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Phase transition in a- $\text{Se}_{85}\text{Te}_{15}$ thin film on thermal annealing

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Abstract

The effect of thermal annealing on the electrical and structural properties has been studied on a thin film of a- $\text{Se}_{85}\text{Te}_{15}$ alloy. The dark (σ_d) and photoconductivity (σ_{ph}) increase sharply with the increase in annealing treatment. There is a sharp drop in the photosensitivity (σ_{ph}/σ_d) of the thin film sample. The dark activation energy (ΔE_d) decreases on thermal annealing treatment. These changes are attributed to the phase transition of the thin film of a- $\text{Se}_{85}\text{Te}_{15}$ from amorphous to crystalline phase. This is supported by the x-ray diffraction measurements, which clearly indicate the said phase transition on subjecting the thin film to prolonged thermal annealing treatment.

1. Introduction

The Se–Te based glassy alloys have created extreme interest due to their greater hardness, higher photosensitivity, higher crystallization temperature (T_c) and glass transition temperature (T_g) and lower ageing effects as compared to pure amorphous Se [1]. The addition of Te to Se changes the properties of glassy Se drastically. The Se–Te based alloy films are taken to be a promising medium, which makes use of a phase change between an amorphous state and a crystalline state. The structure bonding in the case of Se and Te is divalent in nature, that gives rise to one dimensional structure stability of the amorphous materials. The structural bonding in this amorphous matrix is not highly stable. The Te chalcogens in the amorphous state have a strong tendency to crystallize. The transition from amorphous to crystalline state can be induced by several factors, such as heat treatment, incident light, electric field etc. So, the glassy alloys of the Se–Te system, based on selenium, have become materials of considerable commercial, scientific and technological applications [2] as optical recording media because of their excellent laser writer sensitivity, xerography, electrophotographic applications such as photoreceptors in photocopying, laser printing, infra-red spectroscopy, lasers and fibre techniques. Generally, transport properties of chalcogenide glasses depend strongly on the nature and degree of short range order. As chalcogenide glasses have poor thermo-mechanical properties, in order to enlarge their domain of application, it is necessary to increase their

softening temperature and mechanical strength. The structure of a-Se consists of randomly mixed long polymeric Se_n chains in which various portions of a chain have ring fragments in contrast to a structure which is a mixture of Se_n and Se_8 rings [3, 4]. There is an increase in the average chain mass with Te addition, leading to an increase in the glass transition temperature. The addition of Te also increases the concentration of charged valence alternation pair (VAP) type defects, so that the increase in T_g is partly due to Se_3^+ and Te_3^+ type defects connecting neighbour chains and thus limiting the molecular chain mobility [5]. Therefore, the mean coordination number Z increases from two with Te addition. The increase in T_g with Te addition can be assumed to be due to the small fraction of Te atoms that are triply bonded so that they cross-link chains [3, 6]. The viscosity of liquid Se–Te alloys though in liquid state has been observed to decrease with the increase of Te content [7]. The addition of Te to a-Se broadens the distribution of shallow traps shifting the threshold for non-dispersive transport to higher temperatures. In addition, Te alloying which increases disorder drives the valence band mobility edge deeper into the band, increasing hole transport activation [8]. The reduction in the bandgap on the addition of Te is attributed to the lesser energy of Se–Te bonds as compared to that of Se–Se bonds, as has been pointed out by Hanmei *et al* [9].

It is well known that vitreous materials are in a metastable state and various properties such as thermodynamical, electrical and optical properties are changed by annealing below T_g [10]. The changes in these properties are considered to be due to the stabilization of amorphous structures and the realization of more close-packed structures [11]. The thermal annealing may lead to characteristic changes of properties of amorphous materials, i.e. the volume contraction and the increase of the energy gap. The structural transformations have been observed by Abdel-Rahim [12], when the temperature of annealing (T_a) was raised above T_g or subjected to prolonged thermal annealing treatment. The thermal annealing treatment above T_g induces crystallization in semiconducting chalcogenide glasses [13]. The films exhibit continuous grain growth but the crystalline phase does not propagate homogeneously [14]. The electrical characteristics change considerably after annealing. During heat treatment at temperatures up to the T_g the unsaturated defects gradually anneal out, producing a large number of saturated bonds. The reduction in the number of unsaturated defects decreases the density of localized states in the band structure and consequently increases the optical energy gap. The width of the localized state tail decreases with the increase in annealing duration or temperature [15]. Annealing reduces the randomness and effects the adjustment of relative position between the layers. After annealing, the amorphous structure becomes more stable than that before annealing, and there is volume contraction due to decrease of the average interlayer distance. However, the average distance between the nearest atoms in the neighbouring layers becomes larger, so that the energy gap increases because of the narrowing of the energy bands [16, 17].

