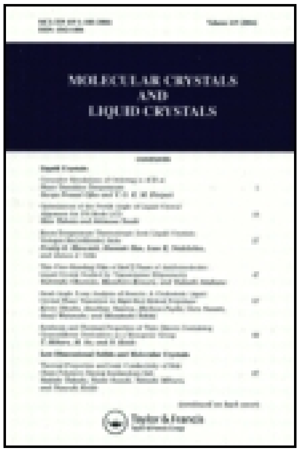

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Yasuo Toko [a] , Bai-Ying Zhang [a] , Takashi Sugiyama [a] , Kazuhisa Katoh [a] & Tadashi Akahane [a b]

[a] R&D Laboratory, Stanley Electric Co., Ltd., 1-3-1 Eda-Nishi, Aoba-Ku, Yokohama, 225, Japan

[b] Department of Electrical Engineering, Faculty of Engineering, Nagaoka University of Technology, 1603 Kamitomioka, Nagaoka, Niigata, 940-21, Japan

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CHARACTERISTICS OF LIQUID CRYSTAL DISPLAY FABRICATED BY ALIGNMENT TRANSCRIPTION METHOD

YASUO TOKO, BAI-YING ZHANG, TAKASHI SUGIYAMA, KAZUHISA KATOH and TADASHI AKAHANE†
R&D Laboratory, Stanley Electric Co., Ltd., 1-3-1 Eda-Nishi, Aoba-Ku, Yokohama 225, Japan
†Department of Electrical Engineering, Faculty of Engineering, Nagaoka University of Technology, 1603 Kamitomioka, Nagaoka, Niigata 940-21, Japan

Abstract We have developed a novel fabrication method of an LCD without rubbing treatment on the substrate surfaces of the cell. In this method, LC alignment is transcribed from an original rubbed substrate to a counter substrate that is coated with non-rubbed polymer, and is fixed on the surface by memory effect of the interface between LC molecules and the polymer surface. This transcribed and memorized alignment on the non-rubbed polymer is rather stable. Therefore, it is possible to fabricate the LCD by putting the transcribed polymer substrate separated from the original substrate upon another substrate. It is found that the LCDs having various alignment such as multi-domain structure can be made easily without generating dust and static electricity caused by the rubbing.

INTRODUCTION

We proposed and investigated the new technologies that are rubbing one side technique[1] and non-rubbing technique[2] for fabricating the TN-LCD. In these techniques, it is important that the LCDs are fabricated by injecting LC materials into the cell in the isotropic phase. Because at least one side substrate surface of these LCDs is not given any alignment treatment, the flow alignment, which depends on injected direction, can be observed when filling the LCs in the nematic phase into the cell. The flow alignment does not disappear by annealing the cell at the temperature of thirty degrees higher than the Tni. This phenomenon indicates the LC molecules touching the non-aligned polymer surface are immobilized and adhere firmly. This is called the memory effect.

This paper reports a novel fabrication method of LCDs that utilizes this interfacial memory effect of LC molecules on the non-treated polymer surface film for obtaining various LC alignment such as multi-domain structure[3]. We call this method Alignment Transcription (AT) method. The AT method has the following features:

1) It is not necessary for any treatment such as rubbing directly on the surfaces of the practical substrate. In general, the rubbing process can not avoid the generation of dust and electrostatic charge. The inner surfaces of the AT-LCD are not affected by them.

2) In the AT method, LC alignment is determined by the aligned original substrate. The original substrate can be used repeatedly for fabricating the AT-LCD. Therefore, multi-domain AT-LCDs are reproduced easily with the same uniform alignment once original substrate has been made. This leads to cost reduction for obtaining multi-domain LCDs, which show wide viewing angle characteristics.
3) The AT method has a feature of aligning LC molecule to a same direction on the non-rubbed polymer. This method is suitable for studying the mechanism of LC alignment on the non-rubbed polymer surface.

