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Thermodynamic and dielectric spectroscopy of a racemic antiferroelectric liquid crystal

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ABSTRACT

The thermodynamic and dielectric spectroscopy of a racemic antiferroelectric liquid crystal (R,S)-4'-(1-methylheptyloxycarbonyl)biphenyl-4-yl 4-[3-(2,2,3,3,4,4,4-heptafluorobutoxy)prop-1-oxy]-2,3-difluorobenzoate at room temperature is reported in this paper. On account of racemization, the material is composed of non chiral SmC and SmC_A phases instead of possessing the conventional chiral phases. Unlike the chiral SmC* phase which shows the Goldstone mode during dielectric investigations, this material in the SmC phase has shown a Domain mode. This relaxation mode possesses weak dielectric strength and temperature dependent relaxation frequency. Two relaxation modes have been observed in the SmC_A phase. The dielectric strength of one of these modes is found to be almost temperature independent whereas that of the other is found to vary inversely with temperature. The relaxation frequencies of both of these relaxation modes have been examined to be directly related to the temperature.

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1. Introduction

In the last two decades, a considerable number of theoretical and experimental works have been devoted to the study of dielectric and electro-optic properties of the ferro- and antiferro-electric liquid crystals (FLCs and AFLCs) [1–10]. Ferroelectricity in the chiral Smectic C (SmC*) phase or ferroelectric (F) phase of liquid crystals (LCs) has been initially reported by Meyer et al. in 1975 [1]. However, antiferroelectricity in the chiral Smectic C_A (SmC*_A) phase or antiferroelectric (AF) phase was first reported by Chandani et al. in 1989 [6]. In the SmC* phase, molecules are tilted at an angle θ with respect to the smectic layer normal (\hat{k}). The molecules rotate through an azimuthal angle ϕ in the adjacent smectic layers and hence spontaneous polarization (\bar{P}_S) rotates from layer to layer forming a helical structure with \hat{k} as the helix axis. This \bar{P}_S is perpendicular to both the \hat{k} and \hat{c} -directors. The SmC*_A phase differs from the SmC* phase in respect of orientation of molecules in adjacent smectic layers. In this phase, the molecules in neighboring layers are tilted in the opposite directions with respect to \hat{k} . Hence, the dipole moments of two adjacent layers are canceled out resulting in the zero net dipole moment. This implies the lack of macroscopic

spontaneous polarization in the AF phase. Because of their specific molecular configuration and arrangement, the FLCs and AFLCs have shown great potential for their use in the electro-optical displays [2,5–8,10]. But, AFLCs are rather better over FLCs due to their tristate switching behavior (double hysteresis), easy DC compensation, microsecond response, hemispherical viewing angle, no ghost effect, gray scale capability and ability of multiplexing in passively addressed matrices [6–8,10]. To obtain quick electro-optic response necessary for their display applications, it is essential to first suppress helix of the F and AF phases of these materials. This situation can be achieved in the surface stabilized FLCs and AFLCs (SSFLCs and SSAFLCs) which are characterized by having the cell thickness less than the pitch of the material [11]. But it is difficult to manufacture cells of such small thickness and that too may be easily damaged from the mechanical shocks. The other method is to apply electric field to the helical states of these materials to unwind their helices. This requires a critical external electric field beyond which the alignment is destroyed. Moreover, such thin cells may not withstand the higher applied voltages. One of the methods to overcome these difficulties is to make a mixture of the R and S enantiomers of the AFLC material in the ratio 1:1, i.e., to make a racemic AFLC material. In this situation, \bar{P}_S of the two enantiomers being in opposite directions, are canceled out due to the opposite optical rotation of their molecules. And thus, the helix does not exist in the racemic materials. This property will be helpful in the fast switching performance of these materials. Moreover, these racemic AFLCs are advantageous from the point of view of the alignment because it is very difficult to align chiral phases.

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