The thermally induced effects are both reversible and irreversible. These effects open the possibility of the use of amorphous chalcogenide semiconductors for various applications such as high density information storage, high resolution display devices, fabrication of diffractive optical elements etc. The effect of thermal annealing is quite important, particularly in the case of glassy alloys having small crystallization temperatures. The thermal stability of chalcogenide glasses in technical applications is a problem of fundamental interest, as the useful operating temperature range is determined by the structural changes and the eventual crystallization occurring at the operating temperature [18]. In addition, the thermal annealing treatment and its effects give an insight into various mechanisms of crystal nucleation and growth. The transport properties are influenced by the structural effects associated with thermally induced transitions [19]. The Se–Te alloys have some advantages over amorphous Se, as far as their use in xerography and other applications is concerned. The main applications of Se–Te alloys are (a) their great storage capacity and a very fast access to information and (b) the

advantage of deleting and introducing new information. But these advantages depend on the stability of the material. The case with the increased use of glassy alloys of Se–Te system based on selenium for optical recording media due to their excellent laser writing sensitivity [19, 20] is similar. The thermal annealing treatment of the sample becomes a much more interesting process, as the memory effects are caused by a direct thermal process.

The annealing may provide a deeper insight into the mechanism of disorder and defect formation in the amorphous chalcogenides. On annealing the absorption edge shifts towards higher energies. The Urbach tail has also been observed to decrease on annealing by Islam *et al* [21]. Soltan *et al* [22], Khan *et al* [23] and Hafiz *et al* [24] have studied the effect of thermal annealing on the optical properties of Se–Te glassy alloys. A lot of research has been done on the study of the effect of thermal annealing on the optical properties of the semiconducting chalcogenide glasses [23–25], which has not been amply supported by corresponding experimental data of the effect of thermal annealing on the electrical properties. So, the effect of thermal annealing on the electrical properties of Se–Te chalcogenide glasses has been dealt with briefly in the present work.

2. Experimental procedure

The glassy alloy of $\text{Se}_{85}\text{Te}_{15}$ is prepared by the quenching technique. Materials (99.999% pure) are weighed according to their atomic percentage and sealed in quartz ampoules in a vacuum $\sim 2 \times 10^{-5}$ mbar. The sealed ampoule is kept inside a furnace where the temperature is increased up to 920 K at a heating rate of 2–3 K min^{-1} . The ampoule is frequently rocked for 24 h at the highest temperature to make the melt homogeneous. The quenching is done in liquid N_2 . The thin film of the alloy is prepared by the vacuum evaporation technique, keeping the substrate at room temperature and a base pressure of $\sim 2 \times 10^{-5}$ mbar using a molybdenum boat. The amorphous nature of the thin film is confirmed by x-ray diffraction (XRD). The composition of the evaporated sample is measured by an electron microprobe analyser (JEOL 8600 MX) on different spots (size $\sim 2 \mu\text{m}$) on the sample. The composition of a $2 \times 2 \text{ cm}^2$ sample is uniform, within the measurement accuracy of about $\pm 0.1\%$. Pre-deposited thick indium electrodes on well degassed Corning 7059 glass substrate have been used for the electrical contacts. A planar geometry of the film (length $\sim 1.78 \text{ cm}$; electrode gap $\sim 8 \times 10^{-2} \text{ cm}$) has been employed for electrical measurements. The thickness of the film is $\sim 5000 \text{ \AA}$. The film is kept in the deposition chamber in the dark for 24 h before mounting it in the metallic sample holder to attain thermodynamic equilibrium as stressed by Abkowitz *et al* [26].

