ABSTRACT

Liquid crystals (LCs) have unique properties, such as fluid-like behavior, and also show some anisotropic properties. Their ability to exhibit anisotropy, birefringence, and fluid-like behavior has been utilized in several domains, like displays, optical systems, sensors, and biomedical devices. The nematic phase among the several mesophases provided by LCs provides greater dynamic control over the other mesophases. The development of novel LC variants featuring enhanced properties for various applications is an expensive and laborious process. Alternatively, to improve the properties of the nematic LC, the integration of nanoparticles and ionic medium in LCs has led to a modulation of the properties of the LC phases. This resulted in a reduction in threshold voltage and an improvement in response time. Furthermore, within the field of liquid crystalline materials, scientific research and technological progress have resulted in the emergence of novel concepts, one of which is the liquid crystal polymer composite.

The effective integration of LCs with polymers facilitates the emergence of various unique effects by adjusting the properties of the polymers and the LCs. LCPCs gained attention for the development of devices such as smart windows, advanced optical encryption, biosensors, flexible and foldable biosensors, energy harvesting devices, and numerous other innovations. The main categories of LCPCs are polymer-dispersed liquid crystals (PDLCs) and polymer-stabilized liquid crystals (PSLCs). PDLCs consist of liquid crystal droplets that range from micron to sub-micron sizes, which are integrated within a continuous polymer matrix. PSLCs incorporate a polymer stabilizing network within the continuous liquid crystal phase. In addition to PSLCs and PDLCs, the polymer exists in a ball/microsphere configuration within the liquid crystal category, classified as a polymer ball-filled liquid crystal. This thesis demonstrates the incorporation of the ionic medium in the LC and the development of the different kinds of LCPCs to fabricate devices such as free-standing optical diffuser, laser speckle contrast reducer, electrically tunable light scattering devices, and tunable phase grating, which have potential applications in the field of electro-optics, foldable displays, and laser-based projection displays.

Chapter one covers the different phases of LCs, liquid crystal polymer composites (LCPCs), their classifications, and their physical properties. The light scattering in the different kinds of LC and LCPCs. Chapter two focuses on the fabrication of PDLC-based free-standing films, LC cells, and experimental methods to characterize the devices. Chapter three discusses the simple and straightforward approach for developing a free-standing film-based optical diffuser fabricated using 4′-Pentyl-4-biphenylcarbonitrile (5CB) nematic liquid crystals and cellulose acetate (CA) biopolymers. Films are fabricated using the solvent-induced phase separation approach. The films are foldable and show stronger light-scattering characteristics. In the films, a continuous cellulose acetate biopolymer network encapsulates micron and sub-micron LC droplets that scatter the light passing through the film. The films exhibit ultrahigh haze (~ 99%). The optimal concentration of LC with CA shows an angular transmission profile close to Lambertian distribution.

Chapter four investigates a nematic liquid crystal with negative dielectric anisotropy termed N-(4-Methoxybenzylidene)-4-Butylaniline (MBBA) doped with cetyltrimethylammonium bromide (CTAB) as a laser speckle contrast suppression device. Ionic medium cetyltrimethylammonium bromide (CTAB) increases ionic concentration, alters the dielectric properties, and improves electrohydrodynamic instability (EHDI). When light passes through the device, the EHDI effect produces dynamic scattering. Due to dynamic scattering, speckle

patterns are generated. The speckle patterns are collected by a charge-coupled device (CCD) camera over a finite exposure time that is adequate to capture the phase modulation due to dynamic scattering. This results in a reduction in the speckle contrast. These investigations show that it reduces speckle contrast without a complicated setup.

Chapter Five covers the development of tunable light-scattering devices without the need for conventional UV or heat-curing methods. The polymer, composed of amino acid-based pseudopeptides, exhibits solvent-dependent self-assembling properties and is integrated into chiral nematic liquid crystals (CLC). In the E7 and CB15-based CLC, pseudopeptide polymer forms the micron-sized ball/sphere, which enhances the light scattering properties of the focal conic state of the CLC and reduces the threshold voltage. The 10 wt. % of the polymer in the CLC reduces the direct transmission twice compared to non-polymer CLC in the focal conic state. The inclusion of the polymer also improves the time required to induce the scattering state.

Chapter Six focuses on dielectric and light scattering properties of the pseudopeptide incorporated negative dielectric anisotropy nematic liquid crystal (nLC). In nLC, pseudopeptide polymer precipitates in the form of micrometer-sized spheres. Polymers enhance ion density, mobility, and conductivity, removing the need for an extra ionic medium to produce a stronger electrohydrodynamic instabilities (EHDI) state. The maximum ion density occurs with the 5 wt % polymer in the nLC, whereas higher values for the diffusion coefficient, ion mobility, and ac conductivity are observed with the 7.5 wt % polymer in the nLC. In the nLC with the pseudopeptide polymer microspheres, light scattering is significantly enhanced in the EHDI state. The pseudopeptide also provides an excellent contrast ratio and decreases the voltage required to produce a light-scattering state in the nLC.

Chapter Seven reports the one-dimensional (1D) and two-dimensional (2D) phase grating using the in-plane switching (IPLS) configuration of the LC cell with a nLC. Changing the orientation of nLC molecules between periodic electrode strips induces periodic refractive index variation. At the high frequency of the electric field, the device generates one-dimensional diffraction patterns that show voltage-dependent diffraction efficiencies in different orders. At low frequencies, it shows one-dimensional diffraction patterns at lower voltage and two-dimensional in certain voltage ranges due to electroconvection rolls between the electrode strips.

The thesis concludes with a discussion of the future scope of the major results and the work presented in this thesis and their possible potential application in several electro-optic devices, such as projection displays, tunable optical diffusers, smart windows, beam steering, and foldable optical technology.