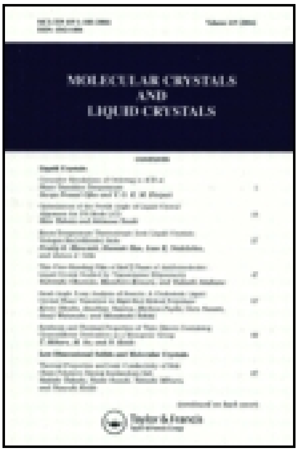

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PTFE DRAWN FILMS AS ALIGNMENT AGENTS FOR LIQUID CRYSTALS

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Abstract It has been reported that thin films of Poly-tetra-fluoro-ethylene (PTFE) deposited in a suitable manner will induce alignment in a liquid crystal[1]. These films are deposited in a one step dry process which offers advantages over polyimide or SiO_2 alignment layer application methods. Investigations of the effect of application conditions (pressure, temperature, deposition velocity) of this type of alignment layer on the quality of alignment in liquid crystals have been carried out. The surface pretilt angle induced in the liquid crystal by such an alignment layer has been measured and the PTFE films induce a low surface pretilt angle of the order of 1°. Some results of attempts to control this pretilt value by varying the conditions under which the alignment layer is deposited are presented. TN devices utilising PTFE alignment layers have been constructed and operating characteristics shown to be comparable to those for devices utilising commercially available polyimide alignment layers. There is a significant reduction in the threshold voltage of the PTFE aligned device as compared to that of a polyimide aligned device both having similiar slope characteristics.

INTRODUCTION

The quality of surface alignment is of utmost importance in the production of good quality liquid crystal devices. In most devices produced at present this is achieved through rubbed polymer coatings or evaporated SiO_2[1]. A technique for applying surface coatings has been investigated, in which the substrate is heated and passed at a constant velocity under a bar of PTFE which is held against the substrate with a constant force. The technique is based on the formation by friction of quasi monocrystalline substrates of PTFE. It is found that the long axes of the PTFE molecular chains align in a highly ordered manner along the direction of rubbing, which will induce alignment in a liquid crystal in contact with the substrate.

Wittman and Smith[2] have reported having successfully aligned nematic liquid crystal materials using surface films of PTFE applied in this way.

DEPOSITION METHOD

A machine has been constructed at Manchester to apply such films. The essential elements are a thermostatically controlled heated stage which carries the substrate in steps of ~1μm at velocities of up to 5mm/s and a gantry holding a piston arrangement which is used to hold a bar of PTFE against the substrate, see Figure 1.

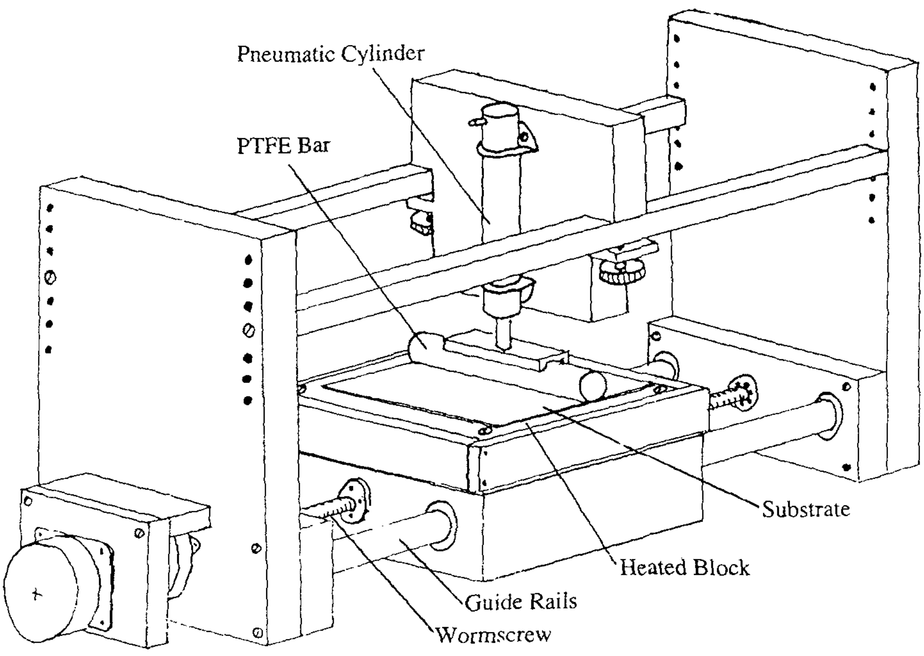

Figure 1 Schematic diagram of the PTFE deposition system.

Description of Apparatus

The heated block carrying the substrate runs on two high strength steel rails of circular cross-section. The table has four linear ball bushings set into it, and these run along the rails. In between these two rails runs a steel wormscrew. A nut is set into the table so that rotation of the screw causes the block to translate along the two rails as the screw is driven by a computer controlled stepper motor via a gearbox. This arrangement allows the table to be translated at speeds of up to $5mms^{-1}$.

