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Preliminary Communication

Effects of the crystallinity of orientation film and mesogenic core of liquid crystals for pretilt angle generation on rubbed polyimide surfaces

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The effect of the crystallinity of polyimide (PI) and of the birefringence of the liquid crystal on pretilt angle generation in nematics on rubbed PI surfaces containing thiophenylene moieties has been demonstrated. The induced optical retardation produced in rubbed PI surfaces decreases on increasing the imidization temperature. We suggest that the pretilt angle of 4-cyano-4'-*n*-pentylbiphenyl (5CB) depends on the crystallinity of the rubbed PI. The order of pretilt angle in NLCs is 5CB > PCH5 ⩾ CCH5 at $RS \geqslant 150$ mm (medium rubbing) on rubbed PI surfaces. We suggest that on rubbed PI surfaces the pretilt angle increases with increasing number of phenyl rings in the NLC core.

Uniform alignment of liquid crystals (LCs) on treated substrate surfaces is very important in both fundamental research and technology [1]. Rubbing is the most widely used technique for LCs; however the detailed mechanism of LC alignment on rubbed PI surfaces is not yet fully understood. Pretilt avoids the creation of disclinations in LC devices. Pretilt is also very important in order to avoid stripe domains in supertwisted nematic LC displays (STN-LCD) [2] and in surface-stabilized ferroelectric liquid crystal devices (SSFLCD) [3]. Pretilt angle generation of the nematic LC (NLC) on alignment layers by unidirectional rubbing has been demonstrated and discussed by many investigators [4–16].

The influence of the crystallinity of the alignment layer on the bistability of the SSFLC is reported by Hartmann *et al.* [17]. The memory state of SSFLCs to small disturbing electric fields decreased when the degree of crystallization of nylon 6.6 alignment layers was raised. Takimoto *et al.* has reported X-ray studies of the degree of the crystallinity of PI films containing thiophenylene moieties as a function of imidization temperature [18].

Recently, we reported the effects of the mesogenic core of the NLCs on polar (out-of-plane tilt) anchoring energy and surface order parameter on rubbed PI surfaces containing thiophenylene moieties [19]. That the polar anchoring energy and surface order parameter depend strongly on the polarizability of the NLCs on rubbed PI surfaces has been demonstrated. However, the effect of the crystallinity of PIs on the NLC pretilt angle has not yet been investigated.

In this communication, we report the effects of the crystallinity of PI films and the birefringence of the NLCs (number of phenyl rings) on pretilt angle generation for three kinds of rubbed PI surfaces.

The polymer molecular structure (Japan Synthetic Rubber Co. Ltd.) is shown in figure 1. The precursors were coated on indium–tin oxide (ITO) coated glass substrates by spin-coating, and imidized at three different temperatures: 350°C (PI(1)); 300°C (PI(2)); and 250°C (PI(3)) for one hour. The PI films were rubbed using a machine equipped with a nylon roller (Y_0-15-N, Yoshikawa

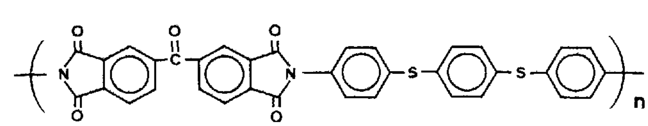

Figure 1. The polymer molecular structure.

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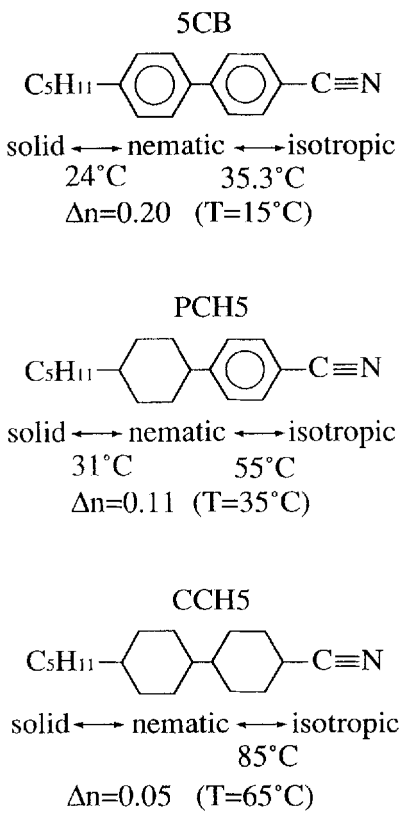

Figure 2. The molecular structure of the three nematic liquid crystals used.

