ELECTRICAL PROPERTIES OF $Se_{85-x}Te_{15}In_x$

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Frequency and temperature dependent ac conductivity and dielectric studies of $Se_{85-x}Te_{15}In_x$ (x= 0, 2, 6, 10, 15) glasses in the form of thin pellets have been made in the frequency range 2 kHz to 50 kHz and temperature range 213K to 293K. Results indicate that dielectric dispersion occurs in the studied frequency and temperature range. Frequency exponent *s* is found to decrease with increase in temperature. The results have been explained on the basis of Correlated Barrier Hopping (CBH) model. Numerical calculations agree well with experimental results. The results show that the frequency and temperature dependent behavior of ac conductivity of the studied materials is predominantly due to bipolaron hopping. Concentration of defect states has also been estimated for the materials. The value of defect states increases with increase in Indium concentration. The dc conductivity decreases with decrease in temperature. The Log σ_{dc} versus 1000/T plots are almost straight lines in whole studied temperature range, indicative of singly activated phenomena having single activation energy.

(Received May 14, 2012; Accepted June 18, 2012)

Keywords: Chalcogenides, activation energy, defect states, hopping conduction.

1. Introduction

Amorphous selenium binary alloys with tellurium have been widely studied due to their (a) great storage capacity and fast to access information (b) the advantage to delete and introduce new information (c) electrophotographic applications such as photoreceptors in photocopying and laser printing [1]. The effect of an impurity in an amorphous semiconductor may be widely different, depending on the conduction mechanism and the structure of material [2]. The impurity may either destroy the dangling bond centres of one sign or form charged centres which are compensated by centres of opposite sign. Under these circumstances activation energy may either increase or decrease. Since the temperature and frequency dependent ac conductivity measurements are useful for the investigation of gap states in amorphous semiconductors [3-10], we report the temperature and frequency dependent ac conductivity studies of $Se_{85-x}Te_{15}In_x$ (x=0, 2, 6, 10, 15) and the results have been explained using CBH model. The dc conductivity behaviour of the above said materials has also been reported.

2. Experimental detail

For the present work, compressed pellets were prepared by grinding bulk-ingots into fine powder and compressing the powder in a die under a hydraulic press (10^3kg/m^2). A three terminal sample holder has been fabricated for the measurement of ac and dc conductivity of pellet- shaped samples. A thermocouple has been inserted inside the sample holder which can be kept close to the sample for the measurement of correct temperature. Vacuum pumping system (model VS -65D , H.H.V. India) has been used to achieve a vacuum upto 10^{-4} to 10^{-5} torr inside the sample holder. A general radio bridge (Model 1615-A) was used for the measurements of frequency –dependent ac

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conductivity and dielectric constant of the materials having large resistivity. The bridge consist of an audio oscillator (model 1311), a tuned amplifier (model 1232-A) and a null detector, which permits balance to a resolution of one part in million. This bridge is designed for the precise measurements of capacitance and conductance. Its direct read-out system minimizes the reading errors and permits rapid operation.

Current voltage characteristics of the sample were studied by applying different voltages in the voltage range 0-30V for all the samples and characteristics were found to be ohmic in nature. Therefore, for dc conductivity measurements, a constant voltage 20V has been applied across all the samples using dc power supply (CROWN DC-regulated Power Supply 0-30V/2A) and the resulting current has been measured with digital nanometer (Digital Nanometer DNM-121, Scientific equipment Roorkee) having least count of 0.1nA.

3. Results and discussion

3.1. dc conductivity behaviour of $Se_{85-x}Te_{15}In_x$

dc conductivity measurements in amorphous semiconductors provide valuable information about the transport mechanism .The majority of amorphous semiconductors (chalcogenides and tetrahedrals) show activated temperature dependence according to the relation (1),

$$\sigma = \sigma_0 \exp(-\Delta E/kT) \tag{1}$$

where ΔE and σ_0 are the activation energy and pre-exponential factor respectively. Fig 1 shows temperature dependence of dc conductivity for $Se_{85-x}Te_{15}In_x$ (x=0, 2, 6, 10, 15) in the temperature range of 213K-293K.

