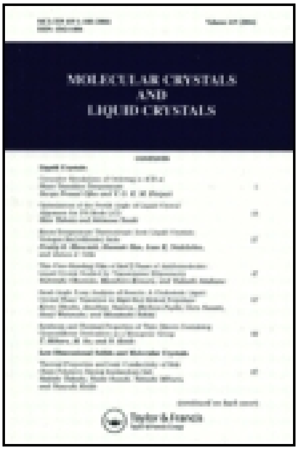

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Generation of High Pretilt Angle of Alignment Transcription Liquid Crystal Display

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Generation of High Pretilt Angle of Alignment Transcription Liquid Crystal Display

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We proposed an alignment transcription liquid crystal display (AT-LCD) which can make multi-domain structure easily without rubbing and photolithography process. However, the AT-LCD had a problem that the pretilt angle of the LCD was rather low (< 0.6°). In this paper, we try to generate high pretilt angle of the AT-LCD by choosing the polyimide materials of the transcribed substrate. Finally, we can obtain high pretilt angle (> 1.2°) by using polyimide film having small surface energy.

Keywords: alignment transcription LCD; surface energy; pretilt angle

INTRODUCTION

One of the most effective way for producing a wide viewing angle LCD is the multi-domain method[1]. However, in order to realize the multi-domain alignment LCD, several times of photolithography process were needed. We proposed a novel fabrication method of an LCD called alignment transcription (AT) method[2] which can realize the multi-domain alignment LCD free from rubbing and photolithography. The torsional anchoring strength of AT-LCD is fairly strong in spite of non-rubbing. In the AT method, LC alignment is determined by the aligned original substrate, and the original substrate can be used repeatedly for fabricating AT-LCDs. Therefore, multi-domain AT-LCDs can be cloned easily once original substrate has been made. This leads to cost reduction for obtaining multi-domain LCDs.

EXPERIMENT

Fabrication Process of AT-LCD

The transcribed substrate was coated with non-rubbed polyimide film and the original substrate was coated with rubbed polyimide film. The original substrate was piled upon the transcribed substrate with an appropriate space (about 5μm) to make the transcription cell. The cell was heated at the temperature where the LC shows the isotropic phase for LC injection. The nematic liquid crystal (NLC) used in our experiment was a fluorinated type mixture.

This cell was cooled down to the room temperature, and the LC changed into the nematic phase from the isotropic phase. All LC molecules were almost aligned along the rubbing direction of the original substrate. The LC alignment is transcribed and memorized to the non-rubbed polyimide film on the transcribed substrate. This process is called transcription process.

The transcribed substrate was separated from the original substrate, and the almost all the LC molecules were removed except for those locating at the surface.

Finally, the transcribed substrate was piled upon another transcribed substrate to form the AT-LCD. Nematic phase LC materials were injected into the AT-LCD. The same type of NLC used in the transcription process was utilized for preparing AT-LCDs. The AT-LCD having 50μm cell gap and anti-parallel alignment was used for measurement of the pretilt angle.

Polyimide Film

Four types of polyimide films PI-1 to 4 (Nissan Chem. Ind.) were used for transcribed substrates in the present experiment as listed in Table I. The PI-1 was also used for original substrates (pretilt angle of rubbed PI-1 is 4.9°). PI-2 to 4 have similar type of main chain, but have little different types of side chain. PI-2 has two types of side chain. The density of the side chain of PI-4 is higher than that of PI-3.

TABLE I Properties of polyimide films and pretilt angle of AT-LCDs.

Polyimide Films	Main Chain Type	Side Chain Type	Annealing Temperature [°C]	Surface Energy [dyne/cm]	Pretilt Angle of AT-LCD [°]
PI-1	Type-A	Type-1	180	40.8	0.4-0.6
PI-2	Type-B	Type-1,2	180	37.2	1.5-2.3
			250	35.1	3.2-4.0
			300	32.7	------
PI-3	Type-B	Type-2	180	39.2	1.2-1.4
			250	39.2	1.1-1.3
			300	36.3	4.3-4.9
PI-4	Type-B	Type-2	180	44.0	0.3-0.5
			250	46.6	0.2-0.3
			300	46.2	0.2

Characteristics of Polyimide Film and AT-LCD

Surface energy was calculated from contact angle method. Pretilt angle was measured by crystal rotation method.

RESULTS AND DISCUSSION

Surface Energy of Polyimide Film

Table I shows the surface energy of the polyimide films, and Fig. 1 shows the annealing temperature dependence of the surface energy of the polyimide films. As shown in Fig. 1, the surface energy can be controlled by the annealing temperature. PI-2 and 3 have small surface energy, and as the annealing temperature of PI-2 and 3 is higher, the surface energy is smaller. On the other hand, PI-4 has larger surface energy than PI-2 and 3, and as the annealing temperature of PI-4 is higher, the surface energy is larger.

