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The Dielectric Properties of Crown Ether Polymer

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ABSTRACT. The dielectric properties such as permittivity, dielectric loss and loss tangent for the dibenzo-18 crown-6 supported on epoxy resin were studied. The measurements were carried out under vacuum in temperature range (280-380)K and frequency range (1-20) kHz. At temperature range (300-320) K the permittivity, ε' was found to be constant and starts to increase approximately linearly at temperature above 320 K. This behaviour occurred at frequencies 1, 5, 10, 15 and 20 kHz, where the values of ε' at these frequencies were coincided. The dielectric loss ε'' was found to be constant at all frequencies at the considered temperature range (300-320) K while at temperatures above 320 K ε'' increases with increasing temperature but decreased with increasing the frequency. The loss tangent, tan δ followed the same trend as ε'' except a maximum occurs at 360 K after which tan δ decreased with increasing temperature. The change at 360 K were related to the glass transition temperature of the polymer.

INTRODUCTION

Studying the dielectric properties of polymers have increased importance because it provide an understanding to the molecular chains which reflect the wide polymer applicationes and usage in engineering, electrical and electronics[1]. These polymers materials are used as insulators in wires, cables, printed circuit boards and in many other electronic devices [2].

Insulators with low permittivity are preferred to be use in the industry of communication coaxial cables to minimize as much as possible the electron density on the conductor surface, whereas the high dielectric constant materials are preferred to be used in the industry of capacitors.

The aim of this paper is to investigate the effect of temperature and frequency variations on the Crown ether epoxy resin permittivity, dielectric loss and loss tangent.

EXPERIMENTAL

Materials

Dibenzo-18-Crown ether-6 (DB-18-CR-6) supported on high molecular weight epoxy resin was used in the preparation of the samples. The preparation and characterisation procedure of these new crown ether derivatives are reported elsewhere [3].

Sample disks with thickness 4 mm and diameter 30 mm were prepared by direct curing of the samples in the mold. A guard electrode system was used with Aluminum foil electrodes to measure the dielectric properties of the specimen [4].

The high and low terminals of the system were connected to RCL Bridge (Model Phillips PM-6302) and function generator (Model Exact-529) to supply the bridge with the desired frequencies. The RCL bridge was calibrated by a Digital RCL Bridge (Model hp-4261A) at 1 kHz and used to measure the capacitance and the loss tangent of the specimen.

The measurements were performed under vacuum (about 10^{-5} mbar) and over a temperature range (260-380) K and frequency (1-20) kHz.

Measurements

The permittivity, ε', was calculated by the following equation, using the measured value of the specimen capacitance, C, and the electrode capacitance, C_o

$$\varepsilon' = \frac{C}{C_o} \quad \text{.... (1)}$$

The dielectric loss, was calculated by equation (2), using the measured values of tan δ and the calculated values of ε' from equation (1)

$$\varepsilon'' = \varepsilon' \tan\delta \quad \text{.... (2)}$$

RESULTS AND DISCUSSION

Permittivity, ε'

The variation of the permittivity, ε', as a function of temperature for the Crown ether epoxy resin is shown in Fig.(1). At temperature range (297-320) K. The permittivity was found to be constant at initial stages and start to increase approximately linearly at temperatures above 320°C. This behaviour occurred at frequencies 1, 5, 10, 15 and 20 kHz, where the values of ε' at these frequencies were coincided. This behaviour can be attributed to the weak orientation of the dipoles with the applied electric field due to the insufficient free volume available to the dipole to orient freely. At temperatures above 320 K the specimen start to expand in volume leading to large free volume and increase in the permittivity values [4].

Fig.(2) shows the relation between the permittivity and the frequency at temperature range (290-370) K. At lower temperatures the frequency variation did not effect on the permittivity. At higher temperatures there is a decrease in the premittivity at the frequencies (1-2) kHz. Decreasing ε' values at low frequency region is conventional behaviour of dielectric materials [5,6]. This decrease can be attributed to the interfacial polarization which is called Maxwell-Wagner Process (MWP). This polarization is due to the accumulation of the charges on the intermediate boundaries between the different components of the molecular chains, i.e., between the epoxy unites and the ether units [6,8]. At high frequencies, ε' is constant due to the vanishing of (MWP) effect and the domain of the orientation polarization which is independent on frequency [9].

