# Temperature Dependence of Optical Parameters by Image Analysis in Nematic Liquid Crystals

Ch. Venkayamma and S. Sreehari Sastry*
[a] Department of Physics,
Acharya Nagarjuna University,
Nagarjuna nagar -522510, India

***Abstract*— In this paper, thermo optical properties of nematic liquid crystal: N-4-methoxybenzylidene-4-butylaniline (MBBA) has been investigated by means of applying Image analysis technique in conjunction with Polarizing Optical Microscope. Textures of liquid crystal complexes are captured. The changes in textural features as a function of temperature are useful to compute the thermo optical properties. These microscopic textures are analyzed using MATLAB software. The investigated thermo optical parameters are optical transmission, Absorption coefficient, Phase retardation, birefringence and order parameter. Experimentally, this is a simple technique to observe the behavior of the optical parameters of different liquid crystals as a function of temperature.**

***Keywords: Nematic Liquid crystal, Thermo optical properties, Textures, Image analysis, MATLAB.***

## 1. INTRODUCTION

The molecular order in the liquid crystalline phases destroys the isotropy (all directions are equivalent) and introduces anisotropy (all directions are not equivalent) in the material. For interactions of liquid crystal material with the surrounding environments a number of physical properties are observed in a liquid crystalline phase which are absent in the isotropic liquid phase [1,2]. It is well known that liquid crystals are very sensitive to temperature and the resultant thermo-optical properties of liquid crystals are most important to study the behavior of light with respect to temperature. These optical properties provide important information regarding the molecular ordering, molecular dynamics and type of molecular interactions in the sample. The optimum performance of newly developed liquid crystal devices is often possible only made by use of materials with above said specified properties. 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 crystal *N*-4-methoxybenzylidene-4-butylaniline (MBBA) has been studied extensively and are used in display devices, biological systems and membranes [3-6]. The physical property molecular anisotropy is very important from the viewpoint of not only molecular theory but also practical applications, because it strongly affects the electro-optical properties of liquid crystal displays, especially the contrast ratio, the viewing angle, and the threshold voltage. Therefore, qualitative determination of the orientational order is one of the primary subjects in fundamental research on liquid crystals and liquid crystal displays. Their versatile usefulness from the experimental to several theoretical proposals made them such a good candidates to study.

There are several techniques to study the temperature dependence of optical properties of liquid crystals. In microscopy, image analysis technique has been developed to aid the interpretation of microscopic images and to extract as much information as possible from image objects . In case of liquid crystals, the analysis of liquid crystal textures obtained from the polarizing microscope is used to study the properties of liquid crystals. Therefore, in this chapter, the image analysis technique is reported in conjunction with POM to obtain thermo-optical properties from the solid phase to the isotropic liquid phase via nematic phases. Image analysis technique has been developed to aid the interpretation of microscopic images and to extract as much information as possible from image objects by means of applying some computational algorithms on image data or intensity values. The investigated thermo optical parameters are optical transmission (OT), Absorption coefficient (AC), Phase retardation, Phase stability, birefringence and order parameter (S). Experimentally, this is a simple technique to observe the behavior of the optical parameters of different liquid crystals as a function of temperature.

## II. EXPERIMENTAL DETAILS

Liquid crystal: MBBA was supplied by Frinton Laboratories, Inc., USA, respectively. The experiment involved a Meopta polarising optical microscope attached with a hot stage 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 color image detected by the camera has a resolution of 1936 X1288 pixels which represents the 24bit true color pixel tone

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 6 Issue 03, March-2017

that ranges from 0 to 255 in R, G, and B colors under crossed and parallel polarizer's with the digital camera of canon made model (EOS Digital REBEL XS/ EOS1000D) of 10.10 mega pixel image sensor. To compute thermo optical properties, Textures of the sample from solid to isotropic phase or isotropic phase to solid phase are recorded in three monochromatic image planes at the wavelengths of 635 nm (red), 530 nm (green) and 470 nm (blue) as a function of temperature. Measurements of thermo-optical properties are carried out on MATLAB platform [7,8]. Thermo optical properties of liquid crystals are defined in terms of image intensity values brifely in [9-11].

