Optical and Thermal studies on CNT doped Liquid Crystal Mixtures

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Abstract

In the present study, effect of CNT on optical and thermal properties of mixed thermotropic liquid crystal mixture was studied by various techniques to understand their physical behavior. Some new mesophases have investigated by optical methods viz. Polarizing Optical Microscopy (POM) and Fabry–Perot Scattering Studies (FPSS). It has been observed that these new phase transition occur along with the known phase transition temperatures. These new phase transitions corresponding to new mesophases were also confirmed by thermal study using Differential Thermal Analysis (DTA). The CNT doped thermotropic liquid mixtures can be used in various display application such as LCD monitor with color variation to enhance performance. Copyright © 2018 VBRI Press.

Keywords: Liquid Crystal (LC), Polarizing Optical Microscopy (POM), Fabry–Perot Scattering Studies (FPSS), Differential Thermal Analysis (DTA), Phase Transition Temperature (PTT).

Introduction

Liquid Crystal (LC) is a thermodynamic state of matter in which the molecules are orientationally ordered though being in dynamic motion. The preferred direction of molecules in the liquid crystal material is known as director. The orientational order of LC molecules is given by a quantity known as order parameter given by $S = (3\cos^2\theta - 1)/2$, where θ is angle of individual domain with director. For a perfectly uniaxially oriented sample value of *S* is 1 whereas for a completely random, isotropic sample S is 0. LCs are soft functional materials and have attracted great deal of attention due to their various applications in display devices, light modulator, temperature sensors and optical communication networks. These materials lie in the temperature range between the solid and isotropic liquid phase and hence the term mesophase is used for them. The structures of these mesophases are based on parallel arrangements of elongated molecules [1–4, 14-18]. When the light enters LC material, it splits into an ordinary and extraordinary ray. The two rays recombine each other when they exit the sample. The state of polarization changes due to phase difference between two rays. Due to this property, LC materials are said to be birefringent in nature. These materials have different mesophases phases like nematic, smectic and cholesteric etc. The phase transitions of LC material between various mesophses occur at thermodynamically defined temperatures, when it undergoes a change in internal order at that temperature. The recognition and classification of various phases can be done with texture studies. The nematic and cholesteric LCs have recently been the subject of renewed interest because they combine the fluidity and anisotropy with specific properties of particles. [5 –7]. The miscibility of two different LC phases is important both for the identification of various liquid crystalline phases and for the preparation of mixtures with well-defined phase transitions. Arnold, Scakmann and Demus developed the miscibility rules which can be summarized as follows: (a) If two LCs are miscible, they are isomorphic and therefore belong to the same type of mesosphase and (b) If two LCs are isomorphic, they need not necessarily be miscible. When two compounds are isomorphic within a certain mesophase, both their thermal transition temperatures and corresponding thermodynamic parameters exhibit continuous dependence on their composition [8-10].

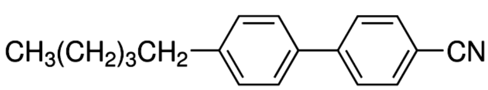
Carbon nanotubes (CNTs) describe a family of nanomaterials made up entirely of carbon which shows unique combination of stiffness, strength and tenacity. They are classified into single walled carbon nanotube (SWCNT) and multiwalled carbon nanotube (MWCNT) depending on the structure and dimensions. SWCNT consist of single layer of cylindrical graphene having lengths from 20 to 1000 nm, whereas MWCNT consist of several concentric graphene sheets of greater dimensions having lengths from 1 to a few microns. MWCNTs have interesting set of properties. Hence they have a wide variety of potential applications in liquid suspensions, polymer solutions, polymer melts, and polymer composites [11-13].

The studies on LC composites, filled with nanoscale colloidal particles present a great scientific and practical interest due to their applications in electromechanical memory, super-elongation, anomalous electro kinetic dispersion and ultra-low percolation thresholds [5,7, 8, 11, 13].

