Band broadening of cholesteric liquid crystal film through the various UV treatments

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Abstract

The formation of cholesteric liquid crystal (CLC) film reflecting a broadbanded visible spectrum by application of a liquid crystalline coating followed by UV polymerization (photo-curing) is described. Also, the formation of patterned coatings obtained by a sequence of UV exposure steps is discussed. Such coatings play an important role in the improvement of the performance of liquid crystal displays. In order to make these CLC films, we synthesized new cholesteric liquid crystal molecules (Ch-chol) containing the active reaction site to UV light and investigated to broaden the bandwidth of these cholesteric filters based on the various UV treatments.

1. Introduction

Linear polarization of light over a large area is conventionally achieved through the use of dichroic polarizers. In spite of their widespread use in displays and other applications, dichroic polarizers have significant limitations including the dissipation of more than 50% of light, the inability to withstand high temperatures, and low damage threshold [1-3].

The use of liquid-crystalline cholesteric filters has been suggested as a potential solution to this problem. They reflect circularly polarized incident light of the same handedness as the cholesteric helix and transmit the one of the opposite handedness, and in a wavelength band that depends on the helical pitch [4-5].

If such a filter is mounted into an LCD backlight as shown in figure 1, the transmitted component can be converted from circularly polarized to linearly polarized through the use of a quarter-wave retardation foil (QWF). The reflected component returns to the backlight and is recycled through internal reflections until it is once again incident upon

