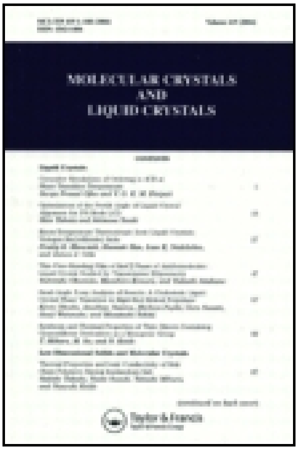

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HYBRID SURFACE-STABILIZED FERROELECTRIC LIQUID CRYSTALS HAVING AN INTERVENING INTERFACIAL LAYER WITH A GRADED TRANSITION TEMPERATURE

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A hybrid surface-stabilized ferroelectric liquid crystal (SSFLC) having an intervening interfacial layer with a graded transition temperature is determined to be successful for preventing the structural transformation from C1 to C2 chevrons during the cooling process. As a result, a zigzag defect-free SSFLC medium with C1 structure can be obtained. A hybrid SSFLC fabricated by deliberately lowering the SmA-SmC phase transition temperature (TAC) in the surface region takes C1-uniform structure, and on the other hand, a hybrid SSFLC having a surface layer with TAC higher than the bulk region prefers twisted orientation to uniform. The C1-twist structure of the layer hybrid SSFLC is caused by the suppression of C1-C2 structural transformation in the surface region due to the bulk region with lower TAC and the easy formation of electrical coupling between the FLC dipole and the substance surface because the bulk region still takes the SmA phase just after the SmA-SmC* transition of the surface region.*

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Keywords: chevron structure; ferroelectric liquid crystal; graded transition; SmA, SmC*

INTRODUCTION

Surface-stabilized ferroelectric liquid displays (SSFLCDs) form the basis of a rapidly developing technology of significant potential impact in display applications, in particular, such as video image displays by taking advantage of their fast response speed [1]. However, it is hard to fabricate a defect-free SSFLCD owing to the appearance of so-called zigzag defect that degrades bistable memory capability and contrast ratio of the display [2,3]. This defect formation can, to some extent, be controlled or eliminated by the application of a low frequency AC electric field [4,5], or by the use of naphthalene-based FLC materials [6,7], high-pretilt alignment films [8,9], low-pretilt alignment films with very smooth surface [10,11], or weak surface anchoring alignment films such as a photo-alignment films [12,13]. However, these methods are neither university effective nor available, and hence, there still remains a great need for a technique to eliminate zigzag defects and improve the electrooptical characteristics in particular contrast ratio of a SSFLCD.

In previous papers, we reported our preliminary research on fabrication of zigzag defect-free SSFLC using an intervening interfacial layer with a graded SmA-SmC* phase transition temperature (T_{AC}) [14,15]. In the hybrid SSFLC, the chevron structure transformation from C1 to C2 can be suppressed during the cooling process by deliberately lowering T_{AC} and decreasing the cone angle towards the substrate surface. As a result, a zigzag defect-free SFFLC medium with C1 chevron structure can be obtained. In this paper, we report a new type of hybrid SSFLC having a surface layer with T_{AC} higher than the host FLC which occupies the bulk region.

EXPERIMENTAL

In order to fabricate the hybrid SSFLC cell, we adopted a combination of two FLC materials which have different T_{AC}: the phase sequence of FLC materials used in this research is shown in Table 1 which includes the C1-C2 transformation temperature of SSFLCs. A weak acetone solution of a FLC material with higher T_{AC}, FELIX-M4851/100, (0.1 wt%) was spun on glass substrates coated with rubbed polyimide film. The polyimide material used was SE-150 (Nissan Chem. Ind.) [10]. The thickness of the LC surface film was measured using photocured mesogenic monoacrylates with an atomic force microscope, and was about 8 nm. Then, the host FLC with lower T_{AC}, FELIX-M4654/100 or CS-1017, was injected during

TABLE 1 Phase Transition Temperature of FLC Materials Used: FELIX (Clariant) and CS (Chisso Petrochem.)

