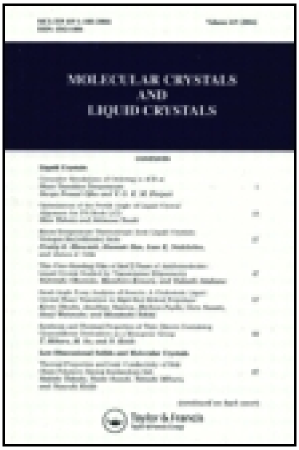

Molecular Crystals and Liquid Crystals Science and Technology. Section A. Molecular Crystals and Liquid Crystals

Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/gmcl19

# Generation of Pretilt Angles in Nematic Liquid Crystal, 5CB, Media Aligned on Polyimide Films Prepared by Spin-Coating and LB Techniques: Effect of Rubbing

Dae-Shik Seo [a], Koh-Ichi Muroi [a] & Shunsuke Kobayashi [a]

[a] Division of Electronic and Information Engineering, Graduate School of Technology, Tokyo University of Agriculture and Technology, 2-24-16 Nakamachi, Koganei-shi, Tokyo, 184, Japan

Version of record first published: 24 Sep 2006.

*Mol. Cryst. Liq. Cryst.*, 1992, Vol. 213, pp. 223–228
Reprints available directly from the publisher
Photocopying permitted by license only

Printed in the United States of America



# Generation of Pretilt Angles in Nematic Liquid Crystal, 5CB, Media Aligned on Polyimide Films Prepared by Spin-Coating and LB Techniques: Effect of Rubbing

DAE-SHIK SEO, KOH-ICHI MUROI and SHUNSUKE KOBAYASHI

*Division of Electronic and Information Engineering, Graduate School of Technology, Tokyo University of Agriculture and Technology, 2-24-16 Nakamachi, Koganei-shi, Tokyo 184, Japan*

*(Received August 27, 1991; in final form October 10, 1991)*

The pretilt angles generated in nematic liquid crystal (5CB) media that are disposed in sandwich type cells and oriented by using various orientation films are shown to depend both on the nature of the orientation films and the rubbing strengths in the following way: first, in a cell with alkyl branched polyimide (PI (1)) prepared by spin-coating, the obtained pretilt angle $\theta_p$ shows a giant peak reaching 51 degrees at the low rubbing strength (RS) region and then it decreases monotonically with the increase of the RS; second, with another alkyl branched PI (PI (2)), the obtained value of $\theta_p$ is around 4 degrees for a wide range of the RS; third, with branchless spin-coated PI (PI (3)) that is featured by its high electrical polarization, the $\theta_p$ increases monotonically with the RS from zero level and tends to saturate and level-off as $\theta_p$ to be 4.5 degrees; fourth, with as stacked PI-Langmuir-Blodgett (LB) films using the same precursors as those used for above mentioned PI (1, 2, and 3), the $\theta_p$ are always nil; finally, contrary to above results, by the application of rubbing on the PI-LB films with a medium RS, the obtained values of $\theta_p$ are shown to take the following order; PI-LB (3) > PI-LB (2) > PI-LB (1). This order is the reverse compared with the data for the spin-coated and rubbed PI films.

*Keywords: liquid crystal, pretilt angle, rubbing, LB films, polyimide*

## 1. INTRODUCTION

The alignment of liquid crystals (LCs) on the treated surfaces of solid substrates is an important issue both for fundamental research and device applications.

Almost all kinds of electrooptic LC devices such as twisted nematic (TN) type, that of super twisted nematic (STN), and ferroelectric (FE) are prepared using various surface alignment techniques: oblique evaporation of SiO films,[1,2] rubbed polymer (e.g., polyimide (PI)) films,[1,3] PI-Langmuir-Blodgett (LB) films,[4] and so forth.

In these alignments of LC molecules it is necessary almost always to give the pretilt angle in order to avoid the creation of defects called disclinations.

