CHAPTER TWO
Jasbir S. Hundal and Navneet Dabra [63]

Chalcogenide glasses based on the cadmium–selenium system, with the selenium composition varying from 0 to 7.5 wt% have been prepared using melt-quenching method i.e., single-roller quenching technique. The X-ray diffraction (XRD) and selected area electron diffraction (SAD) patterns of the CdSe ribbons indicate that the ribbons are amorphous. The transmission electron microscopy (TEM) studies carried out on these ribbons reveal that the constituents are inhomogeneously distributed in these ribbons. The temperature dependence of the electrical resistivity, \( \rho \) and thermoelectric power (TEP) of these ribbons has been studied in the temperature range 30–350°C.

S.M. El-Sayed [64]

The dielectric relaxation spectroscopes of \( \text{Cd}_x\text{Se}_{70-x}\text{Te}_{30} \) (where \( x = 0, 5, 7, 10 \)) alloy have been investigated in the temperature range 298–373 K and in the frequency range 100 Hz to 100 kHz near the percolation threshold. The frequency and temperature dependence on the dielectric constant showed a Debye dielectric relaxation process. Using Debye relation, the dielectric constant (\( \varepsilon' \)), the most probable relaxation time (\( \tau \)) and the barrier height (\( W \)) were estimated for binary ternary chalcogenide systems.
The aim of this article is to familiarize the readers with barrier-cluster model of the non-crystalline semiconductors, which is based on the assumption that in non-crystalline semiconductors, there exist micro-regions separated from each other by potential barriers. We suppose that these micro-regions in chalcogenide glasses are created by closed clusters.

**V. Vassilev, K. Tomova, V. Parvanova and S. Parvanov [66]**

Chalcogenide glasses from the GeSe$_2$–Sb$_2$Se$_3$–PbSe system were synthesized for the first time. The glass-forming region was determinated by the help of visual, X-ray diffraction and electron microscopic analyses.

The basic physico-chemical parameters such as density (d), microhardness (HV) and the temperatures of phase transformations (the glass transition $T_g$, crystallization $T_{cr}$ and melting $T_m$) were measured. Compactness and some thermomechanical characteristics such as volume (Vh) and formation energy (Eh) of micro-voids in the glassy network, as well as the module of elasticity E were calculated.

**Omar A. Lafi, Mousa M.A. Imran and Ma’rouf K. Abdullah [67]**

Differential scanning calorimeter (DSC) has been employed to investigate the glass transition activation energy $E_a$, thermal stability and the glass-forming ability (GFA) of Se$_{90}$In$_{10-x}$Sn$_x$ ($x=2$, 4, 6 and 8) chalcogenide glasses. From the dependence of the glass transition temperature $T_g$ on the heating rate $\beta$, ...
the $E_t$ has been calculated on the basis of Moynihan and Kissinger models. Results indicate that $T_g$ and $E_t$ attain their minimum values at 6 at% of Sn. Thermal stability has been monitored through the calculation of the temperature difference $T_c - T_g$, the stability parameter $S$, the enthalpy released during the crystallization process $H_c$ and the crystallization rate factor $K_p$.

G.P. Kothiyal, Rakesh Kumar, Madhumita Goswami, V.K. Shrikhande, D. Bhattacharya and M. Roy [68]

The preparation of mixed glasses of $\text{As}_2\text{S}_{3-x}\text{Se}_x$ ($x = 0-3$) and $(1-y)\text{As}_2\text{S}_3 y\text{Sb}_2\text{S}_3$ ($y = 0-1$) has been carried out by an in situ pouring technique. X-ray diffraction (XRD) was used to confirm the glassy nature of the materials and monitor diversification. Visible-IR transmission, photoluminescence, refractive index and micro-Raman were measured as a function of composition. Microhardness (MH) and thermal expansion coefficient (TEC) were also measured. Raman peaks in $\text{As}_2\text{S}_3$ and $\text{As}_2\text{Se}_3$ were observed around $338\text{ cm}^{-1}$ and $230\text{ cm}^{-1}$, respectively in this first composition series in which S was replaced by Se.

Vineet Sharma, Anup Thakur, Jeewan Sharma, Vivek Kumar, Sanjeev Gautam and S.K. Tripathi [69]

Se–Te alloys are an important system of chalcogenide glasses from application point of view. The incorporation of Sn additive alters the electrical properties of these alloys. The conductivity measurements have been done on the
thin films of a-Se_{85-x}Te_{15}Sn_{x} (x = 0, 2, 4, 6 and 10 at.%) deposited using vacuum evaporation technique. Both dark (σ_d) and photoconductivity (σ_{ph}) show a maximum for x = 6 at.% of Sn, which, decreases on further Sn addition to the binary Se–Te alloy. The dark activation energy (ΔE_d) shows a minimum for x = 2 at.% of Sn, but increases on further Sn addition.

**M. Mitkova and M.N. Kozicki [70]**

We make a brief review on the effect of silver photo diffusion in Ge-chalcogenide glasses and report some of our recent results in this aspect. Using Raman spectroscopy and X-ray diffraction analysis we demonstrate that the hosting backbone undergoes depletion in chalcogen due to the specific conditions of photo diffusion and the diffusion products are silver chalcogenides. While in the Ge–Se system preliminary binary Ag chalcogenides are forming, in the Ge–S system formation of Ag₂GeS₃ is evidenced.

**V. Vassilev, S. Parvanov, T. Hristova-Vasileva, V. Parvanova and D. Ranova [71]**

Chalcogenide glasses from the As–Te–Sb system were synthesized for the first time. The glass-forming region was determined by the help of visual, X-ray diffraction and electron microscopic analyses. Glasses are obtained mainly in the Te-rich region of the Gibbs diagram.
G.G. Rusu, M. Rusu and M. Girtan [72]

CdZnTe thin films of thickness 450–1400 nm have been evaporated under vacuum onto unheated glass substrates, using a multilayer method. During film deposition, the two evaporation sources, separated by two glass cylinders, were maintained at temperatures of 720 K for Zn and at 925–1200 K for CdTe, respectively. After deposition, the samples were annealed in air up to 775 K. The structural and optical properties of both as-deposited and heat-treated samples were investigated.

A. El-Korashy, A. Bakry, M.A. Abdel-Rahim and M. Abd El-Sattar [73]

Bulk glasses of the Ge$_5$Se$_{25}$Te$_{70}$ system were prepared by the conventional melt-quenching technique. Thin films with a thickness of 150 nm of Ge$_5$Se$_{25}$Te$_{70}$ were prepared by the thermal evaporation technique on glass substrates. The crystallization mechanism has been studied by using differential scanning calorimeter (DSC) technique. The effect of heat treatment on the structure transformation was investigated by X-ray diffraction and the scanning electron microscope.

