

Statistical Parameters and Phase Transition Temperatures of Nematic Liquid Crystals Using Image Analysis Technique

V. Priyanaka, S. Sreehari Sastry *

Department of Physics, Acharya Nagarjuna University, Nagarjunanagar, India

ABSTRACT: Analysis of the textures and phase transitions of room temperature nematic liquid crystal: 4-Cyano-4'-pentylbiphenyl (5CB), is carried out using a polarising optical microscope under crossed polarisers attached with a hot stage and a high-resolution camera. Using MATLAB software, the statistical parameters, such as mean, variance, skewness, kurtosis and entropy of the textures as a function of temperature, are computed. These results show abrupt changes as a function of temperature, indicating the phase transition of the sample. The results are in good agreement with the literature results and the proposed methodology offers a reliable and very sensitive technique to identify mesophase transition temperatures.

KEYWORDS: Phase transition temperatures; thermotropic liquid crystals; statistical image analysis; statistical parameters

I. INTRODUCTION

Liquid crystals (LCs) samples are characterized by the optical and dielectric methods. The application of liquid crystal materials in different types of devices depends upon several properties like Phase transitions, optical birefringence (Refractive index), dielectric anisotropy, electrical conductivity, orientational order parameter etc. The possible applications of liquid crystal based devices like displays, biological systems, and electro optic modulation devices etc depends on the knowledge of optical anisotropy and its temperature variation. Due to their room temperature nematic (N) range, stability over a large temperature region, high birefringence and simple molecular configuration nematic liquid crystals 4-Cyano-4'-pentylbiphenyl (5CB) has been studied extensively and is used in display devices, biological systems and membranes [1-3].

The basic study of any liquid crystal compound involves the identification of phases and transition temperatures. This can be studied by several techniques, such as Polarizing Optical Microscope (POM), Differential Scanning Calorimetry (DSC), Differential Thermal Analysis (DTA) and X-ray Diffraction (XRD) studies. The most widely used technique is POM, which reveals that each different liquid crystal phase has a distinct optical texture [4-6]. However, the identification is often difficult due to subtle optical changes not being perceptible with the naked eye. DSC, DTA are the complementary techniques to POM, but they have some limitations since the transitions with low enthalpy are difficult to observe and the exact type of liquid crystal phase cannot be identified. The level of enthalpy variation gives some information regarding the degree of molecular ordering within a mesophase. XRD experiments are useful to identify ordered mesophase and also to obtain the structure parameters.

Here, the image analysis technique is reported in conjunction with POM to obtain phase transition temperatures of NLCs: 4-Cyano-4'-pentylbiphenyl (5CB) from the solid phase to the isotropic liquid phase via Nematic phase. In this technique, Textures of liquid crystals are recorded using arthroscopic mode of polarizing optical microscope. With respect to temperature, molecular orientation causes the changes in textural features of the sample.

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The changes in such textural features are color, intensity, roughness, randomness etc in textures. The changes in the textural features as a function of temperature give the information to identify the phase transition temperatures of NLC's. The studies have been carried out by analyzing the optical intensities of the recorded textures computationally using MATLAB software (program was coded in MATLAB implemented on Intel (R) 1.80 GHz with 2GB RAM computer).

II. EXPERIMENTAL DETAILS

Liquid crystal 5CB was supplied by Frinton Laboratories, Inc., USA. The experiment involved a Meopta polarising optical microscope attached with a hot stage [7] and a Canon high-resolution colour camera. A commercially available glass slide is used for sample preparation. The slide is of 75 mm length and 25 mm width, a thickness of 1.45 mm, is ground on all sides, cleaned with acetone and is dried at 40°C. This glass slide is simply rubbed in order to make unidirectional alignment in one direction. A small amount of liquid crystalline compound under investigation is placed on the glass slide, which is heated to become isotropic. A small cover slip of thickness of 0.16 mm is placed above the sample and allowed to cool to achieve homogeneous and uniform distribution of the compound. The colour image recorded by the camera has a resolution of 1936×1288 pixels, which represents the 24bit true colour pixel tone that ranges from intensity values 0 to 255 in Red, Green and Blue colours. The translated greyscale image is analysed using MATLAB software [8,9]. Theory related to the computation of statistical parameters from the textures of liquid crystals is explained briefly in [10-14].

