Color variation of Cholesteric Liquid Crystals Depending on Temperature and Dopant Concentration

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In this work, we report a technology of the color variation in the reflective CLC displays depending on the thermodynamic properties and the concentration gap of chiral dopant by the variated temperature. We could find that continuous decrease of the pitch is mainly originated from the dopant solubility below the critical temperature and stepwise decrease of the pitch is dominantly affected by the thermodynamic property above the critical temperature.

1. Introduction

Cholesteric liquid crystals (CLCs) have many merits for applying to color flexible displays since the optical components such as polarizer, color filter, and backlight unit are not required in the reflective CLC displays. CLCs have a helical structure due to the helical twisting power of the chiral dopants mixed in host nematic LC. The director of CLCs has the uniformly twisted arrangement along a perpendicular axis called the helical axis [1]. Due to the unique LC structure, CLC can induce the reflected color with a specific wavelength of the light associated with the CLCs helical pitch. The reflected color of CLCs can be changed by the pitch variation by the external factors. For the application to the electronic paper display, various technologies to diversify the reflected color of CLCs have been investigated such as varying the temperature of the cholesteric LC phase [2], adding different amounts of the chiral compounds [3], using phototunable chiral compounds [4], and applying an external field [1]. Recently, the technology of controlling the pitch by the chiral dopant solubility depending on the temperature is reported. As increasing temperature the chiral pitch decreases in the CLCs due to the effective amount of the solved chiral dopant, contributing the twisting power, increases.

In this work, we report a technology of the color variation in the reflective CLC displays depending on the thermodynamic properties and the concentration gap of chiral dopant by the variated temperature. We could find that continuous decrease of the pitch is mainly originated from the dopant solubility below the critical temperature and stepwise decrease of the pitch is dominantly affected by the thermodynamic property above the critical temperature.

2. Experimental

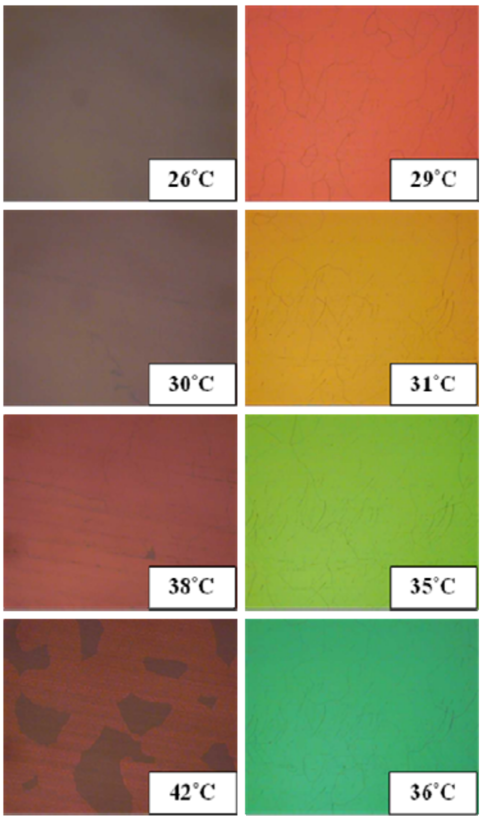
The helical structure of the CLC was generated by doping R-811 (right handed chiral dopant from Merck Co.) in the nematic LC of E7 (from Merck Co.). For making the composite uniformly and homogeneously, we stirred in an isotropic phase for 24 hours. The polyimide alignment layer was spin-coated on the indium-tin-oxide (ITO) glasses and cured them in the appropriated condition on a hotplate. After rubbing the alignment layer, two rubbed substrates were assembled in anti-parallel direction. The CLC with the uniform cell gap of 6 μm was injected into the assembled cells by capillary action in the isotropic phase. Finally, the experimental cell was cooled down slowly to achieve a planar texture.

The diversification of the reflected color depending on temperature was observed using a microscope mounting on a micro furnace. To confirm the variation of the reflectance spectra of the CLC samples, we measured varying temperature from 25 °C to a phase transition temperature of CLC cell with different concentrations of the chiral dopant.

