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Temperature dependence of Legendre moments in thermotropic liquid crystals

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ABSTRACT
Phase transition temperatures of azomethine esters: 3-hydroxy-4-{[(4-iodophenyl)imino]methyl}phenyl alkanoates ($C_{n-1}H_{2n-1}COO$-, *n* = 8, 18) are identified using Legendre moments or Legendre moment coefficients. As a function of temperature, Liquid crystal textures are recorded from the arthroscopic mode of Polarizing Optical Microscope having the attachment of hot stage and camera. In this paper, Legendre moments are computed from the brightness information of liquid crystal textures using MATLAB software. The changes in the textural features with respect to temperature bring the variations in the brightness values, are useful to identify the phase transitions. The abrupt changes in the Legendre moment curve gives information to understand the transition temperatures of liquid crystals. The obtained results are in good agreement with literature.
Keywords: Image analysis, Legendre moments, Liquid crystal, Textures, Transition temperatures,

I. INTRODUCTION

Liquid crystal materials having azo group in the mesogenic core are often studied owing to their interesting performance and properties which enable the applications in display devices, holography, optical switching and storage devices etc [1-3]. Further these liquid crystals having a striking influence on molecular structure and physical properties such as melting and clearing temperatures, molecular linearity, thermal stability and inducing the formation of mesophase. Therefore, in this paper we have considered such kind of azomethine esters comprising terminal iodo substituents [4]. Generally, the basic thing involved in any liquid crystalline material is knowledge of phases and phase transition temperatures. Polarizing microscope technique (POM), X-ray diffraction analysis, Differential Scanning Calorimetry (DSC), Differential Thermal Analysis (DTA) etc. are the well known methods to identify the phase transition temperatures [5-7]. In this paper, Phase transition temperatures of synthesized azomethine esters [4]: 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 using Image analysis technique in conjunction with Polarizing Optical Microscope (POM). In this image analysis technique, image moments named as Legendre moments based approach is used to identify the phase transitions of liquid crystals. Using this technique, phase transition temperatures of different thermotropic liquid crystals like cholesteric, Ferro electric and discotic liquid crystals were identified [8,9].

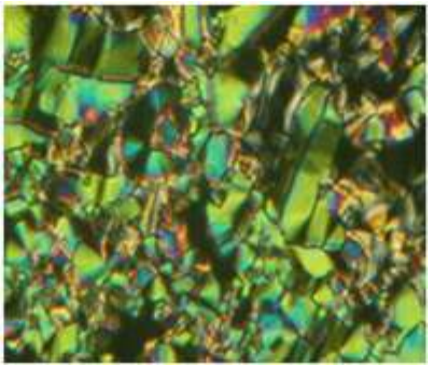
In our previous studies, Legendre moments are computed from gray scale image of liquid crystal textures as a function temperature. In the present study, brightness information of the liquid crystal textures is used to identify the phase transition temperatures. Brightness is an attribute of visual perception in which image is seems to be transmitting specific amount of light and is represented in terms of pixel intensity values. It is our practical interest to use the brightness information of liquid crystal textures in the investigation of phase transitions temperatures as an alternative method. And also the isolation of brightness information from the color space has an important advantage that; the values of brightness will vary with the changes in liquid crystal textures as a function of temperature. Analysis of these brightness values with respect to temperature gives the information to identify the phase transition temperatures of liquid crystals *n*ABIA. The comparative study between the gray scale method and present method also explained in next sections.

II. EXPERIMENTAL

The synthesized azomethineesters [4]:3-hydroxy-4-{[(4-iodophenyl) mino] ethyl}phenyl alkanoates ($C_{n-1}H_{2n-1}COO$-,) where *n* = octyl (8) and octa decyl (18) are used. The experiment involve Meopta Polarizing optical microscope in the arthroscopic mode attached with hot stage described by Gray [10] 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. The brightness information of the image is (computed as in [11]) used for analysis. Theory related to the generation of Legendre polynomial basis, computation of Legendre moments of the textures and drawing the Legendre moment plots of the textures as a function of temperature which gives the phase transition temperatures of liquid crystals are briefly explained in [8,9,12,13]. The defined Legendre moments are computed using MATLAB software [14, 15]. Legendre moment program was coded in MATLAB (implemented on P5 1.6GHz with 2GB RAM computer) for computational analysis.