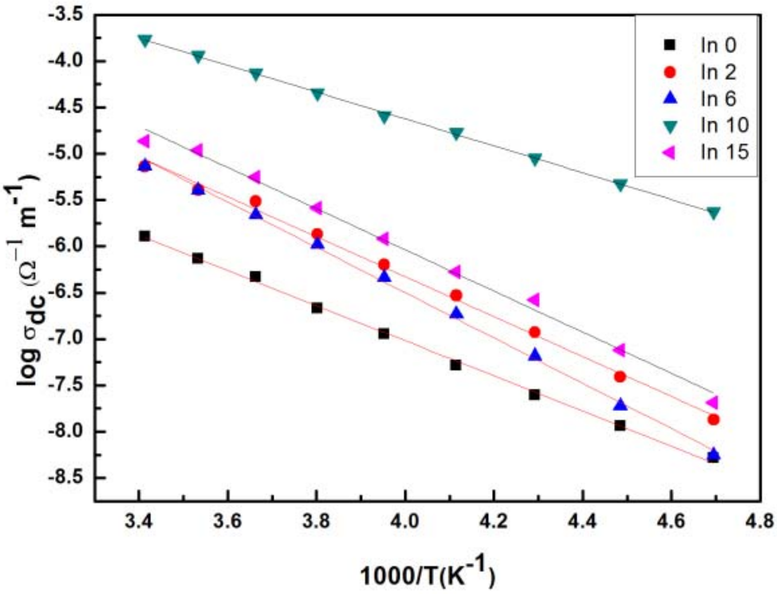

Fig.1 Temperature dependence of dc conductivity

It can be observed from the figure that the dc conductivity is singly activated in the entire temperature range investigated. From the figure, it is evident that dc conductivity increases with increasing temperature. The activation energies for the $Se_{85-x}Te_{15}In_x$ (x= 0, 2, 6, 10, 15) are 0.38eV, 0.43eV, 0.49eV, 0.29eV, 0.44eV respectively. The variation of activation energy with x is shown in Fig 2.

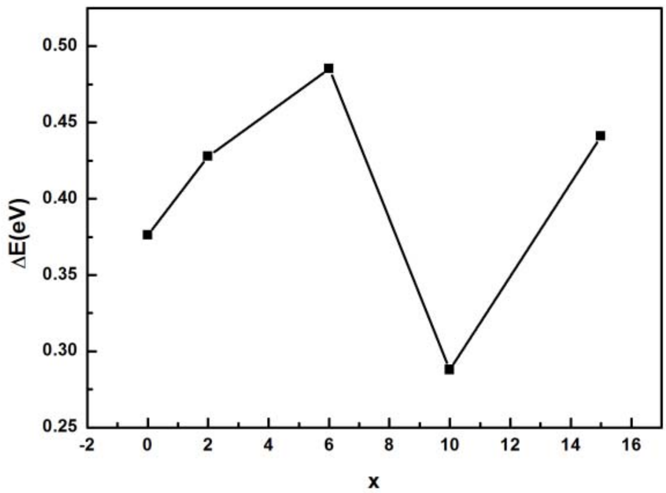

Fig. 2 Variation of activation energy.

3.2. Frequency dependence of ac conductivity behaviour of $Se_{85-x}Te_{15}In_x$

The results of ac conductivity for the $Se_{85-x}Te_{15}In_x$ system at different temperatures and frequencies are shown in Fig 3-7.