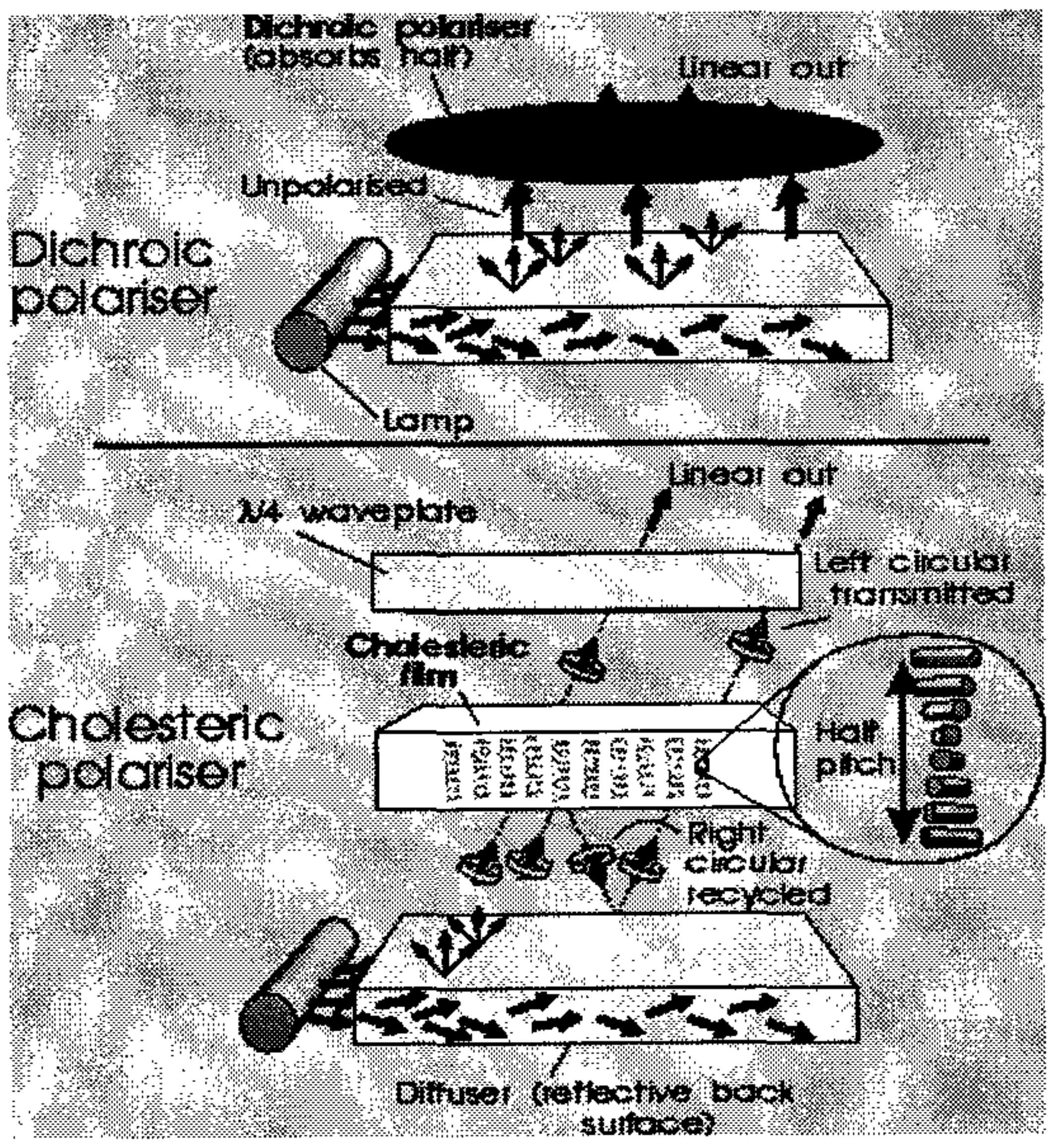


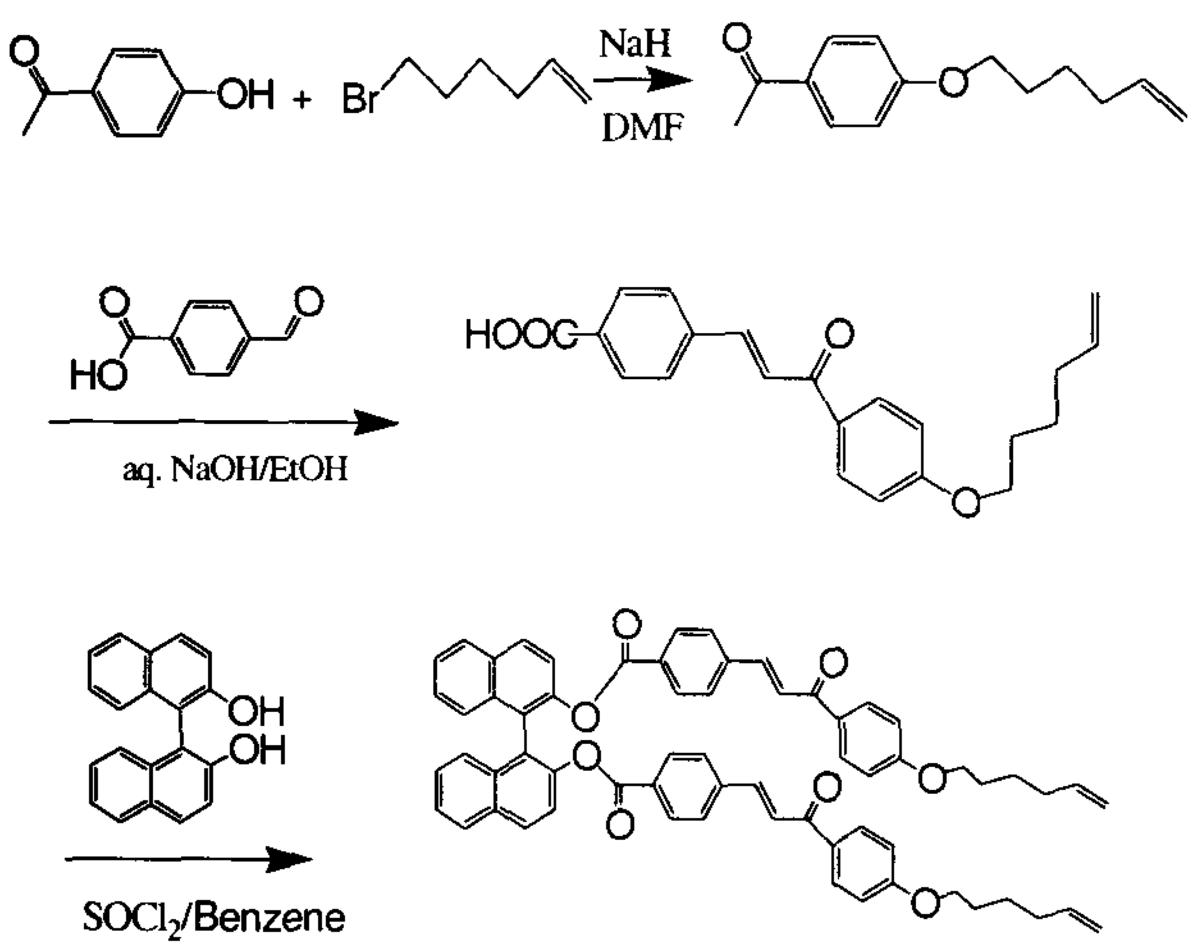
Figure 1 Schematic illustration of a CLC reflective Polarizer

