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Conductance and dielectric anisotropy properties of 4-cyano-4′-hexylbiphenyl-salicylaldimine compound composite liquid crystal exhibiting large positive dielectric anisotropy

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Abstract

The electronic properties of 4-cyano-4′-hexylbiphenyl and salicylaldimine compound **1** liquid crystals have been investigated. The polarizing microscopy and differential scanning calorimetry results show that chiral salicylaldimine compound **1** exhibits enantiotropic smectic A* and SmC* mesophases. The novel 4-*n*-hexyl-4′-cyanobiphenyl/salicylaldimine compound **1** composite showed an extremely large positive dielectric anisotropy. The dielectric anisotropy of the LCs changes from positive type to negative type. The critical frequency f_c values of dielectrical anisotropy for 4-*n*-hexyl-4′-cyanobiphenyl and salicylaldimine compound **1** LCs were found to be 630.50 and 813.01 kHz, respectively. The splay elastic constant K_{11} values of the liquid crystals were calculated and the doping of salicylaldimine compound **1** into 4-cyano-4′-hexylbiphenyl liquid crystal increases the splay elastic constant of 6CB. The parallel conductivity $\sigma_{\parallel}$ values of the liquid crystals are higher than that of perpendicular conductivity $\sigma_{\perp}$ values and conductivity of the 4-cyano-4′-hexylbiphenyl decreases with doping of salicylaldimine compound **1**.

Keywords: Liquid crystal; Dielectric anisotropy; Salicylaldimine; Elastic constants

1. Introduction

4-Cyano-4′-hexylbiphenyl (6CB) is one of the best-known liquid crystalline substances. 6CB, as well as other members of the *n*CB homologous series, is important from the point of view of applications due to the possession of a strong dipole moment, good chemical stability and a convenient temperature range of the nematic phase [1]. Dielectric relaxation spectroscopy has proven to be powerful technique to obtain the valuable information about the molecular properties of nematic liquid crystals. The relationship between static dielectric permittivity and molecular properties of liquid crystals has long been an objective of dielectric studies [2–4]. The anisotropic dielectric properties of liquid crystals play an important role in determining the electro-optical response of liquid crystal devices. Liquid crystal mixtures with a positive dielectric anisotropy are used for most active matrix displays and the image quality of liquid crystal displays (LCDs) is strongly dependent on the dielectric anisotropy of the LC [5]. The physical and optical properties of liquid crystals can be developed by doping of different organic materials and thus, new liquid crystals modified electronic and optical properties may be prepared. The main aim of this study is to prepare new liquid crystal material and develop its electronic properties.

2. Experimental

2.1. Synthesis of the salicylaldimine compound *1*

The chiral salicylaldimine **1** was prepared as described methods previously [6] by the condensation of 4-fluoro

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alkyloxy-2-hydroxybenzaldehyde and (*S*)-4-(2-methylbutoxy)aniline in toluen with *p*-toluensulfonic acid as catalyst and purified by crystallization from acetone/methanol. The compound **1** was characterized by various spectroscopic methods, e.g. ^{1}H, ^{13}C NMR ($CDCl_3$), UV–VIS, IR and mass. The proposed structures are in full agreement with these spectroscopic data. The spectroscopic data for compound **1** are given in Ref. [7]. The chemical structure of the compound **1** is shown in Fig. 1a. Transition temperatures were measured using a Mettler FP 82 HT hot stage and control unit in conjunction with a Nikon Optiphot 2 polarizing microscope, and these were confirmed using differential scanning calorimetry (DSC) (Perkin-Elmer DSC-7, heating and cooling rate: $10\,K\,min^{-1}$).

2.2. Measurements

Before the construction of the cell, indium tin oxide (ITO) covered glass substrates were spin coated with polyvinyl alcohol (PVA) at 2000 rpm and they were cured at 50 °C for 2 h. The thickness of the coating is 100 nm and these coating layers were exposed to surface treatment of unidirectional rubbing with velvet in order to obtain preliminary molecular orientation. The ultimate form of the constructed cell is planar with 2° rubbing tilt. Measurement cell was made up of two glass slides separated by Mylar sheets having 14.1 μm thickness assembled for parallel alignment. The liquid crystal used in this study is 4-cyano-4′-hexylbiphenyl (6CB) (Fig. 1b). This liquid crystal is crystalline below 14.5 °C, nematic in the range 14.5–29.4 °C, and isotropic at higher temperatures. The salicylaldimine **1** (SCL1; 0.1 g) was dissolved within (6CB; 0.03 g). The solutions of 6CB and SCL1 compounds were mixed by ultrasonic effect. The sample cell was filled with 6CB/SCL1 composite. The final cell gap is 14.2 μm. The capacitance–voltage (*C*–*V*) measurements were performed by HIOKI 3532-50 LCR meter at room temperature.