The heated block was made from brass, since this has a high thermal conductivity ensuring an even temperature across the substrate. The block could be heated at a rate of up to 10°C/min and the maximum temperature obtainable was in excess of 200°C. The temperature of the block was stable to 0.2°C over the time taken to coat a typical substate (a few seconds) and to 1°C in the long term.

The PTFE bar was attached to the piston shaft of a double-acting pneumatic cylinder. The piston was driven by nitrogen at pressures of up to 60 psi allowing the PTFE bar to be rapidly applied to and removed from the surface of the glass, with a force dependant upon the gas pressure used.

In use the substrate to be coated is placed along one edge of the recess in the heated block, such that the relative motion of the PTFE bar maintains the position of the substrate against the recess. The substrate is moved at the desired rate, set by the stepping rate or the worm drive motor and gas pressure applied to the cylinder after 1-2mm of the substrate have passed under the edge of the PTFE bar. Gas pressure is applied to lift the piston before the edge of the substrate has been reached.

The cross section of the PTFE bar used in these experiments is shown in Figure 2. Figure 2(a) shows the profile of the bar as it was machined and Figure 2(b) shows the profile of the bar following a number of trials. The effects of temperature and pressure softened the bar and produced a more uniform surface with repeated use. As yet it is unclear how many depostion cycles at which temperatures and pressures, are required in order to 'run in' a new PTFE bar and investigation of the effect of other deposition conditions (temperature, pressure, velocity) could not practically be carried out during this running in period. In order to maintain consistency this initial assessment of deposition conditions has been carried out utilising the PTFE bar used during development to ensure as far as possible that is has been 'run in'.

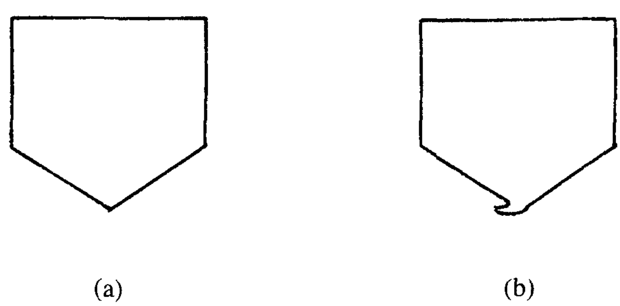

FIGURE 2 Cross section of the PTFE bar used for deposition (see text).

SURFACE CHARACTERISATION

Alignment Quality

As an intial assessment glass microscope slides were treated, varying the deposition conditions systematically. The nematic liquid crystal 5CB was then applied to the surface, and optical microscopy through crossed polarisers was used to assess the quality of alignment. Some of the slides showed alignment comparable with that obtainable using established techniques (eg rubbed polyimide). The best results appeared to be from slides prepared at temperatures between 100°C and 140°C, at speeds of between $1mms^{-1}$ and $2mms^{-1}$. Pressure did not seem to affect quality provided it was maintained above 20 psi.

Surface Pretilt

The surface pretilt of the PTFE films was measured optically using a modified version of the crystal rotation method[3]. For this assessments test cells were made up of nominally 50μm spacing, achieved through the use of chopped optical fibres, with anti-parallel PTFE alignment layers. A first set of measurements were carried out to evaluate films deposited at 75°C, 25 psi and substrate velocities between 0.25mm/s and 2mm/s. These cells were filled with the commercial mixture K15 and first measurements suggested that PTFE films could provide a small surface pretilt of the order of 1°.

The measured pretilts for these cells varied between 0.3° and 1.7°, though this would not appear to be systematic with deposition velocity. Though the quoted values are accurate for the region under test repeated measurements on these same cells also showed variations of the order of 0.5° depending upon the particular area measured. This was believed to be due to variations in the PTFE bar profile, which would lead to variations of the force between PTFE bar and substrate in different regions during deposition, which relates to the running in effects already observed and discussed above. Similar measurements of surface pretilt measured on layers deposited at 125°C showed greater uniformity and virtually no pretilt. With this further evidence it is believed that the surface pretilt observed with the lower temperature films is due to surface roughness effects[4] as will be discussed later.

TWISTED NEMATIC TEST DEVICES

In order to compare the properties of devices using PTFE alignment substrates with those with commonly used alignment agents, a number of TN cells were constructed. These consisted of two glass substrates with ITO electrodes and PTFE alignment layers, arranged so that the alignment directions were orthogonal. They were compared with a commercially available polyimide-aligned TN cell of the same thickness (7.5μm). Both types of cell were filled with a commercially available room temperature nematic mixture, E63 (T_{NI}=87.5°C) from BDH(UK) Ltd.

The transmission as a function of applied voltage of both devices was measured with the cell between crossed polarisers when driven with a 1kHz square wave. Graphs of intensity against applied RMS voltage are shown in figure 3. The difference in threshold voltage is quite clear at 1V and 1.5V for the PTFE and polyimide respectively, although the slopes of both curves at $V_{50\%}$ are virtually identical.

