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Investigations on Certain Microstructural Aspects Related to Thin Film Studies with Applications of Analytical Tools

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Abstract: **Thin films form basic insulation in most of the electrical power apparatus such as rotating machines where thin insulation functions as vital element. The healthy operation of the rotating machine is dependent on optimum, efficient functioning of these thin films. Thin films such as Polystyrene (PS) and Polymethyle methacrylate (PMMA) find good understanding to study optical, structural and A.C. conduction (i.e., electrical properties). The physical properties such as Refractive index (RI), Fourier transform Infrared spectroscopy FTIR provide data to characterise these materials among them A.C. conduction & A.C. activation energy will characterise better than thin materials. In the blended films the frequency dependence plays a dominant role in understanding structural mechanism which determines A.C. conduction of thin film. In the present paper attempts are made in understanding A.C. condition in the material Polystyrene (PS) and Polymethyle methacrylate (PMMA) in both forms of original as well as blended form these have been correlated with analytical tools such as X–Ray Diffractometer (XRD) & Fourier transform Infrared spectroscopy (FTIR) the studies have brought out interesting results such as frequency dependence of A.C. conduction.**

In fact results reveal that blend film have strong frequency dependence of A.C conduction tending toward squire law at higher frequencies. These aspects of micro mechanism & A.C conduction apart from a few striking results obtained are presented for both PS & PMMA films. These results and interpretation to as applied to electrical rotating machines have been discussed in detail in the present research work.

Keywords: Polystyrene (PS) and Polymethyle methacrylate (PMMA), thin films AC conductivity.

1. INTRODUCTION

Since a few decades thin film technology has made rapid growth and development with advent of different kinds of chemical, analytical techniques such as vapour deposition, anodization, film deposition methods and others. This has lead to the progress of micro electronics, optoelectronics and other fields which further require understanding in physical aspects of thin films and their mechanisms. There is hence need to understand variety of thin films such as PS and PMMA, especially in blended form. Also it is known that thin films have large surface to volume ratios and consequently the surface of thin film plays a vital role in determining thin film properties. Thin films in pure forms perform differently with respect to commercial thin films which are generally of hybrid in composition. Hence this can be closely approximated to blended thin films. With this comprehension of the concept of the blended thin films, it is essential to study the nature and behaviour of blended thin films which tend to crystallinity from amorphous nature.

The present literature indicates that, AC conduction studies have been studied from literature it is known that, Black and Geballe have given a detailed interpretation of the frequency dependence of the electrical conduction in amorphous solids. The A.C. conductivity should increase with frequency of the applied and saturate at frequencies high enough to be comparable to the natural frequency of hopping distances and activation energies for all pair's occupied and empty centres [1,2,3]. This is averaging process yields, for simple or multiple hopes the A.C. conductivity σ (ω) in amorphous solids depends on the angular frequency ω obeying relation,

$$\sigma(\omega) \propto \omega^n \qquad \text{———} \qquad (1)$$

Where, n decreases from 1.0 for single hope to 0.5 for multiple hops. This relation is in reasonable agreement with the observation. This increase of n at low temperature is due to the predominance of single holes. This indicates that the frequency dependence of A.C. conductivity saturates at very high frequencies.

2. EXPERIMENTAL DETAILS

AC conductivity studies on thin films have been presented in the following paragraphs. The thin films of PS and PMMA in pure and blended form have been highlighted. The characteristics of thin films of conductivity (σ) verses frequency (f) have been studied at different temperatures. The results have been presented in Fig. 1 to Fig.4 followed by discussions of results on thin films.

AC conduction at different temperatures for pure films of Polystyrenes as shown in Fig.1

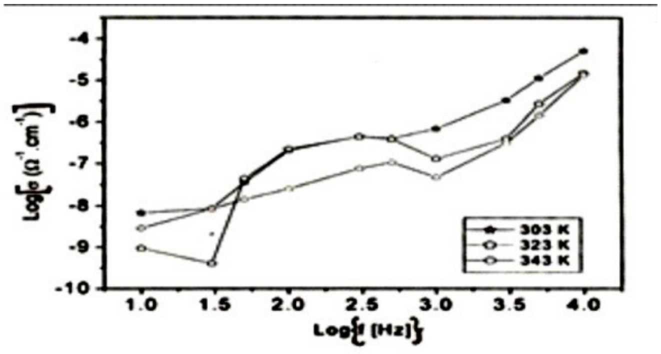

Fig.1 Variation of Log σ with frequency at different temperature for PS pure film

It can be seen from the Fig.1 that, as log f increases there is a incremental rise in logσ for all the temperatures considered (i.e. 303K to 343K). The increase in f will result in increase conductivity nature which in turn is the result of different conduction mechanisms of electrons in thin films. At the temperature of 343K the characteristics of conductivity and frequency are slightly different in the range of log frequency 1.5 to 3.0. Beyond this range and other ranges also increase in trends can be observed in the temperature range considered.

Fig.2 shows the conductivity with frequency for a pure PMMA film at different temperatures.