III. RESULTS AND DISCUSSION

Textures of the azomethine ester liquid crystals viz., 3-hydroxy-4-{[(4-iodophenyl) imino] methyl} phenyl alkanoates ($C_{n-1}H_{2n-1}COO$-,) where n = octyl (8) and octa decyl (18) [4] are recorded using POM as a function of temperature on cooling from the Isotropic phase (I) of the sample to the solid phase. These liquid crystals *n*ABIA (n = 8 and 18) exhibited the enantiotropic Smectic A phase with fan-shaped texture and is shown in Fig. 1. Compound *n* =18 exhibited the common appearance of mosaic Smectic B phase in addition to the Smectic A phase and is shown in Fig. 2.



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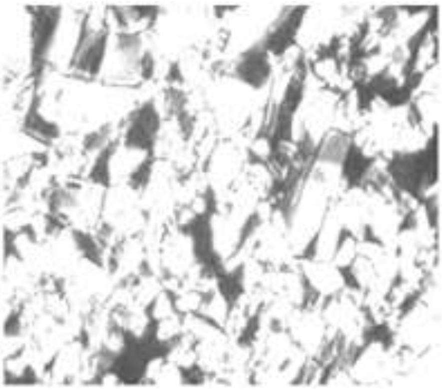

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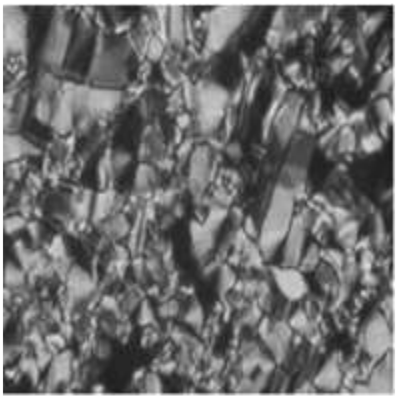

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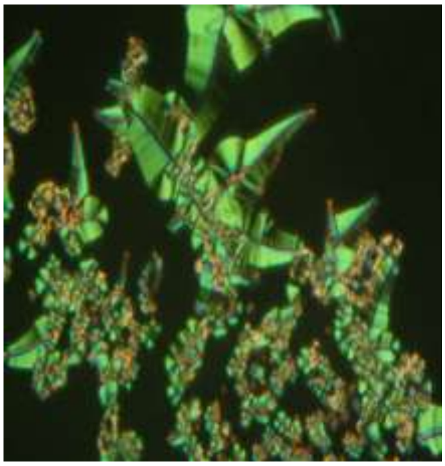
Figure1: Smectic A phase of Liquid crystal: 3-hydroxy-4-{[(4-iodophenyl)imino]methyl}phenyl alkanoates ($C_{n-1}H_{2n-1}COO$-,) (a) in color, (b) in brightness form (c) in grey colour form.



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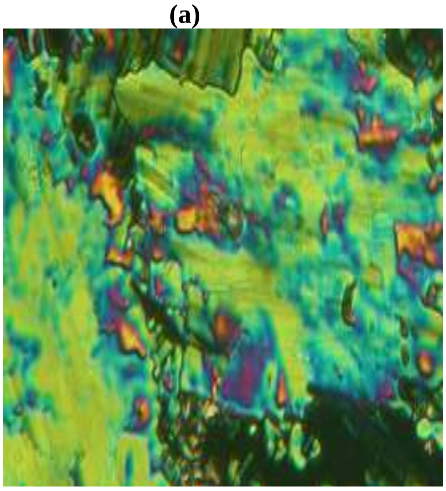