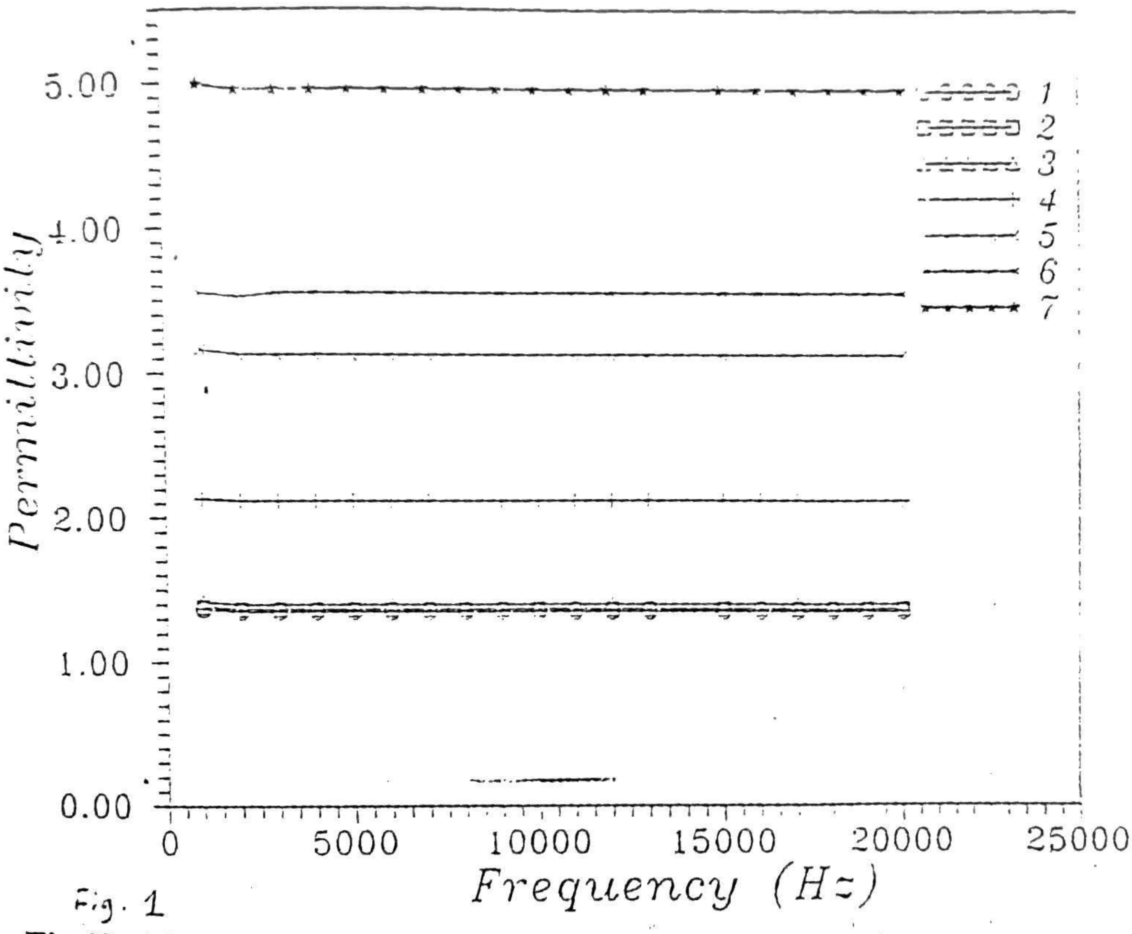

Fig.(1) The permittivity as a function of temperature in frequency range (1-20) kHz.