N. Kushwaha, R.K. Shukla, S. Kumar and A. Kumar [74]

Temperature dependence of dark conductivity and photoconductivity has been studied in amorphous thin films of Se$_{85}$Te$_{15-x}$ Pb$_x$ (2<x<6) at low temperatures (219–300 K). We have observed that, at quite low temperatures, a maximum is found at a particular temperature in dark conductivity and
photoconductivity measurements as a function of temperature. The position of this maximum shifts to higher temperatures at higher intensities.

L.A. Wahab and H.H. Amer [75]

Optical constants of vacuum-evaporated thin films in the Ge$_{1-x}$ Se$_2$Pb$_x$ (x = 0, 0.2, 0.4, 0.6) system were calculated from reflectance and transmittance spectra. It is found that the films exhibit a non-direct gap, which decreases with increasing Pb content. The variation in the refractive index and the imaginary part of the dielectric constant with photon energy is reported.

N. Mehta, D. Sharma and A. Kumar [76]

The present paper reports photoelectric and dielectric studies in glassy Se$_{80-x}$Te$_{20}$ Ag$_x$ (x = 5, 10, 15) alloys. The results show anomalous behavior of transient photoconductivity in the present glassy system.

M.M. Hafiz, A.A. Othman, M.M. Elnahass and A.T. Al-Motasem [77]

The temperature dependence of the DC electrical conductivity $\sigma_{DC}$ was measured in the temperature range from 300–500 K. It was found that there are double activation energies, $E_0$, for Ge$_{20}$Se$_{80-x}$Bi$_x$ (x = 0, 2.5 and 5 at%) films, while there is single activation energy for Ge$_{20}$Se$_{72.5}$Bi$_{7.5}$, when incorporation of Bi = 7.5 at%.

A.A. Othman [78]

Amorphous Sb$_{10}$Se$_{90}$ thin films were prepared by thermal evaporation of the bulk glass. The changes in the optical properties (transmittance,
optical gap, absorption coefficient, refractive index and extinction coefficient) have been measured in the wavelength range 500–900 nm of virgin and ultraviolet (UV) illuminated films.

S.A. Fayek, S.S. Fouad, M.R. Balboul and M.S. El-Bana [79]

The crystallization kinetics of $\text{As}_{30}\text{Se}_{70-x}\text{Sn}_x$ chalcogenide glasses where $x = 0, 1, 2$ and 3 have been discussed under non-isothermal conditions by differential thermal analysis (DTA).

G.A.M. Amin and A.F. Maged [80]

The compositional dependence of electrical conductivity, optical absorption and refractive index of thin films of the $\text{Ge}_1\text{Se}_{9-x}\text{Te}_x$ amorphous system in the range $0 \leq x \leq 4$ is investigated. The obtained results were correlated with the character of the chemical bond for the prepared compositions through a study of parameters such as average heat of atomization and average coordination number.


Chalcogenide glass $\text{Se}_{55}\text{Ge}_{30}\text{As}_{15}$ has amorphous structure in both as-deposited and annealed conditions. The optical properties of the as-deposited and annealed films were studied using spectrophotometric measurements of transmittance, $T(\lambda)$, and reflectance, $R(\lambda)$, at normal incidence of light in the wavelength range 200–2500 nm. Neither annealing temperature nor film thickness can influence spectral response on refractive index and absorption index of films.
A.A. Al-Ghamdi [82]

The optical constants (absorption coefficient ($\alpha$), refractive index ($n$), extinction coefficient ($k$), real and imaginary part of dielectric constant) have been studied for $a$-$Se_{96-x}Te_4Ag_x$ (where $x=0, 4, 8, 12$) thin films as a function of photon energy in the wavelength range (500–1000 nm). It has been found that the optical band gap increases while $n$ and $k$ decreases on incorporation of Ag in Se–Te system. The value of $\alpha$ and $k$ increases, while the value of $n$ decreases with incident photon energy. The results are interpreted in terms of the change in concentration of localized states due to the shift in fermi level.

M.A. Abdel-Rahim, M.M. Hafiz and A.M. Shamekh [83]

Results of differential scanning calorimetric (DSC) under non-isothermal conditions on three compositions of $Ge_xSe_{92-x}In_8$ ($x = 10, 12.5$ and $15$ at%) are reported and discussed. It is seen that these glasses exhibit a double glass transition and single-stage crystallization on heating. The glass transition temperature ($T_g$), the onset crystallization temperature ($T_c$) and the peak temperature of the crystallization ($T_p$) were found to be dependent on the composition and the heating rates.

S. A. Fayek, M. El-Ocker and A. S. Hassanien [84]

Thin films with thickness 100 nm of $Ge_{10+x}Se_{40}Te_{50-x}$ (x ranging from 0.0 to 16.65 at.%) were formed by vacuum deposition at $1.33 \times 10^{-4}$ Pa. The change in electrical resistivity of the films has been measured using coplanar
method. The measurements have been carried out in a temperature range between 400 and 142 K. The values of the electrical activation energy lie in the range of 0.18–0.38 eV.


Electrical conductivity and I–V characteristics have been investigated as a function of thickness in the range (104.4–618.3 nm) and temperature in the range (303–403 K) below the glass transition $T_g$ for thin film samples of Ge-Se-Tl (x=2,3,4) chalcogenide glass system. The DC conductivity results indicate that each composition has single activation energy $\Delta E_a$ in the considered temperature range.

R.S. Sharma, S. Singh, D. Kumar and A. Kumar [86]

The temperature and intensity dependence of photoconductivity measurements has been studied in amorphous thin films of Se$_{80-x}$Ge$_{20}$Ag$_x$ (x = 0, 5, 10) prepared by vacuum evaporation. The dark conductivity ($\sigma_d$) increases and the activation energy ($\Delta E$) decreases as the Ag concentration increases in the present glass composition. The photoconductivity ($\sigma_{ph}$) also increases with an increase in Ag concentration. However, the photosensitivity ($\sigma_{ph}/\sigma_d$) decreases with an increase in Ag concentration.
Kedar Singh, Dinesh Patidar and N.S. Saxena [87]

Simultaneous measurement of effective thermal conductivity ($\lambda_e$) and effective thermal diffusivity ($\chi_e$) of twin pallets of Se$_{100-x}$In$_x$ ($x = 0, 5, 10, 15$, and $20$) glasses, prepared under a load of 5 tons, have been made at room temperature using the Transient Plane Source (TPS) technique. The values of $\lambda_e$ and $\chi_e$ were found to increase initially with the increase of concentration of In in Se–In alloy and had their maximum at 10 at.wt% of indium.

