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AC CONDUCTION AND DIELECTRIC CHARACTERIZATION OF LEAD SELENIDE THIN FILMS FROM VACUUM EVAPORATION TECHNIQUE

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Thin films of PbSe are prepared by vacuum deposition technique on to well cleaned glass substrates. The film thicknesses are measured by quartz crystal monitor method. Thin film capacitors of the type (Al-PbSe-Al) have been fabricated. AC Conduction and Dielectric studies performed on a stabilized samples of thickness 1000Å and 2000Å at various frequencies (20Hz-100KHz) and temperatures (303K-483K).From the AC conduction studies, it is confirmed that the mechanism responsible for the conduction process is hopping. Thermal activation energy is found to decrease with increase in film thickness. The variations of the dielectric constant and loss as function of frequency at different temperature are observed and the results are discussed. Temperature co-efficient of capacitance and permittivity are evaluated.

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1. Introduction

The need for microminiaturized electronic components in the microelectronics industry has provided the greatest stimulus for the investigation of electrical conduction properties of thin films of various materials. Among them, chalcogenide films for new kind of materials with immense qualities of use in many practical applications. PbSe thin film is one such candidate having a range of applications. The applications of these materials are extended to fabricate ideal infrared radiation detectors, infrared emitters and solar control coatings [1-6].For the understanding of basic features of PbSe chalcogenide films and their potentiality in application, the knowledge of the electron states and their behavior with different frequencies and at high fields becomes important. The present paper reports the AC Conduction and Dielectric studies made on PbSe thin films.

2. Experimental details

PbSe thin films are prepared by melting high purity lead selenide in a vacuum of 10^{-6} torr. Thin film samples are prepared on to well cleaned glass substrates kept to room temperature by

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thermal evaporation, using 12A4 Hind Hivac coating unit under a vacuum of 10^{-6} torr. Thicknesses of the films are measured using quartz crystal monitor method.

Thin film capacitors (Al-PbSe- Al) are fabricated using aluminum (99.99 % purity) as top and bottom electrodes and in between PbSe as a sandwich layer for dielectric studies. The capacitance and loss factor (tanδ) are measured in the frequency range of 20Hz to 100 KHz at various temperatures (303K to 483K) using an 819A multi frequency LCR meter.

3. Results and discussion

3.1. AC conduction

Fig.1. Shows the plot of log σ Vs log F at different temperature for the PbSe film of thickness 1000 Å. In the present case the conductance is found to be increasing linearly with increase of frequency. The AC conductivity is found to be varying according to the relation $G_p \alpha f^n$, where the exponent 'n' depends on the temperature and frequency range studied.

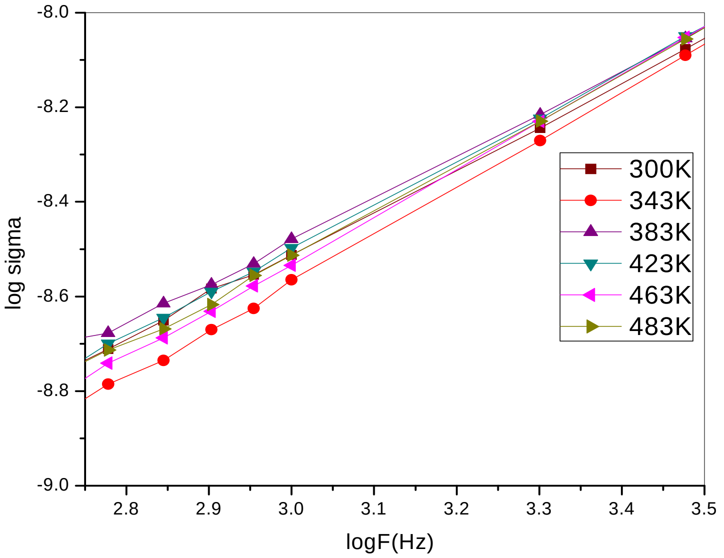

Fig. 1. Frequency dependence of AC conduction for PbSe thin film of thickness 1000 Å

The observed frequency depends upon AC conduction which can be considered to be the sum of two conduction mechanisms, i.e., single polaron and bipolaron hopping. This can be explained on the basis of CBH (Correlated Barrier Hopping) model. According to this model, the conduction occurs via a bipolaron hopping process wherein two electrons simultaneously hop over the potential barrier between two charged defect states (D^+ and D^-) and the barrier height is correlated with the intersite separation, via a columbic interaction. Fig. 2-4 show the experimental AC conductivity as a function of inverse temperature at different frequencies for the PbSe thin films of thickness 500 Å, 1000 Å, and 2000 Å respectively

