Electric Modulus Studies of MWCNTs doped Ferroelectric Liquid Crystal Material DOBAMBC

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Abstract
MWCNTs have been used as a dopant in Ferroelectric Liquid crystals (FLC) 2-methylbutyl 4-(4-decyloxybenzylideneamino) cinnamate (DOBAMBC). The Frequency Dependence of real and imaginary part of electric Modulus is analyzed for pure DOBAMBC and its Guest Host mixture to verify the presence of any relaxation or change in conductivity. At low Frequencies M' has constant value but between frequency 10 KHz to 500 KHz it shows a drastic increase in the value of M' for temperatures 70 and 76° C. With further increase in temperature i.e. at 84 and 88°C, M' has constant value up to frequency 500 KHz. Frequency Dependence of Electric Modulus for MWCNTs +DOBAMBC also confirms their increased conductivity relative to pure FLC. The theory is presented to explain the effect of MWCNTs in this material.

Keywords
Multi Walled Carbon Nano Tubes, Ferroelectric Liquid Crystal, 2-methylbutyl 4- (4-decyloxybenzylideneamino) cinnamate, electric Modulus

I. Introduction
The phenomenon of ferroelectricity in liquid crystals (LCs) was first suggested by the Meyer and co-workers in chiral smectic phase [1]. The first investigated ferroelectric liquid crystal (FLC) by them was 2-methylbutyl 4-(4-decyloxybenzylideneamino) cinnamate (DOBAMBC). Further experiments by Clark and Lagerwall have shown tremendous advantages of electro-optical and dielectric properties of FLCs [2]. Later, a large number of FLCs were investigated with fast E-O switching applicable for various practical devices [3–6]. The uses of these materials in devices led to a never ending demand of improvement in certain physical parameters viz dielectric, electro-optic, surface properties etc. [7-12]. The dielectric and Electric Modulus properties, of the ferroelectric liquid crystals present a special interest in the field of liquid crystals since one can observe the possible dielectric strength of device, influence of the helicoidal texture which is characteristic of these materials etc. The dielectric relaxations have been studied essentially on a theoretical basis first by Zeks and Blinc [13, 14] and more recently by Martinot-Lagarde and Durand [15].
Carbon nano tubes (CNTs), on the other hand, are rolled up sheets of graphene and possess unique electronic and optical properties. The properties of CNTs depend upon their alignment which is controlled by doping in polymers and liquid crystals. The doping of CNTs enhances the properties of host material as well. The dielectric parameters of liquid crystal material are expected to be modified by addition of CNTs.
In this paper, we present the study of effect of Multiwalled carbon nano tubes (MWCNTs) inclusion on electric Modulus parameters of ferroelectric liquid crystal mixture. The inclusion of MWCNTs seems to affect the frequency dependence and bias dependence of electric modulus behavior significantly. The data is analysed in the framework of electric modulus formalism.

II. Experimental Details
In the present study, the investigated material is DOBAMBC. It is a well characterized chiral mesogenic material and it was first compound known to exhibit SmC* phase [1].The material used here was obtained from FRINTON Lab (Vineland,NJ,USA) and used without further purification. Its phase transition Scheme is

$$\xleftrightarrow{76^\circ C} \text{SmC}^* \xleftrightarrow{96^\circ C} \text{SmA} \xleftrightarrow{116^\circ C} \text{Iso}$$

The MWCNTs used to disperse in DOBAMBC were synthesized at the National Physics Laboratory by a chemical vapour deposition method. The diameter of the synthesized MWCNTs ranged from 30−50 nm with a typical length ranging from 0.3 µm to several µm. The MWCNTs have been dispersed in concentration of 1% wt/wt ratio into DOBAMBC. The composite was prepared by mixing MWCNTs with DOBAMBC and then homogenized with an ultrasonic mixer for 1 Hr and uniform dispersion of MWCNT in the composite was ensured.
The dielectric and electric Modulus studies of pure and MWCNT-DOBAMBC composite have been conducted in planar geometry. The sample cells for the present study were prepared by Indium tin Oxide coated glass plates. The planar alignment was obtained by treating the conductive layer with adhesion promoter and coating it with polyvinyl alcohol solution. After drying the polymer layer, substrates were rubbed unidirectionally in parallel fashion. The cell thickness was maintained by placing the Mylar spacer (6µm) in between the plates and then it was sealed with UV sealant. The assembled cells were filled with sample by capillary action above the isotropic temp of DOBAMBC. The dielectric parameters were measured in the frequency range of 50Hz to 1MHz, using LCR Meter (INSTEK 8110G) interfaced with computer for further analysis. The electric Modulus parameters were measured by using dielectric data. The calibration with air and benzene enables the calculation of absolute value of dielectric constant from the measured data.

