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Characterization of PVA Dispersed Cholesteric Liquid Crystal; Investigation of Optical and Dielectric Properties

JES Journal of Electrical Systems

Abstract: - Composite materials by dispersing polymer into cholesteric liquid crystals (CLC) are very useful to minimise many drawbacks of pure liquid crystals like threshold voltage, contrast ratio, stability etc. These materials are used for many applications like light shutters, smart windows in addition to display. The present paper is an attempt to study and compare optical and electrical properties of pure and composite CLC. The polyvinyl alcohol of different concentrations was dispersed to cholesteryl palmitate by chemical method. The study of optical properties was performed by polarizing optical microscopy (POM) and fabry perot scattering studies (FPSS) whereas the dielectric properties were studied by impedance analyser. It was found that the CLC shows more stability and improved performance after dispersing polyvinyl alcohol which may provide new opportunity for potential application of these materials.

Keywords: Polyvinyl Alcohol, Cholesteric Liquid Crystal, Polarizing Optical Microscopy, Fabry Perot Scattering Studies, Dielectric

INTRODUCTION

Liquid crystals are a unique class of soft materials which combine properties of both solids and liquids. They manifest in three primary phases: nematic, smectic, and cholesteric, with our focus on the cholesteric phase. In this phase, molecules adopt a spiral arrangement like a corkscrew, leading to fascinating optical qualities like different bright colours that change with viewing angles. This spiral structure enables selective reflection of circularly polarised light, making cholesteric liquid crystals highly focused for applications like liquid crystal displays due to their adjustable optical features. Additionally, their helical configuration results from a combination of nematic alignment and chirality, allowing them to selectively reflect specific light wavelengths based on their pitch length. This property finds utility in electronic paper displays, sensors for temperature and pressure, optical filters, photonic devices, and innovative smart materials, underlining their adaptability and responsiveness to external stimuli [1-7].

Unlike unpolymerized cholesteric liquid crystals, the helical pitch of polymer cholesteric liquid crystals remains constant with changes in temperature. This remarkable property ensures that the laser's operational wavelength remains stable regardless of temperature fluctuations, making it highly advantageous for various device applications [8-11].

The study of optical and dielectric properties of cholesteric liquid crystals plays an important role in various applications. It can be harnessed for temperature-sensitive labels and indicators, where the changing colour corresponds to temperature fluctuations, making them useful in monitoring equipment or indicating temperature gradients in materials. Additionally, this property finds use in thermochromic inks and coatings for applications like packaging and temperature-sensitive paints, providing visual feedback on temperature changes [12-16].

The dielectric property of cholesteric liquid crystals has advantageous for its application in electrically tuneable photonic devices. When an electric field is applied, these liquid crystals can change their molecular orientation, leading to a shift in the reflected colour or optical properties. This property is crucial for creating flexible and energy-efficient displays, optical switches, and tuneable photonic filters used in electronic devices and information displays [17-20].

The unique optical properties of these liquid crystals, characterised by their capacity to selectively reflect specific wavelengths of light based on the helical pitch, have opened exciting possibilities in various fields. These

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properties enable the creation of electronic paper displays with exceptional colour vibrancy and low power consumption, making them well-suited for applications such as e-readers and signage. Moreover, the tuneable nature of these materials finds utility in sensors and optical filters, offering precise control over reflected colours for environmental monitoring, medical diagnostics, and advanced telecommunications [21-28, 52-57].

Nevertheless, the pure cholesteric liquid crystal has some drawbacks like limited operating temperature range, less stable and limited viewing angle etc. These drawbacks can be overcome by preparing composite materials of liquid crystal with polymer and/or nanoparticle. The polymer dispersed liquid crystal (PDLC) has advantage of simple preparation and proving stability to the compound. For preparation of PDLC as suitable polymer is selected based on its applications. Many researchers have studied/investigated the properties of PDLC, like Yuzhen Zhao et al. studied cholesteric liquid crystal films for bistable reflective displays [47], Feifei Wang et al. reported how the diffusion of dye due to temperature changes affects the way cholesteric liquid crystal films reflect a broad range of colours [48], Alberto Belmonte et al. studied colourful reflective coatings made from structured photonic cholesteric liquid crystal particles [49]. In addition to this, the study of many other researcher inspired us to investigate the properties of polymer dispersed cholesteric liquid crystals[29-46,50-51].