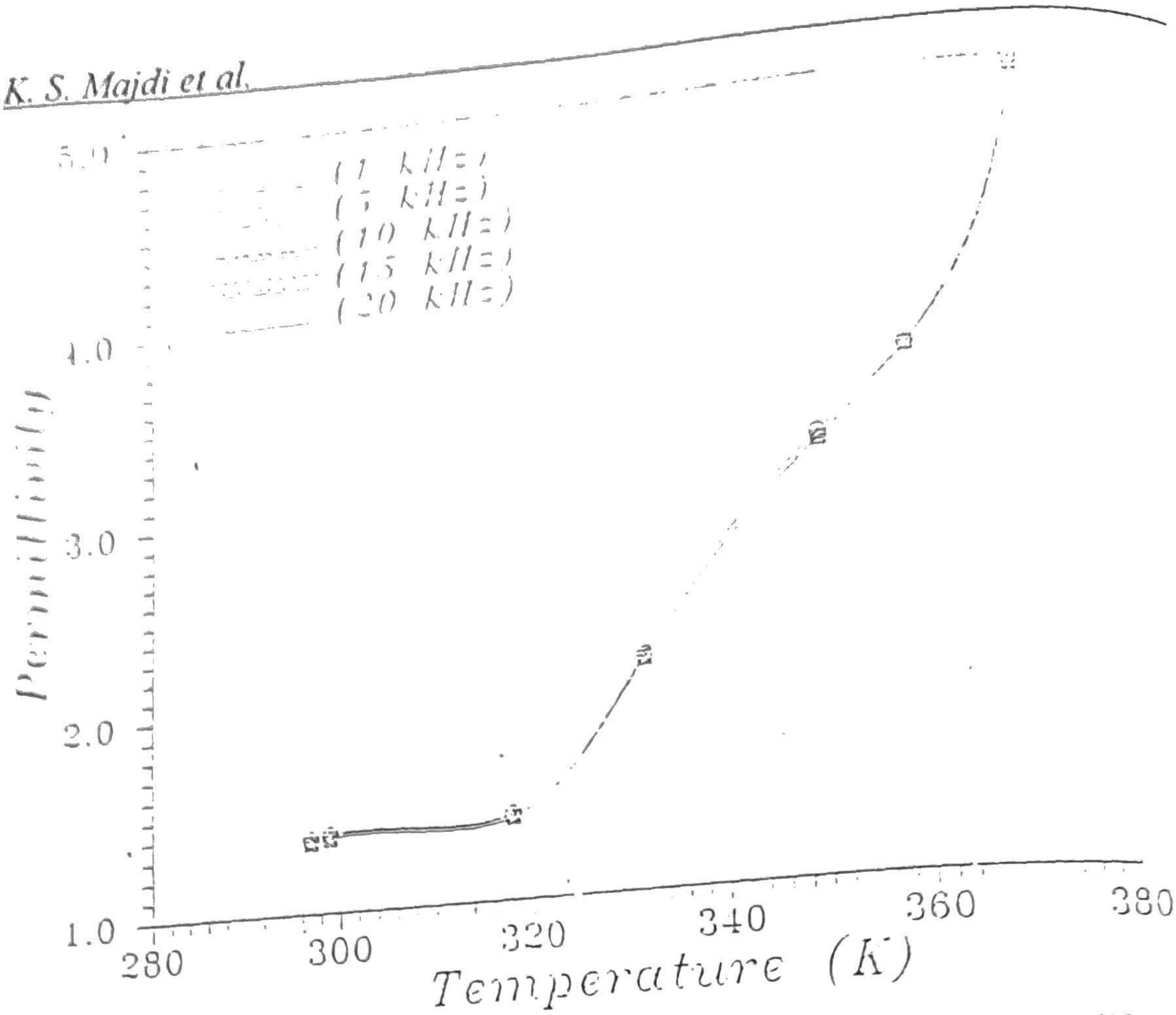

Fig.(2) The permittivity changes as a function of frequency at different temperatures (1: 290 K, 2: 300 K, 3: 318 K, 4: 332 K, 5: 350 K, 6: 360 K, 7: 370 K).

Dielectric Loss, ε''

The variation of the dielectric loss, ε'', as a function of temperature is shown in Fig.(3). The dielectric loss (ε'') was found to be constant at all frequencies under consideration in the temperature range (300-320) K while at temperatures above 320 K ε'' increased with increasing temperature and it decreased with increasing frequency. The weak orientation of the dipoles exhibited at this temperature range due to the molecular chains slow motion leads to slow variation of the dielectric loss. While at higher temperatures the chains motion will increase leading to increase in the free volume which means an increase in the number of dipoles that orient with applied electric field leading to increase the ε'' values with temperature.

Fig.(4) shows the variation of ε'' with frequency. The values of ε'' were high for frequencies below 1 kHz, but it decreased with frequency up to 20 kHz. The decreasing of ε'' with increasing frequency in the range (1-20) kHz can be attributed to the interfacial polarization caused by the heterogenous nature of the system [10]. Similar arguments were suggested by others [11,12,13].

