



Review

Molecular orientation and dielectric anisotropy properties of 4-cyano-4'-n-heptylbiphenyl-TiO₂ liquid crystal compositeM. Okutan^{a,*}, F. Yakuphanoglu^b, O. Köysal^a, S.E. San^a, G.A. Oweimreen^c^a Department of Physics, Gebze Institute of Technology, Gebze 41400, Kocaeli, Turkey^b Department of Physics, Firat University, 23169 Elazig, Turkey^c Department of Chemistry, King Fahd University of Petroleum and Minerals, Dhahran 31261, Saudi Arabia

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ABSTRACT

The molecular orientation and the dielectric anisotropy of the nematic liquid crystal (LC) 4-cyano-4'-n-heptylbiphenyl (7CB) and of TiO₂-doped 7CB have been investigated. The dielectric properties of the LCs exhibit a relaxation peak that shifts to lower frequencies with increasing voltages. The relaxation frequencies of 7CB and 7CB/TiO₂ liquid crystals were calculated and found to decrease as the bias voltage increases. This is attributed to molecular reorientation. The dielectric anisotropy of the LCs changes from the positive type to negative type and the static electric permittivity and dielectric anisotropy values were found to be lower for the 7CB/TiO₂ system.

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1. Introduction

Composites based on liquid crystals (LCs) have attracted much attention over a number of years because of their unique electro- and magneto-optic properties and novel display applications [1]. The relationship between the static dielectric permittivity and the molecular properties of nematic liquid crystals has long been an objective of dielectric studies [2–4]. The static dielectric measurement has been shown to be a successful technique in characterizing molecular anisotropy and intermolecular ordering in nematic liquid crystals. The dielectric permittivity of the nematic liquid crystals is anisotropic due to their long-range orientational order. The dielectric behavior of a nematic liquid crystal is described by two dielectric constants, $\epsilon_{\parallel}$ and $\epsilon_{\perp}$ and the dielectric anisotropy $\Delta\epsilon$, defined as $\Delta\epsilon = \epsilon_{\parallel} - \epsilon_{\perp}$ [5], is an important parameter that determines the lower threshold voltage of a liquid crystal display (LCD) [6]. The development of multimedia LCDs resulted in a strong demand for new liquid crystalline materials with high clearing temperatures, negative dielectric anisotropies and low viscosities. Liquid crystal mixtures with a positive dielectric anisotropy are currently used in most active matrix displays. The mixing of two or more components is of increasing importance and interest because it can result in a composite with a valuable

practical application. Some of the properties of a blend can be different from those of the pure components, and it can behave as new single phase material down to the micro-scale level. Miscibility implies a homogeneous mixture, and pairs can exhibit complete or partial miscibility within a range of concentrations.

2. Experimental detail

Before the construction of the cells, glass substrates covered with indium tin oxide (ITO) were spin coated with a polyamide layer about 100 nm thick then rubbed with a soft cloth in one direction to align the LC molecules. The ultimate form of the constructed cell is planar with a rubbing tilt of about 2°. Each cell consisted of two glass slides separated by Mylar sheets, which is about 14 μ m thickness.

Two samples were prepared; one contains 7CB (obtained from Merck) and the other contains 1% TiO₂ in 7CB (weight/weight). P25 TiO₂ nano-particles were commercially purchased from Degussa AG, and their particle size is of order of 20–30 nm. The 7CB and 7CB-TiO₂ composite samples were mixed ultrasonic effect for 30 min. The liquid crystal cells were filled by capillary action with the prepared samples on hot plate with 45 °C. The experimental arrangement for the dielectric spectroscopy measurements is schematically shown in Fig. 1. These were carried out at room temperature with a high accuracy (typically $\pm 0.17\%$) using an HP4194A impedance gain/phase analyzer. The dielectric parameters were

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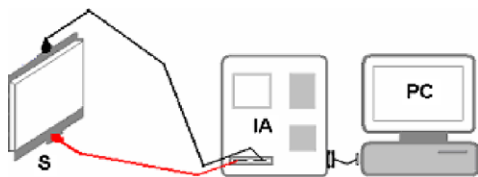


Fig. 1. Experimental set up for electrical measurements. S: sample, IA: impedance analyzer.

measured in the frequency range of 100–15 MHz, using an impedance analyzer interfaced with a computer.

3. Results

The complex dielectric constant ε^* for the liquid crystals is expressed as [7],

$$\varepsilon^*(\omega) = \varepsilon_r(\omega) + i\varepsilon_i(\omega), \quad (1)$$

where ε_r and ε_i the real and imaginary parts of the dielectric constant and their spectra are, respectively, called dispersion and absorption curves. The effect of bias voltage on the dispersion (ε_i versus f) curves

of the 7CB and 7CB/TiO₂ liquid crystals, is shown in Fig. 2(a) and (b), respectively. On contrasting Fig. 2(a) and (b), it is seen that the dielectric constant of the TiO₂-doped 7CB is different from that the 7CB liquid crystal.