## III. RESULTS AND DISCUSSION

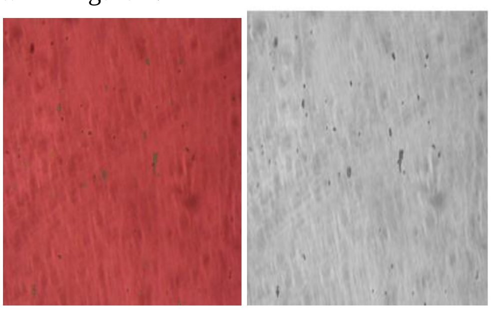
A small quantity of sample is placed on a commercially available glass slide usually which will be kept in the hot stageof the Polarizing Optical Microscope (Meopta DRU 3 Model) to observe the textures of the samples. The accuracy of the temperature measurements is ± 0.10C. The thickness of the liquid crystal slide is equal to 100 µm.The behavior of the nematic 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. Nematic liquid crystal (NLC) MBBA exhibited the plain texture of nematic phase [12]. Phase transition temperatures in Table 1. The phase transition temperatures measured by us is in good agreement with the standard techniques like DSC [13,14].

Table 1: Transition temperatures in ($^0$C)

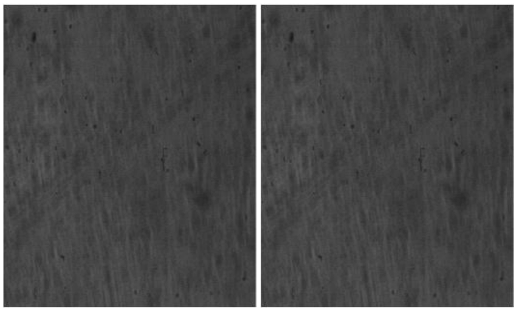
| Compound | Present findings(ºC) | DSC |
|---|---|---|
| MBBA | Cr 27.0 N 44.0 I | Cr 25.0 N 43.0 I |

*(Cr-Crystal, N-Nematic, I-Isotropic)*

Here, thermo optical properties (including phase transition behavior) are investigated using image analysis technique in conjunction with POM on MATLAB platform. In this technique to compute the optical properties as a function of temperature, textures of the compounds are recorded from the solid phase of the sample to the isotropic liquid phase through POM with hot stage and camera attachment. Optical textures of the MBBA liquid crystal are observed between crossed polarizers in RGB color mode, for red color image plane, for green color image plane and for blue color image plane. As a representative nematic texture was shown in Figure 1.



(a) (b)

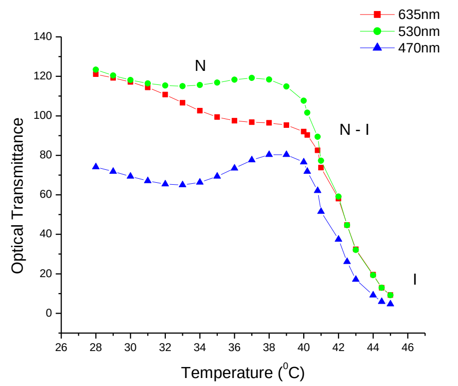


(c) (d)

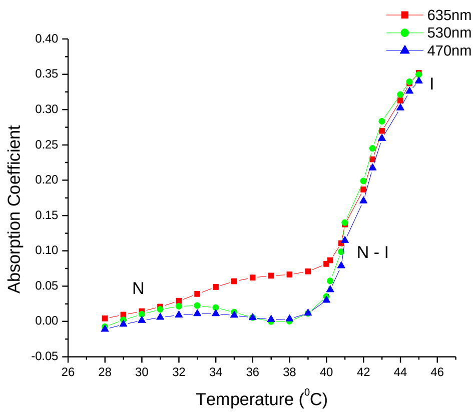
Figure 1: Optical textures (Nematic phase) of MBBA Liquid crystal observed between crossed polarizers at temperature 36ºC. (a) for RGB colour mode; (b) for red colour image plane; (c) for green colour image plane; (d) for blue colour image plane.

For small increments of temperature there are no changes in the textures and recorded textures are remains same like solid phase. As the temperature is increased, changes in textural features occurred reveals the phase transition. While passing a phase from initial phase (solid phase) to other liquid crystal phase or liquid crystal phase to isotropic phase, orientation of the molecules with respect to the temperature affects the transmitted intensity values of the textures in terms of textural feature changes. It gives the information for understanding the thermo optic characteristics of liquid crystals.

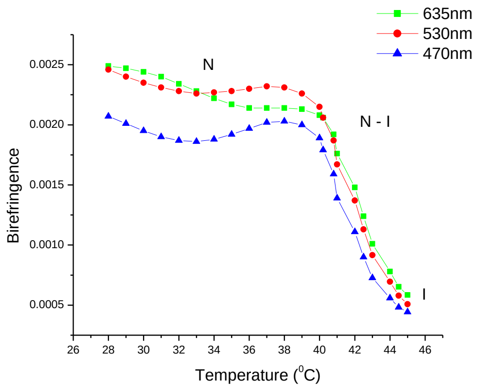
Computed properties are plotted against the temperature and is shown in Figure 2.



