

This article was downloaded by:

On: 25 January 2011

Access details: *Access Details: Free Access*

Publisher *Taylor & Francis*

Informa Ltd Registered in England and Wales Registered Number: 1072954 Registered office: Mortimer House, 37-41 Mortimer Street, London W1T 3JH, UK



## Liquid Crystals

Publication details, including instructions for authors and subscription information:

<http://www.informaworld.com/smpp/title~content=t713926090>

### Dynamics of liquid crystal azimuthal anchoring at a poly(vinyl cinnamate) interface measured in situ during polarized UV light irradiation

V. V. Lazarev; R. Barberi; M. Iovane; L. Papalino; L. M. Blinov

Online publication date: 11 November 2010

**To cite this Article** Lazarev, V. V. , Barberi, R. , Iovane, M. , Papalino, L. and Blinov, L. M.(2010) 'Dynamics of liquid crystal azimuthal anchoring at a poly(vinyl cinnamate) interface measured in situ during polarized UV light irradiation', *Liquid Crystals*, 29: 2, 273 – 279

**To link to this Article:** DOI: 10.1080/02678290110093228

**URL:** <http://dx.doi.org/10.1080/02678290110093228>

PLEASE SCROLL DOWN FOR ARTICLE

Full terms and conditions of use: <http://www.informaworld.com/terms-and-conditions-of-access.pdf>

This article may be used for research, teaching and private study purposes. Any substantial or systematic reproduction, re-distribution, re-selling, loan or sub-licensing, systematic supply or distribution in any form to anyone is expressly forbidden.

The publisher does not give any warranty express or implied or make any representation that the contents will be complete or accurate or up to date. The accuracy of any instructions, formulae and drug doses should be independently verified with primary sources. The publisher shall not be liable for any loss, actions, claims, proceedings, demand or costs or damages whatsoever or howsoever caused arising directly or indirectly in connection with or arising out of the use of this material.

# Dynamics of liquid crystal azimuthal anchoring at a poly(vinyl cinnamate) interface measured *in situ* during polarized UV light irradiation

V. V. LAZAREV†‡, R. BARBERI\*†, M. IOVANE†, L. PAPALINO†  
and L. M. BLINOV†‡

†Istituto Nazionale di Fisica della Materia, c/o Dipartimento di Fisica,  
Università della Calabria, I-87036, Rende (Cs), Italy

‡Institute of Crystallography, Russian Academy of Sciences, 117333 Moscow,  
Leninsky prosp. 59, Russia

(Received 21 October 2000; accepted 20 August 2001)

An automated *in situ* technique for the measurement of the director reorientation at a nematic-aligning photosensitive polymer interface during polarized UV light irradiation has been developed. Using this technique, the photoinduced azimuthal anchoring energy ( $\sim 20$  mJ cm $^{-2}$ ) and the adsorption part of the latter ( $\sim 7$  mJ cm $^{-2}$ ) have been evaluated for the E7-poly(vinyl cinnamate) system. The kinetics of the director reorientation have been shown to be a very slow process ( $\sim 1$  h) and probably controlled by adsorption-desorption of liquid crystal molecules at the interface.

## 1. Introduction

The operation of traditional liquid crystal (LC) devices is based on a change in the director orientation in the LC bulk under the action of external fields. The LC director is fixed at the aligning surfaces and the boundary conditions are unchanged during the reorientation process. Another way to control the reorientation process is to change the anchoring conditions for the LC at the aligning surface [1–5].

One of the most attractive methods for controlling the surface anchoring is the photoalignment technique which uses light-induced anisotropy in photosensitive polymer films. Polarized light illumination of photosensitive aligning layers (azo-compounds [1, 6], polyimides [7–9], cinnamate-based polymers [3, 10, 11], and some others [12, 13]) produces an easy axis along which a liquid crystal is aligned. Poly(vinyl cinnamate) (PVC) and its derivatives are the most investigated materials for this purpose [14–18].

A key parameter of the LC photoaligning layers is the anchoring energy, either zenithal or azimuthal [19]. The azimuthal anchoring is especially important for the applications in which bistable nematic switching [20, 21] is used. The azimuthal anchoring energy is usually determined by twist angle measurements under a polarizing microscope [22]. As a rule, the photoaligning layers are irradiated before filling the cell with a liquid crystal. In

this case the photochemical process at the polymer–air interface might be different from that at the polymer–LC interface. The director reorientation in a filled cell during irradiation of the PVC layer was only studied in [23]. The azimuthal anchoring energy was estimated but no details concerning the dynamics of anchoring was given.

The aim of the present paper is to study the dynamics of LC azimuthal anchoring at an LC–photosensitive polymer interface during *in situ* irradiation of the latter, that is directly in a cell filled with a liquid crystal. As shown later such a process has some important features which shed light on the mechanism of the anchoring. For our study, a model photosensitive compound PVMC, poly(vinyl methoxycinnamate) has been chosen. A new version of the rotating polarizer ellipsometric technique [24] has been used in the measurements, enabling us to make *in situ* measurements of the visible light polarization rotation angle due to a twisted director configuration which, in turn, was induced by the polarized ultra violet (UV) light illumination of the PVMC/nematic interface.

