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Dielectric Absorption and Loss Study for Propanol in 10MHz to 30GHz Frequency Range

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Abstract

The complex permittivity spectra was obtained for Propanol in pure state at 25^0C , and was fitted in Cole-Davidson model, for this purpose time domain reflectometry technique has been deployed in the frequency span of 10 MHz-30 GHz using time domain reflectometry technique. The values of dielectric absorption ε′ and dielectric loss ε″ were also estimated and plotted in the frequency range. The resonance character of the attenuation (the imaginary part of the complex permittivity) can be explained in a similar way. Before the resonance the loss is increasing because the dipoles still can totally orient when the electric field changes direction, so the loss is proportional to the frequency.

Keywords: Complex permittivity spectra, Propanol, dielectric absorption, dielectric loss, Time domain reflectometry.

1. Introduction

Dielectric relaxation occurs when; a dielectric material is polarized by the externally applied alternating field. The decay in polarization is observed on removal of the field. This depends on the internal structure of a molecule and on molecular arrangement. The orientation polarization decay exponentially with time; the characteristics time of this exponential decay is called relaxation time. This phenomenon may occur as; at low frequencies, the dipoles can "follow" the field and ε′ will be high. At high frequencies, the dipoles cannot follow the rapidly changing field - and ε′ falls off. The resonance character of the attenuation (the imaginary part of the complex permittivity) can be explained in a similar way. Before the resonance the loss is increasing because the dipoles still can totally orient when the electric field changes direction, so the loss is proportional to the frequency. After resonance the frequency is so high that the dipoles do not have enough time to orient, so there is less friction and less loss. The permittivity thus acquires a complex characteristic.

The complex permittivity ε* can be written as ε′-jε″, where ε′ is a real part proportional to stored energy and ε″ is imaginary part and it is dielectric loss.

When an alternating field of high frequency is applied to a dielectric material, the dipolar polarization can't reach its equilibrium value fast enough or follow the polarizing field. Due to this, dipoles per unit volume decrease with increase in frequency and hence decrease in permittivity.

Propanol contains three numbered carbon chains with alcoholic group in first position as it is a primary alcohol with formula C_3H_8O. it is highly flammable volatile colorless liquid at room temperature . It is commonly used in dye solutions, lacquer formulations, anti freezing materials etc.

Complex dielectric spectra of certain liquids reported in the literature show multiple relaxation time behavior [1, 2]. The spectra of such liquids show deviations from the Debye dispersion curve. The representation of dispersion curve therefore needs some mathematical modifications. For this purpose, many empirical fitting functions were suggested, including the so-called Cole-Cole, [3] Cole-Davidson [4] and Havriliak- Negami [5] functions. A brief description about these functions is given in the succeeding section.

The aim of the present work is to study the complex permittivity spectra of Propanol in the frequency range of 10MHz to 30GHz using time domain reflectometry technique and to study the dielectric absorption and loss spectra of Propanol at room temperature.

2. Experimental details

2.1 Materials

Propanol was purchased from Merck India Limited and used without further purification.

2.2. Methodology

The basic TDR setup consists of broadband sampling oscilloscope, TDR module and coaxial transmission line. The Tektronix DSA8200 sampling oscilloscope with 30 GHz bandwidth and TDR module 80E08 with step generator unit was used. A 250 mV step pulse with 18 ps incident pulse was fed through Coaxial line system of 50 Ω impedance. Sampling oscilloscope monitor changes in pulse after reflection from the end of line. Reflected pulse without sample $R1(t)$ and with sample $Rx(t)$ was recorded in time window of 5 ns and digitized in 2000 points. The addition $[q(t) = R1(t) + Rx(t)]$ and subtraction $[p(t) = R1(t) - Rx(t)]$ of these pulses is done in oscilloscope memory. These subtracted and added pulses are transferred to PC for further analysis.