In the present study optical, thermal, and dielectric properties of composite films prepared by dispersing polyvinyl alcohol into cholesteryl palmitate were investigated by various techniques.

MATERIALS AND METHOD

The selection of suitable polymer plays an important role for the preparation of polymer dispersed liquid crystal. The two main requirements are matching of refractive index of liquid crystal with polymer and solubility of liquid crystal into polymer. The cholesteric liquid crystal (CLC), cholesteryl palmitate was procured from Sigma Alderich and is named as PLC. There are many methods for preparation polymer dispersed liquid crystals but the polymerization by induced phase separation also known as chemical method is most preferred due to its simple preparation technique. In this method homogeneous mixture of liquid crystal and polymer is taken and polymerized using ultraviolet radiation. During the polymerization process, the liquid crystal form droplets after its separation from polymer matrix. Using chemical method of polymerization, two different concentrations (wt/wt) of polyvinyl alcohol (PVA) was dispersed into cholesteryl palmitate. The composite films having concentration of 80% CLC and 20% PVA is names as AA whereas the film having concentration of 60% CLC and 40% PVA is names as BB in the present work.

RESULT AND DISCUSSION

Fabry-Perot Etalon Spectroscopic Studies

This is the unique technique to investigate the phase transition temperatures in which laser light is incident on different concentrations of liquid crystal as well as on liquid crystals in the polymer matrix. The experiment is performed for minimum ten cycles of heating and cooling to get accuracy. We observed changes in diameter of the Fabry-Perot rings with varying concentration of PVA. The graph of angular diameter (diameter of a particular ring divided by diameter of central ring) which has no unit is plotted against temperature.

Figure 1(a) shows the diameter versus temperature graph for PLC, whereas figure 1(b) and 1(c) shows the graphs for concentrations AA and BB respectively.

