

Dielectric permittivity and AC conductivity of Ge_xS_{1-x} Thin Films

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Abstract

The dielectric permittivity and AC conductivity of Ge_xS_{1-x} samples were measured at temperatures in the range (293- 433 K) and frequencies in the range 100 Hz to 10 MHz..Dielectric permittivity in polycrystalline samples shows an anomaly around 413K due to its amorphous - crystalline phase transition .The A.C activation energy at1kHz estimated from Arrhenius equation is found to decrease from 0.13 to 0.068eV with the increasing of germanium content. In contrast with the polycrystalline samples, all evidence of phase transitions and/or dielectric relaxation disappears in the amorphous samples.

Keywords: Alternative Conductivity; dielectric permittivity , relaxation, germanium , alloy , films.

الخلاصة

تم قياس السماحية النسبية لاغشية Ge_xS_{1-x} في مديدرجات الحرارة (293 - 433 K) وفي مدى التردد 100 Hz الى 10 MHz . اظهرت اسماحية النسبية لاغشية متعددة البلورات سلوك غير اعتيادي عند والذي اعزى الى تحول الطور من العشوائية الى البلورية. لقد وجد ان طاقة التنشيط المحسوبة عند تردد تقل من 0.13 الى 0.068eV مع زيادة المحتوى من الجرمانيوم في الاغشية. لم يلاحظ اي دليل على وجود تحول في الطور او عملية استرخاء في الطور العشوائي.

Introduction

Recently, the amorphous semiconductors and particularly the chalcogenide and chalcogen halide glasses attract strong scientific interest due to the advantages from practical point of view:

- 1-relatively easy deposition in thin film form due to the absence of long-range order;
- 2- opportunity to design and modify the basic and application-relevant properties in wide ranges by small compositional changes;
- 3- attractive optical application-relevant characteristics: wide region of optical transparency, high refractive index, photoinduced effects, which are accompanied by considerable changes in the value of the optical constants as a result of the structural changes of these materials. A great number of amorphous chalcogenide and chalcogen halide materials are successfully applied or are of potential interest for optical storage media [1- 4], IR optical windows, sensors[5- 7], non-linear optical elements [8], solid state electrolytes [9], etc.

Complicated glasses of Ge-S system have been extensively studied by many authors[10,11]. Ge-chalcogenides have been recognized as promising material for optical application due to the wide range of transparency [12]. Silver iodide as compound is at the boundary between anionic crystal and a covalent one. The stable high-temperature form of AgI (a-AgI) is prominent ionic conductor. Complicated chalcogenide glasses with AgI additives are known as good transmitters of electricity [13] but also as photosensitive material suitable for IR optics [14].

Thin films of glassy $(\text{GeS}_2)_{1-x}(\text{AgI})_x$ system have been studied [15] from the respective bulk glasses previously synthesized from the elements with constant Ge:S=1:2 ratio and different amount of AgI ($x= 5, 10, 15, 20$ mol.%). The amorphous nature of the films has been proved by X-ray diffraction (XRD) and electron microscope investigation.

Ternary chalcogenide glass films $\text{Ge}_{23}\text{Sb}_7\text{S}_{70}$ from identical parent bulk glasses were prepared by thermal evaporation (TE) and pulsed laser deposition (PLD) and subjected to 810-nm femto second laser exposure at both kHz and MHz repetition rates [16]. The exposure-induced modification on the glass film's surface profile, refractive index, and structural properties were shown to be a function of laser irradiance, the number of laser pulses per focal spot, and repetition rate. Film response was shown to be related to deposition technique-related density and the number of glass bonds within the irradiated focal volume. The induced changes resulted from a reduction in glass network connectivity among $\text{GeS}_4/2$, GeS_4 , S-S and $\text{S}_3\text{Ge-S-GeS}_3$ units.

Thin film evaporation is problematic when thin film of the respective complicated glass is preparing. Among the sulphur containing chalcogenides GeS_2 belongs to glasses composed of the components with drastically different vapor pressure that reflect to the film structure. The addition of Ge into $\text{Ge}_x\text{S}_{1-x}$ modified the structures within the prepared thin film. AC conductivity and dielectric properties investigation of the thin films as an important task for materials preparation and characterization in view of the above indicated applications.

The aim of present work is to prepare thin films of synthesized new vitreous $\text{Ge}_x\text{S}_{1-x}$ materials. We report the compositional dependence of the basic dielectric properties and structural correlation between the composition and the these properties in terms of the structural modification.

Experimental details

$\text{Ge}_x\text{S}_{1-x}$ alloys has been synthesized using high purity elemental germanium and sulfide is about (99.9999%) with different x content where ($x = 0.1, 0.2, \text{ and } 0.3$). Stoichiometric amounts of the elements are placed in a quartz ampoule, which is evacuated to a vacuum of 10^{-2} Torr and then sealed. The sealed ampoule is placed in a furnace, and then heated at a rate of 337K per hour in steps up to 1000 K. The ampoule is maintained at this temperature for about five hours and then allowed to cool slowly to room temperature. The vacuum unit system, which is used to prepare thermally evaporated $\text{Ge}_x\text{S}_{1-x}$ films, was Edward Coating unit model 306A. Balzer CO. West Germany. All the prepared films are thermally treatment under vacuum of 10^{-2} Torr at different temperature (373 and 423) for one hour. To study the effect of germanium concentration, annealing temperature, and frequency of the applied electric field on the real (ϵ_1) and imaginary part (ϵ_2) of dielectric constant of $\text{Ge}_x\text{S}_{1-x}$ films, the (LRC) meter (model HP-4274A) and (HP-4275A) are used.

Electrodes were formed by applying silver paint or carbon conducting cement (Carbon Adhesive 30GM, Structure Probe, West Chester PA, USA) on both electrodes of the samples. The capacitance C and conductance G of the samples were measured (in parallel mode) with an automatic impedance meter Hewlett-Packard HP-4284A operated in the 100 Hz to 10 MHz frequency range, the specimen was fixed in specimen holder and placed into temperature controlled oven type (Heresies electronic). Three dielectric parameters were measured directly from above setup total resistance (R_T), total capacitance (C_T) and dissipation factor $\tan\delta$ with an accuracy of 0.1%. All measurements were performed under certain frequency range $10^2 - 10^6$ Hz., the temperature range between (293- 433)K, was changed by constant rate of 2K/min. Constant voltage of (0.08V) was applied in all frequency range and temperature as indicated in this work..

When the conductivity is measured with an AC technique of frequency

$\omega = 2\pi f$, the response that characterizes a great variety of materials with diverse chemical

compositions, either crystalline or amorphous, can be written as :

$$\sigma(\omega, T) = \sigma_{DC}(T) + a(T)\omega^s, \quad (1)$$

where $\sigma_{DC}(T)$ is the 'direct current' (or static, $\omega = 0$) conductivity, $a(T)$ is a factor that depends on temperature but not on ω , and s is an exponent in the range $0 \leq s \leq 1$. Equation (1) predicts that if (at certain temperature) σ_{DC} is much less than the second term, then $\sigma(\omega, T) \propto \omega^s$, so that the plot of σ against $\log \omega$ describes a straight line with slope s . On the other hand, if σ_{DC} becomes larger than the second term (by increasing temperature, for example), then $\sigma(\omega, T) \propto \sigma_{DC}(T)$, in this case the AC technique renders a measurement of σ_{DC} , and a plot of σ against ω in log-log scale should give a horizontal straight line. The real and imaginary parts of the complex dielectric constant, ϵ_1 and ϵ_2 respectively, are obtained from C and G according to: $\epsilon_1 = C/C_0$ and $\epsilon_2 = G/\omega C_0$, where C_0 is the geometrical capacitance of the sample ($C_0 = \epsilon_0 A/d$, where ϵ_0 is the permittivity of free space, A the area of electrodes and d the thickness of the sample), and $\omega = 2\pi f$, where f is the measuring frequency. For materials having sizable conductivity it is convenient to express the imaginary part ϵ_2 in terms of an AC conductivity defined as:

$$\sigma = (d/A)G = \epsilon_0 \omega \epsilon_2 \quad (2)$$

The structures of the prepared thin film alloys are demonstrated by X-ray diffraction at room temperature (Siemens D500 diffract meter; $\text{CuK}\alpha 1$ radiation, $\lambda = 1.5405 \text{ \AA}$) of the samples). The total absence of Bragg peaks in the diffraction patterns is clearly evident for $\text{Ge}_x\text{S}_{1-x}$ thin films justifying the classification of these samples as amorphous. In contrast, for $\text{Ge}_x\text{S}_{1-x}$ alloys the observed peaks can be indexed according to the ASTM Cards .