EXPERIMENT

The fabrication processes of the AT-LCD are shown in Figure 1. The transcribed substrates were coated with non-rubbed polyimide films. Four types of polyimide films (Nissan Chem. Ind.) were used for the experiment. Properties of the polyimide films are shown in Table I. We designated these alkyl branched polyimide films PI-1 through PI-4. The original substrate was coated with the PI-4 film. Mechanical rubbing was applied on the surface. [Figure 1(a)(a')]

The original substrate was piled upon the transcribed substrate with an appropriate gap to make the transcription cell, and heated at the temperature where the LC shows the isotropic phase for LC injection. The nematic liquid crystal (NLC) used in our experiment is fluorinated type mixture. [Figure 1(b)(b')]

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. This process is called transcription process, and the holding time of this process is called transcription time. These are very important factors for AT-LCD. [Figure 1(c)]

The original substrate was separated from the transcribed substrate, and the almost all the LC molecules were removed except LC molecules locating at the surface vicinity on the transcribed substrate. [Figure 1(d)(d')]

Finally, the transcribed substrate was piled upon another transcribed substrate to form the AT-LC cell, and nematic phase of the LC materials were injected into the AT-LC cell. Same type of the NLC that was used in the transcription process was used for preparing AT-LCD, and chiral dopant (S-811, Merck) was doped in NLC when fabricating AT-TN-LCD for EO performance measurement. [Figure 1(e)(e')]

TABLE I Properties of polyimide films used for the experiment.

Polyimide Films	Main Chain Type	Alkyl Branch Position	Surface Energy [dyne/cm]	Rubbed Pretilt Angle [°]
PI-1	Type-A	Type-1	45.2	5-6
PI-2	Type-B	Type-2	43.5	6
PI-3	Type-C	Type-1	42.1	6-7
PI-4	Type-C	Type-1	40.8	7-8