the cholesteric layer. Again the light is separated into a reflected and a transmitted component, and again the reflected light is recycled. In an ideal case, all the light will eventually emerge linearly polarized from the cholesteric layer/QWF stack [6]. The cholesteric color filter has many optical properties integrated in one layer. It is not only a color filter, but also a reflector and a polarizer. Such advantages can reduce the total number of optical components in the LCD and lead to cost reduction [7-9]. However, the reflection wavelength is related to the helix pitch and the wavelength bandwidth depends on the birefringence that is typically less than 0.3. In the visible spectrum, the bandwidth is often limited to 100nm that is not suitable for specific purposes such as white-on-black polarizer-free reflective displays.

In order to improve the shortcoming, we synthesized new cholesteric liquid crystal molecules (Ch-chol) containing the active reaction site to UV light and investigated to broaden the bandwidth of these cholesteric filters based on the various UV treatments.

2. Experimental

We designed new photo-curable cholesteric material (Ch-chol), which has two kinds of reactive sites for UV light. Figure 2 shows the structure and the steps of synthesis.



Ch-chol

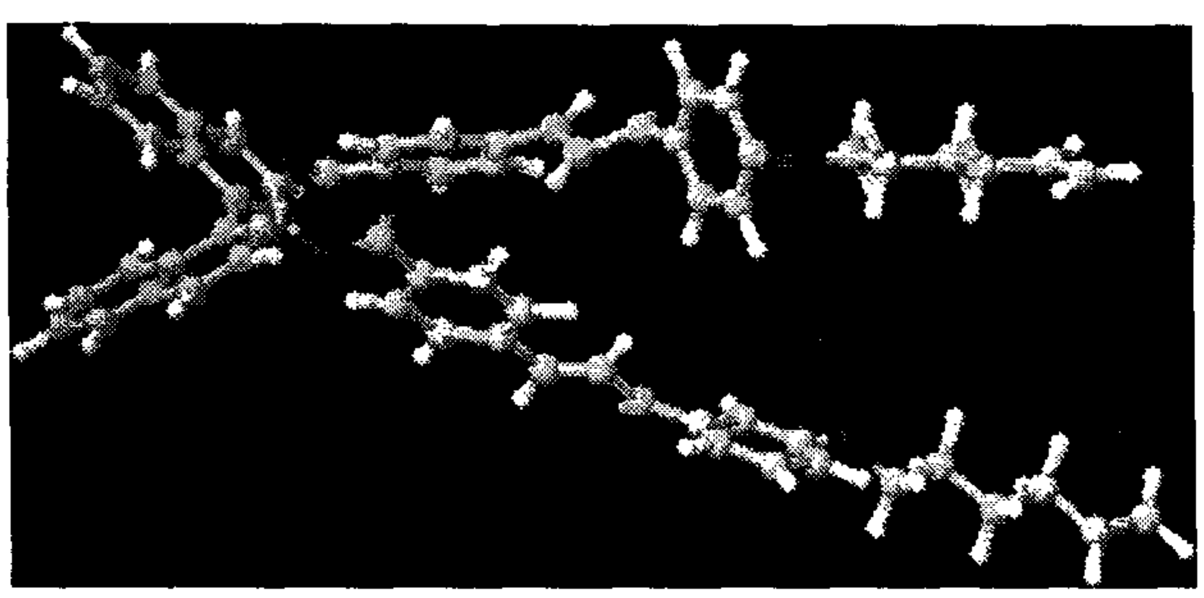


Figure 2 Synthesis of the new photo-curable cholesteric material and the 3-D image

