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Research Article

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Effect of temperature on the electrical properties of polyvinyl chloride at microwave frequencies

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ABSTRACT

The dielectric constant, loss tangent and the a.c conductivity of polyvinyl chloride (PVC) at X- band (8-12GHz) and Ku- band (12-18GHz) microwave frequencies at temperatures ranging from 30 - 100° C have been measured by Von-Hippel method. Our preliminary studies show a peak value of the dielectric constant as 4.73 at 80°C at a Ku – band frequency of 15.9GHz, while the peak value of the conductivity at the same conditions is 9.89 x 10^{-3} s/cm. The results of the temperature variation study of the above mentioned electrical properties at 15.9Hz are presented. These results are compared with the values obtained for the same sample at X-band frequency of 9.4GHz.

Keywords: Polymers, dielectric studies, a.c conductivity, microwave frequencies.

INTRODUCTION

In the recent years electrically conducting polymers represent the important research area with diverse scientific problems of fundamental importance with the potential for commercial applications [1]. Polymers which show high electrical conductivity have been synthesized successfully in the last two decades [2]. The theory of doping led to dramatic increase in the conductivity of conjugated polymers. Recent developments are of relevance to battery technology, and the topic of polymer electrolytes show commercial promise in the areas of power equipments, light weight rechargeable batteries, microelectronics, shielding against electromagnetic interference in machines and other fields. In the field of high frequency device fabrication, the conducting polymers have revolutionized miniaturization and microminiaturization of the devices which is essential to make n electronic device cost effective, efficient and easily deployable at critical sites. Electronic active elements like capacitors, resistors and conducting paths can be made from polymeric materials. For the effective use of dielectric materials in various devices, the knowledge of dielectric constant and the loss factor are essential. Properties cannot usually be stated as constants but must be expressed as functions of temperature and frequency. Variation of the dielectric properties with temperature and frequency throws light on the application of these materials in the optimum conditions [3].

Polymers by virtue of their light weight and ease of fabrication and low cost have replaced metals in several areas of applications. Nowadays electrically conducting polymers which are stable even in doped form have been prepared [4]. Measurements of dielectric parameters of pure and iodine doped PVC films at X-band and Ku-band microwave frequencies have already been reported [5]. In the present work we report, the effect of temperature on the electrical properties of pure and iodine doped PVC at X-band and Ku-band microwave frequencies.

EXPERIMENTAL SECTION

Polyvinyl chloride in the form of fine powder (Molecular weight 48,000) obtained from fluka chemika was used in the experiment. Rectangular blocks of the PVC powder with wave guide dimensions were made using a specially made dye and press. The packing density of the doped and undoped PVC was measured as 0.979gm/cc. Iodine doping was done by Chemical Vapour Deposition(CVD) method. The dielectric measurements of the sample were done by Von-Hippel method [6]. For temperature variation the solid dielectric cell in the microwave bench was covered with a mica sheet and over which heating element was wound. White cement was applied over the heating element with their free ends protruding out. Provision was made for inserting the probe of temperature indicator. A digital temperature indicator with mineral insulated thermocouple as the probe with an accuracy of ±1°C was used for temperature measurements. Heating was done by a variac system. When the temperature of dielectric cell attains the stable state, temperature measurements were done. As the sample is in good contact with the metallic wave guide, it is assumed that the temperature of the wave guide and the sample is the same. To avoid the heat conduction to the other parts of the waveguide, a thin layer of thermal insulator was introduced between the dielectric cell and the other parts of the bench. The temperature was varied by adjusting the a.c voltage by the variac, to the required level. The dielectric constants were calculated using the relations,

Dielectric strength (ξ') $= (\lambda_0/\lambda_c)^2 + (\lambda_0/\lambda_d)^2 (1+(\alpha_d \lambda_d)/2\pi)$.
Dielectric loss (ξ'') $=1/\pi (\lambda_0/\lambda_d)^2 \alpha_d \lambda_d$
Loss tangent ($\tan\delta$) $= \xi''/\xi'$
Dielectric constant (ξ_r) $= \xi' (1+ \tan\delta)$

(Where, λ_0 is the free space wavelength, λ_d is the wavelength in the dielectric and α_d is the attenuation in the dielectric).

