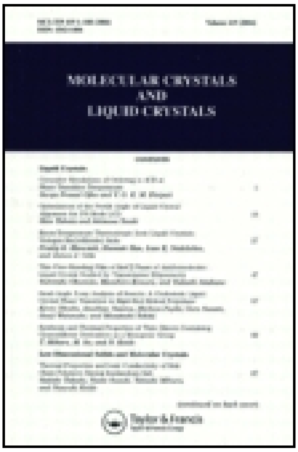

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Temperature Dependence of LC-Molecular Alignment on Rubbed Polymer Layer

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Temperature Dependence of LC-Molecular Alignment on Rubbed Polymer Layer

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Liquid crystal molecules on a rubbed polymer alignment layer are oriented at some polar angle away from the surface. This so-called pretilt angle is an important parameter which determines the electro-optical properties of liquid crystal devices. Therefore, there is a necessity to deeply study generation of pretilt angle and its stability. Several researchers study on this problem but the physical mechanism is not thoroughly understood. Therefore, we have investigated LC pretilt angle and polymer inclination angle and the effect of heat treatment about these angles. We have also studied the relation between LC materials and their pretilt angles as well as the effect of the heat treatment on them. From these results we discuss the mechanism of change in LC pretilt by the heat treatment.

Keywords: liquid crystal, molecular alignment, pretilt angle, temperature dependence

1. INTRODUCTION

The alignment control of the liquid crystal (LC) molecules is very important in fabrication of Liquid Crystal Devices (LCDs). There are several methods to align a liquid crystal at a surface, among which the rubbing method is widely used because of its feasibility for mass production and for treatment of large ares. Using this method, the liquid crystal molecules on a surface are aligned at some polar angle away from the surface. This so called pretilt angle is a marked influence on the electro-optical properties of Liquid Crystal Displays (LCDs) and it is, therefore, an important parameter in design of LC devices. In the previous paper, we described a new method to determine three-dimensionally the inclination of the rubbed polymer in an alignment layer, by which the pretilt of liquid crystal is considered to be determined as we have shown in the previous paper.[1] The problem of change in the pretilt angle according to temperature has already been discussed by several researchers[2-5], however its reason has not yet been clarified. In this report, we show the change of polymer inclination angle and the pretilt angle of liquid crystal on polyimides with and without side chain by the heat treatment, and discuss the mechanism of the change in pretilt of liquid crystal.

2. INFLUENCE OF HEAT TREATMENT ON SUBSTRATE

2-1. Experimental method

We used a side-chain-type polyimide and main-chain-type polyimide, which is usually used for high pretilt and low pretilt alignment, respectively. We applied the polyimide on a glass plate substrates by spin coating, baked it and rubbed the surface with velvet. We express the rubbing density as rubbing strength parameter L.[6] In the experiment we mainly keep it to L=240cm because the inclination angle of polymer is saturated and the alignment stability is sufficiently good by this rubbing density.[1] We baked each substrate with polymer from 50°C to 200°C for 20 minutes after finishing the rubbing. The inclination angle of these polymers were measured by Senarmont method.[7-8] Then, liquid crystal is injected at room temperature to the cells and the pretilt angle of the liquid crystal was measured by an improved crystal rotation method.[9]

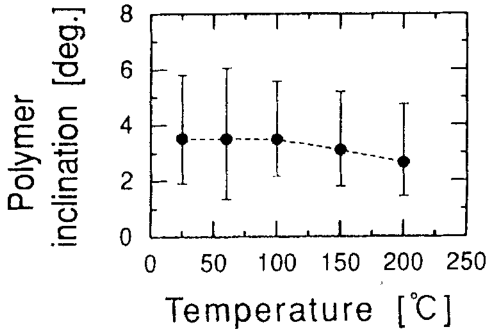


FIGURE 1 Inclination angle of a main-chain polymer with respect to the temperature on heat treatment.

