
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

# Zenithal Anchoring Angle and Anchoring Strength on Oxidized Silane Plates

J. G. Fonseca [a], P. Charue [a] & Y. Galerne [a]

[a] IPCMS/GMO, 23 Rue du Loess, BP-20, 67037, Strasbourg, France

Version of record first published: 24 Sep 2006

To cite this article: J. G. Fonseca, P. Charue & Y. Galerne (1999): Zenithal Anchoring Angle and Anchoring Strength on Oxidized Silane Plates, Molecular Crystals and Liquid Crystals Science and Technology. Section A. Molecular Crystals and Liquid Crystals, 329:1, 597-604

To link to this article: http://dx.doi.org/10.1080/10587259908025986

*Mol. Cryst. Liq. Cryst.*, 1999, Vol. 329, pp. 597-604
Reprints available directly from the publisher
Photocopying permitted by license only





# Zenithal Anchoring Angle and Anchoring Strength on Oxidized Silane Plates

J.G. FONSECA, P. CHARUE and Y. GALERNE

*IPCMS / GMO, 23 Rue du Loess, BP-20, 67037 Strasbourg – France*

Silane coated surfaces are chemically modified by using the post-discharge of an oxygen and nitrogen cold plasma, to produce alignment layers. These oxidized surfaces yield uniform nematic cells, provided that they are previously rubbed unidirectionally. Depending on the oxygen concentration arriving to the sample surface, the zenithal anchoring orientation may be tuned from planar to homeotropic, and tilted in-between. We measure the zenithal anchoring strength in the planar region, for 4-n-pentyl-4'-cyanobiphenyl (5CB), as a function of the oxygen concentration and of temperature. The anchoring strength is found roughly independent of the oxygen concentration, with an extrapolation length ~100 nm for $\Delta T$=1.5K.

*Keywords:* Anchoring Strength; Extrapolation Length; Post-Discharge Plasma; Alignment Layer; Silane Coating; Self Assembled Monolayers

## INTRODUCTION

Self Assembled Monolayers (SAM) are often used as alignment layers for liquid crystals[1], since they easily yield clean uniform surfaces. Here, we start from silane SAM that we then modify by using the post-discharge of a micro-wave plasma. We thus obtain gradual chemical modification of the SAM surface. The anchoring properties of the alignment layers obtained in this manner, are investigated, on both the points of view of the zenithal anchoring angle and of the zenithal anchoring strength.

## SAMPLES PREPARATION

First, ITO coated glass plates (square resistance ≤ 100 Ω, thickness ~25 nm) are unidirectionally rubbed with alumina powder (radius ~ 1-2 μm) in order to draw microscopical stripes on the ITO surface and to fix the azimuthal direction of the liquid crystal. The rubbing of the plates is performed at a constant velocity v ~ 630 mm/s for 6 min. while applying a weight of 3g. The plates are cleaned and submitted to an argon plasma (radio-frequency plasma, t = 5min, Forward Power = 100 W, Reflected Power = 1 W, Pressure = 0.1 torr) immediately before silanization, in order to clean them from organic elements, and to favor good deposition of the silane molecules. They are then silanized with a commercial derivative of octadecyltrichlorosilane (OTS).

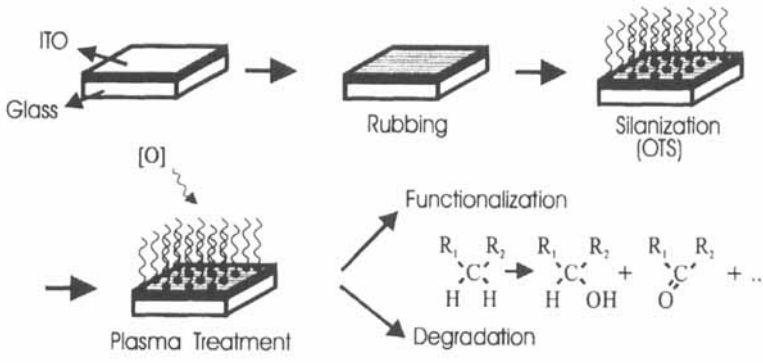


FIGURE 1 . Alignment layer process

Then we place the treated plates in the post-discharge region of a micro-wave $O_2/N_2$ plasma. The oxygen atoms that are produced in this way functionalize the silane surface, and for strong concentrations we observe a degradation of the surface with a loss of organic mass. There [2], the oxygen concentration decays exponentially with the distance to the plasma source (Fig.2). Depending on that distance, one can thus vary the degree of functionalization of the silane surface. In order to have a reproducible process, the temperature and the fluorescence light intensity of the plasma are carefully controlled, as well as the forward and reflected power in the microwave cavity.

