Application of Image Analysis for Liquid Crystals Phase Transition Temperatures

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***Abstract*— Phase transition temperatures of schiff based liquid crystals: 3-hydroxy-4- {[(4-iodophenyl)imino]methyl}phenyl alkanoates ($C_{n-1}H_{2n-1}COO$-, n = 8 and 18) comprising terminal iodo substituent are identified using image analysis technique in conjunction with Polarizing Optical Microscope (POM). In this technique, the statistical parameters of 1st and 2nd kind are computed based on gray level intensities of liquid crystal textures as a function temperature. The changes in the intensities of liquid crystal textures as a function of temperature play a key role to identify the phases and phase transition temperatures. The sudden and abrupt changes like increments or decrements in the statistical parameters give the information to determine the transition temperatures of liquid crystals. The obtained results are in good agreement with literature.**

Keywords: Thermotropic Liquid crystals, phase transition temperature, image analysis,

1. INTRODUCTION

Identification of phases and phase transition temperatures are the basic things for the newly synthesized liquid crystal material. In literature, there are several techniques: Optical Polarizing Microscope (POM), Diffeential Scanning Calorimetry (DSC), Differential Thermal Analysis (DTA), Raman Spectroscopy, etc [1,2] to identify the phase transition temperatures. Here, Phase transition temperatures of schiff based liquid crystals *n*ABIA are identified using Image analysis technique in conjunction with Polarizing Optical Microscope (POM). Using this technique, phase transition temperatures of different thermotropic liquid crystals like nematic, cholesteric, ferro electric and discotic liquid crystals were identified [3-7]. In this paper, phase transition temperatures the synthesized schiff based liquid crystals [8]: 3-hydroxy-4-{[(4-iodophenyl)imino]methyl}phenyl alkanoates ($C_{n-1}H_{2n-1}COO$-, *n* = 8,18) comprising terminal iodo (*n*ABIA) substituent are identified. In this image analysis technique, the statistical parameters of 1st kind: Mean, Standard deviation and Entropy; 2nd kind: Energy, Contrast and Homogeneity [9-11] are computed based on gray level intensities of liquid crystal textures as a function temperature. All these parameters give the information about the textures when they show the changes as a function of temperature.

Generally, liquid crystal is a birefrigent material and this property will vary when the material is under the application of external fields like temperature, pressure, electric field and magnetic field. Here, the external field is temperature [12,13]. On heating or cooling of the material from its solid to isotropic or isotropic to solid state via liquid crystalline state, the value birefringence will change. This can be observed in terms of variations in the textures of liquid crystal material and can be captured as textures of liquid crystals using POM with camera attachment. These variations are nothing but the changes in the intensities of colors. Analysis of these textural intensities with respect to temperature gives the information to identify the phase transition temperatures of liquid crystals *n*ABIA.

II. EXPERIMENTAL DETAILS

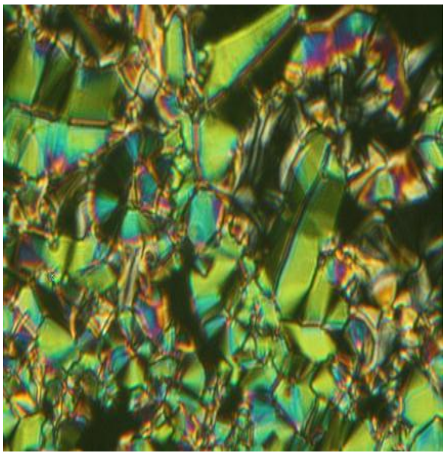
The synthesized Schiff based liquid crystals 3-hydroxy-4-{[(4-iodophenyl)imino]methyl}phenyl alkanoates ($C_{n-1}H_{2n-1}COO$-,) where *n* = octyl (8) and octa decyl (18) [8] are used. The experiment involve Meopta Polarizing optical microscope in the arthroscopic mode attached with hot stage described by Gray [14] and camera attachment for viewing, recording the textures as a function of temperature. The color images or textures of given liquid crystals are recorded using camera with resolution 2592 x 3888 pixels, which represents the 24bit true color pixel tone. Intensity values of the images are ranges from 0 to 255 in Red, Green and Blue colors. The translated gray scale image is used for analysis [3, 4, 9-11] and the defined statistical parameters given in [5-7] are computed using MATLAB software [15,16]. All the defined parameters are extremely sensitive to changes in the textural features of liquid crystals as a function of temperature. MATLAB® Software is used to compute the defined statistical parameters of the image. Image Processing using MATLAB supports images generated by a wide range of devices, including digital cameras. The standard data and image formats include JPEG, JPEG-2000, TIFF, PNG etc. MATLAB provides tools for image analysis tasks such as