El-Sayed M. Farg [88]

In this paper the author analyzed the optical properties of a-Ge$_{30-x}$Sb$_x$S$_{70}$ chalcogenide glass films ($x = 0, 10, 20$ and $30$ at%); the chalcogenide films were prepared by vacuum thermal evaporation. The optical-absorption data indicate that the absorption mechanism is non-direct transition. We found that the optical band gap, $E_{opt}$, decreases from $2.04\pm0.01$ to $1.74\pm0.01$ eV, whereas the refractive index increases with increasing Sb content.

M. Dongol, M.M. El-Nahass, M. Abou-zied and A. El-Denglawey [89]

Thin films of As$_{20}$Se$_{80-x}$Tl$_x$ were prepared by thermal evaporation of the bulk materials. The effect of Tl addition on the electrical properties of As–Se–Tl chalcogenide semiconductors has been studied in the homogeneous glass-forming region through the low- and high-temperature range (173–373 K).
B. Terziyska, H. Misiorek, E. Vateva, A. Jeowski and D. Arsova [90]

Thermal conductivity, $k$, of $\text{Ge}_x\text{As}_{40-x}\text{S}_{60}$ glasses has been measured between 4.5 and 300 K. A variation of $k$ with the composition is found and dependences of its parameters on the mean coordination numbers are established. Analyses have been made within but also independently of the soft-potential model. Some correlations and scaling laws are proposed.

S. A. Fayek [91]

Far infrared transmission spectra of homogeneous compositions in the glassy alloy system $\text{Ge}_{1-x}\text{Sn}_x\text{Se}_{2.5}$ $0 \leq x \leq 0.6$ have been observed in the spectral range 200–500 cm$^{-1}$ at room temperature. The infrared absorption spectra show strong bands around 231, 284 and 311 cm$^{-1}$ which were assigned to $\text{GeSe}$, $\text{SeSn}$, $\text{Se–Se}$. A pronounced peculiarity (maximum or minimum) appeared at around the same value of the average coordination number at $Z=2.65$ for all composition dependence topological phase transition from two-dimensional (2D) layer type to three-dimensional (3D) cross-linked network structures in the glass.

A. Zakery and S. R. Elliott [92]

A review of some properties of chalcogenide glasses and the current status of their applications is given. Techniques to characterize the linear and non-linear properties of these glasses are introduced and used to measure the optical constants of chalcogenide glasses in the form of bulk, thin film and fiber. Different techniques for the fabrication of gratings and waveguides in these glasses are
described. Achievable efficiencies of gratings, as well as propagation losses of fabricated waveguides, are presented.

L. A. Wahab [93]

The results are presented of a study of the electrical and optical properties of vacuum evaporated amorphous thin films in the $S_{0.8}Se_{16}M_{0.2}$ (M=Al, Ag or Cu) system. The activation energy and the pre-exponential factor which appear in the dc conductivity are found to be higher in case of Cu than in case of Ag and Al. The reflectance and transmission are used to measure the optical gap. The glass $S_{0.8}Se_{16}Cu_{0.2}$ behaves as a quasi intrinsic semiconductor (the electrical activation energy is about half of the optical gap). The electrical activation energy is about one-third of the optical gap for the chalcogenide glasses $S_{0.8}Se_{16}Al_{0.2}$ and $S_{0.8}Se_{16}Ag_{0.2}$.

K. Singh and N. S. Saxena [94]

The thermal transport properties of $Se_{80}Te_{10}In_{10}$ chalcogenide glass irradiated by slow neutrons for different time exposures were studied using the transient plane source method. The effective thermal conductivity ($\lambda$) and effective thermal diffusivity ($\chi$) increase with exposure time of the material and reaches to a saturation value. Constant values of effective thermal conductivity and effective thermal diffusivity beyond a certain time exposure could be explained on the basis of decrease of concentration of Se–Te polymeric chains and Se–Te rings.
Miloslav Frumar and Tomas Wagner [95]

Ag-doped chalcogenide glasses and amorphous thin films, their preparation, properties, photodoping, photoinduced surface deposition and applications, are reviewed, expanding on the results obtained recently. The progress obtained is not only connected with better understanding of their structure, chemical bonding and properties but also in application of Ag-containing glasses and films in solid-state batteries, electrochemical sensors and optoelectronics (gratings, microlenses, waveguides, optical memories, non-linear effects).

N.S. Saxena [96]

This talk presents the results of kinetic studies of glass transition and crystallization in glassy Se$_{x-15}$Te$_{15}$Sbx (x = 2, 4, 6, 8 and 10) using differential scanning calorimetry (DSC). In addition the thermodynamic properties of these glasses in the transformation range of temperature have been studied. The glass transition region has been investigated in terms of the activation energy of the glass transition and the dependence of glass transition temperature, $T_g$, on composition and heating rates. The growth kinetics and dimensionality have been investigated using three different models viz: Kissinger, Matusita and Ozawa.

S. P. Singh, S. Kumar and A. Kumar [97]

The present paper reports the d.c. conductivity measurements at high electric fields in vacuum-evaporated thin films of amorphous Se$_{80}$Te$_{20}$,
Se$_{75}$Te$_{20}$Ge$_5$ and Se$_{75}$Te$_{20}$Sb$_5$ systems. Current–voltage (I–V) characteristics have been measured at various fixed temperatures. In all the samples, at low electric fields ohmic behavior is observed. However, at high electric fields ($E \sim 10^4$ V/cm), non-ohmic behavior is observed.

A. K. Pattanaik, C. Borgohain, R. Bhattacharjee and A. Srinivasan [98]

Optical band gap ($E_{\text{opt}}$) for Pb modified Ge–Se–Te bulk glasses has been measured using the photoacoustic (PA) technique. This technique is especially suited for highly absorbing and brittle bulk semiconductors. The composition dependence of the optical energy $E_{\text{opt}}$ of two series of glasses, namely, Pb$_x$Ge$_{42-x}$Se$_{48}$Te$_{10}$ ($3 \leq x \leq 13$) and Pb$_{20}$Ge$_x$Se$_{70}$Te$_{10}$ ($17 \leq x \leq 24$) has been measured by recording the variation of the PA signal as a function of wavelength in the range 400–1200 nm.

