Optical mesophase textures and the enthalpy changes with temperature of a liquid crystal compound 9OBA

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Abstract

In this article, our intention is to observe the mesophase textures of a liquid crystal (LC) compound 4-nonyloxybenzoic Acid (9OBA) in an attempt to understand the nature of dramatic changes of the mesophase transition textures with temperature. The studies of mesophase textures were carried out by using polarizing optical microscope (POM). Mesophase transition temperatures and their corresponding enthalpy changes (during heating) are experimentally deduced from differential scanning calorimetry (DSC). Higher value of enthalpy changes has been observed for the solid crystalline to Smectic C (SmC) transition. The compound 9OBA is found to exhibit nematic and SmC mesosphase and may be useful for the projection display since it exhibits high clearing temperature. Copyright © 2017 VBRI Press.

Keywords: Phase transition, mesophase, optical texture, enthalpy, clearing temperature.

Introduction

Liquid Crystals (LCs) are one of the delicate and beautiful states of matter. This state of matter can be described as condensed fluid states with spontaneous anisotropy. In light of molecular order, LC molecules have the high orientational order found in crystalline solids as well as the low positional order found in liquids or amorphous glasses. In a word, the degree of ordering of molecules in a LC lies between that of an isotropic liquid and a crystalline solid. For this reason, they are also known as mesomorphic phases. They exhibit some properties of crystalline solid and also some properties of liquids e.g. they possess liquid properties like fluidity, formation and coalescence of droplets. At the same time, they exhibit anisotropy in their optical, mechanical, electrical, magnetic properties similar to a solid crystal. LCs has been extensively investigated due to growing of its numerous applications in the field of device technology, industry, consumer product and medical science **[1]**. The greatest technological impact of LCs has been observed in electronic displays where the LC display (LCD) market continues to experience explosive growth. LCs have been seen in small sized displays such as digital wrist watches, calculators, cellular phones, digital cameras, head mounted displays and panel meters and in large-sized displays such as direct-view televisions (TV) and projection TVs. LCDs have the advantages of large resolution and high brightness. The recent applications of LCs include photonic devices such as laser beam steering, variable optical attenuators, recording and storing display images which can be projected onto a large screen. Researches on the LC compounds having high optical birefringence have been growing because it increases response time of the LC devices. The "beyond display" applications of LCs are equally important and numerous. LCs can potentially be used as new functional materials for optical and bioactive materials. Recently, their bio-medical applications have been demonstrated **[2]**. The compound 9OBA is a rod like low molar mass LC. This type of LC is most widely used in electro-optical applications including erasable optical disks, full color "electronic slides" for computer-aided drawing (CAD), and light modulators for color electronic imaging **[3]**. The author M. Ramakrisna *et al.* **[4]** determined the ordinary and extra ordinary refractive index of the compound 9OBA and they also measured the orientational order parameter of this compound. The mesophase transition temperature and also viscoelastic properties of this compound were measured by the author S. Sreehari Sastry *et al.* **[5]**. The author P. V. Datta Prasad *et al.* **[6]** studied the variation of density with temperature of this compound.

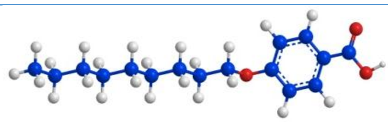
In this paper, our aim is to study the mesophase transition temperatures and the optical mesophase textures of the LC compound 9OBA. To use LC in any field of its application, it is very essential to have the accurate knowledge about the phase transition temperatures and clearing temperature e.g. LC compounds with high clearing temperature are preferable for direct view and projection display. The studies of optical mesosphase texture help us to identify the type of mesophase and its range. The enthalpy changes during heating of this compound have also been conducted.

Experimental

Materials

The LC compound 9OBA has been procured from the Frinton laboratories of USA. Chemical structure of 9OBA is shown in **Table 1**. The purity of the compound is almost 100% and no further purification was done.

Table 1. Chemical structure of the LC compound

LC compound	Chemical Structure
9OAB	

Method

To obtain the textures and phase transition temperatures, LC sample in their powdered form was melted to isotropic temperatures on a clean glass slide and then covered using a cover slip. The optical mesophase textures for the compound 9OBA was conducted using a Leica DM 2500P POM having a Linkam LTS420E hot stage, controlled by Linkysis32 software. The samples were heated and cooled at a rate of 1^oC/min. The accuracy of the POM is 0.01^oC. The photographs of textures were taken during cooling of the sample from isotropic to solid crystalline state. Observation was done under the crossed polarization condition. The phase transition temperatures and phase sequences were studied by using DSC [model: Perkin Elmer, DSC-4000] and enthalpy were measured during heating. Heating and cooling observations were done at the rate of 5°C/min.

