

# Anchoring and Alignment Behavior of Liquid Crystals on Poly(vinyl cinnamate) Thin Films Treated in Various Ways

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## ABSTRACT

Poly(vinyl cinnamate) was chosen as a model alignment layer material, and its thin films were prepared and treated by various combinations of rubbing and linearly polarized ultraviolet light exposure. The surface morphology and polymer segmental orientation of the treated films were investigated in detail. Moreover, anchoring and alignment behaviors of nematic liquid crystals in the treated film surfaces were examined. The measured anchoring and orientation behaviors have been attempted to be understood with taking into account the surface characteristics and the oriented polymer chain segments of the films and their specific interactions.

**Keywords:** alignment layer material, polymer segmental orientation, surface morphology, microgroove, liquid crystal, liquid crystal orientation, liquid crystal anchoring, anchoring energy, liquid crystal display,

## 1 INTRODUCTION

At present, a rubbing process using velvet fabrics is the only technique adopted in the liquid crystal (LC) display industry for the treatment of alignment layer film surfaces in the mass-production of flat-panel LC display devices. This process has become the method of choice because of it is simple and enables the control of LC alignment [1-8]. However, the process has some shortcomings, such as dust generation, electrostatic problems, and poor control of rubbing strength and uniformity. The search for new methods that do not suffer from the shortcomings of the rubbing process has led to the development of several approaches to polymer alignment layer surface treatment based on irradiation of the polymer with linearly polarized ultraviolet light (LPUVL) [9-13]. These techniques have attracted considerable attention in academia and industry because they offer the possibility of rubbing-free production of LC aligning films.

In this paper, we chose poly(vinyl cinnamate) (PVCi) as a model photoalignment layer material, and processed as thin films and further treated their surface with rubbing, LPUVL, and their combinations. For the surface treated films the surface morphology and the polymer chain segmental orientation were examined in detail. Moreover, with these treated films, a series of antiparallel and 90°-

twisted nematic (TN) LC cells were assembled and then the alignment and anchoring energy of LCs were determined. The observed LC alignment and anchoring energy were understood with considering the chemical compositions of the polymer and the LC molecule as well as the surface topography and the polymer segmental orientation in the films.

## 2 EXPERIMENTAL

PVCi solutions in chloroform were spin-coated onto gold-coated silicon wafers for AFM measurements, and onto indium tin oxide (ITO) glasses for optical retardation and LC alignment measurements, and LC cell assemblies. The resulting films were measured to have a thickness of around 100 nm, using a spectroscopic ellipsometer. The first set of films was rubbed using a laboratory rubbing machine. The second set of films was treated by LPUVL exposures. The third set of films was treated by various combinations of rubbing and LPUVL exposure. Surface images were obtained using a tapping mode atomic force microscope. Optical phase retardations were measured using an optical setup described elsewhere [8,9]; the laser beam was incident normal to the surface of the film, and the transmitted light intensity was monitored as a function of the angle of rotation of the film sample with respect to the surface normal.

With the surface treated films antiparallel and TN LC cells were assembled. In the LC cell assemblies, 4-*n*-pentyl-4'-cyanobiphenyl (5CB) [ $n_e$ (extraordinary refractive index) = 1.717 and  $n_o$ (ordinary refractive index) = 1.53] containing 1.0 wt% Disperse Blue 1 (a dichroic dye) was used as a nematic LC. All the prepared LC cells were found to be uniform and homogeneous throughout by optical microscopy. Azimuthal anchoring energy was measured by using an ultraviolet-visible (UV-vis) spectrophotometer equipped with two Glan-Laser prisms. UV-vis spectra were recorded at 0.8 cm<sup>-1</sup> resolution as a function of the angle of rotation of the analyzer in the range 0–180° with an interval of 1.0°. In these measurements, the rotation angles giving a minimum transmittance in the UV-vis spectra were determined. Of the rotation angles for which measurements were carried out, one angle was chosen by considering the nature of the birefringence dispersion of the LC and used for determining the twist angle at which the easy axes of the upper and lower substrates of the cell occur [5,7,8]. The

azimuthal anchoring energies of the LCs on the rubbed PI film surfaces were estimated from the twist angle using the optical parameters of the LC [5,7,8].