## 2. Experimental

Films made of a PVMC sample (NIOPIK, Moscow) were used for the experiments. 1.4% PVMC in cyclohexanone solution was spun at 3000 rpm for 30 s onto ITO-covered fused quartz substrates and dried at 60–70°C for  $\sim 1$  h. Cells were constructed consisting of one substrate with a PVMC layer (still not irradiated) and the other substrate with a planar orienting reference interface

\* Author for correspondence; e-mail: barberi@fis.unical.it

at which the liquid crystal was assumed to be infinitely strongly anchored. In this case, the latter defined an overall initial homogeneous planar texture of liquid crystals (5CB or E7) after cell filling. In order to minimize flow alignment effects, the samples were filled in the isotropic phase and then the temperature was decreased slowly through the isotropic–nematic transition.

The thickness of empty cells was measured by an interferometric technique. The cell gap was controlled by teflon strips and chosen to be large enough (more than  $10\ \mu\text{m}$ ) to be in the Mauguin waveguide regime. Different treatments of the reference surface were used providing very strong anchoring, namely (i) rubbed polyimide AL1254 and (ii) 45 nm thick SiO layers evaporated at an angle of  $60^\circ$ .

A schematic of the experimental set-up is shown in figure 1(a). An 8 mW He-Ne laser beam is divided by a

glass plate and a mirror into two beams, the signal and the reference. The signal beam, linearly polarized by a polarizer, passes through a sample and is then chopped by a rotating analyser. The reference beam is also linearly polarized in the same direction and chopped by the same rotating analyser. Two identical silicon photodiodes each fed by a 22 V d.c. source and supplied with a  $100\ \text{k}\Omega$  load resistor receive modulation signals and deliver electric response signals to the line input of a multimedia card of an IBM/PC computer. The PhysLab software including a set of ‘virtual devices’ (an oscilloscope, a lock-in amplifier, a plotter and some others) was used for automated measurements.

With such an optical set-up, it is possible to measure the relative optical phase shift  $\Delta\Psi$  between the polarization directions of linearly polarized beams in the reference and signal (sample) channels. Indeed, it is easy to show that the time variations of the light intensity transmitted through the analyser rotated by a motor with angular frequency  $\omega$ , is  $I = I_0 \cos^2(\omega t - \Delta\Psi) \equiv (I_0/2) \times \{1 + \cos[2(\omega t - \Delta\Psi)]\}$ . Therefore, the phase angle  $2(\Delta\Psi)$  is measured directly by a lock-in amplifier at a frequency (provided by rotating analyser) of  $2\omega$ . The accuracy of the phase angle measurements is of the order of  $\sim 0.01^\circ$ .

For the measurements, the cells investigated were set into the signal channel of the optical set-up, with the initial planar LC-director orientation,  $\mathbf{L}$ , being parallel to the polarization direction of both polarizers  $\mathbf{P}$ , figure 1(b). Then, one of the fixed angles (designated as  $\Phi_0$  and chosen to be equal to  $90^\circ$ ,  $70^\circ$ ,  $45^\circ$ ,  $20^\circ$  or  $5^\circ$ ) was established between the initial LC-director orientation in the cell (controlled by the strong anchoring direction  $\mathbf{R}$  on the rubbed reference surface) and the expected photoalignment direction at the PVMC surface  $\mathbf{F}_0$  (which, in other experiments, is known to be perpendicular to the polarization direction of the UV pumping light  $\mathbf{P}_{UV}$  [3, 11]). The PVMC/nematic interface was irradiated with linearly polarized UV light through the back of the PVMC-covered ITO–quartz substrate.

The irradiation resulted in an induced photoalignment direction on the PVMC film and forced the LC director at the PVMC-surface to reorient from the initially memorized direction (which was spontaneously established along the opposite substrate rubbing direction  $\mathbf{R}$ ) to a new, UV-induced easy direction  $\mathbf{F}_{easy}$ . This memory effect of the initial orientation (due to the existence of an adsorbed oriented nematic layer on the PVMC-surface just below the I–N transition) is equivalent to the appearance of an easy axis  $\mathbf{L}_{ads}$  with a finite azimuthal anchoring energy  $W_{ads}$ . Therefore, the director reorientation process at the PVMC layer is controlled by a competition between two surface alignment directions: the memorized and UV-induced ones. During cell irradiation a uniformly LC twisted texture forms with a bulk twist

