

“Experimental Study of the Optical and Dielectric Properties of Polyvinyl Alcohol”

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Abstract

Polymer–liquid crystal composites have attracted considerable interest because they can overcome several limitations associated with pure liquid crystals, including high threshold voltage, poor contrast, and limited stability. These materials have potential applications in display devices, light shutters, and smart windows. In the present study, polyvinyl alcohol (PVA) was incorporated into cholesteryl palmitate, a cholesteric liquid crystal, at different concentrations using a chemical dispersion method. The optical behaviour of the pure and PVA-dispersed liquid crystals was examined using polarizing optical microscopy (POM) and Fabry–Perot scattering studies (FPSS). Their dielectric properties were investigated using an impedance analyser. A comparative analysis revealed that the incorporation of PVA improved the stability and overall performance of the cholesteric liquid crystal. The observed changes in optical and electrical behaviour suggest that PVA–cholesteryl palmitate composites may be promising materials for electro-optical applications.

Keywords: Polyvinyl alcohol, Cholesteric liquid crystal, Cholesteryl palmitate, Polarizing optical microscopy, Fabry–Perot scattering studies, Dielectric properties, Polymer–liquid crystal composite.

1. Introduction

Liquid crystals are soft materials that exhibit both fluidity and molecular ordering, giving them unique optical and electrical properties. They are broadly classified into nematic, smectic, and cholesteric phases. Cholesteric liquid crystals (CLCs), also called chiral nematic liquid crystals, possess a helical molecular arrangement that produces selective reflection of light. The reflected wavelength depends mainly on the helical pitch and refractive index, making CLCs attractive for reflective displays, optical filters, sensors, and photonic devices [1-3].

The optical and dielectric responses of CLCs are sensitive to temperature, electric field, and molecular organization. However, pure CLCs may suffer from limited thermal stability, restricted operating conditions, and structural instability. Incorporating a suitable polymer can improve mechanical stability and modify the optical and electrical characteristics of the liquid crystal. Polymer-dispersed liquid crystals have therefore received considerable attention for applications in smart windows, light shutters, displays, and electro-optical devices [4,5].

Polyvinyl alcohol (PVA) is a water-soluble, film-forming polymer with good chemical stability and useful optical properties. Its incorporation into CLCs can influence molecular organization, light scattering, and dielectric behaviour. In the present work, PVA was dispersed at different concentrations in cholesteryl palmitate, a cholesteric liquid crystal [6-8]. The optical properties were investigated using polarizing optical microscopy (POM) and Fabry–Perot scattering studies (FPSS), while dielectric properties were examined using an impedance analyser. The study focuses on comparing pure and PVA-dispersed cholesteryl palmitate to evaluate the influence of polymer concentration on their optical and electrical behaviour [9-12].

2. Materials and Methods

The selection of polymer is important for preparing polymer-dispersed liquid crystal (PDLC) composites. A suitable polymer should have good compatibility with the liquid crystal, particularly with respect to refractive index and solubility. In the present study, cholesteryl palmitate (CLC), procured from Sigma-Aldrich, was used as the liquid-crystal material. The composites were prepared using the polymerization-induced phase separation (PIPS) or chemical method. A homogeneous mixture of cholesteryl palmitate and polyvinyl alcohol (PVA) was prepared and subjected to polymerization. During phase separation, the liquid-crystal component forms domains within the polymer matrix, producing a polymer-dispersed liquid-crystal composite. Two compositions were prepared by varying the PVA

concentration. The composite containing 80 wt% cholesteryl palmitate and 20 wt% PVA was designated as AA, while the composite containing 60 wt% cholesteryl palmitate and 40 wt% PVA was designated as BB. These samples were subsequently used for optical and dielectric characterization.

