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Preliminary Communication

Generation of high pretilt angles of nematic liquid crystal (5CB) on rubbed organic solvent soluble polyimide surfaces with helical backbone structure and trifluoromethyl moieties

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High pretilt angles of nematic liquid crystals (NLC) have been successfully generated on rubbed organic solvent soluble polyimide (PI) surfaces with a helical backbone structure and trifluoromethyl moieties. We have found that the pretilt angle of in 4-*n*-penty-4′-cyanobiphenyl (5CB) on rubbed PI surfaces with trifluoromethyl moieties attached to the lateral benzene rings is larger compared to that on rubbed PI surfaces with trifluoromethyl moieties attached to the polymer backbone. The observed pretilt angle of 5CB on unidirectionally rubbed PI surfaces with trifluoromethyl moieties attached to the lateral benzene rings is about 15 degrees in the wide rubbing region. From these results, it is expected that the microscopic surface structure of the polymer strongly contributes to the pretilt angle generation of the LCs at the surface.

Uniform alignment of liquid crystals (LCs) on treated substrate surfaces is very important for both fundamental research and technology [1]. To obtain the pretilted homogeneous LC alignment for most LC devices, various surface alignment layers, such as rubbed PI [2–9], obliquely evaporated SiO [10], PI–Langmuir–Blodgett (LB) film [11, 12], rubbed polystyrene (PS) [13], and polypyrrole (PP) [14] surfaces, are used. Although rubbing is the widely employed technique for LC alignment, the detailed mechanism of the LC alignment on these rubbed PI surfaces is not yet fully understood. The pretilt angle, which is a very important factor in the alignment process, prevents the creation of reverse tilt disclinations in LC devices. Nowadays, a high pretilt angle is required in order to prevent stripe domains in super twisted nematic LC displays (STN-LCD) [15] and for the proper operation of surface-stabilized ferroelectric liquid crystal displays (SSFLCD) [16]. Pretilt angle generation of NLCs by a unidirectional rubbing treatment on rubbed PI surfaces was demonstrated and has been discussed by many investigators [2–9, 17, 18].

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Previously, we have reported that the generation of a high pretilt angle of 5CB on rubbed PI surfaces containing trifluoromethyl moieties is caused by the fluorine (F) atoms, which was determined by measuring the surface atomic concentration of F/C (carbon) (per cent) by electron spectroscopy for chemical analysis (ESCA) [19]. Recently we also showed the effect of the polar anchoring strength in NLCs on rubbed PI surfaces containing trifluoromethyl moieties on achieving high pretilt angles [20]. It was demonstrated that the polar anchoring strength of 5CB with a high pretilt angle is very small due to the combination of the micro-surface excluded volume effect and the anisotropic dispersion force between the LCs and the weakly rubbed PI surfaces containing trifluoromethyl moieties.

More recently, we have reported the effects of the crystallinity of PI surfaces and the birefringence of the NLCs on the pretilt angle generation for three kinds of rubbed PI surfaces [21].

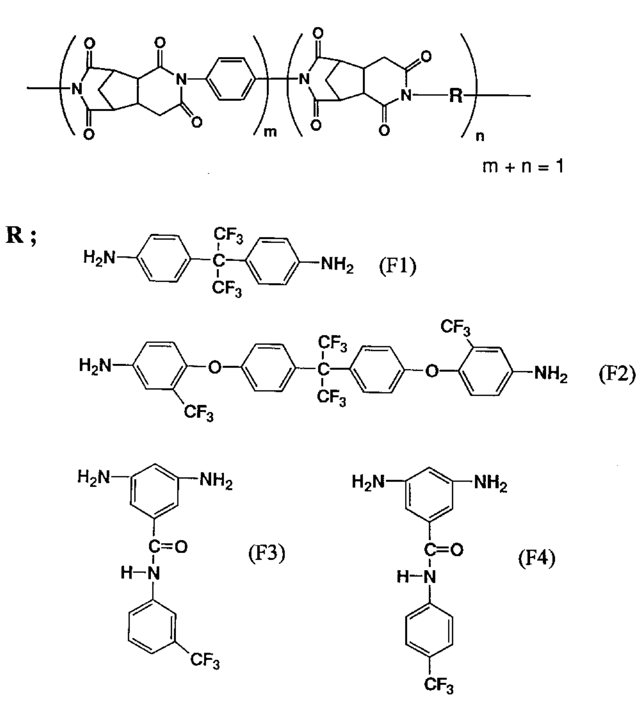

Figure 1. Molecular structures of the four polymers.

In this paper, we report on the generation of high pretilt angles of NLCs by unidirectional rubbing on organic-solvent-soluble PI surfaces with a helical backbone structure and trifluoromethyl moieties.

