

Polymer Dispersed Liquid Crystals (PDLCs): A Mini Review

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Abstract

Polymer dispersed liquid crystals (PDLCs) have piqued the interest of researchers due to their exceptional property of electronically controlled switching mechanism. PDLC devices are sort of smart glazing/film that responds to electrical stimulus by changing its transparency. When liquid crystals are inactive, they are randomly organized, scattering light as it passes through the screen, giving the assembly its transparent, milky look. When a voltage is added, an electrical field forms between the two electrodes, causing the liquid crystals to align and enable light to flow through, thereby rendering the screen transparent. However, difficulties like as low contrast ratio, high operating voltage, and poor mechanical characteristics limit their practical uses. To address these issues, several procedures were implemented, including optimization of molecular structure of monomers and liquid crystals, addition of nanoparticles, and PDLC modification. This mini review will go through the current advancements in the method, preparations, and applications of PDLCs.

Keywords

Polymerization Induced Phase Separation, Polymer-dispersed Liquid Crystals (PDLC), Doping, Applications

1. Introduction

Polymer dispersed liquid crystals (PDLC) were discovered as electrically switchable materials and have remained a source of considerable scientific interest ever since. PDLC composite films are made up of liquid crystal (LC) droplets that are micrometre or nanoscale in size and placed in a polymer matrix. Because of the random orientation of LC droplets in the polymer matrix, these films have a milky white scattering state [1-3]. As a result of the use of PDLC in display technologies, research on these materials has boomed in recent decades, encompassing areas such as quantum dots (QDs) film [4], antipeeping film, diffuse film [5], and organic light emitting diode (OLEDs) components [6], field effect transistors (FETs) [7], solar-energy harvesting [8], and energy storage [9].

When LC is mixed with a polymer at a high temperature and then cooled down at a certain rate, thermally induced phase separation (TIPS) develops, resulting in phase separation and formation of LC domains as the polymer firms. Both the LC and the polymer are dissolved in the same solvent for the solvent-induced phase separation (SIPS) procedure. Phase separation occurs when a solvent evaporates at a particular pace. The LC is combined with a monomer/prepolymer solution to produce a homogeneous solution for the polymerization-induced phase separation (PIPS) technique. The polymer and LC separate from one other when the polymerization progresses during the

liquid–liquid or liquid–gel phase [10, 11]. The LC molecules emerge from the solution and form droplets, which expand until polymerization is complete, i.e., when the polymer matrix has solidified sufficiently [12]. Thermal-initiated polymerization and ultraviolet (UV)-initiated polymerization are two types of PIPS polymerization. The older approach, while offering superior processability, reduced contamination, and high bonding energy, necessitates high temperatures and a lengthy time [13, 14]. For the manufacture of PDLC films, the latter, on the other hand, is quick, solvent-free, and environmentally friendly [15].

In this short review, we will look at recent advances in the production, experimental study, and use of PDLCs, with a particular focus on UV-polymerization. Instead of delving into great depth, only current articles that are specifically linked to UV polymerization, process and material modification approaches to improve the E-O characteristics of PDLCs are referenced. Some publications, however, were very significant and were referenced. Previous reviews of these resources [16-22] might also be used to obtain a thorough grasp of the subject.

2. Preparation of PDLC Composite Film using monomers and liquid crystals

UV-polymerization of (meth)acrylate monomers is commonly used to make PDLC films [23]. In flexible (meth)acrylate monomers, the modification of morphology and E-O characteristics is restricted. As a result, hydroxy, epoxy, branching methylene/methyl, cyclic methylene, phenyl, and bisphenol were added to traditional acrylates [24-28]. The E-O characteristics of PDLC composite films could be improved by changing the hydrogen-bond interaction, the viscosity of acrylate monomers, the refractive index of the polymer matrix, and polymer network morphologies after these structures were integrated into the polymer matrix [29]. An extremely simple and distinctively designed acrylate monomer (A3DA) having a benzene moiety with a dodecyl terminal chain was recently used to create a low-voltage driven PDLC system [30]. The comparison of methyl and acrylate monomers, as well as their terminal structures, was the subject of a recent study [31]. The asymmetrical substitution of the methyl group on the quaternary carbon in the main chain increased steric hindrance, which slowed down polymerization. By switching from a flexible to a rigid monomer structure, the contrast ratio (CR) was increased by a factor of ten. UV-polymerization is commonly used to create PDLC films made up of thiol-ene monomers.

