



e-ISSN: 2319-8753 | p-ISSN: 2347-6710

IJRSET

International Journal of Innovative Research in
SCIENCE | ENGINEERING | TECHNOLOGY

INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN SCIENCE | ENGINEERING | TECHNOLOGY

Volume 11, Issue 1, January 2022

ISSN INTERNATIONAL
STANDARD
SERIAL
NUMBER
INDIA

Impact Factor: 7.569

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6381 907 438

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Image Processing and Fourier Transformations of 4-Hexyloxy Benzylidene 4'-Decyloxy Aniline Liquid Crystal

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ABSTRACT: Image analysis of 4-hexyloxy benzylidene 4'-decyloxyaniline (6O.O10) is studied using software aided technology and its phase transitions were observed through Polarizing Optical Microscope. The observed enantiotropic Nematic and Smectic Phases have shown thermodynamically statistical drift which are in good agreement with the literature of our previous techniques. The optical transmittance, contrast, correlation, energy, homogeneity, variance and other basic statistical parameters of textures of the 6O.O10 liquid crystal were computed and correlated with other techniques. The specific and significant values in the above said parameters were observed in Smectic C, I and Nematic phases of the studied sample. Among all the computations, Nematic phase of the sample is exhibited maximum energy, correlation, homogeneity & all other statistical parameters except contrast which is found minimum when compared to other mesogenic states of the sample. These observations helped the authors to suggest the sample for display device applications at high atmospheric conditions in its Nematic mode of existence. Fractional Fourier transformation based image processing algorithm is applied on the studied sample using MATLAB software.

KEYWORDS: Thermotropic Liquid Crystal, Fourier Transformation, Digital Image Processing, Statistical Parameters.

I. INTRODUCTION

The field of Condensed Matter Physics is always motivated for experimenting and introducing novel techniques in research since 20 - 25 years. The contribution by Condensed matter Physicists to the Modern Technology is appreciable. The interactions of the molecules of these matter are governed by laws of both Classical and Quantum Mechanics. In some systems, the constituent particles were described best by Classical Mechanics and their interactions are free from quantum mechanical effects. Such systems are called as "Soft Condensed Matter". Liquid Crystals are one among the soft condensed matter which play vital role in development of display technology and in the devices of biosensors and so on. The synthesis of novel Liquid crystal material is also a thriving work in the research field and unveiling the physical properties of these novel liquid crystals is also interesting giving good information about their optical, thermal, electrical and magnetic properties.

The information about the physical properties of the synthesized novel liquid crystalline materials help to predict them for suitable applications in engineering, technology and medical fields. There are various characterization techniques to study the properties of novel liquid crystals. The very basic characterization technique involves the Polarizing optical microscopy (POM). Through POM studies, the textures of the sample were identified and their changes with temperature were also observed. This helps to note the phase transition temperatures of the liquid crystal. As Liquid crystal is a state of matter that exists between crystalline state and disordered liquid state.

II. RELATED WORK

The liquid crystals were first studied by Friedrich Reinitzer in 1888 [1] while observing cholesteryl benzoate and showed a hazy liquid phase that changes with temperature. Since then vigorous research was done in getting varieties of liquid crystals and our current work is the extension of optical parameters in terms of statistical mechanics.



The current article is focused on 4-hexyloxy benzylidene 4'-decyloxyaniline (6O.O10) synthesized at our lab and was studied previously for some optical and thermal properties [2]. The application of image processing technique on the digital images of the textures of liquid crystals at various phases and temperatures was started in the 21st century [3-9]. Image analysis is also another technique that is helpful in getting the statistical parameters of the surface orientations of the liquid crystal sample [10-15]. The Fractional Fourier Transformation is further modern technology that was also started applying on the textures of liquid crystals [16-18].

The present study has explained the recollection of phase transition temperatures, textures of 6O.O10 liquid crystal (LC) and image processing, image analysis and Fourier transformations of the textures of the same.

