

# Estimation of The Electrical and Dielectric Properties For $\text{Se}_{98}\text{Te}_2$ and $\text{Se}_{96}\text{Te}_2\text{X}_2$ (X = Zn and Cd) Amorphous Films.

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## Research Article

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# Estimation of the electrical and dielectric properties for $\text{Se}_{98}\text{Te}_2$ and $\text{Se}_{96}\text{Te}_2\text{X}_2$ (X = Zn and Cd) amorphous films.

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## **Abstract:**

Bulk glassy  $\text{Se}_{98}\text{Te}_2$  and  $\text{Se}_{96}\text{Te}_2\text{X}_2$  (X = Zn and Cd) were prepared by melting quenching method. Thin films of various thicknesses (200 – 670 nm) were obtained by the thermal evaporation method. The structure of the prepared compositions was investigated by X-ray and EDX analysis. We studied the effect of Zn and Cd addition on the electric and dielectric properties of  $\text{Se}_{98}\text{Te}_2$  thin films. Our measurements were studied in the temperature range (298-323K) below the glass transition temperature and frequency range (100 Hz-1 MHz). DC conductivity showed a single conduction mechanism by hopping of charge carriers at the band edges for the studied system. The dependence of AC conductivity on frequency is linear with frequency exponent  $s$  lies very close to unit and is independent of temperature. This can be explained by the correlated barrier hopping (CBH) model. The dielectric constant  $\epsilon_1$  and dielectric loss  $\epsilon_2$  noticed to decrease with frequency and increase with temperature. The maximum barrier height  $W_m$  was calculated according to Guinitin .

Keywords: Glasses, AC conduction, dielectric behavior.

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## **1.Introduction:**

Chalcogenide glasses are receiving a great attention due to their applications such as: electronic, memory switching devices, guided wave devices and

infrared telecommunication systems [1-3]. Studying the temperature dependence of dielectric permittivity is of great important for understanding the nature of losses taking place in these materials.

Various models, i.e. quantum mechanical tunneling (QMT) [4, 5], small polaron tunneling [6, 7] large polaron tunneling [6] atomic hopping [6, 7] and correlated barrier hopping (CBH) model [8-10] are used to explain the mechanism of conduction for glassy materials.

Se-Te alloys have Great interest because of their high hardness and smaller aging effects when compared by Se. The additives to SeTe are used to improve its properties. The physical properties of  $\text{Se}_{80}\text{Te}_{20}$  can be changed by changing the concentration of the third additive and also by changing the type of additive. Only few studies are found in literature for changing the additive for the same base. Sharma and Kumar [11] studied the influence of Zn and In in electrical properties of  $\text{Se}_{85}\text{Te}_{15}$  alloy. Also, they study the influence of adding Cd and Ge on the dielectric properties and AC conductivity for  $\text{Se}_{70}\text{Te}_{30}$  alloy [12]. The obtained data are explained according to the lone pair configuration and covalent bonds of the studied compositions. N. Chandel et al. [13] studied the a.c. conductivity of Se Te and SeTe M (M = Cd, In, Sb) alloys. The obtained data are explained according to the correlated barrier (CBH) model. Also, the dependence of dielectric constant ( $\epsilon'$ ) and dielectric loss ( $\epsilon''$ ) on temperature and frequency are studied by S. Srivastava et al [14] for Se Te and Se Te Zn glassy alloys. The ac conductivity of Se Te and Se Te M (M = Cd, In, Sb) alloys has been measured by N. Chandel et al. [15]. The localized states density was obtained and the obtained results are discussed according to the metal induced effects on the conduction mechanism of Se Te alloy.

Zn is chosen as a dopant to Se-Te due to its high electropositive property and intermediate atomic radius as compared to other dopants such as (Sb, Ge, In,

Ag) [16-18]. Zn may work as a modifier because of the electronegativities and atomic radii differences between the elements (Se, Te, Zn). Also, the Cd addition to Se-Te alloy enhancing its electrical properties. The compounds such as  $\text{CdSe}_x\text{Te}_{1-x}$  are used for many applications such as the photo-electrochemical devices or the conversion in photovoltaic. This material has high optical absorbance and near-ideal band gap which makes it a promising material for low-cost applications. The obtained results due to the additives can be explained by the structural transitions in glasses [19].

Studying the AC conduction in Se-Te by adding different additives has been done by different authors [20,21] The frequency behavior for these materials obeys the law  $A\omega^s$ , where  $s$  is the frequency exponent and  $s \leq 1$ . In This study we aim to know the effect of Zn and Cd on the electrical conductivity and dielectric properties of SeTe thin films and which element enhances the conductivity of glassy SeTe more.

## **2. Experimental:-**

Bulk samples of  $\text{Se}_{98}\text{Te}_2$  and  $\text{Se}_{96}\text{Te}_2\text{X}_2$  ( $\text{X} = \text{Cd}$  and  $\text{Zn}$ ) have been prepared by melt-quenching. High pure elements of Se, Te, Cd and Zn have been weighted according to their atomic percentages and sealed under vacuum of  $10^{-5}$  Torr in silica ampoules. Three tubes are prepared and each tube is placed in an oscillatory furnace then heated gradually to  $900^\circ\text{C}$ . The furnace temperature was raised gradually at a rate  $\sim 3\text{-}4^\circ\text{C}/\text{min}$ , then the ampoule quenched quickly in ice water to obtain the material in the glassy state.

Thin films of various thicknesses ranging (200 – 670 nm) were deposited by thermal evaporation under vacuum  $10^{-5}$  Torr. The films were deposited onto glass substrates with upper and lower Aluminium electrodes for sandwich structure by using a coating unit (Edward E-306A). The film thicknesses were measured using Tolansky's method [22]

The structure of the prepared compositions was investigated by X-ray using Philips X-ray unit (PW 1710) supplied with a copper target with Ni filter. The X-ray tube was operated at 40KV and 30mA. X-ray patterns measured in the angular range 4° to 90°, EDX analysis measured using scanning electron microscope type (QUANTA FEG 250).

For DC electrical conductivity  $\sigma_{dc}$ , the resistance  $R$  of thin films is measured by using an electrometer (Keithley type E616A) in the temperature range (298-323K) and  $\sigma_{dc}$  calculated by:

$$\sigma_{dc} = d/RA \quad (1)$$

where  $d$  is the thickness,  $A$  is the cross-sectional area and  $R$  is the resistance.

For measuring AC conductivity and dielectric properties, a programmable automatic RLC bridge (PM 6304 Philips) is used to measure the capacitance  $C$ , the impedance  $Z$  and the loss tangent  $\tan\delta$  directly as a function of frequency (100Hz – 1MHz) and temperature (298-323 K). The total conductivity  $\sigma_t(\omega)$  was calculated from the relation:

$$\sigma_t(\omega) = d/ZA \quad (2)$$

The dielectric constant  $\epsilon_1$  obtained by the relation:

$$\epsilon_1 = d C / A \epsilon_0 \quad (3)$$

where  $\epsilon_0$  is the permittivity of the free space ( $\epsilon_0 = 8.854 \times 10^{-12} F/m$ ). The dielectric loss  $\epsilon_2$  was obtained by the relation:

$$\epsilon_2 = \epsilon_1 \tan\delta \quad (4)$$

where ( $\delta = 90 - \varphi$ ) and  $\varphi$  is the phase angle. All measurements were obtained below the glass transition temperatures ( $T_g \sim 323$  K).

### **3. Results and discussion:**

#### **3.1 Structure Identification**

XRD patterns of  $\text{Se}_{98}\text{Te}_2$  and  $\text{Se}_{96}\text{Te}_2\text{X}_2$  ( $\text{X} = \text{Zn}$  and  $\text{Cd}$ ) thin films are presented in **Fig.(1)**. The presence of only broad humps indicates that the deposited films are amorphous for all investigated compositions.

The EDX spectroscopy for the studied film samples is measured and indicates that the constituent elements percentage were close to the prepared samples as seen in **Table (1)**. Also, the EDX analysis indicates the absence of any other impurities in the studied samples.

#### **3.2 DC conductivity.**

The temperature dependence of DC conductivity ( $\sigma_{dc}$ ) were studied at the temperature range (298 –323 K) for all investigated compositions. The DC conductivity can be represented by this equation [23].

$$(\sigma_{dc}) = \sigma_o \exp \left[ -\frac{\Delta E}{k_B T} \right] \quad (5)$$

Where  $\Delta E$  is the activation energy for DC conduction and  $\sigma_o$  is the pre-exponential factor and  $k_B$  Boltzmann's constant.

**Fig.2(a-c)** shows the variation of  $\ln\sigma_{dc}$  versus  $1000/T$  For  $\text{Se}_{98}\text{Te}_2$  and  $\text{Se}_{96}\text{Te}_2\text{X}_2$  ( $\text{X} = \text{Zn}$  and  $\text{Cd}$ ) thin films of different thicknesses. It can be seen from **Fig.2(a-c)** that the conductivity increases linearly with temperature and there is only one conduction mechanism for all investigated compositions.

Using Eq.(5) the values of  $\Delta E$  and  $\sigma_o$  are obtained and given in **Table (2)**, which suggest that conduction occur by hopping of charge carriers between localized state at the band edges. Also, it can be noticed from **Fig.2(a-c)** that the conduction increases in the sequence  $\sigma_{Cd} > \sigma_{Zn} > \sigma_{SeTe}$  and  $\sigma_{dc}$  increases with temperature for all investigated compositions. These results agree with the density of localized states presented later in **Table (4)**  $N(E_f)_{Cd} > N(E_f)_{Zn} > N(E_f)_{SeTe}$ . The increase in  $\sigma_{dc}$  with the addition of Cd to SeTe is higher than that of Zn, this can be explained in terms of the addition of Zn and Cd to SeTe

leads to a decrease in the bond energy between Se and the additive [24] as shown in **Table (3)**. It can be seen from this table that SeTeCd has a weaker bond energies than that of SeTeZn which in turn weaker than the bonds in case of SeTe. Also  $\Delta E$  decreases with Cd more than that with Zn incorporation and this can be attributed due to the shifting of the Fermi level. For SeTeZn composition, the Zn atoms are incorporated into Se-Te alloy as network converter [25]. The zinc atom either cross-link or enter into the chain and ring structure of Se-Te system.