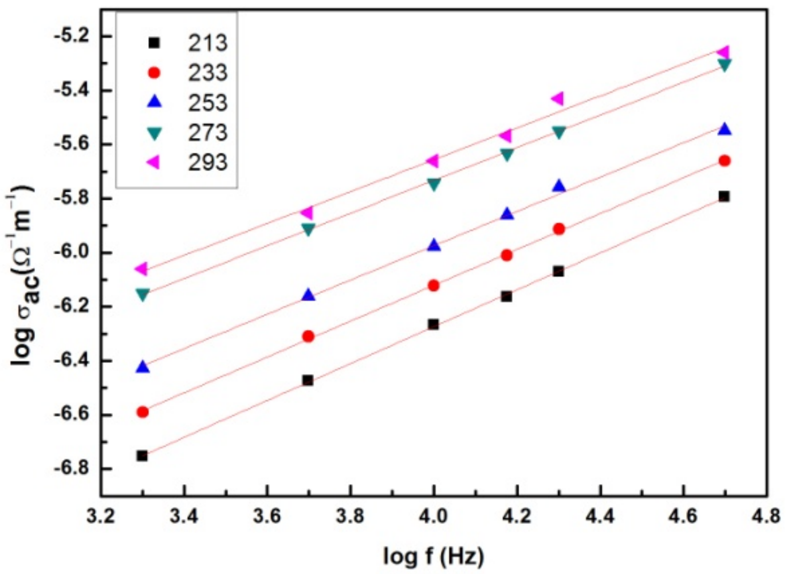

Fig. 3 Log ac conductivity versus log frequency for $Se_{85}Te_{15}$

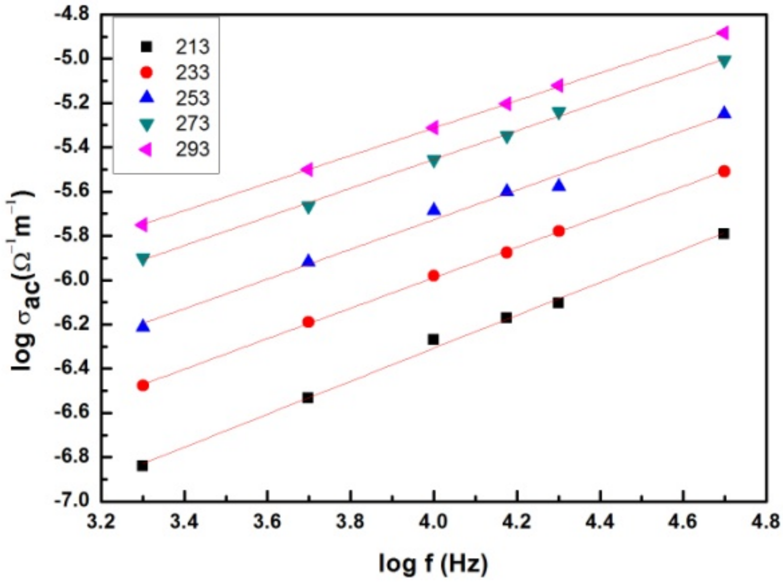

Fig. 4 Log ac conductivity versus log frequency for $Se_{83}Te_{15}In_2$

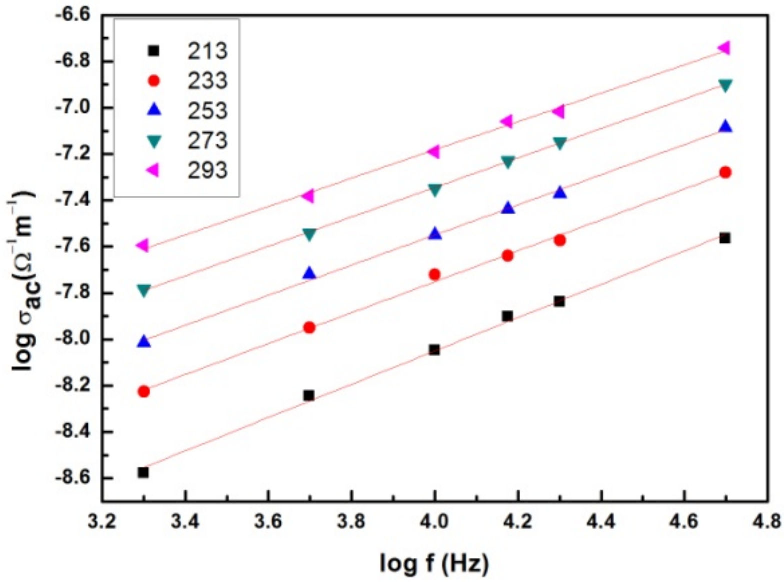

Fig. 5 Log ac conductivity versus log frequency for, $Se_{79}Te_{15}In_6$

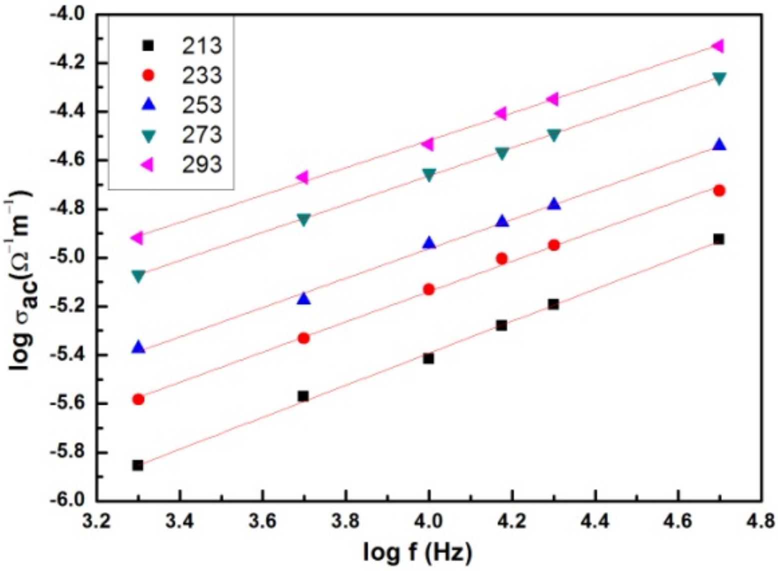

Fig. 6 Log ac conductivity versus log frequency for, $Se_{75}Te_{15}In_{10}$

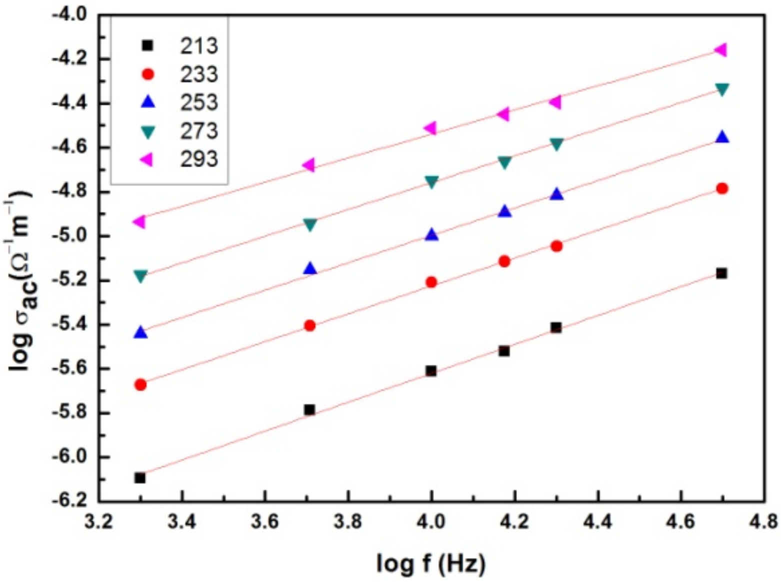

Fig. 7 Log ac conductivity versus log frequency for, $Se_{70}Te_{15}In_{15}$

From these figures it is clear that

$$\sigma_{ac} = A\omega^s \tag{2}$$