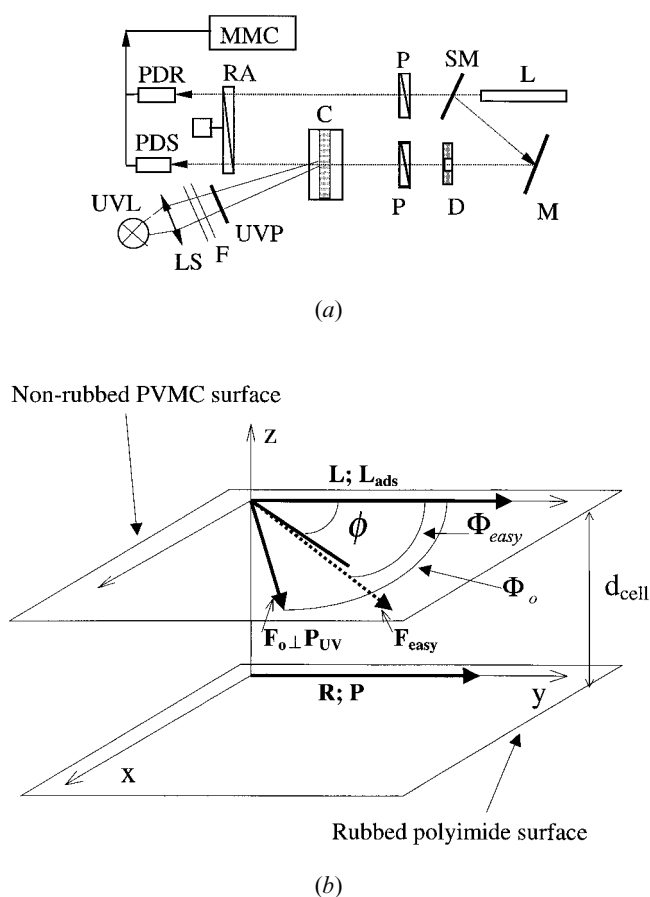


Figure 1. (a) Experimental set-up. L = He-Ne laser; SM, M = mirrors; P = polarizers; D = diaphragm; C = liquid crystal cell; RA = rotating analyser; PDR and PDS = photodiodes in reference and signal channels; MMC = multimedia card for IBM/PC computer; UVL = xenon ultraviolet lamp; LS = lens system; UVP = UV light polarizer; F = a set of UV filters. (b). Orientation of the alignment directions, the surface directors and the polarizers.

angle  $\phi$  dependent on the UV exposure time. A temporal evolution of the induced bulk twist angle (i.e. surface director reorientation at the PVMC/nematic interface) was measured and recorded with the PhysLab software.

The cells were irradiated through a lens system with a pump beam of polarized UV light from a 300 W Cermax Xenon lamp. The exciting light intensity was about  $\sim 50 \text{ mW cm}^{-2}$  behind a set of UV filters (UFS6, UFS5:  $\lambda_{\text{max}} \approx 350 \text{ nm}$ ,  $\Delta\lambda_{0.1} \approx 300\text{--}390 \text{ nm}$ ) and a UV polarizer (ORIEL sheet dichroic UV-polarizer). The pump beam with the polarization direction of UV-light,  $\mathbf{P}_{\text{UV}}$ , along the vertical (s-polarization) was directed to the PVMC-side face of the cell at the angle of  $20^\circ$  to the cell normal. For  $\Phi_0$  variation, the polarizers and the cell under study were rotated around the axis of the probe laser beam, with the UV-polarizer direction fixed along the vertical during all the measurements.

### 3. Results and discussion

Figure 2 shows the time dependence of the intrinsic photoinduced retardation of a 30 nm thick PVMC film (typically used in our experiments) during linearly polarized UV light irradiation. These data were taken under an exposure intensity of  $\sim 50 \text{ mW cm}^{-2}$  with the help of the ellipsometric technique described in detail earlier [24]. The retardation is seen to rise to a maximum of  $\sim 0.1^\circ$  at an exposure of  $\sim 1 \text{ J cm}^{-2}$ . The exposure value corresponding to the maximum birefringence is one fifth of that observed for thicker ( $d=100 \text{ nm}$ ) PVMC films [11]. This may be explained by a less uniform UV light absorbance in the thicker films. The experimental time dependence of birefringence (scatter