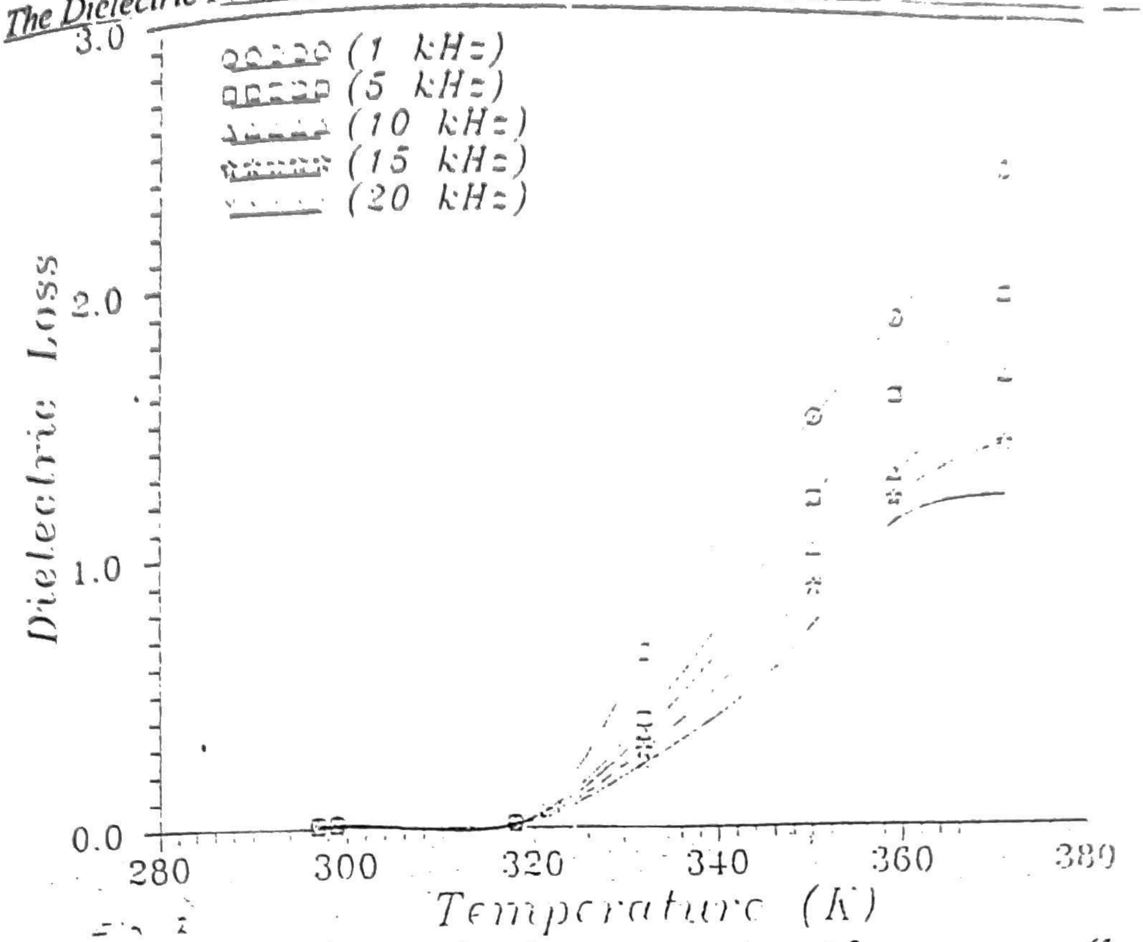

Fig.(3) The dielectric loss as a function of temperature at frequency range (1-20) kHz.