Also, we can see from **Fig. 2(a-c)** that, the electrical conductivity decreases with increasing film thickness for all investigated film samples. This decrease may be attributed to the decrease in defects and the degree of disorder present in the structure [26,27].

### **3.3- AC conductivity**

#### **3.3.1 - The dependence of ac conductivity on frequency:**

The frequency dependence of ac conductivity for  $\text{Se}_{98}\text{Te}_2$  and  $\text{Se}_{96}\text{Te}_2\text{X}_2$  (X=Cd and Zn) at various temperatures is illustrated in **Fig.3(a-c)** for approximately the same thickness as an example. The a.c conductivity is calculated by:

$$\sigma_{ac} = \sigma_{tot}(\omega) - \sigma_{dc} = A_o \omega^s ; \text{ with } s \leq 1 \quad (6)$$

Here,  $\omega$  is the angular frequency,  $\omega = 2\pi f$ ,  $s$  is the frequency exponent,  $A_o$  is a constant and  $f$  is the frequency. Plotting  $\ln\sigma_{ac}$  versus  $\ln\omega$  at different temperatures for the investigated system is illustrated in **Fig.3(a-c)**. It can be seen from the above figure that  $\sigma_{ac}(\omega)$  increases linearly with frequency for all investigated compositions. The values of the frequency exponent  $s$  were obtained from the slopes of straight lines of **Fig.3(a-c)**.

The mean values of  $s$  for each composition are calculated and plotted with temperature as shown in **Fig.(4)**. It is observed that  $s$  has values close to unit for  $\text{Se}_{98}\text{Te}_2$  and  $\text{Se}_{96}\text{Te}_2\text{X}_2$  (X= Cd and Zn) which decrease slightly with temperature.

This behavior is in contrast with the quantum mechanical tunneling (QMT) model [28] which predict the frequency exponent  $s$  equal 0.81. The correlated barrier hopping (CBH) model [29,18] predicts the decrease of  $s$  with temperature for Non-Intimate Valence Alternation pairs (NVAP's), while it predicts the decrease of  $s$  slightly with temperature and  $s$  values close to unit for intimate VAP's (IVAP's) centers [30]. So, our results of  $s$  can be discussed according to CBH model between centers forming IVAP's centers.

The obtained results of **Fig. 4** are agree with that obtained before [31,32]. According to this model, the conduction mechanism contains single and bipolaron hopping of charge carriers between defect states. By increasing the frequency of the applied field the hopping distance decreases [33,34]. Therefore, the probability of jumping charges between defect states increases. This leads to increasing the a.c. conductivity with frequency which agree with the experimental results (**Fig. 3(a-c)**).

### ***3.3.2 - The dependence of Ac conductivity on Temperature:***

The temperature dependence of ac conduction was studied for  $\text{Se}_{98}\text{Te}_2$  and  $\text{Se}_{96}\text{Te}_2\text{X}_2$  (X=Cd and Zn) glassy system at different frequencies (100Hz - 1MHz). **Fig.5 (a-c)** shows  $\ln\sigma_{ac}$  vs  $1000/T$  for the investigated compositions in thin film form. It is noticed that  $\sigma_{ac}$  increases slightly with temperature, which indicates that Ac conduction is a thermally process. The values of AC conduction activation energy  $\Delta E_{ac}(\omega)$  are obtained from the slopes of the lines in **Fig.5 (a-c)** by the aid of this relation:

$$\sigma(\omega) = \sigma_o(\omega)\exp(-\Delta E_{ac}(\omega)/kT) \quad (7)$$

The values of  $\Delta E_{ac}(\omega)$  at different frequencies are obtained for  $\text{Se}_{98}\text{Te}_2$ ,  $\text{Se}_{96}\text{Te}_2\text{Zn}_2$  and  $\text{Se}_{96}\text{Te}_2\text{Cd}_2$  in thin film form and plotted versus  $\ln\omega$  in **Fig. (6)**. This Figure indicates that  $\Delta E_{ac}$  decreases with increasing frequency for all investigated compositions, as obtained for other different materials [35,36]. Increasing the applied field increases the jump of charge carrier's between the localized states, so with increasing frequency the activation energy  $\Delta E(\omega)$  decreases. Also, it is observed that  $\Delta E_{ac}$  for  $\text{Se}_{98}\text{Te}_2$  higher than that for  $\text{Se}_{96}\text{Te}_2\text{Zn}_2$  which in turn higher than that of  $\text{Se}_{96}\text{Te}_2\text{Cd}_2$  which agree with the results obtained before for  $\Delta E_{dc}$ . This behavior may be due to increasing the density of localized states presented in the structure as presented later in **Table 4**.

According to CBH model the charge carrier's hop between the defect states  $D^+$  and  $D^-$ . Each pair of  $D^+$  and  $D^-$  form a dipole with relaxation, which can be explained due to the existence of a potential barrier which the carriers must hop [37]. The process of hopping of the charge carriers here is affected by the localized state density, which calculated from the relation [6].

$$\sigma_{ac}(\omega) = 1/3\pi e^2 kT [N(E_F)]^2 \alpha^{-5} \omega \{\ln(v_{ph}/\omega)\}^4 \quad (8)$$

where  $e$  the electronic charge is  $v_{ph}$  is the phonon frequency ( $v_{ph} = 10^{12}H_z$ ) and  $\alpha$  is the parameter exponential decay of localized states wave functions ( $\alpha^{-1} = 10 \text{ \AA}$ ). Taking the values of  $v_{ph}$  and  $\alpha^{-5}$  [38], the density of localized states  $N(E_F)$  is obtained at 1 kHz and 303K. The calculated values of  $N(E_F)$  are listed in **Table (4)** for the investigated samples. From **Table (4)** the  $N(E_F)$  values increase with the doping of third element (M=Zn and Cd) in a-

Se<sub>98</sub>Te<sub>2</sub> alloy respectively. The increasing order of  $N(E_F)$  is  $(N)_{M=Cd} > (N)_{M=Zn} > (N)_{base}$ , which is agree with the obtained results of conductivity.

This variation can be discussed in terms of changing impurity in the structure of the X-Se bonds. Schotmiller et al.[39] showed the effect of adding elements on the structure of Se using infra-red and Raman spectroscopy. According to them, in amorphous Se about 60% of the atoms are bonded as polymeric chains, and 40% of the atoms have a ring structure. The addition of third element causes a decrease in the Se<sub>8</sub> ring concentration. It favors the polymeric chains and the formation of the rings containing Se-M (M=Zn and Cd) bonds. This can be discussed as the addition of Zn and Cd to SeTe leads to a decrease in the bond energy between Se and the additive [24] as shown in **Table (3)**. It is seen from this table that bond energies for SeTeCd smaller than that of SeTeZn which in turn smaller than the bonds of SeTe. Also, the value of  $\sigma_{ac}$  for the investigated compositions at 1 KHz and 303 K are listed in **Table (4)**, which increases by adding Cd and Zn to SeTe respectively.

### **3.4- Frequency and temperature dependence of dielectric constant ( $\epsilon_1$ ):**

**Fig.7(a-c)** shows  $\epsilon_1$  versus temperature at different frequencies for the investigated compositions of the same thickness as example. At lower temperatures the dielectric constant  $\epsilon_1$  increases slowly and then increases more with increasing temperature. The same results was obtained for all the studied compositions and similar to results obtained before [40, 35, 36, 32].

The increase of  $\epsilon_1$  with temperature is due to the dipole in polar materials cannot orient themselves at low temperature. The orientation of the dipoles is easier when the temperature is increased and increases the orientation polarization value, which increases  $\epsilon_1$  also as illustrated by Sirivastava et al. [41].

The frequency response of  $\epsilon_1$  at different temperatures for all compositions of nearly the same thickness is shown in **Fig.8(a-c)** as example. Clearly with increasing frequency  $\epsilon_1$  decreases. In polar materials and at low frequencies, the change in  $\epsilon_1$  is due to the different types of polarization (ionic, electronic, dipolar or space charge and orientation) polarization, which explain the high values of  $\epsilon_1$  at low frequencies. Ionic polarization takes place due to the displacement of positive and negative ions with respect to each other. The dipolar polarization occurs because the molecules change their direction of rotation into that of the applied electric field. The space charge polarization occurs due to mobile charge carriers at interfaces. With raising f, the dipoles couldn't rotate fast, then they couldn't follow the field. Thus  $\epsilon_1$  is due to the space charge or inter facial polarization only which explain the small values of  $\epsilon_1$  at high frequencies. In our present study, the ionic polarization hasn't a great role in the total polarization where the covalent nature is expected for the studied compositions [42]. It is noticed that  $\epsilon_1$  increases by adding Zn and Cd to SeTe (see **Table 5**).

### **3.5- Temperature and frequency dependence of the dielectric loss $\epsilon_2$ :**

The change of dielectric loss  $\epsilon_2$  for the studied film compositions were investigated in the operating frequency and temperature ranges. **Fig.9(a-c)** shows the dependence of temperature of the dielectric loss  $\epsilon_2$  at various frequencies for  $\text{Se}_{98}\text{Te}_2$  and  $\text{Se}_{96}\text{Te}_2\text{X}_2$  (X= Cd and Zn) films as example. It can be seen that  $\epsilon_2$  increases with temperature for the investigated compositions. It is noticed that the obtained values for  $\epsilon_1$  and  $\epsilon_2$  is small with respect to that obtained before by Arun Kumar et al. [32] for  $(\text{Se}_{80}\text{Te}_{20})_{100-x}\text{Zn}_x$  and is agree with the results obtained for  $\text{Se}_{75}\text{Te}_{25}$  by I.S. Yahia et al. [43].

The dielectric loss composed of two components: first from processes of dielectric polarization and the other from DC conductivity. The dielectric

relaxations are used to study the dielectric losses in the material. According to Stevels [44], the dielectric loss origin is the conduction losses, vibrational losses and dipole losses. The conduction losses involve the migration of ions through long distances. This migration is like that occurs under direct current conduction. The ions jump through the highest potential in the network, when the ions moves, they give some energy to the lattice in the form of heat and the heat lost per cycle proportion to  $(\sigma/\omega)$ . At low values of temperature, conduction, dipole and vibrational losses have small values, while at high temperature dipole, conduction and vibrational losses contribute to the dielectric loss.

