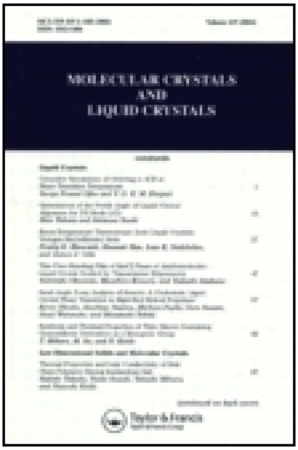
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Transparency of Anisotropic Films Made by Polymerization of UV-Curable Liquid Crystals

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Transparency of Anisotropic Films Made by Polymerization of UV-Curable Liquid Crystals

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Influence of photopolymerization condition of UV-curable liquid crystals on the transparency of optical anisotropic plastic films was investigated. Nematic phase was observed at room temperature in novel compositions investigated in this study. Transparency of the optical anisotropic films was improved by adding the swallow-tailed compounds to UCL-001. Diffusion transmittance reduced as increasing either intensity or total energy of UV irradiation. Retardation of these films decreased as increasing not only intensity but also total energy of irradiated UV light. It was suggested that haze was caused by light scattering from small regions of differing refractive index. Retardation and total transmittance showed opposite behavior against the conditions of UV irradiation.

Keywords: UV-curable liquid crystal; in situ photopolymerization; transparency; haze; anisotropic optical film; retardation

INTRODUCTION

Optical anisotropic materials play an important role in some information technologies. For the last decade, many studies of optical anisotropic materials made from liquid-crystalline materials were reported[1-4]. Broer and Philips researchers reported cholesteric liquid-crystalline film, which was made by in-situ polymerization of oriented polymerizable cholesteric liquid crystals. Takatsu and Hasebe reported in-situ polymerization of a composition consisting of liquid-crystalline monoacrylates, which shows nematic phase at room temperature, in order to make optical anisotropic films[5, 6]. A thick film was required to obtain a large retardation. Thick anisotropic films made from some of the liquid-crystalline monoacrylates show relatively large haze. We synthesized a novel swallow-tailed UV-curable liquid-crystalline compound (compound C) in order to decrease the haze[7]. Novel compositions containing liquid-crystalline monoacrylates and compound C show nematic phase at room temperature. The haze of optical anisotropic films made from these compositions significantly reduced. We studied influence of curing processes including UV intensity and total energy on the transparency and retardation of the films.

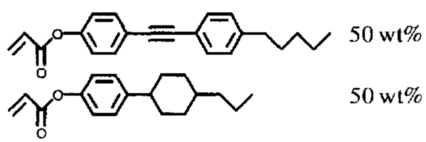

Fig.1 Chemical structure of UCL-001

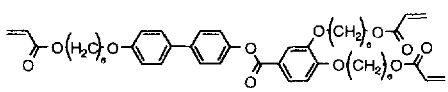

Fig.2 Chemical structure of compound C

EXPERIMENTAL

The compounds used in this research were as follows: UCL-001 was used as a composition of liquid-crystalline monoacrylates. Structure of UCL-001 (Dainippon Ink and Chem., Inc.) is shown in Fig. 1.

Structure of swallow-tailed liquid-crystalline compound C is shown in Fig.2. The compositions for photopolymerization were prepared by adding 1 wt % of photoinitiator (2, 2 - Dimethoxy - 2 - phenylacetophenone) to the mixture of UCL-001 and compound C. As shown in Fig. 3, the mixture of UV-curable liquid crystals was oriented homogeneously in 50-micron gap glass cell coated with polyimide as alignment layer before UV irradiation. In-situ polymerization was carried out with a super high-pressure mercury lump at 366nm at room temperature through sharp-cut filters and/or band-pass filters in order to adjust intensity and total energy of light. When transmittance as a function of total energy was investigated, $250W/m^2$ of light was irradiated for polymerization. Irradiation of $10kJ/m^2$ was carried out for polymerization when transmittance as a function of intensity was examined. After polymerization, total transmittance and diffusion transmittance of the films were measured by the method being defined by ISO 13468-1(JIS K 7361-1) as shown in Fig. 5. Haze was calculated by the following equation;

Haze = Diffusion Transmittance / Total Transmittance $\times$ 100.