A. Abu-Sehly [99]

Differential scanning calorimetry (DSC) data at different heating rates ($5 \leq \alpha \leq 50$ K/min) of Ge$_{20}$Te$_{80}$ chalcogenide glass are reported and discussed. From the heating rate dependences of the glass transition temperature ($T_g$), the onset temperature ($T_o$) and the crystallization peak temperature ($T_p$), the activation energy for glass transition, $E_g$, and the activation energy for crystallization, $E_c$, were derived. The crystallization data are interpreted in terms of recent analyses developed for non-isothermal conditions.
S. Abou El-Hassan [100]

The I–V characteristics of the system Se_{100-x}In_x (where x = 5, 10, 15 and 20 at%) are discussed in terms of Jonscher–Ansari modified Poole–Frenkel type of conduction. The jump distance (d), the charge carrier concentration (n) and the trap depth have been deduced for the system. The DC electrical properties of this system are investigated. According to the Arrhenius equation of conductivity, the activation energy of conduction $\Delta w_1$ and $\Delta w_2$ for the two arms of conductivity has been found in the range from 0.18 to 1.2 eV. Both mobility ($\mu$) and diffusion coefficient (D) are calculated for different compositions at different ambient temperatures.

H. S. Metwally [101]

The AC electrical conductivity and dielectric relaxation of Ge_{30}Sb_{10}S_{60} chalcogenide glasses thin films in the frequency range 100 Hz–100 kHz and in the temperature span 290–450 K are reported for the first time. The DC conductivity and thermoelectric power of such system are also measured. From the DC data, a presence of a wide range of localization is predicted and conduction by hopping in the localized state is the dominant conduction mechanism.

N. Asha Bhat and K. S. Sangunni [102]

In this paper, the author proposing a consistent approach to understand the mechanism of Bi doping in Ge–Se glasses by carrying out specific heat ($C_p$) measurement in Ge_{20}Se_{70-x}Te_{10}Bi_x system for 0 ≤ x ≤ 11. The two softening
temperatures exhibited by heat-treated samples are explained on the basis of 'microscopic phase separation'. The minimum in 'configurational heat capacity' $(\Delta C_p)$ at $x=7.5$ for as-prepared glasses is related to be a feature of chemical threshold.

M. Abu El-Oyoun [103]

The crystallization kinetics of $\text{Bi}_{10}\text{Se}_{90}$ chalcogenide glass has been discussed under non-isothermal conditions using differential scanning calorimetry (DSC). From the heating rate dependence of the glass transition temperature ($T_g$) and crystallization temperature ($T_p$), the values of the activation energy of glass transition ($E_g$) and the activation energy of crystallization ($E_c$) are evaluated.


The authors have analysed the effect of silver content on the optical properties of Ag-doped $\text{Ge}_{10}\text{Sb}_{30}\text{S}_{60}$ chalcogenide glass films; the chalcogenide host layers were prepared by vacuum thermal evaporation. Films of compositions $\text{Ag}_x(\text{Ge}_{0.1}\text{Sb}_{0.3}\text{S}_{0.6})_{100-x}$, with $x \leq 8$ at.%, were obtained by successively photodissolving thin (around 10 nm) layers of silver. The optical constants $(\eta, k)$ have been determined by a method based on the envelope curves of the optical transmission spectrum at normal incidence.
Z. G. Ivanova, E. Cernoková, V. Pamukchieva and J. Šánilová [105]

Calorimetric and dilatometric thermal properties of bulk Ge$_x$Sb$_{40-x}$Se$_{60}$ glasses ($x = 15, 20, 25, 27, 32, 35$) have been investigated by differential scanning calorimetry (DSC) and thermomechanical analysis (TMA). The variations of the difference in specific heat capacity between glass and undercooled liquid $C_p$ and of the glass-transition temperature $T_g$ on the average coordination number $Z$ have been specified. It has been found from the dependence of $T_g$ on the heating rate that the parameter $B$, related to configurational changes in the structure, reaches a maximum at $Z = 2.67$ (i.e. for Ge$_{27}$Sb$_{13}$Se$_{60}$), while $\Delta C_p$ values remain almost constant at $Z \geq 2.67$.

C. Corredor, I. Quiroga, J. Vázquez, J. Galdón, P. Villares and R. Jiménez-Garay [106]

The infrared (IR) absorption spectrum for glassy Sb$_{0.05}$As$_{0.45}$Se$_{0.50}$ was measured in the wave number region 500–900 cm$^{-1}$ at room temperature and in a continuously purged sample compartment, following the polyethylene pellet method. Main structural units in the glassy are considered to be AsSe$_3$ and SbSe$_3$ pyramids, Se$_8$ rings and Se$_n$ chains. By using X-ray diffraction data it was found a structural model with the assumption of tricoordinated As, tricoordinated Sb and dicoordinated Se which confirms the information obtained by means of far-infrared transmission (FIT).
S. A. Fayek [107]

The measurement of d.c. electrical conductivity of the bulk samples of chalcogenide glasses of the system Ge_{10+x}Se_{40}Te_{50-x} \ (x = 0.0, 13.35, 16.65 \text{ at.\%}) are studied. The activation energies are obtained from conductivity measurements, using Mott and Davis equation. The relationship between the energy of decomposition $E_d$ and composition is discussed in terms of the average heat of atomization. The effect of heat treatment on the structure transformation is investigated by X-ray diffraction and scanning electron microscope.

K. Petkov and P. J. S. Ewen [108]

The linear refractive index, $n$, and the position of the absorption edge for thin chalcogenide/chalcohalide films from the systems As–S, As–S–X (X=Bi, Tl or I), and Ge–S–Me (Me=Bi, Tl, As) have been measured before and after exposure to above-bandgap illumination. For compositions containing either As or Ge, the absorption edge was shifted to longer wavelengths (i.e. photodarkening occurred) for As-containing films, and to shorter wavelengths (i.e. photobleaching occurred) for Ge-containing films. As–S–Ge films exhibit either photodarkening or photobleaching, depending on Ge content.


The optical properties of ternary chalcogenide amorphous thin films of chemical composition Ge_{10}As_{15}Se_{75}, deposited by vacuum thermal evaporation,
have been determined and analysed. Normal-incidence optical transmission spectra have been measured in the range from 400 to 2500 nm. From these transmission spectra, the optical constants and average thickness of this particular amorphous ternary material were accurately calculated using an optical-characterisation method based on creating the upper and lower envelope curves of the spectrum, which also allows to obtain a parameter indicating the degree of film-thickness uniformity.

**M. M. Hafiz, M. A. Abdel-Rahim and A. A. Abu-Sehly [110]**

Optical absorption measurements have been made on As$_{46}$Te$_{46}$Ge$_8$ amorphous films with thickness 85–125 nm. The measurements were carried on as-prepared and annealed specimens. The mechanism of the optical absorption follows the rule of non-direct transition. The optical energy gap ($E_0$) increases with increasing the annealing temperature up to 473 K, followed by a sharp decrease with increasing the annealing temperature above the glass transition temperature. Electrical conductivity was measured in the temperature range 80–300 K.