III. RESULTS AND DISCUSSION

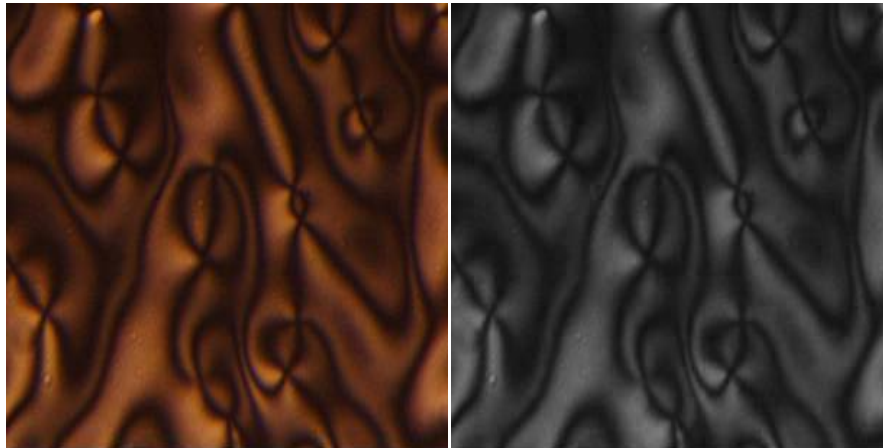
A small quantity of sample is placed on a commercially available glass slide usually which will be kept in the hot stage of the Polarizing Optical Microscope (Meopta DRU 3 Model) to observe the textures of the samples. The accuracy of the temperature measurements is $\pm 0.10^\circ\text{C}$. The thickness of the liquid crystal slide is equal to $100 \mu\text{m}$. The behavior of the liquid crystal is investigated in detail under crossed polarizers. The interaction between polarized light and distorted liquid crystals provides the useful information about the phases and phase structures. Textures of nematic liquid crystals 4-Cyano-4'-pentylbiphenyl (5CB) is recorded using polarizing microscope in arthroscopic mode. The recorded textures of the samples are stored in computer for further processing. MATLAB (implemented on P4 1.6GHz with 512MB RAM computer) is used to read and translate the image into gray scale version, and to compute the statistical parameters. The textures are captured as a function of temperature, till the sample temperatures reach to the isotropic state from solid state. 5CB undergoes a phase transition from crystalline state to a nematic phase at 18°C and from nematic to isotropic phase at 34°C . 5CB exhibited typical textures of nematic phase [5]. Textures of the sample recorded at different temperatures and the textures in true color form and its translated version (gray color) is shown in Figure 1.

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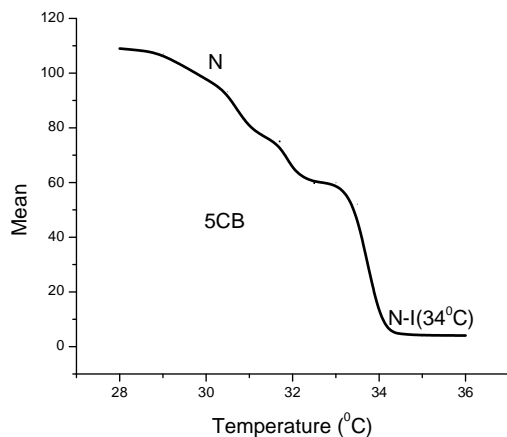
(a)

(b)

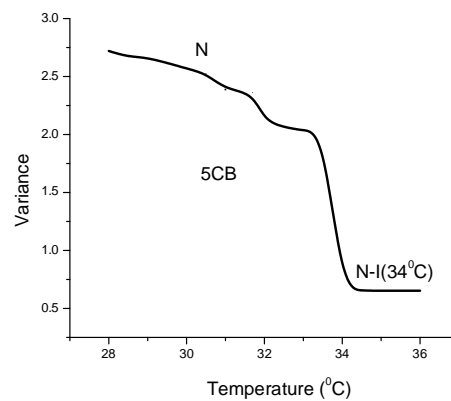
Figure 1: (a) nematic texture of 5CB original (b) its translated version (grey colour) at temperature 33.7°C.

