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PHOTOTUNABLE SELECTIVE REFLECTION OF CHOLESTERIC LIQUID CRYSTALS

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Abstract. The dependence of the helical pitch of a cholesteric liquid crystal based on a composite photosensitive chiral dopant (cChD) on the intensity of light irradiation was studied. The transmission spectra and the selective reflection spectra of cholesteric liquid crystal cells were measured. The concentration of the cChD additive is calculated, so that the peak of selective reflection and its rearrangement occurs in the visible range of the electromagnetic radiation spectrum (380-780 nm). The possibility of photo-control by shifting the peak of the selective reflection of the cChD additive was studied, when exposed to LEDs with wavelengths of 365 nm and 450 nm, while reducing or increasing the intensity, a change in the spiral pitch was observed. Depending on the light intensity, part of the molecules of the chiral additive containing the azo group underwent isomerization, i.e. molecules in the trans-form passed to the cis-form, which led to a spectral shift of the selective reflection peak. If a small intensity of the 365 nm LED was applied, then some of the molecules were forced to transition from the trans- to the cis-form, and then, when illuminated with a 450 nm LED, from the cis- to the trans-form. After reversible rearrangement, the properties of cholesteric liquid crystal changes due to interaction with light, because under the influence of light, the equilibrium ratio of the trans- and cis-isomers of the molecules of the substance changed, which macroscopically changed the torsion force of the chiral additive. Using two LEDs of 365 nm and 450 nm with different emission spectra, a reversible control of the cChD selective reflection peak in the visible range was obtained. The maximum displacement occurred at approximately 145 nm.

Keywords: cholesteric liquid crystals, selective reflection.

Conflict of interests. The authors declare no conflict of interests.

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Introduction

The non-display applications of liquid crystals (LC) for novel LC based devices is the current trend of the LC device technology. Cholesteric liquid crystals (ChLC) are chiral materials possessing unique property of selective reflection in the visible spectral range, are in focus of the R&D interest due to their ability to change the distribution of LC molecules under the action of external influences [1] such as temperature [2], light [3], electric field [4] and etc. Typical cholesteric liquid crystal is achiral nematic liquid crystal mixture doped with a chiral dopant, which ensures the self-organization of the chiral structure of LC molecules. Planar LC cells are applied to achieve vertical orientation of the ChLC helix and obtain homogeneous structure that does not scatter light [5].

Control of the chiral properties of the cholesteric structure means apply a method for reversible change of the helical pitch, which practically is difficult to achieve. Thus control and adjustment of selective reflection requires uniform stretching/compressing of the ChLC helix. The fact is that direct application of the electric field does not bring to continuous change of the helical pitch. Usually the step change of the helix is observed for ChLC, when the voltage is applied to cell electrodes. Once the voltage is switched off a large number of defects appear in the bulk of the material, and the structure becomes optically inhomogeneous scattering the light. In this paper, we suggest a photosensitive optical effect based on a chiral dopant capable to cis-trans isomerization [6] for continuous control of selective reflection.

Results and its discussion

The photosensitive ChLC mixture was obtained by doping nematic LC mixture MLC-6809-000, (Merck, Germany) with composite chiral dopant (cChD), (IChNM NAS Belarus) that comprises non-photosensitive and photosensitive chiral dopants with the same sign of the helical twist. The ChLC mixture was filled into antiparallel LC cells with 20 μm cell gap. Selective reflection spectra were measured by an integrating sphere ISP-30-6-R (Ocean Optics, USA) with spectrometer Maya2000Pro (Ocean Optics, USA). The helical pitch dependence on exposure light intensity was measured as follows. The ChLC cell was exposed to 365 nm light emitting diode (LED) irradiation. The shift of the selective reflection peak subject to light intensity is observed in the ChLC cell reflection spectra (Fig. 1).