III. METHODOLOGY

The characterization of the studied sample 6O.O10 was done through three methods. viz., a) Polarizing Optical Microscope, b) Image Processing and c) Image analysis

a) Polarizing Optical Microscope: The crossed position of Polarizing Optical Microscope (POM) is the basic technique used to find the phases of the studied sample and transition temperatures of the same. The authors had captured the phase transitions of 6O.O10 both in heating and cooling. The used POM is made by Meopta Optical Instruments. The Nikon Digital Camera was attached to the eyepiece of the POM to get the textures of the LC. Its resolution is adjusted to 2816 x 1880 pixels and corresponding intensities were ranged between 0-255. The gray level scaling was done to the images of the textures of phase transitions of 6O.O10 after saving them in a computer having MATLAB software. The sample holder of the POM was connected to Variac for controlled heating and cooling. This made the authors to note the transition temperatures and perfect changes in the sample with high accuracy.

b) Image Processing: The textures of 4-hexyloxy benzylidene 4'-decyloxyaniline (6O.O10) were in the form of digital pictures which were processed using MATLAB software for Fractional Fourier transformation. The coloured images were transformed to gray scale using the code in MATLAB and then transformed using Fourier formulae to get the FFT images of the same.

c) Image Analysis: The image analysis involves getting the physical parameters in terms of statistical values from the images and obtaining surface orientations of the molecules of the sample with respect to incident light and temperature. The current study is focussed to get the textures while cooling the sample from its liquid state to solid state through LC state slowly at the rate of 0.5°C temperature. The photos of the LC was taken every change in half degree temperature and were stored in the Computer having MATLAB software. These photos were first scanned through the code in MATLAB and using corresponding formulae in the form of code the statistical parameters for calculated. The following are the list of statistical parameters computed by the authors and their meaning with mathematical expressions.

i) *Optical Transmittance* : Mean of image is simply arithmetic average of the pixel values in the image. This can be obtained by summing up the all pixel values and divided by the total number of pixels

$$\text{Optical Transmittance} = \frac{1}{N} \sum_{i=1}^m \sum_{j=1}^n I(i, j)$$

ii) *Variance*: Variance defines the variation of intensity around the mean

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

iii) *Skewness*: Skewness defines the symmetry around the mean intensity value.

$$\text{Skewness} = \frac{\left(\sum_{i=1}^m \sum_{j=1}^n I(i, j) - \mu \right)^3}{(N - 1) * S^3}$$

Where S is standard deviation of the image.

iv) *Kurtosis*: Kurtosis is a measure of peakedness. i.e whether the intensity values are peaked or flat around the mean intensity value.

$$Kurtosis = \frac{\left(\sum_{i=1}^m \sum_{j=1}^n I(i, j) - \mu \right)^4}{(N - 1) * S^4}$$

All the defined parameters are extremely sensitive to the changes in the textural features of liquid crystals as a function of temperature.

v) *Contrast*: Contrast is second order statistical parameter and is calculated from grey level co-occurrence matrix (GLCM) of the texture []. The elements of the GLCM represent the relationship between pixel intensity and its neighbouring pixels. The intensity contrast between a pixel and its neighbor is measured by the contrast of texture.

$$Contrast = \sum_{i=1}^m \sum_{j=1}^n (i - j)^2 GLCM(i, j)$$

vi) *Homogeneity*: Homogeneity measures the closeness of the distribution of values in the GLCM. Homogeneous textures will contain only a limited range of gray levels, giving a GLCM with only a few values but relatively high probability P(i,j) for the GLCM values.

$$Homogeneity = \sum_{i=1}^m \sum_{j=1}^n (P(i, j)^2)$$

vi) *Energy*: Like contrast, energy is also a second order statistical parameters and it measures textural uniformity, that is pixel pair repetitions. The maximum energy of the texture of image occurs when the grey level distribution of a given image is either constant or a periodic uniform.

$$Energy = \sum_{i=1}^m \sum_{j=1}^n GLCM(i, j)^2$$

(vii) *Correlation*: Correlation brings out how correlated a reference pixel to its neighbor over an image, is uncorrelated to energy, contrast and homogeneity. The equation for correlation measurement considers the mean and standard deviation for row and column in the matrix as shown.

$$Correlation = \sum_{i=1}^m \sum_{j=1}^n \frac{\{ix\}xGLCM(i, j) - \{\mu_x \mu_y\}}{\sigma_x \sigma_y}$$

where μ_x , μ_y and σ_x , σ_y are the mean and standard deviations of probability matrix *GLCM* along row wise *x* and column wise *y*.