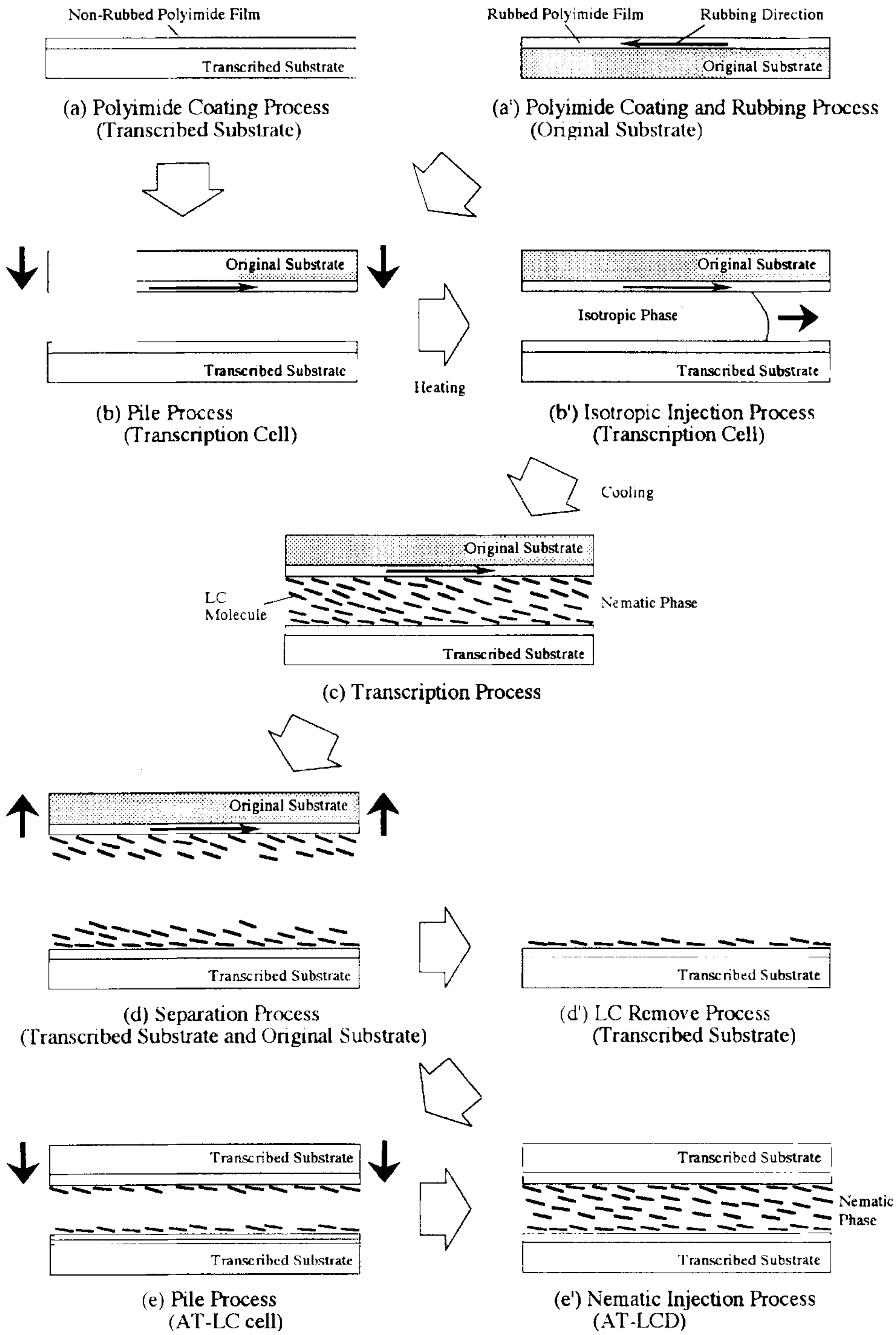

FIGURE 1 AT-LCD Fabrication Processes

Texture was observed by a polarizing microscope. A surface torsional anchoring strength was measured by a new measuring method[4] proposed by our group. Pretilt angle was measured by crystal rotation method. Characteristics of the optical transmission versus applied voltages of the AT-TN-LCD were measured.

RESULTS AND DISCUSSION

A. TEXTURES OF THE ALIGNMENT OF TRANSCRIPTION CELL

Figures 2 (a) and (b) show the textures of the alignment of transcription cell where the cell gap is a parameter. The original and transcribed substrates were coated with rubbed and non-rubbed PI-4 film, respectively. The transcription cell was filled with LC materials without doping chiral agent. The textures were observed under crossed polarizers wherein the polarizer axis was parallel or perpendicular to the alignment direction of the original substrate. Perfectly the same texture having fine irregular parts can be obtained regardless of cell gap as shown in Figure 2. This implies that these fine irregular parts are not due to the disorder of the LC molecular conformation but due to the surface condition of the non-rubbed polymer on the transcribed substrate. These fine irregular parts are not discriminated by the naked eyes. So in this process, precision of the cell gap of the transcription cell is not so important.

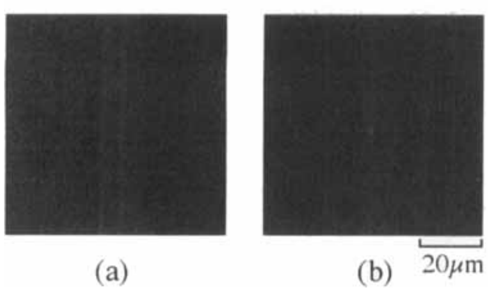

FIGURE 2 Microscopic textures of transcription cells, whose cell gap were controlled to be (a) 5μm, (b) 50μm, respectively.

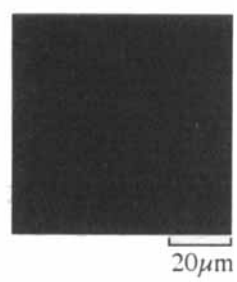

FIGURE 3 Typical Microscopic texture of AT-TN-LCD.

B. TEXTURE OF THE AT-TN-LCD

Figure 3 shows the typical microscopic texture of AT-TN-LCD in between parallel polarizers. This AT-TN-LCD is fabricated by putting two transcribed substrates at right angle to each other and injected LC molecules without chiral agent in nematic phase. The surfaces of the transcribed substrates are coated with non-rubbed PI-4 shown in Figure 3. There exists no difference in the textures of the AT-TN-LCDs fabricated by various polyimide materials on the transcribed substrates. The texture shown in Figure 3 accompanies with fine irregular parts which are the same ones shown in Figure 2.

As shown in Figure 3, surprisingly, the flow alignment is not observed though this LCD was prepared by injecting LC into the cell in the nematic phase. In addition, we observed nearly 90 degrees twist angle of LC conformation without chiral agent doping. These results indicate the surface torsional anchoring strength of AT-LCD is fairly strong.

C. TORSIONAL ANCHORING STRENGTH OF THE AT-LCD

We used four polyimide films listed in Table I for the measurement of the surface torsional anchoring strength of AT-LCDs. Figure 4 shows each surface torsional anchoring strength of AT-LCDs as function of transcription time. It shows that the torsional anchoring strength increases with increasing the transcription time. It means that the memory effect of the non-rubbed polymer film on the transcribed substrate becomes strong when the transcription time is long. In the PI-3 and PI-4, the transcription time dependence of the torsional anchoring strength is larger than that of the other polyimide films, because these films, which have low surface energy as shown in Table I, have properties of repelling LC molecules. This phenomenon indicates that the torsional anchoring strength of AT-LCDs can be easily controlled by transcription time.

In the PI-1 and PI-2, the torsional anchoring strength is strong even in a short transcription time. In other words, these polyimide films have a superior property which makes fabrication time of the AT-LCD shorten.