**E. ernokóvá, Z. G. Ivanova and V. Pamukchieva [111]**

The crystallization kinetics of bulk Ge$_{10}$Sb$_{30}$Se$_{60}$ glass has been studied by differential scanning calorimetry. The effective activation energy of crystallization has been evaluated on the basis of the Kissinger equation and the isoconversion cuts method. The empirical estak–Berggren model has been used
for the description of DSC crystallization data as it provides the best fit to the experimental results.

Afaf A. Abd El-Rahman, A. M. Eid, M. Sanad and R. M. El-Ocker [112]

The influence of composition and film thickness on the optical band gap ($E_g$) and the width of the band tail ($E_t$) of thin solid films of chalcogenide glass system As-Ge-Se were investigated. This was done by an analysis of transmittance (T) and reflectance (R) spectra in the fundamental absorption region. It was found that the magnitude of $E_g$ decreases with increasing Se content. The results were interpreted in terms of the change of cohesive energy (CE) as a function of Se content.

Soon-Mo Song, Se-Young Choi and Yong-Keun Lee [113]

Nucleation and crystal growth rates were studied in a two stage heat-treatment process for Ge$_{30}$Se$_{60}$Te$_{10}$ chalcogenide glass. Maximum nucleation and crystal growth rates were $2.1 \times 10^3$/mm$^3$ min (at $280^\circ$C) and $0.4$ µm/min (at $330^\circ$C), respectively. The IR transmittance, thermal expansion coefficient ($\alpha$), microhardness and fracture toughness of the resulting glass-ceramics were determined. For a specific crystal size, the microhardness and fracture toughness increased and $\alpha$ decreased with increasing crystal volume fraction.

Paul Klocek and Luigi Colombo [114]

The fundamental optical properties of Se-based chalcogenide glasses were investigated. Glass compositions of Ge-Se and Ge-Sb-Se were fabricated and
characterized. The index of refraction, material dispersion, bandgap absorption, optical bandgap, and intrinsic light scattering are reported for these glasses. A Sellmeier formalism was used to obtain the oscillator strengths and excitation energies of the glasses.

E. Márquez, P. Villares and R. Jiménez-Garay [115]

Some electrical and switching properties characteristic of chalcogenide glassy semiconductors, obtained by the melt-quench method, were analyzed. A theoretical relationship was found between steady-state current increase and voltage, and was confirmed experimentally.


In this paper the author reported the results of a systematic study examining the relationship of bond type and concentration to the linear and non-linear optical properties of As–S–Se glasses. The effects of iso-structural substitution of Se for S and the resulting impact on structure and the non-linear refractive index, $\eta_2$, are discussed. Non-linear optical properties of As–S–Se chalcogenide glasses were measured by the Z-scan technique at 1.6 µm, and measured $\eta_2$ up to 400 times the $n^2$ for silica were observed.

S. Iizima, M. Sugi and M. KikuchiK. Tanaka [117]

Changes in the conductivity of chalcogenide glass by heat treatment at a constant temperature on the lower side of the transition region were studied.
Using DSC analysis, it was suggested that the nature of the treatment is a stabilization process closely related to the observed increase of the conductivity.

A. Vako, D. Leal and I. Srb [118]

Infrared spectra of different oxides of Se, As and Ge have been studied in bulk under defined conditions. It has been shown that the KBr pellet technique is often inapplicable for infrared measurement.

Infrared spectra corresponding to two different types of incorporation of oxygen into amorphous selenium are reviewed.


Transport measurements have been performed on the conducting state of a memory-type chalcogenide glass, of composition $\text{Te}_{81}\text{Ge}_{15}\text{As}_{4}$. DC resistivity was measured from $4^\circ\text{K}$ to $300^\circ\text{K}$ and indicates no carrier freeze-out occurs down to $4^\circ\text{K}$. The resistance ratio, $(300^\circ\text{K})/(4^\circ\text{K})$, was found to be 2.5. AC conductivity measurements at room temperature showed only an 18% increase in $\sigma(\omega)$ up to 150 khz. Hall effect experiments at 100 Hz show no dependence of carrier concentration on temperature from $77^\circ\text{K}$ to $300^\circ\text{K}$, and indicate a room temperature mobility of 85 cm$^2$/V-sec.

S. V. Phillips, R. E. Booth and P. W. McMillan [120]

This report describes some of the work carries out at the Nelson Research Centre on structural changes, including glass to crystal transition of two
glasses from the Ge-As-Si-Te system which exhibit "threshold" and "memory" switching. An anomalous irreversible resistivity change in the threshold type glass was ascribed to the formation of a thin crystalline surface layer on the bulk glass.

A. R. Hilton [121]

Glasses based on S, Se, and Te have been under study for a number of years as possible infrared optical materials. Though amorphous in nature, their optical properties are similar to those of crystalline semiconductors. Chalcogenide glasses, as they are called, become transparent on the long wavelength side of an absorption edge while their long wavelength cutoff is determined by a lattice type absorption.

M. A. Abdel-Rahim [122]

Calorimetric studies of chalcogenide alloy glasses Ge_{50-x}Se_{50}Te_x (x = 10, 20, 40 at%) have been performed by continuous heating rates. The crystallization mechanism has been studied by differential scanning calorimeter (DSC), scanning electron microscopy (SEM) and X-ray diffraction. From the heating rate dependence of the glass transition temperature T_g and the crystallization peak temperature T_p, the kinetic parameters of crystallization were calculated and their composition dependence were discussed.

M.M. Hafiz, A.H. Moharram, M.A. Abdel-Rahim and A.A. Abu-Sehly [123]

The optical absorption of as-prepared and thermally annealed As_{24.5}Te_{71}Cd_{4.5} thin films was measured. The optical energy gap E_0 increased from
0.58 to 0.85 eV with increasing thickness of the as-prepared films from 58 to 125 nm. Films annealed at temperatures higher than 423 K showed a decrease in $E_0$.

The electrical conductivity of the as-prepared and annealed films was measured in the temperature range 80–300 K.

N.A. Hegab and M. Fadel K.A. Sharaf [124]

Se$_{90-x}$Sb$_x$Bi$_{10}$ chalcogenide glasses with a Sb content varying in the range 35–45 atomic percentage were prepared by quenching from the melt. The amorphous nature of thin film form prepared by thermal evaporation technique was established by X-ray diffraction. Switching effects were observed in the deposited thin films of the system under test with the threshold voltage $V_{th}$ increasing noticeably with the film thickness and decreasing exponentially with temperature in the thickness range 40–1400 nm and temperature region 300–350 K.