Generations of the pretilt angles by means of the adjustment of the evaporation angle is widely known[1,2]; and those based on the rubbing technique were demonstrated and discussed by many investigators[5–11]; Becker et al. reported how the

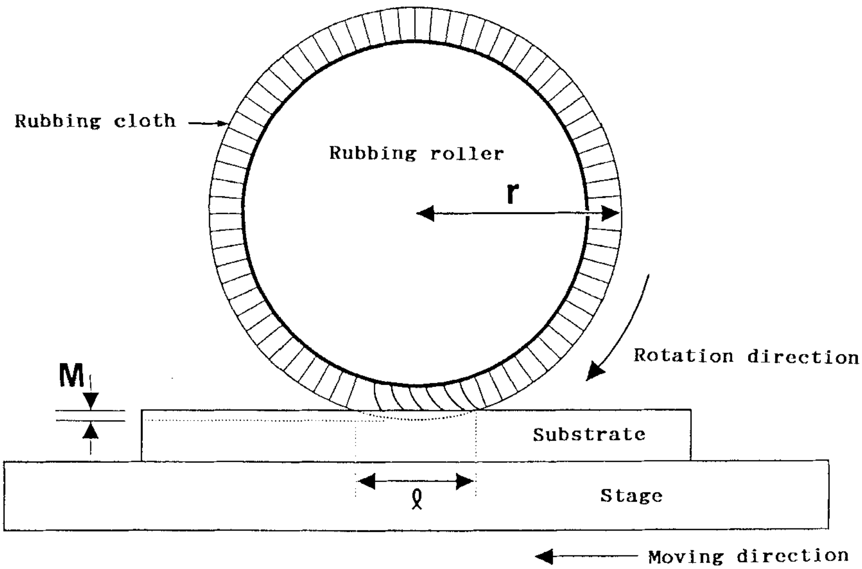


FIGURE 1 A schematic drawing of the rubbing machine. The depth of the deformed region of the cloth designated by M due to the contact is an important parameter characterizing the rubbing strength.

obtained pretilt angles depend both on the orientation films and rubbing strength but the obtained pretilt angles were 1.5 degrees at best.

The advent of the STN-LCD technology in 1985 needed the generation of a high pretilt angle of 5 degrees or more[12]; this task has been resolved by one of the authors (S.K.) and his coworkers by using alkyl branched polyimide films which are properly rubbed.[5–7]

This research has been done with the aims of knowing how the pretilt angles depend on the nature of the PI films that are prepared by the ordinary spin-coating or LB techniques and also on the rubbing strength.

## 2. EXPERIMENTAL

### 2.1 Sample Cells

The used NLC was 5CB and it was aligned to form a monodomain medium in a sandwich cell. Several samples were fabricated by using different kinds of polyimide (PI) which were prepared either by spin-coating or the LB technique. The PI-LB films were the Y-type and had 9 molecular layers.[13]

Concretely the following five different precursors for PI were used:

PI (1), it consists of molecules having an alkyl-branch and a cyclobutane part featured by the small electrical polarization.

PI (2), also with an alkyl-branch and a cyclobutane part but medium polarization.

PI (3), alkyl-branchless and with cyclobutane, the largest polarization.

PI (4), alkyl-branchless and with cyclopentane, medium polarization.

PI (5), cyclopentane was substituted by cyclobutane of PI (4).

All the precursors were polyimidized, but we use the same notations as PI (i) for the polyimde film of the number i.

We fabricated samples A through C using spin coated PI (1) through PI (3), respectively; and also those of D through H using LB films made of PI (1) through PI (5).

Rubbing was done in an antiparallel way to form a splay deformation free medium using a machine whose drum was wrapped with a nylon cloth. A schematic drawing of a central part of the rubbing machine is shown in Figure 1.

Each sample cell had a common LC layer thickness of 60 ± 0.3 μm.

### 2.2 Pretilt Angle Measurement

For measuring pretilt angles we used the method of crystal rotation[14,15] up to 10 degrees and that of magneto capacitive null method[16] for above 10 degrees.

All these measurements were done at room temperature (22°C).

### 2.3 Rubbing Strength

The degree of working done by the rubbing on the orientation films can be evaluated by observing the optical retardation occurred in the rubbed surface of the film[5] or the power consumption of the motor of the rubbing machine.[8]

An expression for the rubbing work or rubbing strength is given in the past literatures.[8,17] In this research, we adopted the following expression for the rubbing strength RS for convenience:

$$RS = NM(2\pi rn/\nu - 1), \qquad (1)$$

where N is the number of the repeated times of the rubbing (usually $N = 1$ in our case), M is the depth of the deformed fibers of the cloth due to the pressed contact (mm), n is the rotation rate of the drum ($1000/60(s^{-1})$), $\nu$ is the translating speed of the substrate (7.0 mm/s), and r is the radius of the drum.

As illustrated in Figure 1, we adopted the parameter M as the most important adjustable parameter to control the rubbing strength while the other parameters were kept constant.