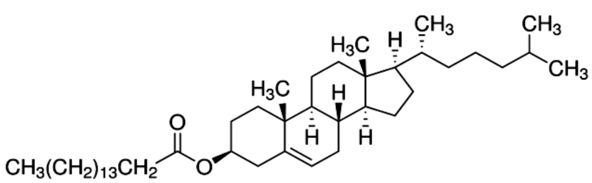
The optical and thermal investigations were performed using Polarizing Optical Microscopy (POM), Fabry–Perot Scattering Studies (FPSS) and Differential Thermal Analysis (DTA). Our investigations report the improvement in performance of LC composite after doping MWCNT. These materials can be used for wide range of scientific and industrial applications. It was investigated that MWCNT improves the distinctive electro-physical, photonic and electro-optic characteristics of liquid crystals (LCs) used in optical device and display applications. Doping of LC with CNTs allows reduction of the response time and driving voltage. It also suppresses the parasitic backflow and image sticking typical for LC cells.

Experimental

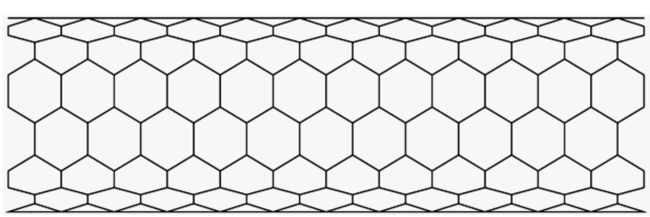
The nematic LC, 5CB (4′-Pentyl-4-biphenylcarb-onitrile liquid crystal (98%), cholesteric LC Palmitate (97%) and MWCNT (>90% carbon basis) were procured from Sigma-Aldrich and used without further purification. The structure of LC and MWCNT is shown in **Fig. 1** below.



(a) Molecular structure of 5CB



(b) Molecular structure of Palmitate



(c) Structure of MWCNT

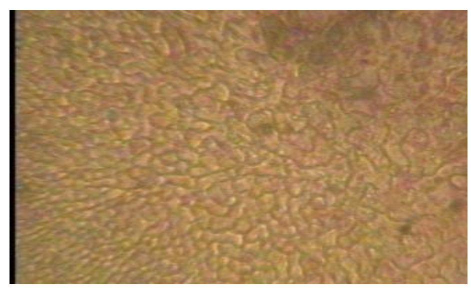
Fig. 1. Structure of LC and MWCNT.

The MWCNT was mixed with Oleic acid and Heptane in appropriate proportion (wt/wt) then this mixture was doped with equal amount (wt/wt) of 5CB and Palmitate LC by ultra-sonication method. The ultrasonicator ensures homogeneous distribution of MWCNT in LC mixture. The mixtures were kept in vacuum for 8 hours for evaporation of heptane completely. The heptane acts as carrier liquid and oleic acid as a dispersing agent (both were procured from Sigma Aldrich.) The resulting sample contains small concentration (~0.1%) of MWCNT.

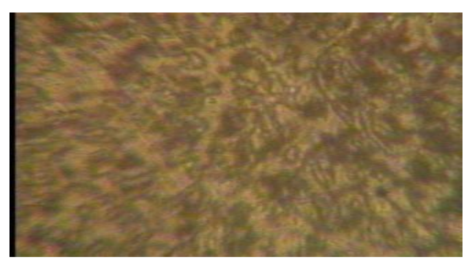
Results and discussion

Polarizing Optical Microscopy (POM)

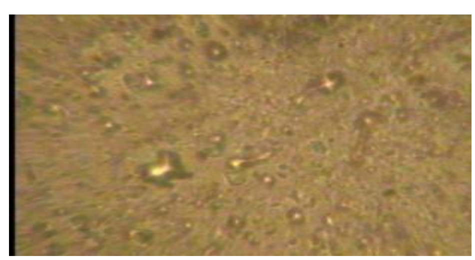
Polarizing Optical Microscopy (POM) is the most widely used investigation technique for identifying different phases when used for miscibility of binary mixtures. Depending on the boundary condition and the type of phase, varies textures are obtained which are characteristic of a particular phase. These textures were found to change when material enters from one phase to another. In the present study Carl-Zeiss (Jena) Amplival Polarizing Microscope is used. The sample under investigation was sandwiched between two transparent cover slips and placed for observation on the heating stage under the microscope objective. The textures were studied and photographed for various heating and cooling cycles. The textures for LC composite and MWCNT doped LC composite is shown in **Fig. 2** and **Fig. 3** respectively.