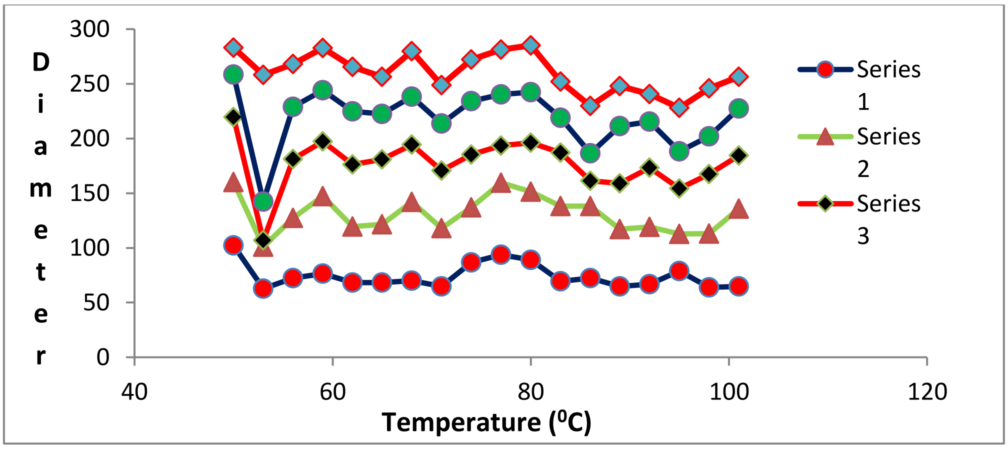


Figure 1(a): Diameter versus temperature graph for PLC

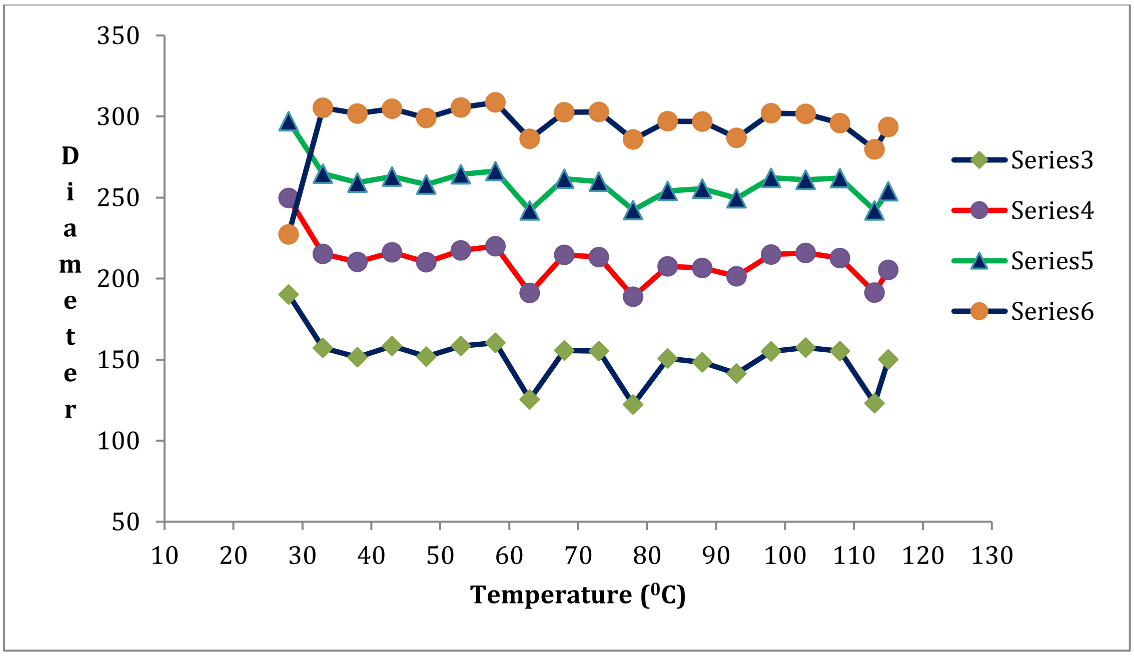


Figure 1(b): Diameter versus temperature for AA

The PLC shows transitions at temperatures 56 ^{0}C, 73 ^{0}C, 86 ^{0}C and 107 ^{0}C. The concentration AA shows transition temperatures are 60 ^{0}C, 78 ^{0}C, 90 ^{0}C and 110 ^{0}C. It was found that it forms dupin cyclide phase near room temperature. The transition temperature for concentration BB was found at 60 ^{0}C, 68 ^{0}C, 82 ^{0}C and 100 ^{0}C.