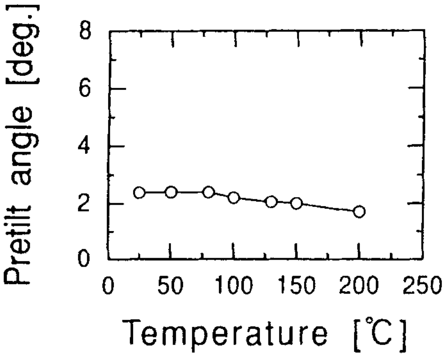


FIGURE 2 Pretilt angle of liquid crystal induced after heat-treatment of substrates with the main-chain polymer.

2-2. Experimental results and Discussion

The inclination angle of a main-chain polymer with respect to the temperature of heat treatment is shown in Fig.1. It is seen that the polymer inclination is not changed by the heat treatment. Next we injected a liquid crystal(ZLI-1844 from Merck Co., Ltd) into cells made by these substrates, and we measured their pretilt angle. The results are shown in Fig.2. Almost no change in pretilt angle was observed with respect to heat-treatment temperature. We have also examined the effect of heat-treatment by using various liquid crystals with different average dielectric constants, $(\varepsilon_1 + \varepsilon_2)/2$, where ε_1 and ε_2 are dielectric constants parallel and perpendicular to the major axis of molecule as shown in Fig.3. It is confirmed from this result that the pretilt angle of liquid crystal is almost independent of LC material. We also examined a side-chain polymer. The same results as in the case of the main-chain polymer are shown in Figs.4-6. We can see that the polymer inclination and the pretilt angle of a liquid crystal do not change with temperature of heat treatment.

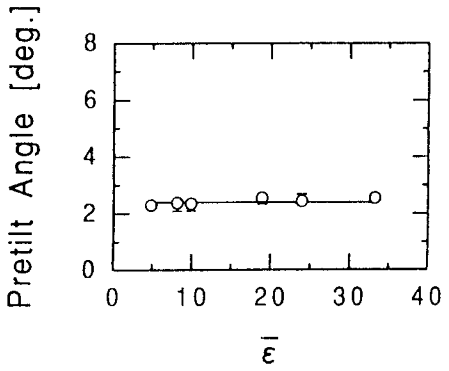


FIGURE 3 Pretilt angle of liquid crystals on the main-chain polymer as a function of dielectric constant of the liquid crystals.

3. INFLUENCE OF A HEAT TREATMENT AFTER INJECTION OF LIQUID CRYSTAL

3-1. Experimental method

In our experiment, we used two kinds of polyimide mentioned in the previous section. We spin-coated the polyimide onto a glass plate, baked it and rubbed with velvet (L=240cm). We made the sandwich cell with two substrate treated by antiparallel rubbing, injected liquid crystals into cells on room temperature. We used typical liquid crystals with small dielectric constant(ZLI-1132 from Merck Co.,Ltd.) and with large dielectric constant (ZLI-1844 from Merck Co.,Ltd). We measured the pretilt angles of these cells by increasing the temperature up to 120°C, and then decreasing it

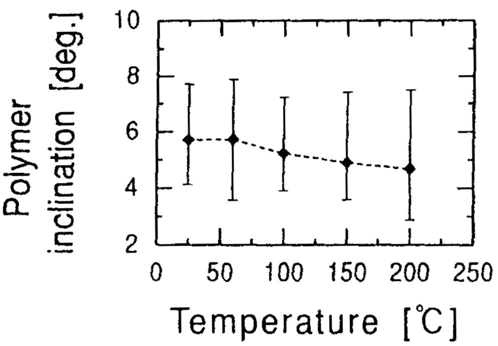


FIGURE 4 Inclination angle of a side-chain polymer with respect to the temperature of heat treatment.