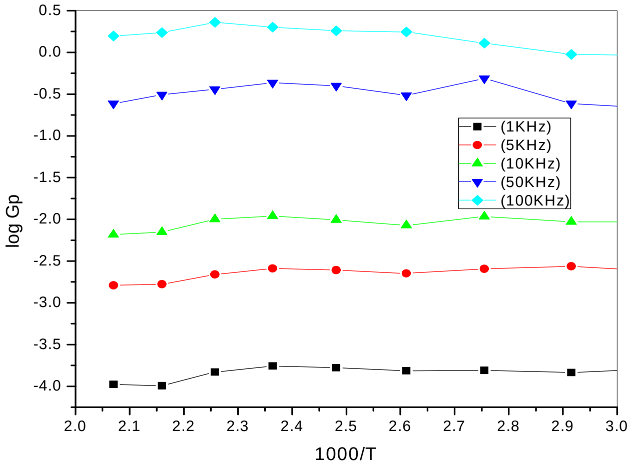

Fig.2.Dependence of temperature on conductance of thickness 500 Å.

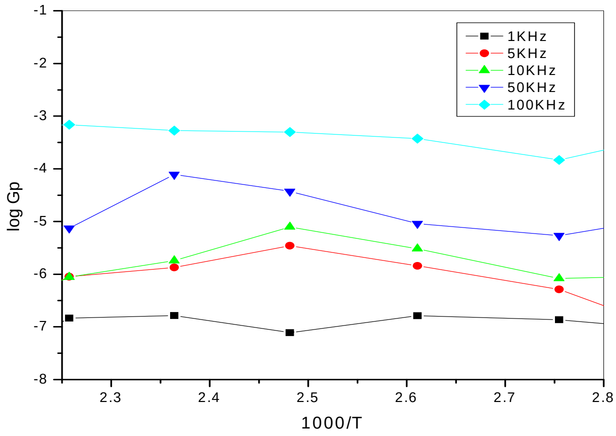

Fig.3. Dependence of temperature on conductance of thickness 1000 Å.

Table I. Variation of activation energy with frequency and film thicknesses.

Frequency	Activation Energy (eV)		
	500Å	1000 Å	2000 Å
10kHz	0.6356	2.0566	0.7095
100kHz	0.6355	0.6547	0.6547

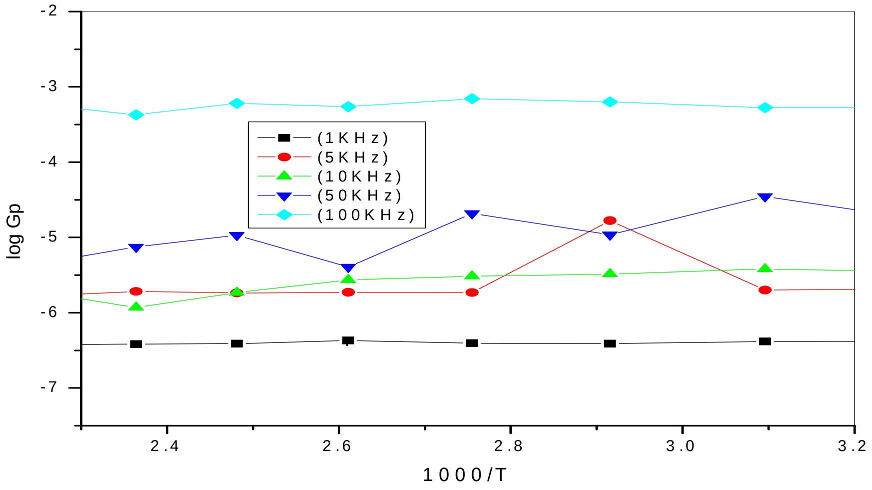

Fig. 4. Dependence of temperature on conductance of thickness 2000 Å.

For all thicknesses, the conductivity is observed to be temperature dependant. Activation energies have been determined from the slopes of these curves at two different frequencies. The calculated activation energy decreases with increase in frequency, which is given in Table I. This can be possible due to the increase of applied field frequency and enhances the electronic jumps between the localized states [7].

3.2. Effect of frequency

Fig.5 shows that the variations in the capacitance, with frequency for the PbSe thin films having thickness 1000Å at different temperatures. The capacitance decreases with increasing frequency, but at high frequencies the capacitance is almost constant.