The captured images or textures are stored in computer for further processing. Read the image from database, through preprocessing and it represents the image as a matrix where every element of the matrix has a value corresponding to bright/dark pixel at the corresponding position or feature of an image. The statistical parameters of the textures are computed using Equations given in [12-14] with the help of MATLAB Software.

Once the parameters are computed, the plots are drawn for parameters as a function of temperatures and are shown in Figures 2.



(a)



(b)

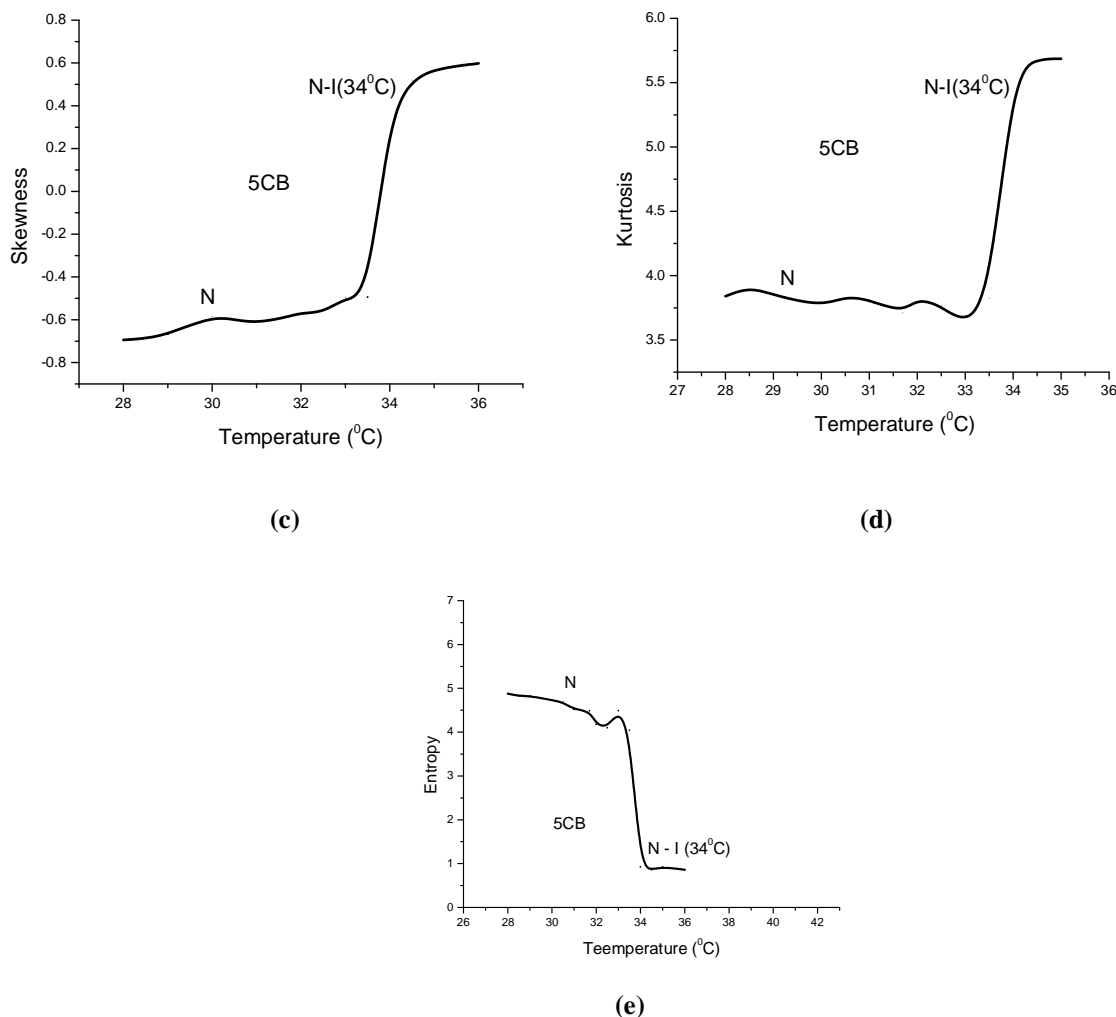


Figure 2: Stastical parameters (a) mean; (b) variance; (c) skewness; (d) kurtosis; (e) entropy; as a function of temperature where the phase transitions are indicated for 5CB on heating. (Cr-Crystal, N-Nematic, I-Isotropic)

When the temperature filed is applied to the liquid crystal sample, phase change occurs due to disturbance in directions of the molecules from initial state (like solid or isotropic liquid). This can be observed in terms of changes in textural features using POM. As a function of temperature, parameters computed from these textures also show the abrupt changes or discontinuities in their values. Therefore, the temperature corresponds to abrupt change in statistical parameters curve represents the transition temperature of samples. This implies that proposed methodology is very sensitive in identification of phase transitions of liquid crystals. The behavior of statistical parameters curves of thermotropic liquid crystals is different