The photoconductivity of the amorphous thin film is studied by mounting it in a specially designed metallic sample holder where heat filtered white light (200 W tungsten lamp) can be shone through a transparent glass window. A vacuum of about 10^{-3} mbar is maintained throughout these measurements. The results are found to be the same in higher vacuum $\sim 10^{-5}$ mbar also, which is verified in the laboratory. The intensity of light is measured by a digital Luxmeter (Testron, model TES-1332). The photocurrent (I_{ph}) is obtained after subtracting dark current (I_{d}) from the current measured in the presence of light. For measurement of transient photoconductivity, light is shone on the thin film sample and the rise of I_{ph} is noted manually from a digital picoammeter (model DPM-111). The accuracy in I_{ph} measurements is typically 1 pA. The film was first annealed at 331 K for 2 h. This temperature is less than the T_{C} ($T_{\text{C}} = 378 \text{ K}$) of the $\text{Se}_{85}\text{Te}_{15}$ glassy alloy. The temperature dependence of dark and photo-conductivity of the thin film of a- $\text{Se}_{85}\text{Te}_{15}$ glassy alloy has been measured after annealing it at a temperature of 334 K for successively increasing annealing durations. The thin film of a- $\text{Se}_{85}\text{Te}_{15}$ was annealed till it crystallized. This paper reports the

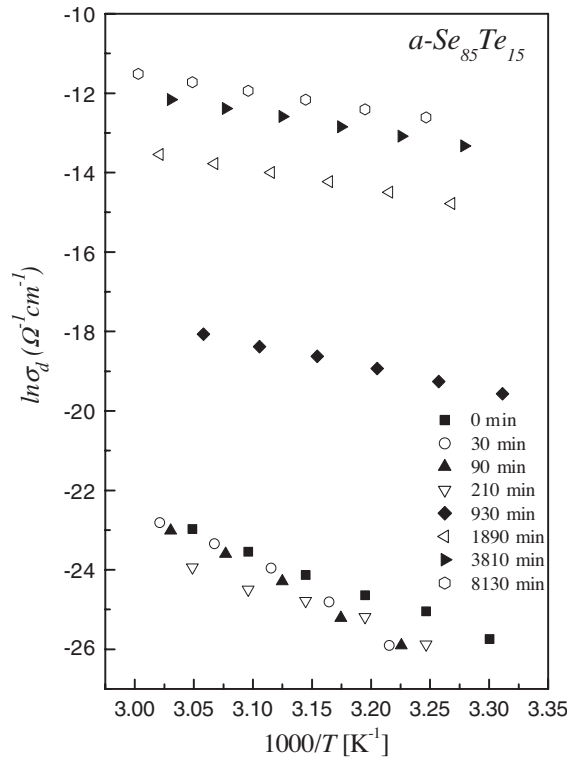


Figure 1. Temperature dependence of dark conductivity (σ_d) at various annealing durations (t_a) for $a\text{-Se}_{85}\text{Te}_{15}$ thin film.

dc conductivity and steady state photoconductivity measurements in $a\text{-Se}_{85}\text{Te}_{15}$ thin film as a function of temperature (301–331 K) and intensity (1–1035 lx). White light has been used for the photoconductivity measurements. The thin film used for the present measurements has been found to be Ohmic up to 100 V. The I – V curve has been found to be symmetric and linear. The thin film has been found to be highly photoconducting in the amorphous state. The stability of the annealed thin film during exposure to light has also been studied. No permanent change in dark conductivity, activation energy or photosensitivity has been observed after exposing the thin film to white light for 2 h at room temperature.

3. Results and discussion

The DC conductivity measurements yield valuable information about the conduction mechanism in amorphous semiconductors. Chalcogenide glasses normally show an activated temperature dependent dark conductivity according to the Arrhenius relation

$$\sigma_d = \sigma_0 \exp\left(\frac{-\Delta E_d}{k_B T}\right)$$

where ΔE_d is the activation energy for dc conduction, k_B is the Boltzmann's constant and σ_0 is the pre-exponential factor.

Figure 1 shows the temperature dependence of dark conductivity (σ_d) of the thin film of $a\text{-Se}_{85}\text{Te}_{15}$ glassy alloy measured after each successive annealing at a fixed temperature of

Table 1. Variation of σ_d and ΔE_d with the progress in thermal annealing treatment of a-Se₈₅Te₁₅ thin film.