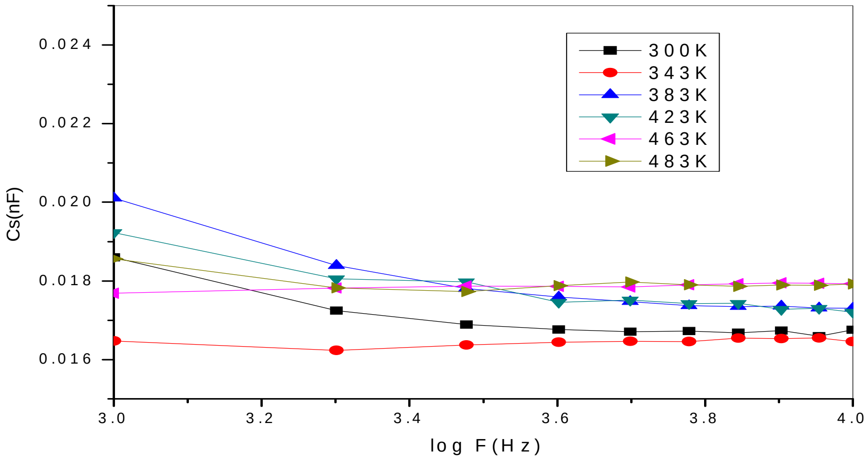

Fig.5. Variation of capacitance C_s with log frequency at different temperatures for PbSe Thin film of thickness 1000 Å

The large increase in capacitance with decrease of frequency can be explained on the basis of charge carriers being blocked at the electrodes [8].

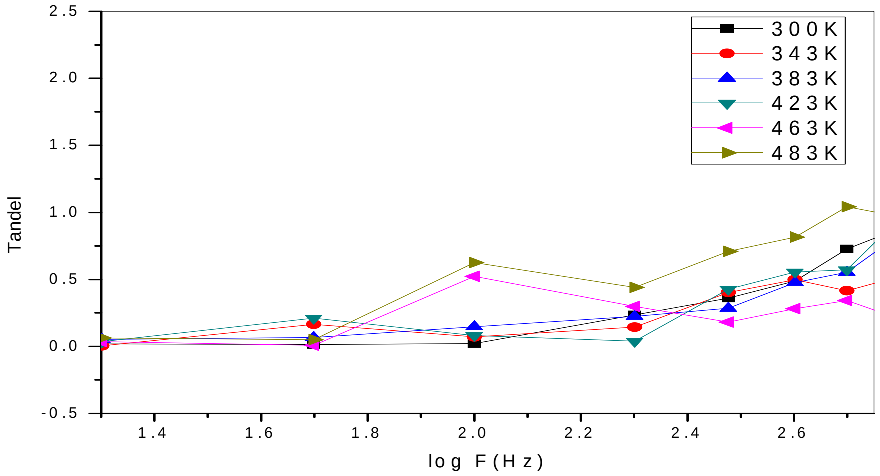

Fig. 6. Variation of tan δ with log frequency at different Temperatures for PbSe thin film of thickness 1000 Å

The variation of loss tangent (tan δ) with frequency at different temperature for PbSe thin film of thickness 1000 Å as shown in Fig.6 and the loss factor is found to increase with increase in frequency and also with increase in temperature, even at lower frequencies it is found almost constant. The increase in loss factor at high frequencies may be due to the effect of lead resistance [9].

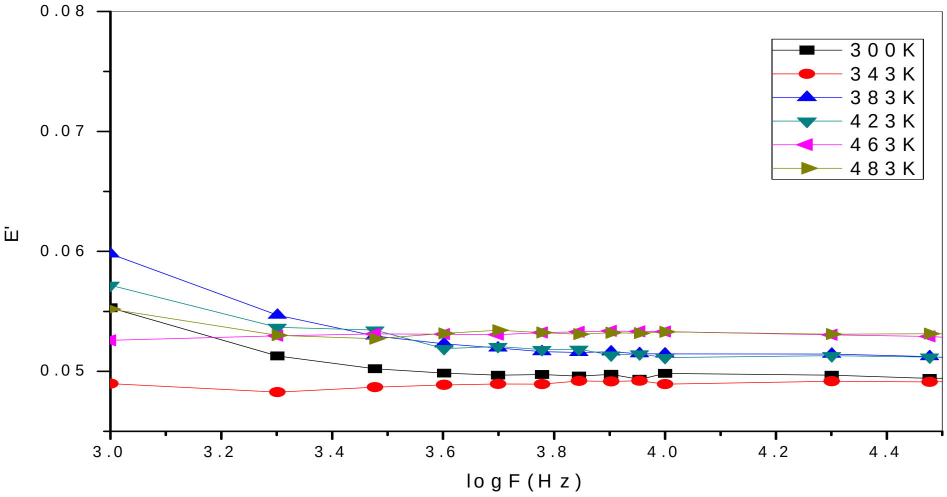

Fig. 7. Variation of Dielectric constant ε' with log frequency at different temperatures for PbSe Thin film of thickness 2000 Å

The Fig.7 indicates the variation of dielectric constant, which founds to be decreasing with increase in frequency. The variation of the dielectric constant is dependent on temperature. It can be attributed to the presence of interfacial polarization mechanism [10].