Unlike earlier studies, Zhang et al. [32-34] examined the impact of LC molecule architectures (fluorinated LC molecules, alkene-terminated LC molecules, and cyano-terminated tolane LC molecules) on the morphology and E-O characteristics of PDLC composite films. Doping fluorinated LC molecules into commercial LC (E8) yielded the LC component, which was fixed at 50.0 wt.% in PDLC composite films. The fluorinated LC molecules' doping concentrations and terminal chain lengths impacted the physical characteristics (such as dielectric anisotropy, refractive index, and viscosity) of the LC and polymer network shape, as well as the E-O properties of the PDLC composite material. The fluorinated LC molecules' doping concentrations and terminal chain lengths impacted the physical characteristics (such as dielectric anisotropy, refractive index, and viscosity) of the LC and polymer network shape, as well as the E-O properties of PDLC composite films. The results indicated that the optimum 8.0 wt percent doping fluorine LC molecules allowed them to achieve the composite films' considerably reduced driving voltage. Using alkene-terminated LC molecules or cyano terminated tolane LC molecules, the ideal E-O characteristics of PDLC composite films with low driving voltage, high CR, and quick response time were produced using the aforementioned study techniques.

3. Preparation of PDLC Composite Film using Nanoparticles

In traditional PDLCs, the LC, monomer, and initiator are all combined together. An all-organic system, however, has several limits. Doping with nanoparticles (NPs) improved the optical, thermal, and mechanical durability of the polymer matrix, as well as its interaction with the LC. At the polymer/LC interface, NPs primarily impact the dielectric constant, refractive index, and anchoring forces. Various kinds of NPs have been investigated in order to produce high-quality PDLC films. Several recent instances of the characteristics of NPs-doped PDLC are given below.

ZnO, MgO, CuO, BTO, BaTiO₃, Fe₃O₄, TiO₂ [35-41] and other inorganic NPs were doped into PDLCs, and the driving voltage was decreased. These particles were identified to have an influence on the dielectric constant of the medium or to create local field effects, reducing the driving voltage. Doping ferroelectric NPs caused spontaneous polarization, which improved E-O properties [41, 42]. Mishra et al. [35] from Mumbai University in India reported the fabrication of PDLC films with embedded CuO, ZnO, and Zn, NPs utilizing the SIPS method.

In recent years, research has shown that metallic NPs-doped PDLC films have improved E-O, dielectric, and optical characteristics. Low driving voltages and high CR were found in Ag and Au-doped films in particular. Surface plasmon excitations at metal-LC interfaces were attributed to this, which increased the local electric fields [43, 44]. The combined effect of light scattering from nano-sized LC droplets and local field amplification surrounding the silver NPs resulted in random lasing from dye-doped PDLCs containing Ag NPs.

4. Applications

PDLCs are suitable for promising applications in photovoltaics, switching gratings, lasers, energy-saving smart windows, light shutters, optical elements, sensors, smart food packaging, electrically switchable high-fold-helix spiral phase plates, microlenses, and biocompatible materials, as well as biomedical devices, due to the efforts dedicated to fabrication methods and various outstanding properties.

5. Conclusion

Significant advances have been achieved in the production, characteristics, and application of PDLC composite films, as outlined in this mini review. The electro-optical characteristics of PDLC films were improved by structural modification of monomers and liquid crystals, two-step polymerization, and doping nanoparticles. The two-step polymerization method, in particular, cleared the path for improved electro-optical and mechanical performance of PDLC composite films. Meanwhile, substantial advances in applications such as antipeeping films, diffuser films, QDs films, OFET, OLED and sensor components, energy harvesting, photovoltaics, actuators, biomedicine applications, and so on have been made. PDLC composite films, with their advantages of ease of preparation, large-area production, cost-efficiency, and flexibility, promise to encourage and expand the development of next-generation displays, smart windows, wearable gadgets, and sensors.

The simulation characteristics in Diode (D3) has observed. The temperature measurement is 25°C with zero amps that can pass through capacitor filter and also power loss became minimum, indicates the simulation results of D3 in EC-SPEC during testing and simulations.

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