The in situ polymerization of reactive liquid crystals has been processed. In this process a mixture of cholesteric liquid crystals with a small amount of a radical photo initiator (Irgacure 907 from Ciba-Geigy) is introduced in the isotropic phase over 100°C by capillary in a 13μm thick glass cell which contains a very thin rubbed polymeric alignment layer. In order to control the center of the wavelength band of the reflected light, we mixed some nematic liquid crystal into the cholesteric mixture. The nematic liquid crystal used has a positive dielectric anisotropy. After alignment in the nematic phase, a fast UV-induced polymerization process is started to form a polymer and in this way stabilize the anisotropic optical properties of the monomers. By using a photo mask, photolithographic effects can be performed on the coating.

The spectral characteristics are obtained by unpolarized spectrophotometry (HP 8453) in transmittance mode and at ambient temperature. It is checked that negative peaks are due to reflectance and not to absorbance.

3. Results and discussion

Carboxylic acid containing the chalcone structure (see figure 2) was converted into the acid chloride through the reaction with thionylchloride. The new photo-curable cholesteric material (Ch-chol) was obtained from a reaction (S)-(-)-1,1'-Bi-2-naphthol with the highly reactive acid chloride of chalcone derivative. This product was confirmed by FT-IR and H-NMR spectroscopy.

When the cholesteric liquid crystal film is perfectly aligned, the liquid crystal molecules have the planar texture in which the helix is perpendicular to the glass plate. If the cholesteric layer is not perfectly aligned, however, there are various domains in the cholesteric