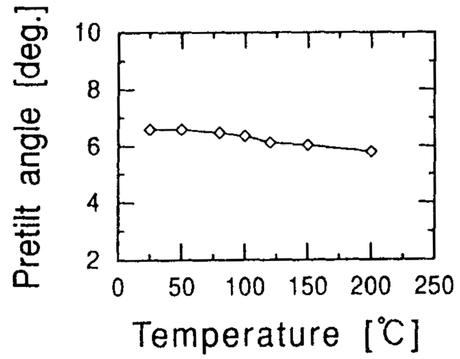


FIGURE 5 Pretilt angle of liquid crystal induced after heat-treatment of substrates with the side-chain polymer.

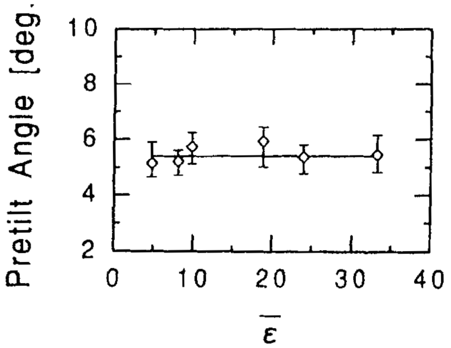


FIGURE 6 Pretilt angle of liquid crystals on the side-chain polymer as a function of dielectric constant of the liquid crystals.

to room temperature. We also measured the change of pretilt angle for various liquid crystals with different dielectric constants by heat-treatment (120°C, 20 minute).

3-2. Experimental results and Discussion

The temperature dependence of LC pretilt on the main-chain polymer is shown in Fig.7. The pretilt angles of the typical two liquid crystals increase with increasing of temperature, while they irreversibly decrease when the temperature is decreased to room temperature. This irreversible change is larger for the liquid crystal with larger dielectric constant.

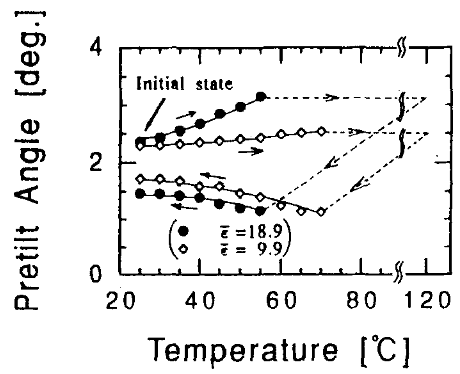


FIGURE 7 Pretilt angle of liquid crystals with respect to the temperature (alignment layer: main-chain type polyimide, rubbing strength parameter L=240cm).

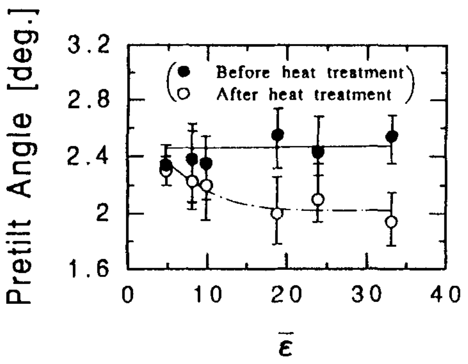


FIGURE 8 Pretilt angle of liquid crystals before and after the heat-treatment as a function of their dielectric constant (alignment layer: main chain type polyimide, baking temperature: 120°C)

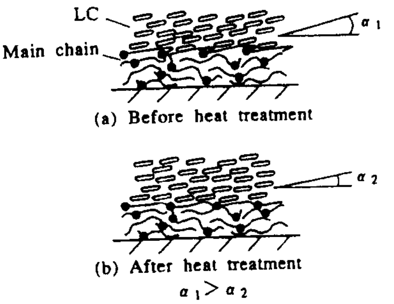


FIGURE 9 Schematic model of alignment before and after the heat treatment in the case of main-chain polymer.