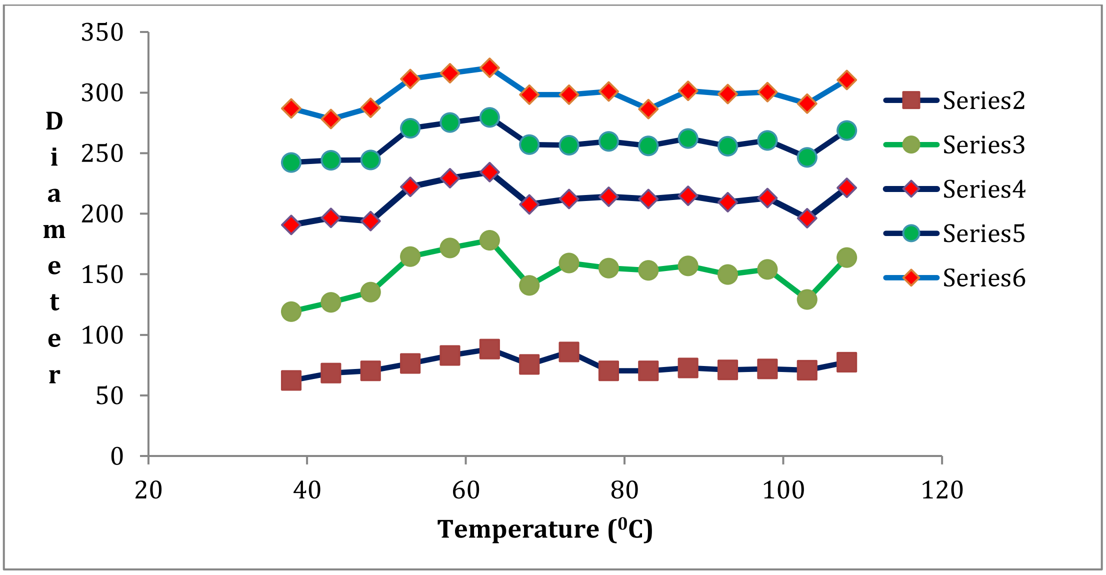
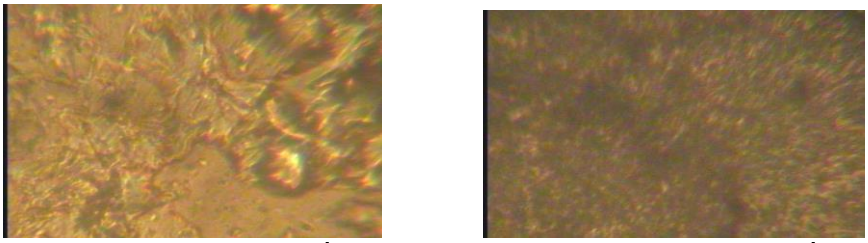


Figure 1(c): Diameter versus temperature for BB

Polarizing Optical Microscopy (POM)

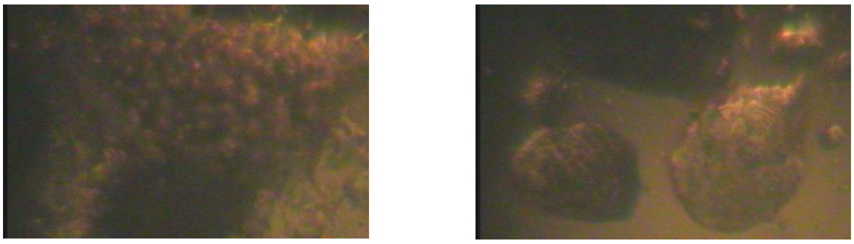
The mesomorphic behaviour of pure CLC and its composite with two different concentrations of polyvinyl alcohol were observed with the help of POM.

The reorganisation of molecules in a different layer of composite and melting of alkyl chains in composite is responsible for mesophase.



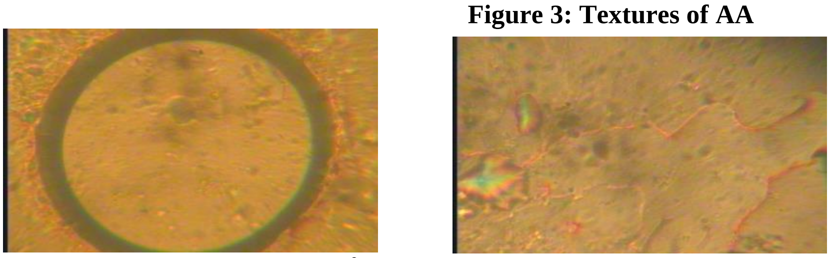
(a) Fan like stucture at 62.1 ^{0}C **(b) Schlieren nematic at 80.4 ^{0}C**