Results and Discussion

1- $\text{Ge}_{0.1}\text{S}_{0.9}$ Thin Films

The variation of total conductivity $\sigma_t(\omega)$ versus angular frequency for $\text{Ge}_{0.1}\text{S}_{0.9}$ films and with different thermal treatment (293-433K) deposited at room temperature is plotted in Fig.(1), it is clearly that $\sigma_t(\omega)$ increased slightly with (ω) in the low frequency range, this ascribed to the interfacial polarization where the polarization is slightly changed and $\sigma_t(\omega)$ becomes less frequency dependent i.e the D.C conductivity has being significant due to the excitation of charge carriers near the extremities of the valence and the conduction band, $\sigma_t(\omega)$ increased rapidly in the higher frequency range which referred to the electronic polarization and the conductivity is pure A.C. Equation (1) predicts that if at certain temperature σ_{DC} is much less than the second term, then $\sigma(\omega, T) \propto \omega^s$, so that the plot of $\ln \sigma$ against ω describes a straight line with slope (s), the values of (s) were listed in table (1). It is clear that (s) values less than unity which confirmed the hopping mechanism, On the other hand value of s increases with increasing of treating temperature hence the adopted model is small polaron (SP) while s decreases with increasing oven temperature, hence the adopted model is correlated barrier hopping model (CBH).

The values of A.C activation energy (E_{ac}) for $\text{Ge}_{0.1}\text{S}_{0.9}$ films were determined from the plot of $\ln \sigma_t(\omega)$ against the reciprocal of absolute temperature shown in Fig (2). The estimated E_{AC} illustrates in Table(2) at selected frequencies (1kHz, 10 kHz and 100 kHz). It is clear that each sample revealed one conduction mechanism and hence one activation energy, moreover the values of E_{AC} decreased with increasing of frequency while E_{AC} increases with annealing temperatures, moreover E_{AC} increases from 0.130 to 0.190 eV while it decreases from 0.130 to 0.101 eV when (ω) increases from 1kHz to 100kHz and T_a increases from 293 to 423K. The decreasing of E_{AC} can be explained as the action of thermal heating as rearrangement of the localized states and eliminate the vacancy. The decreasing of (E_{ac}) with increasing of frequency is resulting from the increasing of vibrating energy supplying from the increasing frequency of electric field which cause the decreasing of (E_{AC}) values, this affirms the conductivity is pure AC.

Fig. (3- A,B,and C) present the results of temperature dependence of the real part of the dielectric constant ϵ_1 for selected frequencies (1,10,100kHz) for $\text{Ge}_{0.1}\text{S}_{0.9}$ annealed at different temperatures. We observe that as dielectric properties for deposited $\text{Ge}_{0.1}\text{S}_{0.9}$ and annealed at 373K are relatively insensitive with temperature. There are two dispersion peaks, name α and β can be distinguished from the spectrum each of them represent individual relaxation process. A very pronounced α peak around 410K, and a weak β peak are approximately at 310K. The origin of α dispersion is relaxation process in the crystalline phase, while the β dispersion is due to the motion of molecules in the amorphous phase (glass transition T_g), since T_g is associated with the amorphous phase occurs at temperature T_g at the molecules constituents mobile, various methods are used to determine T_g , e.g. dilatometry, heat capacity, the most reliable value are probably derived from the dilatometry. T_g occurs at range of temperatures rather than certain one since it found dependent on the thermal history of materials. The permittivity of $\text{Ge}_{0.1}\text{S}_{0.9}$ is around 13.368 at 100Hz another observation is ϵ_1 decrease in systematic sequence with the increase of frequency. In contrast the behavior displays by residual $\text{Ge}_{0.1}\text{S}_{0.9}$ sample treated at elevated temperature, there is no sign of phase transformation although ϵ_1 decreases with the frequency and increase with temperature.

The variation $\log \epsilon_1$ versus $\ln \omega$ which were drawn in Fig. (4-A,B,andC) for the deposited $\text{Ge}_{0.1}\text{S}_{0.9}$ and annealed at different temperatures. According to Deby's of intrinsic relaxation time ϵ_1 predicts that these curves must be symmetrical around (ω_D) , where the angular frequency (ω_D) corresponds to maximum absorption (according to the equation $\omega_D=1/\tau$) where (τ) represent the most probable value of a spread of relaxation times.

One can be seen that the dielectric loss absorption bands disappear for annealed $\text{Ge}_{0.1}\text{S}_{0.9}$ films especially those which treated at high oven temperatures (i.e, $T \geq 433\text{K}$), while the residual of the deposited samples declares these bands within the frequency range employed the relaxation time τ were calculated and were listed in Table (1A). The observed energy maxima disappear from the spectrum of the most of annealed samples can be understood by considering the relaxation process which is in this case β -relaxation evidence from the particular molecular mechanism and local nature originating mainly from the motion of charge carriers. Also due to structural defects. On the other hand It is clear that (τ) values for annealed samples decrease with increase T_a this result was estimated since the thermal treatment rises the force of intermolecular, while the increase of (τ) value attributes to the formation of barrier.

2- $\text{Ge}_{0.2}\text{S}_{0.8}$ Thin Films

The variation of total conductivity $\sigma_t(\omega)$ versus angular frequency for $\text{Ge}_{0.2}\text{S}_{0.8}$ films and with different thermal treatment (293-433K) deposited at room temperature is plotted in Fig.(5). It is clearly that $\sigma_t(\omega)$ increased slightly with (ω) in the low frequency range, this ascribed to the interfacial polarization where the polarization is slightly changed and $\sigma_t(\omega)$ becomes less frequency dependent i.e. the D.C conductivity has being significant due to the excitation of charge carriers near the extremities of the valence and the conduction band, while $\sigma_t(\omega)$ increased rapidly in the higher frequency range which referred to the electronic polarization and the conductivity is pure A.C implying a strong reduction of DC conductivity. The values of slope(s) are listed in table (1). It is clear that (s) increase with annealing and oven temperature which make the most suitable model is small polaron (SP) also s value attain high nearly constant value for samples annealed at high temperature which assists these samples reach to stable structure.

The values of A.C activation energy E_{AC} for $\text{Ge}_{0.2}\text{S}_{0.8}$ films were determined from the plot of $\ln \sigma_t(\omega)$ against the reciprocal absolute temperature as plotted in Fig.(6), Table (2) reveals the estimated value at selected frequencies (1kHz, 10 kHz and 100 kHz). It is obvious that each sample revealed one activation energy (E_{AC}), moreover the values of (E_{AC}) decreased with increasing of frequency annealing temperatures, moreover (E_{AC}) decreases from 0.144 to 0.079 eV and from 0.144 to

0.103eV when (ω) increases from 1kHz to 100kHz and T_a increases from 293 to 423K this results from the increasing of vibrating energy supplying from the increasing of frequency of electric field which cause the decreasing of (E_{AC}) values and creating of new state in the gap respectively.