Results and Discussion

Mesophases transition temperatures and phase identification

POM is a standard tool in the identification of LC phases and phase transitions. Every LC phase possess their own characteristic textures. Therefore, a particular phase and its transition temperature can be determined by observing the textures under POM. The mesosphase transition temperatures both during heating and cooling have been observed by POM are shown in **Fig. 1**.

It was found that the compound exhibits high clearing temperature (140^oC) and the range of SmC and nematic of this compound are almost same. It was found from the study of optical mesophase texture that the profile of compound 9OBA contains SmC and nematic mesophase.

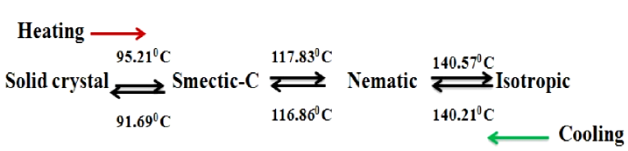


Fig. 1. Phase transition temperatures of the compound 9OBA.

SmC is a phase of LC compounds where the molecules possess long range orientational order along with positional order and the molecules make a tilt angle with the orientational layer. In nematic phase, LC molecules only have long range orientational order but do not have any long range positional order. **Fig. 2(b)** and **Fig. 2(c)** represent the nematic and SmC mesophase textures for the compound. It has been found that 9OBA exhibits nematic marble texture and SmC Schlieren texture **[7, 8].** The optical texture for the isotropic to nematic phase transition is shown in the **Fig. 2(a)** and solid crystalline texture is shown in **Fig. 2(d).**

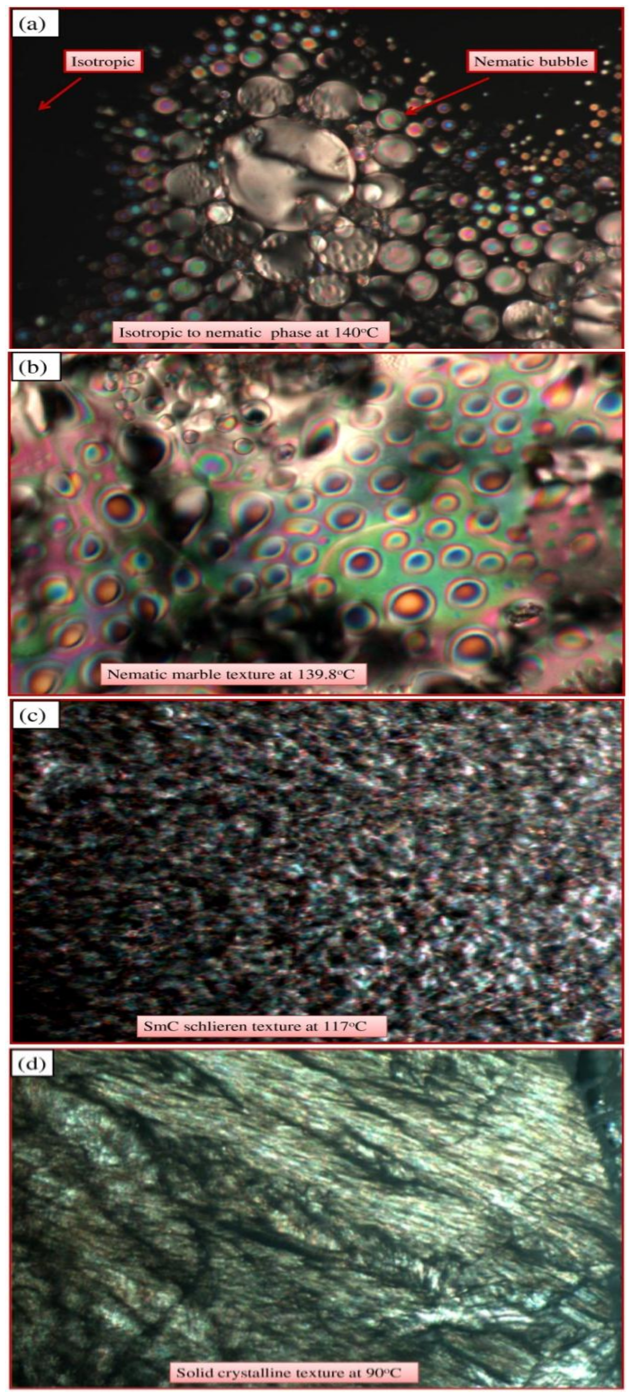


Fig. 2. Mesophase optical texture of the compound 9OBA.