	Phase sequence (°C)				
Liquid crystal	Iso.	N*	SmA	SmC* (C1-C2)	Cryst.
FELIX-M4851/100	76	71	66.8	(66.2)	< −20
FELIX-M4654/100	74	65	58.7	(58.0)	< −10
CS-1017	70	64	55.0	(54.0)	−20

the isotropic phase by capillary action into an empty 2 μm-thick cell, in which the rubbing directions were set parallel. The SSFLC cells thus fabricated were characterized by the observation of microscopic textures.

RESULTS AND DISCUSSION

Figure 1 shows the microscopic photographs of SSFLC cells at the Iso-N* phase transition temperature of host FLC. In a conventional SSFLC cell, a rubbing pattern can be observed. However, in a hybrid SSFLC cell, the rubbing pattern is hardly observed and thus it is obvious that the surface regions which have a different clearing point from the bulk FLC exist even though the surface regions cannot be observed with a conventional microscope due to its very thin layer. Therefore, the surface FLC material does not widely diffuse and completely dissolve into the bulk.

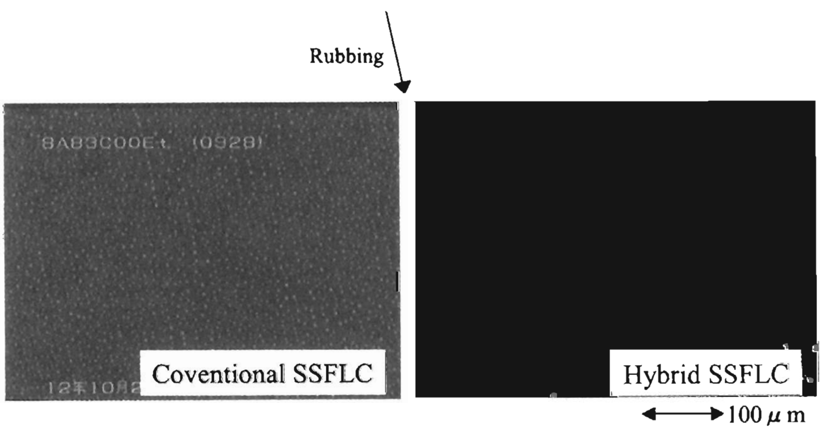

FIGURE 1 Microscopic textures of SSFLC cells at Iso.-N* transition temperature (hybrid SSFLC = CS1017/M4851).

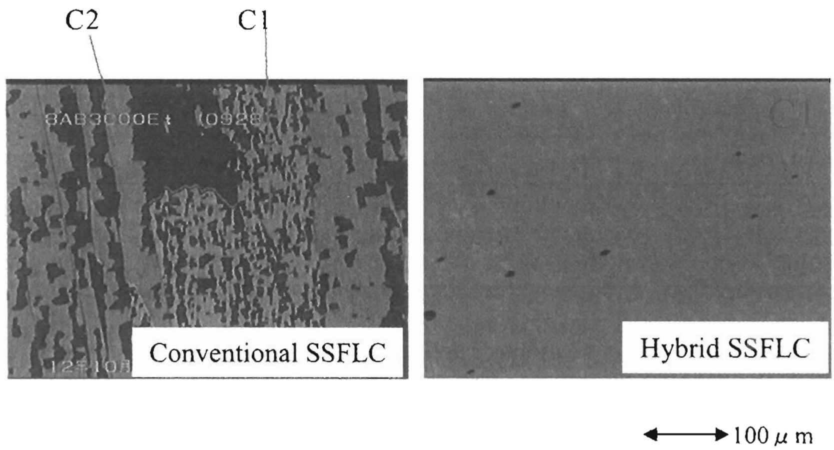

FIGURE 2 Microscopic textures of SSFLC cells at room temperature (hybrid SSFLC = M4654/M4851).

Figure 2 shows the microscopic textures of the conventional and the hybrid SSFLCs fabricated using FELIX-M4654/100 as a host FLC and FELIX-M4851/100 as a LC surface film, that were cooled gradually to room temperature. In the conventional SSFLC, zigzag defects appeared as a result of the C1-C2 structural transformation. On the other hand, the hybrid SSFLC showed the C1-chevron structure without zigzag defects and was identified as a C1-twist state which revealed a bluish color in a dark state. For CS-1017, almost the same results were obtained.