The actual rubbing work $W$ per unit area may be proportional to RS as $W = a \cdot \mathrm{RS}$, where "$a$" is the proportional coefficient and a function of the coefficient of the kinetic friction and the energy transfer ratio between two contacting surfaces, and so forth.[18]

## 3. RESULTS AND DISCUSSION

First of all, we examined the relationship between the induced optical retardation occurring in the orientation film due to the rubbing and the rubbing strength RS defined by equation 1.

The results are shown in Figure 2 for the spin-coated PI (1) through PI (3). A

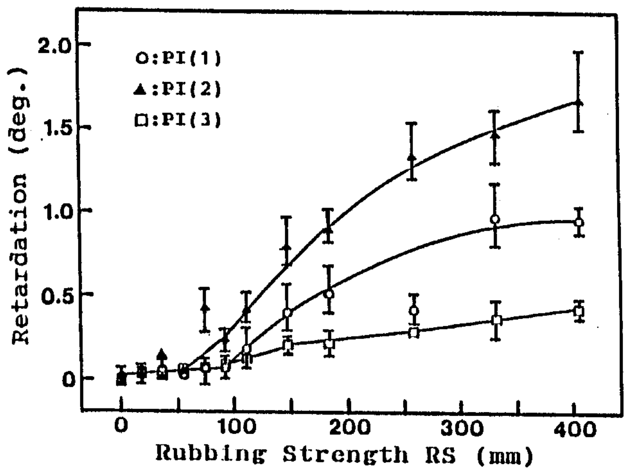


FIGURE 2 Observed retardation for samples with PI (1), (2), and (3) films versus rubbing strength.

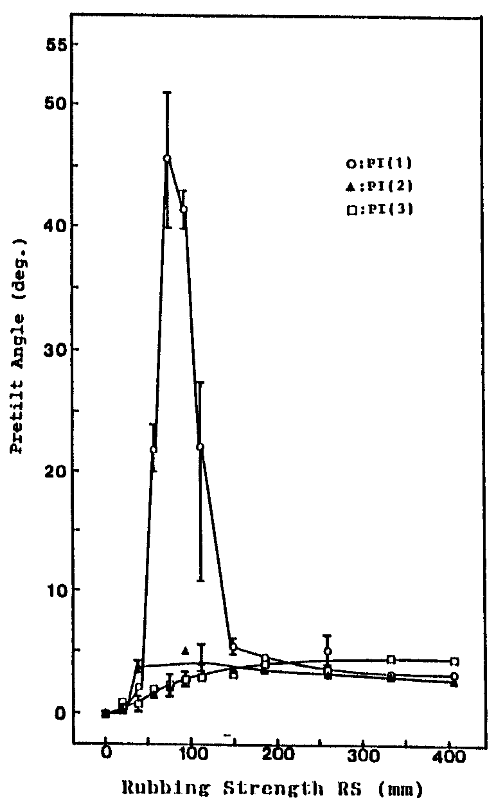


FIGURE 3 Observd pretilt angles for sample cells with PI (1), (2), and (3) films versus rubbing strength.

TABLE I

The pretilt angles in sample cells with various orientation films

| Orientation Films | Pretilt Angle (deg.) Rubbing Strength RS (mm) | | | | |
|---|---|---|---|---|---|
| | 0 | 114 | 189 | 335 | 406 |
| A : PI(1) | | 22.0 | 4.6 | 5.1 | 3.2 |
| B : PI(2) | | 5.2 | 3.5 | 3.1 | 2.5 |
| C : PI(3) | | 2.4 | 3.6 | 3.6 | 4.4 |
| D : PI-LB (1) | 0.2 | | 1.7 | | |
| E : PI-LB (2) | 0.2 | | 2.5 | | |
| F : PI-LB (3) | 0 | | 3.0 | 2.5 | 2.0 |
| G : PI-LB (4) | 0 | | 0.5 | | |
| H : PI-LB (5) | 0 | | 0 | | |

monotonic increase of the induced retardation $\Delta n$ with RS for each film is seen in Figure 2.

The obtained pretilt angles in the cells with spin-coated and rubbed PI (1) through PI (3) versus rubbing strength RS is shown in Figure 3.

The cell with PI (1) films shows a giant peak reaching 51 degrees for RS = 76.5 (mm) and hereafter the pretilt angle goes down to the level of 4 degrees or less. This material is useful for generating a high pretilt angle above 5 degrees.