The observed variation of the loss factor ε_i with frequency at different voltages is shown in Fig. 3(a) and (b) for the 7CB and the 7CB/TiO₂ systems, respectively. The dielectric loss attains a maximum that increases and shifts to lower frequencies as the applied voltage increases. This maximum corresponds to the relaxation frequency. The relaxation frequency can be determined by the following relaxation [8]:

$$\frac{v}{u} = (\omega\tau_0)^{1-\alpha}, \quad (2)$$

where

$$v = [(\varepsilon_0 - \varepsilon_r(\omega))^2 + (\varepsilon_i(\omega))^2]^{1/2}, \quad (3)$$

$$u = [(\varepsilon_r(\omega) - \varepsilon_\infty)^2 + (\varepsilon_i(\omega))^2]^{1/2}, \quad (4)$$

where ε_0 is the limiting low-frequency dielectric constant and ε_∞ the limiting high-frequency dielectric constant, τ_0 is the average

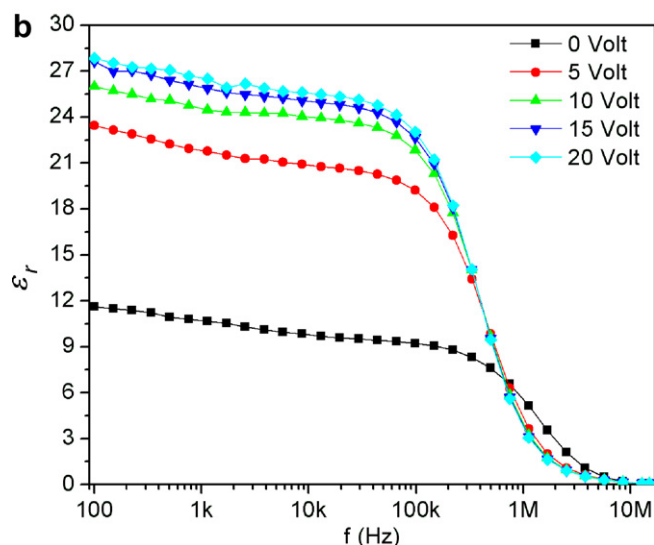
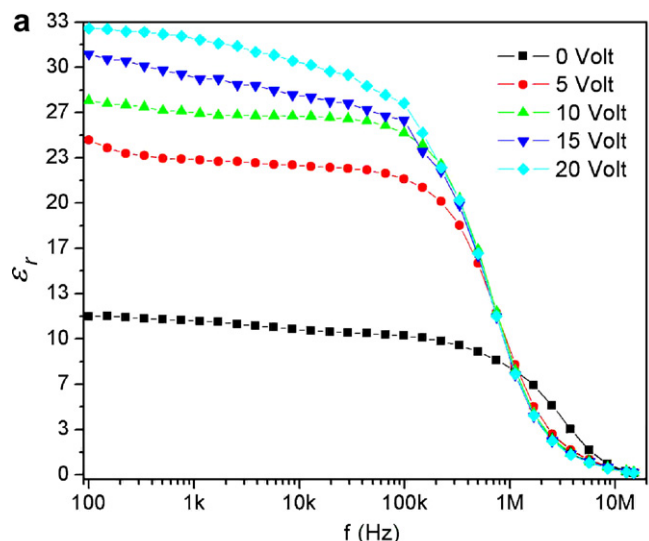


Fig. 2. Dependence of real dielectric constant on frequency (ε_r -log f) plots; (a) 7CB, (b) 7CB/TiO₂.

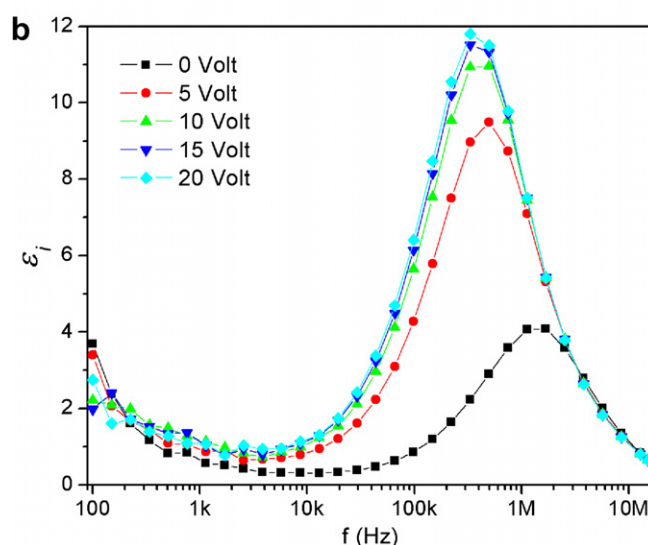
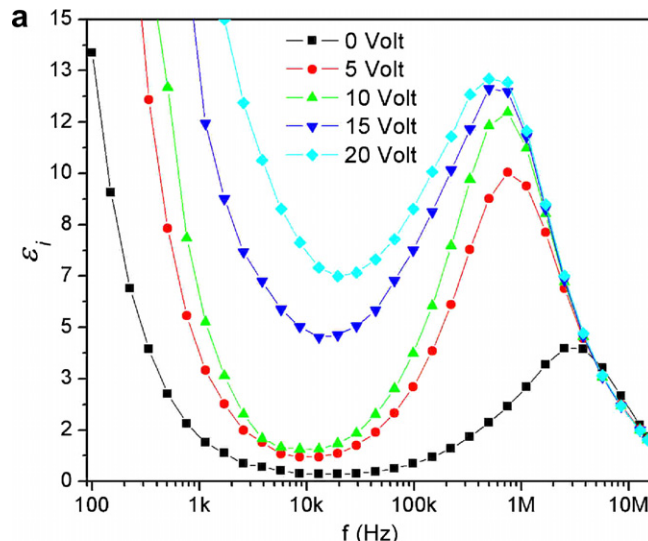


Fig. 3. Dependence of imaginary dielectric constant on frequency (ε_i -log f) plots; (a) 7CB, (b) 7CB/TiO₂.

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