The conductivity (σ) was calculated using, $\sigma = \omega \xi_o \xi''$

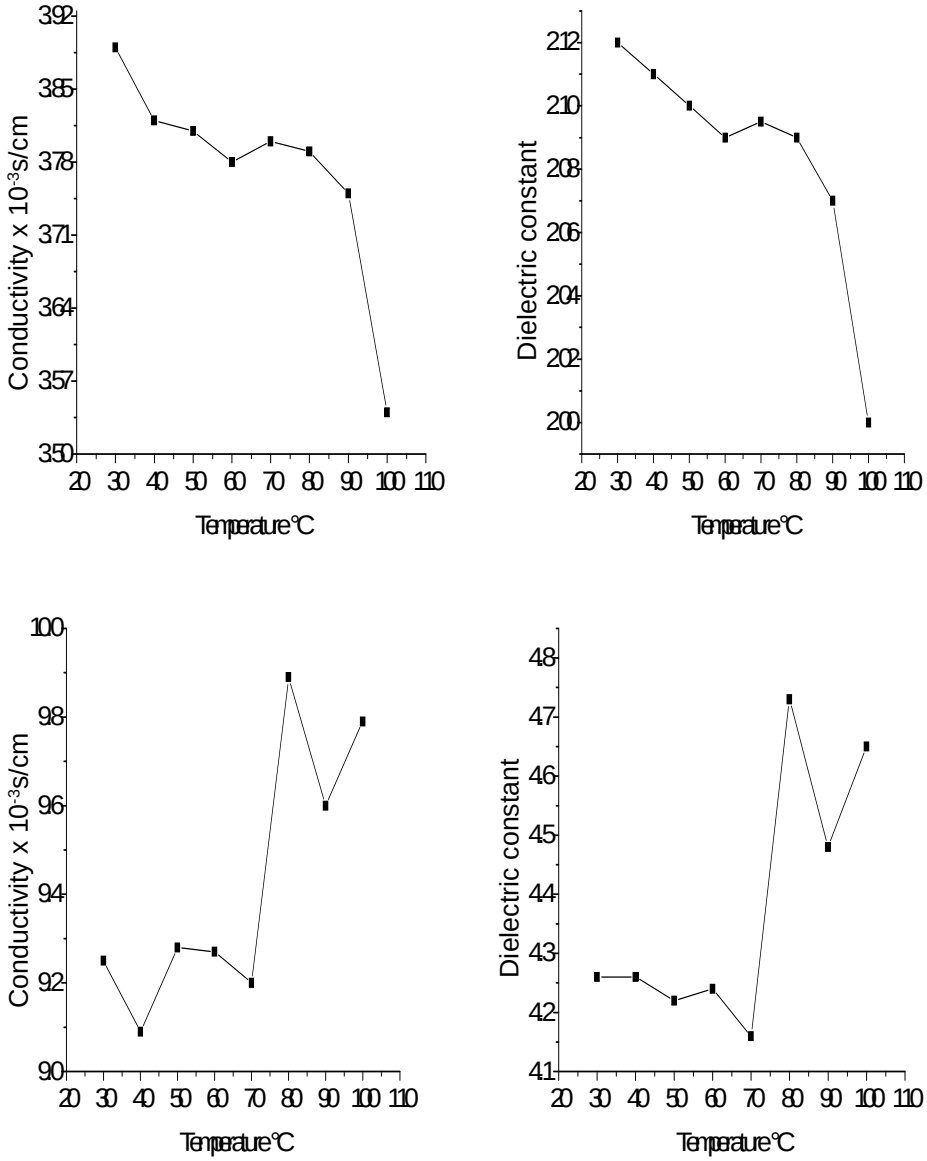
(Where ω is the angular frequency; ξ_o is the permittivity of free space- 8.854×10^{-14}F/cm)

RESULTS AND DISCUSSION

Dielectric constant and the conductivity of uploaded PVC at the X- band frequency of 9.40GHz at various temperatures ranging from 30-100°C were measured, and the results are shown in figure 1-2. The dielectric constant shows a peak value of 2.12 at 30°C and a minimum value of 2.00 at 100°C, while the conductivity shows a peak value of 3.38×10^{-3}s/cm at 30°C and a minimum of 3.54×10^{-3}s/cm at 100°C. The results of the dielectric constant and conductivity at the Ku-band microwave frequency of 15.90GHz for the undoped sample at different temperatures are shown in figure 3-4. The results show a peak value of dielectric constant as 4.73 at 80°C and a minimum value of 4.16 at 70°C , while the conductivity shown a maximum value of 9.89×10^{-3} s/cm at 80°C and a minimum value of 9.09×10^{-3}s/cm at 40°C. The results of the peak value of iodine doped PVC at 15.90GHz are given in table1 along with the results of undoped sample.

Table 1. Peak Values of dielectric properties of PVC

Frequency GHz	Doping	Temperature °C	Dielectric Constant	Dielectric loss	Conductivity X 10^{-3}s/cm
9.4	Undoped	30	2.12	0.74	3.89
15.9	Undoped	80	4.74	1.12	9.89
15.9	Iodine Doped	30	4.75	1.25	10.62



The d.c conductivity studies of PVC [7] show a value of the order of 10^{-10} to 10^{-12}s/cm. Dielectric and loss tangent study of pure and iodine doped PVC at 9.40GHz microwave frequency by Dube[8] gives the value of 3.4 for the dielectric constant by a technique developed by Dube and Natarajan [9] to study thin films.

CONCLUSION

In the present study at 9.40GHz, the dielectric constant has been estimated as 2.11 and at 15.90GHz as 4.26 at room temperature. This small variation may be due to the reason the Von-Hippel method gives less accurate measurements as claimed by Dude and the difference in the packing of the molecules in thin films and the method used in our studies. The a.c conductivity in the present study has been estimated at 9.40GHz as $3.89x10^{-3}$s/cm and at 15.90GHz as $9.25x10^{-3}$s/cm at room temperature. The value of the conductivity measured at 9.40GHz more or less agrees with the value obtained by Dube. The peak value of dielectric constant (4.73) and conductivity ($9.89x10^{-3}$s/cm) has been observed T 80°C at Ku-band frequency of 15.90GHz in the temperature variation study. The

conductivity versus temperature study of PVC by Meenakshi maruthamuthu et al gives a change of slope in the logo versus 1000/T graph at 84°C, predicting a phase transformation at 84°C. The sudden jump in the value of dielectric constant and conductivity observed at 80°C is in agreement with their observation of phase transition at 84°C.

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