Annealing time t_a (min)	σ_d ($\Omega^{-1} \text{ cm}^{-1}$)	ΔE_d (eV)
0	5.22×10^{-12}	0.93
30	1.04×10^{-12}	1.36
90	1.30×10^{-12}	1.31
210	2.86×10^{-12}	0.80
930	2.97×10^{-9}	0.51
1890	2.92×10^{-7}	0.43
3810	1.32×10^{-6}	0.41
8130	2.62×10^{-6}	0.39

334 K. The plots of $\ln \sigma_d$ versus $1000/T$ are straight lines for each annealing time in the investigated temperature range 301 to 331 K. This implies that the conduction in a-Se₈₅Te₁₅ glassy alloy is an activated process having a single activation energy (ΔE_d). The activation energy for dc conduction (ΔE_d) has been calculated from the slope of $\ln \sigma_d$ versus $1000/T$ curves. The value of σ_d increases with increase in temperature irrespective of the duration of annealing. But, it decreases for initial annealing followed by an increase on prolonged thermal annealing treatment.

Figure 2 shows the plot between the dark conductivity (σ_d) and activation energy (ΔE_d) with the progress in thermal annealing treatment duration (t_a). As the time of annealing treatment increases, σ_d also increases with a subsequent decrease in activation energy (ΔE_d). The σ_d initially decreases with the increase in ΔE_d (till the annealing time of 90 min) (as shown in the inset of figure 2). The value of σ_d increases and ΔE_d decreases on annealing the thin film for time more than $t_a = 90$ min. However, it was after 930 min of annealing time that the film of a-Se₈₅Te₁₅ showed an appreciable change in its behaviour, with σ_d increasing from 5.22×10^{-12} to $2.97 \times 10^{-9} \Omega^{-1} \text{ cm}^{-1}$ and ΔE_d decreasing sharply from 0.93 to 0.51 eV. Further annealing treatment increased the conductivity more rapidly with decrease in activation energy till the end of the annealing treatment, i.e. $t_a = 8130$ min. After 8130 min of annealing treatment, the sample crystallized and the conductivity reached the range of the order of $10^{-6} \Omega^{-1} \text{ cm}^{-1}$ and the activation energy decreased to about 0.39 eV. The values of σ_d and ΔE_d are given in the table 1 for different annealing durations. This is quite likely due to the partial crystallization of the amorphous film after annealing from $t_a = 930$ min up to the long time $t_a = 8130$ min at this temperature. The crystallized nature of the thin film of a-Se₈₅Te₁₅ alloy has also been confirmed from the x-ray diffraction curve of the film, before and after the annealing treatment in figure 3. The curves show the development of prominent peaks on annealing the thin film for longer duration. The changes in dark conductivity depend on the initial Fermi level position in the material. In slightly n-type material the Fermi level is pushed down towards the centre of the energy gap, and in p-type material the Fermi level is pushed up to the centre [27]. σ_d (the Fermi level) depends on the distribution of the donor or acceptor-like states. Hence, depending on the distribution of the new states, the σ_d increases, decreases or remains unaltered after thermal (and light) treatments.

Figure 4 shows the temperature dependence of steady state photoconductivity on the thin film of a-Se₈₅Te₁₅ alloy. Plots of $\ln \sigma_{ph}$ versus $1000/T$ are straight lines in the measured temperature range 301–332 K at all the annealing durations. This indicates that the photoconduction in this glassy alloy is an activated process having a single activation energy for photoconduction. The slopes of the curves have been used to calculate the photoactivation

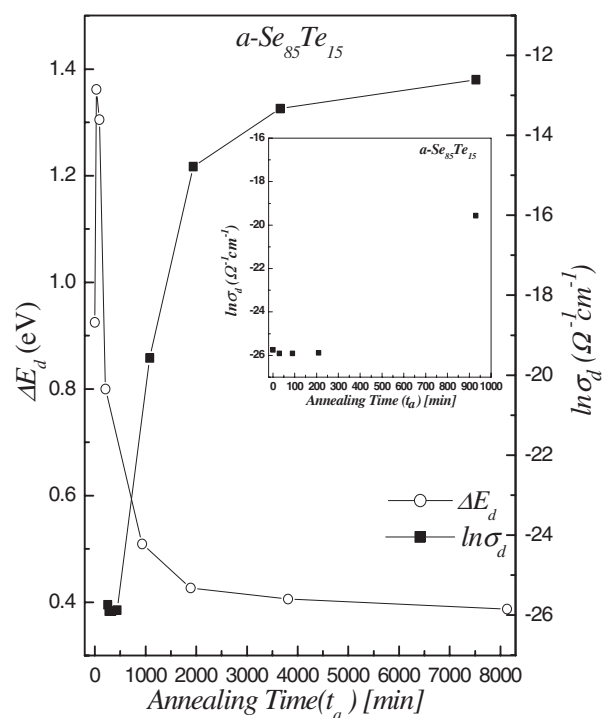


Figure 2. Variation of σ_d and activation energy (ΔE_d) with the progress in thermal annealing treatment duration (t_a).