The twist alignment of the hybrid SSFLC may occur easily due to the electrical coupling between SmC* dipole and substrate surface, because the bulk FLC still remains in the SmA phase after the SmA to SmC* phase transition of the surface FLC during the cooling process, as shown in Figure 3. On the other hand, in the case of hybrid SSFLC with lower T_{AC} surface [14,15], a uniform alignment of the bulk FLC forms earlier than the SmA to SmC* phase transition of the surface FLC during the cooling process, and then the SSFLC having uniform orientation can be obtained.

It is thought that the C1 chevron structure of the hybrid SSFLC with higher T_{AC} surface is obtained owing to no occurance of the C1-C2 structural transformation of the surface FLC after the SmA to SmC* phase transition of it during the cooling process, as shown in Figure 4, because any texture change which originated in the transformation of it hasn't been observed. It is guessed that there are two possibilities of the reason why the C1-C2 transformation of the surface FLC does not occur. One is *a*) what the bent SmA layer of bulk FLC which is caused by pretilt fixes the

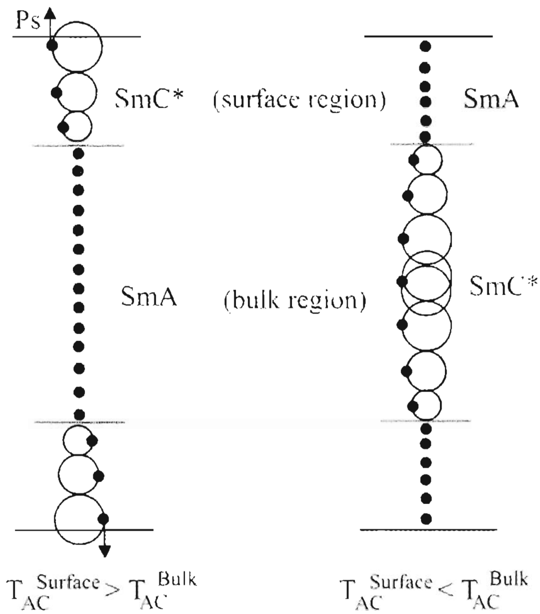

FIGURE 3 Schematic models of twist and uniform structure formation in hybrid SSFLCs.

direction of inclination of the SmC* layer in the surface region (see Fig. 5), and another one is *b*) what the interfacial layer similar to a hybrid SSFLC having lower T_{AC} surface prevents its transformation (see Fig. 6). In order to confirm the reliability of the latter, we fabricated a hybrid SSFLC cell

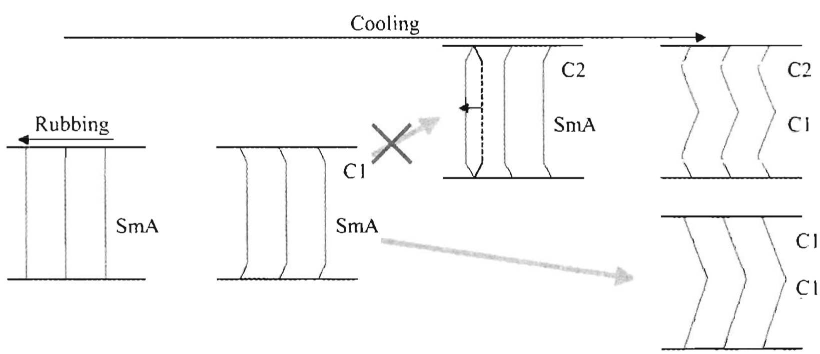

FIGURE 4 Schematic model of C1 structure formation in the hybrid SSFLC.