IV. EXPERIMENTAL RESULTS

The studied Liquid Crystal 4-hexyloxy benzylidene 4'-decyloxyaniline (6O.O10) exhibited enantiotropic phases of Nematic, Smectic C, Smectic I and Solid to Solid transitions were also observed. The chemical Formula of 6O.O10 is shown in Fig.1

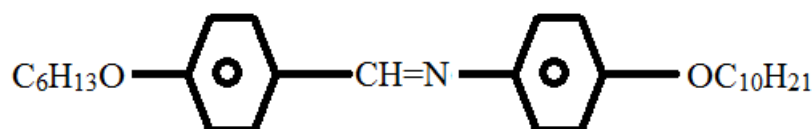


Fig.1 Chemical Formula of 6O.O10

The textures of the LC in cooling cycle is shown in Fig.2 at clear phase observations. The corresponding temperatures were also mentioned below each texture.

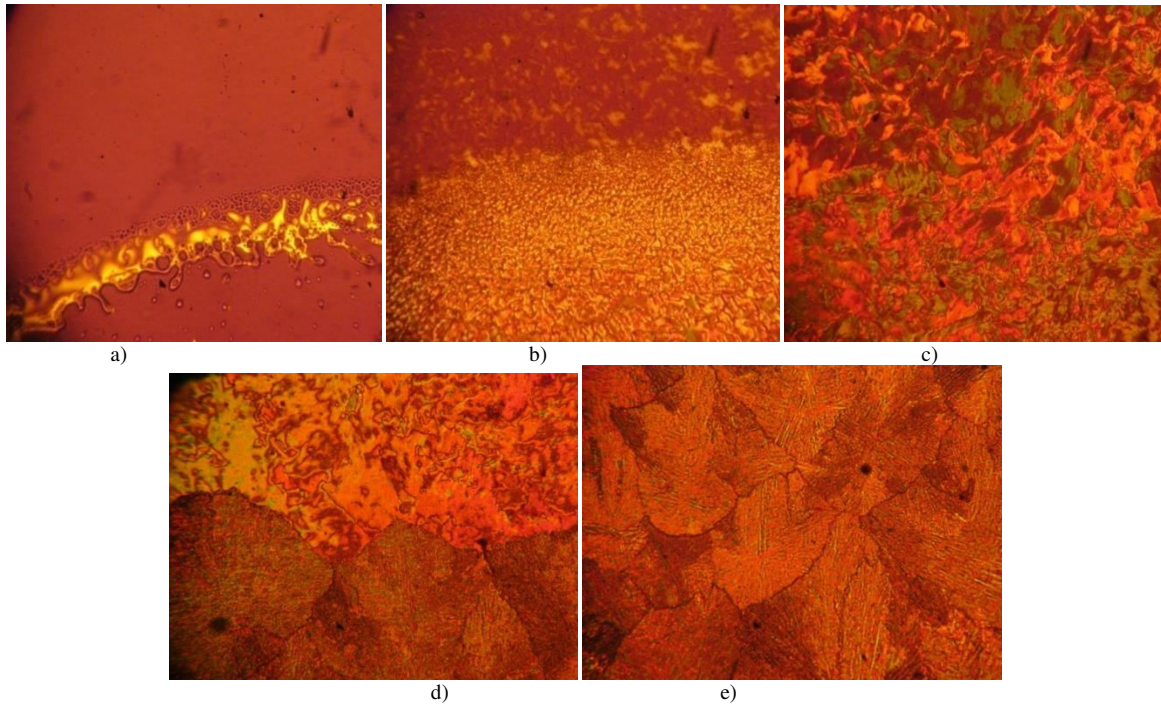


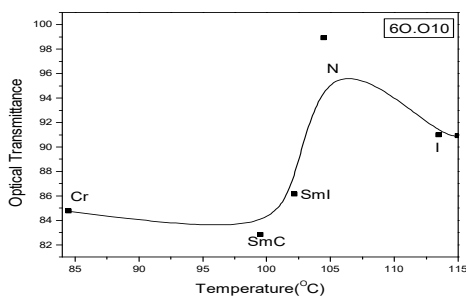
Fig.2 Phase transitions and textures of 6O.O10 a) Isotropic to Nematic @ 113.5^oC b) Nematic to Smc @ 104.5^oC c) SmC to SmI @ 102.2^oC d) SmI to Solid-1 @ 99.5^oC e)Solid-1 to Solid-2 @ 84.5^oC

