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

Tilt Angle Measurement on a Homogeneously Aligned Liquid Crystal

Iqbal A. Khan [a], Syed W. Azam [a], Sarah Akhtar [a] & Rizwan Mahmood [b]

[a] Department of Physics, University of Karachi, Karachi, 75270, Pakistan

[b] Department of Physics, Slippery Rock University, Slippery Rock, Pennsylvania, 16057, USA

Version of record first published: 24 Sep 2006

To cite this article: Iqbal A. Khan, Syed W. Azam, Sarah Akhtar & Rizwan Mahmood (1999): Tilt Angle Measurement on a Homogeneously Aligned Liquid Crystal, Molecular Crystals and Liquid Crystals Science and Technology. Section A. Molecular Crystals and Liquid Crystals, 329:1, 89-97

To link to this article: http://dx.doi.org/10.1080/10587259908025929

Mol. Cryst. Liq. Cryst., 1999, Vol. 329, pp. 89-97
Reprints available directly from the publisher
Photocopying permitted by license only

Tilt Angle Measurement on a Homogeneously Aligned Liquid Crystal

IQBAL A. KHAN[a], SYED W. AZAM[a], SARAH AKHTAR[a] and RIZWAN MAHMOOD[b]

[a]*Department of Physics, University of Karachi, Karachi-75270, Pakistan and*
[b]*Department of Physics, Slippery Rock University, Slippery Rock, Pennsylvania 16057, USA*

We have measured tilt angles in a homogeneously aligned liquid crystal (LC) cell on a glass substrate. These measurements are made as a function of polyvinyl alcohol (PVA) concentration in water, number of rubs, sample thickness and temperature. The liquid crystals used are E-31 and E-310 (E. Merck). For E-310 material, the tilt angles are 2.10 ± 0.50 and 2.50 ± 0.50 degrees for 20 and 60 micron thick samples respectively and are independent of temperature within the accessible range of 25<t<60 Celsius. E-31 data, however, show linear temperature dependence of the tilt angle for samples of 20, 80, and 140 microns thickness. This study finds that the alignment of LC molecules improves with increasing number of rubs and is optimum at 40 rubs, beyond which it makes no effect up to 250 rubs.

Keywords: liquid crystals; homogeneous; tilt angle

INTRODUCTION

Liquid crystal displays have become an essential commodity in modern instrumentation including computers. Since 1960's when first liquid crystal (LC)[1] display cell was developed, tremendous amount of work has been done and still continues to improve the quality of display. The quality of a display is directly related to good alignment of LC molecules on a glass substrate.

Significant amount of work has been done to understand surface alignment of LC molecules on a substrate. In this regard, the work of Janning[2], Kahn et al[3], Goodman[4], Haller[5], and Okano[6] is worth mentioning. Cognard[7] and Jerome[8] have reviewed anchoring of liquid crystal molecules on a glass substrate.

The alignment can be homogeneous when the molecules of liquid crystals lie parallel to the surface of the substrate or it can be homeotropic when the molecules are oriented normal to the substrate. However, a display, in general, requires homogeneous alignment. A popular method for homogeneous alignment is to use polyvinyl alcohol (PVA)-water solution. This solution is coated on the substrate and leaves a thin film after it is dried. The substrate is rubbed by a linen cloth or a nylon brush to create tiny grooves on the PVA film. Other methods[9] have also been reported in the literature.

In a homogeneous alignment, molecules may not be exactly parallel to the substrate thus, making a small angle called tilt angle θ_t. A smaller θ_t is desired because it results in a better contrast. There are various interactions at the liquid crystal-substrate interface that determine the orientation of liquid crystal molecules. Such interactions include dispersion forces, and the distortion of the orientation field of the LC due to the grooved surface of the substrate. The Friedel-Creagh-Kmetz (FCK) rule[10] of experimental observation suggests that the alignment of the LC film to the solid surface is determined by the surface interaction energies. Let λ_L be a macroscopic description of the strength of LC-LC interaction and λ_s be the solid surface excess energy. In essence, FCK rule suggests that the homogeneous alignment is achieved if $\lambda_s > \lambda_L$ whereas homeotropic alignment occurs if $\lambda_s < \lambda_L$.