The branches on the surface of the orientation film that is oriented by the proper rubbing are thought to play a role in generating a pretilt angle in terms of the steric interaction between LC molecules and branches.[11]

The data for PI (2) represented by full triangles show that the obtained pretilt angles $\theta_p$ rise up rapidly in the lower region of RS and show a broad hump with $\theta_p = 3.5$ degrees; then it decreases gradually.

The obtained $\theta_p$ for the cell with PI (3) films represented by open squares increases monotonically and shows a saturation toward about 4.5 degrees.

This unique behavior may be attributed to the molecular structure of this material featured by its high electrical polarizability.

Concerning the pretilt angles occurring in the cells with PI-LB films the results were as follows: no pretilt occurred in all the cells with stacked PI-LB films regardless of the materials.

However by performing rubbing the pretilt was generated; the obtained pretilt angles mainly at RS = 189 mm are shown in Table I.

The obtained value of $\theta_p$ is shown to take the following order: (PI-LB (3)) > (PI-LB (2)) > (PI-LB (1)).

This order is just the reverse compared with data for the spin-coated and rubbed PI films.

## 4. CONCLUSION

The pretilt angles generated in nematic liquid crystal (5CB) media that are disposed in sandwich type cells and oriented by using various polyimide orientation films, which are prepared by spin-coating and the LB technique, are shown to depend both on the nature of the orientation films and the rubbing strengths.


## Acknowledgment

The authors would like to thank Dr. H. Yokoyama of Electrotechnical Lab. and Dr. A. Kohno of RIKEN for valuable suggestions and discussions; Mr. Y. Yabe of Fujitsu Kiden Co., H. Fukuro of Nissan Chemical Industries Co., M. Nishikawa of Japan Synthetic Rubber Co., C. Saka of Chisso Co. for providing materials and for valuable discussions.


## References


1. J. Cognard, *Mol. Crystl. Liq. Cryst. Supplement.* **1**, 1 (1982).
2. K. Hiroshima and H. Obi, Proc. of the 3rd International Display Research Conference (in Kobe), 334 (1983).
3. H. Yokoyama, *Mol. Cryst. Liq. Cryst.*, The 100th Anniversary of Liquid Crystal Research (S. Kobayashi ed.), **165**, 269 (1988).
4. H. Ikeno, A. Ohsaki, M. Nitta, N. Ozaki, Y. Yokoyama, K. Nakaya and S. Kobayashi, *Jpn. J. Appl. Phys.*, **27**, 475 (1988).
5. S. Kuniyasu, H. Fukuro, S. Maeda, K. Nakaya, M. Nitta, N. Ozaki and S. Kobayashi, *Jpn. J. Appl. Phys.*, **27**(5), 827 (1988).
6. H. Fukuro and S. Kobayashi, *Mol. Cryst. Liq. Cryst.*, **163**, 157 (1988).
7. K. Yoshida, H. Fukuro and S. Kobayashi, *Proc. of the SID*, **28**, 755 (1987).
8. M. E. Becker, R. A. Kilian, B. B. Kosmowski and D. A. Milynski, *Mol. Cryst. Liq. Cryst.*, **130**, 167 (1986).
9. A. Moseley, B. M. Nicholas and P. A. Gass, *Displays*, **8**, 17 (1987).
10. R. W. Filas and J. S. Patel, *Appl. Phys. Lett.*, **50**, 1426 (1987).
11. T. Sugiyama, S. Kuniyasu, D.-S. Seo, H. Fukuro and S. Kobayashi, *Jpn. J. Appl. Phys.*, **29**(10), 2045 (1990).
12. T. J. Schefffer and J. Nehring, *Appl. Phys. Lett.*, **45**, 1021 (1984).
13. H. Maeda, M. Yoshida, B. Y. Zhang, M. Kimura, A. Mochizuki and S. Kobayashi, Eurodisplay '90 (in Amsterdam), 260 (1990); to be published in *Proc. of the SID* (1991).
14. L. Komitov, G. Hauck and H. D. Koswing, *Cryst. Res. and Tech.*, **19**, 253 (1984).
15. T. J. Scheffer and J. Nehring, *J. Appl. Phys.*, **48**, 1783 (1977).
16. K. Toriyama and T. Ishibashi, Non-emissive Electrooptic Display, (A. R. Kmetz and K. F. Von Willinen ed.) Plenum, P145 (N.Y. 1976).
17. T. Uchida, M. Hirano and H. Sakai, *Liquid Crystals*, **5**, 1127 (1989).
18. A. Kohno (private communication).