3.3. Temperature coefficient of capacitance and permittivity

The temperature coefficient of capacitance (TCC) is an important parameter for assessing the expected behavior of thin film circuits. The temperature dependence of the capacitance for various constant frequencies is shown in Fig.8. The temperature coefficient of capacitance has been evaluated using the relation.

$$TCC = \gamma_c = \frac{1}{C}\frac{dC}{dT} \tag{1}$$

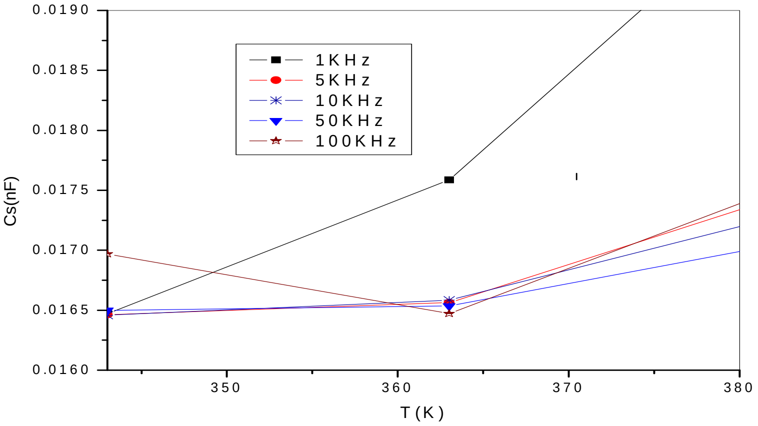

Fig. 8. Temperature dependence of capacitance at different frequencies for PbSe thin film of thickness 1000 Å

The temperature coefficient of capacitance is found to be 6.8737x10^{-3} ppm/K at 1 KHz and at room temperature.

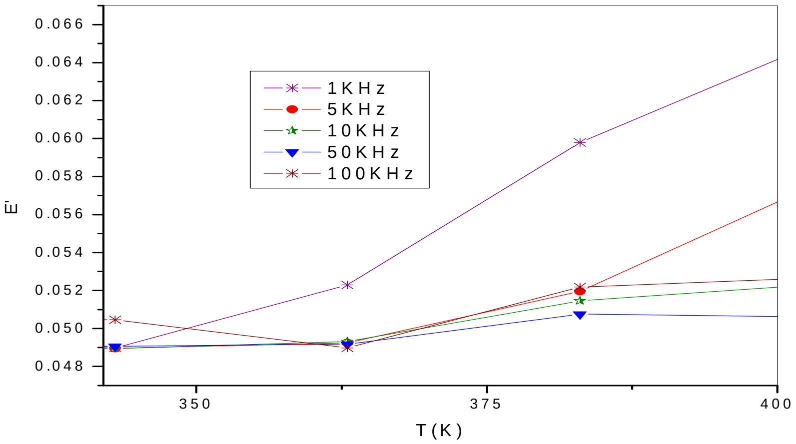

Fig. 9. Temperature dependence of permittivity at different requencies for PbSe thin film of thickness 1000 Å

Temperature coefficient of permittivity (TCP) has also been determined from the Fig.9, by using the relation,

$$TCP = \gamma_p = \frac{1}{\varepsilon'}\frac{d\varepsilon'}{dT} \tag{2}$$

The value of TCP obtained for 1 KHz and at room temperature is 6.7502x10^{-3} ppm/K.Since the capacitance of a capacitor is proportional to the permittivity of the capacitor dielectric; it is possible to relate TCC to TCP by the equation

$$TCC = \alpha + TCP \tag{3}$$

Where α is the linear expansion coefficient and is evaluated as 0.1235 X 10^{-3} ppm/k.

4. Conclusion

The dependence of AC Conduction on frequency at different temperature reveals the mechanism of AC Conduction is hopping. The Dielectric properties of pure PbSe thin films have been studied in a wide range of frequencies and temperature. In the low frequencies and at higher temperature, the capacitance is dependent on both temperature and frequency. This may be due to the blocking of charge carriers at the electrodes. The loss factor is found to be increasing with increase in frequency and also with increase in temperature in a higher frequency region. It may be due to the effect of lead resistance.

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