Preparation of Photosensitive Cholesteric Liquid Crystals

Changhua Yang[1], Huangxin Gan[1], Yang Liu[1, *]

[1]College of Information Science and Technology, Donghua University, 2999 North Renmin Road,
Songjiang District, Shanghai 201-620, China

Abstract

In this study, photo-responsive cholesteric liquid crystals (CLCs) were prepared by blending E7 with a photo-responsive chiral radical, CHAD-3C-S. Subsequently, the UV triggered tunable photonic band gap of the prepared CLCs was investigated using a polarized optical microscope (POM) and a spectrometer. It was found that a tunable reflection color within the visible range was produced in response to UV irradiation, accompanied by a red shift of the reflection signal in the spectra. Moreover, the time required to tune the reflection signal located at 660 nm from 410 nm has been determined to be a mere 49 s, a significant reduction in comparison to other literature reports. These findings provide compelling evidence that CHAD-3C-S exerts a regulatory influence on the photonic band gap (PBG) of CLCs, and that the basic modulation approach has been successfully established.

Author Keywords

Cholesteric Liquid Crystal, Photonic Band Gap, Photosensitive

1. Introduction

Liquid crystals (LCs) are a type of soft matter that exist in a fluidic state and It has the anisotropy of crystals [1]. The constituent molecules are oriented in an orderly fashion and can be categorized into diverse mesophases [2]. In the nematic phase, the long axes of liquid-crystal (LC) molecules exhibit a uniform average orientation. Conversely, in the cholesteric phase, chiral dopants are usually added to induce the LC molecules to arrange into different layers [3]. The partial guide is perpendicular to the crank shaft [4], and each layer is rotated at an angle relative to the adjacent layer [5]. This rotation gives rise to a periodic helical superstructure [6] and a variation in Bragg reflection [7] within cholesteric liquid crystals (CLCs). Non-mesogenic additives of the nematic host [8], such as the chiral dopant present in the resultant CLCs, modify the characteristics of the LC and endow the mesogenic material with novel structures and functions.

In this study, CLCs were fabricated by blending the CHAD-3C-S chiral dopant into E7, and the pitch of the CLCs was precisely regulated by ultraviolet light irradiation. The photonic band gap of the CLCs was found to undergo a change as a result of the cis-trans isomerization of CHAD, and this was characterized using a polarized optical microscope (POM) and spectrometer. The fundamental modulation approach and general principles have been fully elucidated, thereby establishing a robust theoretical foundation for subsequent practical applications.

2. Experimental

Materials: Cholesteric liquid crystals (CLCs) were prepared by blending nematic liquid crystal (E7, $n_e = 1.746$, $n_o = 1.521$, $\varepsilon_{/\!/}=19$, $\varepsilon_{\perp}=5.2$, $\gamma_1=235.1$mPaS, $K_{11}=11.6$pN, $K_{33}=19.1$, Instec, USA) with photo-responsive chiral radical CHAD-3C-S (obtained from NCOPTIX, China) in a mass ratio of 90:10.

Devices and Characterization: The glass slides (Ningbo Nanotech Advanced Materials Co., Ltd., China) were subjected to an ultrasonic cleaning process in isopropanol (IPA, 99.9%, Sinopharm Chemical Reagent Co., Ltd., China), acetone (99.9%, Sinopharm Chemical Reagent Co., Ltd., China), and ethanol (99.7%, National Pharmaceutical Group Chemical Reagent Co., Ltd., China) for a duration of 15 minutes each. Subsequently, the glass slides were subjected to a drying process in an oven maintained at 60°C for a duration of 30 minutes. Subsequently, the slides underwent a hydrophilic treatment utilizing a digital ultraviolet ozone system (PSD UV 12, Novascan Technologies, USA), and were then spin coated with a commercial polyimide (PI, DL-2193, Shenzhen Dalton Electronic Materials Co., Ltd., China) at 200 rpm for 25 seconds and 3000 rpm for two minutes. The PI-coated glass slides were subjected to a preliminary baking process at 100 °C for 20 minutes, followed by a subsequent baking process at 200 °C for an additional two hours. The prepared glass slides were then subjected to a rubbing and assembly process in an anti-parallel fashion with a cell gap of 10 μm. The CLCs were injected into the cells via capillary action. The cis-trans isomerization of the chiral radical CHAD-3C-S in the hybrids was subjected to UV irradiation (UV-LED, AC220, 365 nm, 40 W, Zigu Co., Ltd., China). The resulting reflection change was characterized using a polarized optical microscope (POM, BXP 51, Olympus) and a spectrometer (Ocean Optics, USB 2000+).