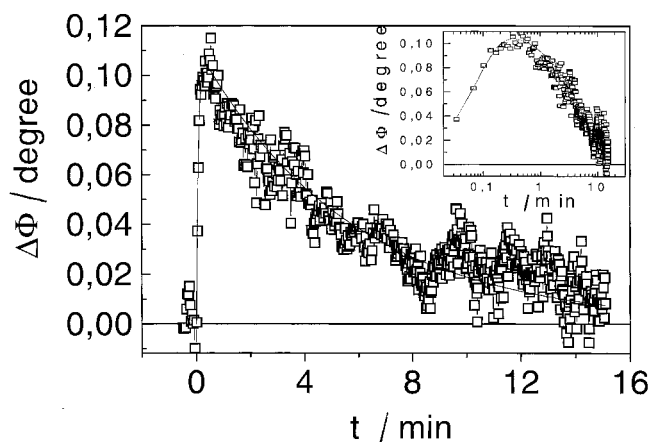


Figure 2. UV exposure time dependence of the optical phase retardation ( $\lambda = 632.8 \text{ nm}$ ) of a  $\sim 30 \text{ nm}$  thick PVMC film spun onto an ITO-covered fused silica substrate under UV illumination ( $I = 50 \text{ mW cm}^{-2}$ ) through the back of the substrate. The solid line is a fit calculated from the expression:  $\Delta\Phi(t) = 0.112^\circ \times [1 - \exp(-t/0.08)] \exp(-t/5.6)$ . Inset: the same curves on a logarithmic scale (the phase delay of the substrate is subtracted).

curve in figure 2) is well fitted by the expression:  $\Delta\Phi(t) = A[1 - \exp(-t/T_1)] \exp(-t/T_2)$  with fitting parameters:  $A = 0.112^\circ$ ,  $T_1 = 0.08 \text{ min}$ ,  $T_2 = 5.6 \text{ min}$  (solid curve in figure 2). The same form for the time dependence will be used later for the azimuthal anchoring energy surface potential to fit an evolution of the director reorientation at the nematic/PVMC interface during the same UV light exposure.

Figure 3 shows the time dependence of the UV light-induced angle  $\phi$  of the director reorientation in a  $12 \mu\text{m}$  thick cell filled with the liquid crystal E7 for different polarization angles  $\Phi_0$  (different irradiated spots in the same cell). For each curve, there is a sharp increase in the angle  $\phi$  during the first 1–2 min just after switching on the UV irradiation. Then after the following 20–30 min of continuous UV exposure, the angle  $\phi$  smoothly approaches some asymptotic value. For each experimental curve, the latter is considerably less than the corresponding angle  $\Phi_0$ . After switching off the UV irradiation, the plateau value of  $\phi$  decreases a little. First, there is a quick decrease due to a small decrease in temperature and the corresponding changes in the nematic order parameter and elastic constant,  $K_{22}$ . This temperature-dependent jump is followed by a very slow decrease of the plateau  $\phi$ -value, which may be attributed to some gliding of the director at the surface towards the original direction.

By comparing the two processes shown in figures 2 and 3 controlled by the same UV light irradiation, it is easy to see that their characteristic times are quite different. While evolution of the PVMC-film birefringence covers some tens of seconds, the director reorientation

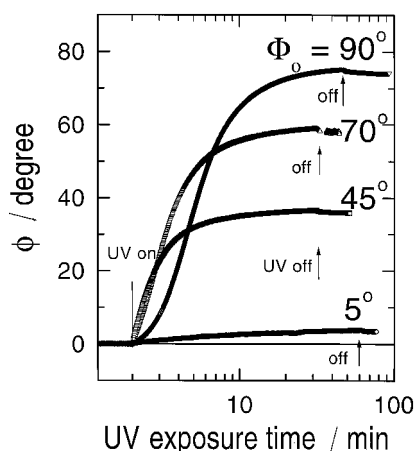


Figure 3. Time dependence of the UV light-induced angle of the director reorientation for different values of the angle,  $\Phi_0$ , between the photoalignment direction at the PVMC interface and the rubbing direction at the polyimide reference interface. UV exposure time  $t_{\text{irr}} = 45 \text{ min}$  (for  $\Phi_0 = 90^\circ, 5^\circ$ ) and  $t_{\text{irr}} = 30 \text{ min}$  (for  $\Phi_0 = 70^\circ, 45^\circ$ ). The  $\sim 12 \mu\text{m}$  thick cell was filled with E7.

till saturation requires hours. The latter can be explained by slow adsorption–desorption phenomena which occur at the interface and accompany the director reorientation process. The same behaviour of the director reorientation was also characteristic of cells with another reference surface (made of SiO) and a different LC (5CB).

It should be noted that, in our experiments, the characteristic relaxation time of the twist deformation,  $t_d$ , is much shorter than the observed time of the director reorientation  $t_r$  (i.e. the time of the surface anchoring energy variation). Indeed,  $t_d$  can be estimated by the expression  $t_d \approx \gamma_1 d^2 / \pi^2 K_{22}$  [19]. The twist viscosity  $\gamma_1 \sim 1$  dyne s cm<sup>-2</sup> (5CB, 25°C), the twist elastic constant  $K_{22} = (0.3–0.9) \times 10^{-6}$  dyne (5CB-E7, 20°C), the cell thickness  $d = 10–20$  μm; hence,  $t_d \approx 0.1–0.3$  ms, i.e. much shorter than  $t_r$  which is of the order of minutes (see figure 3). Under these conditions, the director distribution in the cell at each instant should be determined by a minimum of the free energy of the uniformly twisted LC (including surface terms). Assuming strong azimuthal anchoring at the rubbed reference surface, the free energy per unit area for a simple quadratic form of the surface potentials can be written as:

$$F = \frac{1}{2} K_{22} \phi^2(t)/d + \frac{1}{2} W_{\text{ads}}(t) \phi^2(t) + \frac{1}{2} W_{\text{UV}}(t) [\phi(t) - \Phi_{\text{easy}}]^2 \quad (1)$$

where the first term is the integrated bulk energy contribution and the two last terms are the azimuthal surface anchoring energies for the two competitive alignment directions on the PVMC-surface: the memorized one (due to adsorption of aligned LC molecules) and the UV-induced one.  $\phi(t)$  is the time-dependent angle of the surface director reorientation at the PVMC surface (i.e. the induced bulk twist angle of the cell at the instant in time,  $t$ ).

Assuming an exponential time-dependent form for the amplitude of the surface anchoring energy term due to adsorption (called the adsorption anchoring energy)  $W_{\text{ads}}(t) = W_{\text{ads}}^0 \exp(-t/\tau_2)$ , where  $W_{\text{ads}}^0$  is the magnitude of the adsorption anchoring energy for  $t=0$ , and a simple phenomenological expression for  $W_{\text{UV}}(t)$  [18] is  $W_{\text{UV}}(t) = W_{\text{sat}} [1 - \exp(-t/\tau_1)]$ , where  $W_{\text{sat}}$  characterizes the saturated value of the anchoring strength of the PVMC film after a sufficiently long UV irradiation, we can easily derive the torque equilibrium equation at the PVMC-surface:

$$0 = K_{22} \phi(t)/d + W_{\text{ads}}^0 \exp(-t/\tau_2) \phi(t) + W_{\text{sat}} [1 - \exp(-t/\tau_1)] [\phi(t) - \Phi_{\text{easy}}]. \quad (2)$$

From equation (2) an analytical expression for  $\phi(t)$  can be obtained:

$$\phi(t) = \Phi_{\text{easy}} \left/ \left\{ 1 + \frac{K_{22}/d + W_{\text{ads}}^0 \exp(-t/\tau_2)}{W_{\text{sat}} [1 - \exp(-t/\tau_1)]} \right\} \right. \quad (3)$$

Here  $W_{\text{ads}}^0$ ,  $W_{\text{sat}}$ ,  $\tau_1$ ,  $\tau_2$  are parameters found by fitting the experimental data.  $\Phi_{\text{easy}}$  is the angle characterizing the easy axis direction  $\mathbf{F}_{\text{easy}}$  induced by UV exposure in a particular experiment—the angle between  $\mathbf{F}_{\text{easy}}$  and  $\mathbf{L}$  directions, see figure 1(b).

Here we must emphasize that the  $\mathbf{F}_{\text{easy}}$  alignment direction differs markedly from the expected  $\mathbf{F}_0$ . It is not a surprising result because during the director reorientation there is a volume torque exerted on the LC director at the PVMC-surface which prevents it from being aligned along  $\mathbf{F}_0$ .

There are at least two possible mechanisms responsible for the phenomenon. Consider the first one which can be explained within the framework of the surface interaction potential. The surface interaction potential of a PVMC film in contact with a liquid crystal should have azimuthal asymmetry due to the interaction with the twisted LC medium. This means that, at least for the top PVMC surface layer, which is responsible for the LC alignment, the initial distribution of the photo-reactive bonds would differ from the azimuthally symmetric distribution in the bulk of the same PVMC film or at the interface of any irradiated PVMC film with air. In the latter, the selectivity of the photochemical polymerization reaction is defined by the UV polarization direction,  $\mathbf{P}_{\text{UV}}$ , and, as said above, results in the easy axis direction  $\mathbf{F}_0$  perpendicular to  $\mathbf{P}_{\text{UV}}$ . In the case of the interface between the PVMC film and a liquid crystal initially aligned along some direction not coinciding with  $\mathbf{F}_0$  (e.g. fixed by the rubbing direction  $\mathbf{R}$  of the opposite plate) the easy axis is induced in a compromise direction deviated from the expected one  $\mathbf{F}_0$  (toward, e.g.  $\mathbf{R}$ ). Thus, the corresponding twist angles  $\Phi_{\text{easy}}$  differ from  $\Phi_0$ .

The second mechanism can be considered in terms of the easy axis gliding. Imagine that, at the very beginning of the UV light exposure, the induced easy axis direction coincides with the expected  $\mathbf{F}_0$ . The amplitude of the induced azimuthal surface anchoring at this moment is very small for the corresponding surface torque to balance the exerted LC bulk torque. That is why the easy axis orientation would deviate (by gliding) from the expected direction  $\mathbf{F}_0$  to  $\mathbf{R}$ , to diminish the exerted bulk torque. With growing UV light-induced anisotropy of a PVMC film, the corresponding surface torque increases and at some moment (approximately corresponding to when the maximum birefringence is reached)

a new position of the easy axis direction  $\mathbf{F}_{\text{easy}}$  would be obtained, for which a balance of all torques involved is established. At present, we cannot distinguish between these two models but, fortunately, numerical fitting of experimental data with both models leads to the same values of anchoring energies. For the sake of simplicity we accept the first model.