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 6 Issue 02, February-2017

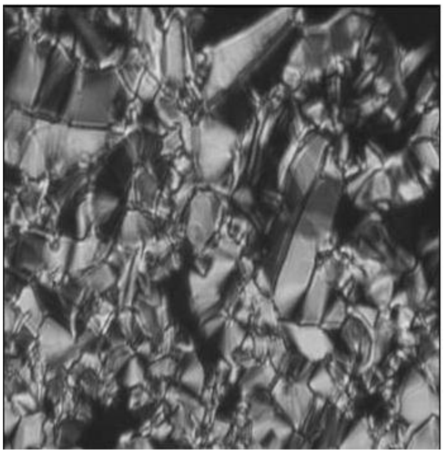
statistical analysis, feature extraction, and property measurement. The phase transition temperatures were measured using a Mettler Toledo DSC823 differential scanning calorimeter (DSC) at a scanning rate of 10∘ Cmin−1.

III. RESULTS AND DISCUSSION

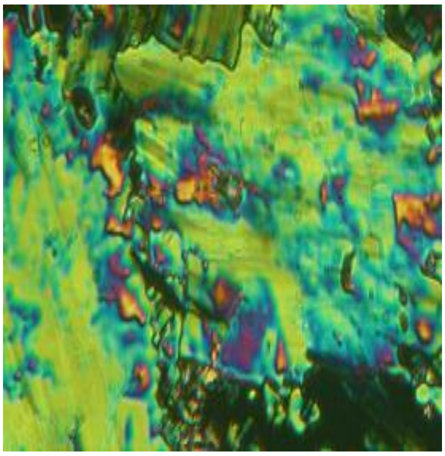
The present analysis deals with the transition temperatures of Schiff based liquid crystals *n*ABIA where *n* = octyl (8) and octa decyl (18). Textures of given compounds are recorded using polarizing microscope in arthroscopic mode attached to the high resolution camera. The textures of liquid crystals are captured as a function of temperature, from the Isotropic state of the sample to the solid state. Compound *n*ABIA (*n* = 8) exhibited the enantiotropic smectic A phase with fan-shaped texture. Compound *n* =18 exhibited the enantiotropic smectic A phase and smectic B phase. This is because the increase of length of terminal alkanoyloxy chain led to the enhancement of the smectic properties. Textures of the samples are shown in Figures 1 and 2.



(a)



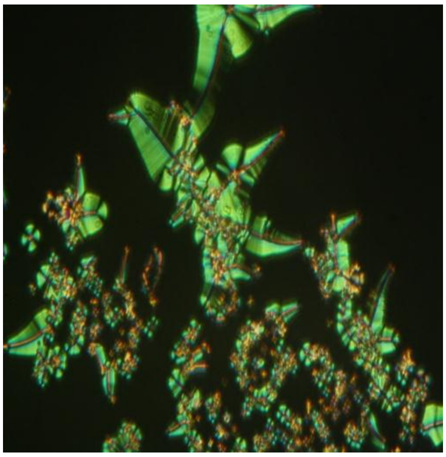
(b)



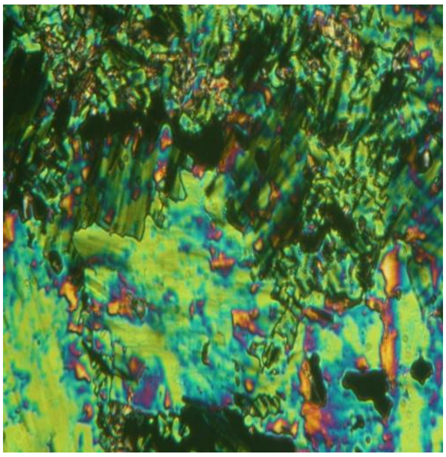
(c)

(d)

Figure1: optical textures of Liquid crystal: 3-hydroxy-4-{[(4-iodophenyl)imino]methyl}phenyl alkanoates ($C_{n-1}H_{2n-1}COO$-,) (a) Smectic A phase, (b) Smectic A phase (gray colour); (c) Smectic B phase; (d) Smectic A phase (gray colour).