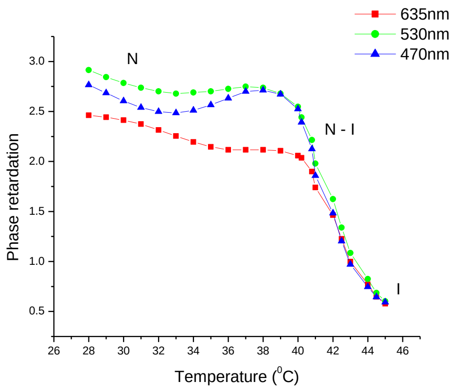

(a)




(b)




(c)




(d)

Figure 2 : Optical properties of MBBA
(a) Optical transmittance; (b) Absorption coefficient;
(c) Birefringence; (d) Phase retardation.
(N- Nematic; I-Isotropic).

Figure : 2 (a, b) shows the variations in the values of optical transmittance, Absorption Coefficient (AC) at the transitions Cr – N and N - I. This is due to the fact that, at different phases depending on wavelengths, there are changes in the textural features as function of temperature. The value of optical transmittance slowly decreases with increasing temperature near to N - isotropic phase transition and as soon as the sample goes to the isotropic phase the value of optical transmittance is zero and the texture would appear dark in color in between crossed polars and is shown in Figures 2. A sudden increase in the value of AC is observed in Figures 3(b). This contributes the maximum value of AC in isotropic state. In this phase the molecular orientation is random and there is no transmission of light and the value of AC is less in liquid crystal phase. On heating of the sample, there is a discontinuities in the values of absorption coefficient takes place in the biphasic region of N – I temperature interval. The steep change in the values of AC infers the sharp transformations in textures. Optical transmittance of the sample is inversely proportional to the Absorption coefficient (AC) .

Figure 2(c) clearly indicates that the birefringence values at three wavelengths are plotted against the temperature. Here, computation of birefringence relies on observing an intensity change in the textures of liquid crystals. In all, a general trend is observed as temperature increased for each liquid crystal sample, there are major changes appear in the textures of samples depending on wavelengths. At the lowest temperatures the texture similar in texture like solid phase. However, as temperature increased, the texture became smoother depending on alignment of molecules in sample. At higher temperatures, the sample brightness began to decrease continuously and uniformly, until no birefringence is observed. The absence of birefringence property in isotropic liquid state is the reason for the zero value of brightness. This is attributed to the destruction of molecular alignment that led to the decrease of birefringence value to zero [15]. Liquid crystal coexistence regions (Cr-LC, LC-I) are commonly marked by an abrupt change in birefringence due to an immediate loss of all birefringence in a particular region of the sample. The small variations in the optical parameter curves other than transitions are due to change in the refractive index of the samples which results the continuous color changes as a function of temperature. However, birefringence of liquid crystal shows uniform and continuous loss of birefringence in its coexistence region, which is quantitatively depicted through the curvature of Figure 2(c). Figure 2(d) shows the temperature dependent phase retardation of MBBA liquid crystal. As a function of temperature, phase change occurs due to disturbance in directions of the molecules. Changes in phase retardation values are function of single variable $\Delta n$. In solid phase liquid crystal molecule directors remain undisturbed and no phase change occurs. While passing the phase, orientation of molecular directions results small changes in the phase retardation values. In this regime the value of phase retardation is inversely proportional to temperature. This can be clearly observed for two samples at three wavelengths. The larger $\Delta n$ is, the larger the phase shift obtained.

A simple procedure is used for the determination of the order parameter ($S$) from the birefringence measurements. Order parameter of the liquid crystals is determined from the Kuczynski equation by using the direct measurement of birefringence values. The values of $(\Delta n)_0$, $\beta$ are obtained from the linear regression method using equations in [ 9-11].

The temperature dependent birefringence values of the samples are used to compute the temperature dependent order parameter of the MBBA. These measurements are made in the phase transition regions of Cr - N - I phase of the sample and the measured order parameter values are plotted against the temperature.