III. Results and Discussion
The electric modulus is the reciprocal of the permittivity $M^*=1/\varepsilon^*$. Although it was originally introduced by Macedo [16] to study space charge relaxation phenomena, M* representation is now widely used to analyze ionic conductivities.[17] Generally, for a pure conduction process, a relaxation peak would be observed in the frequency spectra of the imaginary component M" and no peak would take place in the corresponding plot of ε". However, for a dielectric relaxation process, a relaxation peak appears in both the M* and ε * representation. Comparisons of the ε * and M* representations have been used in this paper to distinguish localized dielectric relaxation processes from long-range conductivity [18].
Physically, the electric modulus corresponds to the relaxation of the electric field in the material when the electric displacement remains constant, so that the electric modulus represents the real dielectric relaxation process, which can be expressed as [16] M*(ω)

$$= 1/\varepsilon*(\omega) = M' + i M'' = M_\infty [1 - \int_0^\infty (\frac{-d\Phi}{dt}) \exp(-i\omega t)\, dt]$$

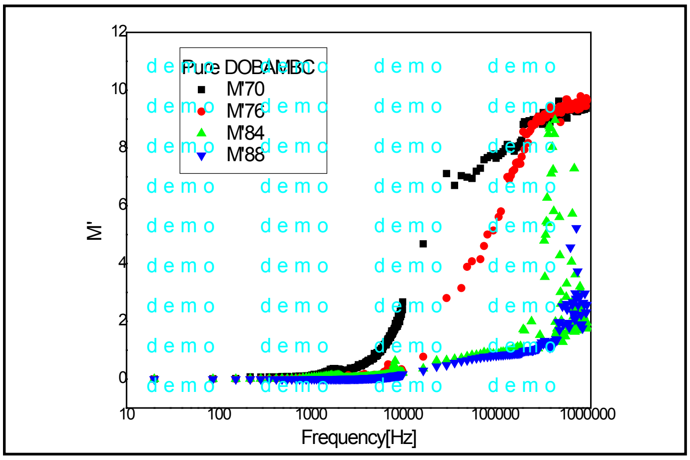

Fig. 1(a): Frequency dependence of real part of Electric modulus of Pure DOBAMBC at different temperatures.

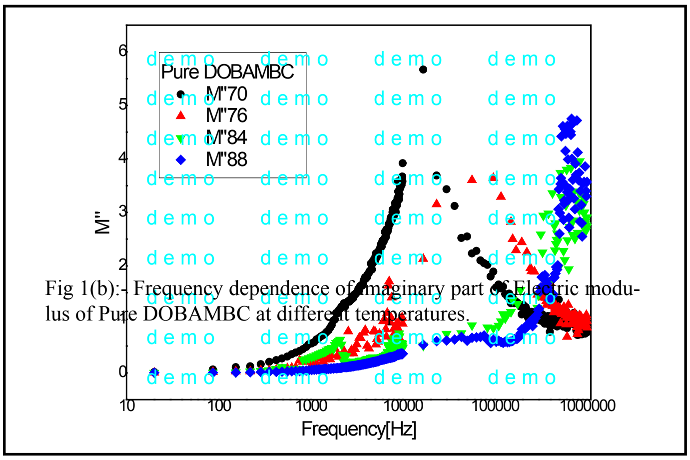

Fig. 1(b): Frequency dependence of imaginary part of Electric modulus of Pure DOBAMBC at different temperatures

