Propagation of Polarized Optical Signal Through Gold Nanorods Blending Cholesteric Liquid Crystals

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Abstract

The incorporation of nanomaterials into cholesteric liquid crystals (CLCs) for helical templating not only effectively modulates the pitch of the CLCs but also provides a robust methodology for investigating the self-assembly characteristics of nanomaterials. In this study, an innovative blending method was employed to explore the helical assembly properties of gold nanorods (Au NRs) within a photo-tunable CLCs. The specific operation enabled the precise control of both the pitch of the CLCs and the helical self-assembly of Au NRs through the use of ultraviolet (UV) irradiation technology. It is notable that the system formed by this regulation not only exhibits excellent and stable reflective performance comparable to traditional CLCs but also possesses a unique ability to efficiently modulate the flux of incident light at near-infrared wavelengths. The synergistic regulation mechanism constructed by the helical assembly of Au NRs and the CLCs actively promotes the development of traditional liquid crystal display technology and paves the way for highly promising new avenues of research in the field of multi-layer information encryption.

Author Keywords

Gold Nanorod, Liquid Crystal, Photonic Band Gap

1. Introduction

The phenomenon of chirality is pervasive in the natural world. The advancement of chiral materials and the investigation of photonic devices are inextricably linked to the transfer of chirality between matter and photons [1]. Gold nanomaterials have been the subject of considerable research interest. In particular, helically assembled gold nanomaterials have been demonstrated to exhibit excellent chiral optical activity, providing significant chiral bias between matter and photons. A substantial body of research has been conducted on helically assembled gold nanomaterials [2-3], including studies on the connection of gold nanorods (Au NRs) by DNA origami technology [4], double helix assembly of heterodimer gold nanoclusters [5], and other related topics.

Liquid crystals (LCs) constitute a class of self-assembled dynamic functional soft materials, exhibiting notable anisotropy. The combination of nanomaterials with LCs is a frequently employed treatment method. This approach can alter the LC phase and its intrinsic characteristics, while also elucidating the properties of nanomaterials [6]. LCs can act as a host for the majority of nanomaterials, enabling self-assembly and transformation, particularly in the case of gold nanomaterials. Hybrids formed by doping gold nanomaterials into LCs have significant applications in display, sensing and other fields [7]. A substantial body of research has been conducted on the mixing of helically assembled gold nanomaterials with LCs, with the objective of elucidating the methodology for measuring and transferring the chirality of nanomaterials. For instance, some researchers employ chiral binaphthyl thiol to terminate the helical structure of gold nanorods and combine them with 5CB to examine the helical assembly and amplification of chirality [8]. Hybrids of LCs and gold nanomaterials have the potential to be applied in a number of different areas. For example, these materials have potential applications in the development of optical devices such as smart windows and tunable nano antennas. Furthermore, light can serve not only as an energy source but also as a means of exploring information and regulating the asymmetry of CLCs [9] and helical gold nanorod assemblies [10]. Nevertheless, dynamic modulation remains a topic of ongoing research, and the preparation of suitable adjustable hybrid materials presents certain challenges.

The objective of this study is to propose the use of nematic LCs and photosensitive chiral agents for the preparation of CLCs. Subsequently, the combination of helically assembled Au NRs with CLCs enables the pitch to be dynamically modulated, while also facilitating the control of chiral optical properties. Additionally, the interaction between polarized light and the hybrid material was investigated. The integration of helically assembled Au NRs into CLCs not only demonstrates the manifestation of chirality at the macroscopic level but also enables the dynamic modulation of its pitch and optical asymmetry. This has the potential to significantly advance the research and development of display and optical devices.

2. Experimental

Materials: Hexadecyl trimethyl ammonium bromide (CTAB) functionalized Au NRs (r=15nm, l=56nm, 0.05mg/ml in CH_2Cl_2, Beijing Zhongkeleiming Daojin Technology Co., Ltd., China), nematic LCs (E7, n_e=1.746, n_o=1.521, Instec, USA), and the photo-responsive chiral radical CHAD-3C-S (NCOPTIX, China) were used as received. CLCs were prepared by directly mixing E7 and CHAD-3C-S under a weight ratio of 90:10. Subsequently, Au NRs were incorporated into the CLCs through the addition of Au

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NRs solutions, with the final concentration of Au NRs reaching 0.05 wt%. To evaporate the CH_2Cl_2, the final hybrids were stirred at 45°C for a period of three hours.

