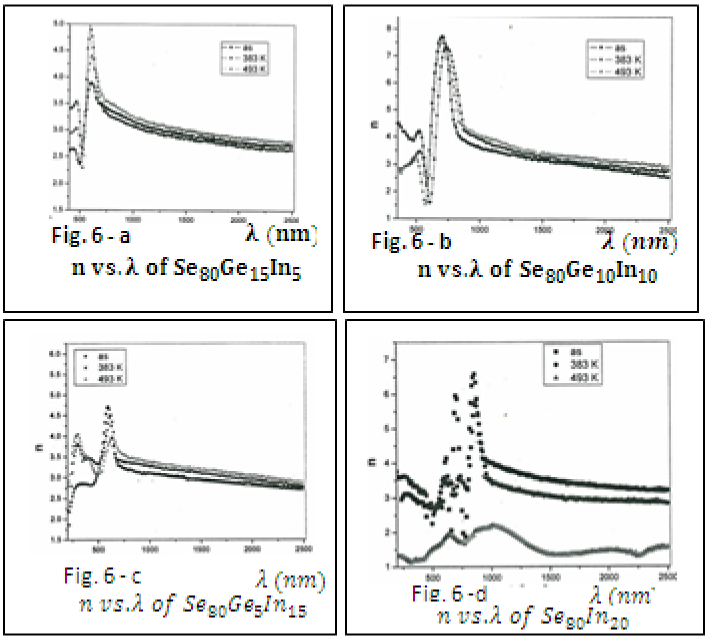

Fig. 6 - a n vs. λ of $Se_{80}Ge_{15}In_5$

Fig. 6 - b n vs. λ of $Se_{80}Ge_{10}In_{10}$

Fig. 6 - c n vs. λ of $Se_{80}Ge_5In_{15}$

Fig. 6 - d n vs. λ of $Se_{80}In_{20}$

These figures ensure the nonlinearity behavior of the optical parameters all over the given spectral wavelength range, before and after annealing.

The relation, $n - \lambda$, shows slight changes in the peaks intensities as well as slight shift towards longer wavelength as the samples were annealed at 383k and re- annealed at 493k, fig. (6_{a-d}).

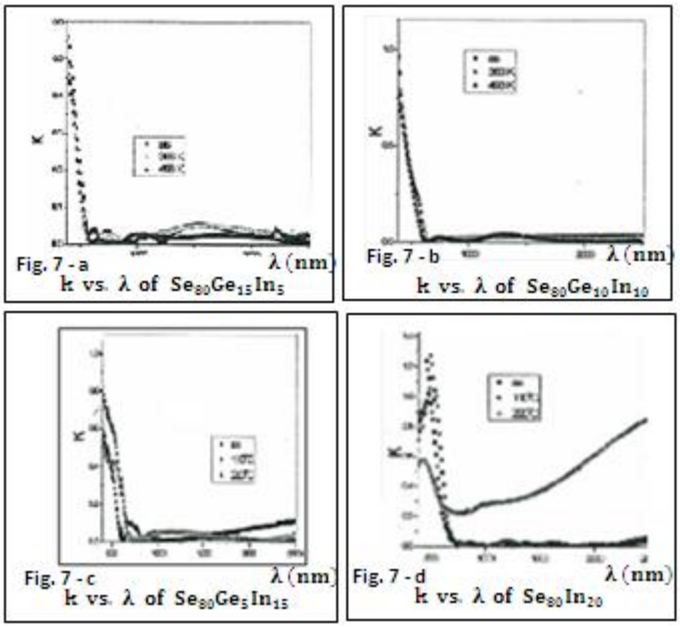

Fig. 7 - a k vs. λ of $Se_{80}Ge_{15}In_5$

Fig. 7 - b k vs. λ of $Se_{80}Ge_{10}In_{10}$

Fig. 7 - c k vs. λ of $Se_{80}Ge_5In_{15}$

Fig. 7 - d k vs. λ of $Se_{80}In_{20}$

The curves, $k - \lambda$, show that the start values of k for thermally treated samples were larger than their values for green samples, fig. (7_{a-d}). These figures show that the value of k decreases abruptly, accompanied with shifting in the offset point towards longer wavelength as the annealing temperature increases.

The absorption coefficient (α) has been decreased as the samples annealed at 383k and decreased more as the annealing raised to 493k, specially at higher photon energies, fig. (8_{a-d}).

