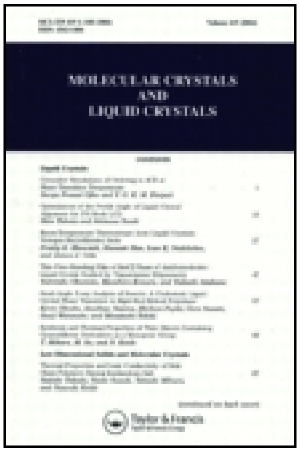

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Alignment and Photopolymerization of UV-Curable Liquid Crystals

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Alignment and photo polymerization of UV-curable liquid crystals in conjunction with non-polymerizable liquid crystals are discussed.

Keywords: liquid crystalline monomer; retardation film

INTRODUCTION

To compensate birefringence effect of Super Twisted Nematic Liquid Crystal Displays (STN-LCDs) in a wide temperature range, retardation film showing a reversible retardation change with temperature has been investigated[1,2]. Kuwabara *et al* reported that retardation film obtained by stretching polycarbonate film in which non-polymerizable liquid crystals are dispersed shows temperature dependence of retardation, *i.e.* the retardation of the film decreases with increasing temperature[2]. The dependence is attributable to a relaxation of the alignment of the liquid crystals dispersed in the stretched polycarbonate film. This effect of the liquid crystals has great potential to fabricate various types of retardation film which has temperature dependence of retardation.

To introduce temperature dependence of retardation into retardation film without stretching process, we have investigated the fabrication of retardation film by *in situ* photo polymerization of aligned nematic mixture of non- polymerizable liquid crystals and liquid crystalline monomers, UV-curable liquid crystals[3]. Since non-polymerizable liquid crystals are completely miscible with UV-curable liquid crystals before photo polymerization, good and homogeneous dispersion of non-polymerizable liquid crystals in the polymer made of UV curable liquid crystal can be obtained after photo polymerization. We report the effect of addition of non-polymerizable liquid crystals on the alignment of the UV-curable liquid crystals during photo polymerization. And we discuss the temperature dependence of retardation of the film.

EXPERIMENTAL

UCL-001 (optical anisotropy at λ=589nm: Δn=0.152, nematic-isotropic liquid phase transition temperature: T_{NI}=46°C) comprising liquid crystalline monoacrylates in Figure 1 was used as UV curable liquid crystals in this study. The liquid crystals show nematic phase at room temperature. 1wt% of photo initiator, Irgacure-651 supplied by Ciba-geigy Inc., was added to UCL-001 before photo polymerization. LC-A (Δn=0.185 at λ=589nm, T_{NI}=35°C), LC-B (Δn=0.227 at λ=589nm, T_{NI}=63°C) and LC-C (Δn=0.207 at λ=589nm, T_{NI}=96°C) were used as non-polymerizable liquid crystal. These liquid crystals consist of cyano-biphenyl homologues.

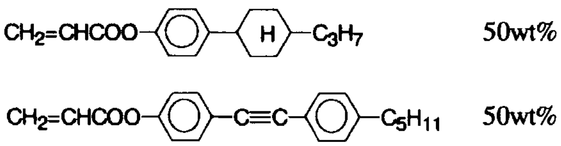

FIGURE 1 Chemical structures of UCL-001

ALIGNMENT OF UV-CURABLE LIQUID CRYSTALS DURING PHOTO POLYMERIZATION

To investigate the effect of addition of non-polymerizable liquid crystal on the alignment and photo polymerization of the UV-curable liquid crystals, we measured retardation change during *in situ* photo polymerization at λ=632.8nm of the 4-μm-thick-uniaxially aligned nematic mixture of UCL-001 and LC-A under UV-irradiation (1mW/cm^2) at 25°C. Figure 2 shows the retardation change with UV-irradiation time. The retardation value is normalized at before photo polymerization.