The transition temperatures observed from POM and Image analysis were tabulated in Table 1 below which show a good agreement in transition temperatures and phase observations.

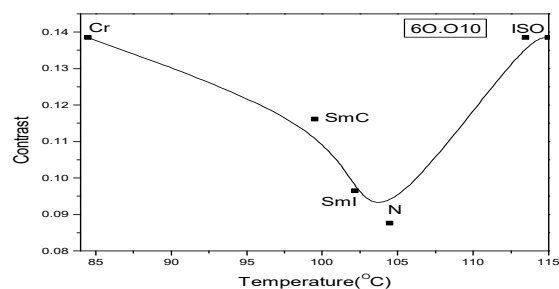
Table 1. Phase Transition temperatures of 6O.O10 through POM and Image Analysis

POM						Image Analysis			
COMPOUND	PHASE	MELTING	CI	NC	NI	PHASE	CI	NC	NI
6O.O10	Solid - Sm C - N (Heating)	94.26 (Sm C)	NO	105.74 (N)	114.35 (Liquid)	Cooling only			
	N-C-I-Solid (Cooling)	92.5	89.0 (Sm C)	104.3 (Sm I)	113.4 (N)		89.0	106	114

Thermodynamical statistical parameters computed from MATLAB software were plotted against temperature which are as shown below in Fig.3



a)



b)