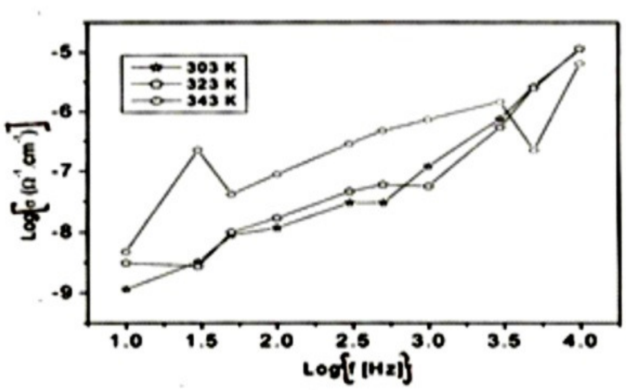

Fig.2 Variation of Log σ with frequency at different temperature for PMMA pure film

It can be seen from Fig.2 that, the conductivity σ increases with frequency for PMMA pure film. Conductivity also increases with temperature. Further, the incremental increase of conductivity at temperature of 343K is quite large as compared to those increases at the temperature of 323K and 303K.

When PMMA and PS are blended the combined film of PMMA and PS with 75:25 blending has shown interesting results. The conductivity characteristics with frequency are depicted in fig.3

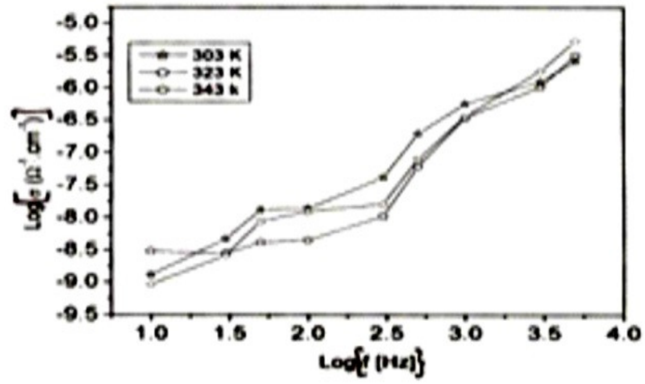

Fig.3 Variation of Log σ with frequency at different temperature for PMMA 75-PS25 film

The characteristics of conductivity and frequency in the log scale show more linearity compare to other cases presented previously. The increased conductivity in thin films sample over entire frequency range is always resulted for blended thin films as shown in the Fig.3 the conductive mechanism also is operational to bring about electronic mode of conduction in the energy bands at all the three temperatures namely, 303K, 323K and 343K.

The conductivity characteristics with respect to temperature are shown in fig.4 for blended thin films of PMMA and PS.

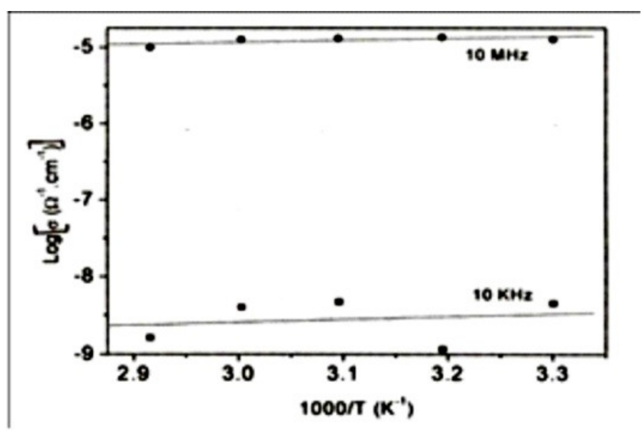

Fig. 4 Log σ versus 1000/T (K^{-1}) for PMMA 25- PS 75 film

The results suggests that, conductivity and temperature are influenced to the measurement frequency for the type of material i.e. PMMA or PS.

The characteristics are entirely different at two different frequencies of 10 KHz and 10 MHz. Therefore the blending ratios of PMMA and PS are very important as can be inferred from figures. The measurements/studies are made at 10 MHz and 10 kHz & it has been found that there is a wide gap between the two characteristics of 10 KHz and 10 MHz for all the temperatures studied. The frequency and temperature will definitely affect conductivity of the films and blended films.

3. DISCUSSIONS

However there are a few cases where squire law dependence is observed [4]. This is explained on the basis of two centre hopping as

$$\sigma' \alpha \omega^2 \quad \_\_\_\_\_\_\_\_\_\_ \quad (2)$$

The conductivity increases as the squire of the frequency. The dielectric films that have high densities of localized levels in the forbidden gap also exhibit the hopping mechanism. The presence of compensated donors and acceptors in the crystalline dielectric also associates the hopping process with them. These properties could be expected in the case of amorphous substances. In these substances, electronic transmission between mapping levels suggests a more fundamental hopping mechanism, which gives the mott $T^{1/2}$ [5]. Jonscher has theoretically shown that the change in the character of the carriers is related to the slope of the log σ versus frequency curves.

4. CONCLUSIONS

The A.C. conduction studies have shown that, the conduction mechanism in pure and blend PS and PMMA films. The A.C. conductivity is found to follow a $\sigma_{ac}\ \alpha\ \omega^n$ relation in both pure and blend films. The increase in conductivity at high temperatures (>343 K) is due to the increase of crystallinity in the films. In the blend films a strong frequency dependence of conduction tending towards squire law at higher frequencies has been observed. This dependence indicates that the electron hopping mechanism is responsible for the A.C. conduction.

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