Figure 2: Textures of PLC



(a) Honeycomb texture at 52.3 ^{0}C **(b) Smectic A phase at 82.5 ^{0}C**

Figure 3: Textures of AA



(a) Polymer Droplet at 80 ^{0}C **(b) Boundaries of Polymer at 82 ^{0}C**

Figure 4: Textures of BB

The PLC shows fan like stucture at 62.1^{0}C and Schlieren nematic texture at 80.4 ^{0}C. The concentration AA shows Honeycomb texture at 52.3 ^{0}C and Smectic A phase at 82.5 ^{0}C whereas for concentration BB Honeycomb texture was at 52.3 ^{0}C and at 82.5 ^{0}C it shows Smectic A phase. The layers are mainly in oblique positions with respect to the slides. Only lines of flare and translational dislocations occur. The polygonal texture is defined by a set of horizontal segments of hyperbolae, at the level of the coverside, which form a polygonal lattice, and vertical segments which are attached to each polygonal edge.

Electrical Properties

The dielectric properties are useful for polar molecules to understand molecular properties. When an electric field is applied then alignment of molecules changes which result changes in dipole moment and polarizability. The dielectric properties were investigated using Precision Impedance Analyser (Wayne Kerr 6500B, Chichester, West Sussex, and UK).

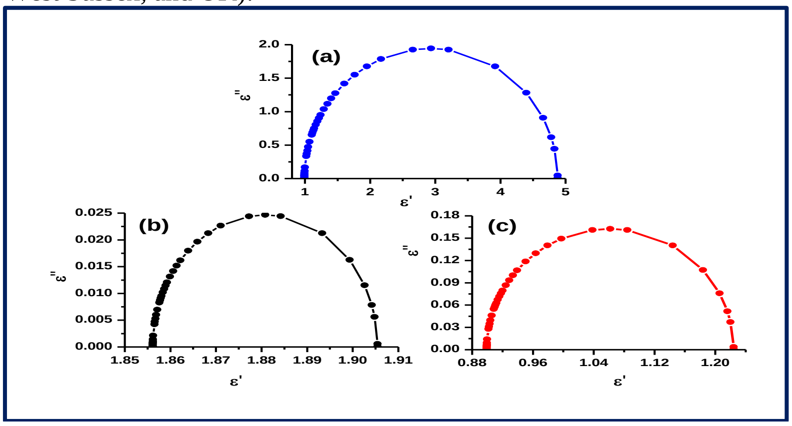


Figure 5: Cole-Cole Plot for PLC, concentration AA and BB

The blue line (figure a) in the Cole-Cole plot shows dielectric behaviour of CLC. It was found that the dielectric constant changes from 1 to 5 and dielectric loss is 1.75. The dielectric graph of concentration AA (figure b) is shown with black line. The dielectric constant lies between 1.85 to 1.905 and dielectric loss is 0.0205. The red line (figure c) shows values of real dielectric constant from 0.882 to 1.225 and dielectric loss is 0.15.

CONCLUSIONS

The polyvinyl alcohol of two different concentrations were dispersed into cholesteric liquid crystal by chemical method. The various mesophases and phase transition temperature were investigated by POM. The phase transition temperature was also confirmed by FPSS. It was found that number of mesophase and transition temperature changes after dispersing PVA to CLC. The electric investigation shows increase in dielectric constant and decrease in dielectric loss for composite material. Therefore, we can say the PVA changes the phase behavior in addition to the dielectric properties. The PVA also increases the conductivity of the material along with the inherent mechanical strength of the material. These results may provide new opportunities for the research community as it may become the promising materials for optical sensor and tunable laser sources with low cost.

ACKNOWLEDGMENT

We wish to express our sincere thanks to Prof. (Dr.) V. N. Rajasekharan Pillai, Vice-Chancellor of Somaiya Vidyavihar University and Dr. Suresh Ukarande, Principal, K. J. Somaiya College of Engineering, for encouragement and support towards this research work.

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