3. Results and Discussion

The chemical structure of azobenzene CHAD-3C-S is illustrated in Figure 1. It can be observed that the azobenzene CHAD-3C-S incorporates an azo bond (-N=N-), which serves as the fundamental structural unit enabling its photochromic performance. In response to a range of illumination conditions, the photochromic CHAD-3C-S undergoes a cis-trans isomerization. Specifically, the CHAD-3C-S undergoes a spontaneous transition from the trans to the cis structure when exposed to ultraviolet light, and undergoes a revert transition from the cis to the trans structure when irradiated with 532 nm light or heated. The light-controlled interchange between the trans and cis configurations enables the CHAD-3C-S to switch between rod-like and bent structures, thereby triggering the reorientation and phase transformation of LCs, which in turn results in alterations to the properties of CLCs.

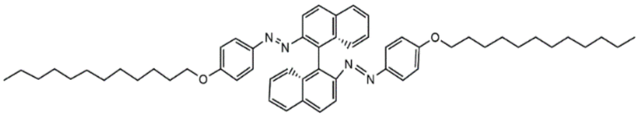

Figure 1. The chemical structure of photo-responsive chiral radical CHAD-3C-S.

Bragg's law posits that CLCs possess the capacity to selectively reflect a specific wavelength of light. The center of this specific wavelength can be calculated using the following formula,

$$\lambda = \mathrm{n}\mathrm{P} \quad (1)$$

in which P represents the pitch of the helical superstructure, while n represents the average refractive index of the liquid crystal matrix. It could be seen that by modulating the pitch of CLCs, the photonic band gap characteristic changes, and a tunable reflection could be observed under POM observation and in reflection spectra. It was observed that modulating the pitch of CLCs resulted in a change in the photonic band gap characteristic, which in turn led to a tunable reflection. This was evidenced by both POM observation and reflection spectra. As shown in Figure 2, a gradual red shift of the reflection signal was evident upon UV irradiation, with the reflection signal at 420 nm exhibiting a red shift to 660 nm within a 49-second timeframe. Furthermore, the redshift of the reflection signal was evident upon observation under POM, as shown in Figure 3. The initial reflection observed was purple, and it gradually transformed into blue, cyan, green, yellow, orange, and red, respectively, with the additional continuous UV irradiation of 6s, 10s, 28s, 32s, 40s and 49s. These observations are in accordance with the results indicated in the reflection spectra, thereby demonstrating the success in fabricating photo-responsive CLCs.

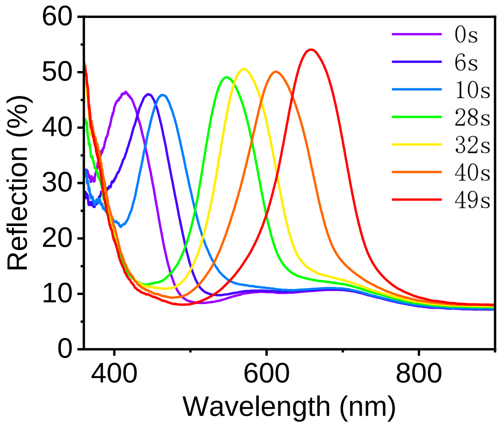

Figure 2. The dynamic reflectance spectra versus UV illuminating time of CLCs.

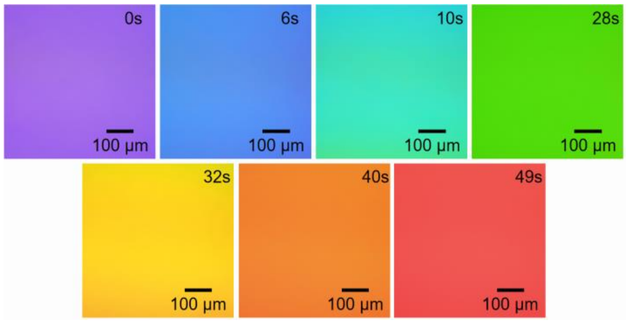

Figure 3. The POM images of CLCs versus UV illuminating time.

4. Conclusion

In conclusion, the photo-responsive CLCs were prepared by blending nematic LCs with the chiral dopant CHAD-3C-S, and the pitch modulation with the corresponding reflection modulation was successfully investigated upon UV irradiation. During the photo-tuning process, a red-shift in the reflection signal was observed from 410 nm to 660 nm, with a clear transition from violet to red across the entire visible wavelength range within 49 seconds. These findings illustrate the prospective applications of our prepared CLCs in a range of devices beyond display.

5. References

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