The torsional anchoring strength of AT-LCDs is fairly strong in spite of non-rubbing, and is comparable to that of rubbed LCD.

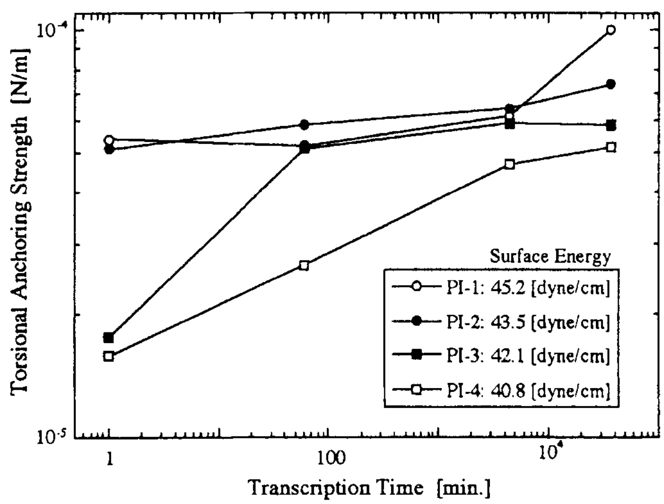

FIGURE 4 Transcription time dependence of the torsional anchoring strength of the AT-LCDs using four kinds of polyimide films.

D. PRETILT ANGLE OF AT-LCD

Table II shows the pretilt angles of the four types of AT-LCD. The PI-4 coated cell shows the highest pretilt angle, but the value is only 0.4°-0.6°. This is not high enough for practical TN-LCDs and multi-domain TN-LCDs, because the reverse tilt disclination lines appear in short time (only a few seconds) after the voltage is applied to the cell. The length of the alkyl branch of polyimide films is adjusted as follows: PI-4>PI-2=PI-3>PI-1, and the density of the alkyl branch is as follows: PI-1>PI-4>PI-3, while the density of PI-2 can not be compared to other polyimide films due to the difference of position where the alkyl branch attaches. The order of pretilt angles corresponds with the order of the length of the alkyl branch, but does not coincide with that of the density.

TABLE II Pretilt angle of the AT-LCD.

Polyimide Films	Pretilt Angle of AT-LCD [°]
PI-1	0.1-0.2
PI-2	0.2-0.4
PI-3	0.2-0.3
PI-4	0.4-0.6

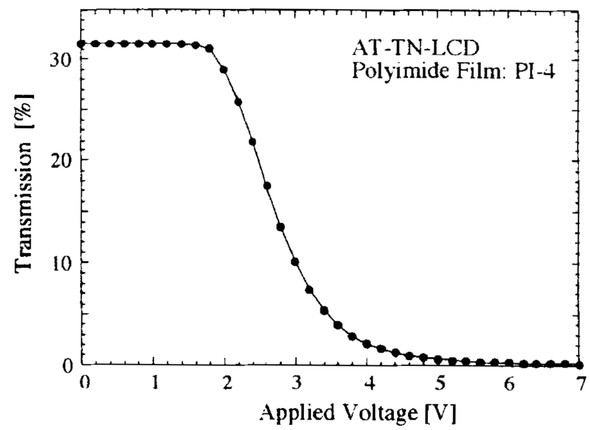

FIGURE 5 Typical EO performance of AT-TN-LCD.

E. EO PERFORMANCE OF AT-TN-LCD

EO performance of the normally white mode of the AT-TN-LCD using the PI-4 film is shown in Figure 5. Enough EO characteristics for active matrix LCDs can be obtained. The AT-TN-LCD has a obvious threshold characteristics compared to conventional rubbed TN-LCDs. This suggests the polar anchoring strength of the AT-TN-LCD is strong enough.

CONCLUSIONS

We developed and investigated a novel LCD, called alignment transcription (AT) LCD. In the AT-LCD, LC alignment is transcribed from the original substrate to the counter substrate. The transcribed substrate does not suffer any damage in this alignment process in contrast to the conventional rubbing technique.

The torsional anchoring strength of the AT-LCD is fairly comparable to rubbed LCD. The pretilt angle can be also transcribed by this method. EO performance of the AT-TN-LCD is almost the same as that of the conventional rubbed TN-LCD.

As the pretilt angle generated in this method has not been enough for obtaining perfectly defect free TN-LCDs yet, we are now trying to generate high pretilt angle by using this method. The results will be published in near future.

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