We present in Fig. (7- A,B,and C) results of temperature dependence of the real part of the dielectric constant ϵ_1 for selected frequency(1,10,100kHz) for $Ge_{0.2}S_{0.8}$ annealed at different temperatures. there is no sign of phase transformation from the behavior displays by as deposited $Ge_{0.1}S_{0.9}$ and that treated at low temperature although ϵ_1 decreases with the frequency and increases with temperature, While the residual sample treated at elevated temperature shows the amorphous \rightarrow crystalline phase transition.. Another observation of ϵ_1 that decrease in systematic sequence with the increase of frequency.

Fig.(8-A,B,andC) showed the variation of (ϵ_i)with frequency for $Ge_{0.2}S_{0.8}$ annealed at different temperatures, the dielectric loss absorption bands disappear for all deposited $Ge_{0.2}S_{0.8}$ films except those treated at high oven temperatures (i.e, $T \geq 393K$). The disappearance observed of energy maxima from the spectrum of ϵ_i from the most of annealed samples can be understood by considering the relaxation process which mentioned before. β -relaxation evidence from the particular molecular mechanism and local nature originating mainly from the motion of charge carriers. Also due structural defects. On the other hand It is clear that τ values show an non systematic sequence with increasing of thermal treatment in the range 293-433K. The decreasing of τ with increasing of thermal treatment is due to rising the force of intermolecular, while the increase of τ value attributes to the formation of barrier.

3- $Ge_{0.3}S_{0.7}$ Thin Films

The variation of total conductivity $\sigma_t(\omega)$ versus angular frequency for $Ge_{0.3}S_{0.7}$ films and with different thermal treatment (293-433K) deposited at room temperature annealed at (373 and 423K) are plotted in Fig.(9). It is clearly that $\sigma_t(\omega)$ increased rapidly in the low frequency range i.e. the AC conductivity is dominated or σ_{DC} conductivity is much less than the σ_{AC} which referred to the electronic polarization and the conductivity is pure A.C.

In contrast with previous samples the slope(s), decrease with the increasing of T_a and oven temperature thus the suitable model for these samples is the (CBH) as seen from table (5). The most noticeable remark is s values of as deposited $Ge_{0.3}S_{0.7}$ films reach unity which reflect that these samples attain very stable structure.

The values of A.C activation energy E_{AC} for $Ge_{0.3}S_{0.7}$ films were determined from the plot of $\ln \sigma_t(\omega)$ against the reciprocal absolute temperature as in Fig.(10), Table(2) illustrates the E_{AC} values at selected frequencies (1kHz, 10 kHz and 100 kHz), the results show that each sample revealed one activation energy E_{AC} , moreover the values of E_{AC} decreases with increasing of frequency while E_{AC} increase with annealing temperatures, moreover E_{AC} decreases from 0.068 to 0.019 eV while it increases from 0.068 to 0.23eV (ω) increases from 1kHz to 100kHz, when T_a increases from 293 to 423K respectively, the decreasing of E_{AC} with the increasing of frequency is resulting from the increasing of vibrating energy supplying from the increasing of frequency of electric field which cause the decreasing of E_{AC} values while the increasing of E_{AC} can be explained as the action of thermal heating as rearrangement of the localized states and eliminate the vacancy.

Fig. (11- A,B,and C) show results of temperature dependence of the real part of the dielectric constant ϵ_1 for selected frequency(1,10,100kHz) for $Ge_{0.3}S_{0.7}$ annealed at different temperatures. There is no sign of phase transformation from the behavior displays by as deposited $Ge_{0.3}S_{0.7}$ and that treated at low temperature although ϵ_1 decreases with the frequency and increases with temperature. The residual sample treated at elevated temperature shows the amorphous \rightarrow crystalline phase transition, another observation is ϵ_1 decrease in systematic sequence with the increase of frequency. and decreases somewhat with temperature. ϵ_1 display two small maxima around 310 and 410 K. The peak amplitude depend on crystallinity and impurities. The lower temperature relaxation is associated with glass

transition temperature while the higher temperature peak is attributed to the amorphous \rightarrow crystalline phase transition,

The relation between $\log(\epsilon_i)$ versus $\ln \omega$ are plotted in Fig. (12-A,B,andC).

For $\text{Ge}_{0.3}\text{S}_{0.7}$ annealed at different temperatures, one can be seen the dielectric loss absorption bands appear for l as deposited $\text{Ge}_{0.3}\text{S}_{0.7}$ films for all oven temperature within the frequency range employed while the lose bands disappear from most of the annealed samples treated, the relaxation time τ were calculated and were listed in Table (1C).

Conclusions

Thus from the previous results and in general we can put these notations:

- 1-From the variation sequence of the (s) values with germanium content one can adopt the CBH model to explain our results of $\text{Ge}_x\text{S}_{1-x}$ samples, the steady values of s reflects the high stability of structure of $\text{Ge}_x\text{S}_{1-x}$.
- 2-The increasing of germanium content in the $\text{Ge}_x\text{S}_{1-x}$, s exhibits proceeding increment i.e the conductivity is pure AC, germanium addition enhancement the structures of the prepared samples
- 3-Increasing of germanium content and annealing temperature decreases the relaxation time values, the lose peaks declares only by samples treated at high oven temperature.
- 4-If we assume that prolonged exposure to thermal treatment of $\text{Ge}_x\text{S}_{1-x}$ samples attain crystalline structure thus the reduction of E_{AC} with thermal treatment can be interpreted in terms of Seto's grain boundaries trapping theory [17] which assumes the presence of large amount of trapping states at the grain boundary able to capture free charge carries, these charged states at grain boundary creates potential barriers, which oppose the passage of carriers from grain to neighboring ones. the addition of Ge compensates these sites which in turn responsible about the increasing of conductivity (reduction of E_{AC} values).

The composition dependence of the optical band gap and DC activation energy show that the values of the optical band gap E_g decrease as the Ge content increases.. The compositional variation of the band gap can be explained in terms of structural arguments. In the chemical-bond approach to explain the structure and properties of various complicated chalcogenide glasses several assumption were put: 1- atoms of one type are more favorable linked with atoms of a different type; 2- bonds are formed in sequence of decreasing bond energy until all available vacancies are filled; 3- each atom is coordinated by $(8-N)$ atoms, where N is number of outer shell electrons.

According to this assumption the structure of the investigated films can be presented as consisting of completely cross-linked structural units of GeS .

The most likely bonds in the films under investigation have bond energy as follows:

Ge – S 551 kJ.mol^{-1}

S-S 213 kJ.mol^{-1}

Ge-Ge 185 kJ.mol^{-1}

The bond energies values exclude the application of random covalent network model for structure explanation where Ge-Ge bonds are possible. Bonds such as S-S have also lower possibility of existence due to their lower bond energy. We suggest that most favorable structural units are $\text{GeS}/2$ The tetrahedral $\text{GeS}_4/2$ units are corner bridged. The increase in the Ge amount is associated with an increase in the number of Ge-Ge bonds and increase in the number of metallic bonds in the film. Thus the lower E_{AC} and higher conductivity of films can be explained. The almost linear decrease of the DC activation energy with Ge content is attributed also to the structural transformation in the films after Ge introducing. The incorporation of Ge atoms in the S matrix is connected with an increase of the disorder and an increase in the number of localized states within the band gap. According to Davis and Mott [18] the presence of high density of localized states in the band structure is responsible for

lower values of the optical gap. It seems that our experimental data agree well with Davis and Mott suggestion.