(a) Schileren texture at 52 ^{0}C

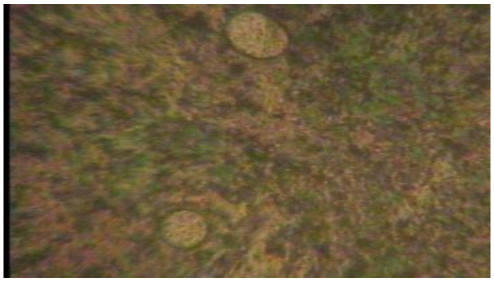


(b) Nematic Schileren at 58 ^{0}C

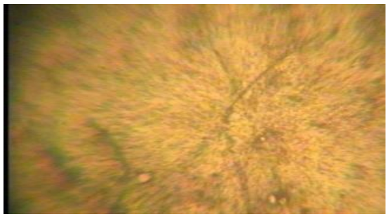


Nematic Droplet at 64 ^{0}C

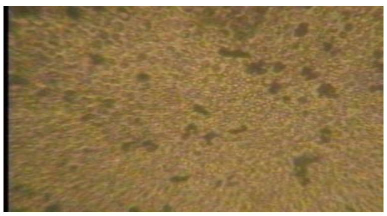
Fig. 2. Textures of Composite LC .



(a) Nematic Schileren at 30 ^{0}C



(b) Nematic threaded at 45 ^{0}C



(c) Nematic Droplet at 34.8 ^{0}C

Fig. 3. Textures of MWCNT doped LC.

The Phase Transition Temperatures (PTTs) investigated by POM is shown in **Table 1** below.

Table 1. PTTs of investigated by POM.

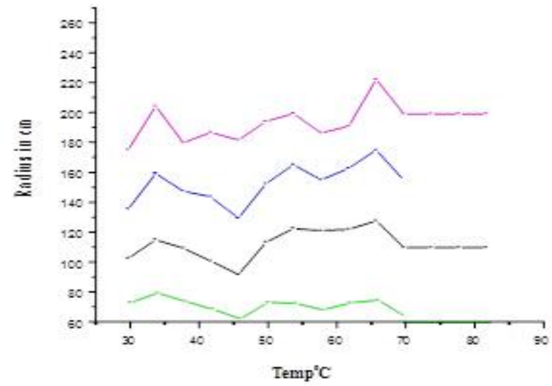
Sample	PTTs (in ^{0}C)
Composite LC	30, 32, 34, 40, 42, 45, 52, 55
MWCNT doped LC	30, 32, 36*, 42, 45, 50*, 53*, 60*

* shows enhancement in PTT.

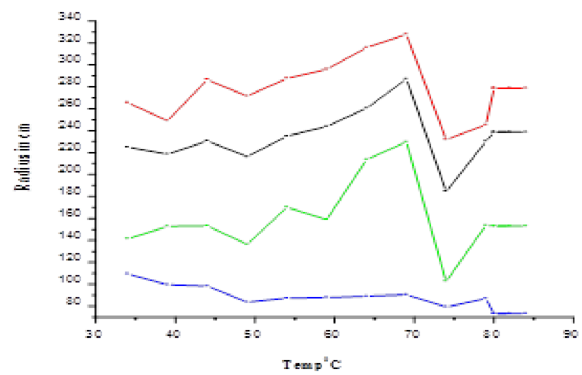
The PTTs observed by POM indicate that MWCNT doped LC not only widens the temperature range but also enhances the PTT of LC composite. The textural pattern on further heating transformed into the isotropic liquid at 70^{0}C.

