Mini-Review

Materials

Selective Reflection of Cholesteric Liquid Crystals

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Cholesteric liquid crystal materials with selective reflection characteristics are used in a variety of applications due to their unique optical properties, including liquid crystal photovoltaic panels, light enhancement films, liquid crystal dimming glass, liquid crystal dimming films, laser protection, and infrared stealth. At the moment, researchers have offered a variety of effective strategies for extending the range of reflection. The reflection wavelength of the cholesteric phase has been effectively widened through the investigation of each material system, laying the groundwork for the practical application of cholesteric phase liquid crystal materials.

Keywords: Cholesteric Phase; Liquid Crystal; Selective Reflection; Application

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IN nature, matter is typically classified as solid (including crystalline and amorphous), liquid, or gas. When external conditions change, the majority of substances transition straight between phase states. However, certain substances with unusual structures do not transition directly from a crystalline to a liquid state but rather pass through a sequence of intermediate states, one of which is a crystal-like fluid and the other of which is a liquid-like crystal. The first is referred to as the liquid crystal state, whereas the second is referred to as the plastic crystal state. The phrase "liquid crystal" refers to substances that are in the liquid crystal state, that is, an orientated ordered fluid intermediate between an isotropic liquid and a totally ordered crystal. Due to the tight enthalpy and entropy changes associated with the liquid crystal phase transition, the liquid crystal state is a thermodynamically stable phase state.

The seemingly contradictory term "liquid crystal" accurately captures its unique phase state, which possesses both crystal anisotropy and liquid fluidity. The primary differences between crystals, liquid crystals, and liquids are as follows: liquids are isotropic; crystals have both orientational and positional order; and liquid crystals have only orientational order. Under the influence of external fields such as magnetic fields, electric fields, temperature, light irradiation, or mechanical stress, liquid crystal molecules can be organized or modified in molecular order, consequently altering the device's optical properties (1, 2).

Among the numerous liquid crystal phase states, the cholesteric phase exhibits a unique self-assembled helical structure and selective light reflection capabilities (3). The cholesteric phase is commonly referred to as the chiral nematic phase since it is regarded as a particular condition of the nematic phase. There are two primary mechanisms by which the cholesteric phase is formed (4). The first is that chiral carbon atoms or other asymmetric structures are contained within the molecule, and the second is that chiral chemicals are incorporated into nematic or smectic liquid crystals. The second approach is currently used to prepare the vast majority of cholesteric liquid crystals.

The selective reflection property of cholesteric liquid crystals has paved the way for their application. Not only may the cholesteric liquid crystal broad-wave reflective film be utilized as a light-enhancing film in liquid crystal displays, but it can also be used as a reflective layer in the fields of energy conservation, laser protection, and so on (5). However, how to broaden the spectral band within the required reflection spectrum range remains a critical issue for cholesteric liquid crystals.

The creation of cholesteric liquid crystals with a pitch gradient distribution is a straightforward and successful technique for producing broadband reflective films. Broer et al. synthesized a cholesteric liquid crystal film with a broad-wave reflection effect by combining bifunctional chiral liquid crystal polymerizable monomers, ultraviolet light absorption dyes, and photoinitiators (6). Under ultraviolet light, an ultraviolet light intensity gradient can be created from top to bottom in the thickness direction of the liquid crystal cell due to the presence of ultraviolet light absorption dyes (7). Due to the fact that difunctional polymerizable monomer molecules are consumed more rapidly than monofunctional polymerizable monomer molecules during the reaction, difunctional monomers polymerize more rapidly and tend to diffuse to the upper surface, whereas monofunctional monomers polymerize slowly. Rather than that, it prefers to spread downward (8). Given the helical pitch gradient distribution structure with the helical pitch progressively increasing from top to bottom, the composite film material may reflect right-handed circularly polarized incident light in the visible wavelength range of 400-750 nm (9).

Since the production of a photoresponsive chiral binaphthalene molecule containing an azobenzene chromophore and combined it with a nematic liquid crystal to form a cholesteric liquid crystal (10), organically combining the structural designs of cholesteric phase liquid crystals resulted in the creation of a photoresponsive layered cholesteric phase liquid crystal composite film material. Three layers of cholesteric liquid crystals are stacked to make the film material; the first and third layers are prepared via spin coating and subsequent polymerization, while the second layer is poured via capillary action. Not only do the produced films exhibit multiple reflection bands, but they also exhibit photoresponsivity (11). Kralik et al. superimposed three-layer cholesteric liquid crystal samples that reflected blue, green, and red light, respectively, and found that their reflected wavelengths successfully covered the visible light region. They also investigated the use of a quarter-wave plate as a display backlight source as the system's light-brightening effect (12). Furthermore, a polymer-stabilized cholesteric liquid crystal film was created with left-handed characteristics in a liquid crystal cell device and then used a wash-out pour method to refill the cholesteric liquid crystal with d-binaphthyl chiral azo molecules. As a result, a cholesteric liquid crystal film with an optically tunable double reflection band was created and the entire reflection effect can be achieved in a specific wavelength band when the left- and right-handed helical pitches are identical (13).

Additionally, it is an excellent way of fabricating broadband reflective cholesteric liquid crystal films by varying the helical twisting force of chiral chemicals in order to generate a non-uniform distribution of the helical pitch. A composite system was produced consisting of a photoresponsive binaphthylazochiral molecule, an upconverting nanoparticle, and a nematic liquid crystal (14). Instead of ultraviolet light, 980 nm near-infrared light is used to control the composite material's selective reflection, and the chirality of the binaphthylazo chiral molecule is indirectly controlled by adjusting the intensity of the near-infrared light; this then regulates the helical pitch of the liquid crystal composite material (15). By combining a liquid crystalline polymerizable monomer, a nematic liquid crystal, and a chiral chemical, a polymer-stabilized cholesteric liquid crystal film with a broadening reflection wavelength was created (16).

In sum, cholesteric liquid crystal materials have garnered considerable attention due to their unique structure, selective light reflection, and broad application possibilities. Researchers continue to innovate by optimizing the structure of chiral compounds, perfecting the system of liquid crystal materials, and developing new research methods, resulting in the widespread use of cholesteric liquid crystals with selective reflection in liquid crystal photovoltaic panels, optical brightness enhancement films, liquid crystal dimming glass, liquid crystal dimming film, laser protection, and infrared stealth. The development of novel material systems, the discovery of novel methodologies, the simplification of the preparation process, and the reduction of prices will be the dominating paths of future study in the field of selective reflection cholesteric liquid crystal research.■

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