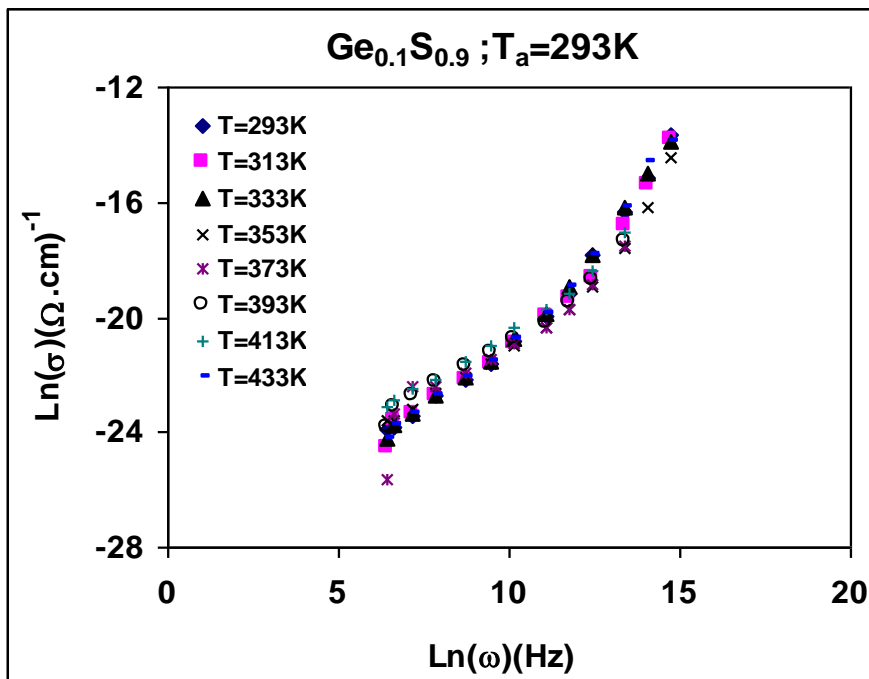


Fig.(1) The variation of $\ln \sigma_{AC}(\omega)$ with $\ln(\omega)$ for as deposited $Ge_{0.1}S_{0.9}$ thin films and annealed at different temperatures.

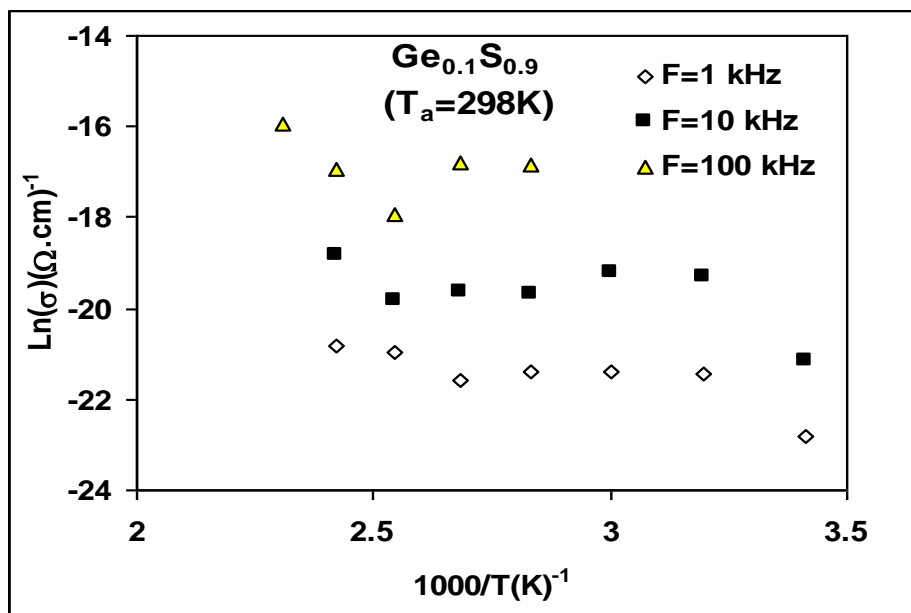


Fig.(2) The temperature dependence of $\ln \sigma$ versus reciprocal absolute temperature for as deposited $Ge_{0.1}S_{0.9}$ thin films and annealed at different temperatures.

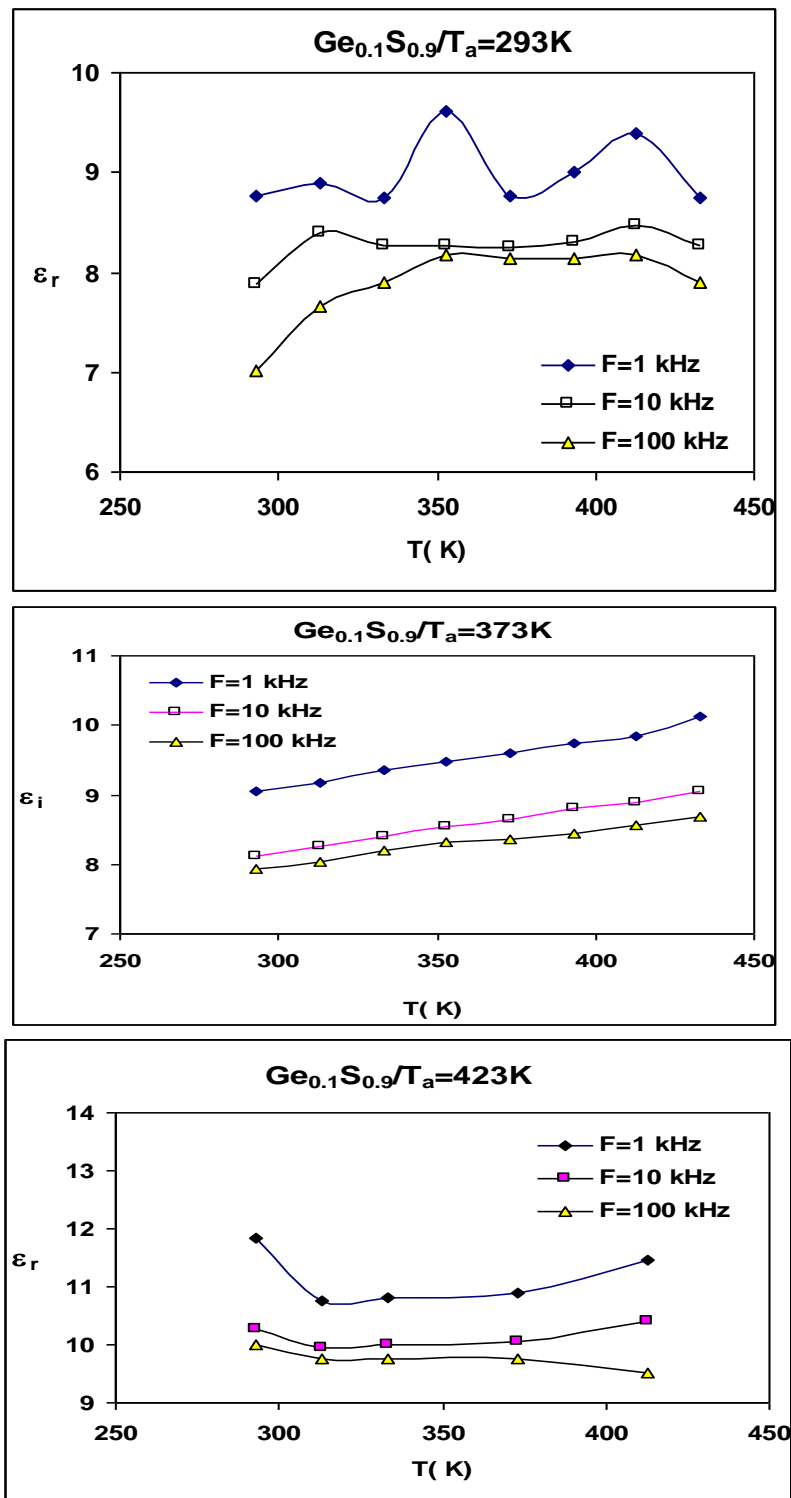


Fig. (3- A,B,and C) The variation of ϵ_r with temperature for as deposited $\text{Ge}_{0.1}\text{S}_{0.9}$ thin films and annealed at different temperatures.