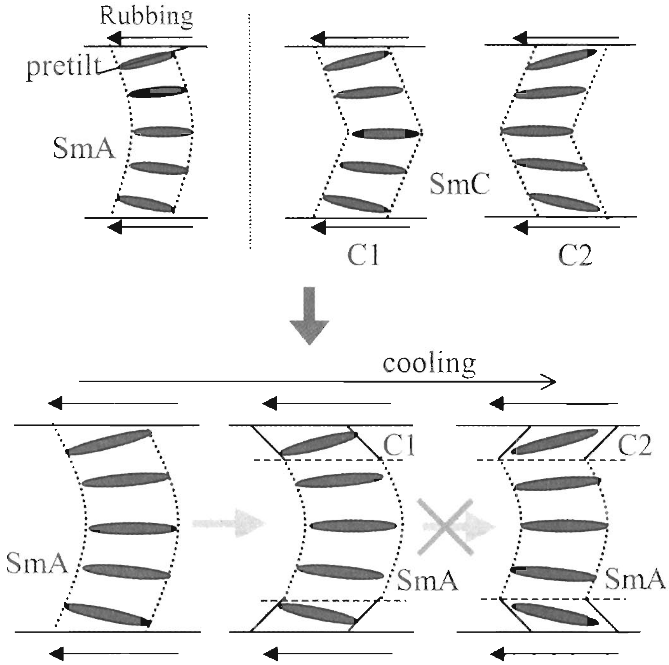

FIGURE 5 Schematic model of bent layer structure.

having a lower T_{AC} surface only on the one-sided substrate, in which the host FLC touched directly another-sided substrate. Figure 7 shows the microscopic texture of the hybrid SSFLC thus fabricated by the use of FELIX-M4654/100 as a host FLC and FELIX-020 [14,15] as a LC surface film. It is found that zigzag defect-free C1 structure can be obtained even in the hybrid SSFLC in which the only one-sided substrate surface is treated. Therefore, the latter possibility still remains. In order to clarify which of the two possibilities effectively works, we fabricated the same hybrid SSFLC cell having lower T_{AC} surface on the one-sided substrate except for setting the rubbing directions anti-parallel. It is usually known that in a conventional SSFLC cell with anti-parallel rubbed films treated equally, two chevron structures are essentially equal except for the direction of chevron layer inclination and then always coexist (see Fig. 8). If the SmA layer is able to fix the SmC* layer, the hybrid SSFLC with anti-parallel rubbed films would take the only one chevron structure, while if not, two chevron structures might coexist, as shown in Figure 9. Figure 10 shows microscopic textures of SSFLCs with anti-parallel rubbed films. It is found that zigzag defects appear and thus two chevron structures coexist even in the hybrid SSFLC. Therefore, the suppression of the C1-C2 structural transformation

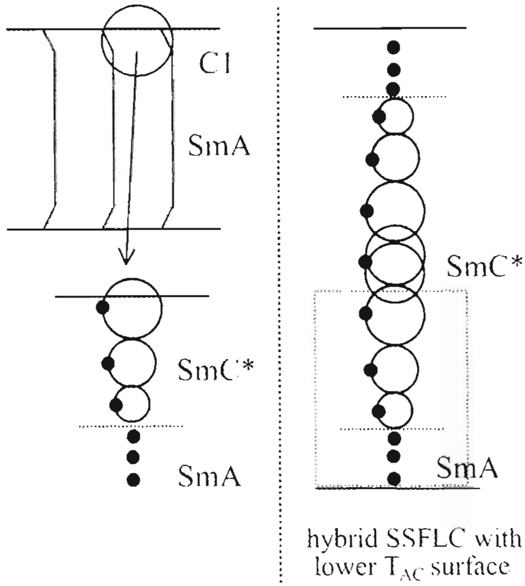

FIGURE 6 Schematic alignment structure of interfacial layer of hybrid SSFLC.

in the SmC* surface of the hybrid SSFLC with higher T_{AC} surface is due to the interfacial layer in which T_{AC} lowers and the cone angle decreases towards the bulk region.

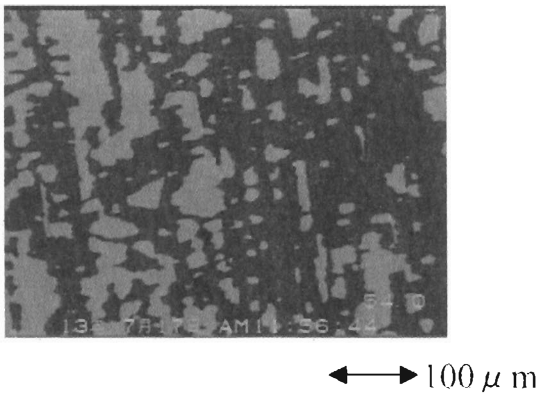

FIGURE 7 Microscopic texture of SSFLC with a lower T_{AC} surface layer on one-sided substrate.