In our experiments, the angles  $\Phi_{\text{easy}}$  were measured by polarization microscopy just after terminating the  $\phi(t)$  automated measuring procedure. A sample was set under a polarizing microscope with a crossed polarizer and analyser. The rubbed plate of the cell was fixed on the microscope stage with the rubbing direction along the polarizer direction. The UV-exposed PVMC-plate was rotated with respect to the fixed rubbed plate to reduce the observed twist until the full extinction position occurred. In this position the LC texture was untwisted planar, i.e. the UV-induced easy direction on the PVMC-plate coincides with the rubbing direction on the opposite plate, and the angle of the PVMC-plate rotation equals the angle  $\Phi_{\text{easy}}$ .

We have also checked the possibility of a virtual director deviation on the rubbed polyimide surface. This was done by a weak misalignment of the polarizer position around the extinction direction, and for all the UV-induced twist textures, within the experimental uncertainty of  $\pm 0.5^\circ$ , we observed no surface director deviation from the rubbing direction. So, in our experiments, the strong anchoring condition was indeed held on the rubbed polyimide surface.

Knowing  $\Phi_{\text{easy}}$  and the LC cell parameters ( $d, K_{22}$ ), the fitting procedure can be implemented and the azimuthal anchoring energy magnitudes obtained. The two typical fitting curves (dotted lines) calculated with formula (3) are shown in figure 4 with the corresponding experimental curves (solid lines) previously shown in figure 3 for  $\Phi_0 = 45^\circ$  and  $90^\circ$  and corresponding angles  $\Phi_{\text{easy}} = 37.5^\circ$  and  $78^\circ$  measured independently. The fitting parameters obtained are:  $W_{\text{sat}} = 22.5 \text{ merg cm}^{-2}$  and  $21.2 \text{ merg cm}^{-2}$ ,  $\tau_1 = 2.1 \text{ min}$  and  $32 \text{ min}$ ,  $W_{\text{ads}}^0 = 6.9 \text{ merg cm}^{-2}$  and  $7.0 \text{ merg cm}^{-2}$ ,  $\tau_2 = 3.0 \text{ min}$  and  $2.1 \text{ min}$ , respectively, for  $\Phi_0 = 45^\circ$  and  $90^\circ$ .

Thus, considering the evolution of the director reorientation at the PVMC/nematic interface as a result of a competition between two local azimuthal anchorings, the original surface anchoring (due to the adsorption memory of the initial bulk LC alignment) and induced anchoring (due to irradiation of PVMC-film with linearly polarized UV light), we succeeded in finding the magnitudes of the two azimuthal surface anchoring energies  $W_{\text{ads}}$  and  $W_{\text{UV}}$ . The first one is the adsorption part of the surface anchoring energy and characterizes the adsorption properties of the PVMC/LC interface, the second

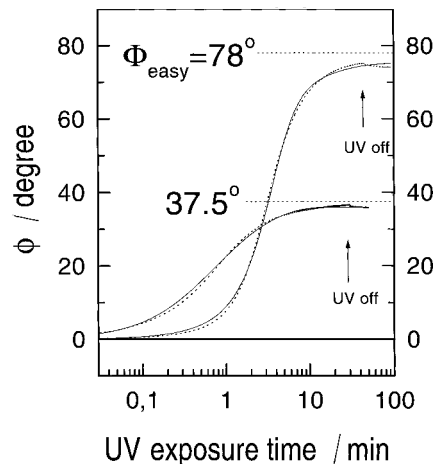


Figure 4. Typical fits for the two experimental curves (shown in figure 3) calculated with equation (3) for the angles  $\Phi_{\text{easy}} = 37.5^\circ$  and  $78^\circ$  (experimentally measured) and for the fitting parameters:  $W_{\text{sat}} = 22.5 \text{ merg cm}^{-2}$  and  $21.2 \text{ merg cm}^{-2}$ ,  $\tau_1 = 2.1 \text{ min}$  and  $32 \text{ min}$ ,  $W_{\text{ads}}^0 = 6.9 \text{ merg cm}^{-2}$  and  $7.0 \text{ merg cm}^{-2}$ ,  $\tau_2 = 3.0 \text{ min}$  and  $2.1 \text{ min}$ , respectively for  $\Phi_0 = 45^\circ$  and  $90^\circ$ .

is UV light-induced and characterizes the PVMC film ability to bind LC molecules under linearly polarized UV light illumination. As one can see from the fits, the adsorption part of the surface anchoring is not as weak as may be thought ( $\sim 7 \text{ merg cm}^{-2}$ ) and puts a technological limit for a weakest possible surface anchoring in this system.