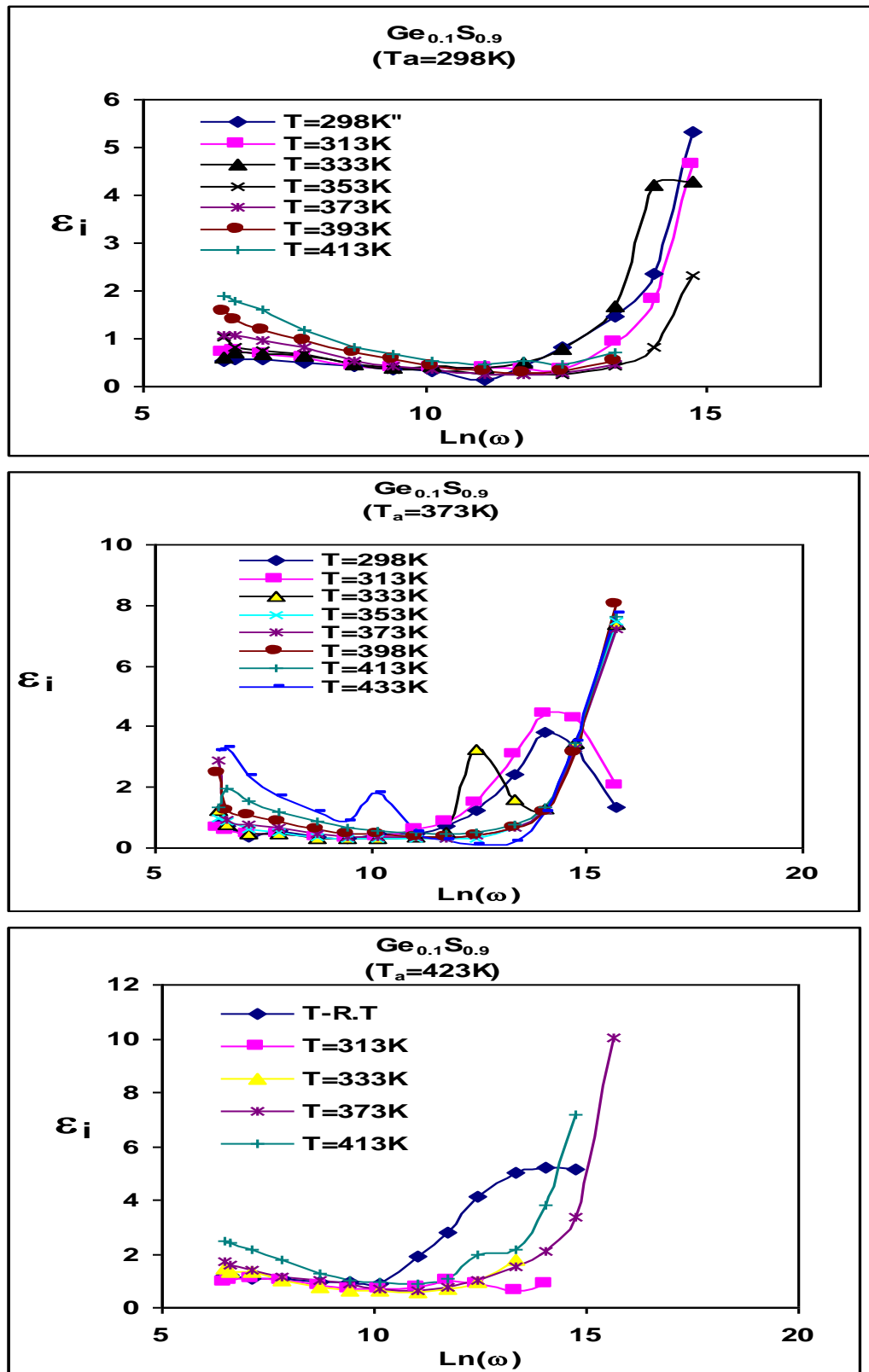


Fig. (4-A,B,andC) The variation of ϵ_i with $\ln\omega$ for as deposited $\text{Ge}_{0.1}\text{S}_{0.9}$ thin films and annealed at different temperatures.

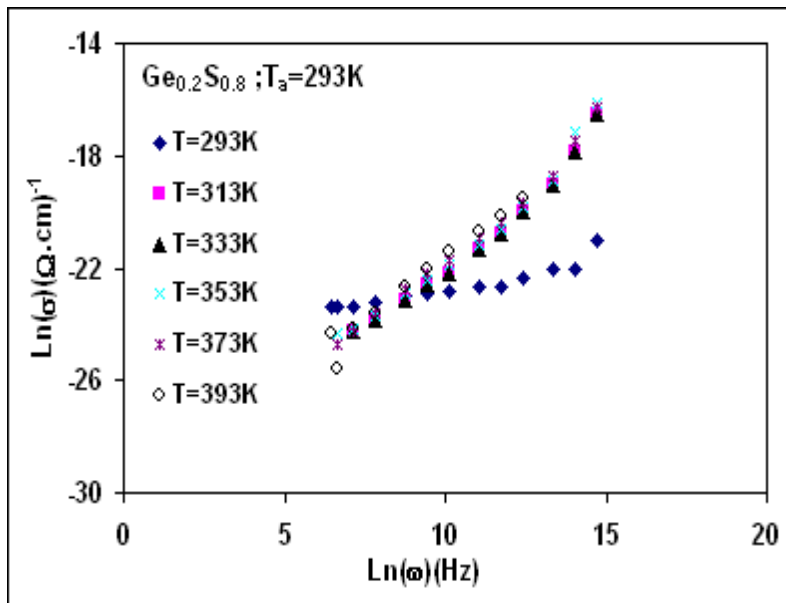


Fig.(5) The variation of $\ln \sigma_{AC}(\omega)$ with $\ln(\omega)$ for as deposited $Ge_{0.2}S_{0.8}$ thin films and annealed at different temperatures.

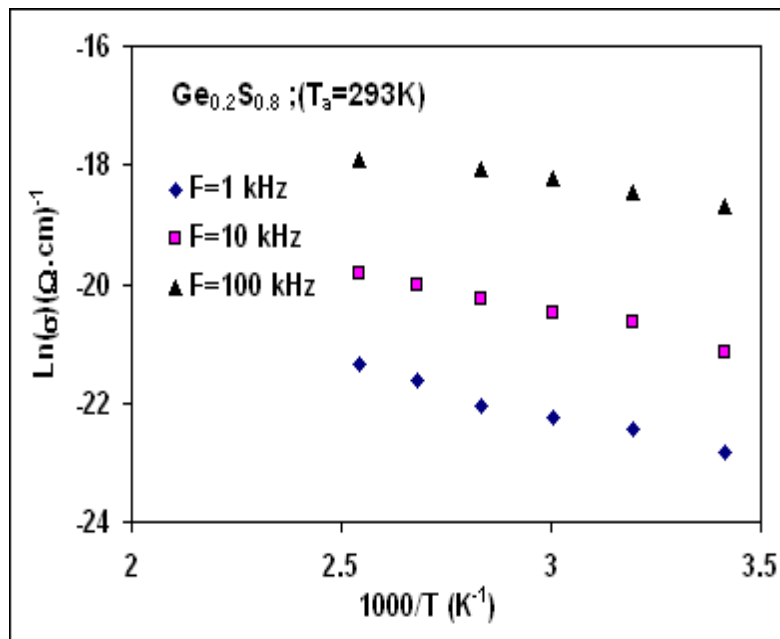


Fig.(6) the temperature dependence of $\ln \sigma$ versus reciprocal absolute temperature for as deposited $Ge_{0.2}S_{0.8}$ thin films and annealed at different temperatures.