The molecular structures of the four polymer used in this study (Japan Synthetic Rubber Co., Ltd.) are shown in figure 1. Here F1 and F2 are polymers with trifluoromethyl moieties attached to the polymer backbone, and F3 and F4 are polymers with trifluoromethyl moieties attached to the lateral benzene rings. The precursors were coated on indium–tin oxide (ITO) prepared glass substrates by spin-coating, and imidized at 180°C for one hour. The PI films were unidirectionally rubbed using a machine equipped with a nylon roller (Y0-15-N, Yoshikawa Chemical Industries Co., Ltd.). The definition of the rubbing strength, *RS*, was given in previous papers [7, 11, 19], and it is given by

$$RS = NM\left(\frac{2\pi rn}{v-1}\right), \qquad (1)$$

where N is the number of times the substrates were 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 rotational speed of the drum ($1000\,\mathrm{rpm}^{-1}$), v is the translational speed of the substrate ($7{\cdot}0\,\mathrm{mm\,s}^{-1}$), and r is the radius of the drum.

Sandwich-type cells with a thickness of $60 \pm 0{\cdot}5\,\mu\mathrm{m}$ were assembled with the glass substrates keeping the rubbing direction antiparallel to each other. The pretilt angles of the LCs in the nematic phase were measured by the crystal rotation method [22] at room temperature. For the optical retardation measurements, a He–Ne laser (632·8 nm) with a 2 mW output power was used as the light source. The system consisted of a polarizer, an acoustic modulator, an analyser and the output signal was detected with a photodiode [5].

Figure 2 shows the variation of the pretilt angle of 5CB on four kinds of rubbed organic-solvent-soluble PI surface as a function of *RS*. The pretilt angle of 5CB is small on the F1 and F2 PI surfaces. It is clear that the pretilt angle of 5CB is small on rubbed PI surfaces with trifluoromethyl moieties attached to the polymer backbone. High pretilt angles of 5CB were obtained on the F3 PI surface. The pretilt angle saturates around $RS=50\,\mathrm{mm}$ and then decreases with *RS* on this rubbed PI surface. For medium values of *RS*, the pretilt angle is about 15 degrees and does not vary much. On the F4 PI surface, we obtained homeotropic alignment at all values of *RS*. This large pretilt angle of 5CB generated on the rubbed F3 and F4 PI surfaces is due to the trifluoromethyl moieties attached to the lateral benzene ring.

Figure 3 shows the measured optical retardation on the four unidirectionally rubbed PI surfaces as a function of *RS*. The induced optical retardation increases with *RS* for all four PI surfaces and is due to the increased orientation and stretching of the polymer chains caused by a mechanical stress arising from the rubbing process. The induced optical retardation on the rubbed PI surfaces with trifluoromethyl moieties attached to the lateral benzene rings is smaller than that on rubbed PI surfaces with trifluoromethyl moieties attached to the polymer backbone. We suggest that the smaller optical

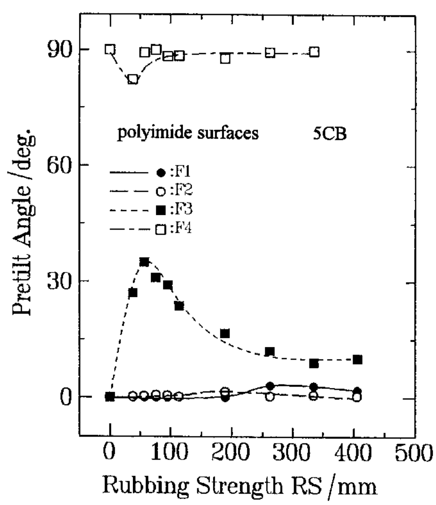

Figure 2. Pretilt angle of 5CB for the four rubbed organic-solvent-soluble PI surfaces as a function of *RS*.

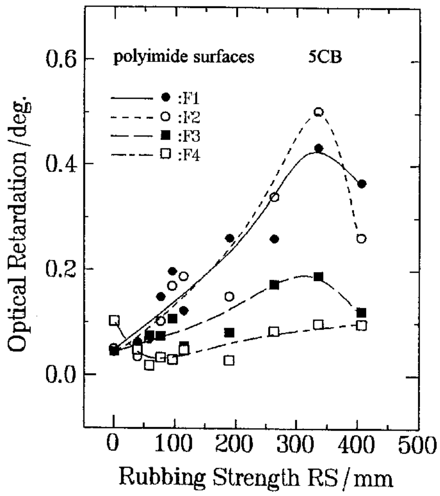

Figure 3. Induced optical retardation produced for the four rubbed organic-solvent-soluble PI surfaces as a function of *RS*.

retardation of the rubbed PI surfaces, where the trifluoromethyl moieties are attached to the lateral benzene rings, is observed to which the CONH moiety is oriented at a large angle relative to the polymer chain direction.

In conclusion, we have found that the pretilt angle of 5CB on rubbed PI surfaces with trifluoromethyl moieties attached to the lateral benzene rings is larger compared to that of rubbed PI surfaces with trifluoromethyl moieties attached to the polymer backbone. The observed pretilt angle of 5CB was about 15 degrees in the wide rubbing region on rubbed PI surfaces with trifluoromethyl moieties attached to the lateral benzene rings. Finally, it is expected that the microscopic surface structure of the polymer strongly contributes to this high pretilt angle generation of the LCs on the surface.

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