J. B. Ramírez-Malo, E. Márquez, P. Villares and R. Jiménez-Garay [125]

The optical transmission spectra of amorphous As-S films of composition As$_{35}$S$_{65}$ prepared by thermal evaporation are measured over the 300 to 2000 nm spectral region. A straightforward method suggested by Swanepoel is successfully applied for determining the layer thickness, refractive index and absorption coefficient; this last value is derived according to four different formulae.
Cheng Jijian [126]

This paper deals with the experimental results associated with the phase separation, nucleation and crystallization of chalcogenide glasses. Experiments demonstrate that the phase separation may be affected by small amounts of additives. It has been found that some chalcogenide glasses could be converted into glass-ceramics without phase separation.

S. K. Srivastava, P. K. Dwivedi and A. Kumar [127]

The present paper reports on the steady state and transient photoconductivity in amorphous thin films of $\text{Se}_{100-x}\text{In}_x$ ($x = 5, 10, 15, 20, 30$). It is observed that various electrical parameters show a discontinuity at $x = 15$ suggesting a mechanically stabilized structure at this concentration as pointed out by Phillips in chalcogenide glasses.

M. Casas-Ruiz, R. A. Ligero, J. Vázquez and R. Jiménez-Garay [128]

The $\text{Cu}_{0.08}\text{Ge}_{0.18}\text{Te}_{0.74}$ bulk glass was prepared by the melt quenching technique. Differential thermal analyses were performed at different heating rates. Crystallization occurs in two stages at peak temperatures of 484.8 and 492.8 K (at 8 K min$^{-1}$), with enthalpies $\Delta H_1 = 0.19$ and $\Delta H_2 = 0.10$ kJ mol$^{-1}$. The crystallization mechanism was examined through analysis of the data under non-isothermal conditions and the activation energies for crystal growth were also evaluated.
C. Wagner, P. Villares, J. Vázquez and R. Jiménez-Garay [129]

The crystallization reaction of Sn$_{0.08}$As$_{0.26}$Se$_{0.66}$ chalcogenide glass was taken as a reference for determining the kinetic parameters (activation energy, $E$, reaction order, $n$, and frequency factor, $K_0$) which describe the said reaction by differential scanning calorimetry and using non-isothermal techniques.

N. Afify, M. A. Abdel-Rahim, A. S. Abd El-Halim and M. M. Hafiz [130]

Results of differential scanning calorimetry (DSC) at different heating rates on Se$_{0.7}$Ge$_{0.2}$Sb$_{0.1}$ glass are reported and discussed. From the heating rate dependence of glass transition, crystallization onset and peak crystallization temperatures values for the glass transition activation energy, $E_t$, and the crystallization activation energy, $E_c$, were evaluated. The results are consistent with surface and one-dimensional crystallization for this glass.

Nasser Afify [131]

Results of differential scanning calorimetric (DSC) under isothermal and non-isothermal conditions on Se$_{0.7}$Te$_{0.3}$ glass are reported and discussed. By using the Johnson-Mehl-Avrami equation, the effective activation energies for crystal growth, $E_G$, have been evaluated and the crystallization mechanism has been studied. The results indicate that the crystallization process is a two-dimensional growth.
Bulk samples of chalcogenide glasses of the system \( \text{As}_{33}\text{Se}_{67-x}\text{Sn}_x \) (with \( x = 0, 1, 3, 5, 7 \) at.% Sn) were measured for dc conductivity and thermoelectric power (TEP). From conductivity and TEP observations, the activation energies are obtained. The activation energy is dependent on Sn concentration in the system. The difference of activation energies calculated from dc conductivity and TEP measurements \( \Delta E = E_\sigma^\ast - E_s^\ast = 0.13 \text{ eV} \) is obtained. The difference of activation energies is explained on the basis of long range potential fluctuations existing in the bulk of the material due to the random distribution of charge centers.

Nasser Afify [133]

From the DSC study, the \( \text{Se}_{0.6}\text{Ge}_{0.2}\text{Sb}_{0.2} \) chalcogenide glass has two amorphous phases and its crystallization takes place in two overlapping processes. By annealing as-prepared samples at 244°C for 2 h, the second phase can be observed. From X-ray diffraction measurements, the first phase identified is \( \text{Sb}_2\text{Se}_3 \) and the second phase is \( \text{GeSe}_2 \).

J. Lucas [134]

Halide and chalcogenide glasses which are superior to oxide glasses in transmitting light in the mid IR, allow optical operations in the 3–5 and 8–12 μm atmospheric optical windows. The specific family of fluoride glasses has been
specially developed in order to achieve ultralow loss optical fibers and waveguiding in the 0.3 to 5 µm region.

**Keiji Tanaka [135]**

The optical properties of amorphous subjected to uniaxial compression up to 100 kbar have been studied. \( \text{As}_2\text{S}_3 \) glass undergoes elastic deformation, this results in photoelastic anisotropy at pressures below 5 k bar. At higher pressure, the material is fractured, but the cracked powders are squeezed into a transparent flake.

**Keiji Tanaka [136]**

Structural changes and mechanisms of stress-induced squeezing phenomena in some amorphous materials have been studied in comparison with the behavior following hydrostatic compression and the features observed in stressed crystalline solids. X-ray diffraction patterns of squeezed \( \text{As}_2\text{S}_3 \) and As are in support of anisometric medium-range structural orders.

**Min Szukwei, Yang Hanmei and Zhang Xiaowei [137]**

In this paper the authors investigated the influence of a small quantity of added Sn on the crystallization behavior of Te-Se-As glasses. It was found that a small quantity of added Sn could speed up the rate of crystallization and decrease the weight loss during crystallization. There was no marked influence on the reflectivity change before and after crystallization up to the addition of 4.2 wt.% Sn.
New families of infrared transmitting glasses were prepared in the ternary Ge-S-Br and Ge-S-I systems. These glasses contain both chalcogen and halogen elements and will be referred to as “chalcohalide glasses”. A series of samples containing different amounts of halogen and chalcogen elements were prepared. Infrared transmittance of the glasses extends up to 10 µm which is comparable to well-known chalcogenide glasses.

Using X-ray diffraction and differential scanning calorimetry (DSC) the structure and the crystallization mechanism of Se$_{0.8}$Te$_{0.2}$ chalcogenide glass have been studied. From the radial distribution function, the short-range order of the amorphous phase has been discussed. The lattice parameter of the crystalline phase has been determined by using the Cohen least-squares method.

Results of differential scanning calorimetry (DSC) under isothermal conditions on Se$_{70}$Ge$_{20}$Sb$_{10}$ glass are reported and discussed. By using the Avrami equation the activation energy for crystal growth (EG) has been evaluated and the crystallization mechanism has been studied. The results indicate that the crystallization process is a one-dimensional growth.
S. Etienne, J. Perez, S. Peytavin and M. Ribes [141]

This work is a contribution to the understanding of ionic transport phenomenon in chalcogenide glasses. The dynamics of mobile species and the relaxational behavior of the glassy matrix near and below $T_g$ are studied through mechanical spectrometry measurements. The intrinsic relaxation phenomena of the glassy matrix are studied against composition and the effect of thermal history is shown. The characteristic time for elementary jumps of silver ions is measured.

