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Characteristic dielectric parameters of para-, ferro- and antiferro-electric phases of (S)-4-(1-methylheptyloxycarbonyl)phenyl-4′-(6-pentanoyloxyhex-1-oxy)biphenyl-4-carboxylate

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ABSTRACT

Frequency and temperature dependence of dielectric parameters of a liquid crystalline compound (S)-4-(1-methylheptyloxycarbonyl)phenyl-4′-(6-pentanoyloxyhex-1-oxy)biphenyl-4-carboxylate under planar orientation of the molecules have been investigated in the frequency range 1 Hz–10 MHz. This compound possesses smectic paraelectric (SmA*), ferroelectric (SmC*) and antiferroelectric (SmC_A^*) phases. Dielectric spectroscopy suggests the existence of a relaxation mechanism in the SmA* phase, which behaves as a soft mode. In the SmC* phase two relaxation modes are observed. One mode continues from the SmA* phase with decreasing dielectric strength and the other has characteristics of the Goldstone mode. Two dielectric relaxation modes have been observed for the SmC_A^* phase. These two modes are related to the antiferroelectric ordering and the helical structure of the SmC_A^* phase.

1. Introduction

Smectic ferroelectric (SmC*) and antiferroelectric (SmC_A^*) phases of liquid crystals are some of the important areas of currently active researches. The ferroelectric phase exhibits unusual electric properties very much suited for electro-optical applications, in particular for high-resolution liquid crystal displays [1,2]. The antiferroelectric phase is considered as even more promising from an application point of view. Antiferroelectric liquid crystal (AFLC) displays have a number of attractive features such as intrinsic dc compensation, video speed capability, gray scale, wide viewing angle and no ghost effect [3].

Dabrowski's group has synthesized several highly tilted AFLCs with alkanoyloxy or perfluoroalkanoyloxy group in a terminal chain [4–6]. In the present work, we report dielectric studies on one enantiomeric member of this series, namely, (S)-4-(1-methylheptyloxycarbonyl)phenyl-4′-(6-pentanoyloxyhex-1-oxy)-biphenyl-4-carboxylate (4H6Bi(S)). The molecular structure of the compound is given in Fig. 1. The transition temperatures (°C) and corresponding enthalpies (kcal/mol) of this compound as obtained from differential scanning calorimeter (DSC) and thermo-microscopic (TM) texture studies in the heating cycle are given in Table 1 [5].

2. Experimental

(S)-4-(1-methylheptyloxycarbonyl)phenyl-4′-(6-pentanoyloxyhex-1-oxy)biphenyl-4-carboxylate was prepared as previously described [4]. The dielectric cell in the form of a parallel-plate capacitor was prepared using indium tin oxide (ITO)-coated glass plates (having sheet resistance of 25 Ω/□) for planar alignment of the sample. The dielectric data were acquired during cooling cycle in the frequency range 1 Hz–10 MHz using an impedance gain/phase analyzer (Solartron, model SI-1260) coupled with a Solartron dielectric interface (model-1296) for a sample thickness of 10 μm. An ac electric field of 0.5 V_{rms} is applied through electrodes. Temperature of the sample was controlled with the help of a hot stage (Instec model HS-1) having an accuracy of ±0.1 °C. Actual temperature near the sample was determined by measuring the thermo-emf of a copper–constantan thermocouple using a six and half digit multimeter with an accuracy of ±0.1 °C.

The measured data were analyzed using generalized Cole–Cole equation [7,8], which is written as

$$\varepsilon^* = \varepsilon' - j\varepsilon'' = \varepsilon'(\infty) + \sum_i \frac{(\Delta\varepsilon)_i}{1 + (j\omega\tau_i)^{(1-h_i)}} + \frac{A}{\omega^n} - j\frac{\sigma_{ion}}{\varepsilon_0\omega} - jB\omega^m \quad (1)$$

where ε_0 (= 8.85 pF/m) is the free space permittivity and $\varepsilon'(\infty)$ is the high-frequency limiting value of the relative permittivity.

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