The retardation of the films was measured at 633 nm using He-Ne laser.

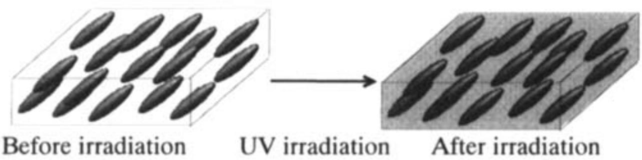

Fig. 3 In-situ polymerization of oriented liquid crystal

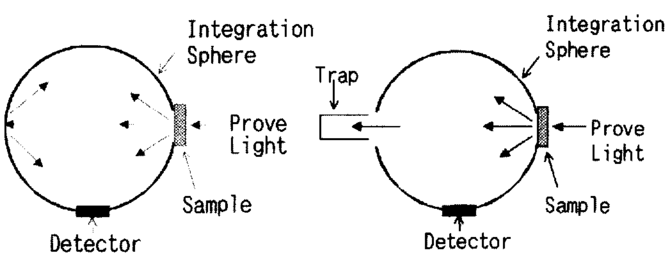

Fig. 4 Measurement of transmittance (ISO 13468-1)

RESULT AND DISCUSSION

The physical properties of the liquid-crystalline mixtures were summarized in Table 1. All mixtures show nematic phase at room temperature. It was found that nematic to isotropic phase transition temperature increased and birefringence decreased as the amount of compound C increased.

Table 1 Physical properties of the compositions

Compositions	UCL-001	C1	C2	C3
UCL-001(wt%)	100	90	80	70
Compound C(wt%)	0	10	20	30
Tni	46	47	48	50
n_e	1.662	1.659	1.658	1.656
n_o	1.510	1.512	1.512	1.513
Δn	0.152	0.147	0.146	0.143

Fig. 5 shows plots for total transmittance and diffusion transmittance as a function of light intensity. Before irradiation, haze was 3.4% for all the samples. Total transmittance of the compositions of UCL-001 and compound C was larger than that of UCL-001. It was found that diffusion transmittance decreased as the amount of compound C increased. The diffusion transmittance tended to decrease as increasing intensity of polymerization light. There is a tendency that transparency of optical anisotropic film could be improved by adding compound C to UCL-001. Moreover, transparency was improved by increasing light intensity.

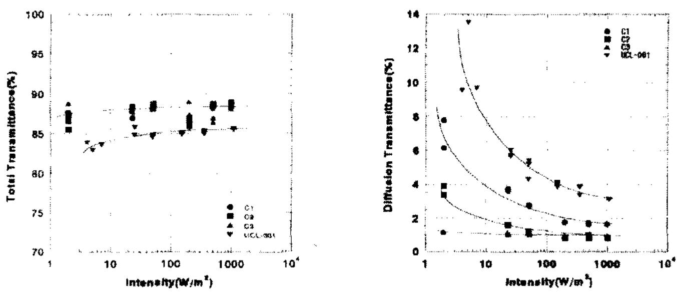

Fig. 5 Plots for total transmittance and diffusion transmittance as a function of light intensity

Fig. 6 shows plots for total transmittance and diffusion transmittance as a function of irradiation energy. It was found that diffusion transmittance reduced as increasing irradiation energy. When the composition contains compound C at a level of 20 wt % or 30 wt %, diffusion transmittance was almost independent of light intensity and total energy.