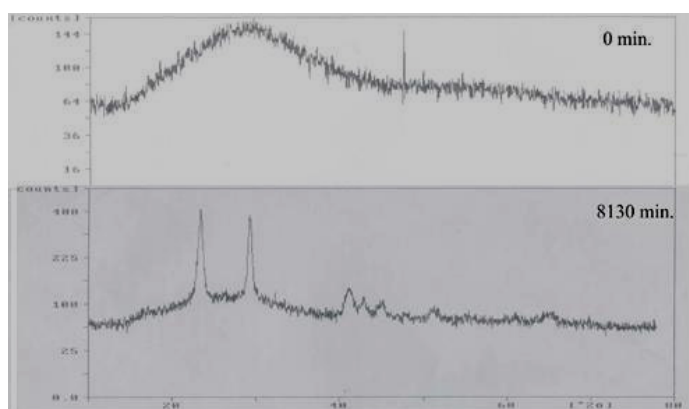


Figure 3. The x-ray diffraction curves of the thin film of a-Se₈₅Te₁₅ alloy before and after the annealing treatment (i.e. $t_a = 0$ and 8130 min).

energy (ΔE_{ph}). The activation energy for photoconduction has been found to be much smaller than the dark conduction. The σ_{ph} increased with the increase in temperature and with the increase in intensity at all temperatures. The value of σ_{ph} also behaves similarly to σ_d variation on thermal annealing treatment; i.e., after decreasing for initial annealing treatment, it increases sharply after annealing for prolonged duration, indicating a transition from amorphous to

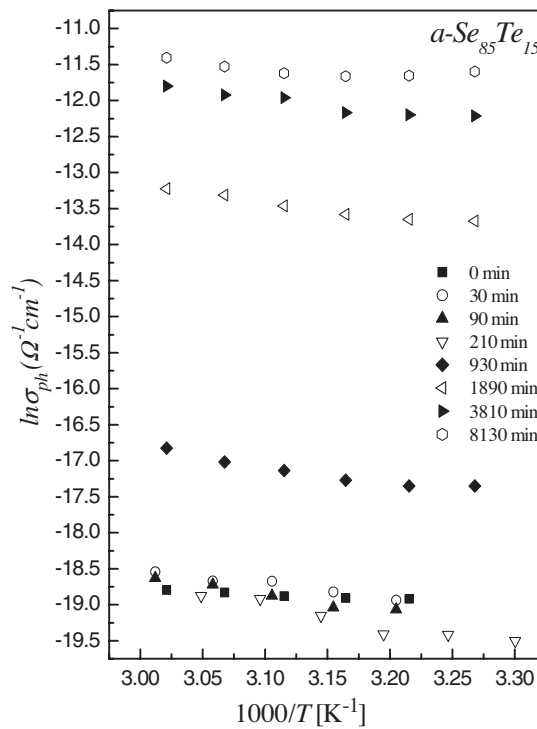


Figure 4. Temperature dependence of photoconductivity (σ_{ph}) at various annealing durations (t_a) for a- $\text{Se}_{85}\text{Te}_{15}$ thin film.

crystalline state. To have a better idea of this variation, figure 5 shows the variation of σ_{ph} and a related parameter i.e. photosensitivity ($\sigma_{\text{ph}}/\sigma_{\text{d}}$) with the progress in thermal annealing duration on the a- $\text{Se}_{85}\text{Te}_{15}$ thin film at room temperature. The value of σ_{ph} decreases until 210 min of annealing, followed by a steep rise in σ_{ph} up to 8130 min of annealing treatment. This change of σ_{ph} is also supported by the changing pattern of photoactivation energy (ΔE_{ph}). The ΔE_{ph} starts to increase from 0.06 eV at $t_a = 0$ min to 0.24 eV till 210 min of annealing treatment and then decreases sharply to 0.07 eV after 8130 min of annealing treatment on the a- $\text{Se}_{85}\text{Te}_{15}$ thin film. Similarly, the value of $\sigma_{\text{ph}}/\sigma_{\text{d}}$ first increased up to $t_a = 30$ min of annealing treatment, followed by a sharp decrease from 1084 at $t_a = 0$ min to about 3 after 8130 min of thermal annealing.