3. Results and Discussion

3.1 Fabry–Perot Etalon Spectroscopic Studies

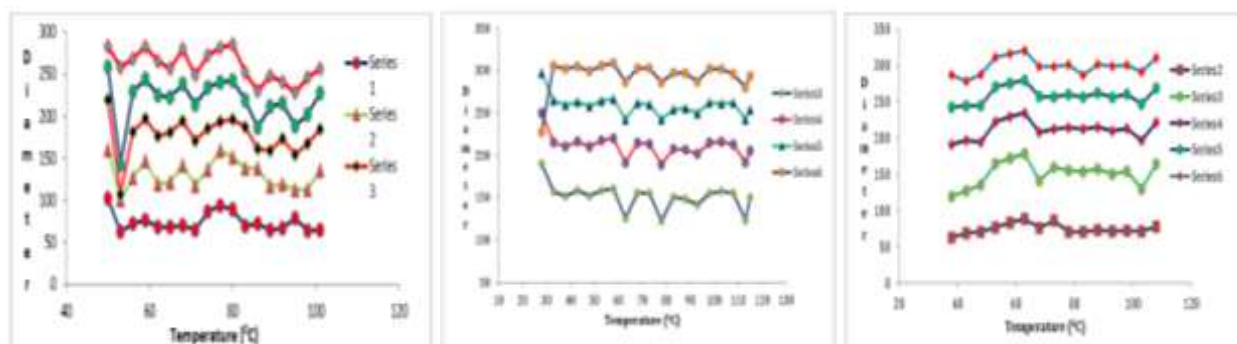
Fabry–Perot Etalon Spectroscopy is an effective technique for determining the phase-transition behaviour of liquid crystals. In the present study, laser light was incident on pure cholesteryl palmitate (PLC) and PVA-dispersed CLC composites (AA and BB) during controlled heating and cooling cycles. Measurements were repeated for at least 10 heating–cooling cycles to ensure reproducibility. The variation in the diameter of Fabry–Perot interference rings was recorded with temperature. The angular diameter, defined as the ratio of the diameter of a selected ring to that of the central ring, was plotted against temperature. The resulting curves were used to examine the phase-transition behaviour of the samples. Figure 1(a) represents the angular diameter versus temperature for pure PLC, while Figures 1(b) and 1(c) correspond to the AA and BB composites, respectively. The changes in ring diameter with PVA concentration indicate the influence of polymer dispersion on the phase behaviour of the cholesteric liquid crystal. The PLC shows transitions at temperatures 560C, 730C, 860C and 1070C. The concentration AA shows transition temperatures are 600C, 780C, 900C and 1100C. It was found that it forms dupin cyclide phase near room temperature. The transition temperature for concentration BB was found at 600C, 680C, 820C and 1000C.

Figure 1. Angular diameter versus temperature for (a) pure cholesteryl palmitate (PLC), (b) 80 wt% CLC–20 wt% PVA composite (AA), and (c) 60 wt% CLC–40 wt% PVA composite (BB).

3.2 Polarizing Optical Microscopy (POM)

The mesomorphic behaviour of pure cholesteryl palmitate (PLC) and its PVA-dispersed composites was investigated using polarizing optical microscopy (POM). The observed textures provide information about the molecular organization and phase transitions of the liquid-crystal systems. The incorporation of PVA modifies the molecular arrangement and interfacial interactions within the cholesteric liquid crystal, resulting in noticeable changes in the observed textures. The formation and rearrangement of molecular layers, together with the thermal melting of alkyl chains, contribute to the development of different mesophases in the composite systems. The POM observations confirm

that
PVA



concentration influences the mesomorphic behaviour of cholesteryl palmitate.

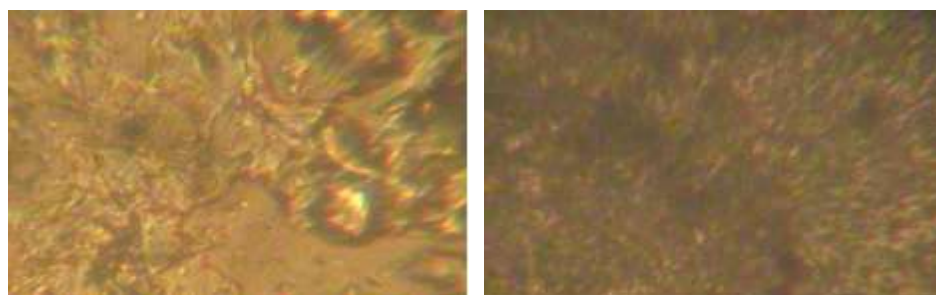


Figure 2. Polarizing optical microscopy textures of pure cholesteryl palmitate (PLC): (a) fan-like texture at 62.10 °C and (b) schlieren nematic texture at 80.40 °C.



Figure 3. Polarizing optical microscopy textures of the AA composite: (a) honeycomb texture at 52.30 °C and (b) smectic A phase at 82.50 °C.

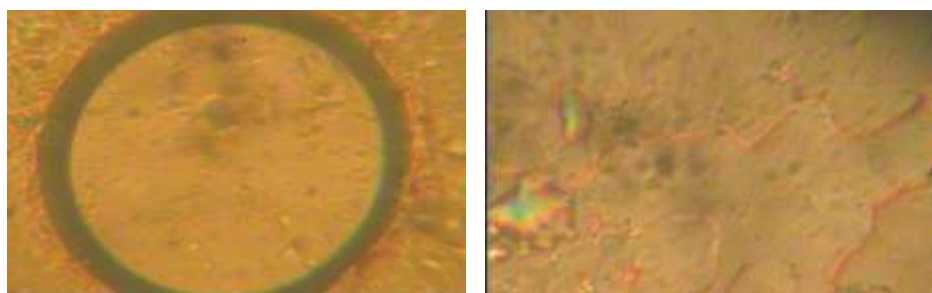


Figure 4. Polarizing optical microscopy textures of the BB composite: (a) polymer droplets at 80.0 °C and (b) polymer boundaries at 82.0 °C.