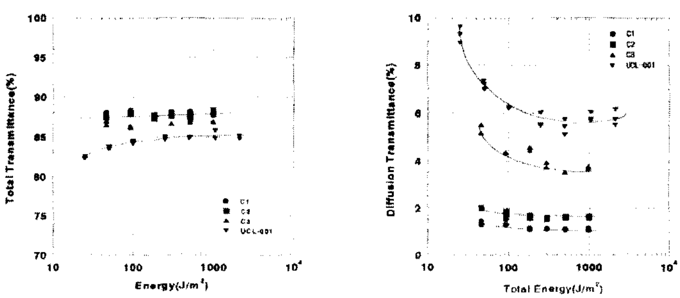

Fig. 6 Plots for total transmittance and diffusion transmittance as a function of irradiation energy

Photographs using confocal laser scanning microscopy were shown in Fig. 7. It was suggested that there were changes of distribution in refractive indices caused by domains in the film made from UCL-001. The size of these domains is sub-micron order. It was suggested that the light scattering from these domains caused haze in this system. On the other hand, there was no changes of distribution in refractive indices in the films made from the composition including 30 wt% of compound C.

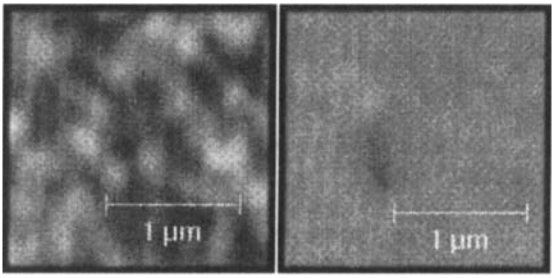

Fig. 7 Microscopic observations of the optical anisotropic films

Fig. 8 shows plots for retardations of the films as a function of irradiation intensity and total energy. It was found that retardation reduced as increasing either intensity or total energy. When the compositions which contained 10 wt% of compound C or 20 wt% of compound C were used for in-situ polymerization, the retardations of optical anisotropic films were small compared with the case of UCL-001 only. When the composition which included 30 wt % of compound C was used, retardations of the films were as same level as those of UCL-001.

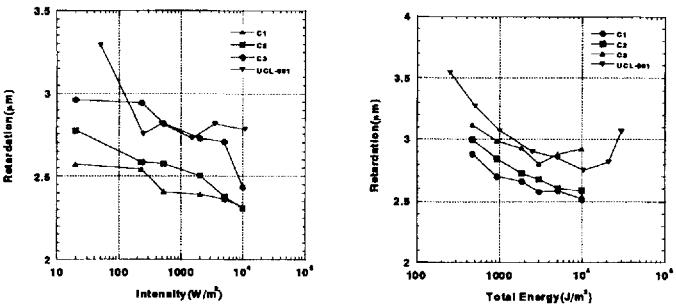

Fig. 8 Plots for retardations as a function of irradiation intensity and total energy

Relation between total transmittance and retardation was shown in Fig. 9. A trade-off between total transmittance and retardation was observed in this system. Total transmittance was improved by adding 30wt% of compound C to UCL-001 without decreasing retardation.

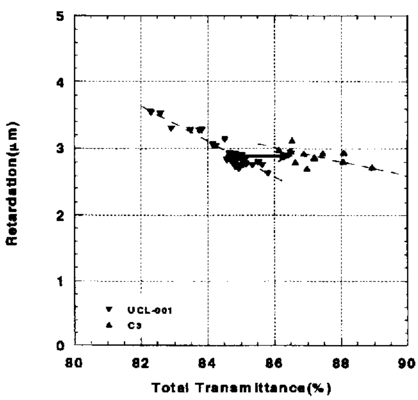

Fig. 9 Relation between total transmittance and retardation

CONCLUSION

Influence of UV intensity and total energy of in-situ polymerization on transparency and retardation of optical anisotropic films was investigated. Nematic phase was observed at room temperature in the compositions including compound C and UCL-001. As the amount of compound C added to UCL-001 increased, transparency of optical anisotropic films was improved. Diffusion transmittance reduced as increasing either intensity or total energy of irradiated UV light. Total transmittance was almost independent of intensity or total energy. The changes of distribution in refractive indices caused by the domains were observed. It was suggested that the light scattering from these domains caused haze in this system. Retardation decreased as increasing either intensity or total energy of UV irradiation. A trade-off between retardation and total transmittance was observed in this system.

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