Enthalpy changes with temperature

DSC study of liquid crystalline compounds provides the phase transition temperatures and the order of their transitions i.e. first order or second order transition. It provides more precise determination of phase transition temperatures and transition enthalpies. The transition temperatures of the LCs are obtained by measuring the enthalpy change associated with each transition. The values of enthalpy changes associated with transitions are useful guide for phase identification. The phase transition temperatures observed by DSC **(Fig. 3)** are in good agreement with the POM data which indicates the purity of the compound 9OBA.

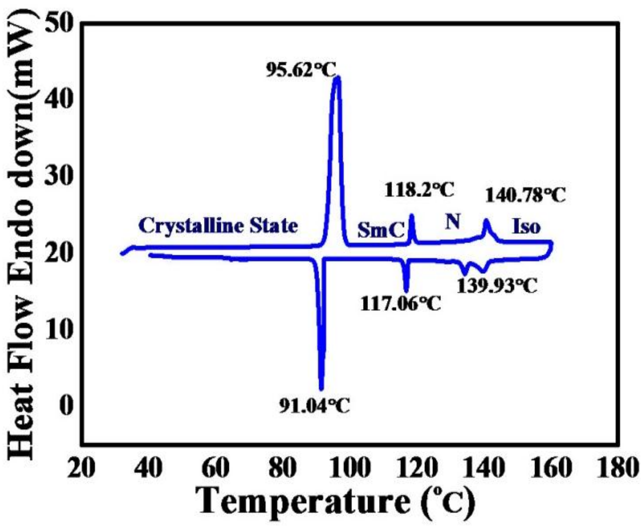


Fig. 3. DSC thermographs of the LC compound 9OBA.

Enthalpy changes corresponding to each mesophase transition during heating are shown in **Table 2**. At the temperature 95.62°C, an amount of 35.2798 kJ mol^{-1} energy was found to be released which indicates a large disruption of packing order of the LC molecules.

Table 2. Enthalpy change of the LC compound 9OBA during heating.

Phase Transition	Temperature (°C)	ΔH$_f$ kJ/mol
Solid crystalline – SmC	95.62	35.279
SmC – Nematic	118.2	1.237
Nematic – Isotropic	140.78	0.8532

In the case of solid crystalline to SmC transition, LC molecules change their positional and orientational order which requires a large amount of energy. At 118.2 °C, it is observed that 1.2371 kJ mol^{-1} amount of energy has only been released during SmC to nematic transition, where molecules maintain the orientational order. But, a small disruption has been occurred in the positional order. At the temperature 140.78°C, molecules loose both the orders and become an isotropic liquid by releasing 0.8532 kJ mol^{-1} energy. So, crystalline solid to SmC transition is a 1st order transition whereas SmC to nematic and nematic to isotropic are 2nd order transition.

Conclusion

It was observed from the POM study that the profile of the compound 9OBA contains nematic and SmC schlieren textures. It has also been found from the POM and DSC study that the compound exhibits high clearing temperature. At the SmC, LC mesophase molecules lost their long range positional order, they have only orientational and short range positional order. Due to this reason, in case of solid crystalline to SmC transition, LC molecules require a large amount of energy as a result exhibits high enthalpy values. When the local packing order of the molecules is destroyed except the orientational order, LC material shows nematic phase and hence comparatively lower energy has been found to release in the SmC to nematic transition, as a result we obtain low enthalpy values. If the compound 9OBA exhibits low optical anisotropy, it may be useful for the direct view and projection display since it exhibits high clearing temperature.

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Author's contributions

Conceived the plan: SP; Performed the experiments: SP; Data analysis: SP, AN; Wrote the paper: SP. Authors have no competing financial interests.

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