(a)



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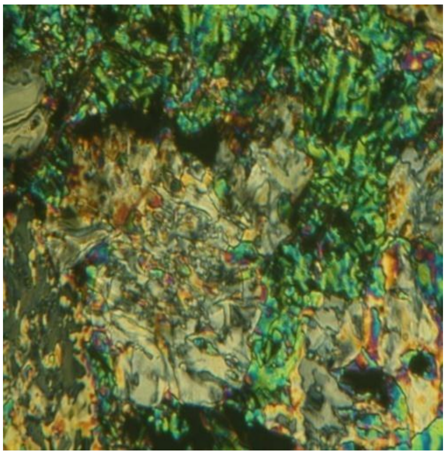

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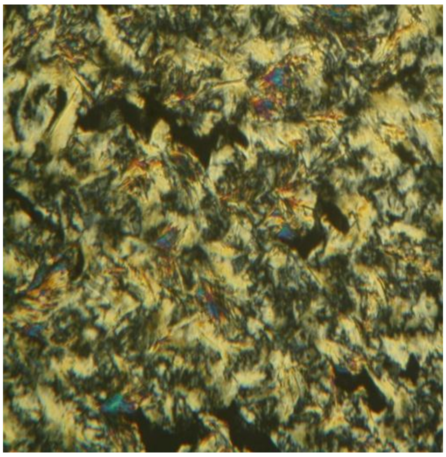
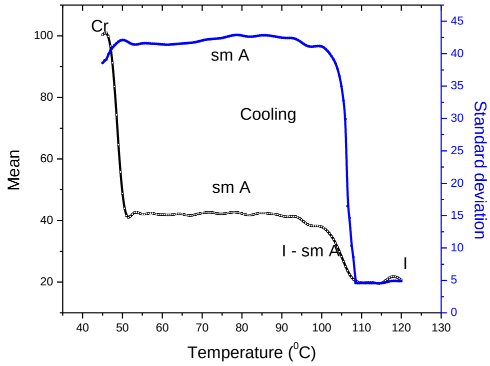


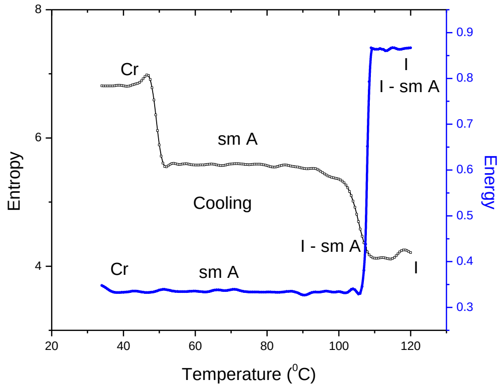
(d)

Figure2: optical textures of Liquid crystal: 3-hydroxy-4-{[(4-iodophenyl)imino]methyl}phenyl alkanoates ($C_{n-1}H_{2n-1}COO$-,) (a) I - Smectic A phase, (b) Smectic A - Smectic B phase; (c) Smectic B – Cr phase, (d) Cr phase

From the equations given in [5-7], statistical parameters of the liquid crystal textures are computed using MATLAB software. On cooling, compounds undergo a phase transition from the isotropic state to the solid state via an intermediate smectic phases at different temperatures and are shown in Figure 1 and 2. Once the parameters are computed, the plots are drawn for the parameters as a function of temperatures from isotropic state to the solid state. The plots are shown in Figures (3 &4).



(a)



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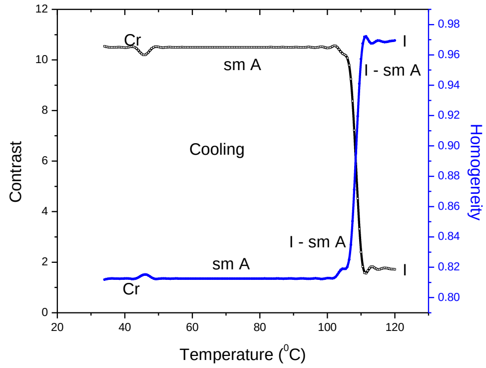
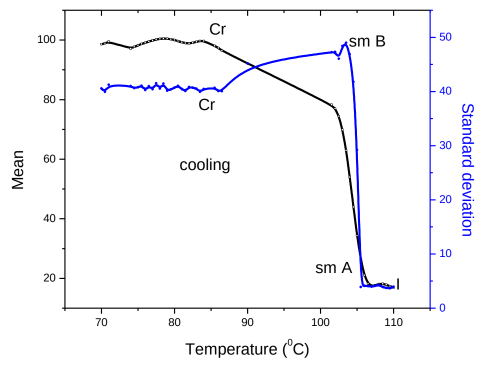
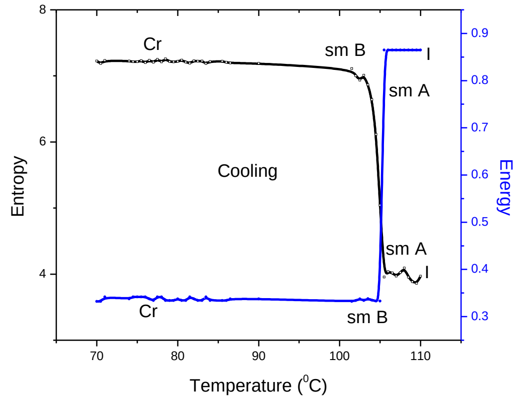