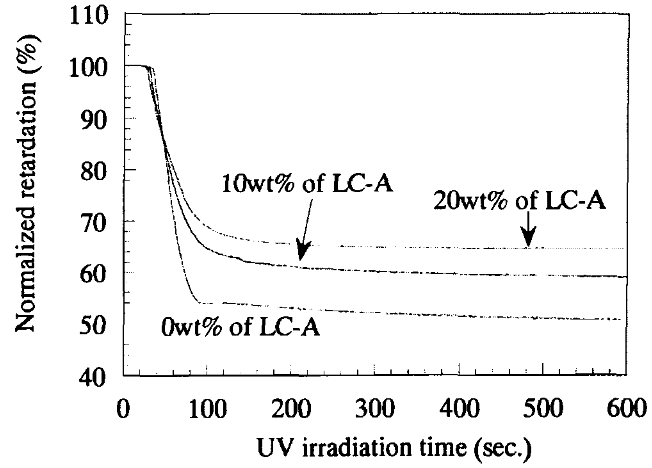

FIGURE 2 Normalized retardation vs. UV-irradiation time

In case of 0wt% of LC-A (100wt% of UCL-001), the retardation decreases rapidly just after the initiation of photo polymerization and decreases gradually after that. Completion of the photo polymerization leads to a constant value of the retardation about 51% of retardation before photo polymerization. The 49% of loss of retardation is due to a small deformation of the alignment of mesogenic cores of UV curable liquid crystals[3]. In conjunction with non- polymerizable liquid crystal, the loss of retardation is about 41% for 10wt% of LC-A, and about 35% for 20wt% of LC-A. The loss of retardation decreased with increasing the concentration of LC-A. This suggests that the alignment of mesogenic cores of UCL-001 is not interfered by addition of LC-A during photo polymerization. We also measured the retardation change using LC-B and LC-C as non-polymerizable liquid crystals. Table 1 summarizes Δn of the nematic mixture before photo polymerization and the normalized retardation after photo polymerization. The loss of retardation does not depend on T_{NI} of non-polymerizable liquid crystals and depends on the concentration of non-polymerizable liquid crystals.

TABLE I Physical data of nematic mixture

Composition of nematic mixture	Δn before polymerization	Normalized retardation after polymerization(%)
80wt% of UCL-001 20wt% of LC-A	0.167	65
80wt% of UCL-001 20wt% of LC-B	0.167	63
80wt% of UCL-001 20wt% of LC-C	0.173	64

TEMPERATURE DEPENDENCE OF RETARDATION FILM

Effect of concentration of non-polymerizable liquid crystals

We have fabricated the retardation film by using procedure illustrated in Figure 3. A glass substrate was removed from the retardation film to avoid thermal stress caused by mismatch of the thermal expansion coefficient of glass and the retardation film. Then the retardation film was treated at 120°C for 30 minutes for aging. Figure 4 shows the temperature dependence of retardation of the film made of nematic mixture of UCL-001 and LC-A.

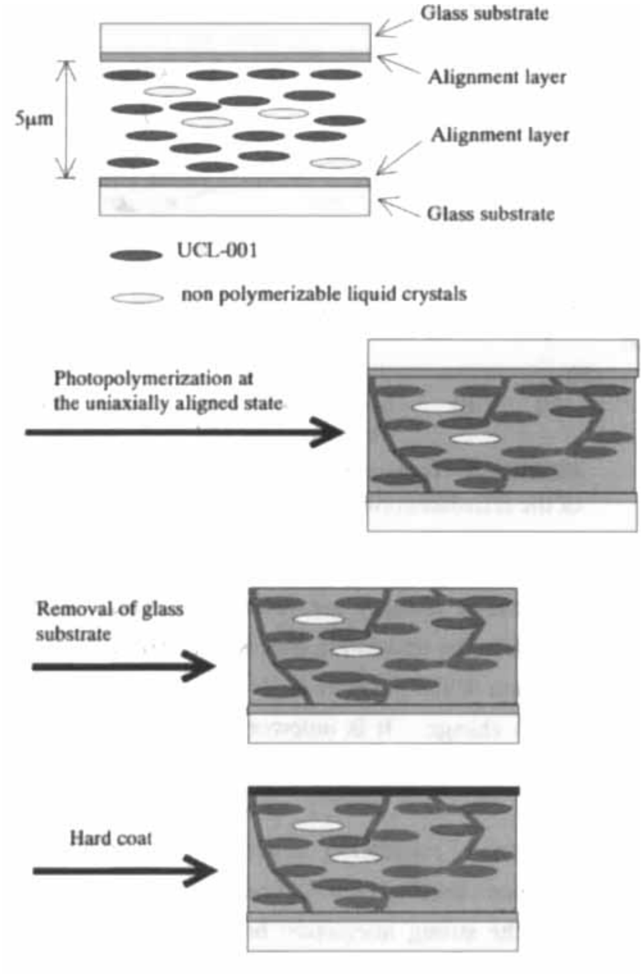

FIGURE 3 Fabrication of the retardation film.

The retardation value is normalized at 30°C. In case of 0wt% of LC-A, the normalized retardation is 99% even at 120°C. On the contrary, the normalized retardation at 120°C is 92% for 10wt% of LC-A and 85% for 20wt% of LC-A. The temperature dependence of retardation becomes sensitive to temperature with increasing the concentration of LC-A.

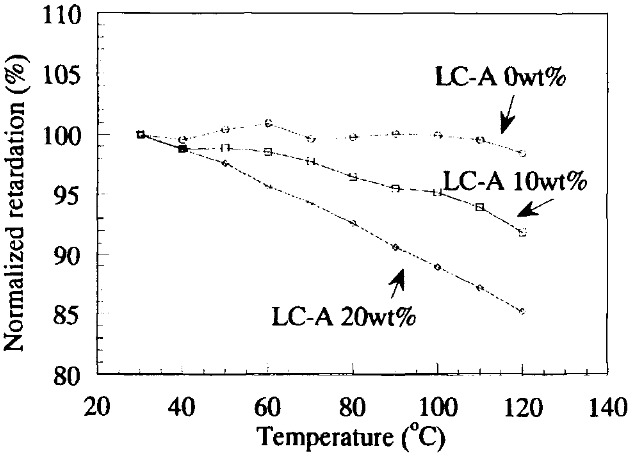

FIGURE 4 Temperature dependence of retardation of the retardation film.