**Fig.(10)** shows the dependence of  $\epsilon_2$  on frequency at various temperatures in the range (298-323K) for films of the samples of nearly the same thickness. It is seen that  $\epsilon_2$  decreases with increasing frequency,  $\epsilon_2$  at low and medium frequencies has the highest values due to the conduction loss of ion migration, ion jump and also the ion polarization loss. However, at high frequency the ion vibrations is responsible for dielectric loss because the charge carriers vibrate through a dielectric so at higher values of frequency  $\epsilon_2$  decreases.

It can be noticed that the addition of **Zn** and **Cd** to SeTe increases the values of  $\epsilon_2(\omega)$  in the investigated samples respectively as in **Table (5)**. The observed increase with **Cd** additive is higher than that with **Zn**. This may be due to the charged defect centers formation by metal additives and the decrease in bond energy between Se and the additives **Cd** and **Zn** as we explained before.

Mott et al. [45] expressed that electron hops between localized sites when the sample is placed in an electric field. The charge carriers hop from a donor to acceptor state, according to this the pair of sites form dipole. So, the dielectric properties of chalcogenide glasses can be studied by considering a set of dipoles. The dipole has a relaxation time which depends on its activation energy [46] and

attributed to the potential barrier  $W_m$ , at which the carriers hop [6].  $W_m$  as suggested by Elliott [8] is due to the columbic interaction between two neighboring sites forming a dipole.

Guintini et al. [47] study the dielectric loss  $\epsilon_2$  of chalcogenide glasses where  $\epsilon_2$  follows the power law ( $\epsilon_2 = B\omega^m$ ),  $B$  is constant and  $m$  linear with  $T$  as given from the equation.

$$m = -4 k_B T / W_m \quad (10)$$

$W_m$  is the required energy that moves the electron to infinity.

The results of  $\epsilon_2$  for the investigated compositions obeys the power law with frequency at various temperatures. **Fig.11(a-c)** confirms this behavior when  $\ln\epsilon_2$  versus  $\ln\omega$  plots gives straight lines at different temperatures. The slopes of these lines give the values of the power  $m$ . The values of  $m$  for the studied samples in thin film form of nearly the same thickness are plotted with temperature as seen in **Fig.12(a-c)**. It is observed from this figure that  $m$  linearly decreases with temperature as seen before [47, 48]. Values of  $W_m$  calculated for the studied samples from **Fig.12(a-c)** and given in **Table (5)**, the obtained values of  $W_m$  decrease with the addition of Zn and Cd to SeTe respectively. Similar results were obtained before [49]. The results were in good agreement with the hopping theory of charge carriers suggested by Elliott [8]. These results are agree with the results obtained for  $\sigma_{ac}(\omega)$ ,  $\Delta E(\omega)$  and  $\epsilon_1$ , mentioned above.

The CBH [18, 8] model applied to most chalcogenide semiconductors, describes the charge carriers across the defect states  $D^+$  and  $D^-$ . According to Giuntini model [47], each pair of  $D^+$  and  $D^-$  form a dipole with relaxation energy. The addition of Cd and Zn in the  $Se_{98}Te_2$  glassy alloy lead to the increase of  $\epsilon_1$  and  $\epsilon_2$  (see **Table (5)**). This increase explained in terms of the bonding nature in the system, it can be explained as the impurity atom addition in the binary alloy may lead to decreasing the stronger bonds density than other bonds in the structure i.e, the weaker bond density increases in the studied

compositions, which are responsive to electric field more than the stronger bonds. Thus the values of  $\epsilon_1$  and  $\epsilon_2$  increase with impurity addition in the studied system.

### **Conclusions:**

Dc conductivity for  $\text{Se}_{98}\text{Te}_2$  and  $\text{Se}_{96}\text{Te}_2\text{X}_2$  ( $\text{X} = \text{Zn}$  and  $\text{Cd}$ ) thin films indicate that there is only one conduction mechanism and the conduction occur by hopping of charge carriers between localized state at the band edges. The conductivity increases in the sequence  $\sigma_{\text{Cd}} > \sigma_{\text{Zn}} > \sigma_{\text{SeTe}}$  and  $\sigma_{\text{dc}}$  increases with temperature for the investigated system. The increase in  $\sigma_{\text{dc}}$  can be explained in terms of the addition of Zn and Cd to SeTe leads to a decrease in the bond energy between Se the host element and the additive, where SeTeCd has weaker bonds than that of SeTeZn which in turn weaker than the bonds in case of SeTe.

The research work reveals that Zn and Cd doping influences the dielectric properties and a.c. conductivity of Se-Te alloy.  $\sigma_{\text{ac}}(\omega)$  increases linearly with frequency for all investigated compositions. The obtained values of the frequency exponent  $s$  are close to unity for  $\text{Se}_{98}\text{Te}_2$  and  $\text{Se}_{96}\text{Te}_2\text{X}_2$  ( $\text{X} = \text{Cd}$  and  $\text{Zn}$ ) which decrease slightly with temperature. So, the temperature dependence of  $s$  discussed on the basis of CBH model between centers forming *IVAP*'s centers.

Both of dielectric constant  $\epsilon_1$  and loss  $\epsilon_2$  increase with temperature and decrease with increasing frequency. The addition of Cd and Zn in the  $\text{Se}_{98}\text{Te}_2$  glassy alloy lead to the increase of  $\epsilon_1$  and  $\epsilon_2$ , this increase explained in terms of the bonding nature in the system. The impurity atom addition in binary alloy lead to decreasing the stronger bonds density more than other bonds in the network structure. The observed increase with Cd additive is higher than that with Zn, this may be due to the charged defect centers formation by metal

additives and the decrease in bond energy between Se (the host element) and metal additives Cd, Zn as we explained before. The low values of dielectric constant and dielectric loss for the studied system suggests that this system has vital importance for various non-linear optical properties and their applications.

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**Conflict of interest: This is to confirm that there is no conflict of interest.**

Ref:

[1] A.V. Stronski, in: Proc. NATO Advanced Research Workshop on Micro-electronic Interconnections and Assembly, Eds. G. Haraman, P. Mach, Kluwer Academic, Netherlands 1998, p. 263.

[2] E. Maquez, T. Wagner, J. M. Gonzalez-Leal, A.M. Bernal-Oliva, R. Prieto-Alcon, R. Jimenez-Garay, P. Ewen, Controlling the optical constants of thermally-evaporated  $\text{Ge}_{10}\text{Sb}_{30}\text{S}_{60}$  chalcogenide glass films by photo doping with silver J. Non-Cryst. Solids 274 , 1-3 (2000) 62-68.

[3] V. F. Lyubin, M. Klebanov, A. Feigel, B. Sfez, Films of chalcogenide glassy semiconductors: New phenomena and new applications, Thin Solid Films 459, (2004) 183-186.

[4]M.Pollak, On the frequency dependence of conductivity in amorphous solids., Philos, Mag.. 23 (1971) 519-543.

[5]A.Ghosh, Transport properties of vanadium germanate glassy semiconductors Phys, Rev, B 42 (1990) 5665-5676.

[6] M. Pollak and G. E. Pike, ac Conductivity of Glasses, Phys. Rev. Lett. 28 (1972)1449-1451.

[7] A. Kondo, K. Shimakawa and Y. Inagaki, On the a.c. conduction in evaporated SiO films, J. Phys. 16 (1983) 5211-5216.

[8] S. R. Elliott , Temperature dependence of ac conductivity of chalcogenide glasses, Philos, Mag. B, 37 (1978) 553-560.

[9] Singh and K. Shimakawa., In Advances in Amorphous Semiconductors. CRC Press. Usa (2003).

[10] K. Shimakawa, On the temperature dependence of a.c. conduction in chalcogenide glasses, Philosophical Magazine B., 46 (1982) 123.

[11] J. Sharma and S. Kumar, Role of metallic Zn and In additives in the electrical and dielectric properties of  $\text{Se}_{0.85}\text{Te}_{0.15}$  glassy alloy, Turk .J .Phys. 35 (2011) 349-358.

[12] J. Sharma and S. Kumar, Role of Additives (Cd and Ge) on the Ac Conductivity and Dielectric Relaxation of  $\text{Se}_{70}\text{Te}_{30}$  Glassy Alloy., Glob. J.Sci Front, Res. Phys. And Space Sci, 13 (2013) .

[13] N. Chandel, N. Mehta, A. Kumar, Investigation of a.c. conductivity measurements in a- $\text{Se}_{80}\text{Te}_{20}$  and a- $\text{Se}_{80}\text{Te}_{10}\text{M}_{10}$  (M = Cd, In, Sb) alloys using correlated barrier hopping model Current Applied Physics 12(2012 )405 -412 .

- [14] S. Srivastava, N. Mehta, C. P. Singh, R. K. Shukla, A. Kumar, Dielectric parameters in  $\text{Se}_{70}\text{Te}_{30}$  and  $\text{Se}_{70}\text{Te}_{28}\text{Zn}_2$  chalcogenide glasses Physica B 403(2008 ) 2910-2916.
- [15] N. Chandel, N. Mehta, A. Kumar, Estimation of Density of Localized States in Amorphous  $\text{Se}_{80}\text{Te}_{20}$  and  $\text{Se}_{80}\text{Te}_{10}\text{M}_{10}$  ( $\text{M} = \text{Cd}, \text{In}, \text{Sb}$ ) Alloys Using AC Conductivity Measurements, J. Electronic Materials , 44(2015 ) 2585–2591.
- [16] B.S. Patial, Neha, J. Prakash, R. Kumar, S.K. Tripathi, N. Thakur, Dielectric Properties and AC Conductivity Measurements of Amorphous  $\text{Ge}_{15}\text{Se}_{85}$  Glass, J. Nano Electron.Phys. 5 (2013) 02019.
- [17] N. Sharma, B.S. Patial, N. Thakur, On the dielectric study and AC conductivity measurements of Sb additive Se–Te chalcogenide alloys, Appl. Phys. A 122 (2016) 209.
- [18] S. R. Elliot, A theory of a.c. conduction in chalcogenide glasses, Philos, Mag., 36, (1977)1291.
- [19] S.A. Fayek, S.M. El-Sayad, Effect of composition and forming parameter on evaporated CdSeTe films deposited at room temperature, J. Phys. Chem. Solids 63 (2002)1-8.
- [20] D. K. Goel, C. P. Singh, RK, Shukla and A, Kumar, J. Mater, Sci, Dielectric relaxation in glassy  $\text{Se}_{80-x}\text{Te}_{20}\text{Ge}_x$  , 35 (2000) 1017.
- [21] N. Chandael, N, Mehta, A, Kumar, Study of thermally activated a.c. conduction in a- $\text{Se}_{80}\text{Te}_{20}$  and a- $\text{Se}_{80}\text{Te}_{19.5}\text{M}_{0.5}$  ( $\text{M} = \text{Cd}, \text{In}, \text{Sb}$ ) alloys, Solid State Sci, 13 (2011) 257.