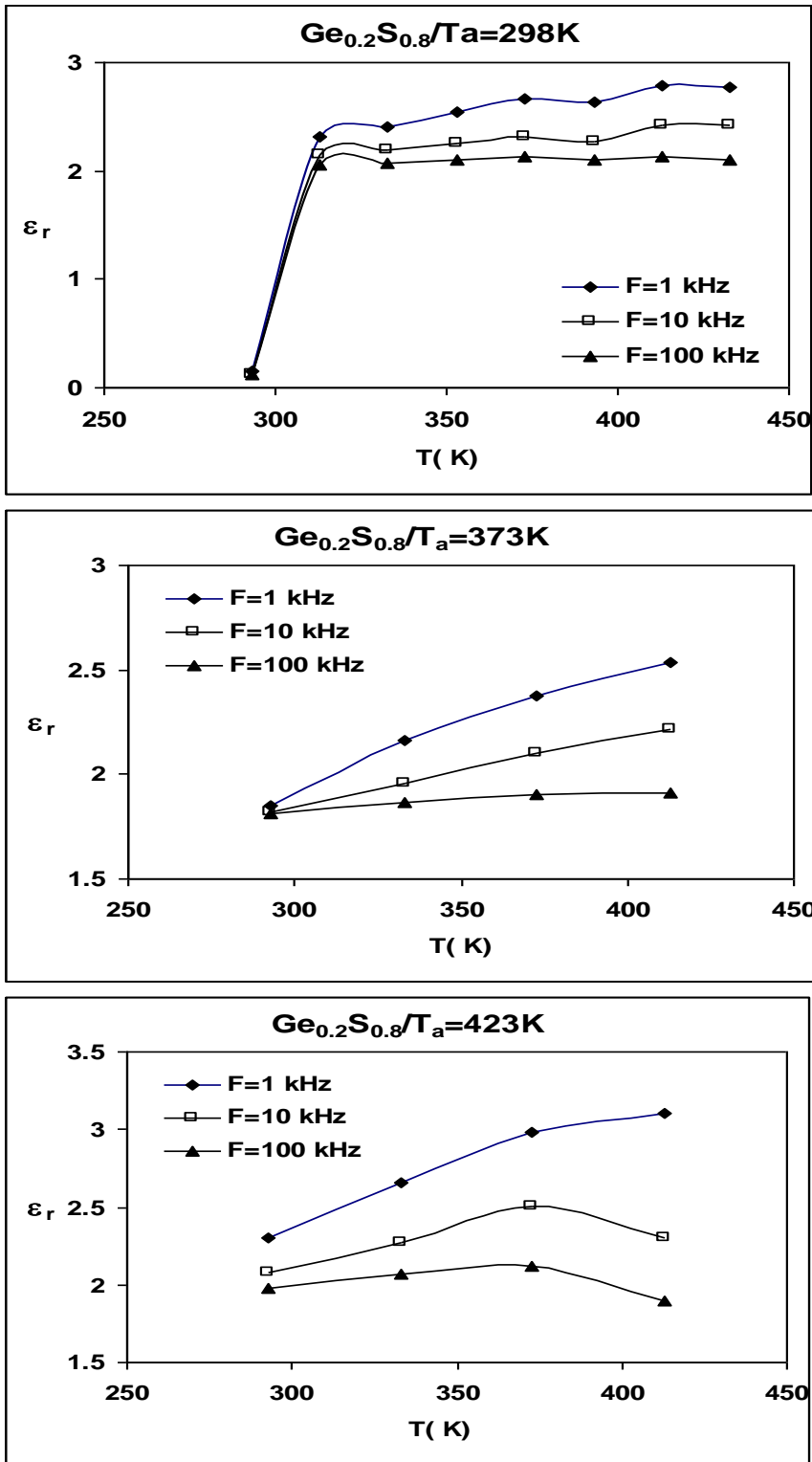


Fig. (7-A,B,and C) The temperature dependence of ϵ_r with temperature for as deposited Ge_{0.2}S_{0.8} thin films and annealed at different temperatures.

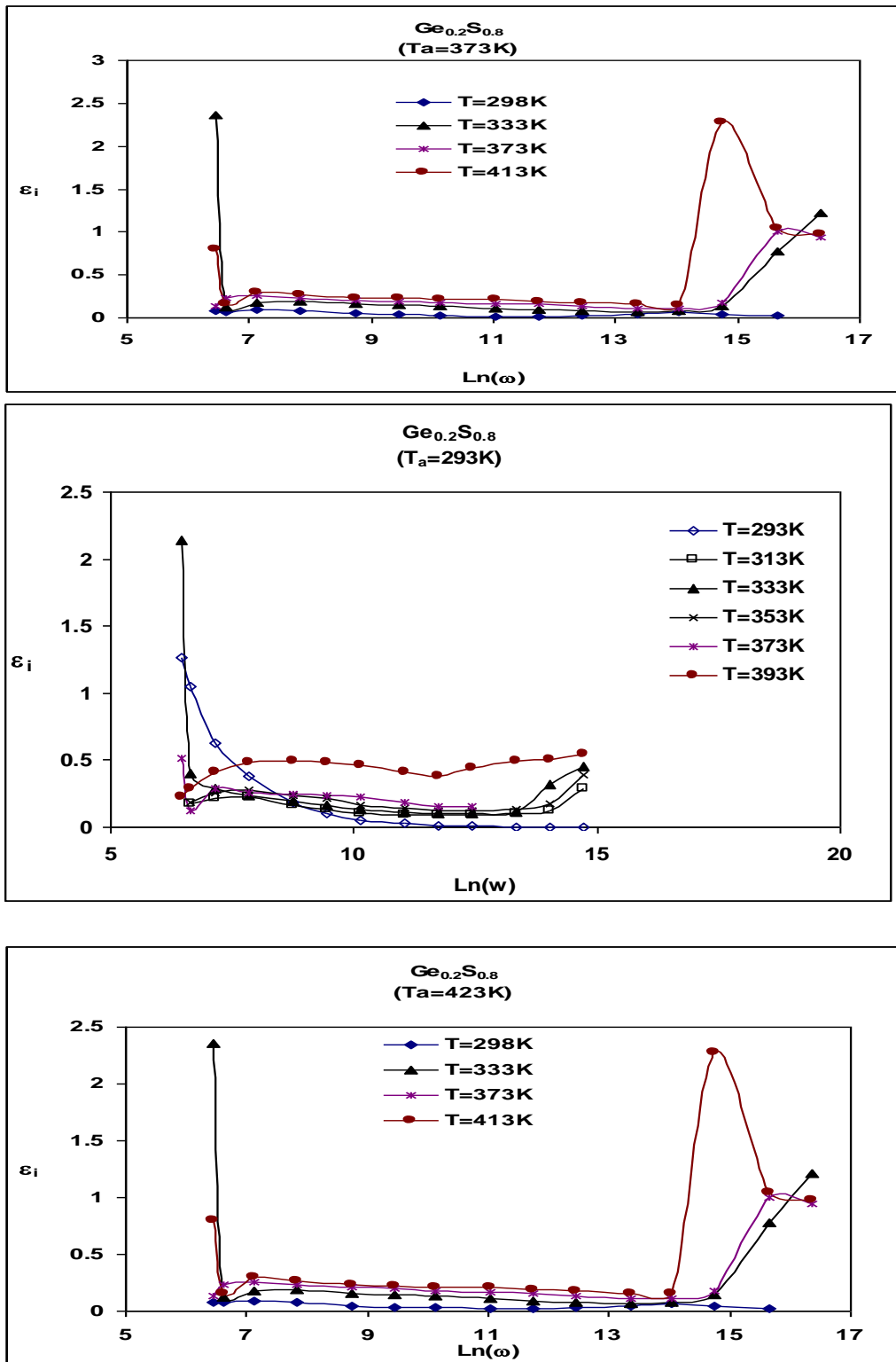


Fig. (8-A,B,andC) The variation of ϵ_i with $\ln\omega$ for as deposited $\text{Ge}_{0.2}\text{S}_{0.8}$ thin films and annealed at different temperatures.

