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TEMPERATURE DEPENDENCE OF POLAR ANCHORING STRENGTH OF NEMATIC LIQUID CRYSTAL ALIGNED ON RUBBED SIDE CHAIN LIQUID CRYSTALLINE POLYMER

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Abstract We have investigated the temperature dependence of the polar anchoring strength of nematic liquid crystal aligned homogeneously on glass substrates treated with side chain liquid crystalline polymer poly (4-cyanophenyl-4'-ethoxybenzoyloxy) acrylate (LCP100). The polar anchoring strength of rubbed LCP100 films is seen to be quite strong and comparable to that of rubbed polyimide films. The temperature dependence of orientational extrapolation length failed to show a critical divergence instead a very small increase on approaching the N-I transition. This indicates that the surface order parameter is quite strong and hence the polar anchoring energy weakens quite gradually.

INTRODUCTION

Of late, there has been a great deal of activities in the field of liquid crystal displays to understand the mechanism of surface mediated alignment of the liquid crystal molecules. It is generally known that a precise alignment of the liquid crystal (LC) molecule is very much essential for the optimal performance of the liquid crystal display (LCD) devices[1]. Various techniques[2-6] are in practice to achieve such defect free alignment of the LC molecules. Among these the most widely used method is the rubbing of the polymer and in particular the polyimide surface. It has been argued[7] that by rubbing the polymer surface, the chains are stretched along that direction and the optical anisotropy is induced. This not only helps in realizing the homogeneous alignment of the LC molecules but also in generating the pretilt angle (θ). A non-zero θ is indispensable for the efficient functioning of the LCD. In spite of the large amount of research efforts, the detailed mechanism of the rubbing technique in achieving the LC alignment is not yet fully

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understood. There has been quite a number of reports on the temperature variation of both θ[8-12] and the polar anchoring strength of nematic liquid crystal aligned on rubbed polyimide[13-15] and other[16-18] orientation layers.

Recently, we reported[19] that the rubbed surface of side chain liquid crystalline polymer (SCLCP) films can generate high pretilt angle and are capable of aligning LC molecules. In this paper we present the results of our investigation on the temperature dependence of the polar anchoring strength of nematic liquid crystal aligned on rubbed LCP100 films.

EXPERIMENTAL

Side chain liquid crystalline polymer LCP100 was obtained from Merck for the experiment. The chemical structure of LCP100 along with the transition temperatures is given in figure 1. Polymer was dissolved in Tetrachloroethane solvent. The polymer film was coated on indium-tin-oxide (ITO) coated glass substrates by spin coating the filtered polymer solution. The film was baked at 150°C for 30 minutes and then annealed for 4 hours at temperature very close to its clearing temperature. The polymer film was rubbed using a rayon cloth. 65μm thick spacer film was used to define the cell thickness in our test cells. We used commercially available liquid crystalline mixture (BL001) obtained from Merck and was injected into the cells.

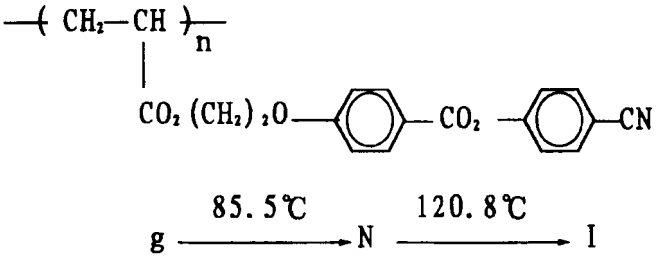

Figure 1. The chemical structure of side chain liquid crystalline polymer LCP100.

To estimate the polar anchoring energy, we used "high electric field technique."[16] A schematic picture of the experimental set-up is shown in figure 2. For evaluating the extrapolation length, a sinusoidal voltage was applied step by step from 0V to 100V. The

capacitance (C) and the optical phase retardation (R) were measured simultaneously as a function of the applied voltage (V). In the high voltage range R/R_0 is linearly related to 1/CV where R_0 is the optical phase retardation before the application of the voltage. To realize a good voltage range wherein this linear relationship is valid, we made use of thick cells. Lock-in amplifier was used to measure the cell capacitance and optical phase retardation was measured by rotating the analyser.

To ensure the quasi-equilibrium state, the voltage scanning rate was set precisely at each stage. Therefore it is very much necessary to carefully control the sample temperature over a long time. The sample cell was positioned inside a specially designed precision temperature controlled heater. During the measurements the temperature stability was better than ± 10 mK.

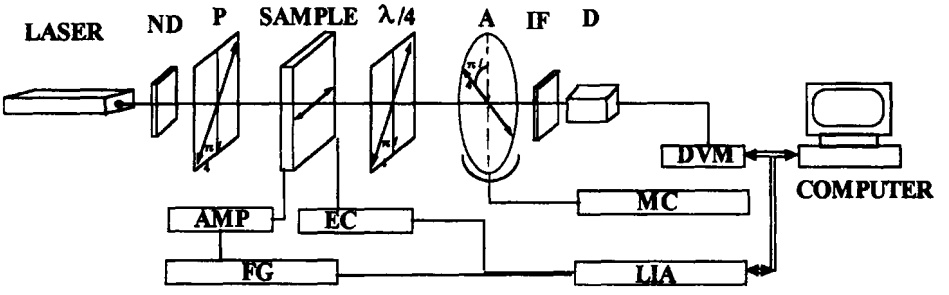

Figure 2. A schematic sketch of the experimental set-up. ND : neutral density filter, P: polarizer,A: analyser, IF: interference filter, D: photo diode, DVM: digital volt meter, MC:micro-controller,LIA:lock-in amplifier, FG: function generator, AMP- amplifier

RESULTS AND DISCUSSION

Figure 3 shows an example of the measured cell capacitance and retardation at room temperature as functions of the applied voltage. A clear Freedericksz transition can be seen occurring at the threshold voltage. Such clear Freedericksz transitions were observed at all temperatures. As can be seen from the figure 3, the retardation decreased continuously as the voltage was increased above the Freedericksz threshold. The change in the values of retardation was found to be reversible and no hysteric behavior was observed within the limits of experimental error. Capacitance value was found to increase continuously with the voltage and the rate decreased enormously at high voltages.