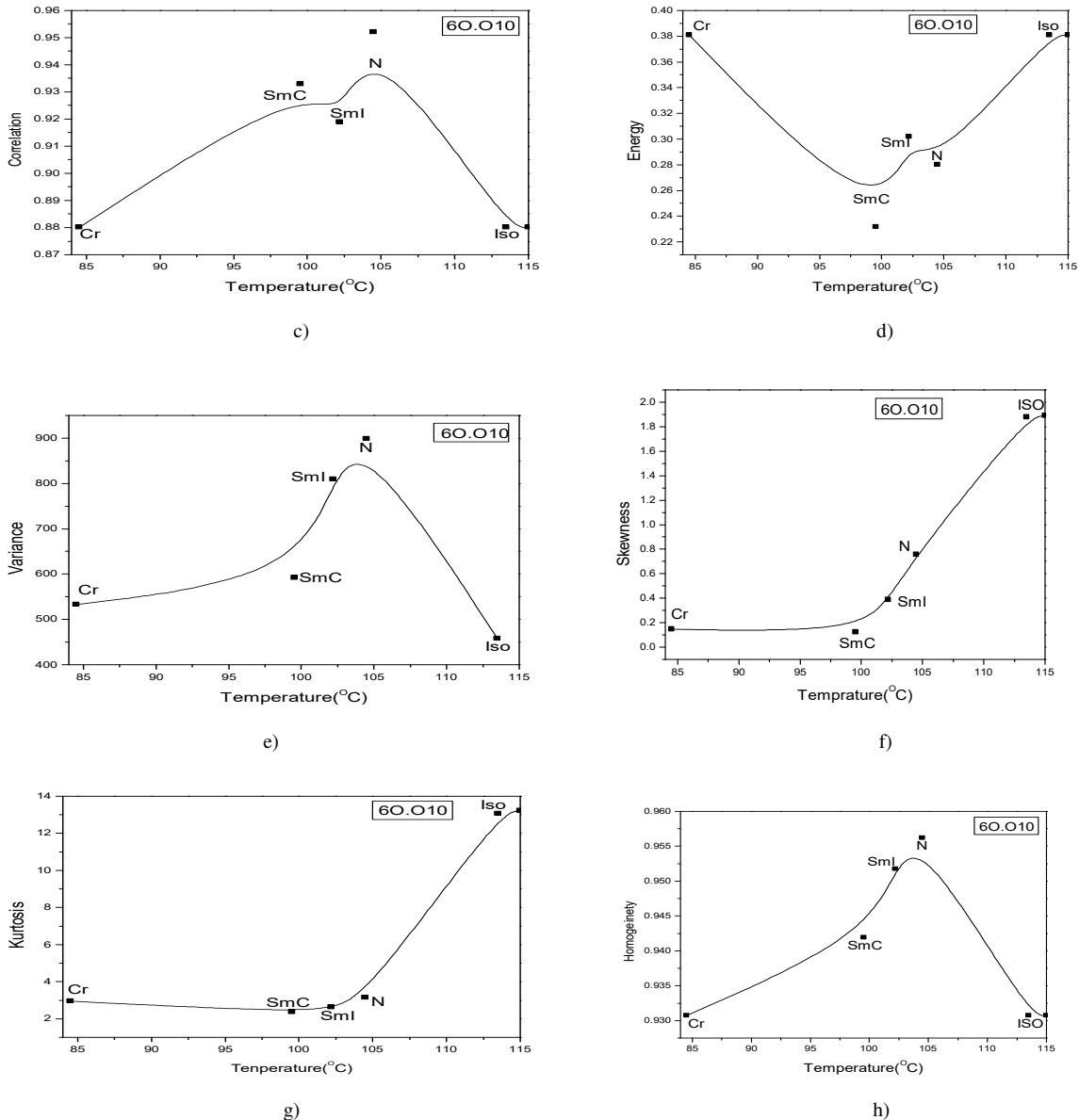


Fig.3 Thermodynamical Statistical Parameters of 6O.O10 a) Optical Transmittance b) Contrast c) Correlation d) Energy e) Variance f) Skewness g) Kurtosis h) Homogeneity with temperature variation

In Fig.3, the computed statistical parameters were Optical transmittance, Contrast, Correlation, Energy, Homogeneity, Variance, Skewness and Kurtosis. These were computed by taking the input from the digital images of the textures of the LC in proper order. These parameters have physical significance in the characterization of the Liquid Crystal material. The variation of each parameter with temperature also shows the change in state of molecular arrangement of the sample on the surface level. As the incident light undergoes polarization after passing through the liquid crystal sample the emitted light has different electric field vector vibrations which were analyzed through the pixel processing of the images.

This study is supported the novel technique to obtain the phase transition temperatures of the studied material. The Image analysis also supported the existence of Nematic, Smectic C, Smectic I and Solid 1-Solid 2 phases of 6O.O10.

The numerical values of Contrast, Correlation, Energy, Homogeneity, Mean, Variance, Skewness, Kurtosis and Standard Deviation at different temperatures were tabulated in Table 2.

Table 2. The Statistical Parameters of 6O.O10 from Image Analysis

Temp	contrast	correlation	Energy	Homogeneity	Mean	Variance	Skewness	Kurtosis	Stadard deviation
84.5 (S2)	0.1385	0.8802	0.3808	0.9307	84.769	533.231	0.1495	2.9700	23.092
99.5 (S1)	0.1161	0.9330	0.3021	0.9419	85.838	792.681	0.1841	2.6758	22.15
102.2 (SmC)	0.0964	0.9589	0.2315	0.9517	86.142	899.123	0.3880	2.7254	21.57
104.5 (SmI)	0.0876	0.9821	0.2804	0.9652	98.926	913.254	0.7576	3.1532	19.98
113.5(N)	0.0754	1.2802	0.3808	0.9707	99.980	978.486	1.8804	13.0758	18.41

The Table 2 informs that the contrast of the image decreases as temperature is increasing and Nematic phase possess the minimum contrast in the texture. The statistical parameters of correlation and homogeneity in the intensity of the image is increasing under the same variation of the temperature. The energy values are minimum in Sm C state of the sample. The parameters of mean, variance, skewness, kurtosis and standard deviations were also shown their trend in increasing way as moving from Solid 2 to Nematic via Solid 1, Sm C and Sm I phases.