where s is the frequency exponent and A is a constant. The decrease in slope with increasing temperature clearly indicates that the value of s decreases with increasing temperature for all samples. The temperature dependence of s for $Se_{85-x}Te_{15}In_x$ (x=0, 2, 6, 10, 15) is given in Fig 8. Moreover, the value of s is decreasing slowly with rise in temperature for each glass.

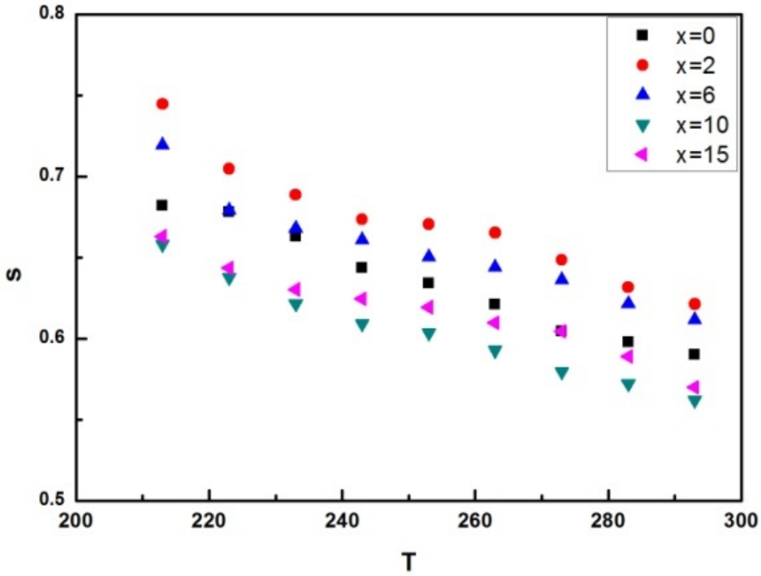

Fig. 8 Temperature dependence of frequency exponent s for different samples

The above results can be easily explained using correlated barrier hopping (CBH) model [3-4,11]. According to this model,