As is seen from figures 3 and 4, the real onset of the director reorientation process for  $\Phi_0 = 90^\circ$  is considerably delayed from the beginning of UV light irradiation. The  $\Phi_0 = 90^\circ$  case is a special one due to its higher symmetry, and several authors [4, 5] have reported a threshold behaviour of the director reorientation in this situation. We have not observed true threshold behaviour for  $\Phi_0 = 90^\circ$ , perhaps, because of a divergence of the UV lamp beam which may break the full symmetry in our experiment. But the characteristic time constant  $\tau_1$  responsible for the time dependence of the UV-induced anchoring amplitude increased dramatically with respect to the other cases where  $\Phi_0 \neq 90^\circ$  (compare  $\tau_1 = 32 \text{ min}$  for  $\Phi_0 = 90^\circ$  and  $\tau_1 = 2.1 \text{ min}$  for  $\Phi_0 = 45^\circ$ ). This results in some time delay of the  $\Phi_0 = 90^\circ$  curve (a shift to the right along time axis in figure 3).

The other feature of the  $\Phi_0 = 90^\circ$  case is the appearance of the oppositely twisted domain texture of the LC. A polarizing microscope image of such a texture is shown in figure 5 (the right spot). All the other spots induced at different values of  $\Phi_0 \neq 90^\circ$  show perfect twist textures with a good contrast (see an example in figure 5, the left spot,  $\Phi_0 = 70^\circ$ ) and high time stability (at least, for several months).

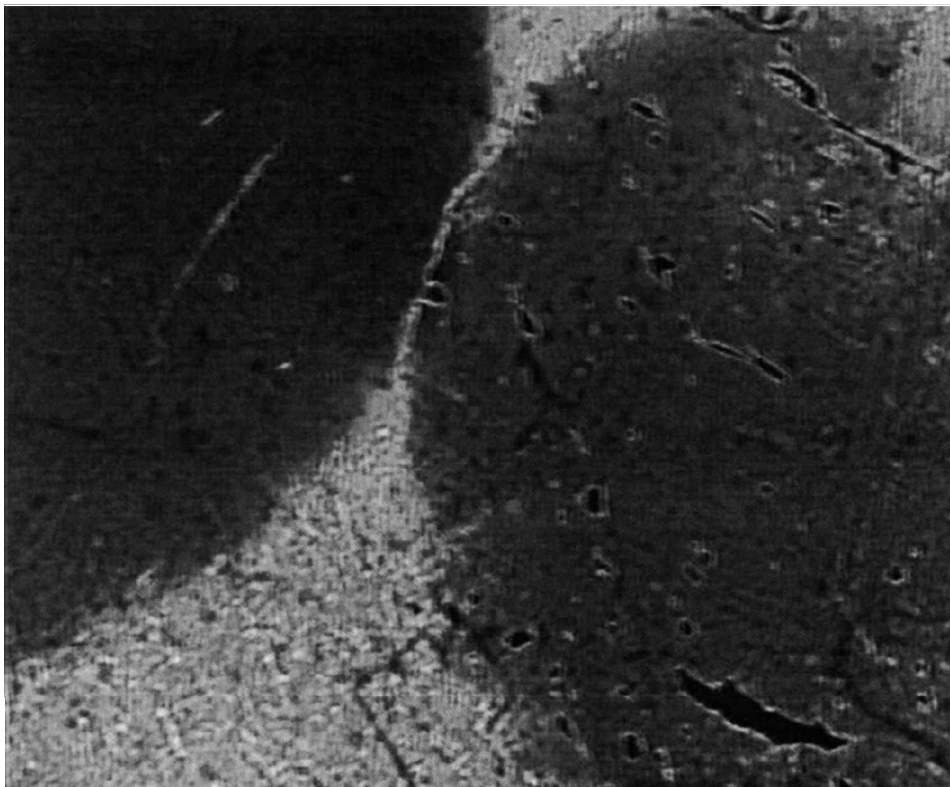


Figure 5. Images of two UV light-induced twist texture spots seen under the microscope. The rubbed AL1254-polyimide plate of the cell faced the polarizer with the rubbing direction parallel to the polarization direction of the polarizers. The analyser axis is uncrossed through  $70^\circ$  with respect to polarizer ( $\Phi_0 = 70^\circ$  for the left spot,  $\Phi_0 = 90^\circ$  for the right spot).

