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UNIFORMITY IN BIAS TILT FOR NEMATICS ORIENTED BY POLYVINYL ALCOHOL SURFACE LAYERS

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ABSTRACT

Uniformity in bias tilt, for the polyvinyl alcohol(PVA)surface layer induced orientation of nematic liquid crystals, could be achieved for large area display panels, if one of the transparent electrodes is first directionally rubbed with fine abrasive; then both the electrodes coated with PVA, followed by directionally buffing the chemisorbed layers in the same direction. Uniformity may be due to increased 'train' configuration of the adsorbed macromolecule by falling on to microgrooves and maintaining the same sense of asymmetry for the looped segments.

INTRODUCTION

In the previous communications[1,2], we have reported that boundary surface layers of monomolecular polyvinyl alcohol deposited on transparent indium-tin oxide (ITO) electrodes induced parallel alignment of most available nematic liquid crystals with positive dielectric anisotropy. Twisted nematic liquid crystal (TNLC) displays, of larger area (typically 12 X 30 cm), prepared by this technique showed transient splitting of electrode segments when the applied voltage is turned on or off. This is due to the formation of field-induced domains arising from differences in bias tilt angles at ϕ and $-\phi$. Small amount of cholesteric additives did not eliminate the effect, suggesting that it has nothing to do with the chirality variations in different areas of the same panel. To prevent such domains, the bias tilt angle should be uniform so that the same sense of turn is maintained by the aligned molecules when field is turned on. As a further improvement to PVA orientation technique, we found that uniformity in bias tilt could be achieved if one of the transparent electrode surface is first directionally rubbed with fine abrasive, then coated with PVA, followed by buffing the adsorbed layer. The differentially treated electrodes is useful in assembling matix-addressed panels, since the electrode with the matrix does not require rubbing.

EXPERIMENTAL

One of the transparent electrodes, carrying the common electrode of the future display, is directionally rubbed with 0.5 to 1.0 μm grit-size diamond or corundum paste, with hand or by means of a motor-driven, velvet-coated cylinder. The rubbed electrode is thoroughly degreased, and cleaned in ultrasonic tank to free any adhering particles. It is immersed in 0.02% PVA solution containing 0.01% ethyl silicate for one hour. The counter electrode, possibly carrying the matrix, is dipped in dilute silica immersion bath (from E.Merck) for 55 minutes and subsequently in PVA solution for 5 minutes, after a short dry-up. Both the glass plates are blown dry with filtered, compressed air and dried at $120^{o}C$. The chemisorbed PVA layers are mechanically buffed with a Aramid cylinder. Care is taken to maintain the directions of buffing and the previous abrasive rubbing the same. Both the glass plates are further maintained at $180^{o}C$ for final curing. The polyimide thermoplastic sealant is screen-printed on the glass plates before the curing step. TNLC displays (8-15 μm thickness) are prepared by turning the two plates by 90^{o} with respect to the direction of buffing and sealed after drop filling. The orientation thus achieved is highly reliable and has tested life-time over 3 years (still working) using biphenyls as well as phenyl cyclohexanes. Heilmeier-Zanoni[3] type of guest-host cells are also prepared by the same technique, where anthraquinone dyes in cyanobiphenyls are used, without 90^{o} twist.

The critical step in achieving uniform bias tilt is the maintanance of the direction of abrasive rubbing identical to that of buffing the chemisorbed polymer layer. When the directions are antiparallel, nonuniformity in bias tilt appeared. Evenly scribbed ITO plates with PVA coating and subsequent directional buffing also resulted in poor uniformity in bias tilt. Both the electrodes of a given display can be directionally rubbed with fine abrasive, followed by PVA deposition and buffing to yield uniform bias tilt. However, matrix incorporated displays may have problems due to the possible damage of fine matrix elements during rubbing.

Methods for tilt angle measurements, adsorption studies using C^{14} marker and electrooptical investigations are identical to those in reference 2.

RESULTS AND DISCUSSION

From the experiments of Zocher[4] and Chatelain[5], it is known that directional rubbing of glass substrates induces planar alignment of nematics. However, directional rubbing alone does not yield reliable orientation since the alignment is dependent on fatty contaminants. Indeed, very clean scribbed glass plates often resulted in perpendicular orientation[6]. In the present series of experiments, directionally rubbed clean electrodes, without PVA adsorption always showed textured alignment (as in Fig.6a of reference 2). PVA chemisorption and subsequent buffing of the chemisorbed surface layer, alone leads to perfect planar alignment. These results suggest that on rubbed surfaces, chmisorbed PVA molecules are the one which bring about the alignment.