The intensity dependence of σ_{ph} at room temperature after each annealing time gives valuable information regarding the nature of recombination processes occurring within the material. Figure 6 shows the intensity dependence of σ_{ph} at room temperature with the progress in thermal annealing duration. The $\ln \sigma_{\text{ph}}$ versus $\ln F$ curves are straight lines, which indicates that the photoconductivity (σ_{ph}) follows a power law with intensity (F),

$$\sigma_{\text{ph}} \propto F^\gamma \quad \text{where } 0.5 \leq \gamma \leq 1.0.$$

For $\gamma = 0.5$, the recombination is predominantly bimolecular in nature,

$= 1.0$, the recombination is monomolecular in nature.

For $0.5 < \gamma < 1.0$, according to Rose [28], the value of γ cannot be understood by assuming a set of discrete trap levels but requires the existence of a continuous distribution of traps in the

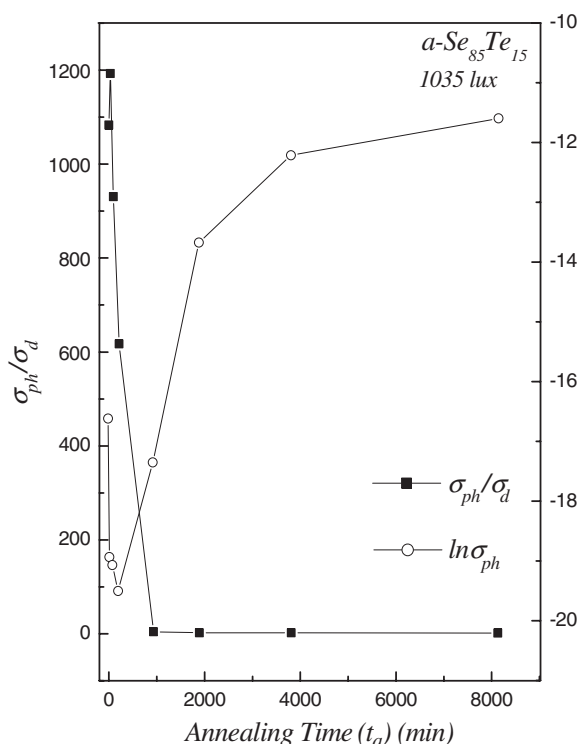


Figure 5. Variation of σ_{ph} and photosensitivity (σ_{ph}/σ_d) with progress in thermal annealing duration t_a on the a-Se₈₅Te₁₅ thin film at room temperature.

mobility gap. The value of γ has been found to be approximately equal to 0.5, irrespective of the annealing duration. The value of $\gamma = 0.5$ suggests a bimolecular recombination on photoexcitation. This type of behaviour has also been observed in other chalcogenide glasses [29, 30]. The photocarrier generation rate 'g' follows the relation $\sigma_{ph} \propto g^{0.5}$, indicating a continuous distribution of localized states that exist in the mobility gap of a-Se₈₅Te₁₅ glassy alloy. The results can be explained on the basis of the model proposed by Main and Owen [31] and Simmons and Taylor [32]. This model provides the information of the energy location of discrete sets of localized states in the energy gap of the amorphous glass thin films. The concept of charged coordination defects with negative- U energy could be responsible for such states [31]. The D^+ and D^- centres can act as discrete traps for photogenerated electrons and holes, thereby giving rise to neutral D^0 sites, which, due to polaronic lattice deformation, produce energy levels roughly midway between the band edges and the Fermi level. The recombination rate of electrons is proportional to the number of holes. In the non-equilibrium condition, most of the holes and electrons are generated after the exposure of light at D^0 centres, and these centres decrease by the recombination process ($2D^0 \rightarrow D^+ + D^-$) when the illumination is stopped. The nature of variation of I_{ph} with intensity is similar in all cases (i.e. for different annealing times). The above measurements have been carried out keeping the films at a constant temperature for about half an hour. Abkowitz [33], however, pointed out that the relaxation to thermal equilibrium may take quite a long time at each temperature. This indicates that the above measurements may represent data when the trap densities were not in a fully relaxed state.