- [22] S. Tolansky, Introduction to Interferometry (Longman, London,1955).
- [23] N. F. Mott, E. A. Davis, Electric process in non-crystalline materials (Clarendon, Oxford, 1979), p. 428
- [24] M. A. Afifi, M. Fadel, E. G. El-Metwally and A. M. Shakra, Electrical properties of amorphous  $\text{Se}_{70}\text{Ge}_{30-x}\text{M}_x$  system, where M represents silver, cadmium or lead, vacuum 77, (2005) 259.
- [25] R.S. Kundu, K.L. Bhatia, N. Kishore, P. Singh, C. Vijayaraghavan, Effect of addition of Zn impurities on the electronic conduction in semiconducting  $\text{Se}_{80-x}\text{Te}_{20}\text{Zn}_x$  glasses., Phil. Mag. B 72 (5) (1995) 513–528.
- [26] H.A. Zayed, Fizika A, 4 (1995) 45.
- [27] Z.S. El-Mandouh, J. Appl. Phys., 78 (1995) 7158.
- [28] X.H. Le cleach. Lois de variations et ordre de grandeur de la conductivité alternative des chalcogénures massifs non cristallins., J. Phys. (France) 40 (1979) 417-428.
- [29] M. Kastener, H. Fritzsche, Defect chemistry of lone-pair semiconductors, Philos. Mag. B 37 (1978)199.
- [30] C. Angell, Mobile Ions in Amorphous Solids., Ann. Rev. Phys. Chem. 43 (1992) 693.

- [31] P. Mannu, M. Palanisamy, G. Bangaru, S. Ramakrishnan, A.Kandasami , P.Kumar, Temperature-dependent AC conductivity and dielectric and impedance properties of ternary In–Te–Se nano composite thin films., Applied Physics A 125(2019) 458.
- [32] A. Kumar, V. Singh, H. Singh, P. Sharma, N. Goyal, Electronic transport properties of  $(\text{Se}_{80}\text{Te}_{20})_{100-x}\text{Zn}_x$  ( $2 \leq x \leq 6$ ) chalcogenide alloys, Physica B: Condensed Matter 555 (2019) 41–46.
- [33] V. Chithambaram, S. Jerome Das, S. Krishnan, Synthesis, optical and dielectric studies on novel semi organic nonlinear optical crystal by solution growth technique., J. Alloy. Comp. 509 (2011) 4543.
- [34] I.A. Niel, Use Of Chalcogenide Glass In Thermal Infrared Telescopes Proc. SPIE 237 (1980) 422.
- [35] E. Abd El-Wahabb , A. M. Farid · A. M. Shakra, AC conduction and current voltage characteristics of  $(\text{Sb}_2\text{Se}_3)_2(\text{Sb}_2\text{Te}_3)_1$  thin films., Applied Physics A (2018) 124-666.
- [36] A.M. Shakra, M. Fadel and S.S. Shenouda , Response of electrical and dielectric parameters of  $\text{ZnIn}_2\text{Te}_4$  thin films to temperature and frequency Physica B 586 (2020) 412082.
- [37] S. Asokan, M.M.V. Prasad, G. Parathasarathy, Mechanical and Chemical Thresholds in IV-VI Chalcogenide Glasses., E.S.R. Gopal, Phys. Rev. Lett. 62 (1989) 808.

- [38] N.A. Hegab, M.A. Afifi, H.E. Atyia, A.S. Farid., ac conductivity and dielectric properties of amorphous  $\text{Se}_{80}\text{Te}_{20-x}\text{Ge}_x$  chalcogenide glass film compositions., *J. Alloys compd.*, 477 (2009) 925.
- [39] J. Schottmiller, M. Tabak, G. Lucovshy, and A. Ward, In stabilities in semiconducting glass diodes D, *J. Non Cryst. Solids* 4, (1970) 80.
- [40] E.G. EL-METWALLY and A.M. SHAKRA , Influence of Ag, Cd or Pb Addition on Electrical and Dielectric Properties of Bulk Glassy Se-Ge, *Journal of ELECTRONIC MATERIALS*, Vol. 47, No. 8, 2018.
- [41] K.K. Srivastava, A. Kumar, O.S. Panwar, K.N. Lakshminarayan, Dielectric relaxation study of chalcogenide glasses., *J. Non-Cryst. Solids* 33 (1979) 205–224.
- [42] C. Kittel, *Introduction to Solid State Physics (Dielectrics and Ferroelectrics)*, 8th edition, John Wiley and Sons, 2004.
- [43] I.S. Yahia , N.A. Hegab , A.M. Shakra , A.M. AL-Ribaty , Conduction mechanism and the dielectric relaxation process of a- $\text{Se}_{75}\text{Te}_{25-x}\text{Ga}_x$  ( $x= 0, 5, 10$  and 15 at wt%) chalcogenide glasses., *Physica B* 407 (2012) 2476–2485.
- [44] J. M. Stevels, *Handbuch der Physik in Flugge (Ed)*, Ed., Spring, berlin, (1975) p. 350.
- [45] N. F. Mott, E.A. Davis, R. A. Street, States in the gap and recombination in amorphous semiconductors., *Philos. Mag.* 32 (1975) 961.

[46] A. E. Steen, H. Eyring, The Deduction of Reaction Mechanisms from the Theory of Absolute Rates , J. Chem. Phys. 5 (1937) 113.

[47] J. C. Giuntini, J. V. Zanchetta, D. Jullien, R. Enolie, P. Houenou, Temperature dependence of dielectric losses in chalcogenide glasses , J .Non-Cryst. Solids 45 (1981)57.

[48] Sh.A. Mansour, I.S. Yahia, G.B. Sakr, Electrical conductivity and dielectric relaxation behavior of fluorescein sodium salt (FSS)., Solid State Commun. 150 (2010)1386.

[49] S. Kumar, M. Husain, M. Zulferquar, Dielectric relaxation in the glassy a–Se–Te–Ga system., Phys. B 387 (2007) 400.

## Figures

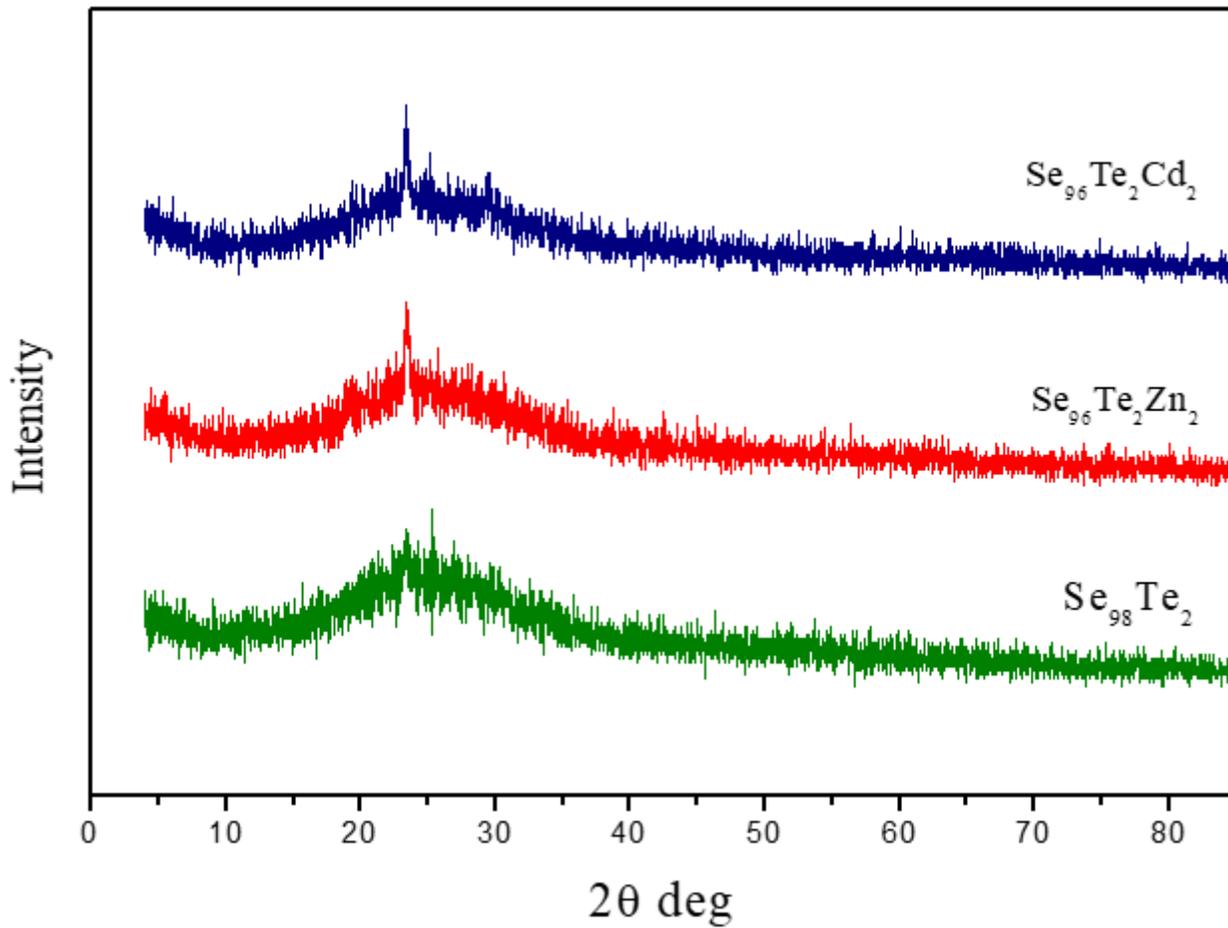
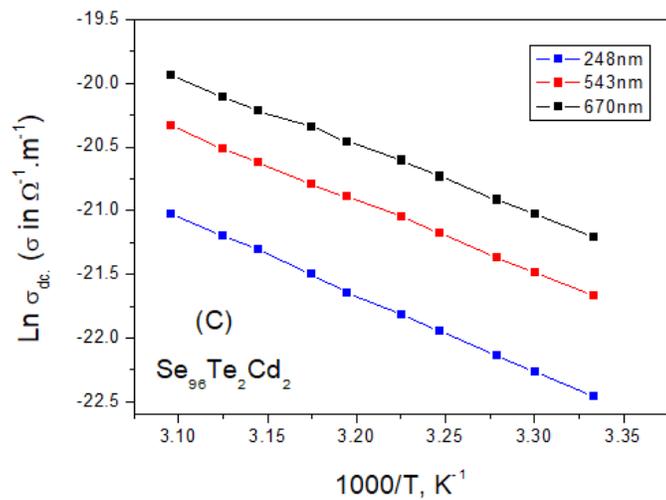
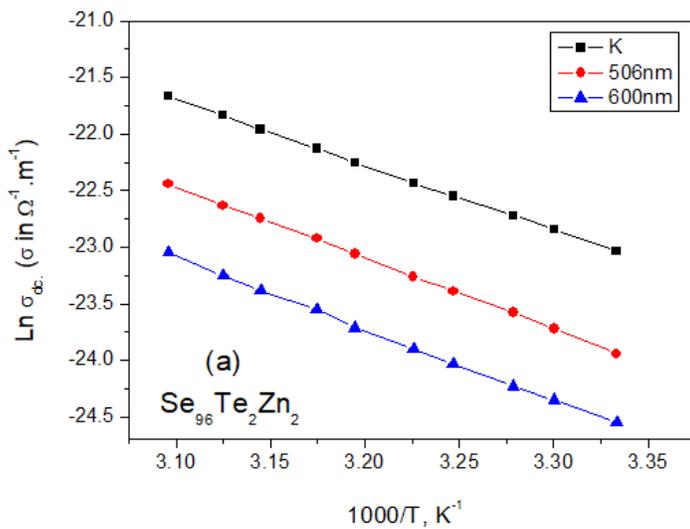
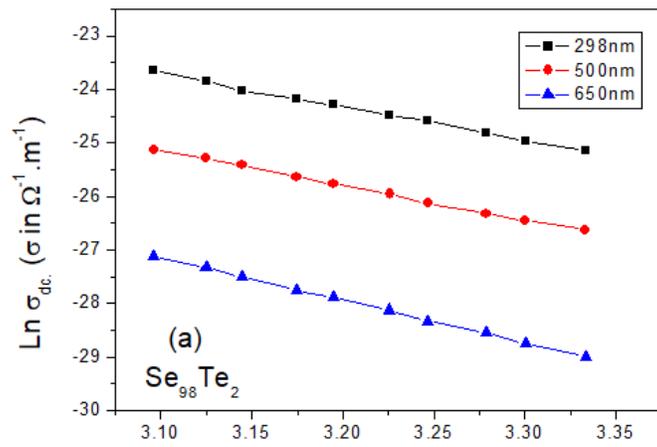