$$\sigma_{ac} = n\,\pi^2 N N_p\,\kappa\,\omega\,R_\omega^{\,6}/24 \qquad (3)$$

where n is the number of polarons involved in the hopping process, R_ω is the hopping distance for the condition $\omega\tau = 1$ and is given by [11]

$$R_\omega = 4ne^2/\,\kappa\,[W + kT\ln(\omega\tau_0)] \qquad (4)$$

NN_P is given by [11]

$$N\,N_P = N^2{}_T \qquad \text{(for bipolaron hopping)}$$

$$N\,N_P = N^2{}_T \exp\left(-U_{eff}/2kT\right) \qquad \text{(for single polaron hopping)}$$

where N_T is the number of density of states.

The value of frequency exponent s is calculated from equations (3) and (4) and is approximately equal to [4],

$$s = \frac{d(\ln\sigma_{ac})}{d(\ln\omega)} = 1 - \frac{6kT}{W - kT\ln(1/\omega\tau_0)} \qquad (5)$$

$$W = W_M \qquad \text{(for bipolaron hopping)}$$

$$W = W_1 \text{ or } W_2 \qquad \text{(for single polaron hopping)}$$

In general the experimentally obtained ac conductivity is given by

$$\sigma_{ac} = \sigma_b + \sigma_s$$

where σ_b is the contribution from bipolaron hopping and σ_s is the contribution from single polaron hopping. In general single polaron hopping is dominant at low temperatures and bipolaron hopping is dominant at high temperatures.

Equation (5) shows decrease in value of s with rise in temperature. This behavior has been shown by the glasses under study in the studied temperature range (Fig 8).Using relation (5) for different values of W_M and τ_o, theoretical values of s were calculated at different temperatures.

The theoretical and experimental values of s at different temperatures have been plotted. The best fits are shown in Fig 9-13.