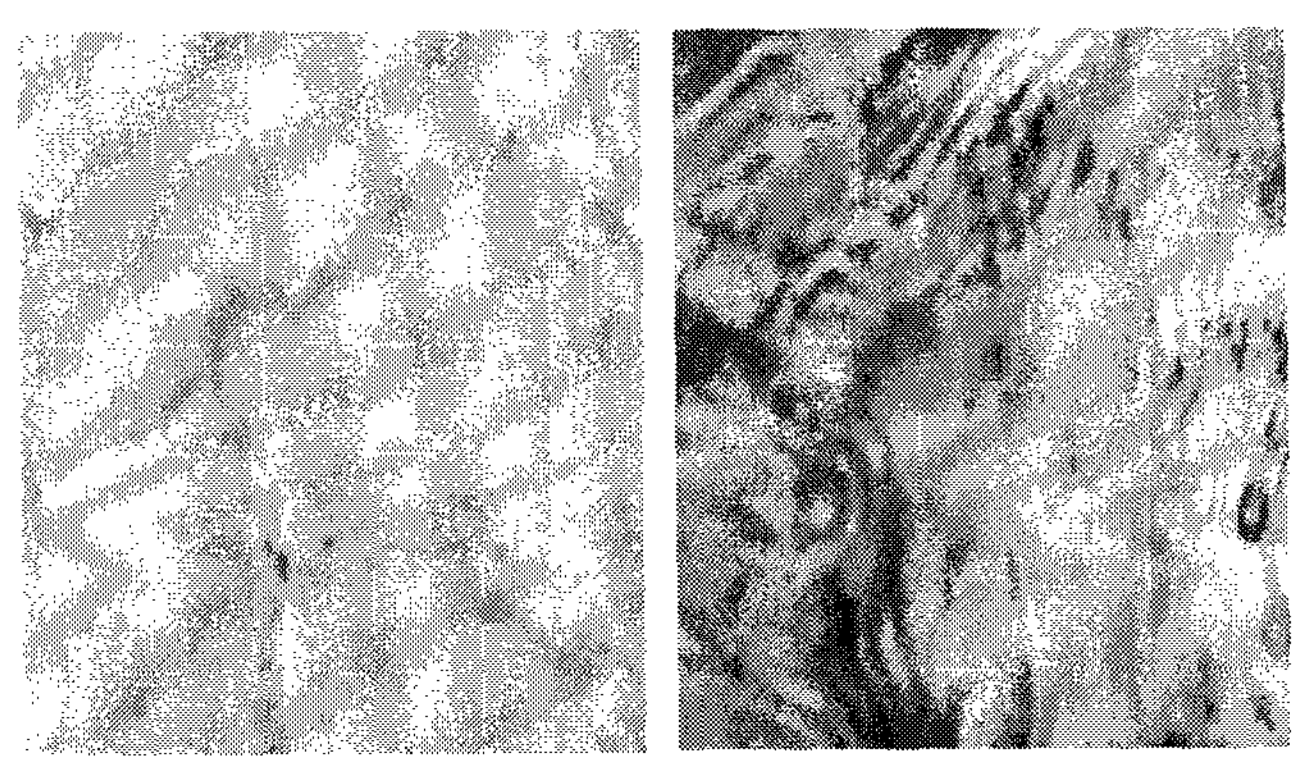


Figure 3 a planar texture and an imperfect planar texture after photo curing

layer (see figure 3). The cholesteric layer with the good planar texture reflects polarized light in a specular way, while the layer with the imperfect planar texture reflects polarized light in a diffuse way.

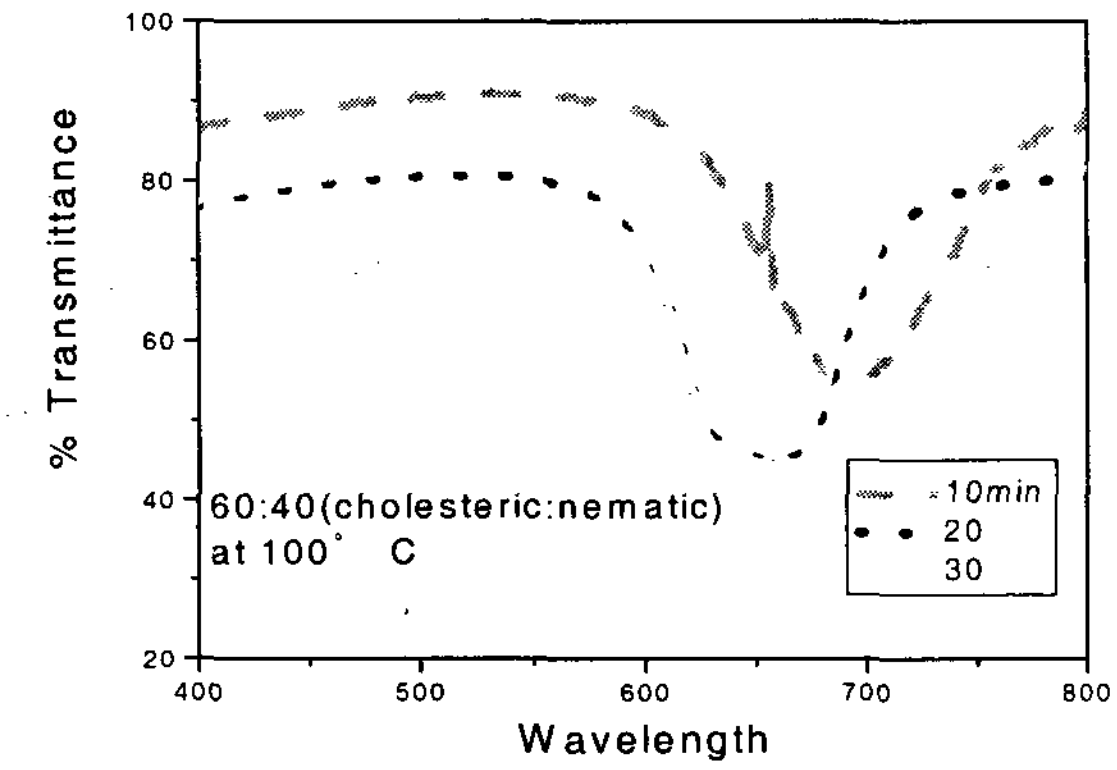


Figure 4 Transmittance of CLC films depending on the curing time (cholesteric LC / nematic LC =60/40)

After irradiation, there is an important modification of the liquid crystal's pitch. There is a shift of the pitch towards the lower wavelengths. Modifying the UV intensity slightly changes the location of the pitch and the bandwidth measured at half-height is almost of 100nm as shown in figure 4.