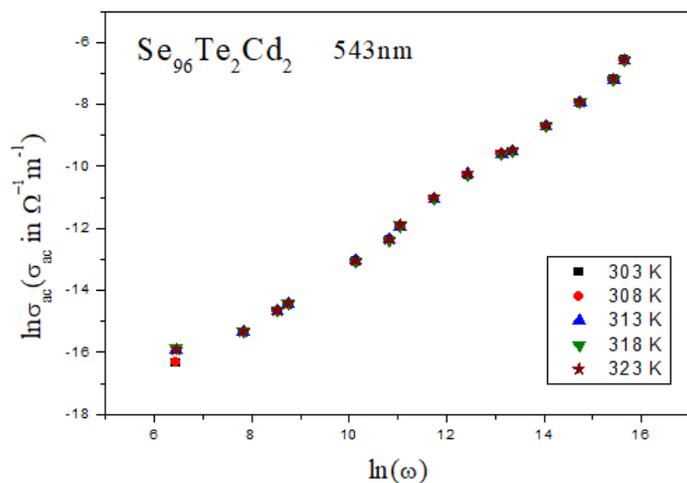
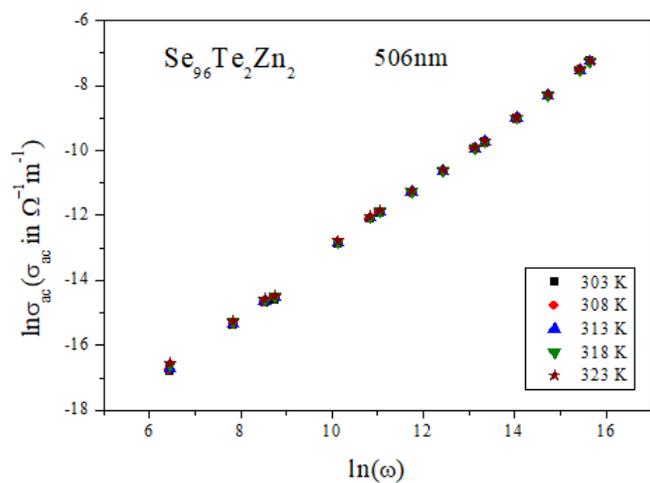
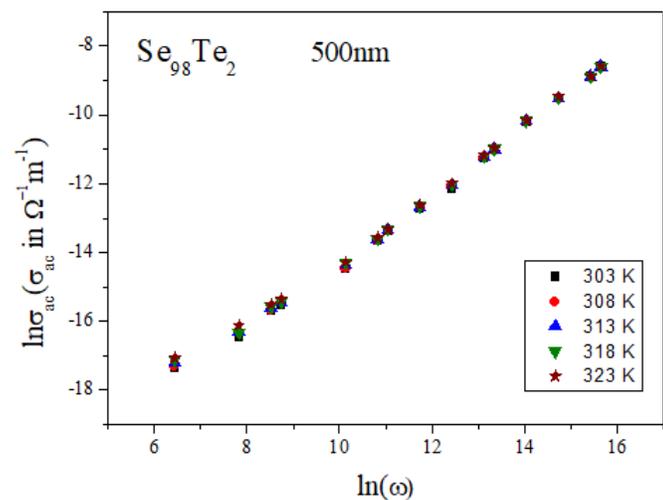
Figure 1

X-ray diffraction patterns for the as-prepared  $\text{Se}_{98}\text{Te}_2$  and  $\text{Se}_{96}\text{Te}_2\text{X}_2$  ( $\text{X} = \text{Zn}$  and  $\text{Cd}$ ) thin films.



**Figure 2**

(a-c) Temperature dependent of DC conductivity for  $\text{Se}_{98}\text{Te}_2$  and  $\text{Se}_{96}\text{Te}_2\text{X}_2$  ( $\text{X} = \text{Zn}$  and  $\text{Cd}$ ) thin films of different thicknesses.



**Figure 3**

(a-c) frequency dependence of the ac conductivity  $\sigma_{ac}(\omega)$  for Se<sub>98</sub>Te<sub>2</sub> and Se<sub>96</sub>Te<sub>2</sub>X<sub>2</sub>(X= Cd and Zn) films at different temperature.