The POM observations revealed distinct mesomorphic textures in pure cholesteryl palmitate (PLC) and the PVA-dispersed composites. Pure PLC exhibited a fan-like texture at 62.10 °C, followed by a schlieren nematic texture at 80.40 °C. The AA composite showed a honeycomb texture at 52.30 °C and a smectic A phase at 82.50 °C. Similarly, the BB composite exhibited a honeycomb texture at 52.30 °C, followed by a smectic A phase at 82.50 °C.

The observed textures indicate changes in molecular organization caused by the incorporation of PVA. The molecular layers are predominantly oriented obliquely with respect to the substrate. The textures are characterized mainly by flare lines and translational dislocations. In the polygonal regions, horizontal segments of hyperbolic structures form a polygon-like lattice near the cover-slip surface, while vertical segments extend from the individual polygonal boundaries. These textural features provide evidence of the influence of PVA on the molecular arrangement and mesomorphic behaviour of cholesteryl palmitate.

3.3 Electrical Properties

Dielectric measurements provide valuable information about the molecular polarization, dipole moment, and polarizability of materials. Under an applied electric field, the orientation of polar molecules changes, resulting in variations in their dipole moments and polarization. In the present study, the dielectric properties of pure and PVA-dispersed cholesteric liquid crystal samples were investigated using a Precision Impedance Analyzer (Wayne Kerr 6500B, Chichester, West Sussex, UK). The measurements were carried out to evaluate the influence of PVA concentration on the electrical response of the liquid-crystal composites.

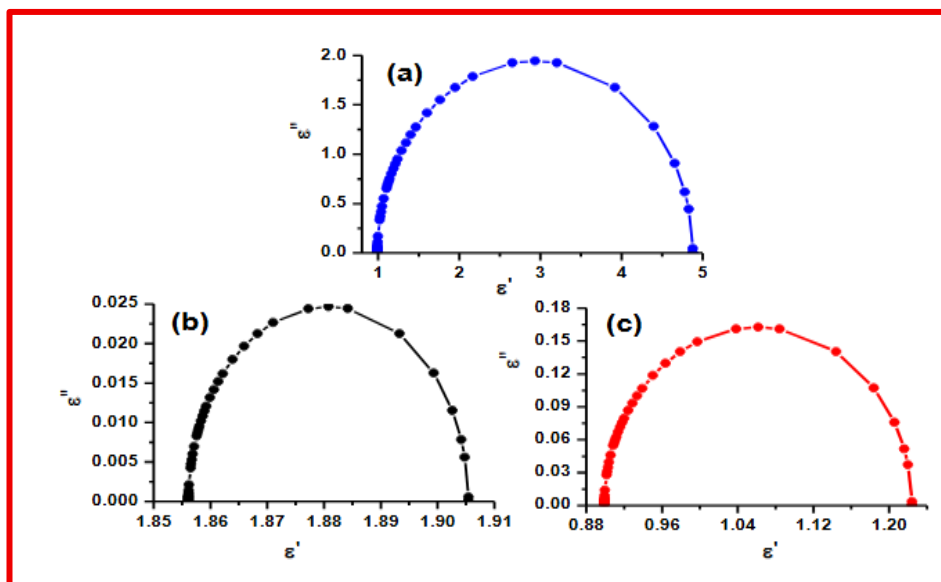


Figure 5. Cole–Cole plots of pure cholesteryl palmitate (PLC) and PVA-dispersed composites: (a) PLC, (b) AA, and (c) BB.

The blue curve in Figure 5(a) represents the dielectric behaviour of pure cholesteryl palmitate (CLC). The dielectric constant varies from 1 to 5, with a dielectric loss of approximately 1.75. The AA composite, represented by the black curve in Figure 5(b), exhibits dielectric constant values ranging from 1.85 to 1.905, with a dielectric loss of 0.0205. The red curve in Figure 5(c), corresponding to the BB composite, shows real dielectric constant values between 0.882 and 1.225, with a dielectric loss of approximately 0.15.

4. Conclusion

The present study examined the optical and dielectric behaviour of polyvinyl alcohol (PVA)-dispersed cholesteryl palmitate, with emphasis on the effect of polymer concentration on the mesomorphic and electrical properties of the cholesteric liquid crystal. Fabry–Perot spectroscopic measurements revealed noticeable changes in phase-transition temperatures with the incorporation of PVA, confirming its influence on the molecular organization of the liquid-crystal system. Polarizing optical microscopy further demonstrated distinct textural changes, including fan-like, honeycomb, schlieren, and smectic A textures, depending on composition and temperature. The dielectric investigation using Cole–Cole analysis showed significant variation in dielectric constant and dielectric loss among pure PLC, AA, and BB composites. In particular, the AA composition exhibited comparatively low dielectric loss, indicating reduced dielectric dissipation and stable electrical behaviour. Overall, PVA incorporation effectively modifies the structural, optical, and dielectric characteristics of cholesteryl palmitate. The obtained results indicate that PVA–CLC composites have potential for applications in electro-optical and optical switching devices.

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