International Journal of Scientific Research in Science and Technology
Print ISSN: 2395-6011 | Online ISSN: 2395-602X (www.ijsrst.com)
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High Frequency Dielectric Properties of DMA with 1, 4-Dioxane using picosecond Time Domain Reflectometry

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ABSTRACT

The Complex dielectric spectra $\varepsilon^*(\omega)=\varepsilon'-j\varepsilon''$ of binary mixture of N, N –dimethylaniline (DMA) with 1,4 Dioxane were obtained in the frequency range 10 MHz to 30 GHz using Time Domain Reflectometry (TDR) technique. The static dielectric constant (ε_0) and relaxation time (τ) have been obtained. On the basis of dielectric parameters intermolecular interaction are predicated.

Keywords : Time Domain Refelctometry, Complex Dielectric Spectra, Relaxation Time.

I. INTRODUCTION

The dielectric properties of a substance such as dielectric constant, dielectric loss, relaxation time have provided an insight into the structure of the molecules of the system. In liquids, the molecule has rotational freedom and its dispersion occurs at microwave frequency. Hence studying the dielectric properties at microwave frequency will reveal the dielectric relaxation of polar molecules and its variation with respect to the interaction with the neighbouring polar as well as non polar molecules. Deogaonkar & coworkers [1] found that aniline and N, N-dimethylaniline (DMA) form complexes with o-chlorophenol through hydrogen bonding at room temperature. In the present paper, the detail study of dielectric behaviour of N, N-dimethylaniline-1, 4 dioxane (DMA-DX) mixture in the frequency range of 10 MHz to 30 GHz using Time Domain Reflectometry (TDR) at temperature 25^{0}C. On the basis of dielectric parameters, intermolecular interaction and dynamics of molecules are discussed.

II. EXPERIMENTAL METHOD AND DATA ANALYSIS

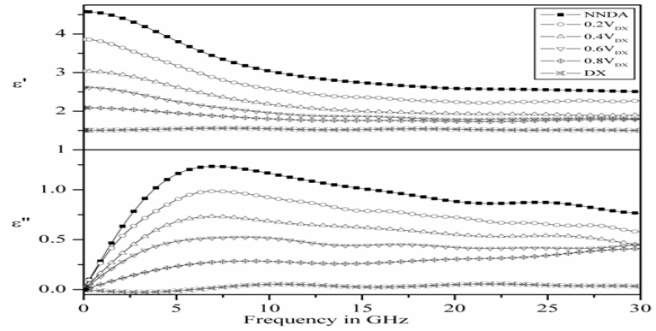
The dielectric spectra were obtained by the time domain reflectometry (TDR) technique. The Tektronix model no. DSA8200 Digital Serial Analyzer sampling mainframe along with the sampling module 80E08 has been used for the time domain reflectometry (TDR). A repetitive fast rising voltage pulse with 18ps incident rise time was fed through coaxial line system of impedance 50 ohm. Sampling oscilloscope monitors changes in step pulse after reflection from the end of line. Reflected pulse without sample R_1 (t) and with sample R_x (t) were recorded in time window of 2ns and digitized in 2000 points.

The time dependent data were processed to obtain complex reflection coefficient spectra $\rho^*(\omega)$ over the frequency range from 10 MHz to 30 GHz as [2, 3].

$$\rho^*(\omega)=\left(\frac{c}{j\omega d}\right)\left[\frac{p(\omega)}{q(\omega)}\right] \quad (1)$$

where $p(\omega)$ & $q(\omega)$ are Fourier transforms of [R_1 (t)-R_x (t)] and [R_1 (t) +R_x (t)] respectively, c is the speed of

light, ω is the angular frequency, d is the effective pin length and j= $\sqrt{-1}$. The complex permittivity spectra ε*(ω) was obtained from reflection coefficient ρ*(ω) by applying calibration method as described earlier [4].The dielectric permittivity ε′ and dielectric loss ε″ of DMA with1, 4 Dioxane at 25˚C are shown in Figure. From dispersion plot it is observed that in DMA-DX system dielectric loss is independent of volume fraction of DX.



III. RESULTS AND DISCUSSION

The complex dielectric permittivity data were fitted to a Havriliak-Negami model using non linear least squares fit method in order to extract dielectric relaxation parameters with the following expression [5].

$$\varepsilon^*(\omega) = \varepsilon_\infty + \frac{\varepsilon_0 - \varepsilon_\infty}{[1+(j\omega\tau)^{1-\alpha}]^\beta} \quad (2)$$

where ε*(ω) is complex permittivity at an angular frequencyω, ε0 is the static permittivity, ε∞ permittivity at high frequency, τ is the relaxation time, α is shape parameter representing symmetrical distribution of relaxation time and β shape parameter of an asymmetric relaxation curve. Equation (2) includes Cole-Cole (β=1), Davidson-Cole (α=0) [6], and Debye (α=0, β=1) relaxation models. The dielectric relaxation model for fitting dielectric parameters suitable for present systems is Davidson-Cole model. Therefore the complex permittivity spectra has been fitted in Davidson-Cole model with (α=0) and β (0 <β ≤ 1) as one of the fitting parameters along with ε0 &τ. The values of dielectric parameters ε0 and τ obtained from equation (2) for DMA-DX with volume fraction of DX at 250C are reported in table. The experimental values of ε0 and τ are in good agreement reported earlier [7, 8]. It can be observed that ε0 decrease with increase in volume fraction of DX. The τ values are nearly constant upto 0.60 fraction of DX in DMA and after that decreases. The decrease in τ values indicates that number of dipoles decreases in the solution.

Vol. Frac. of DX	ε_0	τ
0.0	4.486(2)	21.01(3)
0.2	3.90(1)	21.67(24)
0.4	3.82(2)	21.48(40)
0.6	3.46(3)	21.43(59)
0.8	2.760(3)	16.42(26)
1.0	2.301(2)	7.2(20)

IV. CONCLUSION

The complex dielectric permittivity spectra of DMA with DX have been studied at 25^{0}C, using time domain reflectometry technique in the frequency range 10 MHz to 30 GHz. The values of ε_0 shows systematic change with increase in volume fraction of DX in the system. The τ values are nearly constant upto 0.60 fraction of DX in DMA and after that decreases. The decrease in τ values indicates that number of dipoles decreases in the solution.

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