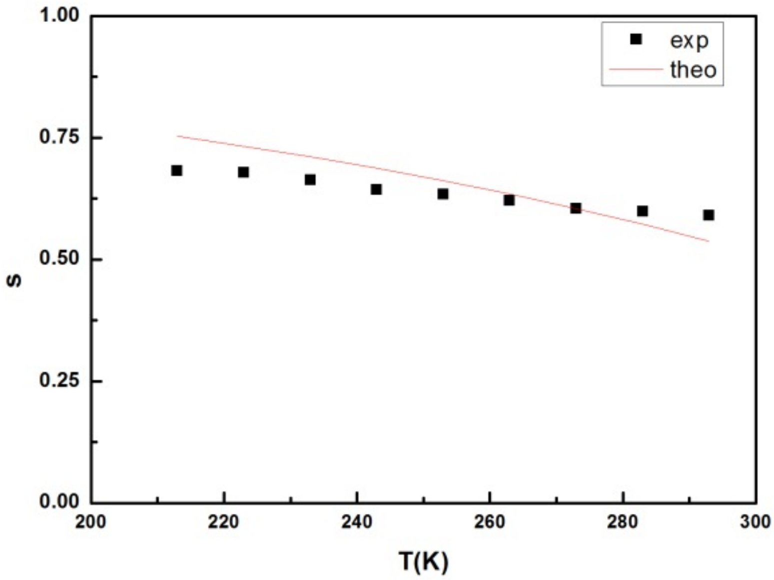

Fig. 9 s-T fitting graphs for $Se_{85}Te_{15}$

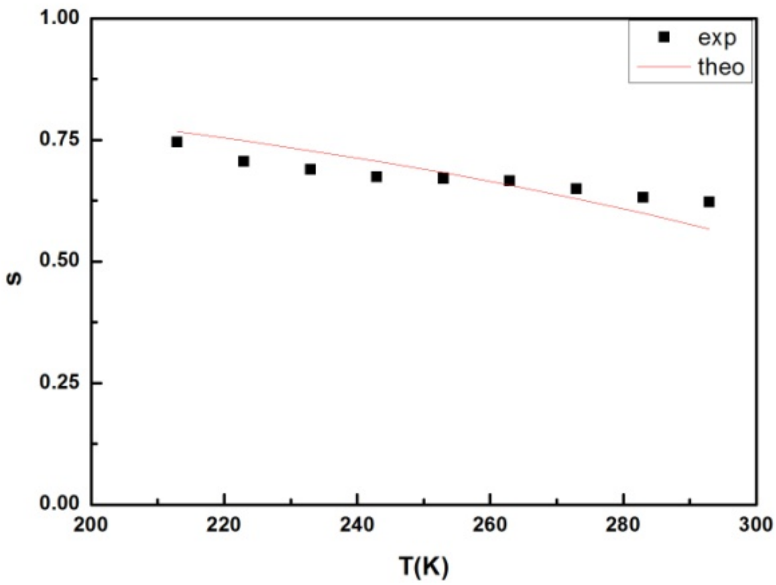

Fig. 10 s-T fitting graphs for $Se_{83}Te_{15}In_2$

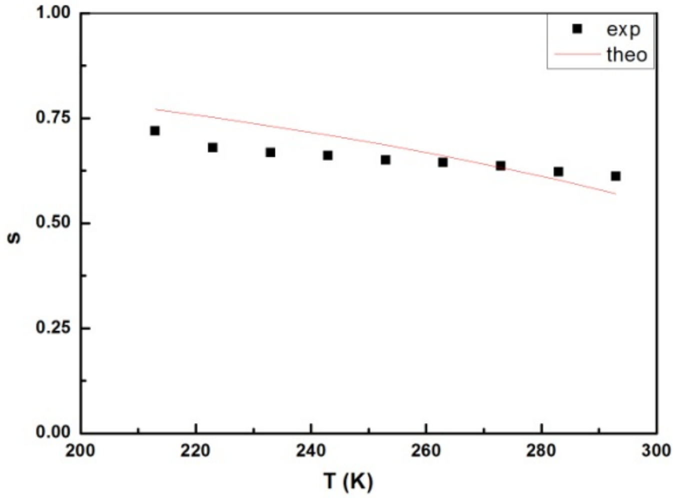

Fig. 11 s-T fitting graphs for $Se_{79}Te_{15}In_6$

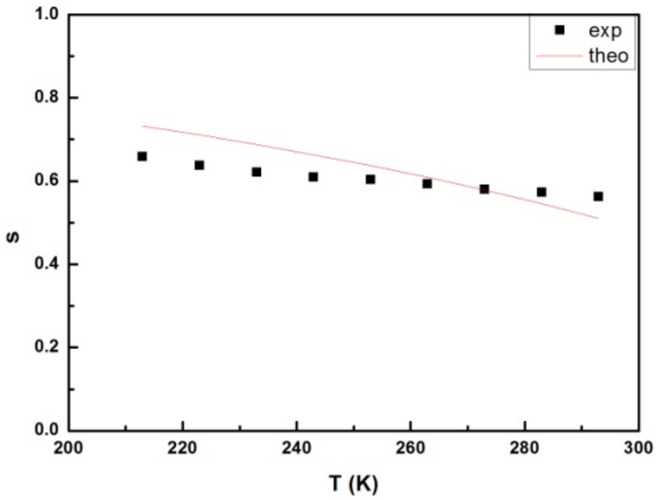

Fig. 12 s-T fitting graphs for $Se_{75}Te_{15}In_{10}$

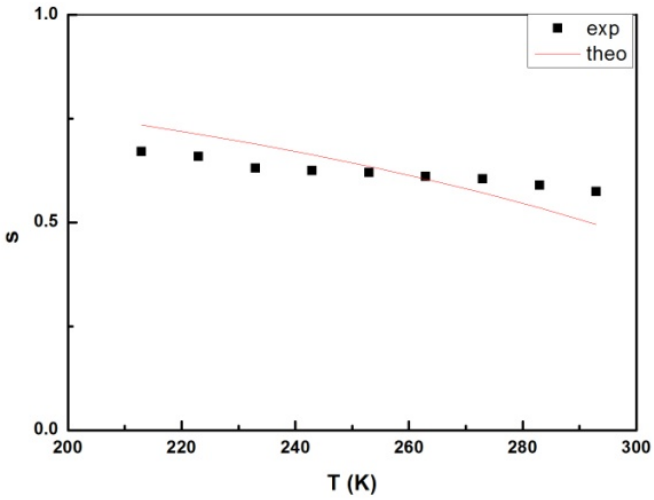

Fig. 13 s-T fitting graphs for $Se_{70}Te_{15}In_{15}$

s-T graphs do not fit well for W_1 or W_2 at any temperature, thereby indicating that single polaron hopping does not contribute much to the conduction mechanism in the studied temperature range as expected. The parameters W_M and τ_o obtained from the best fits are given in table. W_M follows the pattern followed by activation energy.