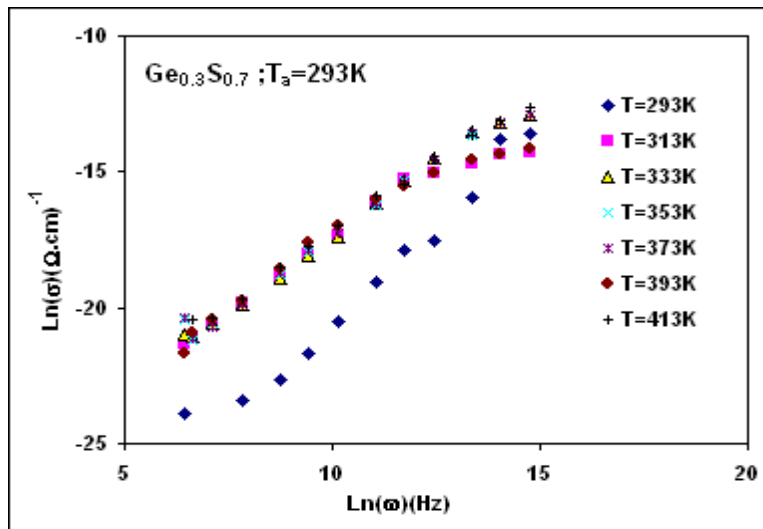


Fig.(9) The variation of $\ln \sigma_{AC}(\omega)$ with $\ln(\omega)$ for as deposited $\text{Ge}_{0.3}\text{S}_{0.7}$ thin films and annealed at different temperatures.

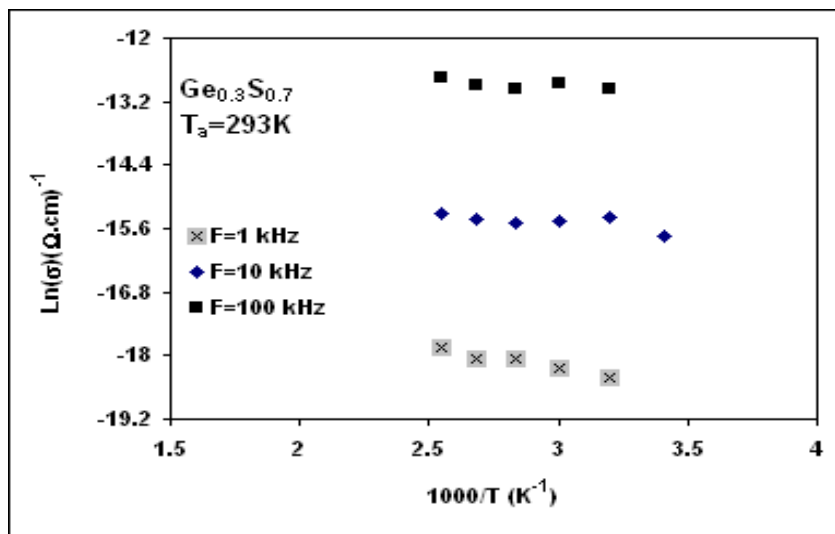


Fig.(10) the temperature dependence of $\ln \sigma$ versus reciprocal absolute temperature for as deposited $\text{Ge}_{0.3}\text{S}_{0.7}$ thin films

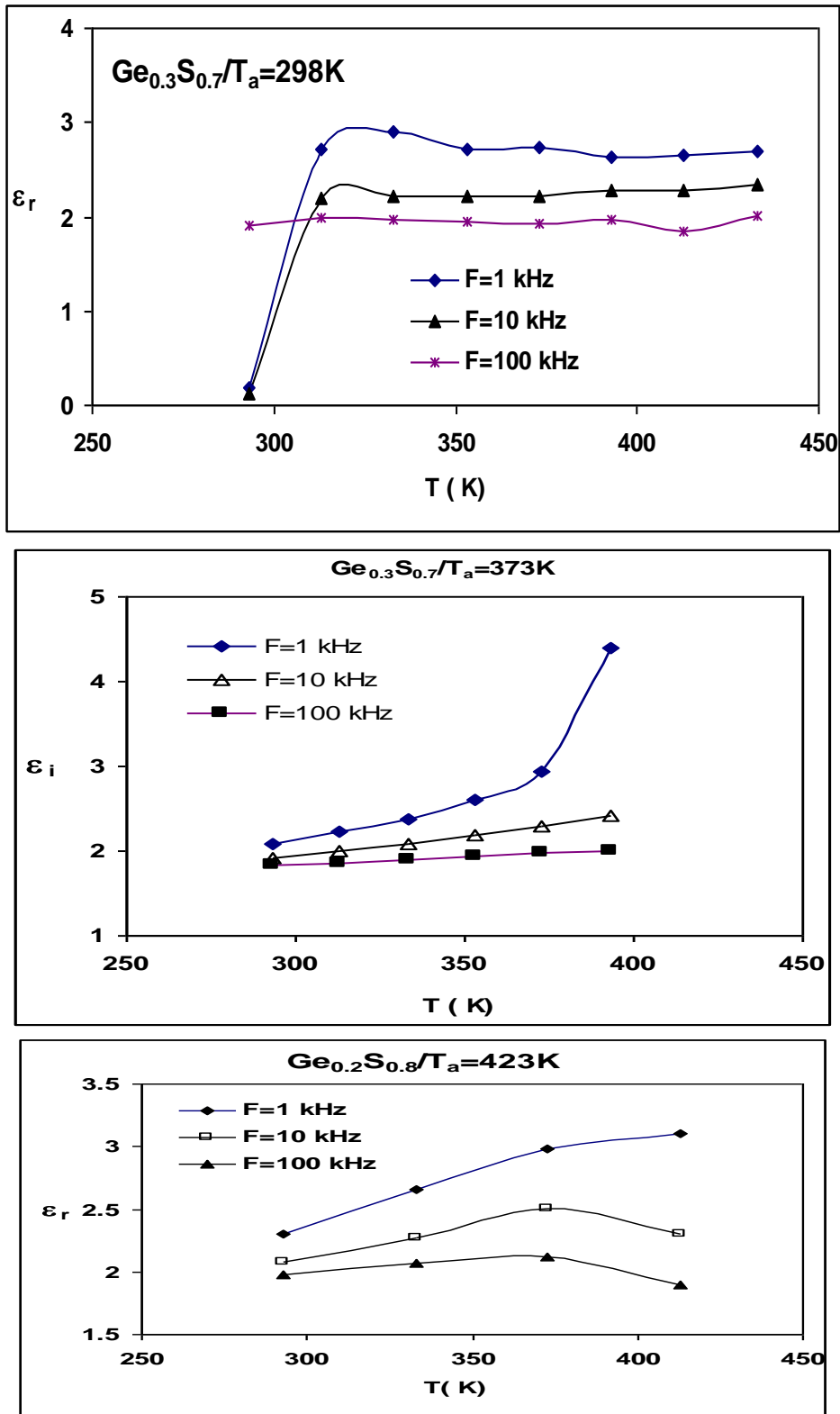


Fig. (11-A,B,andC) The variation of ϵ_r with temperature for as deposited $\text{Ge}_{0.3}\text{S}_{0.7}$ thin films and annealed at and annealed at different temperatures .