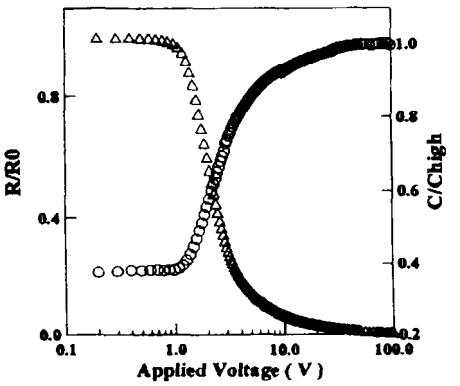

Figure 3. Typical changes in the values of capacitance (O) and retardation (Δ) with the applied voltage for the nematic liquid crystal BL001 between the rubbed LCP100 films.

At each temperature R/R_0 was plotted against 1/CV for V > 10V and then performed a linear least squares fitting of the data. The plots of R/R_0 versus 1/CV corresponding to three temperatures are shown in figure 4. The most notable feature in this diagram is that there is a good linearity in all the three plots. The extrapolation lengths (d_e) have been deduced from their intercepts with the ordinate axis. With the knowledge of the splay elastic constant (K_{11}), the polar anchoring energy, $E_a = K_{11}/d_e$, can be estimated. It is seen that the polar anchoring energy is found to be > $1x10^{-3}$ J/m^2. This value is quite comparable with that reported[18] for the rubbed

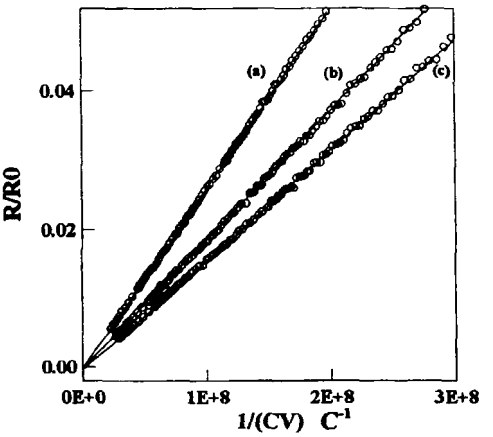

Figure 4. The plots of R/R_0 versus 1/CV for three different temperatures, (a)49.92, (b) 54.7 and (c) 56.97°C.

polyimide films and hence can be regarded as strong anchoring.

A plot of d_e as a function of temperature is shown in figure 5. Also shown for the sake of comparison is the data for the conventionally used polyimide PI AL5417. It is quite significant to notice that d_e only slightly increases but fails to show a divergent behavior near the N-I transition unlike in the case of obliquely evaporated SiO films. Moreover, away from the N-I transition, d_e is found to be smaller for a cell with LCP100 as the orientation layer than that for a cell with PI AL5417 films. In our previous publication[20] we have reported that the rubbed surfaces of LCP100 films generate higher pretilt angle than the rubbed films of PI AL5417. Hence it can be inferred that higher pretilt angle will lead to smaller values of d_e, a result in agreement with the earlier reports[13].

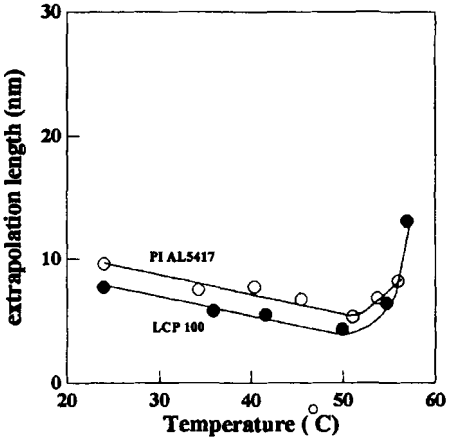

Figure 5. The temperature dependence of the extrapolation length for BL001 material aligned on rubbed orientation layers.

It should be remarked that Sugiyama et al.[13] have observed such non-divergent behavior of d_e near the N-I transition. They analysed the result based on the Van der Waals model. This model assumes d_e to consists of two parts- one,$d_e(1)$, related to the bulk order parameter and the other,$d_e(2)$, to the surface order parameter. They showed that $d_e(1)$ increases slightly while $d_e(2)$ decreases with temperature. Recently, Seo et al.[14] have measured the temperature dependence of the polar anchoring energy for rubbed PI-LB films with odd and even number of alkyl chain lengths. They found the anchoring energy to be more for even number of carbons. They attributed this to the relatively high

surface order. They associated the diverging behavior of d_e of 5CB on rubbed PI-LB films with odd number of carbons to the rapidly decreasing surface ordering near the clearing temperature. In the light of the above discussion, it is clear then that the rubbed surface of LCP100 must be possessing good crystallanity and the surface order parameter decreases slowly near the clearing temperature.

CONCLUSION

We have carried out a precise measurement of temperature dependence of d_e for the nematic liquid crystal molecules aligned on the rubbed surface of LCP100. The polar anchoring energy for the nematic material is found to be quite strong and comparable to that of the rubbed polyimide films. This is because of the relatively high surface ordering caused by the crystallanity of the rubbed surface. The LC orientation depends very much on the surface ordering of the orientation layers. As a result, the polar anchoring energy weakens quite slowly near the N-I transition.

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