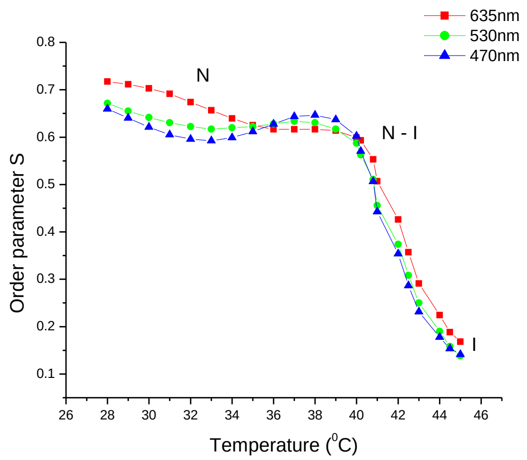



Figure 3: Temperature dependence of order parameter of MBBA
*(Cr – Crystal , N - Nematic, I-Isotropic).*

The order parameter (S) shown in Figure 3 is maximum in N transition state and it goes on decreasing as the temperature is incremented towards the isotropic phase of the sample which has the lowest order parameter of the order of 0.14. The values of order parameter during the transition from the N - I phases are in the range of 0.71 to 0.14. Here the parameters are computed purely based on gray level intensity vales of the image textures , where as in the other case the parameters are obtained based on the light transmitted intensity, molecular polariz abilities, refractive indices and densities of the sample etc . The phase transitions from Cr – N – I are very well established in all plots of thermo optical properties which is also further confirmed from the order parameter graph.

## IV. CONCLUSIONS

Thermo optical properties of room temperature Nematic liquid crystal: MBBA is investigated using Image analysis technique on MATLAB plat form. As a function of temperature, the sample undergoes different phase transitions showing different textures. Textural features of the samples in relation to temperature provided the information approximately suitable to determine the optical properties of the samples. The computed thermo optical parameters all plotted against temperature well established the different transitions and their corresponding transition temperatures under investigation.

## ACKNOWLEDGEMENTS

The authors acknowledge Dr. K. Mallika for help rendered in this work 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.

## REFERENCES

[1] S. Chandra Sekhar, Liquid Crystals, Cambridge University Press, New York,1992.
[2] Shri Singh., Liquid crystals Fundamentals, World Scientific Publishing
Co. Pte.Ltd.Singapore, 2002.
[3] Liquid crystals and advanced organic materials, Department of chemistry, University of York. Heslington:York; Available from:http://www.york.ac.uk/chemistry/staff/academic/d-g/jgoodby/.
[4] S.M.Kelly, Hand book of Advanced Electronic and Photonic Materials and Devices, Academic Press, U.S.A, 2000.
[5] Quan Li, Liquid Crystals Beyond Displays – Chemistry, Physics and Applicatiions John Wiley & sons, New Jersy, 2012.
[6] J.W. Scott, D.J. Gregory, P.C. Gregory, Liquid Crystals : Frontiers in Biomedical Applications, World Scientific Publishing Co.Pte.Ltd, Singapore, 2007.
[7] Rafel C. Gonzalez, Richard E. Woods, Steven L. Eddins, Digital Image Processing Using MATLAB (Gatesmark, Natick, 2009), Vol.2. p.1.
[8] C.J.Solomon, T.P. Breckon , Fundamentals of Digital Image Processing: A Practical Approach with Examples in Matlab, Wiley-Blackwell, Chichester, UK, 2011.
[9] Sreehari Sastry, S. T. Ha , B. Gowri Sankara Rao , K. Mallika and T. Vindhya Kumari, Optical properties of a mesogen by image analysis, Liquid Crystals, Vol: 39(11), 1414-1419, 2012.
[10] S. Sreehari Sastry, Sandeep Kumarb , T. Vindhya Kumaria , K. Mallika , B. Gowri Sankara Rao and Ha Sie Tiong, Liquid crystal parameters through image analysis, Liquid Crystals, Vol: 39(12), 1527-1537, 2012.
[11] S. Sreehari Sastry , K.Mallika, T.Vishwam,S. Lakshminarayana, Ha Sie Tiong, Image analysis method to study electro-optic parameters of nematogens, Liquid Crystals, Vol: 41(4), 558-571, 2014.
[12] I.Dierking, Textures of liquid crystals, Wiely-VCH Verlag GmbH Co., Weinheim, 2003.
[13] E.B. Priestley, P.J. Wejtowicz and P. Sehg, Introduction to liquid crystals, RCA Laboratories, Princeton, New Jersey, 1974
[14] Kaustabh Dan, Madhusudan Roy,Alokmay Datta, Detection of a new 'nematic-like' phase in liquid crystal-amphiphile mixture by differential scanning calorimetry, AIP Conference Proceedings, Vol: 1591, 64-66, 2013.
[15] P.S. Pershan, Structure of Liquid Crystals, World Scientific publishing Co. Pte. Ltd, Singapore, 1988.