Result and discussion

Fig.1 reflects frequency dependence of real and imaginary part of complex permittivity spectra, at entire composition range at 25 ^{0}C.The Fourier transformations of the pulse and data analysis were done earlier to determine complex permittivity spectra ε*(ω) using non-linear least square fit method.[6,7] Complex permittivity spectra are described by Havriliak-Negami function given by [8]

$$\epsilon^{*}=\epsilon_{\infty}+\frac{(\epsilon_{0}-\epsilon_{\infty})}{[(1+j\omega\tau)^{1-\alpha}]^{\beta}}, \qquad (1)$$

Which includes the Cole–Cole[9] (β=1), Cole–Davidson[10] (α=0) and Debye[11] (α=0, β=1) relaxation spectral function in limiting form. The complex permittivity spectra have been fitted in Cole -Davidson type model using nonlinear least squares fit method to determine the dielectric relaxation parameters. It can be observed from Fig. 1 that real part ε' (dielectric constant) of complex permittivity spectra shows slow decrease up to frequency 6.6 GHz thereafter rapid fall can be observed in higher frequency regime.

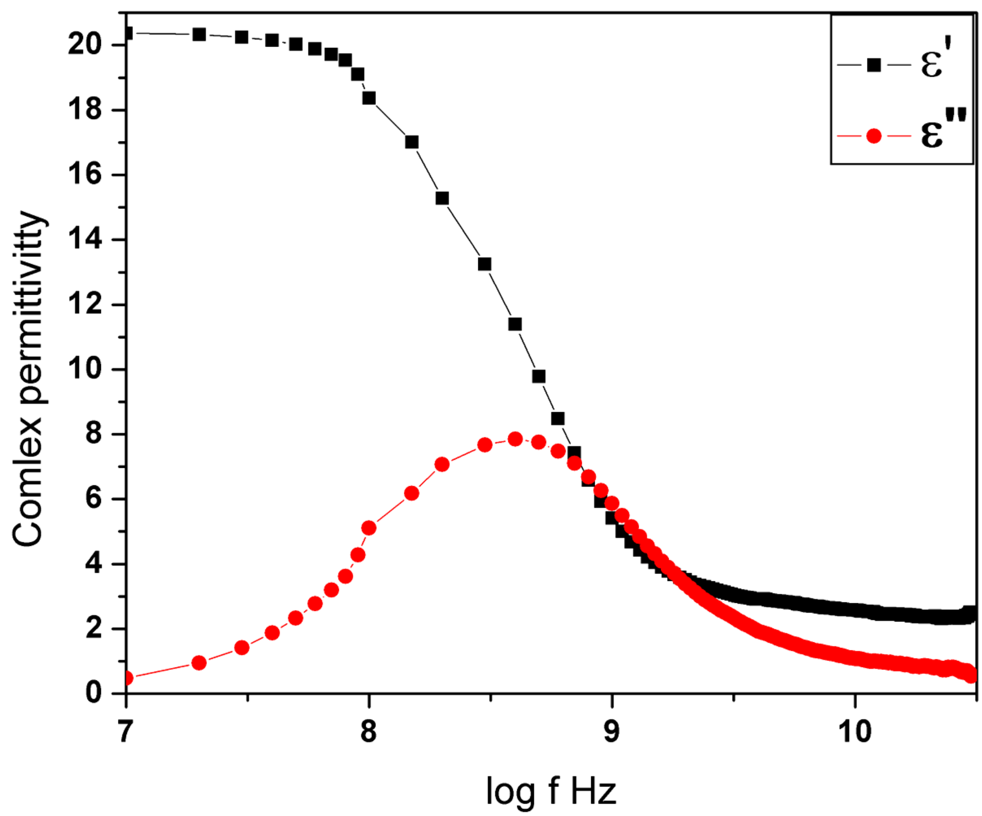

Fig.1 Complex permittivity spectra for Propanol at 25^{0}C

The decrement in dielectric constant with an increase in frequency can be attributed to continuous changes in the applied field which the dipoles cannot follow up.[12]Conversely the imaginary part ε″ (dielectric loss) shows a peak in the higher frequency side at frequency 1 GHz, it also shows shifting of dielectric loss peak towards higher frequency regime a sharp decrease with further increase of frequency.

Concluding remarks

The present investigation reports complex permittivity spectra of Propanol in frequency span of 10MHz to 30GHz. The decrement in dielectric constant with an increase in frequency can be attributed to continuous changes in the applied field which the dipoles cannot follow up. Conversely the imaginary part ε″ (dielectric loss) shows a peak in the higher frequency side at frequency 1 GHz, it also shows shifting of dielectric loss peak towards higher frequency regime a sharp decrease with further increase of frequency. Real part ε′ (dielectric constant) of complex permittivity spectra shows slow decrease up to frequency 6.6 GHz thereafter rapid fall can be observed in higher frequency regime.

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