#### 4. Conclusions

The dynamics of the LC director reorientation at a nematic (E7)/PVMC-film interface exposed to linearly polarized UV light has been studied. The direction of the UV light-induced easy axis has been proved to be rotated from the normal-to-UV polarization direction due to a torque exerted by the light-induced twist in the bulk of the liquid crystal. The evolution of the director reorientation is described in terms of a competitive action between two surface anchorings: one due to the adsorption memory of the LC bulk alignment at the non-irradiated PVMC-surface; the other induced at the PVMC film surface by polarized UV illumination. The photo-induced azimuthal anchoring has been shown to reach values of  $\sim 20\text{--}23$   $\text{merg cm}^{-2}$ . The value of the adsorption part of azimuthal anchoring is of  $\sim 7$   $\text{merg cm}^{-2}$ , which means that a weaker azimuthal anchoring is hardly achievable in this system. The time of the director reorientation is controlled by a slow adsorption-desorption process and is of the order of an hour, while the birefringence-inducing time in the PVMC film under study is several seconds.

We are grateful to Dr S. P. Palto for useful discussions and PhysLab software; also to Mr V. Massaro for preparing SiO aligning layers. The work has been carried out in the framework of the Copernicus (grant no. IC15-CT96-0744) program, an INTAS program and INFN ‘Progetto Sud’.

#### References

- [1] GIBBONS, W., SHANNON, P., SUN, S.-T., and SWETLIN, B., 1991, *Nature*, **351**, 49.
- [2] GIBBONS, W., KOSA, T., PULFFY-MUHORAY, P., SHANNON, P., and SUN, S.-T., 1995, *Nature*, **377**, 46.
- [3] DYADYUSHA, A., MARUSHI, T., REZNIKOV, YU., RESHETNYAK, V., and KHIZHNYAK, A., 1992, *JETP Lett.*, **56**, 17.
- [4] VOLOSHCHENKO, D., KHIZHNYAK, A., REZNIKOV, YU., and RESHETNYAK, V., 1995, *Jpn. J. Appl. Phys.*, **34**, 566.
- [5] DYADYUSHA, A., MARUSHI, T., and REZNIKOV, YU., 1995, *Mol. Mat.*, **5**, 183.
- [6] BLINOV, L. M., 1996, *JNOPM*, **5**, 165.
- [7] WEST, J. L., WANG, X., KELLY, Y., and JI, J., 1995, *Proc. SID*, **26**, 703.
- [8] NISHIKAWA, M., TAHERI, B., and WEST, J., 1998, *Proc. SID*, **29**, 131.

- [9] CHEN, J., JONSON, D. L., BOS, P. J., WANG, X., and WEST, J. L., 1996, *Phys. Rev. E*, **54**, 1599.
- [10] MARUSHI, T., and REZNIKOV, YU., 1993, *Mol. Mat.*, **3**, 161.
- [11] SCHADT, M., SCHMITT, K., KOZENKOV, V., and CHIGRINOV, V., 1992, *Jpn. J. Appl. Phys.*, **31**, 2155.
- [12] PALTO, S. P., YUDIN, S. G., GERMAIN, C., and DURAND, J., 1955, *J. Phys. (Fr.) II*, **5**, 133.
- [13] SCHADT, M., SEIBERLE, H., and SCHUSTER, A., 1996, *Nature*, **381**, 212.
- [14] VORFLUSEV, V., KITZEROW, H.-S., and CHIGRINOV, V., 1997, *Appl. Phys.*, **A-64**, 615.
- [15] BRYAN-BROWN, G., and SAGE, I., 1996, *Liq. Cryst.*, **20**, 825.
- [16] SCHADT, M., 1997, *Mol. Cryst. Liq. Cryst.*, **292**, 235.
- [17] HASHIMOTO, T., SUGIYAMA, T., KATOH, K., SAITOH, T., SUZUKI, H., IIMURA, Y., and KOBAYASHI, S., 1995, *Proc. SID*, **24**, 877.
- [18] BARBERI, R., BOVENT, J. J., GIOCONDO, M., and IOVANE, M., 1998, *J. Appl. Phys.*, **84**, 1321.
- [19] BLINOV, L. M., and CHIGRINOV, V. G., 1993, *Electrooptic Effects in Liquid Crystal Materials* (New York: Springer).
- [20] BARBERI, R., GIOCONDO, M., and DURAND, G., 1992, *Appl. Phys. Lett.*, **60**, 1085.
- [21] BARBERI, R., and DURAND, G., 1997, *Handbook of Liquid Crystal Research*, edited by P. Collings and J. Patel (Oxford: Oxford University Press), p. 567.
- [22] BARBERI, R., DOZOV, I., GIOCONDO, M., IOVANE, M., MARTINOT-LAGARDE, PH., STOENESCU, D., TONCHEV, S., and TSONEV, L. V., 1998, *Eur. Phys. J.*, **B6**, 83.
- [23] MARUSHI, T., REZNIKOV, YU., VOLOSHCHENKO, D., and RESHETNYAK, V., 1994, *Mol. Cryst. Liq. Cryst.*, **251**, 209.
- [24] PALTO, S., BARBERI, R., IOVANE, M., LAZAREV, V., and BLINOV, L., 1999, *Mol. Mater.*, **11**, 277.