The purpose of the present work was to explore the experimental parameters that affect tilt angle. A knowledge of such parameters would be helpful for a display designer as well as for a chemist to synthesize and characterize new materials. For this study, we considered the concentration of

PVA (in water) solution, number of rubs, cell thickness and temperature of the cell to be the potential parameters.

The tilt angle can be obtained by measuring the intensity of a laser beam transmitted through a liquid crystal test cell. The complete experimental setup is described in the next section and is shown in figure 1. Basically, a rotation of the display cell about the vertical axis produces an interference fringe pattern, due to the birefringence of LC and in turn a phase shift between the emergent ordinary and extraordinary rays. A computer generated interference pattern is shown in the insert of figure 2. The pattern is obtained by using the expression[11] of transmitted intensity:

$$I = I_o \sin^2(\delta/2) \text{ where } \delta = 2\pi h/\lambda\{n_e/A - n_o/B\}, \text{ where} \quad (1)$$

$$A = \cos\left[\arctan\left((n_o/\sin(\omega-\theta))^2-(n_o/n_e)^2\right)^{-1/2}\right]$$

$$B = \cos\left[\arcsin(\sin(\omega-\theta)/n_o)\right]$$

δ = phase shift introduced by the LC layer

h = sample thickness

n_o = refractive index for the ordinary ray

n_e = refractive index for the extraordinary ray

ω and θ are the incident and shift angles respectively

A zero shift angle gives an extremum of intensity of the fringe pattern at 0°, whereas in case of non zero shift, the extremum intensity is shifted by an amount θ. The tilt angle is then obtained by measuring this shift, θ. For smaller angle, the expression[12] for θ_t is approximately given by

$$\theta_t = \theta/(n_o + n_e)$$

For nematic LC, typical values of n_o and n_e are 1.50 and 1.70 respectively. The tilt angle is then given by

$$\theta_t = 0.3\,\theta$$

EXPERIMENTAL DETAILS

The glass slides of 1 square inch were cleaned, dried, and coated with a solution of PVA in water. The cleaning was done by a method suggested by de Jeu[13]. The PVA concentrations used were 0.1, 0.2, and 0.3 weight percent in distilled water. The solution was filtered through a 0.45 micron Millipore filter before coating the glass slides. The slides were then baked at 105°C for about eight hours; were subsequently rubbed in a unidirectional sense by a piece of felt cloth attached to an aluminum block of about 100 gm mass. The felt-aluminum assembly was passed on the slide without exerting any extra pressure. The sample sandwiches were thus made from the slides with 0, 1, 2, 10, 20, 40, 60, 80, 100, and 250 rubs. The liquid crystal was then filled into the sample cells using the capillary action. The samples used copper wire or mylar sheet as spacers and their thickness were nominally 20, 80, and 140 microns for E-31 and 20 & 60 microns for E310 materials.

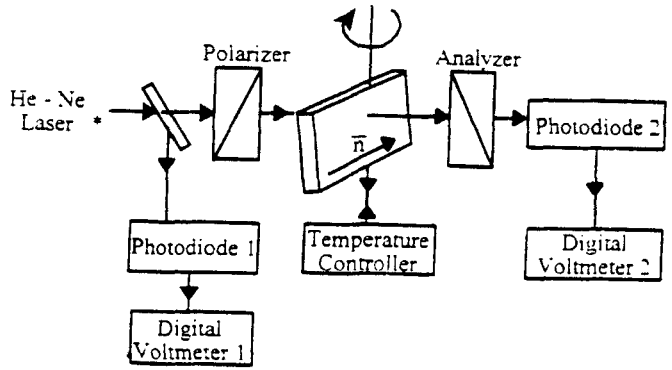

FIGURE 1 Experimental Setup

Optical transmission of the sample cells was measured using the setup shown

in figure 1. Alignment of the optical system was accomplished by turning on the laser one hour prior to the data collecting in order for laser intensity to be stabilized. Orientation of the polarizer and analyzer was checked with out the sample. The analyzer was first adjusted in such a way that the reflected laser light was sent back to the source in order to make plane of analyzer normal to the laser beam. Then the sample and polarizer were introduced one by one using the same procedure as mentioned above. The sample was rotated about the horizontal axis under white light to ensure that the director is oriented along the horizontal direction. Finally, the photo diode is adjusted to optimize the transmitted intensity.