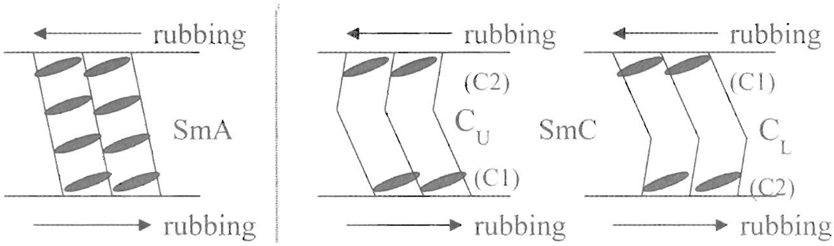

FIGURE 8 Schematic alignment structure of anti-parallel rubbing cell.

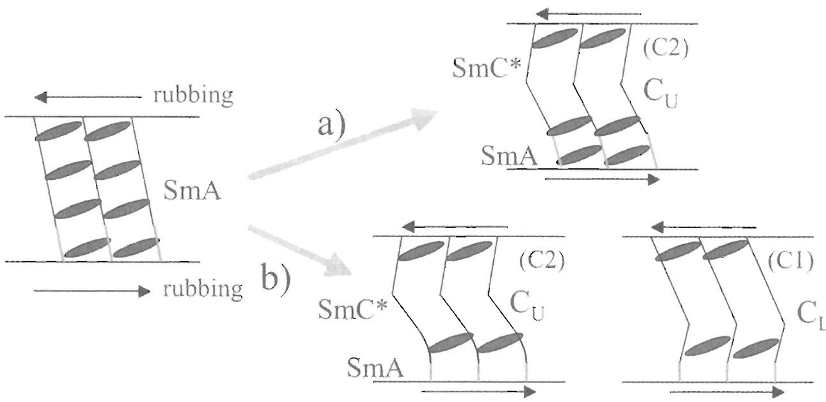

FIGURE 9 Alignment structure models in hybrid anti-parallel rubbing cell with one-sided lower T_{AC} surface.

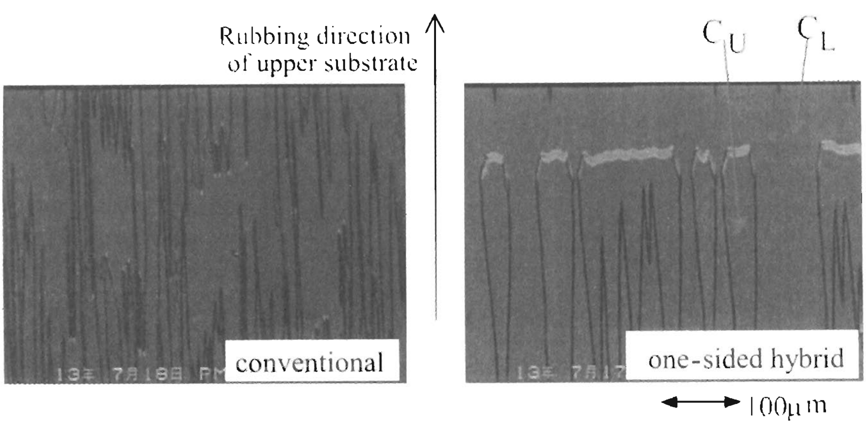

FIGURE 10 Microscopic textures of anti-parallel rubbing SSFLC cells.

CONCLUSIONS

A hybrid SSFLC having an intervening interfacial layer with a graded transition temperature is successful in preventing the C1-C2 transformation during the cooling process, and then a zigzag defect-free SSFLC medium with C1 structure can be obtained. A hybrid SSFLC fabricated by deliberately lowering T_{AC} in the surface region takes C1-uniform structure, while a hybrid SSFLC with higher T_{AC} surface takes C1-twist structure. The C1-twist of the latter hybrid SSFLC is caused by the suppression of C1-C2 structural transformation in the surface region due to the interfacial layer, in which T_{AC} lowers and the cone angle decreases towards the bulk region, and by the easy formation of electrical coupling between the FLC dipole and the substrate surface.

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