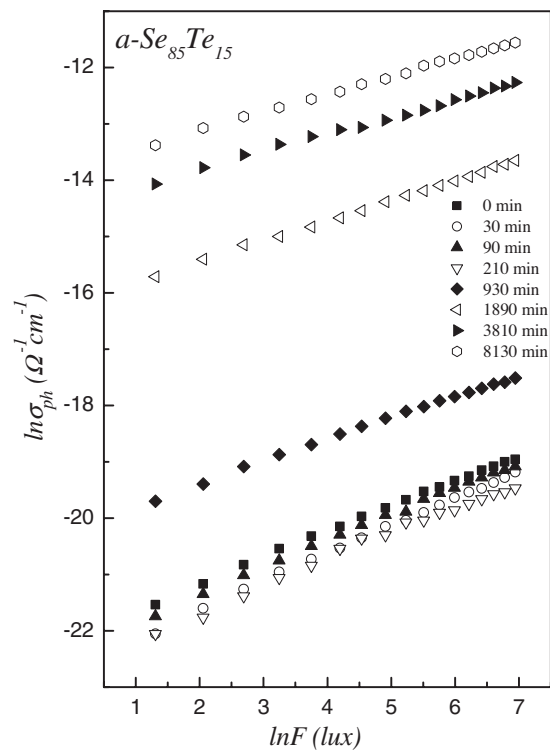


Figure 6. Intensity (F) dependence of σ_{ph} at room temperature at various thermal annealing durations (t_a).

The method of transient photoconductivity is a very useful technique to determine the energy distribution of various species of gap states, which influence the carrier mobilities and lifetimes in chalcogenide glasses, assuming the response to be controlled by multi-trapping processes [34]. This method is very valuable to judge the material quality for various photoconductive applications. For initial annealing times there is a sharp rise in the photocurrent (I_{ph}), with a distinct peak value of photocurrent, and after the illumination is switched off the decay has been observed to be very fast (results not shown here). As the annealing treatment increases, the peak in the rise curve diminishes. This may be due to the decrease in photosensitivity with progressive annealing ($I_{ph}/I_d \approx 1084$ to 3). Analysing the decay curves indicates that as the annealing treatment increases the decay of photocurrent is quite slow. A persistent photocurrent (asymptotic value) is also observed at all temperatures and intensities for all observations after annealing duration of 930 min ($t_a \geq 930$ min) during the decay of photocurrent.

The conductivity (or resistivity) of amorphous semiconductors and their temperature dependence provides information on the type of electronic conduction which dominates in that particular glassy alloy. An initial decrease in dark conductivity (σ_d) with a corresponding increase in activation energy (ΔE_d) on initial thermal annealing treatment ($t_a = 90$ min) is attributed to the reduction of disorder in the atomic bonding between neighbours and hence a decrease in the density of tail states adjacent to the band edge. The dangling bonds along with some unsaturated bonds [35] are produced during the deposition of amorphous films [36] and these dangling bonds are responsible for the formation of some defects in the film. Such

defects produce localized states in amorphous solids. The presence of a high concentration of localized states in the band structure is responsible for the decrease of ΔE_d . During the annealing treatment, the defects are gradually annealed out [37], producing a larger number of saturated bonds.

The reduction in the number of unsaturated defects decreases the density of localized states in the band structure, due to which the mobility gap changes [12], and hence a decrease in σ_d and an increase in ΔE_d is observed at the initial annealing treatments (up to $t_a = 90$ min). However, at higher annealing times, the obvious decrease in the activation energy with an increase in the electrical conductivity can be interpreted in terms of the amorphous to crystalline transformation.

During this transformation, the thermally induced crystalline phase grows, causing a rapid increase in the electrical conductivity with a consequent decrease in ΔE_d . During thermal annealing of the thin film of amorphous $\text{Se}_{85}\text{Te}_{15}$ glassy alloy at a temperature near the glass transition temperature for longer durations, enough vibration energy is present to break some of the weaker bonds, thus introducing some translational degrees of freedom to the system. Consequently, crystallization via nucleation and growth becomes possible [22]. The amount of crystalline phase increases with increasing annealing duration [38, 39]. The area occupied by the crystalline particles increases, where some of them may be interconnected and some isolated, due to which there may be a sharp decrease in bandgap. The induced crystalline phases are responsible for the increase in electrical conductivity of the annealed film. The electrical conductivity has been found to be thermally activated in the considered temperature range (301–331 K). The decrease in energy gap and the increase in the width of localized state tails with the increase in annealing treatment duration can be interpreted by assuming it to be the product of surface dangling bonds around the crystallites [40] during the process of crystallization [23]. Further annealing treatment causes the crystallites to break down into smaller crystals, thereby increasing the number of surface dangling bonds on the surface of the film [41]. These dangling bonds are responsible for the formation of some types of defects in the highly polycrystalline solids. As the number of dangling bonds and defects increases with the increase in the annealing treatment, the concentration of localized states in the band structure also increases gradually.