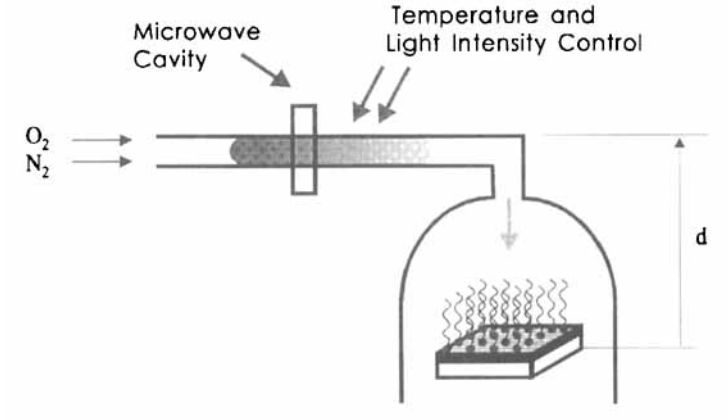


FIGURE 2 . Plasma experimental setup

Cells are prepared with these plates, with parallel azimuthal orientations and a spacing in the range of 5μm - 10 μm. We choose the cyanobiphenyl compound (5CB) for it is a room temperature nematic with high dielectric anisotropy and birefringence. It is a well known nematic and our experimental results can directly be compared with data already published on other interfaces. The liquid crystal is introduced in the isotropic phase and uniformly oriented cells are obtained.

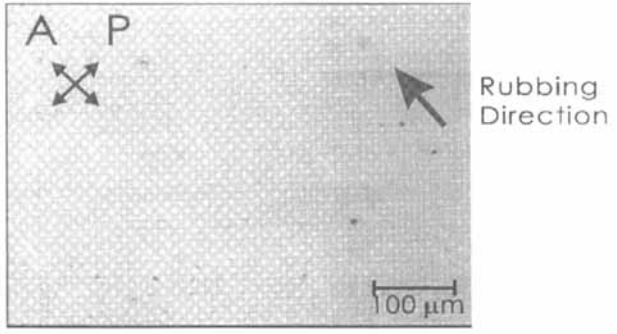


FIGURE 3 . Typical 5CB sample between cross polarizers

## ANCHORING ANGLE

The zenithal anchoring angle θ is determined from the measurement of the optical path difference in the sample cell. For intermediate tilted anchorings (θ between 15° and 75°), a direct measurement of the optical path difference δ is made in normal incidence, and the anchoring angle is determined from the relation:

$$\delta = \Delta n \; D \; \sin^2 \theta \qquad (1)$$

where Δn is the birefringence of the liquid crystal, and D the sample thickness. For planar or homeotropic anchorings the prism technique[3] is more accurate. In this case, also one only needs to measure the sample thickness and the optical path difference for different incidence angles (α = 19°,0°,-19°), to both determine the anchoring angle and the birefringence of the liquid crystal.

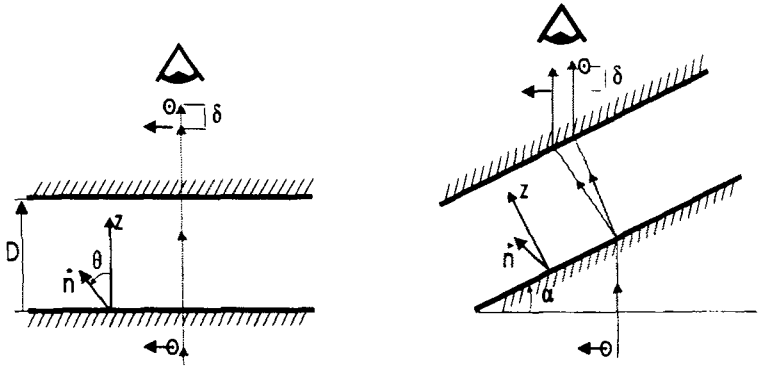


FIGURE 4 . Normal and oblique measurements of the optical path difference

The anchoring angle results are shown in Fig.5 as a function of the distance to the plasma source. At low concentrations (large distances) the nematic director keeps perpendicular to the surface (homeotropic anchoring). As the oxygen concentration increases, the anchoring starts to tilt , and after a critical concentration the anchoring becomes planar. As may be seen on Fig.5, the anchoring process is reproducible, with a tuning tolerance of ~ 1 cm.