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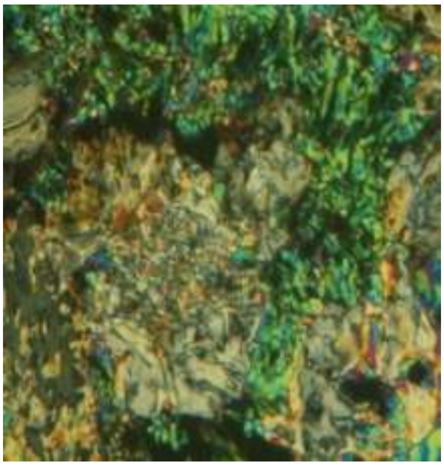

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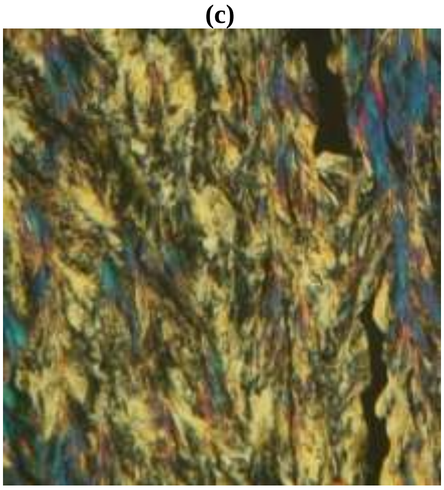

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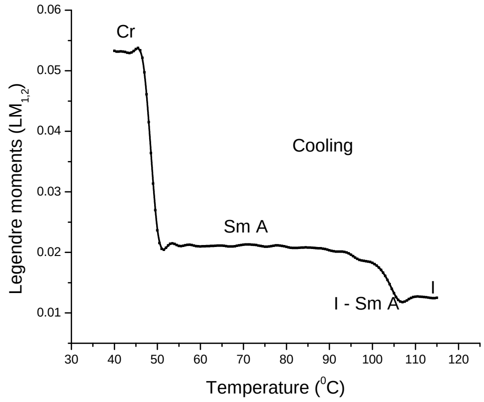
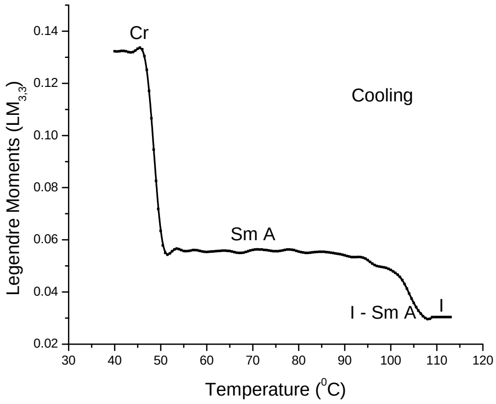
Figure 2: optical textures of Liquid crystal: 3-hydroxy-4-{[(4iodophenyl)imino]methyl}phenyl alkanoates ($C_{n-1}H_{2n-1}COO$-,) (a) I - Smectic A phase, (b) Smectic B phase of *n* =18; (c) Smectic B – Crystal phase,

(d) Crystal phase.

From the equations given in [8, 9, 12, 13], Legendre moments are computed by projecting the Legendre polynomial on brightness values of the texture. Here, the considered maximum moment Legendre polynomial order is 3. Once the moments are computed, the plots are drawn for moments as a function of temperatures of the samples from isotropic state to the solid state. As a representative case, Co-ordinate positions of Legendre moments [8,9] are selected randomly to draw the plots and are shown in Fig. 3 & 4.