Where $M_\infty = (\varepsilon_\infty)^{-1}$ is the asymptotic value of M'(ω), and Φ (t) is the time evolution of the electric field within the material. Figure 1(a) and 1(b) shows the real and imaginary parts of electric modulus, M' and M", respectively, as a function of frequency at various temperatures for pure DOBAMBC. At low Frequencies M' has constant value but between frequency 10 KHz to 500 KHz it shows a drastic increase in the value of M' for temperatures 70 and 76° C. with further increase in temperature i.e. at 84 and 88°C, M' has constant value up to frequency 500 KHz. After that it shows a slight increase in the value of M'. Peaks appearing in M" [Fig 1(b)] shifts to higher frequency with increase in temperature however no such peaks appear at temperature 84 and 88°C. Similar trend is observed in Figure 2(a) and 2(b) representing the real and imaginary parts of electric modulus as a function of frequency at various temperatures for 1% MWCNTs + DOBAMBC. In this case, however, at lower frequencies M' approaches zero confirming the presence of ionic polarization in the studied temperature range. The peak observed in Fig. 1 & 2 is purely due to conduction process. The relaxation behavior in electric modulus of doped materials is comparatively more clear representing the conducting nature of doped material.

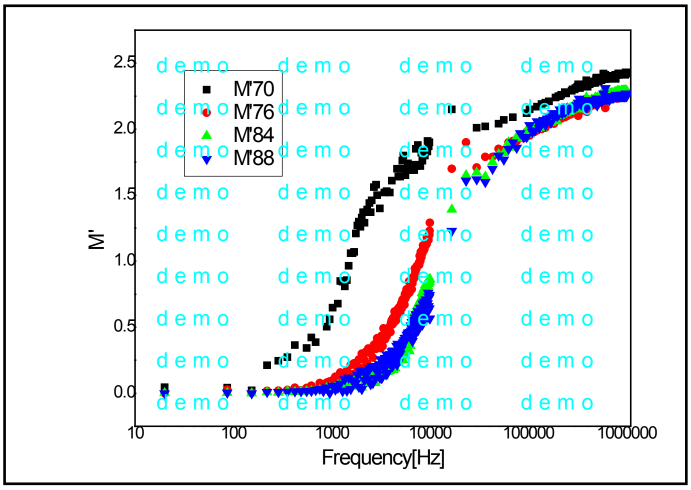

Fig. 2(a): Frequency dependence of real part of Electric modulus of 1% MWCNTs + DOBAMBC at different temperatures.

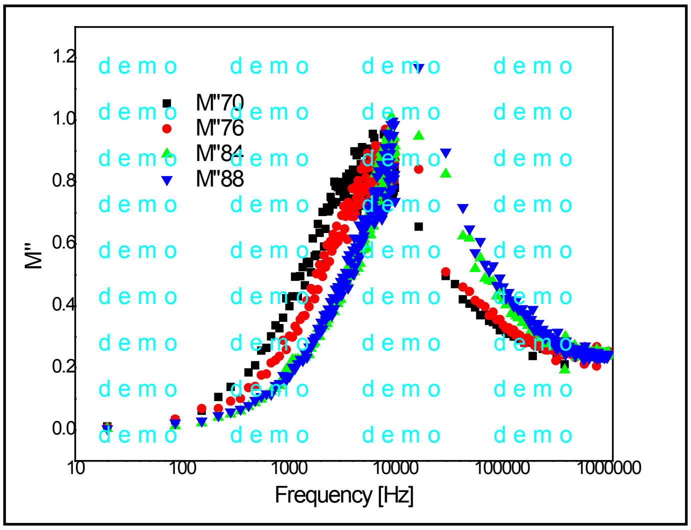

Fig. 2(b): Frequency dependence of imaginary part of Electric modulus of 1%MWCNTs+ DOBAMBC at different temperatures.

IV. Conclusion

In summary, we observe that addition of a low concentration of nanotubes into a ferroelectric liquid crystal matrix to form composites, have attracted much attention because of their unique dielectric and electric modulus properties. It was observed that for pure DOBAMBC in SmC*, the inclusion of even 1% MWCNTs in DOBAMBC results in a large decrease in the value of dielectric permittivity due to the increase in the conductivity of MWCNTs + DOBAMBC composite. Frequency Dependence of Electric Modulus for MWCNTs + DOBAMBC also confirms their increased conductivity relative to pure FLC.

V. Acknowledgment

We thank Dr Rajesh K. Mahajan (Principal J C DAV College, Dasuya) for his support in this project. The financial support from Department of Science and Technology, New Delhi is gratefully acknowledged.

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