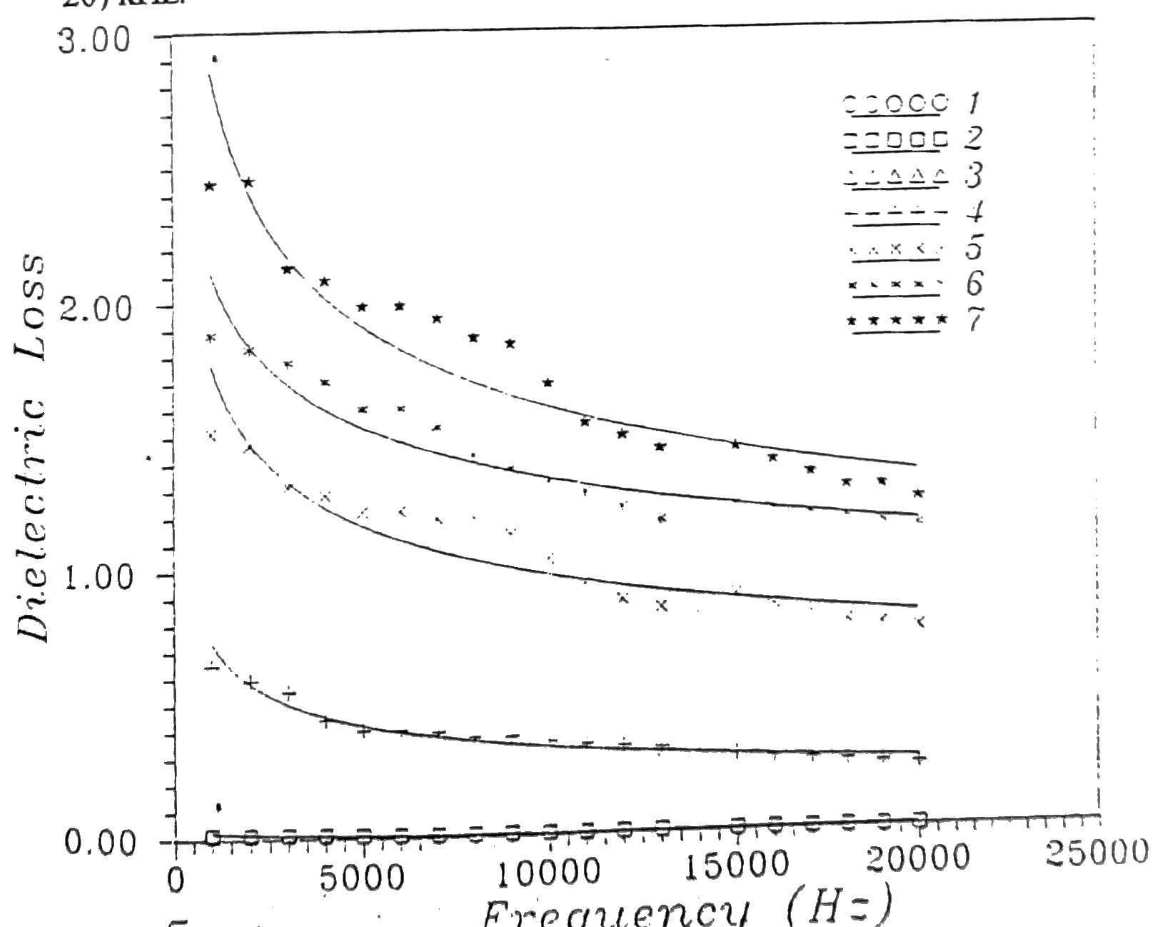

Fig.(4) The dielectric loss as a function of frequency at different temperatures (1: 290 K, 2: 300 K, 3: 318 K, 4: 332 K, 5: 350 K, 6: 360 K, 7: 370 K).

Loss Tangent, tan δ

The variation of the loss tangent, tan δ as a function of temperature and frequency are shown in Fig.(5) and Fig.(6) respectively. The loss tangent followed the same trend as ε'' except a maximum occurs at temperature 360 K after which tan δ decreased with increasing temperature. The change at 360 K may be considered as a glass transition for this polymer.