Chemical Industries Co. Ltd.). The definition of the rubbing strength, *RS*, was given in previous papers [5, 7, 13]:

$$RS = NM(2\pi rn/v - 1) \quad (1)$$

where N is the number of times the substrate is rubbed ($N = 1$, in this work), M is the depth of the fibres of the fabric deformed due to the pressed contact (mm), n is the rotation rate of the drum ($166\,s^{-1}$), v is the translation speed of the substrate ($7{\cdot}0\,mm\,s^{-1}$), and r is the radius of the drum.

We used three kinds of NLCs having different mesogenic cores: 5CB, PCH5, and CCH5, with 3, 2, and 1 phenyl rings and birefringences of 0·19 (25°C), 0·11 (35°C), and 0·05 (65°C), respectively (see figure 2). The LC cell was assembled with antiparallel-rubbed surfaces. All the sandwich-type cells had a LC layer thickness of $60 \pm 0{\cdot}5\,\mu m$. The optical retardation measurement system is shown in figure 3. The light source was a He–Ne laser (632·8 nm) with 2 mW output power. The optical retardation measurement system consists of a polarizer, an acoustic modulator, an analyser and a photodiode detector. The pretilt angles of the LC media in the nematic phase were measured using the crystal rotation method [20]. The pretilt angles for the three NLCs were measured at a

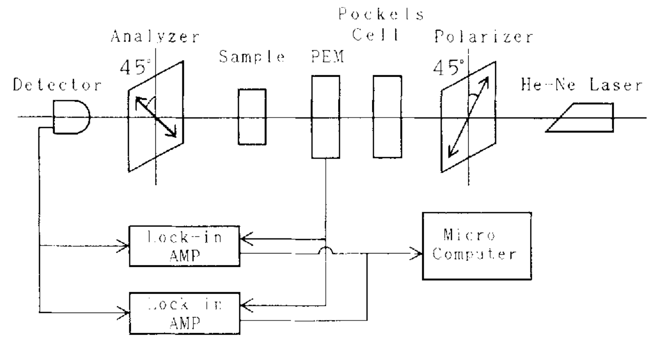

Figure 3. The optical retardation measurement system.

temperature 10° below the nematic–isotropic transition (T_{NI}) temperature.

Figure 4 shows the induced optical retardation produced in three kinds of rubbed PI imidized at different temperatures. It is evident that the induced optical retardation for all of the PI surfaces increases with the *RS*. We consider that the induced optical retardation increases with the *RS* on a PI surface, because of increased orientation of the PI polymer chains and expansion of the PI chain by rubbing. The induced optical retardation decreases with increasing imidization temperature. In a previous paper, the crystallinity of PI surfaces containing thiophenylene moieties was found to increase with increasing imidization temperature [18]. However, the induced optical retardation decreases with increasing imidization temperature on rubbed PI surfaces in this work. From these results, we considered that the induced optical retardation is related to the crystallinity of the PI in rubbed PI surfaces.

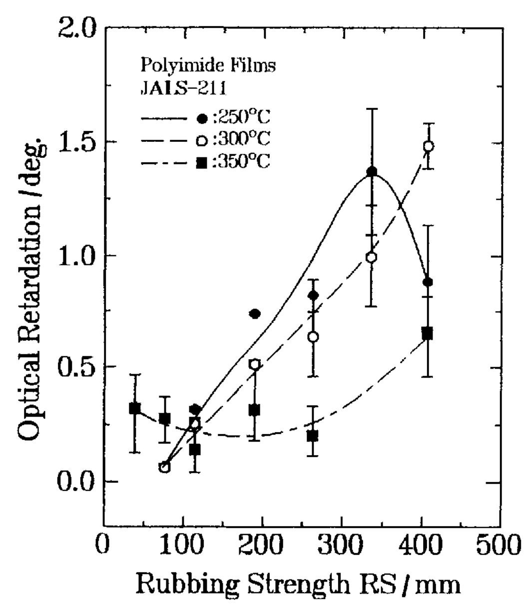

Figure 4. The induced optical retardation produced in the three rubbed PI films imidized at different temperatures.