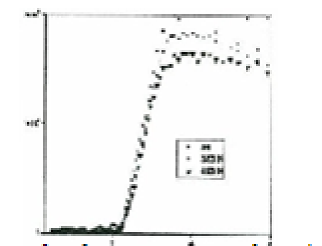

Fig.[8-a] hν eV)
α vs. hν of $Se_{80}Ge_{15}In_5$

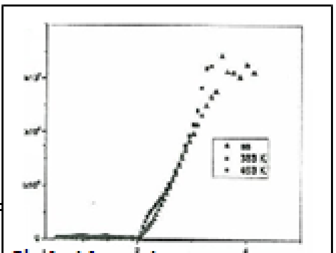

Fig.[8-b] hν (eV)
α vs. hν of $Se_{80}Ge_{10}In_{10}$

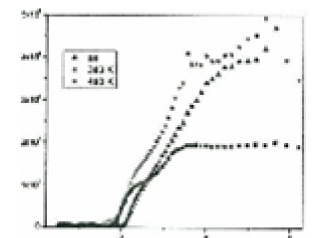

Fig.[8-c] hν (eV)
α vs. hν of $Se_{80}Ge_5In_{15}$

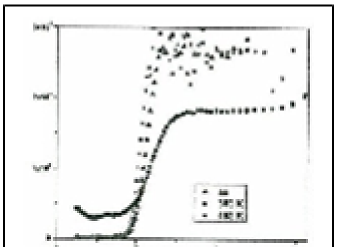

Fig.[8-d] hν (eV)
α vs. hν of $Se_{80}In_{20}$

The changes of the absorption coefficient (α), leads to the change of the optical energy gap (E_g^0) as the samples were thermally annealed at 383k and 493k, fig. (9_{a-d}).The values of the optical energy gap are tabulated in table(1) for all samples under different conditions of thermal treatment.

Table (1) The values of the optical energy gap

Sample In (x)	Green Sample e.V	Annealed at 383k e.V	annealed at 493k e.V
0	2.15	2.00	1.95
5	2.00	1.90	1.7
10	1.95	1.80	1.6
15	1.80	1.70	1.55

IV. Discussion:

The nonlinear behavior of (T), (R), (n), (k) and(α), as given in the figs. $(1-9)$ may be due to the dependence of these physical quantities on the spectral intensity at the given wavelength. This Can serve to the production of variable optical parameters material, such as (n), (k),(α), and (E_g^0).

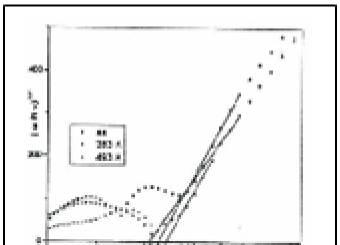

Fig. [9-a] hν
Energy gap of $Se_{80}Ge_{15}In_5$

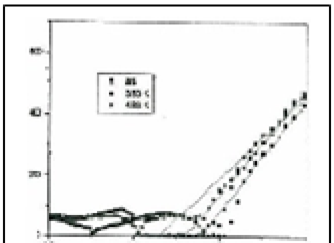

Fig. [9-b] hν
Energy gap of $Se_{80}Ge_{10}In_{10}$

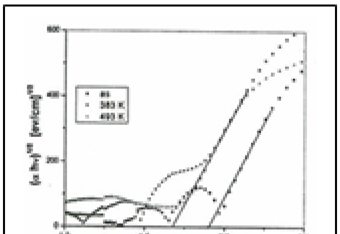

Fig. [9-c] hν
Energy gap of $Se_{80}Ge_5In_{15}$

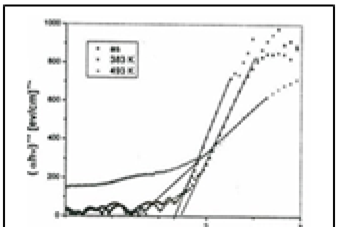

Fig. [9-d] hν
Energy gap of $Se_{80}In_{20}$

The abrupt decrease of the extinction coefficient k at the offset wavelength and its shift towards longer wave length, may be due to the partial conversion of the samples' smooth surface at high photon energies into to somewhat rough surface at low photon energies. This means that the bonding connections of the sample surface atoms are in the best manner at high photon energies. The detected decrease of k values as photon energy decreases leads to the decrease of the absorption coefficient(α) .This in turn leads to the decrease of the optical energy gap$\left(E_g^o\right)$ This may be attributed to some type of photo-darkening, leading to the narrowing of the optical energy gap$\left(E_g^o\right)$. This narrowing of the optical energy gap was revealed as the Indium content increased, as well as the increase of the annealing temperature, table (1).This may be due to the formation of some ordered phases, which may be developed in a proper condition as the sample thermally annealed at 383k for one hour, and the optimum condition may be reachable as the annealing temperature increases as revealed by rising the annealing temperature from 383k to 493k.

V. Conclusion:

The detected non-linearity of (T), (R), (n) , (k), and (E_g^0)recommend the use of this system for the production of graded optical parameters. The decrease of both of the absorption coefficient(α), and the the optical energy gap (E_g^0) may support the use of this system as new windows characterized by minimum losses for optical fibers communication. Also the narrowing of the optical energy gap as Indium content increases and as annealing temperature Increases may encourage scientists to employ this system as a row material for high efficiency photovoltaic solar cell.

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