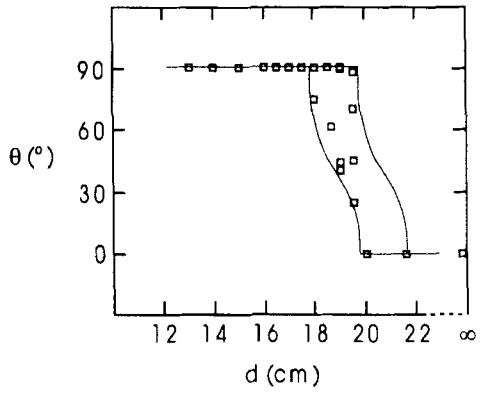


FIGURE 5 . Anchoring angle variations as a function of distance to the plasma source

## ZENITHAL ANCHORING STRENGTH

The orientation of a nematic liquid crystal submitted to an applied electric field, perpendicular to the cell surfaces, results from the competition between a volume torque of electric nature, given by:

$$\Gamma_V = \int_0^{D/2} \left| \vec{P}.\vec{E} \right| dz \tag{2}$$

and a surface torque proportional to the anchoring strength of the interface,

$$\Gamma_S = K_a \delta\theta_S . \tag{3}$$

Here, $K_a$ is the anchoring strength coefficient and $\delta\theta_S$ is the variation of the director angle at the surface. In the case of planar anchorings, the nematic director is parallel to the surface for voltages below the Frederiks transition. For higher voltages, the nematic molecules tend to be aligned with the electric field and we observe a distortion of the director throughout the cell. For a finite anchoring strength, the electric field orients the molecules not only in the volume of the cell but also at the surface, and in this case $\theta_S(V>V_{th}) < \theta_S(V<V_{th}) = \pi/2$. On calculating the distortion $\theta(z)$, one can determine the extrapolation length $\xi_\theta$, which is connected to the anchoring strength by the relation:

$$\xi_\theta = \frac{K_{11}}{K_a} \tag{4}$$

where $K_{11}$ is the splay elastic constant of the liquid crystal. The extrapolation length represents the distance between the real surface of the cell and a virtual surface where the anchoring is once again planar.

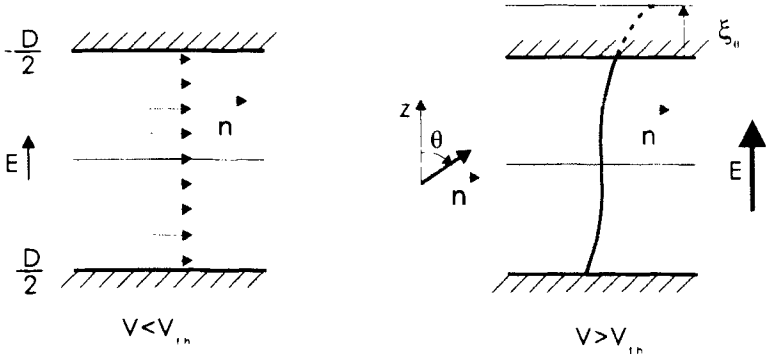


FIGURE 6 . Director distortion below and above the Frederiks transition

The free energy can be expressed in terms of the sample parameters that are measured (sample thickness, birefringence, Frederiks voltage, optical path difference) and other parameters taken from literature[4,5]. Numerical minimization of free energy allows us to determine the director distortion $\theta(z)$. The calculation takes into account the electric field variations due to the distortion. They are related to the electric displacement D which is constant, by the relation $E = \varepsilon(z)\, D$. The anisotropy of the elastic constants and the effects of flexoelectricity [6] are also taken into account. By extrapolating the calculated distortion from the sample surface, we obtain the extrapolation length $\xi_0$.