A. B. Gadkari and J. K. Zope [142]

The measurement of DC electrical conductivity and thermoelectric power of the bulk samples of chalcogenide glasses of the system Se$_{70}$Te$_{30}$, Se$_{70}$Te$_{30-x}$In$_x$ ($x = 1, 3, 5, 7, 9\%$ atomic weight) are studied. The activation energies are obtained from conductivity and thermoelectric power measurements, using Mott, Davis and Fritzsche equations.

David Adler [143]

The current theory of the electronic structure of amorphous semiconductors is reviewed. It is now clear that the properties of covalent amorphous solids simply represent the predominant mode of chemical bonding in the material. As in crystalline semiconductors, the electrical transport properties are controlled by the nature of the defects present.
K. K. Srivastava, A. Kumar, O. S. Panwar and K. N. Lakshminarayan [144]

The paper reports dielectric measurements carried out for a variety of threshold and memory alloys of glassy As-Ge-Te and Se-Ge-Te at different temperatures (83 to 373 K) and various frequencies (0.2, 0.5, 1.0, 2.6 and 5.0 MHz). It is found that the glassy system of chalcogenides exists in the form of molecular dipoles which remain frozen at low temperatures and, as the temperature is increased, the molecules attain freedom of rotation at temperatures which are sometimes as low as 253 K. All the materials displayed dielectric dispersion in the radio frequency range.

Tri Nang Tran and M. OkudaT. Matsushita [145]

The random network model for amorphous alloys proposed by White has been developed for the system irradiated with light. The model suggests that the photobleaching in GeSe₂ film and the photodarkening in AsSe film may be due to change in the number of the bonds.

S. R. Elliot [146]

The influence of the association of charged defects into intimate pairs on a.c. conduction is discussed in the light of the fundamental mechanism being that of the simultaneous hopping of two electrons over the barrier separating two oppositely charged defect centres, the barrier height being correlated with the intersite separation via the Coulomb interaction.
L. G. Aio, A. M. Efimov and V. F. Kokorina [147]

The refractive index frequency dependence in the 1–11 µm range for As-Se, Ge-Se and As-Ge-Se glassforming systems and for three- and four-component systems obtained by substitution of antimony, bismuth, tin, lead, sulphur and tellurium for arsenic, germanium and selenium, being their periodic system counterparts, is investigated.

A. Giridhar, Sudha Mahadevan and A. K. Singh [148]

Results of measurements of the thermal expansion coefficient are reported for eight glass compositions of the Ge-Se-Te system. For \((\text{GeSe}_2)_{100-2x}\text{Se}_x\text{Te}_x\) glasses, an increase of the glass transition temperature \(T_g\) and of \(\Delta\alpha\) (the change in thermal expansion coefficient, \(\alpha\), during glass transition) is seen with decreasing SeTe content. For \((\text{GeSe}_2)_{23.33}\text{Se}_{30-x}\text{Te}_x\) glasses, \(\alpha\), \(T_g\) and \(\Delta\alpha\) are invariant with composition. The results obtained presently, when examined along with those obtained for other chalcogenide glasses, indicate that chalcogenide glasses are not necessarily in a stage of isofree volume during glass transition.

Noboru Tohge, Hideaki Matsuo and Tsutomu Minami [149]

The electrical properties such as thermoelectric power, electrical conductivity and drift mobility have been studied on the chalcogenide glasses in the system Pb-Ge-Se. It has been found that the glasses in a certain composition
range exhibit n-type conduction, as the second case in chalcogenide glasses, following the Bi-containing glasses.

A.M. Flank, D. Bazin, H. Dexpert, P. Lagarde, C. Hervo and J.Y. Barraud [150]

The structures of some amorphous chalcogenide glasses existing around the As$_{17}$Ge$_{23}$Se$_{20}$Te$_{40}$ compositions have been investigated using EXAFS. Absorption data were obtained at the K edge for As, Se, and Ge and the L$_m$ edge for tellurium. Amorphous binary or ternary compounds such as As$_2$Se$_3$ and As$_{15}$Ge$_{30}$Se$_{55}$ have also been considered to build the model presented here.

S. Asokan, G. Parthasarathy, G. N. Subbanna, E. S. R. Gopal [151]

The effect of pressure on the electrical resistivity of bulk Si$_{20}$Te$_{80}$ glass is reported. Results of calorimetric, X-ray and transmission electron microscopy investigations at different stages of crystallization of bulk Si$_{20}$Te$_{80}$ glass are also presented. A pressure induced glass-to-crystal transition occurs at a pressure of 7 GPa. Pressure and temperature dependence of the electrical resistivity of Si$_{20}$Te$_{80}$ glass show the observed transition is a pressure induced glassy semiconductor to crystalline metal transition.

Yu. G. Vlasov, E. A. Bychkov and B. L. Seleznev [152]

Transport properties of Ag$_{42.5}$As$_{(42.5-x)}$Se$_x$Te chalcogenide glasses, have been studied. Vitreous alloys containing up to 20 at.% Te appeared to be mainly silver ion conductors. Tellurium-rich glasses (x>20 at.% Te) are non-
crystalline p-type semiconductors. The first tellurium additions (2–8.5 at.%) loosen the structure of the glass and cause the increase of ionic conductivity by 3–4 times.

**Takeshi Kawaguchi and Shigeo Maruno [153]**

Photoelectric cells of chalcogenide glasses containing a large quantity of Ag exhibit a photovoltage of several tens of millivolts. The photovoltage increased at the early stage of illumination and was gradually followed by decrease. The polarity of the photovoltage for illuminated electrode changes from positive to negative and finally the photovoltage reached to the saturation level.

**Mao Xilai and Yang Peihong [154]**

This paper is a report on observations of the optical absorption in bulk chalcogenide glasses or films of the quarternary AsSSe$_x$Te$_{1-x}$ system under Nd: glass laser irradiation. The sample was placed outside the laser cavity, and the nonlinear effect of the light transmission varying with the laser power was observed, and the light transmission of the sample increased by about 30%.

**G. H. Frischat, Ulrike Brokmeier and Angela Rosskamp [155]**

Thirty different glass compositions of the system Se-Sn-As were prepared. The glasses were then characterised by measuring the properties: glass transition temperature, $T_g$; density, $\rho$; elastic constants, $E$, $G$, $K$ and $\mu$; load-independent microhardness, and elastic recovery, $r$. In most cases the dependence
between property and chemical composition is non-linear. This effect is discussed with respect to different structural units in the glasses.

