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Statistical Parameters of Some Ferroelectric Liquid Crystals through Image Analysis Technique

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Abstract

The phase distinction temperature of ferroelectric liquid crystals having left-side terminal chain lengths n=8 and 9 and the same right-side chain length m=6 (VC-145 and VC-144) have been taken into consideration for the present study. The image investigation technique in concurrence through polarising optical microscopy is proposed for the evaluation of statistical parameters. The optical textures of the above series of compounds are recorded at different liquid crystalline phase temperatures. The properties such as "mean, standard deviation, entropy, energy, contrast and homogeneity" are estimated by analysing the optical textures of the samples using MATLAB software and results are discussed. The image investigation technique is a novel, simple technique for analysing the above-said parameters.

Keywords: Ferroelectric Liquid Crystals, Image Analysis Technique, Optical Textures, Statistical Parameters, Transition Temperatures

1.0 Introduction

The usage of soft condensed materials depends on their physical characteristics and the behaviour of their replay to extraneous agitations[1,2]. These self-organising supramolecular designs have a wide-ranging utilisation in various areas of engineering like optical data and processing arrangements, photogenic devices like optical switches, mobile phones, smart cards, and unified display devices[3-7]. The human eye is ideal at distinguishing characteristic arrangements of outlines as well as colours. During the preceding time, the consideration of visual image transformations beneath the ocular microscope has regularly continued as the first practice hired to determine the phase transformation temperatures of every novel arrangement. Yet, it needs to be recognised as a comprehensive and qualitative tactic and an unbiased, as well as calculable approach, would be more beneficial. In this respect, an image investigation procedure has been established to support the interpretation of microscopic images to extract the maximum statistics from the images of objects[8].

Image investigation is the withdrawal of eloquent data from textures by putting computation procedures and algorithms to image facts. These procedures calculate the data and quantities placed on the grey-level intensities of

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the image pixels. Strictures calculated through the ocular pictures of compounds concerning temperature are convenient to recognise transition temperatures, optic characteristics and order limitation belongings of the samples[9-15].

2.0 Computation of Statistical Parameters

Computational trials and algorithms are used to extract data from the liquid crystal images or textures gained at different temperatures. The withdrawal of data from an image/texture is called image investigation. To attain the arithmetical constraints, the image analysis techniques are applied to grey-level intensities over image pixels. Via statistical computation, the provincial features of the grey level value in the vicinity of every point in the image can derive a calculated statistical parameter against the distribution of the provincial feature. "Mean, standard deviation, entropy, energy, contrast and homogeneity" are the strictures computed through the pictures of mesogens concerning temperature. In the current effort, MATLAB operating system was utilised to excerpt the statistical parameters data of liquid crystals 1. Hydroxy amino phenyl octyloxy benzoate (VC-145) and 2. Hydroxy amino phenyl nonyloxy benzoate (VC-144) from the image investigation system.

An image stands as a two-dimensional function with m by n size, with m pixels in the perpendicular order besides n pixels over parallel order. In mathematical terms, the texture may be signified through I (i, j), where i and j represent the garb of the copy. The entire quantity of pixels across the picture is m * n = N, $0 \le i \le m$, $0 \le j \le n$. The distinct arithmetical strictures are as trails[16].

i. Mean (μ): Mean of an image is actuated as the moderate levels of intensity assessments of the picture I(i,j);

ii. $$\mu = \frac{1}{N}\sum_{i=1}^{m}\sum_{j=1}^{n} I(i,j) \qquad \text{------- (1)}$$

iii. Standard Deviation (SD) of the picture: It is the square root of the divergence. The deviation is the alteration of the intensity of the average rate of the picture. If the divergence amount is close to the mean, the S.D. is lesser S.D. of the Picture:

iv. $$\sqrt{\frac{\sum_{i=1}^{m}\sum_{j=1}^{n}\left(I(i,j)-\mu\right)^2}{N-1}} \qquad \text{------(2)}$$

The above-said Statistical limits are reckoned from the picture's Grey Leveled Concurrence Matrix (GLCM).

v. Entropy: The numerical quantity of entropy is the quantity of disorder Ness of the grey level standards across the texture. It denotes in what way arbitrarily the grey levels exist in a copy. The entropy of copy I is extracted by knowing the probability P of a precise grey-level price obtained in that picture.

The entropy of a picture:

vi. $$-\sum_{i=1}^{m}\sum_{j=1}^{n} P_{(i,j)} \log\left(P_{(i,j)}\right) \qquad \text{----- (3)}$$

vii. Energy of an image: It signifies the textural consistency, i.e., pixel duo recurrences. The extreme energy of the texture happens when the grey-level spreading of a specified copy is either a contrast or a sporadic uniform.

The energy of a copy:

viii. $$\sum_{i=1}^{m}\sum_{j=1}^{n}\left(GLCM(i,j)\right)^2 \qquad \text{------ (4)}$$

ix. Contrast of an image: It is the variance in photographic characteristics that styles an entity (or its illustration in a copy) distinct as supplementary matters in addition to the contextual over the similar arena of sight. The problem is the portion of the intensity contrast among a pixel beside its surroundings across the entire picture.

Contrast of an image:

x. $$\sum_{i=1}^{m}\sum_{j=1}^{n}(i-j)^2\, GLCM(i,j) \qquad \text{------(5)}$$

xi. Homogeneity of an image: It is the homogeneousness of any picture. Consistent texture comprises limited grey levels, giving a GLCM by individual rare values but comparatively large probability (P(i, j)) for the GLCM principles. Consequently, the totality of squares will be large. Energy and homogeneity stand alike, the one change is that energy contemplates the rudiments of the GLCM and homogeneity contemplates the possibility of GLCM standards.