(a)



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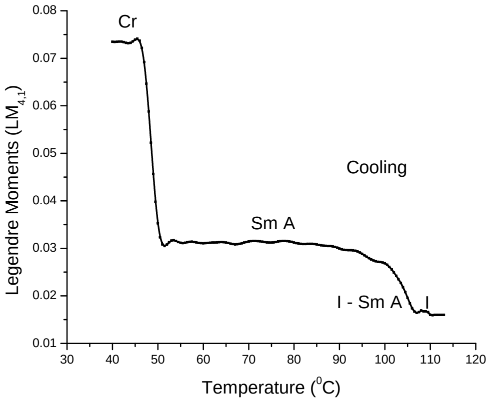

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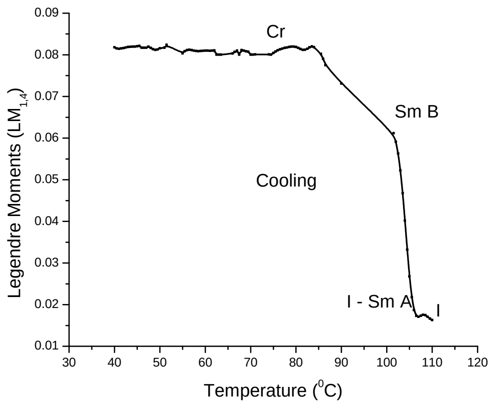
Figure 3: Legendre moments plots of 3-hydroxy-4-{[(4-iodophenyl) imino]methyl}phenyl alkanoates ($C_{n-1}H_{2n-1}COO$-, where *n* = 8) as a function of temperature where the phase transitions are indicated.
(Cr - Crystal , Sm A–Smectic A, I-Isotropic)



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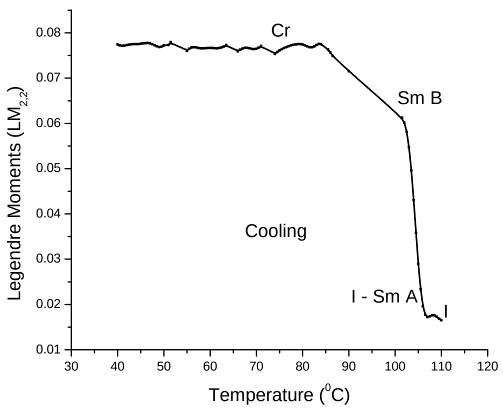

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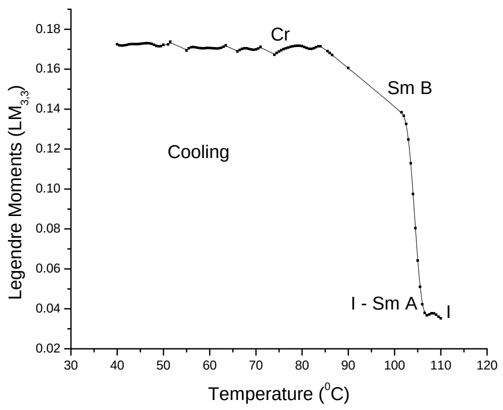

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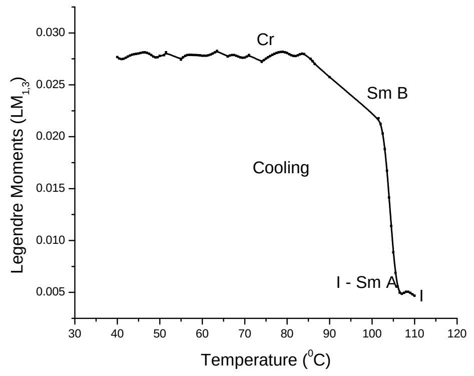
Figure 4: Legendre moments plots of 3-hydroxy-4-{[(4-iodophenyl) imino] methyl} phenyl alkanoates ($C_{n-1}H_{2n-1}COO$-, where *n* = 18) as a function of temperature where the phase transitions are indicated.
(Cr - Crystal , Sm A–Smectic A, Sm B – Smectic B, I-Isotropic)