Satoshi Itoh, Takeo Fujiwara and Makoto Okazaki [156]

The structural models of chalcogenide glasses $\text{As}_x\text{S}_{1-x}$ for $x = 0.2$ and 0.5 have been constructed by the three-step procedure and the characteristic dependence of atomic scale structure on the As content has been analysed. The As-S bonds are most favorable and the distributions of bond lengths and bond angles are very narrow around their minimum energy configurations.

J. A. Savage [157]

Over the past two decades chalcogenide glasses have been researched in order to assess their suitability as passive bulk optical component materials for 3–5$\mu$m and 8–12$\mu$m infrared applications. This research has led to a greater understanding of the physical properties of these materials, and the present paper concentrates on the optical properties and applications of these bulk chalcogenide glasses.

P. C. Taylor and K. L. Ngai [158]

Transient hole transport measurements in undoped $\text{As}_2\text{Se}_3$ and Se and in doped $\text{As}_2\text{Se}_3$ are explained without recourse to the presence of deep traps. We suggest that the conduction process involves small polarons as originally proposed by $E_{\text{min}}$. Correlations between the measured activation energies and the
dispersion in the Se and As$_2$Se$_3$ systems as well as the dependences of the drift mobilities and the dc mobilities on doping in As$_2$Se$_3$ are explained.

V. L. Averyanov, A. V. Kolobov, B. T. Kolomiets and V. M. Lyubin [159]

It is shown here that photodarkening magnitude is defined by light intensity and the temperature at which the film is irradiated; the temperature dependence of the photodarkening value being a function of the wavelength of the exciting light. The kinetics of photodarkening for different wavelengths at various temperatures and kinetics of thermal bleaching are also studied.

Takeo Fujiwara, Satoshi Itoh and Makoto Okazaki [160]

The structural model for the chalcogenide glass has been constructed by using a three-step procedure, which consists of the random packing of atoms, the structural relaxation and the reformation of bonds. At the final stage of this procedure, every atom is located at a position of minimum local energy.

P. L. Sherrell and J. C. Thompson [161]

Measurements of the electrical conductivity of Ag-doped bulk As$_2$S$_3$ glasses have been made as functions of temperature, pressure, frequency and Ag doping level. A Debye-like loss peak was observed near $10^4$ Hz. The frequency of the loss peak is dependent on temperature, pressure and doping level, but these dependences are different from those of the dc conductivity.
C. H. Seager and Rod K. Quinn [162]

DC conductivity and Seebeck measurements have been carried out at temperatures below $T_g$ on well characterized bulk samples of amorphous $\text{As}_2\text{Te}_3$, $\text{As}_2\text{Se}_3$, and $\text{As}_2\text{S}_3$. Several models for conduction in these materials have been compared to the data. It is concluded that the models involving polaron hopping conduction are in better agreement with available data than are models involving hopping in the tails of localized band-tail states.

H. Tichá and M. Frumar [163]

The optical transmittance of chalcogenide glasses $\text{Ge}_2\text{SbSe}_7$ (I), $\text{Ge}_3\text{SbSe}_6$ (II), $\text{GeSb}_2\text{Se}_7$ (III) and $\text{GeSbSe}_3$ (IV) was studied in the near infrared spectral region, 0.7–25 $\mu$m. The long wavelength tail of the absorption edge can be described by Urbach's rule. At higher absorption levels the absorption coefficient $K$ depends quadratically on the energy of incident radiation.

C. L. Dargan, P. Burton and C. P. Bloomer [164]

An investigation has been carried out into the use of thin film chalcogenide glass memory switches for addressing large-area electroluminescent displays. Material preparation of the bulk glass used as a starting material and the subsequent r.f. sputtering process used to produce thin films are discussed in some detail.

Electrical conduction in various inorganic glasses was studied as a function of hydrostatic pressure up to 2000 atm and phenomenologically classified into electronic, ionic and mixed types. In electronically conducting glasses such as As-Se chalcogenide glasses and Fe₂O₃-P₂O₅ glass, the conduction is enhanced by application of pressure.

D. Brasen [166]

Glassy As₂Te₃ is obtained by splat cooling. The resulting homogeneous glass is shown to have a conductivity which is exponentially dependent upon temperature with activation energy of 0.3 eV. This energy may be continuously increased by partially crystallizing the glass. Switching characteristics of the glass are similar to those of other chalcogenide glasses except for the fact that in pulse switching the sample may be put entirely into the or memory state by increasing the pulselength of the pulse generator and then brought back into the switching state by decreasing the pulse width.

Ronald E. Smith [167]

Amorphous mixtures of As₂Se₃-As₂Te₃, As₂Se₃-Tl₂Se, As₂Se₃-Sb₂Se₃, and As₂Se₃-As₂S₃ have been studied by Electron Spin Resonance and X-ray diffraction as a function of composition and annealing temperature. The ESR signals obtained indicate spin concentrations ranging from 10¹⁴ to 10¹⁸ per cm³,
depending on composition and thermal treatment. Both Gaussian and Lorentzian derivative line shapes were observed near the free electron g-value with the exception of one set of samples.

D. L. Kinser, L. K. Wilson, H. R. Sanders and D. J. Hill [168]

Electrical conductivity, switching, D.T.A., and electron microstructures are presented for a series of the chalcogenide glasses As$_2$Te$_3$-As$_2$Se$_3$. DTA observations were conducted on each of these glasses to determine the relative glass stability. Bulk threshold switching observations were conducted on a compositional series of glasses.

G. V. Bunton [169]

A study using replica electron microscopy, scanning electron microscopy, electron diffraction, X-ray diffraction, sputter etching and differential thermal analysis of the structural properties of glasses having a range of compositions within the As-Te-Ge-Si quaternary system has shown that phase separation generally occurs in the bulk material.

A. E. Owen and J. M. Robertson [170]

The dc and ac conductivity, thermoelectric power, optical absorption and carrier mobility of As$_2$S$_3$, As$_2$Se$_3$ and some other chalcogenide glasses are described and discussed. The question of band or hopping conduction is considered and it is concluded that although the ac conductivity involves hopping,
the dc properties are best viewed in terms of a band model with a "mobility gap" as introduced by Mott and Cohen.

**J. T. Edmond [171]**

Glasses in the systems $\text{As}_2\text{S}_3-\text{As}_2\text{Se}_3$ and $\text{As}_2\text{Se}_3-\text{As}_2\text{Te}_3$ have been studied. Optical absorption at room temperature and electrical conductivity at temperatures between $30^\circ \text{C}$ and $150^\circ \text{C}$ have been measured. It is concluded that no single model of conductivity is applicable to all materials. The results are consistent with the suggestion that the conductivity may be controlled by potential barriers arising from structural and compositional fluctuations.