Light from a 1.0 mw helium-neon laser (wavelength = 632.8 nm) was made incident to the sample cell which was placed between two crossed polarizers. The polarizers were at 45° from the vertical whereas the direction of the LC molecules was horizontal but normal to the laser beam. The transmitted beam was received by a photo diode and its response was recorded on a digital voltmeter (Kaise, model SK06111). The variations in the laser beam intensity were monitored by reflecting a fraction of the incident beam from the glass slide onto another photo diode whose response was again read on similar digital voltmeter. This information was later used to normalize the transmitted intensity of laser.

The sample cell was equipped with a heater/temperature controller and was capable of rotation about horizontal and vertical axes. The temperature was controlled by a PID controller to within +/- 0.1 Celsius. The set point was obtained within a minute. However, 15 minutes were allowed between the two data points in order for the sample to attain equilibrium temperature. The accuracy in the measurement of the tilt was estimated to be +/- 0.1 degrees. The range of rotation about the horizontal and vertical axes was 360° and 40° respectively. The rotation about the horizontal axis was used to check the

quality of the alignment of LC molecules. A thermocouple was used as a temperature sensor. The cell quality was checked under a polarizing microscope before collecting the intensity data. Figure 2(a) shows transmitted intensity vs. incidence angle for E-31, the cell thickness was 20 micron and the data were taken at 45° C, while Figure 2(b) is a theoretical plot using equation 1. The data were reproducible within the experimental uncertainties.

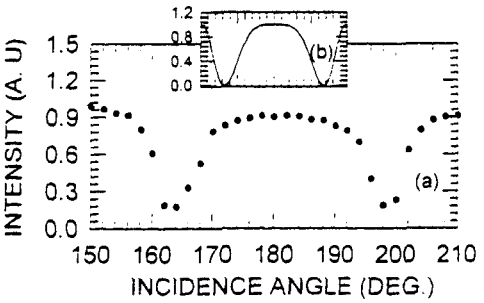

FIGURE 2 Intensity vs. incidence angle (a) circles-experimental, (b) Inset-theoretical (solid line)

RESULTS

Our studies revealed that samples without any rub gave partial homogeneous alignment. The polarizing microscope showed few patches with homogeneous alignment. Samples with one rub gave some improvement. However, as few as 2 rubs on PVA coated slides gave sufficient homogeneous alignment. The samples studied using the optical transmission set up as well as a polarizing microscope concluded that the number of rubs from 10 to 250 did not make significant difference in

alignment. The 40 rubs, however, gave best quality samples. Similarly the 0.1, 0.2, and 0.3 weight percent concentration of PVA did not result in any .

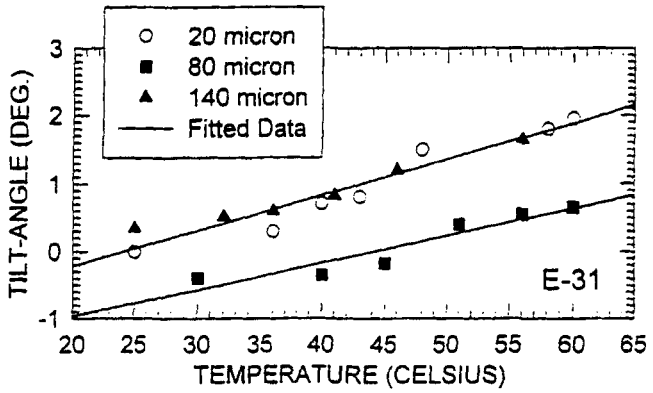

FIGURE 3 Tilt angle dependence on temperature. 80 micron data are shifted by -0.5 degrees

noticeable difference in the orientation and alignment. Thus, we decided to use 40 rubs and a 0.1 weight percent solution of PVA in water. Therefore, the remaining potential parameters for the tilt angle were temperature and thickness of the sample

The samples with different thickness were studied from room temperature to near the isotropic temperature (~60 Celsius). The tilt angles were extracted from the data of intensity versus incident angle and plotted as a function of temperature. For E-31 material, the tilt angle was found to be a linear function of temperature and was as large as 2.00° for 20 & 140 micron and 1.20° for 80 micron thick samples (See figure 3).