3. Results

Figure 1 shows the reflected color of the CLC samples with 27.5 wt. % and 42.5 wt. % chiral dopant. In the case of CLC cell mixed the chiral dopant of 27.5 wt. %, we could obtain the cholesteric phase under a range of the temperature from 26 °C to 44 °C. However, as shown in fig. 1(a), the reflected color was slightly shifted to the red color under whole temperature range showing the cholesteric phase. In the other side, we could confirm the color shift from red to green in the mixed condition of 42.5 wt. % chiral dopant (fig. 2(b)). In this cell, the cholesteric phase was preserved from 28 °C to 37 °C. After that, to verify the quantified value of the color variation depending on temperature, we measured the reflectance spectrum of the CLC cells with different amounts of chiral dopants.

Through the results of measured reflectance spectrum, we could obtain the center wavelength on the different temperature.



(a) (b)

Figure 1 Microscopic textures of the change in reflected colors at different temperatures of the CLC samples mixed with (a) 27.5 wt. % and (b) 42.5 wt. % chiral dopant

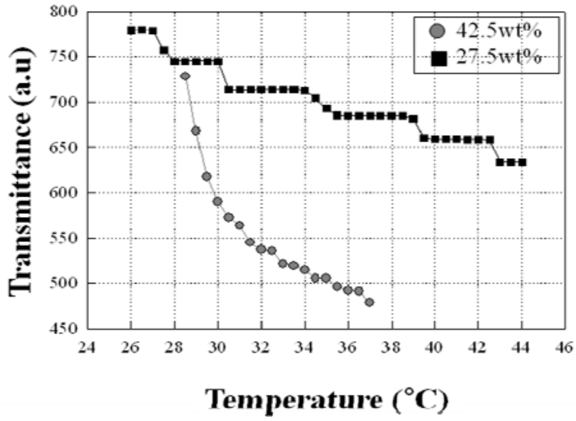


Figure 2 Measured results of the central wavelength of the CLC samples with the different concentrations of the chiral dopant: 27.5 wt. % and 42.5 wt. %.

Figure 2 is the result of the center wavelengths as a function of the temperature of the CLC samples with the chiral dopant of 27.5 wt. % and 42.5 wt. %. In a low concentration of the chiral dopant, the corresponding center wavelength to the selective reflection was stepwise decreased when the temperature was increased. In this condition, known as the thermal vibrations, the pitch variation by increase of the helical twisting power of the chiral dopant within the cholesteric phase just depends on the thermodynamic properties of the CLC molecules [5]. With increasing temperature, the thermal vibration strength was increased and thus the twisting angle variation between nearest neighboring molecules was increased. The increase of the angle variation resulted in reducing the helical pitch of the CLC.

As the concentration of the chiral dopant was increased, the corresponding wavelength was rapidly decreased up to a certain critical temperature (about 32 °C). After the critical temperature, the pitch variation is similar to that in the low concentration (mixed 27.5wt. % chiral dopant), that is, the wavelength gradually goes down stepwise with increasing temperature. In the state of the upper critical temperature, the pitch change is induced in the molecular thermodynamic properties previously mentioned directly. However, in the regime of the lower critical temperature, the stepwise variation of the corresponding wavelength did not observed clearly due to the rapid variation. In this condition, the solubility of the chiral dopant in the nematic LCs dominantly affects the pitch variation [6]. The amount of the chiral dopant contributing the twisting power strongly depends on temperature.

4. Conclusion

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In this work, we propose a technology for expanding the range of color variation of CLC cell by controlling the concentration of chiral dopant. The corresponding wavelength rapidly goes down due to both contribution of the thermodynamic behavior and the dopant solubility. The critical temperature corresponding to the dopant solubility was gradually increased with increasing the concentration of the chiral dopant. This means that the critical solubility (fully dissolved concentration) gradually increases.

5. Acknowledgement

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References

[1] H. Xianyu, T.-H. Lin, and S.-T. Wu, *Appl. Phys. Lett.* **89,** 091124 (2006).
[2] P. N. Keating, *Mol. Cryst. Liq. Cryst.* **8**, 315 (1969).
[3] E. M. Korenic, S. D. Jacobs, S. M. Faris, L. Li, *Color Res. Appl.* **23,** 210 (1998).
[4] G. D. Filpo, F. P. Nicoletta, and G. Chidichimo, *Adv. Mater.* **17,** 1150 (2005).
[5] P. N. Keating, *Mol. Cryst. Liq. Cryst.* **8,** 315 (1969).
[6] N. Tamaoki, *Adv. Mater.* **13,** 1135 (2001).