The microscopic image also is observed when the temperature changes. Up to the clearing point about 125°C, the wavelength decreases with increasing temperature. After photo-polymerization around 100°C, however, an almost constant reflection wavelength is obtained up to 180°C.

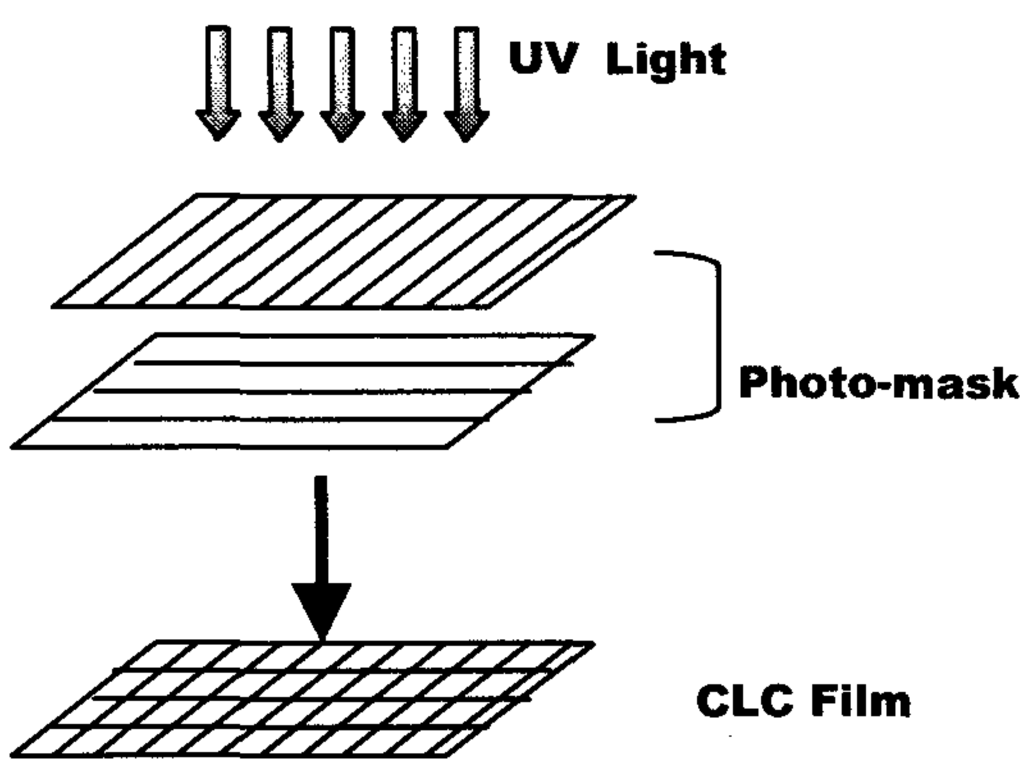


Figure 5 Color formation process for the new photo curable CLC film

Figure 5 also shows how the broadening range of color are made by one irradiation step using a patterned mask between the light source and a coating of the material.