For E-310 material, however, the tilt angle did not reveal any

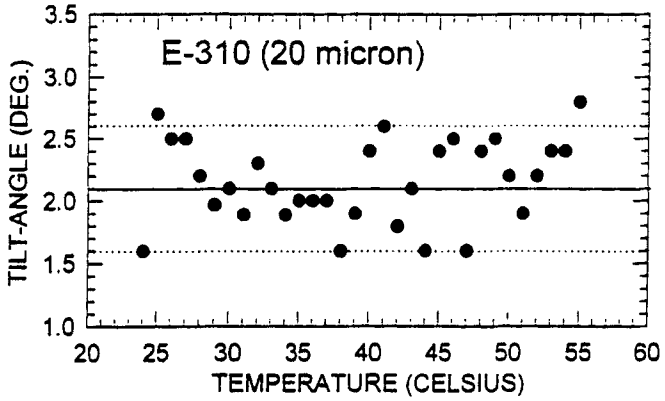

FIGURE 4 Tilt angle as a function of temperature

temperature dependence and was found to be 2.10 ± 0.50 and 2.50 ± 0.50 degrees for 20 and 60 micron thick samples respectively. One such plot for 20 microns thickness is shown in Figure 4. The difference in the behavior of E-31 and E-310 materials may be attributed to the structure of these materials which is different from each other. Table 1 shows selected physical properties of these materials as provided by the manufacturer.

TABLE 1 Physical properties of the compounds used

Compound	S-N (Celsius)	N - I (Celsius)	Δn	η_{20} (cSt)
E-31	-9	61.6	0.227	43.0
E-310	< -20	62.0	0.133	51.9

CONCLUSIONS

For both the compounds, E-31 and E-310, measurement of the tilt angle in the nematic phase has been made as a function of PVA concentration, number of rubs, temperature and thickness of the LC cell. This study leads to the conclusion that the parallel alignment is relatively insensitive to the concentration of the PVA solution and number of rubs for the materials studied. It has been shown that in E-31 compound, the tilt angle depends non-linearly on temperature and is largest near the isotropic temperature whereas for E-310 compound, it is found to be independent of temperature. The behavior of the tilt angle is independent of sample thickness for both the compounds.

*Authors acknowledge Pakistan Science Foundation for the grant under the project no. **S-KU/PHYS(74)** and National Talent Pool, Pakistan and United Nations Development Program under **TOKTEN** for supporting the visit of **RM** to the University of Karachi. We also acknowledge the support of EM Industries for providing us with E-31 material.

References

[1] William, R. J., Chem. Phys., **39,** 384 (1963).
[2] Janning, J. L., Appl. Phys. Lett. **41** 73 (1972).
[3] Kahn, F. J., Taylor, G. N., and Schonborn, H., Proc. IEEE, 61, 823 (1973).
[4] Goodman, L. A., RCA Review, **35,** 477 (1974).
[5] Haller, I., Prog. Solid State Chem., **10**, 103 (1975).
[6] Okano, K., Matsuura, N., and Kobayashi, S., JJAP, 21, L109 (1982).
[7] Cognard. J. Mol. Cryst. Liq. Cryst. Suppl. **1,** 1–74 (1982).
[8] Jerome, B., Rep. Prog. Phys. **54,** 391–455 (1991).
[9] Hiroshima, K., JJAP, **21** L761 (1982); Wintucky, E. G., Mahmood, R., and Johnson, D. L., NASA, Technical Report (TM-81378), (1978).
[10] Creagh, L. T., Kmetz, A. R., Mol. Cryst. Liq. Cryst., **24,** 59 (1973).
[11] Born, M. and Wolf, E. *Principles of Optics,* Sixth Ed. Pergaman Press, New York (1980).
[12] Scheffer, T. J. and Nehring, J. J. Appl. Phys., 48, 1783 (1977).
[13] De Jeu, W. H., *Physical Properties of Liquid* Crystalline *Materials,* Gordon and Breach (1979).