The significant variations in the computed Legendre moment values which were shown in Fig. 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 brightness 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 texture appears 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 (shown in Fig. 2) and can be captured as textures of liquid crystals using POM with camera attachment. Analysis of these brightness values 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 Legendre moments curve at temperature corresponding to the transition temperature of samples [8,9]. Not only the lower order moments but also higher order moments are useful to investigate the phase transitions of liquid crystals. Despite having its high computational complexity, the application of the legendre moment polynomial function is appreciated on following its sensitivity especially when higher order moment calculations are necessitated. The phase transition temperatures obtained from the present study Image analysis technique in conjunction with POM are shown in Table 1 along with the values in the literature for comparison [4].

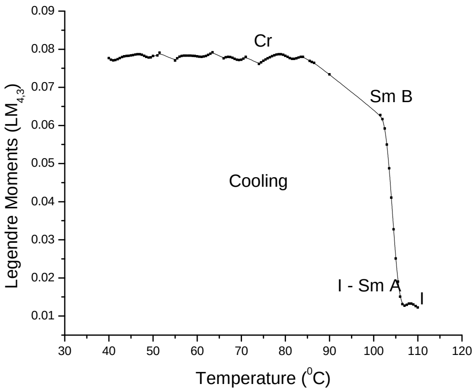
Table 1. Phases and Phase transition temperatures of Schiff based liquid crystals *n*ABIA.

Compound	Phases (*n*ABIA)	Phase transition temperatures (^{o}C) DSC[4]	Image analysis
8ABIA	I – Sm A - Cr	107.8 - 36.4	107.5 – 46.0
18ABIA	I –Sm A –Sm B - Cr	107.4–104.6 –79.5	106 – 102.5 –78

(Cr: Crystal; Sm A – Smectic A; Sm B – Smectic B; I: Isotropic).



(a)



(b)

Figure 5: Legendre moments plots of gray scale 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 A–Smectic A,Sm B – Smectic B, I-Isotropic)

Legendre moment plots computed from the gray scale images are shown in Fig. 5. From the plots it is observed that, there is no difference in Legendre moments of gray scale and brightness images in terms of behavior and magnitude (Legendre moments magnitude always < 1). Generally, in gray scale images, the intensity of the image is represented by the range of shades of gray (in terms of number from decimal 0 – 255) without apparent color. Brightness is an attribute of visual perception in which image is seems to be transmitting specific amount of light and it refers to how bright the image or object is. From the color space, Gray scale image is computed by forming the weighted sum to the primary colors (R, G, and B) and Brightness is computed simply by adding the intensity of three primary colors. Both are represented by the same pixel intensity values with different magnitudes which results the small difference in the computational time. Therefore, these two are differed in terms of visual perception to the human eye only. This was clearly shown in Figure 1. The changes in the textural features with respect to temperature bring the variations in the brightness values as well as gray shade intensity values which are useful to identify the phase transitions. From this we can conclude that, analysis of these textural intensities of gray scale images and brightness images are useful to identify the phase transition temperatures of liquid crystals. The advantage of using Legendre moments approach is that, these moments are invariant to the image noise and blurring which are usually happen while recording the textures. For the moment of order or the polynomial of order 3, 10, the computational time or CPU-elapsed time required to compute the Legendre moments of the brightness and gray scale images textures is shown in Table 2.

Table 2: CPU elapsed times of brightness and gray scale images.

Image	Moment order	CPU elapsed time (in seconds)
Brightness	3	3.3
	10	13.6
Gray scale	3	3.7
	10	14
	20	42.1

IV. CONCLUSION

Phase transitions of azomethine ester liquid crystals computed from brightness information of the textures using Legendre moments are not only efficient but also reliable. Each moment of the texture is useful to identify the transition temperatures of the sample and these moments are invariant to the image noise and blurring which are usually happen while recording the textures.

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