(c)

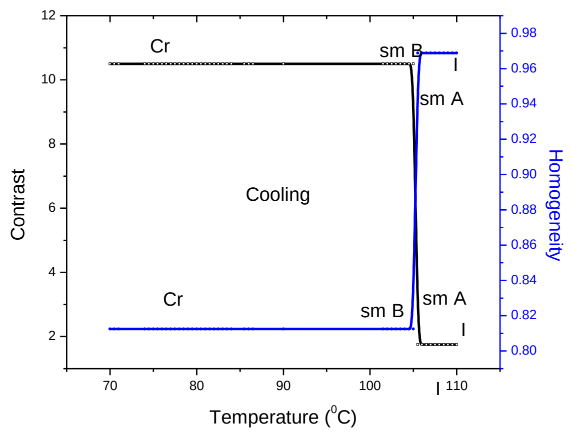
Figure 3: Computed parameters from the textures of 3-hydroxy-4-{[(4-iodophenyl)imino]methyl}phenyl alkanoates ($C_{n-1}H_{2n-1}COO$-, where n = 8) as a function of temperature where the phase transitions are indicated.
(Cr - Crystal , sm A–Smectic A, I-Isotropic)



(a)



(b)



(c)

Figure 4: Computed parameters from the textures of 3- hydroxy- 4-{[(4-iodophenyl)imino]methyl} phenyl alkanoates ($C_{n-1}H_{2n-1}COO$-, where *n* = 18) as a function of temperature where the phase transitions are indicated. *(Cr - Crystal , sm B–Smectic B , sm A–Smectic A, I-Isotropic)*

The significant variations in the computed parameter values which were shown in Figures 3 and 4 are due to the fact that transition in phases caused the changes in the textural features. Either on heating or on cooling cycles, changes in the textural features takes place as a function of temperature and this will be more identifiable at the transition which is indication of phase transition. Small changes in the textural features bring variations in the transmitted intensity or gray values, which are useful to compute the desired parameters. As a function of temperature, the value birefringence will vary. In Isotropic phase, due to the absence of birefringence property the textures appear dark in color. By increasing the temperature, the birefringence property reappears due to the occurrence of transition from isotropic phase to mesogenic phase. This can be observed in terms of variations in the textures of liquid crystal material and can be captured as textures of liquid crystals using POM with camera attachment. Analysis of these textural intensities with respect to temperature gives the information to identify the phase transition temperatures of liquid crystals *n*ABIA. Therefore, the distinctive and abrupt changes observed in the parameters curve at temperature corresponding to the transition temperature of samples [3-7].

For compounds *n*ABIA, *n* =8 and 18; Statistical parameters mean and standard deviation, show the abrupt changes at the texture transitions which relates the phase transitions temperatures of the liquid crystals and was shown in Figures: 3 (a & b), 3 (a & b). Energy is a measure of uniformity in texture and entropy is a measure of randomness. Therefore, entropy and energy shows the opposite behavior and are shown in Figures 3 (c & d) and 4 (c & d). Homogeneity and Contrast show the opposite behavior, because homogeneity increases with less contrast of textures and is shown in Figures 3 (e & f) and 4 (e & f). Like in DSC, the statistical parameters of 2nd kind Contrast and homogeneity does not show much variation in the values at the transitions of smectic B – Cr phases. But this is true for some samples like *n* =18. This can be observed from Figures 3 and 4. The parameter values computed from the textures at that temperatures are correlated to each other and their differences does not contribute to show abrupt changes. But, these features show abrupt change for the transition from I – liquid crystal phase or liquid crystal phase - I of any liquid crystal. This is because of large differences in mean intensity values of the textures before reaching to the isotropic state on heating and isotropic to liquid crystal state on cooling. While at the same time the first and second order statistical parameters shows abrupt changes at the transition for the sample *n* = 8. Present findings and literature results of transition temperatures of samples are shown in Table1. The obtained results are in good agreement with literature values [8].