Devices and Characterization: The glass slides (Ningbo Nanotech Advanced Materials Co., Ltd., China) were subjected to ultrasonic cleaning in isopropanol (IPA, 99.9%, Sinopharm Chemical Reagent Co., Ltd., China) and acetone (99.9%, Sinopharm Chemical Reagent Co., Ltd., China) for 20 minutes each. Subsequently, the glass slides were hydrophilized using a digital UV ozone system (PSD UV 12, Novascan Technologies, USA), and a commercial polyimide (PI, DL-2193, Shenzhen Dalton Electronic Materials Co., Ltd., China) was spin-coated on and subsequently rubbed. The standard LC cells were assembled by bonding two PI-coated glass slides with a 10 µm-thick tape. Subsequently, the helical Au NRs doped LCs hybrids were capillary injected into cells and sealed using glue. As the chiral radical CHAD-3C-S in hybrids undergoes cis-trans isomeric transformations in response to UV illumination, the pitch of the hybrids can be tuned by illuminating the as-prepared LC cells using a UV-LED (AC220, 365 nm, 40 W, Zigu Co., Ltd. China). The chirality of Au NRs helical assemblies within the CLC host was examined by means of a light path constructed in the laboratory with a 635 nm laser as the light source.

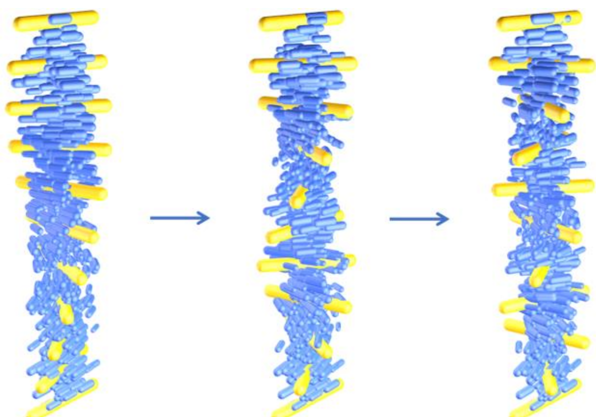

Figure 1. Schematic morphological asymmetry changes of Au NRs blending CLCs.

3. Results and Discussion

The nematic LCs doped with CHAD represent a promising avenue for the preparation of photo-responsive CLCs. Subsequently, Au-NRs are introduced into the prepared CLCs. The pitch and reflection color of the hybrid can be modified by ultraviolet light-emitting diodes (UV LEDs) irradiation. By modifying the duration of the irradiation, the pitch of the hybrid can be modified, thereby enabling the dynamic adjustment of color and wavelength within the visible light range. As illustrated in Figure 1, a schematic representation of CLCs encapsulating Au NRs has been provided. It is evident that the morphological asymmetry of the hybrid with Au NRs blending CLCs can be dynamically modulated.

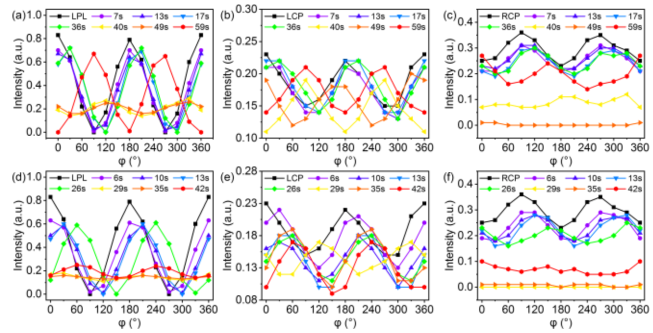

Figure 2. The plots of the light flux through the CLCs cell and 0.05 wt% Au NRs blending CLCs cell versus the pitch when they are illuminated by (a,d) LP light, (b,e) LCP light and (c,f) RCP light.

The occurrence of chiral selection in Au NRs blended with CLCs has been substantiated through the irradiation of the LC cell with left-handed (LCP) and right-handed (RCP) circularly polarized light, respectively. This enables an investigation of the transmission of a polarized optical signal through the hybrid. Irradiation of the LC cell with linearly polarized light (LP) demonstrates that the light flux remains linearly polarized at varying angles. As illustrated in Figure 2a, when the pitch of the CLCs was adjusted to approximately 407.16 nm, a notable reduction in the light flux was observed as a result of the formation of oscillations. Similarly, following the blending of Au NRs in CLCs, the significant extinction characteristic of Au NRs resulted in a notable reduction in the light flux across a wider NIR wavelength range (Figure 2d). Upon inserting an HWP capable of producing a π/2 phase retardation and a QWP capable of producing a π phase retardation between the polarizer and the liquid crystal cell, the incident LP was converted to an LCP. This resulted in a comparable light flux across CLCs and Au NRs blending CLCs, as shown in Figure 2b,e. This indicates that the hybrid allows for the selective propagation of LCP signals. In contrast, when the HWP was removed to tune the LP to become RCP, the light flux in the NIR wavelength was found to be reduced once more as shown in Figure 2c,f, thereby demonstrating that the hybrid is capable of selective propagation of the LCP signal.

4. Conclusion

In conclusion, we employed CHAD blending nematic LCs to prepare light-responsive CLCs, and prepared a hybrid by blending CLCs with Au NRs. The pitch and photonic band gap of this hybrid can be tuned primarily through triggering the photoisomerization transition of CHAD. It was found that the blending Au NRs were left-handed organized with CLCs, and greatly modulated the propagation of optical signal. These findings have significant implications for research into next-generation displays and also offer a new avenue for the field of multi-level signal modulation.

5. Acknowledgements

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6. References

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