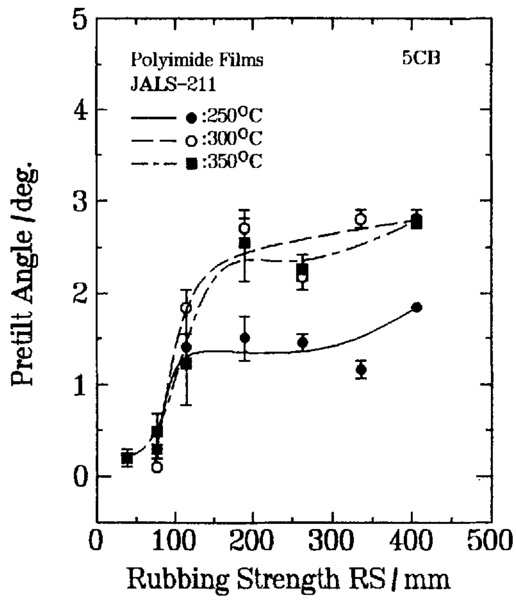

Figure 5. Pretilt angle of 5CB on the three rubbed PI surfaces imidized at different temperatures as a function of *RS*.

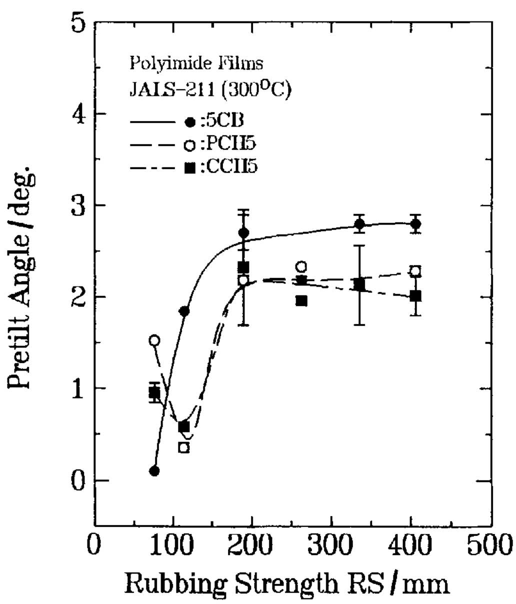

Figure 6. Pretilt angle for the three NLCs on rubbed PI surfaces imidized at 300° C as a function of *RS*.

Figure 5 shows the pretilt angle for 5CB on the three PI surfaces as a function of *RS*. The pretilt angles saturate with *RS* at above *RS* = 150 mm on all rubbed PI surfaces. The pretilt angle of 5CB increases with the increasing imidization temperature on rubbed PI surfaces. It is considered that the pretilt angle of 5CB on rubbed PI surfaces increases with the increasing crystallinity of the PI due to the higher imidization temperature. That is the crystallinity of PI on rubbed surfaces contributes to the pretilt angle.

The pretilt angles for the three NLCs on rubbed PI (2) surfaces imidized at 300°C are shown in figure 6. It is seen that the order of pretilt angle is 5CB > PCH5 ⩾ CCH5 on rubbed PI surfaces. The pretilt angle increases with the increasing number of phenyl rings of the NLCs. Since the birefringence of the NLCs increases with increasing number of phenyl rings we conclude that the pretilt angle on rubbed PI surfaces increases with increasing NLC birefringence.

In conclusion, we suggest that first the induced optical retardation produced in rubbed PI surfaces decreases with increasing imidization temperature; secondly the pretilt angle of 5CB is contributed to by the crystallinity of rubbed PI; thirdly the pretilt angle is strongly related to the number phenyl rings of the NLCs on rubbed PI surfaces.

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