for different compounds because it depends on the textural features and parameters of the individual compounds. Mean and variance shows the similar curve behavior for all corresponding compounds. They decrease slowly with increasing temperature near liquid crystalline to isotropic phase transition and as soon as the sample goes to the isotropic phase it achieves the value of nearly equals to zero. This can observed from Figure 2.

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Thermal behaviour of liquid crystals is evaluated with those reported in the literature by several authors using or techniques like DSC [6,15]. DSC thermo grams (at heating rate of 10⁰C/min and 2⁰C/min) of 5CB sample with heat flow values are shown in Figure 3. In some systems peaks correspond to the isotropic transition are not resolved.

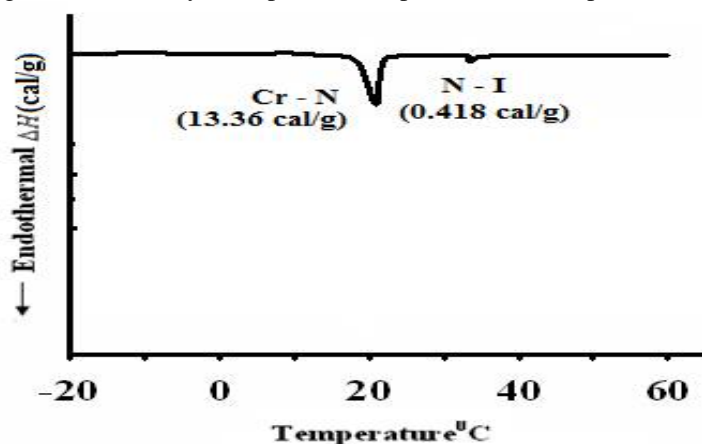


Figure 3: DSC Thermogram of 5CB.

The observed textures and transition temperatures of 5CB is in good agreement with those available from the literature. The transition temperatures of proposed methods and other techniques are shown in the Table 1.

Table 1: Transition temperatures in (°C)

Compounds	Present findings (°C)	Literature Results [DSC]
5CB	Cr 18.0 N 34.0 I	Cr (10 - 22.5) N - I (35.0 - 36.5)

IV. CONCLUSION

The present study demonstrates that statistical image analysis in conjunction with polarizing optical microscopy is a reliable and sensitive technique to identify the phase transition temperatures of thermotropic nematic liquid crystals.

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