Initial rubbing with abrasive lowers the tilt angle(Fig.1). The diminusion in tilt angle is more pronounced for the electrodes which are immersed in PVA for longer duration. In a larger area panel (12 X 15 cm), the variation in bias tilt from area to area is within $\pm$ 0.15°. Adsorption studies using

C^{14} marked PVA showed that the amount of macromolecule chemisorbed on rubbed surfaces are lower than those of the untreated electrodes. It is reported[6-8] that directionally rubbed and etched surfaces generally induce planar alignment through physical mechanism, probably due to the existence of microgrooves. This is confirmed by the planar alignment noticed on the replica of rubbed surfaces by Dreyer[9]. Scanning electron microscope observations revealed the microgrooves on rubbed

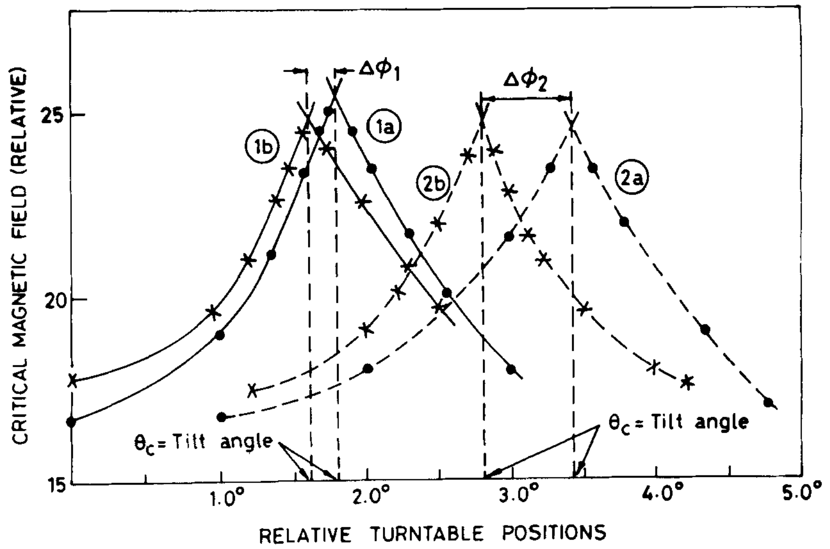

Fig.1: The effect of rubbing on bias tilt angle, measured by critical magnetocapacitance method. Curve 1(a) and 1(b) are of electrodes immersed in PVA for 5 min; 2(a) and 2(b) are of those immersed for 55 min. 1(b) and 2(b) are of rubbed surfaces. LC used is a mixture of cyanobiphenyls with aryl esters.

electrodes used in the present experiments.

The facts that the uniform bias tilt is obtained only when the directions of abrasive rubbing and that of chemisorbed layer buffing are the same and that the uniformity is lost when the two directions are antiprallel or when the scribbing is even (not directional), suggest that the microgrooves generated by directional rubbing cannot have symmetric depth profile ie. they may be slanting. Since the surface concentration of PVA on rubbed surface is lower when compared to that on similarly treated, but not rubbed, surface, the macromolecules may be aligning themselves along the microgrooves with increased 'train' segments and consequently the 'loop' segments are located further apart. When buffed in the same direction as of rubbing, the loop segments get titled and are fixed during curing through homolytic condensation. When the buffing direction is opposit, the loops located at the deeper part of the grooves remain more symmetric (Fig.2) while those on the shallower part become asymmetric due to more intimate contact with the buffing wheel. The orientation of nematic molecules, arising from steric, dipolar and dispersion effects, will not be spatially identical for loops of different symmetry. This will affect the uniformity in bias tilt angle of the oriented nematic cell.

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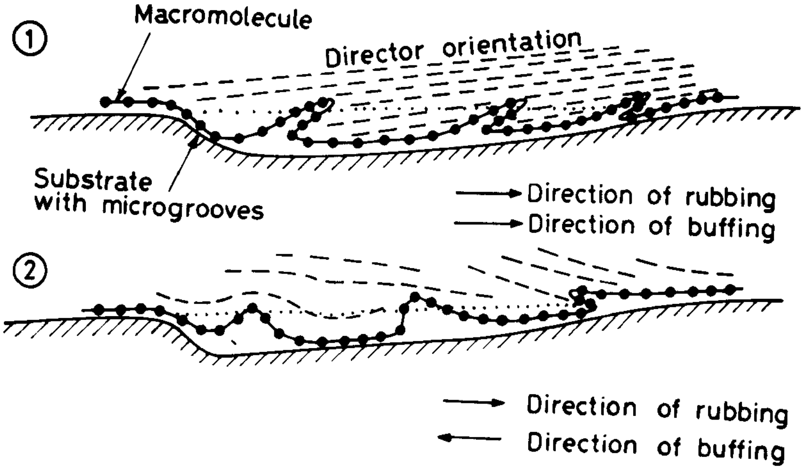

Fig.2: Schematic representation of adsorbed macromolecule on the substrate with microgrooves. The directions of substrate rubbing and the buffing of adsorbed PVA layer are (1) parallel; (2) antiparallel. The microgrooves are shown with asymmetric depth profile. For details see reference 2.

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