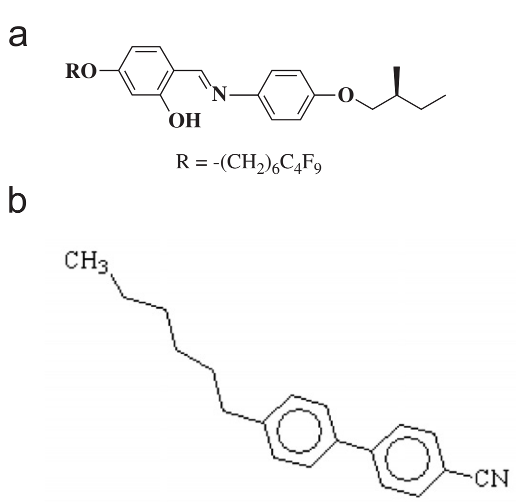

Fig. 1. The chemical structures of the liquid crystals: (a) salicylaldimine compound **1** and (b) 4-cyano-4′-hexylbiphenyl (6CB).

3. Results and discussions

3.1. Liquid crystalline properties of the salicylaldimine compound 1

The salicylaldimine compound **1** exhibits liquid crystalline properties and shows thermotropic enantiotropic mesophases. The investigations by polarizing microscopy and DSC show that it exhibits chiral smectic mesophases. The texture of the mesophases has been detected by polarizing microscopy (Fig. 2). The DSC curve of the compound **1** confirms the phase transition temperatures detected under microscope (Fig. 3). The transition temperatures and the thermodynamic data of the compound **1** are given in Table 1. The chiral salicylaldimine **1** with semifluorinated alkyl chains exhibits enantiotropic smectic A* and smectic C* mesophases. The SmA* phase can be detected by the typical fan-like texture which can be aligned homeotropically. The SmA*–SmC* transition is characterized by the formation of a *schlieren* texture in the homeotropically aligned regions of the SmA*.

3.2. Determination of dielectric anisotropy and elastic constant values of SCL1/6CB liquid crystal composite

Figs. 4(a,b) show the plot of capacitance–voltage of 6CB and 6CB/SCL1 liquid crystals for $\Delta\varepsilon > 0$ at different frequencies. The capacitance values increase from the initial value $C_{\perp}$ to the final value $C_{\parallel}$. The plots indicate a threshold voltage and reorientation occurs above a threshold voltage. This voltage is called as Frederiks threshold voltage. Frederiks threshold electric field is a key parameter for any electro-optical applications of liquid crystal materials. This transition is the result of the competition between two orientational effects, which are the orientations of the director field at the boundary and due to an external electrical field. The applied electric field to LC

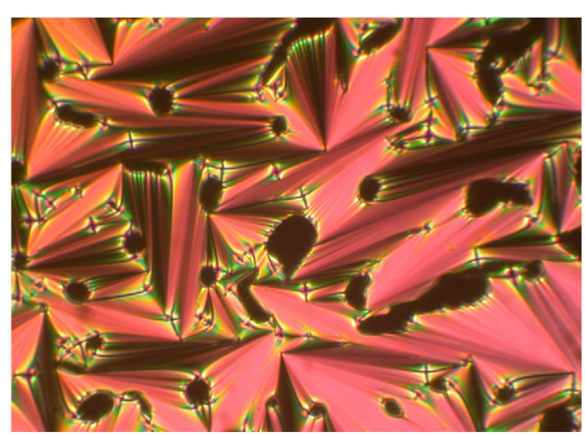

Fig. 2. Polarized light optical photomicrograph of the mesophase of compound **1** as observed on cooling smectic A* phase at 136 °C.