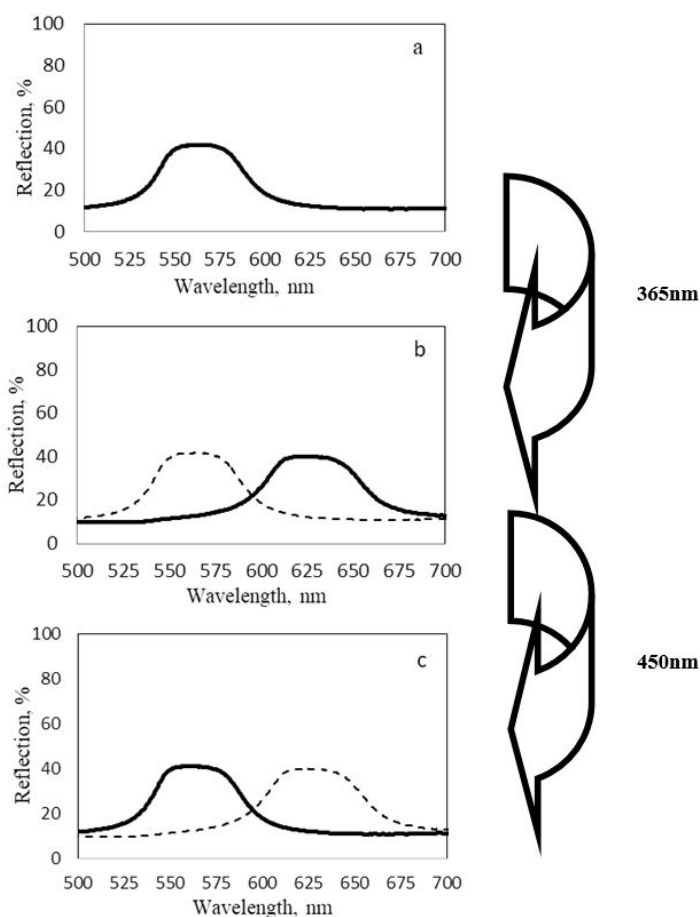


Fig. 1. Reflection spectra of ChLC cell when irradiated with 365 nm and 450 nm LEDs: a) initial position of selective reflection peak; b) the position of selective reflection peak in cis-state upon 365 nm exposure; c) the position of selective reflection peak in trans-state upon 450 nm exposure followed after 365nm exposure

Depending on the 365 nm light intensity a part of cChD molecules with azo groups undergoes trans-cis isomerization, i.e., molecules in the trans-state changes to the cis-state. Light exposure with 450nm LED induces reverse process of cis-trans isomerization, i.e., molecules in the cis-state

changes to the trans-state. Due to the difference of the helical twisting power of the cis- and trans-state of the photosensitive chiral dopant the photoinduced change of the helical pitch and, hence, the spectral position of the selective reflection peak is observed.

The maximum shift of the selective reflection was 145 nm. Performing consequent exposure with 365 and 450 nm LEDs' light obtain reversible control of selective reflection peak subject to the ratio of trans and cis isomers that determine the helical pitch. Next, the possibility of controlling the displacement of the selective reflection peak of the ChLC cell with targeted wavelength reflection was investigated. The ChLC cell was simultaneously illuminated with 365 nm and 450 nm LED light of different intensities. At the same time, the spectral position of the selective reflection peak was continuously changing within the exposed area of the sample until the resultant spectral position of the peak was reached. The resultant peak position depends on the percentage of the intensity of the LEDs (Fig. 2).

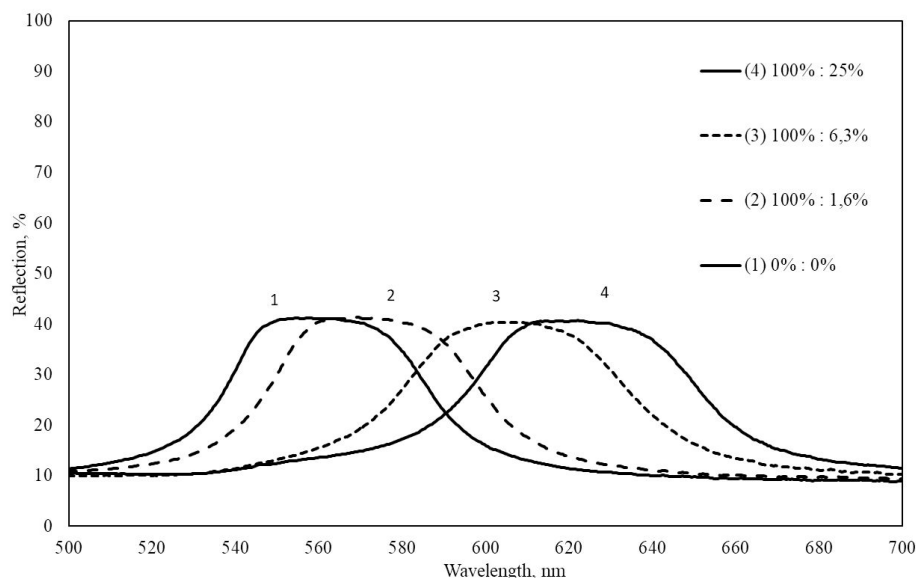


Fig. 2. Reflection spectra of the LC cell during simultaneous exposure with 365 nm and 450 nm LEDs light for different intensity ratios $I_{450}^{\%} : I_{365}^{\%}$

In order to obtain the given spectral position of the selective reflection peak, it is necessary to realize a controlled photodynamic equilibrium mode. In this case, the ratio of the intensities of the LEDs 365 nm and 450 nm ensures a photo-induced transition of the photosensitive cChD molecules from the trans-state to the cis-state under the exposure of 365 nm light, and from the cis-state to the trans-state under the action of 450 nm light. Changing the intensity ratio leads to the change of the photodynamic equilibrium of states of the photosensitive cChD that determines the helical twisting power of the chiral dopant, and, hence, the change of the helical pitch and the spectral position of the selective reflection peak.

Conclusion

Cholesteric liquid crystal material with reversible photo tunable wavelength shift of the resonance peak up to ~ 145 nm was developed. Controlled shift of selective reflection peak of the ChLC mixture is achieved by LED intensity adjustment due to the implementation of the photodynamic equilibrium of cis-trans chiral isomers of the chiral dopant enabling phototunable selective reflection of the cholesteric liquid crystal mixture.

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Authors contribution

Chepeleva D.S. realized conducting experiments and data processing, writing the paper.
Yakovleva A.S. realized chemical synthesis and material mixtures preparation.
Murauski A.A. realized experiments planning and supervision, results analysis and discussion.
Kukhta I.N. realized quantum mechanical modelling of chiral materials, results analysis and discussion, proof reading.
Muravsky A.A. realized work planning, work coordination, results analysis and discussion, writing the paper.

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