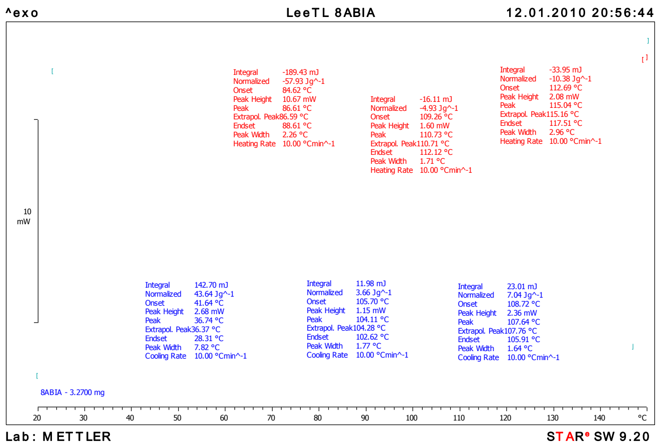
Table 1. Phases and Phase transition temperatures of Schiff based liquid crystals *n*ABIA.

Compound nABIA	phases	Phase transition temperature(ºC)	
		DSC	Image analysis
8ABIA	I-Sm A-Cr	107.8– 36.4	107.5– 46.0
18ABIA	I-SmA-Sm B - Cr	107.4-104.6-79.5	106.0-102.5- 78.0

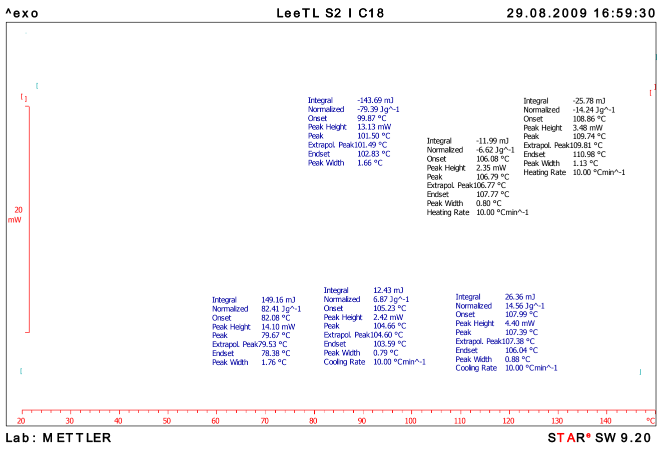
The behaviors of statistical parameter curves are different for different compounds. On cooling, the Schiff based liquid crystal (*n*ABIA) where *n* = 8 , exhibits the transition from isotropic to smectic A phase at temperature

107.5^{0}C and second transition from smectic A to solid phase at temperature 46.0^{0}C. The azomethine liquid crystal n = 18 exhibits the transition from isotropic to smectic A phase at temperature 106.0^{0}C and second transition from smectic A to smectic B phase at temperature 102.5^{0}C and third transition from smectic B to solid phase at temperature at 78.0^{0}C. The mesophase range for the compound n = 8 (61.5^{0}C) is more compared to the compound n =18 (28.0^{0}C). This is due to the fact that, the increase of alkyl chain length from n = 8 to 18, leads to the dilution of mesogenic core [17].

DSC thermograms shown in Figure 5 and the phase transitions of the liquid crystals are also given in table 1. It is noted that the phase transitions are reasonably in good agreement with the two techniques.



a. DSC thermogram of 8ABIA



b. DSC thermogram of 18ABIA

Figure 4: DSC thermograms of nABIA where n=8 & 18

IV. CONCLUSIONS

Schiff based liquid crystals n = 8 exhibited the enantiotropic smectic A phase and n =18 exhibited the enantiotropic smectic A phase and smectic B phase. Statistical parameters of 1st and 2nd kind computed from the textures of samples are successful in identifying the phase transitions between the isotropic – solid phase. Results are in good agreement with DSC.

V. ACKNOWLEDGEMENTS

The authors gratefully acknowledge University Grants Commission Departmental Special Assistance at Level I program No. F.530/1/ DSA- 1/2015 (SAP-1), dated 12 May 2015, and Department of Science and Technology-Fund for Improving Science and Technology program No.DST/FIST/ PSI–002/2011 dated 20-12-2011, New Delhi, to the department of Physics, Acharya Nagarjuna University for providing financial assistance.

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