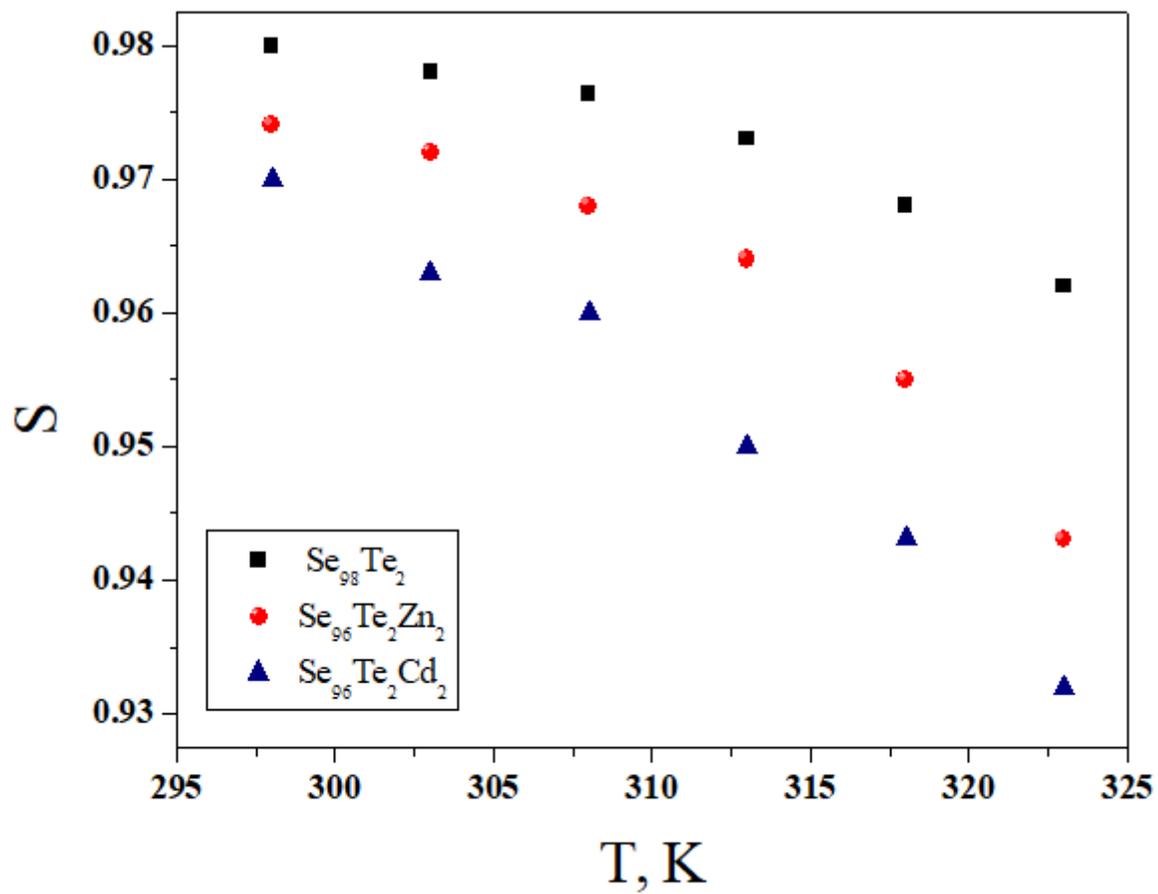
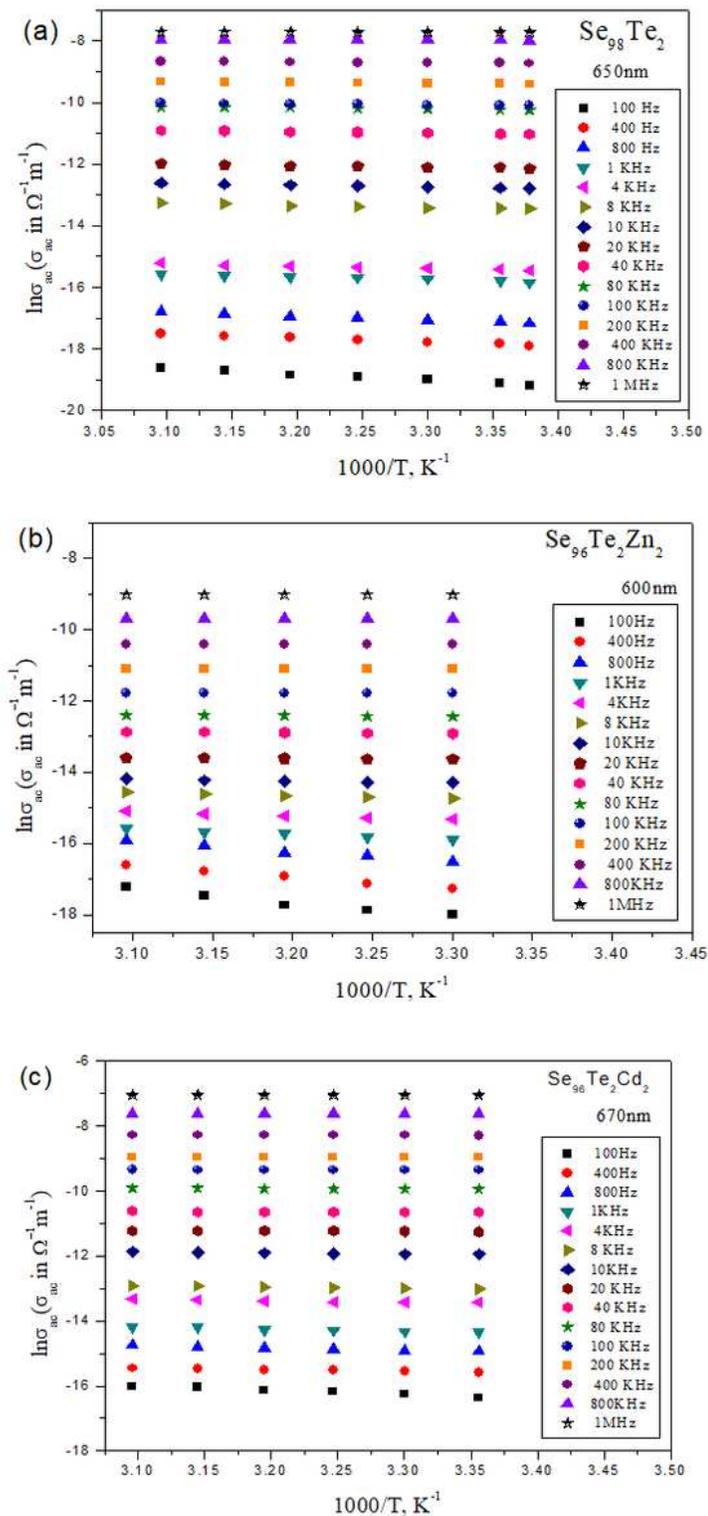


Figure 4

Temperature dependence of the frequency exponent  $s$  for  $\text{Se}_{98}\text{Te}_2$  and  $\text{Se}_{96}\text{Te}_2\text{X}_2$  ( $\text{X} = \text{Cd}$  and  $\text{Zn}$ ) films.



**Figure 5**

(a-c). Temperature dependence of the ac conductivity  $\sigma_{ac}(\omega)$  for  $\text{Se}_{98}\text{Te}_2$  and  $\text{Se}_{96}\text{Te}_2\text{X}_2$  ( $\text{X} = \text{Cd}$  and  $\text{Zn}$ ) films at different frequencies.

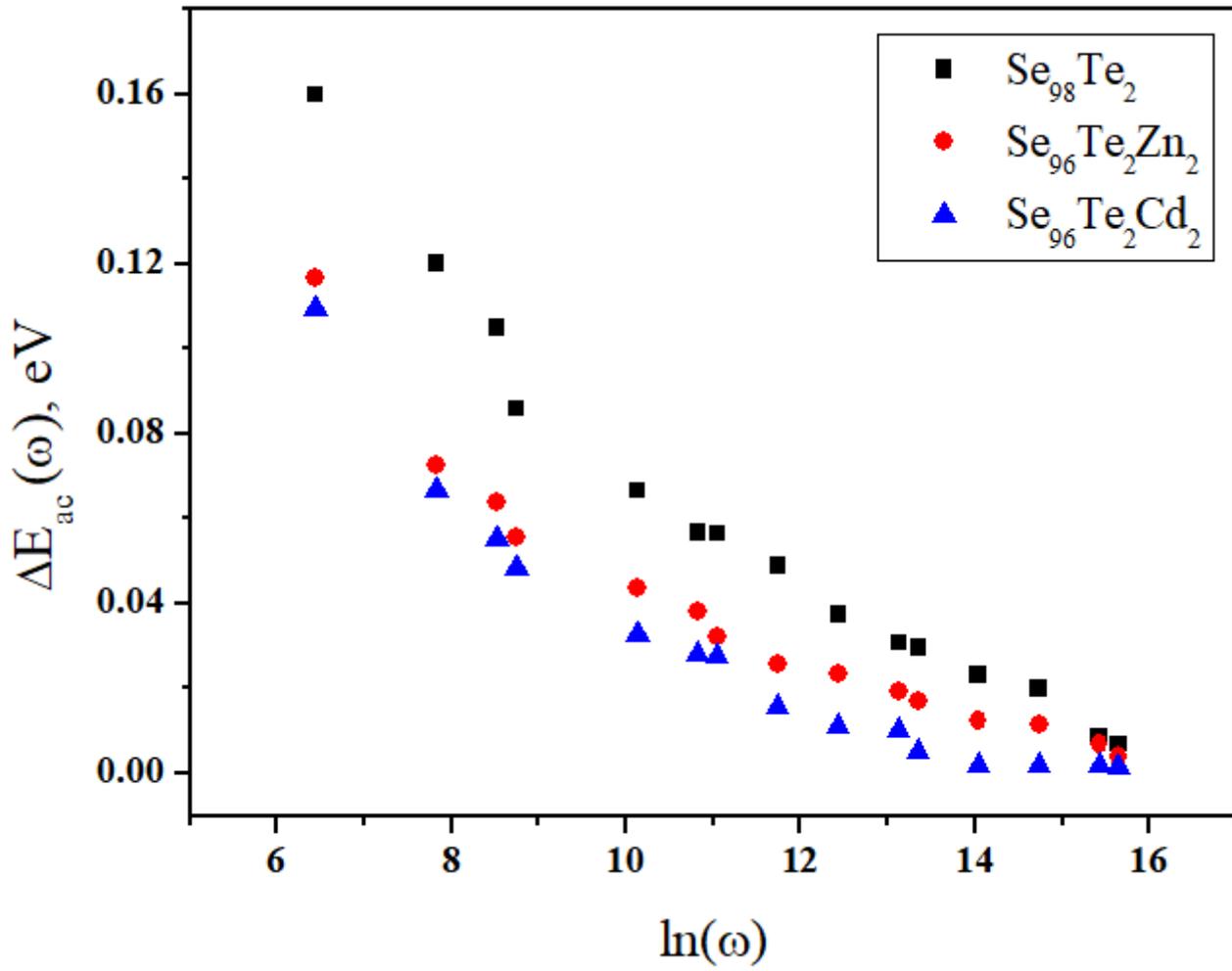
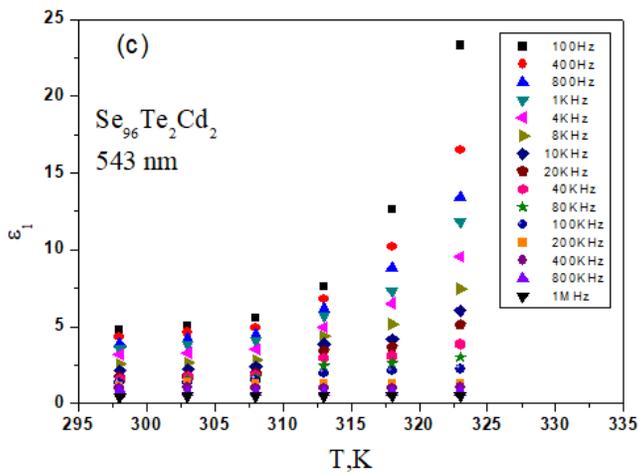
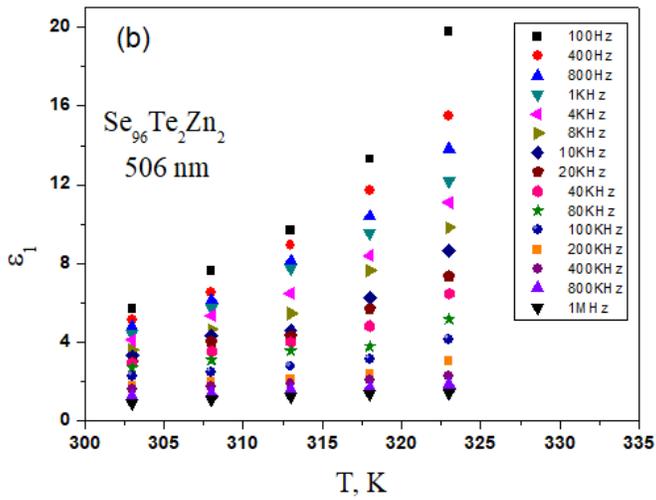
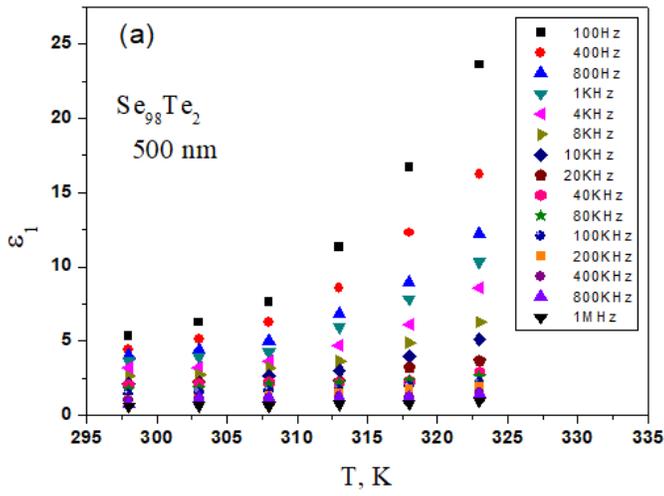


