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Effect of DC bias and cell thickness on the characteristic dielectric parameters of the relaxation modes of an antiferroelectric liquid crystal

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ABSTRACT

The temperature and bias field dependent dielectric parameters of an antiferroelectric liquid crystal (AFLC) (S)-4-(1-methylheptyloxycarbonyl)phenyl-4′-(6-pentanoyloxyhex-1-oxy)biphenyl-4-carboxylate (4H6Bi (S)) have been investigated in the frequency range 0.1 Hz–10 MHz for homogeneously aligned sample cells of thicknesses 10 and 4 μm. This material possesses non polar paraelectric SmA*, polar ferroelectric SmC* and anti polar antiferroelectric SmC^*_A phases. Dielectric strength and relaxation frequency of the soft mode are almost independent of the cell thickness. On the other hand, dielectric strength of Goldstone mode (observed in the SmC* phase) is significantly diminished, whereas its relaxation frequency is increased with the decreasing cell thickness. The dielectric strengths of the usual antiferroelectric relaxation modes increase with DC bias whereas the relaxation frequencies are independent of both the DC bias and cell thickness. The domain mode in the SmC* phase and a new relaxation mode in the SmC^*_A phase appear as a consequence of helix unwinding taking place due to application of DC bias.

1. Introduction

The dielectric spectroscopy has been proven to be an important tool for investigating various collective and non-collective molecular relaxation processes existing in various liquid crystal phases. These relaxation processes have been studied by several authors [1–3]. Non-collective molecular processes correspond to the independent motions of individual molecules, where the macroscopic change in the average alignment of molecules is not detected. On the other hand the collective processes arise from the collective motion of molecules. The latter are directly related to electro-optical switching properties of the liquid crystal cells. Usually, the non-collective molecular processes appear at higher frequencies than the collective ones implying that the individual molecular motions are faster than the collective ones. Soft mode (SM) and Goldstone mode (GM) belong to the class of the collective modes. SM arises due to the collective tilt angle fluctuations and GM due to collective phase fluctuations of the directors within the smectic layers. The contribution of SM has been observed in the SmA* phase, mostly in a narrow temperature range near the SmC*–SmA* transition temperature [1]. However, in general SM has not been observed in the SmC* phase due to the dominant contribution of GM to the dielectric permittivity ($\varepsilon'_\perp$). For the observation of SM in this phase also, the helix of the phase must be suppressed so that GM can be made to disappear [3]. The unwinding or suppression of helix could be achieved by the application of DC bias perpendicular to the smectic layer normal or by reducing the thickness of the cell substrate less than the pitch of the material. The helix unwinding phenomenon also enables one to see the other collective relaxation processes in the SmC* phase such as domain modes (DM) in the bulk and near the surface [4,5]. However, the unwinding of the helix of the SmC^*_A phase due to application of electric field leads to the field induced phase transition from the antiferroelectric (AF) to the ferroelectric (F) state and accounts for the dynamics of the pre-transition phenomenon occurring between the AF and F states [6–8]. This leads to the appearance of a new relaxation mode in the AFLC phase below the frequently observed antiferroelectric modes lying in the kHz and MHz frequency region. Many authors have reported the effect of DC bias on the characteristic dielectric parameters such as dielectric strength ($\Delta\varepsilon_\perp$) and relaxation frequency (f_R) of the relaxation modes of the SmC^*_A phase which are visible even without the DC bias [9–16]. However, there was no similarity between the DC bias dependence of these parameters. Also, very few authors have reported the appearance of the new relaxation mode due to the application of DC bias [9,16]. Still the dependence of the dielectric parameters of this new mode on the DC bias has been hardly found. Similarly, the thickness dependence of the dielectric parameters of the different relaxation modes of various smectic phases has not been widely studied. However, Ray et al. [17,18] have reported the effect of cell thickness on the dielectric parameters but for the SmC* phase only. The thickness effect on these parameters for the relaxation modes of the SmC^*_A phase is still available in scanty.

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