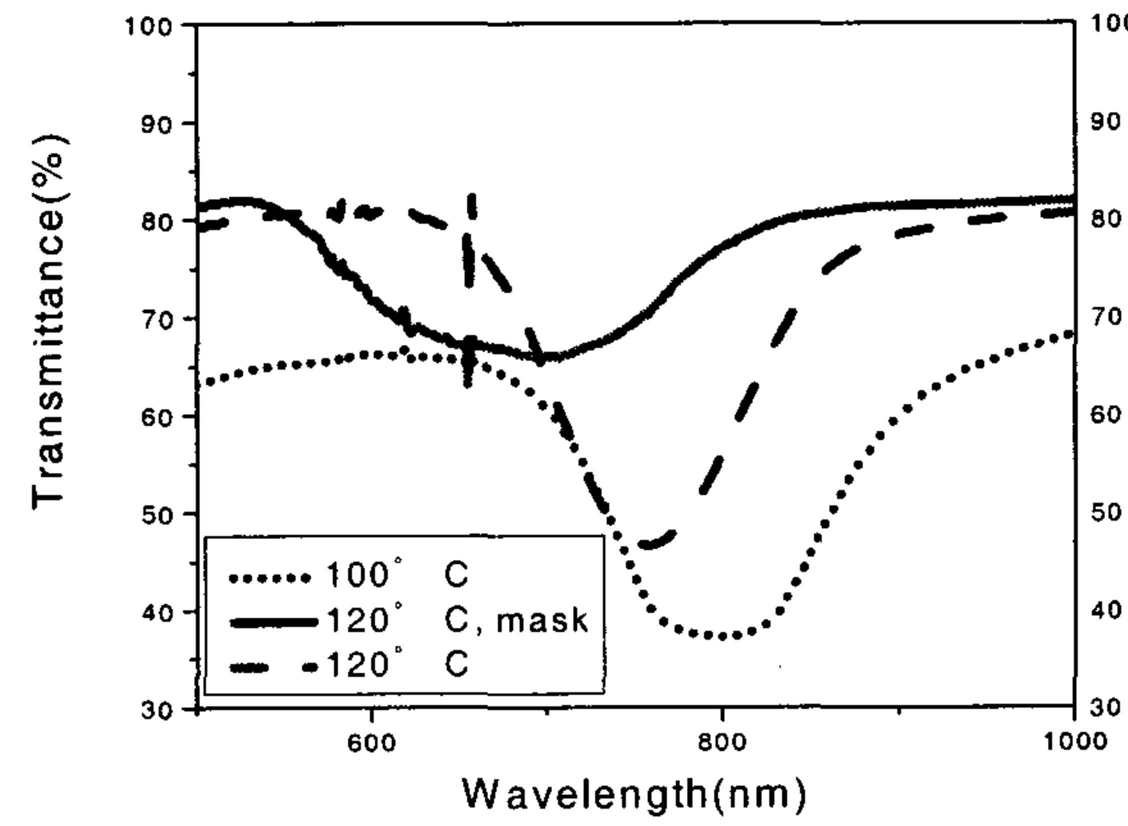


Figure 6 Transmittance spectra of the CLC films made in several curing conditions.

When cured at 100°C, the film was not clear and the light scattering was observed. The light scattering is due to a focal conic texture exhibiting polydomains. This is the result of a competition between LC molecules close to the polymer network which have a tendency to contribute to a stable planar reflecting texture and the other molecules which is to destroy this order by untwisting the helix. While cured at the 120°C, that film reflected the light shifted to blue and has the high vividness of color. There was appears that the band broadened by using the photo-mask. It is caused of a factor that two as a consequence of a UV-curing occurring when the cholesteric pitch changes. We can think that this broadening is the result of memory effects introduced by the polymer network, which has been built in a CLC medium for which a major structural characteristic such as the helical pitch was changing.

4. Conclusion

The wavelength (λ) of the light which is reflected by the cholesteric layer is depending on the pitch P and the average refractive index ñ. The spectral width of the reflected light is depending on the pitch and the birefringence Δn ($\Delta\lambda = P\Delta n$) that is typically less than 0.3. In the visible spectrum, the bandwidth is often limited to 100nm that is not suitable for specific purposes such as white-on-black polarizer-free reflective displays.

In order to broaden the band of the reflected light, we synthesized new cholesteric liquid crystal molecules (Ch-chol) containing the active reaction site to UV light and investigated to broaden the bandwidth of these cholesteric filters based on the various UV treatments.

Acknowledgement

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