### 3 RESULTS AND DISCUSSION

The LPUVL-treated films showed very smooth surface; in contrast, the rubbed films reveal groove textures, which are commonly observed in other rubbed polymer films. The films treated with rubbing and LPUVL exposure in combinations showed a surface texture, which is similar to those observed in the rubbed films (Figure 1). Here it is noteworthy that the films treated with LPUVL exposure and subsequently rubbing revealed relatively smoother surfaces than those of the films treated with rubbing and subsequently LPUVL exposure.

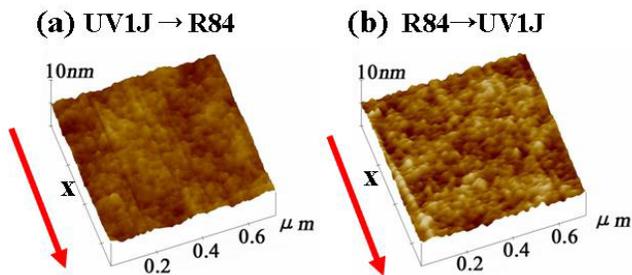


Figure 1: AFM height image of PVCi films treated with the LPUVL exposure and rubbing in the sequence and vice versa.

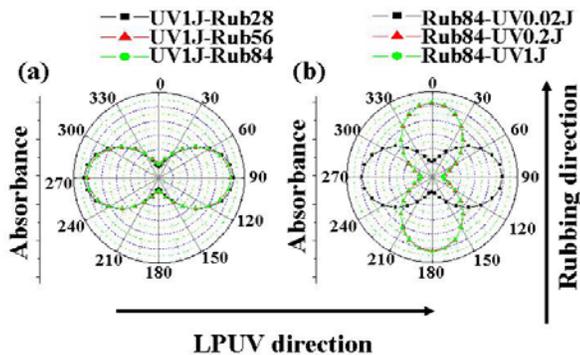


Figure 2: Polar diagrams of LC cell fabricated from PVCi film doubly treated by rubbing and LPUVL exposure.

Figure 2a shows the LC alignment director of LC cells in which the films were first irradiated to LPUVL at  $1.0 \text{ J/cm}^2$  and then rubbed with various rubbing strengths. All the LC cells show that the LC alignment director in the CL cell lies along the direction of  $90^\circ \leftrightarrow 270^\circ$ , which is same with that observed in the LC cells assembled with only rubbing treated films. These results provide important information on the LPUVL exposed and subsequently

rubbed films and their ability to align LC molecules as follows. The polymer chain and segmental orientation at the surface of LPUVL and rubbing treated film is governed by the last surface treatment process (i.e., rubbing), rather than by the overall history of the surface treatment processes. The oriented polymer chain and segments made at the film surface by the last surface treatment process control the LC alignment director, which can override the LC interactions with the microgrooves developed at the film surface.

Figure 2b shows the LC alignment director of LC cells in which the films were first rubbed with a rubbing strength of 84 and then irradiated to LPUVL at various exposure doses. In the LC cell, the LC alignment director depends on the surface treatment history. In case of the film first exposed to LPUVL at  $0.2 \text{ J/cm}^2$  and followed by the rubbing, along the direction of  $90^\circ \leftrightarrow 270^\circ$ , which is same with that observed in the LC cells assembled with only rubbing treated films. In this case, the LPUVL exposure dose is weak, and thus the LC alignment in the cell is governed by the first surface treatment process whose surface treatment strength is relatively much stronger than the LPUVL exposure. However, when the LPUVL exposure dose to the films was increased, the LC alignment in the LC cell is controlled by the last surface treatment process (i.e., LPUVL exposure).

Detailed data interpretations and discussions will be given with considering the film surface treatment sequences and process parameters, chemical compositions of LC and polymer, film surface topography, polymer segmental orientations, and LC interactions.

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