Homogeneity of an image:

xii. $$\sum_{i=1}^{m}\sum_{j=1}^{n}\left(P(i,j)\right)^2 \qquad \text{------(6)}$$

3.0 Inferences

Optical textures of the ferroelectric liquid crystals are recorded with reference to temperature on space heating the sample from dense to isotropous state. These samples have transitioned from solid to transparent liquid via smectic and nematic phases. The recorded optical textures at various mesogenic stages are exemplified in Figures 1 and 2.

The nature of statistical parameter curves obtained for VC-144 and VC-145 through image analysis are represented in Figures 3, 4 and 5. The outcomes are deliberated.

The phase transition temperatures attained through these studies are the same as those measured by DSC thermograms and shown in the Table 1.

The conversions with small enthalpy are hard to perceive and it is not conceivable to recognise the particular kind of LC stage. Yet, in the existing procedure, the tiny dissimilarities in the intensity rate will carry substantial variations in phase conversion curvatures and calm to recognise the phase conversions of the mesogens.

The individual and unexpected deviations detected in the graphs at transition temperatures of the mesogenic substances make the present procedure a delicate procedure for the quantification of phase alteration of LC compounds.

The mean is the middle level of intensity of the image then the standard deviation is the distinction of intensity surrounding the mean. At phase transition, the molecules in a sample orient in a particular direction mean and slandered deviation decrease as shown in Figure 3.

The energy is a quantity of homogeneousness in the picture and entropy is disorderliness. During phase change molecules in LC compounds are set in a particular order hence the energy increases and the disorder of molecules decreases therefore entropy decreases as shown in Figure 4.

Homogeneity and contrast show opposite behaviour at phase variation. Homogeneity increases the contrast of textures as it becomes low as represented in Figure 5.

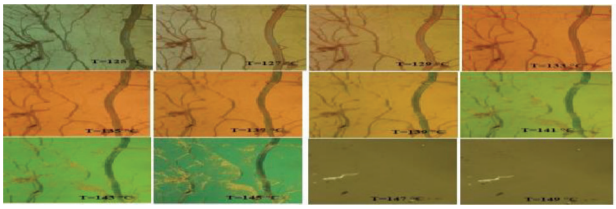


Figure 1. POM Textures of VC-144.

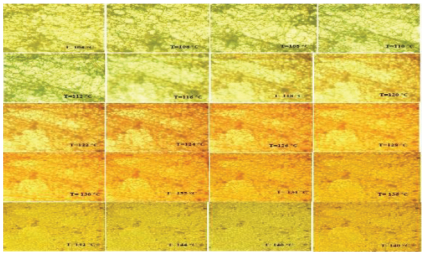


Figure 2. POM Textures of VC-145.

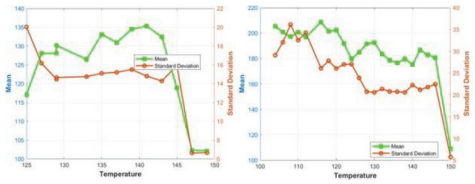


Figure 3. The variation of mean and standard deviation vs temperature in VC-144 and VC-145.

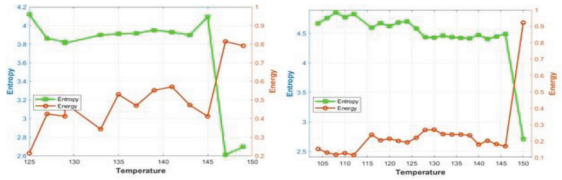


Figure 4. The variation of entropy and energy vs temperature in VC-144 and VC-145.

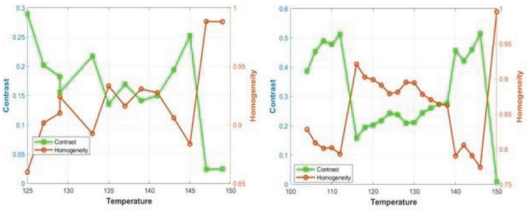


Figure 5. The variation of contrast and homogeneity vs temperature in VC-144 and VC-145

Table 1. Transition temperatures of VC-144 and VC-145 by DSC and image analysis technique (^{0}C).

Compound	Crystal		Smectic-A		Nematic		Isotropic	
	DSC	Image Analysis	DSC	Image Analysis	DSC	Image Analysis	DSC	Image Analysis
VC-144	85.5	85.3	113.2	113.1	145.2	145.0	145.4	145.5
VC-145	83.2	83.2	107.8	107.6	149.2	149.4	149.4	149.6

Table 2. Statistical parameters computed from optical textures at N-Iso transition

Compound	Mean	SD	Energy	Entropy	Contrast	Homogeneity
VC-144	102	6.50	0.200	0.820	0.025	0.985
VC-145	108	7.00	0.210	0.920	0.015	1.000

4.0 Conclusions

This procedure is unassuming, less multipart and consistent. Unlike other methods, there is no need to organise dissimilar arrangements except to assemble with Polyoxymethylene (POM). The critical idea is that this system clearly illustrates transitions, which are acknowledged to be present but are superficial when witnessing textural changes by eyes.

Liquid Crystal thermometers portray temperatures as colours and can be used to follow temperature changes caused by heat flow. Usually, in mines, there is heat fluctuation, hence liquid crystal thermometers can be used as heat sensors.

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