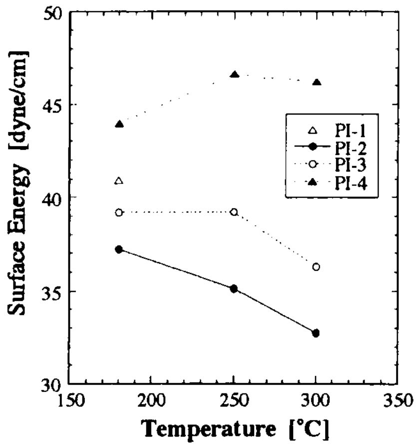

Fig. 1 Annealing temperature dependenc of surface energy of polyimide films.

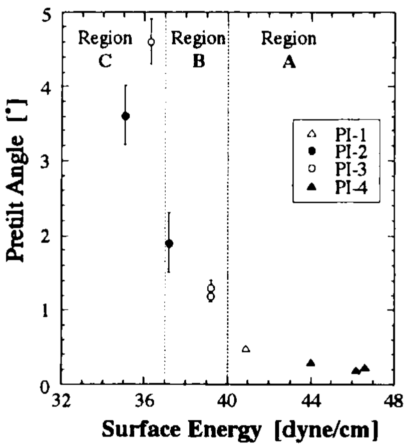

Fig. 2 Surface energy dependence of pretilt angle of AT-LCDs.

Pretilt Angle of AT-LCD

Table I shows the pretilt angle of the AT-LCDs with each types of polyimide film. The pretilt angle of AT-LCD with PI-2 annealed at 300°C could not be measured, because of this LCD shows vertically random LC alignment instead of uniform alignment. Furthermore, PI-2 annealed at 250°C and PI-3 annealed at 300°C also showed vertically random alignment partially, but these LCDs also had uniformly aligned part in the LCD. Then the pretilt angle at a uniformly aligned part of these LCDs could be measured. From Table I, the vertically random alignment appears when the surface energy is small. This tendency agrees with general LC alignment.

Fig. 2 shows relationship between the surface energy and the pretilt angle of AT-LCDs. The pretilt angle of AT-LCD is closely related to the surface energy, namely, as the surface energy is smaller, the pretilt angle is higher.

Fig. 2 is divided into three regions (A, B and C) by the surface energy of polyimide films (A > 40dyne/cm > B > 37dyne/cm > C).

The AT-LCDs located in the region A (PI-1 and PI-4) show very low pretilt angle (< 1°) and uniform LC alignment. PI-4 has similar structure with PI-3 except that the density of side chain is high. However, the pretilt angle of AT-LCD using PI-4 does not coincide with that of PI-3. This phenomenon indicates that the pretilt angle of the AT-LCD depends on the surface energy of polyimide film rather than the structure of polyimide. The pretilt angle of rubbed LCD using PI-1 is the highest (about 4.9°) among the polyimide films used in this experiment, but the pretilt angle of AT-LCD using PI-1 is not so high (about 0.5°). From this result, mechanism of generating the pretilt angle of AT-LCD is considered to be different from that of rubbed LCD.

The AT-LCDs located in the region B show relatively high pretilt angle (> 1.2°) and uniform LC alignment. PI-2 and 3 annealed at low temperature are assigned to region B. Surface energy and pretilt angle of AT-LCDs using PI-3 annealed at 180°C and 250°C are approximately same. The pretilt angle of AT-LCD using PI-2 annealed at 180°C is high (about 1.9°), but the uniformity of pretilt angle is poor. The reverse tilt disclination lines of the AT-LCDs located in the region B appear after the voltage is applied to the LCDs in an instant, but the lines disappear within 1sec.

The AT-LCDs located in the region C show rather high pretilt angle (>3°), and no reverse tilt disclination lines can be seen in the uniform alignment area of the AT-LCDs. On the other hand, vertically random alignment appears partly or entirely in these AT-LCDs. Therefore, it is difficult to apply the AT-LCDs located in the region C for practical use.

The surface energy of PI-2 and 3 can be controlled within region B or C by adjusting their annealing temperature. We expect that both high pretilt angle (> 2°) and perfectly uniform alignment of AT-LCD can be obtained simultaneously by controlling the annealing temperature of the PI-2 and 3.

CONCLUSIONS

We tried to generate high pretilt angle of AT-LCDs. We found that the pretilt angle of the AT-LCD depends on the surface energy of polyimide films. As the surface energy is smaller, the pretilt angle is higher. But when the surface energy is too small, vertically random alignment appears in the AT-LCD instead of uniform alignment. As a conclusion, we can obtain relatively high pretilt angle (1.2-1.9°) and uniform alignment of the AT-LCD by controlling the surface energy of polyimide film ranging from 37 to 40 [dyne/cm].

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