The value of κ has been calculated from capacitance measurements at different frequencies in the studied temperature range for all the materials and the values of κ are given in the table 1.

3.3 Temperature dependence of ac conductivity

Figs. 14-18 show inverse temperature dependence of ac conductivity for the system under study. From the graphs it is clear that ac conductivity decreases with decrease in temperature. The weak temperature dependence of ac conductivity in the studied temperature range is most likely due to the dominance of bipolaron hopping[11].

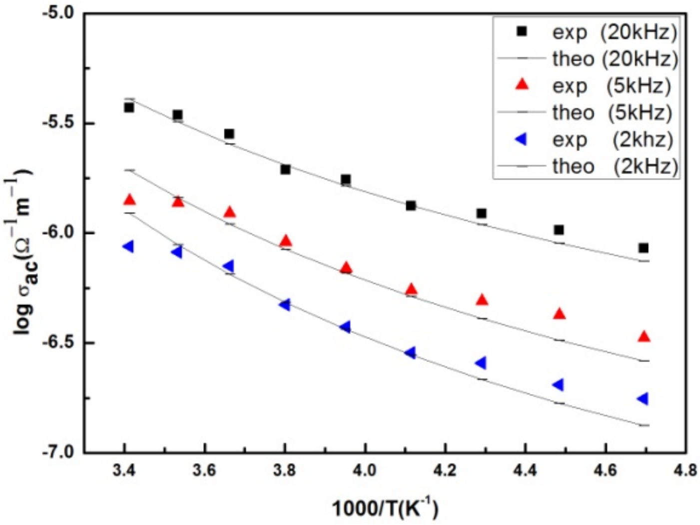

Fig. 14 Temperature dependence of ac conductivity for $Se_{85}Te_{15}$

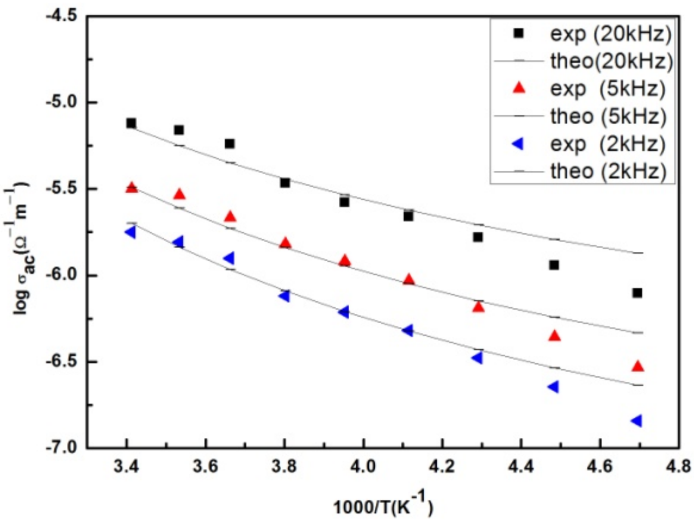

Fig. 15 Temperature dependence of ac conductivity for $Se_{83}Te_{15}In_2$

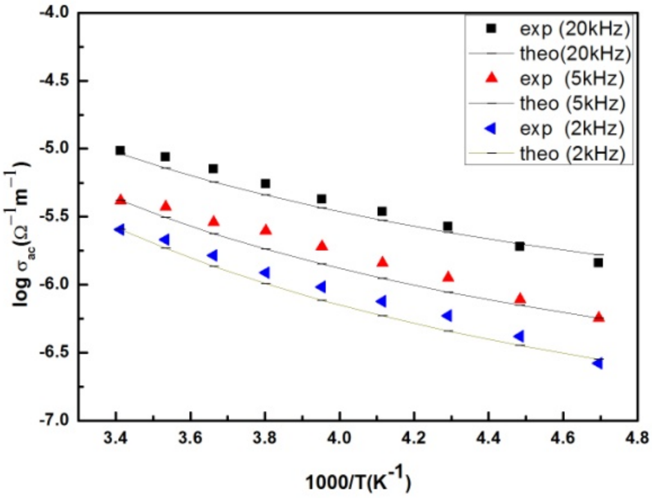

Fig. 16 Temperature dependence of ac conductivity for $Se_{79}Te_{15}In_6$

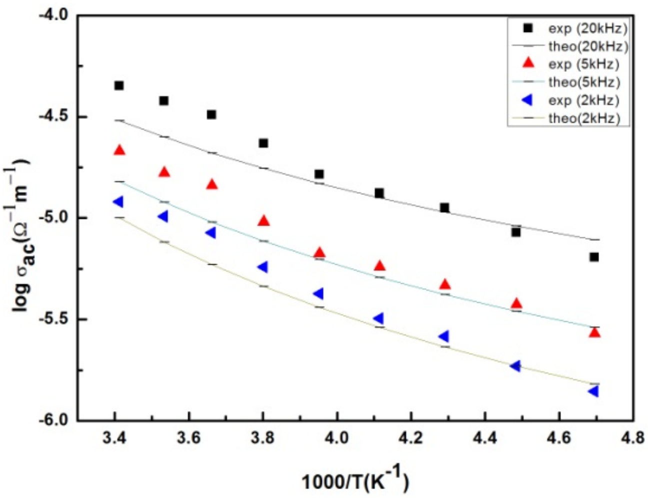

Fig. 17 Temperature dependence of ac conductivity for $Se_{75}Te_{15}In_{10}$

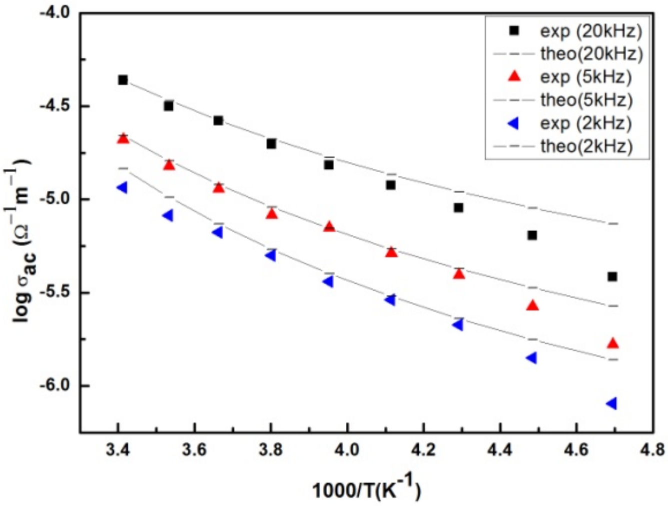

Fig. 18 Temperature dependence of ac conductivity for $Se_{70}Te_{15}In_{15}$

Theoretical calculations of ac conductivity have been done using (3), (4) & (5) for bipolaron hopping using the parameters W_M and τ_o obtained from the best s-T fits (Fig 8-12) and the parameter κ obtained from capacitance measurements. Different values of N_T were used to obtain best fits with experimental results. Various parameters finally used for calculating the ac conductivity are listed in table 1.