In the studied region (where the anchoring is planar), the anchoring strength is found to be roughly independent of the oxygen concentration (Fig. 7). Interestingly (Fig.8), one observes a critical behavior as a function of temperature near the nematic - isotropic transition, consistent with the one reported for other alignment layers[7].

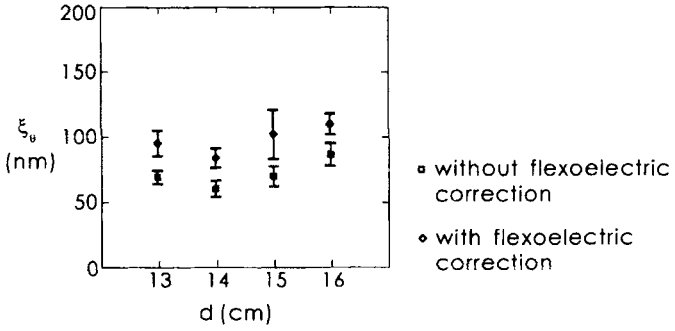


FIGURE 7 . Extrapolation length *versus* distance to plasma source for 1.5K below the nematic isotropic transition ($\Delta T$=1.5K). The calculations are performed with and without taking into account the flexoelectric effect.

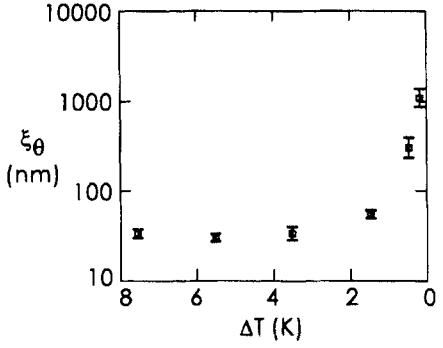


FIGURE 8. Temperature dependence of the zenithal extrapolation length for d = 14 cm, without flexoelectric correction

## CONCLUSIONS

The method used to determine the zenithal extrapolation length can be considered as a variation of the "high electric field" technique[8]. However, it does not need any capacitance measurement, which are integrated measurements in all cell surface, difficult to make under an electric field. The use of capacitance measurements also assumes a uniform cell thickness in all its surface. Here, the measure is local, which allows the measurements not to be affected with inhomogeneities that may exist in alignment layers. Another advantage of our method is that there is no limitation on sample thickness, in opposition with the typical cell thickness of 50 μm needed for the "high electric field" technique. On the other hand, the result is not

obtained from a straightforward graphical resolution, and a numerical calculation has to be performed by using a rather simple computer program.

The plasma treatment which is used to modify the silane surfaces, shows a good reproducibility. It can be applied to tune the anchoring from the planar to homeotropic orientations. We observe small variations of the anchoring strength with the oxygen concentration grafted onto the silane surface, in the planar anchoring region. We find an intermediate anchoring strength, with an extrapolation length of ~100 nm at $\Delta T$=1.5K.

**Acknowledgments**

J. G. Fonseca thanks the Portuguese Government for the Ph.D. Scholarship PRAXIS XXI D/9178/96

## *References*

[1] J.F. Khan, Appl. Phys. Lett., **22**, 386 (1973)
[2] P. Hubert, Ph.D. Thesis, ULP Strasbourg (1996)
[3] P. Hubert, H. Dreyfus, D. Guillon, Y. Galerne, J. Phys. II France, **5**,1371(1995)
[4] G.P. Chen, H. Takezoe, A. Fukuda, Liquid Crystals, **5**, 241 (1989)
[5] D.A. Dunmur, M.R. Manterfield, W.H. Miller, J.K. Dunleavy, Mol. Cryst. Liq. Cryst. **45**, 127 (1976)
[6] I. Dozov, G. Barbero, J.F. Palierne, G. Durand, Europhys. Lett. 1 (**11**), 563 (1986)
[7] H. Yokoyama, S. Kobayashi, H. Kamei, J. Appl. Phys. **61** (9), 4501 (1987)
[8] H. Yokoyama, H.A. van Sprang, J. Appl. Phys. **57** (10), 4520 (1985)