Fabry–Perot Scattering Study (FPSS)

The samples were studied using He-Ne laser as an optical source. The experimental set up consists of He–Ne laser, a Fabry-Perot Etalon, spectrometer, electric heater and temperature sensor. The sample under investigation scatters the laser light at 45 degrees to the incident beam. The light scattered by sample was allowed to fall on the Fabry-Perot Etalon. The Fabry-Perot rings were observed through the spectrometer eyepiece. The radius of the rings changes due to mesophase transition of the sample. The radius of Fabry-Perot rings were measured at various temperatures. The experiment was repeated for various heating and cooling cycles for consistency. The radius temperature graph is shown in **Fig. 4**.



(a) Radius Temperature graph of composite LC



(b) Radius Temperature graph of MWCNT doped composite LC

Fig. 3. Radius Temperature Graph of FPSS.

The Phase Transition Temperatures (PTTs) investigated by FPSS is shown in **Table 2** below.

Table 2. PTTs of obtained by FPSS.

Sample	PTTs (in ^{0}C)
Composite LC	34,38, 42, 46, 50, 59, 62, 66
MWCNT doped LC	34, 39*, 44*, 49*, 54*, 59, 64*, 66

* shows enhancement in PTT.

The FPSS technique support PTTs obtained by POM and also shows that it is extended by 1 ^{0}C to 4 ^{0}C.

Differential Thermal Analysis (DTA)

A Differential Thermal Analysis (DTA) is used to compare the thermal properties of a sample against a standard reference material which has no transition in the temperature range of interest. The DTA is performed using FP99- Mettler Toledo. The sample under investigation is placed in aluminum crucible and another empty crucible and kept inside hot stage as reference. The DTA thermographs of composite LC and MWCNT doped LC is shown in **Fig. 4** and **Fig. 5** respectively.

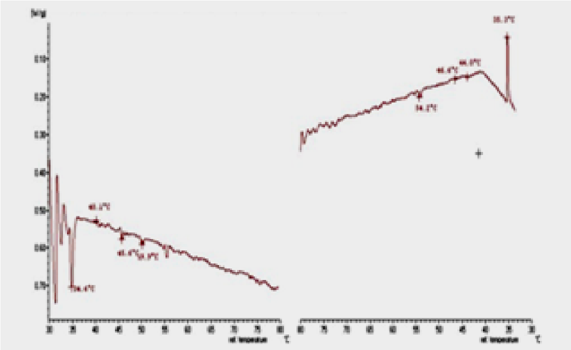


Fig. 4. DTA Thermograph of composite LC.

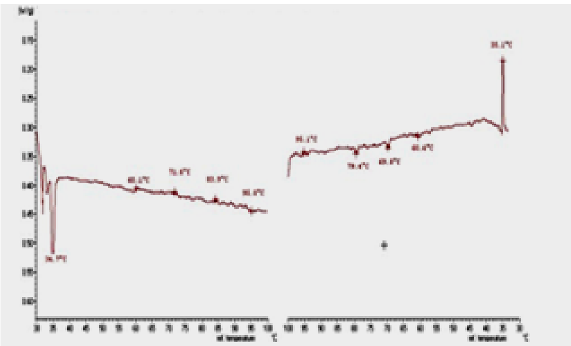


Fig. 5. DTA Thermograph of MWCNT doped LC.

The Phase Transition Temperatures (PTTs) investigated by DTA is shown in **Table 3** below.

Table3: PTTs of obtained by DTA

Sample	PTTs (in ^{0}C)
Composite LC	32.6, 45.6, 49.9
MWCNT doped LC	34.7*, 46.1*, 51.6*

* shows enhancement in PTT.

The enthalpy for composite LC was found as 4.69 J/g whereas for MWCNT doped LC it was found as 3.71 J/g. It shows enhances in performance of MWCNT doped composite LC.

Conclusion

The optical and thermal properties of LC composite and MWCNT doped LC composite is investigated. The PTTs obtained by various techniques support each other. The observed PTTs clearly indicate that the doping of MWCNT in LC composite enhances PTTs. This indicates that doping MWCNT with composite LC improves optical and thermal properties, which enable variety of new useful and beneficial applications. The improved properties of these composites material can be used for large number like color variation in LCD monitor.

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