According to Mott and Davis [25], a value of σ_0 in the range 10^3 – $10^4 \Omega^{-1} \text{ cm}^{-1}$ in chalcogenide glasses indicates that the conduction takes place mostly in the extended states. For conduction in localized states, σ_0 is two to three orders smaller than that of the extended states and should become still smaller for the conduction in the localized states near the Fermi level. It also confirms that the electronic conduction in amorphous Se–Te glassy alloys take place via extended states at room temperature and above, as has been observed by Parthasarathy *et al* [42]. The observed values of ΔE_d and σ_0 ($=1.54 \times 10^4 \Omega^{-1} \text{ cm}^{-1}$) for $\text{Se}_{85}\text{Te}_{15}$ glassy alloy thin film prior to annealing treatment has been found to be approximately similar to the values measured by Venugopal Reddy *et al* [43]. As the annealing treatment progresses, the values of ΔE_d and σ_0 ($=7.83 \Omega^{-1} \text{ cm}^{-1}$ at $t_a = 8130$ min) decrease, indicating a change in the band structure whereby the conduction takes place mainly by localized states near the Fermi level.

The steady state photoconductivity helps us to identify the recombination centres, defects and the position of discrete energy levels produced by them in the energy gap of amorphous semiconductors. The dependence of photocurrent on temperature and on the intensity of illumination helps to identify the monomolecular or bimolecular recombination behaviour. The photoactivation energy (ΔE_{ph}) decreases, with a consequent increase in photoconductivity (σ_{ph}), on progress in annealing treatment. The value of σ_{ph} increases exponentially in the measured temperature range, 301–331 K, for all annealing times. The increase in σ_{ph} with

progressive annealing indicates that the material is becoming more photoconducting in absolute physical terms. In general, σ_{ph} obeys the relation [25]

$$\sigma_{\text{ph}} \propto (\text{carrier mobility}) \times (\text{carrier life time}).$$

The observed increase of σ_{ph} may be related to the increase in the carrier mobility due to crystallization. However, the bandgap and optical absorption coefficient [22] may also change during crystallization, which also influences the σ_{ph} . Moreover, the influence of grain boundaries and tissue structures can also be taken into account, as the structural changes are quite likely on crystallization. In the absence of these details the exact reason for the increase in σ_{ph} upon thermal annealing treatment cannot be predicted.

Photosensitivity ($\sigma_{\text{ph}}/\sigma_{\text{d}}$) is an important parameter, which determines the use of a particular material for solar cell and other photoconductive applications. The decrease in $\sigma_{\text{ph}}/\sigma_{\text{d}}$ on partial crystallization may be due to the increase in the dark conductivity. $\sigma_{\text{ph}}/\sigma_{\text{d}}$ may also decrease due to the increase in the density of defect states. Generally, the increase or decrease in the defect density results in the decrease or increase in the photosensitivity respectively. The initial increase in the conductivity and $\sigma_{\text{ph}}/\sigma_{\text{d}}$ can be explained on account of the reduction in the number of unsaturated defects, which decreases the density of localized states in the band structure, consequently increasing the bandgap and the energy gap.

4. Conclusion

The effect of thermal annealing on the electrical properties, i.e. dark and photoconductivity, on a thin film of a- $\text{Se}_{85}\text{Te}_{15}$ glassy alloy has been studied. Both of them, after a small decrease, increase with the increase in thermal annealing duration. The dark activation energy decreases after a small increase initially with the increase in thermal annealing treatment. The photosensitivity, an important parameter wrt the application point of view, also decreases sharply with annealing. These changes in the electrical parameters can be attributed to high concentration of localized states in the a- $\text{Se}_{85}\text{Te}_{15}$ thin film and can be interpreted in terms of the amorphous to crystalline transformation induced due to thermal annealing treatment on the film.

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