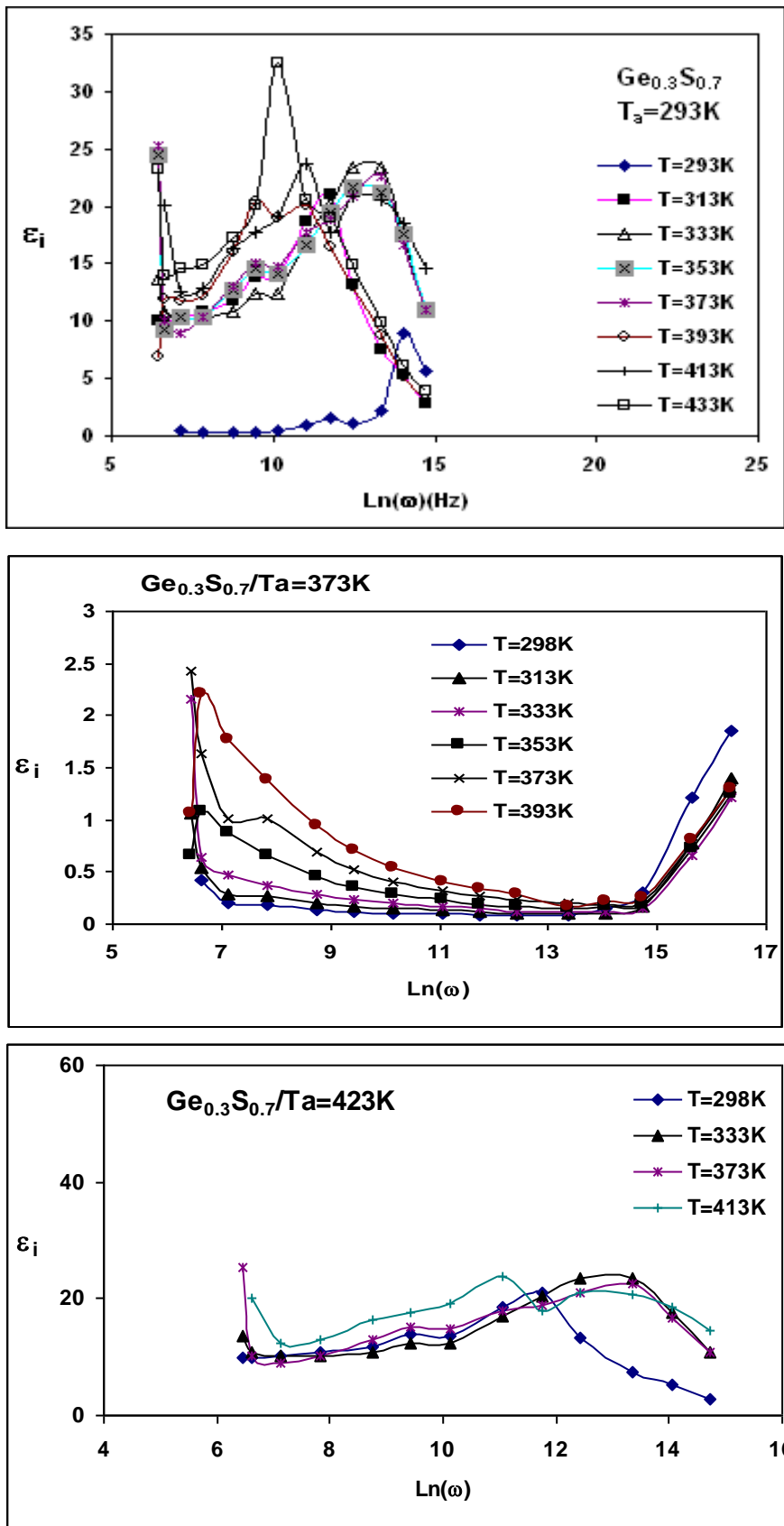


Fig. (12-A,B,andC) The variation of (ϵ_i) with $\ln \omega$ for as deposited $\text{Ge}_{0.3}\text{S}_{0.7}$ thin films and annealed at different temperatures.

Table (2) Illustrates the values of E_{AC} of Ge_xS_{1-x} thin films.

$Ge_{0.1}S_{0.9}$	Frequency(kHz)	$E_{AC}(eV)$		
		Ta=293K	Ta=373K	Ta=423K
	1			
	10	0.13	0.120	0.190
	100	0.106	0.070	0.174
$Ge_{0.2}S_{0.8}$	1	0.101	0.020	0.159
	10	0.144	0.141	0.103
	100	0.123	0.112	0.086
$Ge_{0.3}S_{0.7}$	1	0.079	0.073	0.063
	10	0.068	0.200	
	100	0.027	0.145	
		0.019	0.880	

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Ge_{0.1}S_{0.9}ThinFilms(A)							
Oven Temperature (K)	As deposited			Ta=373K		Ta=423K	
	s	τ		s	τ		s
293	0.88	25x10 ⁻⁵		0.89	2.5x10 ⁻³	0.5x10 ⁻⁵	0.91
313	0.72	8.334x10 ⁻³	25x10 ⁻⁵	0.81	-----	-----	0.82
333	0.7	8.334x10 ⁻³	25x10 ⁻⁵	0.76	-----	-----	0.82
353	0.75	-----		0.68	-----	-----	-----
373	0.77	8.334x10 ⁻³	1x10 ⁻⁵	0.71	-----	-----	0.84
393	0.75	-----		0.73	-----	-----	-----
413	0.74	-----		0.70	25x10 ⁻⁵		0.60
433	0.88	5x10 ⁻⁵		0.54	2.5x10 ⁻³	0.5x10 ⁻⁵	-----
Ge_{0.2}S_{0.8}ThinFilms (B)							
Oven Temperature (K)	As deposited			Ta=373K		Ta=423K	
	s	τ		s	τ		s
293	0.22	-----		0.75	5x10 ⁻³	0.5x10 ⁻⁵	0.86
313	0.757	5x10 ⁻⁵		0.80	-----	-----	-----
333	0.747	-----		0.89	5x10 ⁻³	0.1x10 ⁻⁵	0.88
353	0.752	-----		0.98	-----	-----	-----
373	0.849	5x10 ⁻⁵		0.84	2.5x10 ⁻³	10x10 ⁻⁵	-----
393	0.907	8.33x10 ⁻³	0.5x10 ⁻⁵	0.907	-----	-----	0.89
		0.25x10 ⁻³	2.5x10 ⁻⁵				
		1x10 ⁻³					
413	-----	8.33x10 ⁻³	-----	-----	5x10 ⁻³	0.5x10 ⁻⁵	0.88
433	-----	8.33x10 ⁻³	5x10 ⁻⁵	-----	-----	-----	-----

Ge_{0.3}S_{0.7}ThinFilms(C)							
Oven Temperature (K)	As deposited			Ta=373K		Ta=423K	
	s	τ		s	τ	s	τ
293	1	5x10⁻⁵	5x10⁻⁵	0.84	-----	0.829	-----
313	0.92	5x10⁻³	5x10⁻⁵	0.88	-----	0.928	8.33x10⁻³
333	1		1x10⁻⁵	0.73	-----	-----	-----
353	1	5x10⁻³	1x10⁻⁵	0.76	8.33x10⁻³	-----	-----
373	1	5x10⁻³	1x10⁻⁵	0.71	8.33x10⁻³	0.956	5x10⁻³ 10x10⁻⁵ 0.1x10⁻⁵
393	1	8.334x10⁻³ 5x10⁻³		0.71	8.33x10⁻³	-----	-----
413	0.94		10x10⁻⁵ 2.5x10⁻⁵	----	-----	0.888	5x10⁻³
433	0.87		25x10⁻⁵	-----	-----	-----	-----