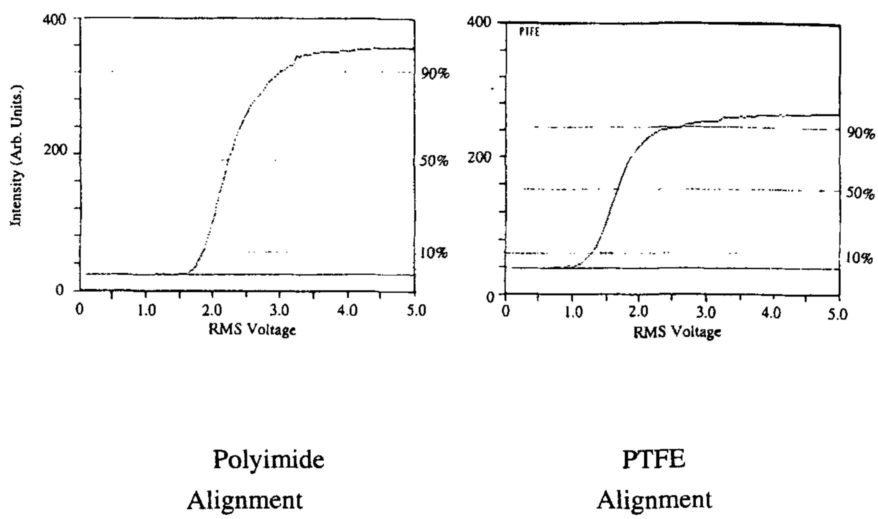

FIGURE 3 Transmission vs applied voltage for TN Cells, filled with E63, at room temperature (25°C)

DISCUSSION

Good quality alignment has been easily achieved over a significant area of several cm^2 and it is reasonable to expect that this technique could be applied to larger substrates (≈A4) with little difficulty. The cells examined thus far would suggest that at higher velocities (≈2mm/s) there is some variation in the PTFE deposition giving slightly degraded alignment. However, a useable film of PTFE is produced at velocities as high as 1mm/s. For practical purposes this would allow an A4 panel to be coated in around 30 seconds which compares very favourably with the multi-step and energy intensive processes required for rubbed polymers.

The TN cells we have constructed contained some domains of reverse twist. This has proven difficult to eliminate even when the sample is doped with a twisting agent. We believe the effect arises because the PTFE alignment layer induces negligible surface pretilt. It has been shown[2] that rubbed polymer alignment techniques will always induce a non-zero pretilt because the two-stage process of applying the polymer to the glass and then rubbing it means that the polymer chains can never lie in a plane parallel to the plane of the glass. The present technique aligns the polymer chains as it applies them and thus they must lie parallel to the plane of the glass, inducing the liquid crystal molecules to do likewise.

Ideally the process requires a bar machined specially to be free from surface defects, it has been confirmed that this can be achieved by machining along the length of the PTFE bar and running in.

Pooley and Tabor[6] found two distinct types of behaviour when PTFE is rubbed onto a surface. At low rubbing speed and high temperatures the PTFE has a very low coefficient of friction (m=0.05) and a thin layer of strongly oriented chains is deposited. This ranges from 30 to 200 Angstroms thick. At high speeds and lower temperature, m is about 0.3, and the PTFE is deposited in irregular 'packets' hundreds of Angstroms thick. These findings would further suggest that the observed pretilt with films deposited at lower temperatures are as a result of surface roughness.

Research by Meyer[6], found that speeds of the order of $1mms^{-1}$, temperatures of between 100°C and 150°C, and pressures of between 1 and 8 bar were optimum, with the pressure being the least important parameter. These results are consistent with those presented here, unfortunately the dimensions of the piston were not specified, so the force could not be related to that used in this study.

Electron microscopy studies showed that the surfaces thus produced were not molecularly smooth but stretched for considerable distances along the direction of rubbing.

PTFE falls within the group of materials having monoclinic or triclinic crystallographic structure required for good surface alignment of ferroelectric liquid crystals. It is to be expected therefore that such PTFE films would also give good quality FELC devices[7]. Our preliminary measurements, to be reported later, confirm this prediction using commercially available FLC mixtures.

CONCLUSIONS

An alternative technology for deposition of alignment layers for liquid crystals has been presented, this uses drawn films of PTFE to induce planar alignment. It has been demonstrated that these films may be applied to both glass and ITO coated substrates and that good quality alignment may be achieved.

The surface pretilt of nematic liquid crystals on such substrates has been investigated as a function of the conditions of deposition of the film. These studies would suggest that certain conditions will give a surface pretilt, possibly induced by surface roughness.

Twisted Nematic devices made using such alignment layers have been shown to have threshold characteristics comparable to those of similar devices using rubbed polyimide alignment layers. The threshold voltage for PTFE alignment layers has been observed to be significantly lower than that on polyimide coated substrates. Due to the crystallographic class of PTFE it is to be expected that such PTFE films would also give good quality alignment in FELC devices.

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