Table. 1 Parameters for CBH model.

Glass	W_M(eV)	τ_0(s)	κ	N_T(cm^{-3})
$Se_{85}Te_{15}$	0.76	6×10^{-13}	12.2	1.5×10^{20}
$Se_{83}Te_{15}In_2$	0.80	3×10^{-13}	14.2	3.5×10^{20}
$Se_{79}Te_{15}In_6$	0.82	1.5×10^{-13}	16.6	6×10^{20}
$Se_{75}Te_{15}In_{10}$	0.62	6×10^{-11}	19.0	1×10^{21}
$Se_{70}Te_{15}In_{15}$	0.72	1×10^{-12}	23.6	2×10^{21}

Calculated values of conductivity obtained at different temperatures and frequencies have been plotted as solid curves ,data points obtained experimentally have been superimposed on these curves(Fig 13-17).An agreement between experimental and theoretical results clearly indicates that bipolaron hopping is dominantly responsible for ac conductivity in the present system in the studied temperature and frequency range.

4. Conclusions

The ac conductivity behaviour of $Se_{85-x}Te_{15}In_x$ (x = 0, 2, 6, 10, 15) has been explained by CBH model in the studied temperature and frequency range. The frequency and temperature dependent behavior of ac conductivity of the studied materials is predominantly due to bipolaron hopping. W_M follows the pattern followed by the activation energy. The value of defect states and dielectric constant appear to increase with increase with increase in Indium concentration. The dc conductivity is singly activated in the entire temperature range investigated and increases with increase in temperature.

Acknowledgements

The authors are thankful to UGC, New Delhi for financially assisting the major research project.

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