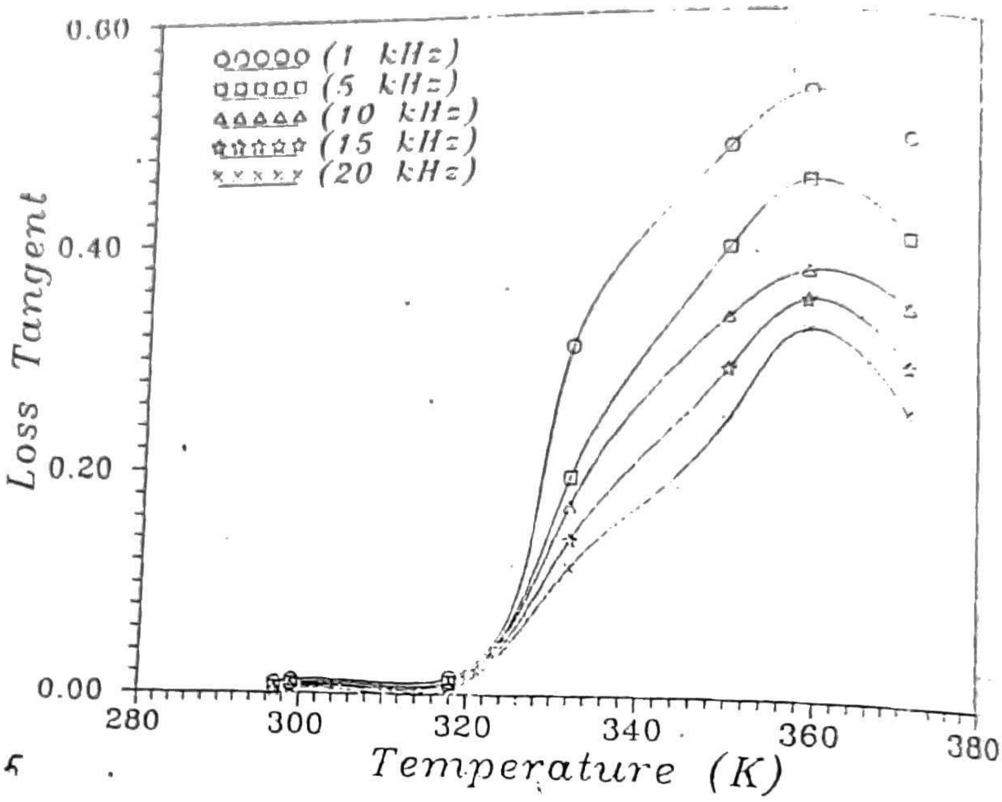

Fig.(5) The loss tangent as a function of temperature at frequency range (1-20) kHz.

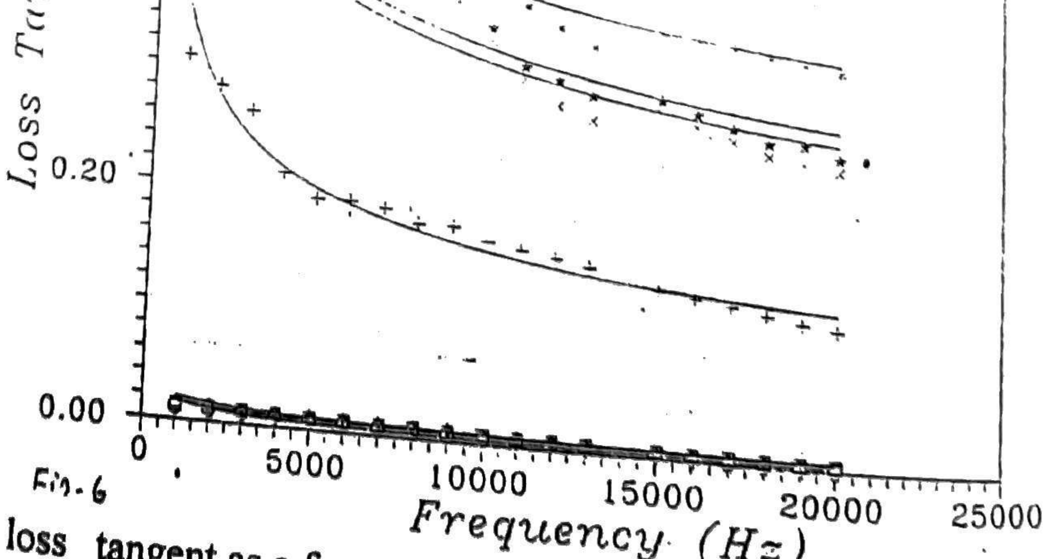

Fig.(6) The loss tangent as a function of frequency at different temperatures (1: 290 K, 2: 300 K, 3: 318 K, 4: 332 K, 5: 350 K, 6: 360 K, 7: 370 K).

CONCLUSIONS

1. Increasing in permittivity, dielectric loss and loss tangent values were obtained as a result of increasing Crown ether epoxy resin temperature.
2. Constant permittivity was obtained at frequency range (1-20)kHz, but the dielectric loss and loss tangent decreased with increasing frequency in the range (1-20)kHz especially at temperatures above 335 K.
3. The structural transitions can be obtained from the loss tangent-temperature spectrum for dielectric polymers.

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