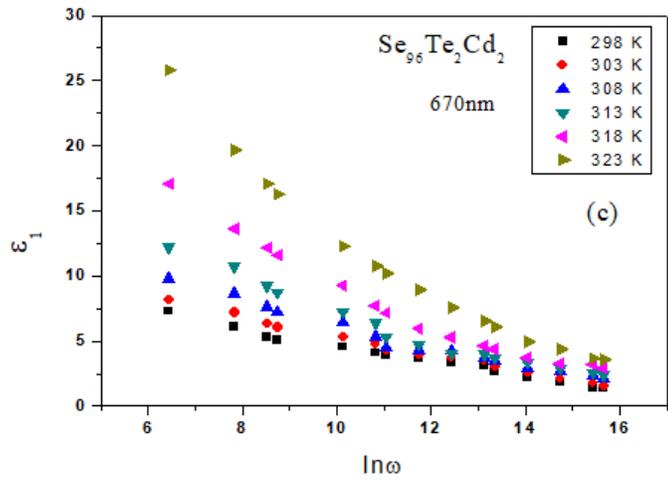
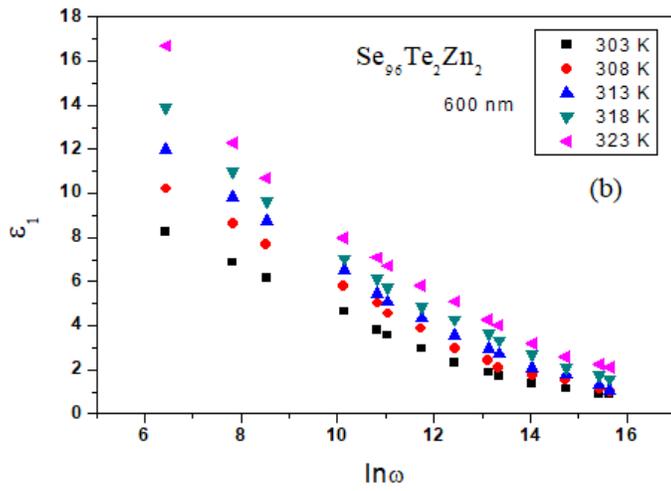
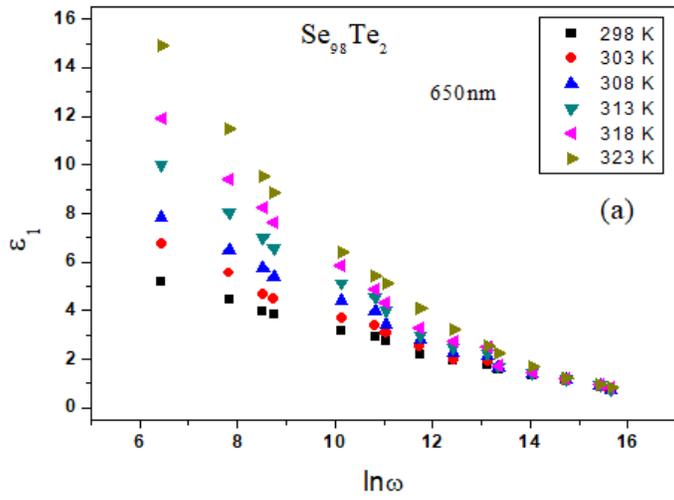
Figure 6

Frequency dependence of the conduction activation energy  $\Delta E_{ac}$  for  $\text{Se}_{98}\text{Te}_2$  and  $\text{Se}_{96}\text{Te}_2\text{X}_2$  (X= Cd and Zn) films.



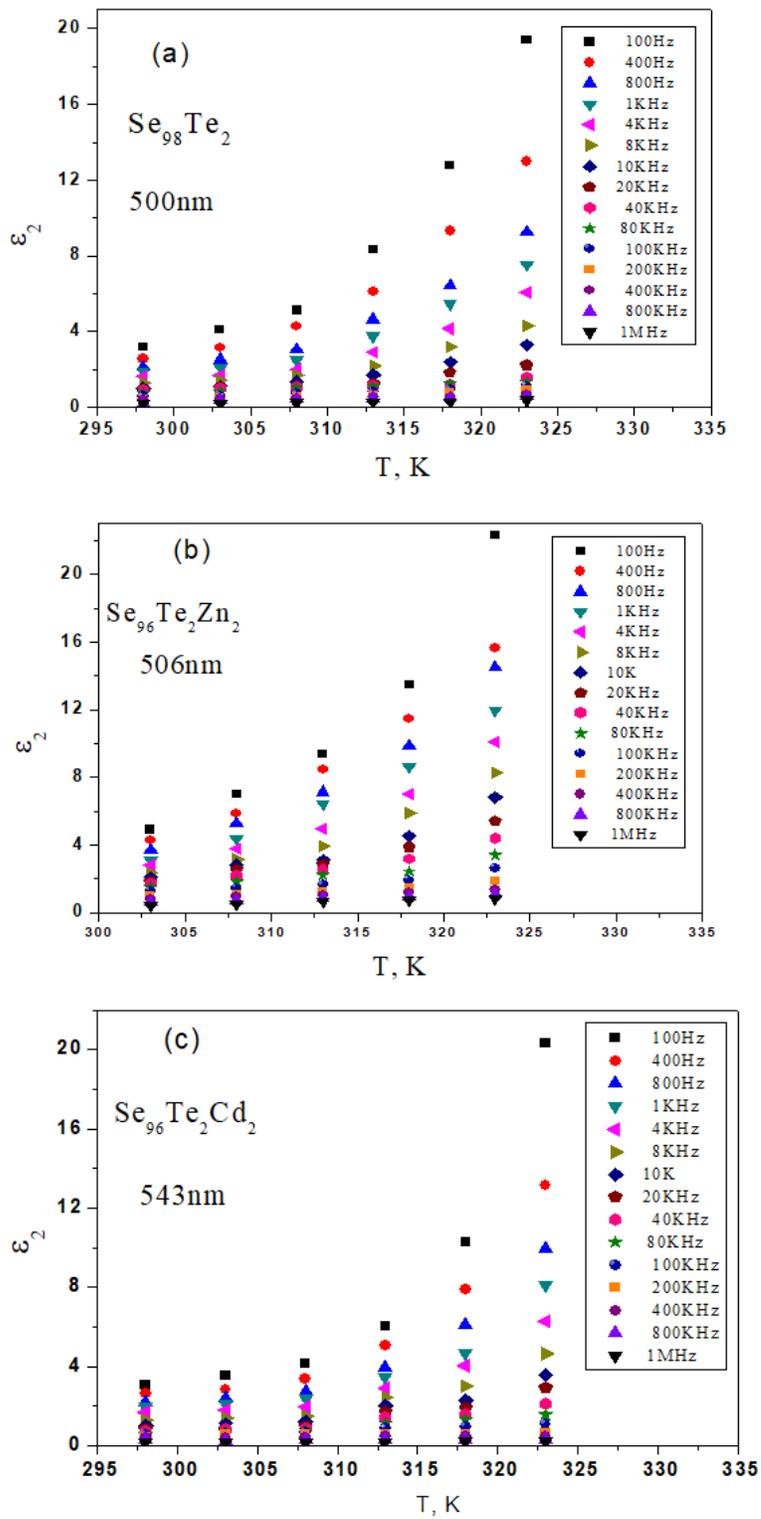
**Figure 7**

(a-c). Temperature dependence of dielectric constant  $\epsilon_1$  for  $\text{Se}_{98}\text{Te}_2$  and  $\text{Se}_{96}\text{Te}_2\text{X}_2$  ( $\text{X} = \text{Cd}$  and  $\text{Zn}$ ) films at different Frequencies.