The variations in the statistical parameters are very helpful in getting the morphology of the studied material and the observations are in support of phase transitions obtained by POM.

Further, Fractional Fourier Transformations were done to these images through MATLAB with another coding and the transformed images were shown in Fig.4 The Figures a) to e) were the original textures at clear phase observations which were cropped to size 256X256 and the figures f) to j) were their respective gray scale leveling. The figures k) to o) were the Fractional Fourier transformed images of the same textures.

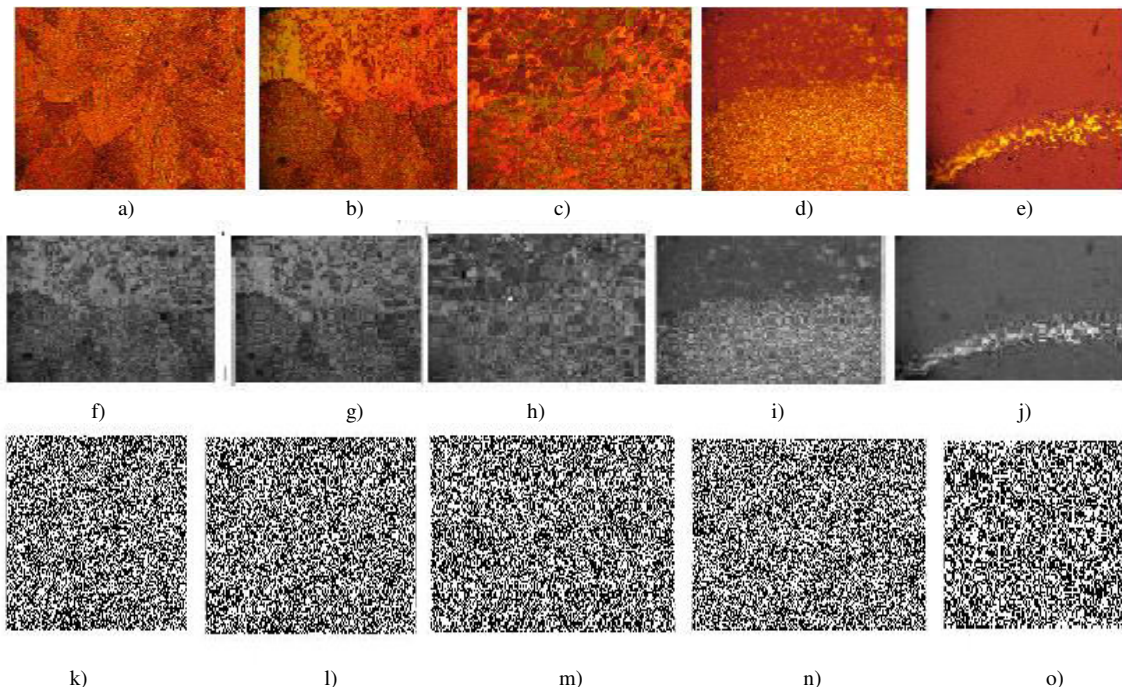


Fig.4 POM images of 6O.O10 a) Solid 1 b) Solid 2 c) Smectic C d) Smectic I e) Nematic phases and their corresponding Gray scale levelling from f) to j) and FFT processed from k) to o)

V. CONCLUSION

This article in detail explains about the Phase changes of 6O.O.10 Liquid Crystal material with increasing temperature and decreasing temperature. The enantiotropic Nematic and Smectic C phases were observed through POM, Image Processing and Image Analysis techniques. The Monotropic Smectic I phase is observed only in cooling



cycle. Image processing of the sample helped the authors to transform into Fourier space which can be directed the authors to propose the decoding and encoding of the materials. Further, Fourier Coefficients can be calculated using these transformations. The image analysis computations were done to obtain the statistical parameters optical transmittance, homogeneity, energy, contrast, correlation, skewness, mean, kurtosis and standard deviation. These parameters were also helped to again confirm the phase transition temperatures of the material and morphology of the material. This made the authors to suggest the sample for display device and biosensor applications in its nematic or Sm I state for better results.

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