Since these retardation changes are reversible, change of the order of alignment of LC-A in the retardation film is responsible for the retardation change. Relaxation of the polymer made of UCL-001 is not responsible for the retardation change. It is noteworthy that the retardation change was observed even above 35°C up to 120°C. The alignment of LC-A is normally isotropic above T_{NI}(35°C), which means that LC-A can not contribute to generate retardation under normal circumstance. This unusual phenomenon observed over 85 degrees temperature range suggests the existence of the strong interaction between LC-A and the polymer made of UCL-001. Kuwabara *et al* reported similar phenomenon, however the observed temperature range of the phenomenon was 10 degrees at most[2]. Wide temperature range of the phenomenon in present system would be attributable to good dispersion of LC-A in the polymer made of UCL-001.

Effect of transition temperature of non-polymerizable liquid crystals

Figure 5 shows the temperature dependence of retardation of the film by using LC-A (T_{NI}=35°C), LC-B(T_{NI}=63°C) and LC-C(T_{NI}=92°C) as non-polymerizable liquid crystals.

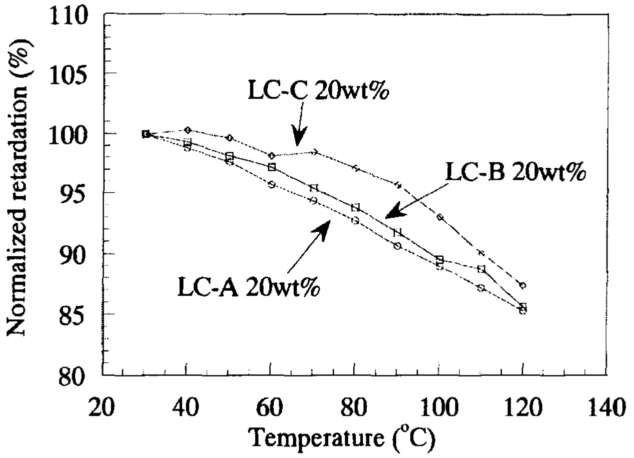

FIGURE 5 Temperature dependence of retardation of the retardation film

The retardation value is normalized at 30°C. Although the temperature dependence becomes sensitive to temperature with decreasing T_{NI} of non-polymerizable liquid crystals, the effect of T_{NI} on the temperature dependence of retardation is not so significant as the effect of the concentration of non-polymerizable liquid crystals. This would be due to that the alignment of non-polymerizable liquid crystals is affected dominantly by the interaction between non-polymerizable liquid crystals and the polymer made with UCL-001.

THERMAL STABILITY OF RETARDATION FILM

We examined the thermal stability of the retardation film made of nematic mixture of UCL-001 and LC-A. Figure 6 shows the effect of heating at 100°C on the retardation of the film. The retardation value is normalized at before heating. The film shows good thermal stability, with a change in retardation of less than 2% after 10hours.

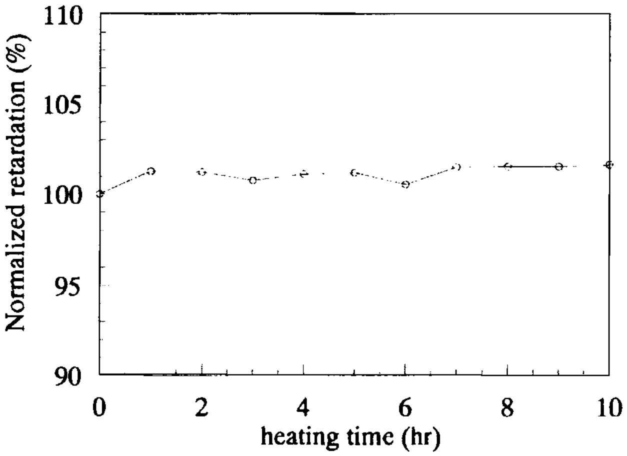

FIGURE 6 Normalized retardation vs. heating time.

CONCLUSION

We have fabricated the retardation film showing a reversible retardation change with temperature by *in situ* photopolymerization of aligned nematic mixture of UV curable liquid crystals and non-polymerizable liquid crystals. The temperature dependence of the retardation of the film depends on the concentration of the non-polymerizable liquid crystals. The alignment of UV-curable liquid crystals during the photo polymerization has been investigated. Addition of non-polymerizable liquid crystals does not interfere the alignment of UV curable liquid crystals during photo polymerization.

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