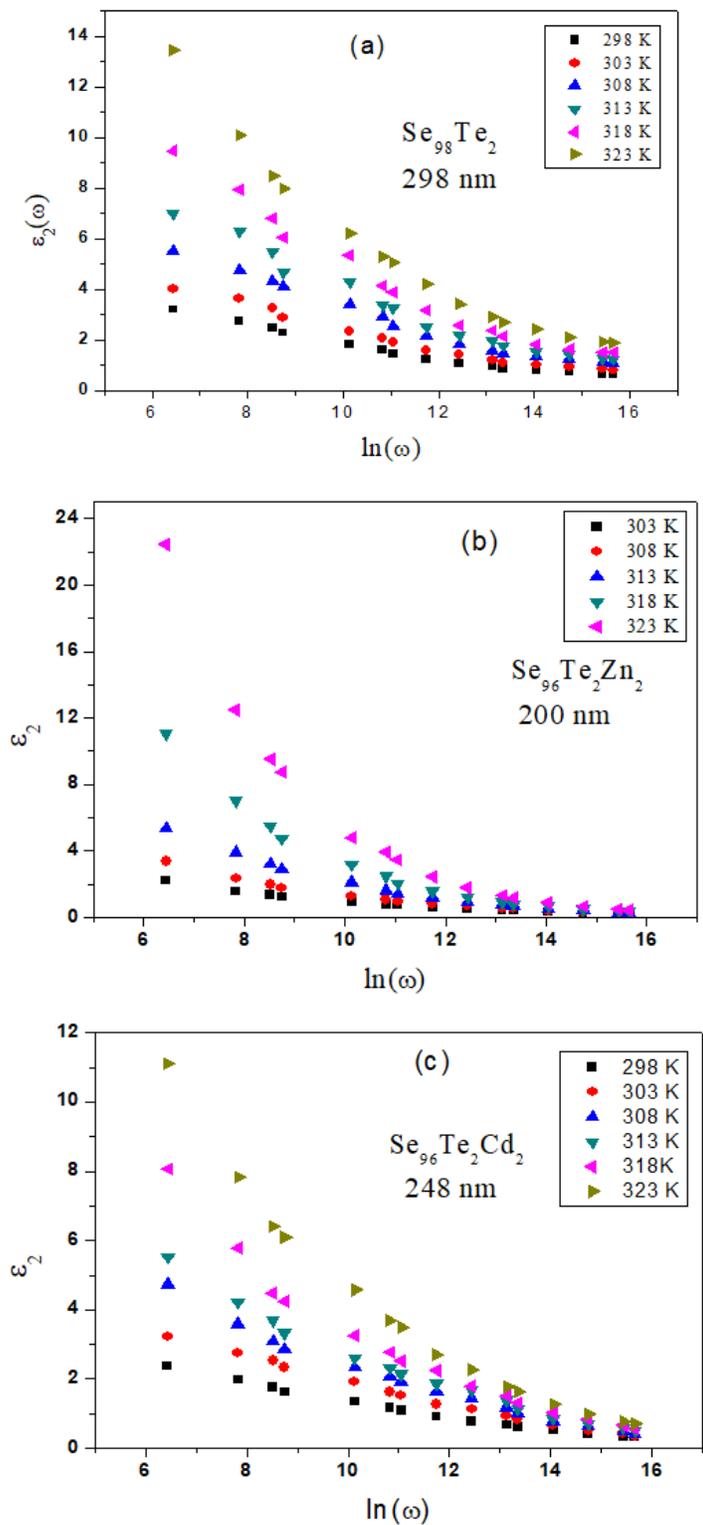
**Figure 8**

(a-c). Frequency dependence of dielectric constant  $\epsilon_1$  for  $\text{Se}_{98}\text{Te}_2$  and  $\text{Se}_{96}\text{Te}_2\text{X}_2$  ( $\text{X}=\text{Cd}$  and  $\text{Zn}$ ) films at different temperature.



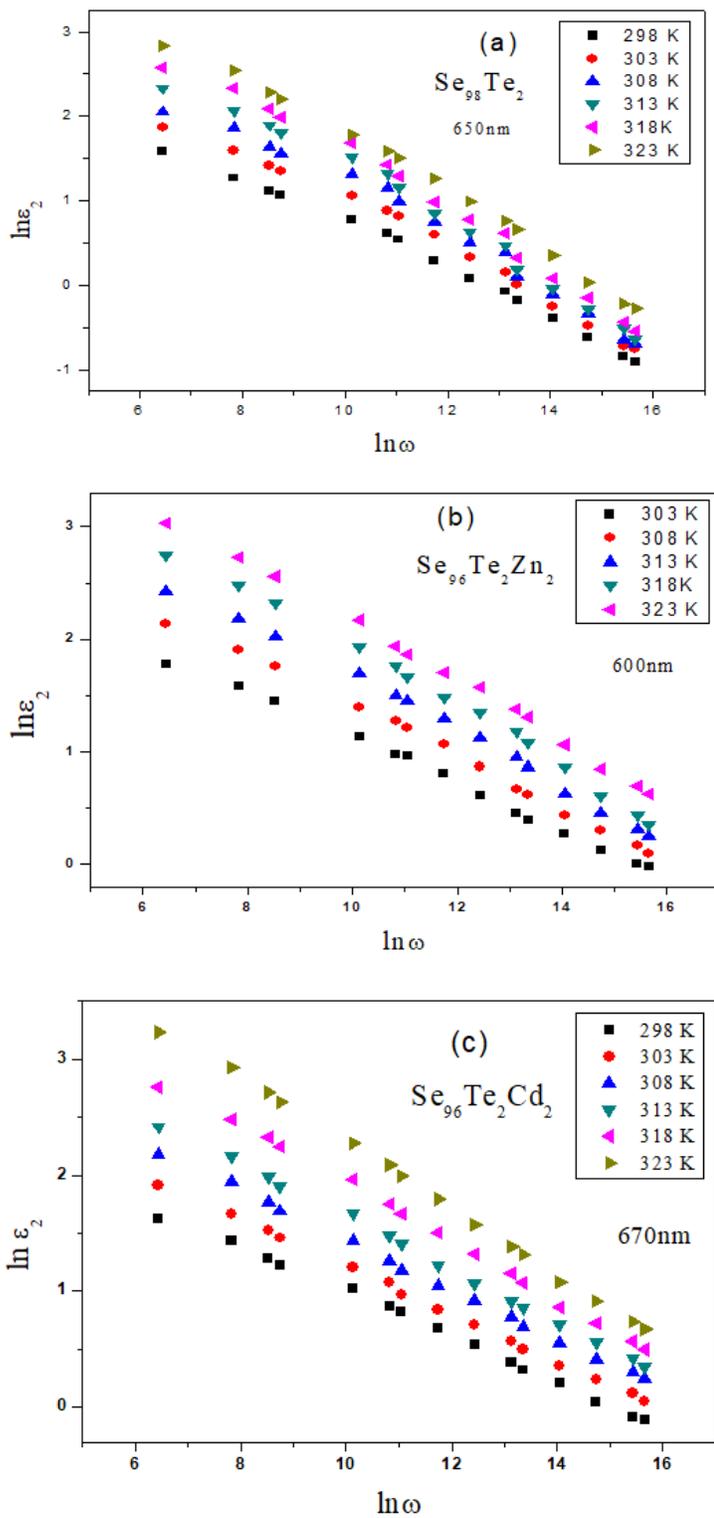
**Figure 9**

(a-c). Temperature dependence of  $\epsilon_2$  for  $\text{Se}_{98}\text{Te}_2$  and  $\text{Se}_{96}\text{Te}_2\text{X}_2$  ( $\text{X}=\text{Cd}$  and  $\text{Zn}$ ) films of nearly the same thickness at different frequencies.



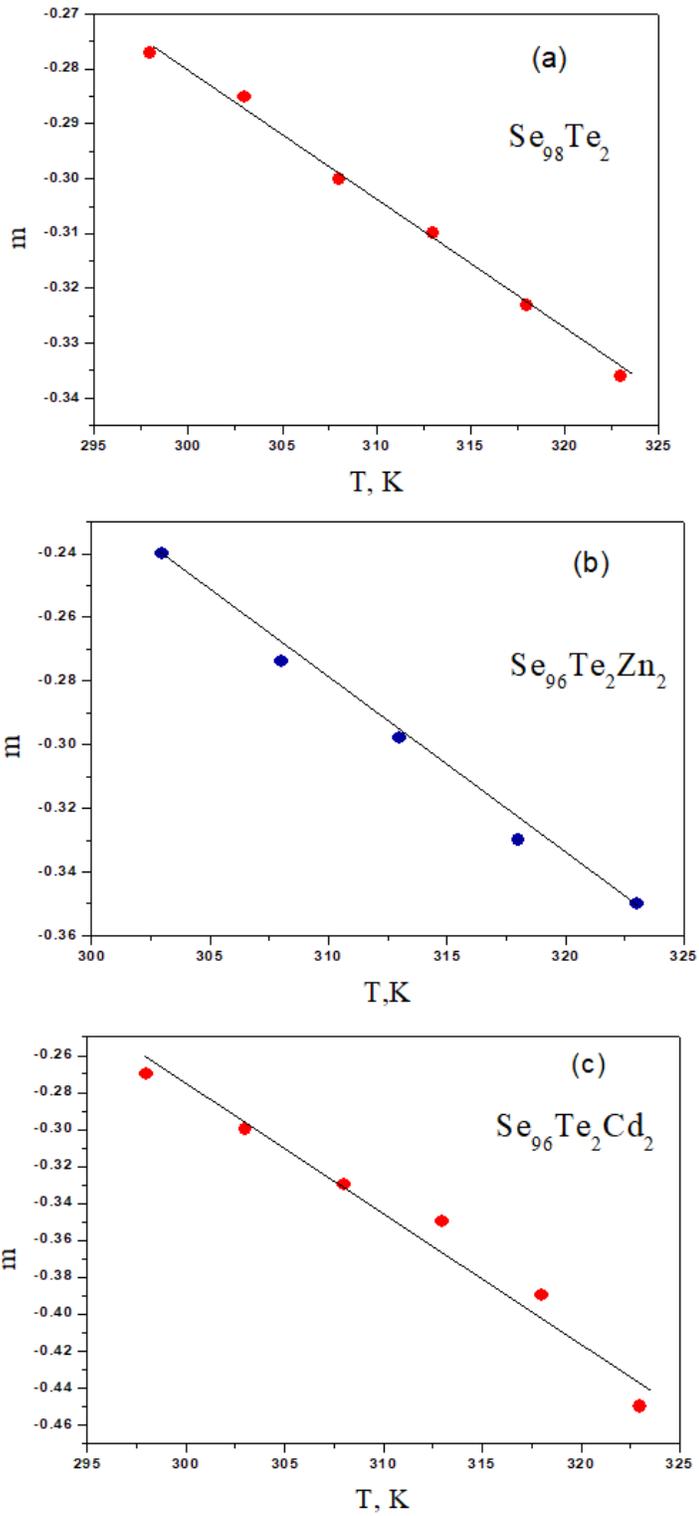
**Figure 10**

(a-c). Frequency dependence of dielectric loss  $\epsilon_2$  for  $\text{Se}_{98}\text{Te}_2$  and  $\text{Se}_{96}\text{Te}_2\text{X}_2$  ( $\text{X} = \text{Cd}$  and  $\text{Zn}$ ) films at different temperatures.



**Figure 11**

(a-c). Plot of  $\ln \epsilon_2$  versus  $\ln \omega$  at different temperatures for  $\text{Se}_{98}\text{Te}_2$  and  $\text{Se}_{96}\text{Te}_2\text{X}_2$  (X= Cd and Zn) film compositions.



**Figure 12**

(a-c) Temperature dependence of the experimental mean value of  $m$  for  $Se_{98}Te_2$  and  $Se_{96}Te_2X_2$  ( $X= Cd$  and  $Zn$ ) films.