



# Thermodynamic and bias field investigation of an antiferroelectric liquid crystal

Suman Kumari<sup>a,\*</sup>, I.M.L. Das<sup>a</sup>, R. Dabrowski<sup>b</sup>

<sup>a</sup> Physics Department, University of Allahabad, Allahabad 211002, India

<sup>b</sup> Institute of Chemistry, Military University of Technology, Warsaw 00-908, Poland

## ARTICLE INFO

### Article history:

Received 18 August 2011

Received in revised form

19 September 2011

Accepted 28 September 2011

Available online 5 October 2011

### Keywords:

Dielectric spectroscopy

Antiferroelectric

Ferroelectric

Relaxation mode

Dielectric strength

Relaxation frequency

## ABSTRACT

Dielectric spectroscopy of an antiferroelectric liquid crystal material (S)-4-(1-methylheptyloxycarbonyl)phenyl-4'-(6-pentanoyloxyhex-1-oxy)biphenyl-4-carboxylate 4H6Bi(S) for its helical phases has been carried out under bias electric field in the frequency range 0.1 Hz–10 MHz. Bias field investigation has been carried out in order to explore new relaxation modes. Dielectric characterization of the material, when carried out as a function of DC bias, reveals soft mode around 350 kHz and domain mode at  $\sim 100$  Hz in the  $\text{SmC}^*$  phase as a consequence of suppression of Goldstone mode due to helix unwinding. In the  $\text{SmC}_A^*$  phase a field induced new relaxation mode has been investigated at 8.0 kV/cm having relaxation frequency from 100 Hz to 600 Hz with increasing bias electric field.

© 2011 Elsevier B.V. All rights reserved.

## 1. Introduction

In recent years some of the most exciting results, both scientific and technological, have been drawn from the antiferroelectric liquid crystals (AFLCs) [1]. Liquid crystals exhibiting an antiferroelectric phase generally possess the phase sequence Iso– $\text{SmA}^*$ – $\text{SmC}_B^*$ – $\text{SmC}_B^*$ – $\text{SmC}^*$ – $\text{SmC}_B^*$ – $\text{SmC}_A^*$ – $\text{SmI}_A^*$ –Cr upon cooling, if they exist [2].  $\text{SmA}^*$  phase is paraelectric and is identified as a non tilted smectic phase while the others are the tilted phases. The liquid crystal materials, exhibiting  $\text{SmC}^*$  phase, are ferroelectric in nature and are characterized by layered structure in which the director  $\hat{n}$  is tilted by an angle  $\theta$  with respect to the smectic layer normal ( $\hat{k}$ ). In fact,  $\text{SmC}^*$  phases possess a geometry, which in combination with chirality results in a spontaneous polarization ( $\vec{P}_S$ ) along  $\pm \hat{c} \times \hat{k}$ , where  $\hat{c}$ -director is the projection of the molecules (or director  $\hat{n}$ ) on the smectic plane. This in-plane spontaneous polarization spirals about  $\hat{k}$  in a helical fashion. On the other hand the  $\text{SmC}_A^*$  phase is the antiferroelectric phase and is distinguished from the  $\text{SmC}^*$  phase by its anticlinic interlayer coupling, which causes the  $\hat{c}$ -directors of the adjacent layers to be almost antiparallel and so that of the spontaneous polarization [3]. These polarization vectors, being in opposite direction thus,

cancel out leading to a lack of macroscopic spontaneous polarization. But this cancellation, being not perfect, gives rise to a residual spontaneous polarization ( $\delta \vec{P}$ ) that spirals in a helical fashion and hence forms the helical structure of the  $\text{SmC}_A^*$  phase. The helicoidal structure of these smectic phases can be deformed by either making surface stabilized cells (in which cell thickness is less than pitch of the material) within which the LC materials are confined or by an external electric field applied perpendicular to the helical axis [4–7]. The destruction of the helices highly affects the dielectric properties of the AFLC materials and lead to the appearance of new relaxation modes. These effects can be investigated using the dielectric relaxation spectroscopy [7].

The temperature dependent dielectric parameters viz. dielectric permittivity ( $\epsilon'_\perp$ ), dielectric strength ( $\Delta \epsilon_\perp$ ) and relaxation frequency ( $f_R$ ) of the material (S)-4-(1-methylheptyloxycarbonyl)phenyl-4'-(6-pentanoyloxyhex-1-oxy)biphenyl-4-carboxylate 4H6Bi(S) have been reported earlier by Kumari et al. [8]. The dielectric spectrum of the investigated material contains the soft mode (SM) in the  $\text{SmA}^*$  phase, Goldstone mode (GM) in the  $\text{SmC}^*$  phase and the two characteristic relaxation modes (AFM1 and AFM2) in kHz and MHz regions in the  $\text{SmC}_A^*$  phase, respectively. Bias field studies of these two modes of  $\text{SmC}_A^*$  phase are scanty. Even in a few reported studies, there is no similarity of bias field dependence of the dielectric properties of AFM1 and AFM2 [9–13]. Moreover, reports on the appearance of new relaxation modes and variation of their dielectric parameters with the bias electric field have been limited.

\* Corresponding author. Tel./fax: +91 532 2460993.

E-mail addresses: [suman2301@gmail.com](mailto:suman2301@gmail.com) (S. Kumari), [profimldas@yahoo.com](mailto:profimldas@yahoo.com) (I.M.L. Das).