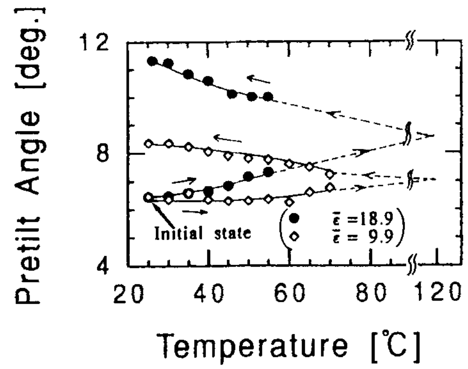


FIGURE 10 Pretilt angle of liquid crystals with respect to the temperature (alignment layer: side chain type polyimide, rubbing strength parameter L=240cm).

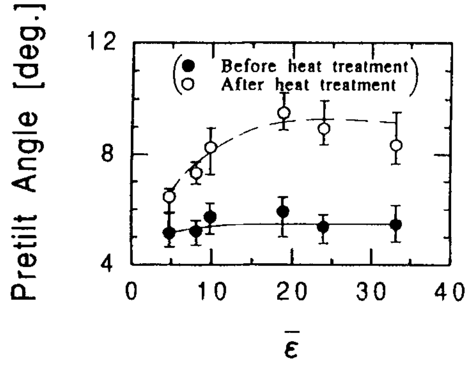
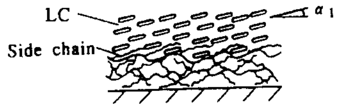
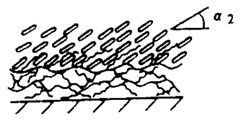


FIGURE 11 Pretilt angle of liquid crystals before and after the heat-treatment as a function of their dielectric constant (alignment layer: side chain type polyimide, baking temperature: 120°C)

Fig.8 shows the pretilt angle for various LCs with different dielectric constant before and after the heat-treatment of 120°C (above the clearing point of Liquid Crystals) for 20 minutes. We can see the pretilt angle before heat treatment has no dependence on LCs and is almost the same as the inclination angle of the polymer, but it decrease more largely with higher dielectric constant. From these results, we can consider the molecular morphology of polymer on the surface changes by solvent effect of LCs. Fig.9 shows a schematic model for the pretilt change by heat treatment, considering these facts. In the case of the side-chain polymer, the experimental results are shown in Fig.10. The pretilt angle of liquid crystal increase when the temperature increases up to 120°C and then decreases to room temperature. As the results, the pretilt angle increases irreversibly from the initial state. This magnitude varies for LCs with different dielectric constants. Then we measured pretilt angle before and after heat treatment by using various liquid crystals with different dielectric constants. This results are shown in Fig.11. We can see from this figure that the pretilt angle before heat treatment does not change with dielectric constant and almost coincides with polymer inclination. The pretilt angle after heat treatment increases with the dielectric constant of liquid crystal. We consider that this reason is caused by the solvent effect of liquid crystal, by which the flexibility of a side chain increases a little and therefore the polymer inclination increases. The stronger the polarity of liquid crystal is, the more significant the solvent effect becomes. A schematic model of pretilt angle before and after heat treatment are shown in Fig.12.



(a) Before heat treatment



(b) After heat treatment

$\alpha_1 < \alpha_2$

FIGURE 12 Schematic model of alignment before and after the heat treatment in the case of side-chain polymer.

4. CONCLUSION

A large change in LC-pretilt angle on rubbed polymer layer by heat treatment was observe. It is found that the initial state of pretilt angle does not depend on liquid crystal and its angle is almost the same as polymer inclination angle. However, the pretilt angle significantly changes the heat treatment of the LC-cell, and the change is larger for the liquid crystal with large dielectric constants. From these results, we consider the change caused by the change of polymer morphology on the surface due to solvent effect of LC, and liquid crystals with large dielectric constant or large polarity give relatively strong solvent effect because of the large interaction between polymer and liquid crystal.

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