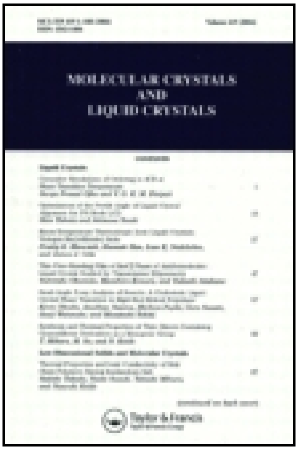

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Liquid Crystal Surface Alignment Treatment Giving Controlled Low Angle Tilt

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LIQUID CRYSTAL SURFACE ALIGNMENT TREATMENT GIVING CONTROLLED LOW ANGLE TILT

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ABSTRACT We report methods of simultaneous or sequential oblique evaporations of silicon monoxide at angles of 30° and 5° to glass substrates. These permit parallel homogeneous alignment of liquid crystals to be obtained concomitant with a controllable surface tilt angle of the director. The range of tilt angles obtained is from 0° to about 45° depending on the liquid crystal materials used. The low surface tilts obtained using these methods should be of use in producing improved twisted nemetic display devices.

INTRODUCTION

Liquid crystal alignment techniques employing obliquely vacuum evaporated silicon monoxide films have been reported by Janning(1) and Guyon et al(2). An extension of this method using coatings of magnesium fluoride has been demonstrated by Lowde and Raynes(3). It has been found that these methods give an alignment of the director along the evaporation direction and tilted at about 25° to 45°(4) to the surface of the coating if the evaporation is carried out at less than some critical angle (~15°) to the substrate. A typical evaporation angle is 5°. If the angle of evaporation is greater than this, then the coating so obtained aligns the director orthogonal to the direction of evaporation and with zero tilt to the surface. A typical evaporation angle in this case is 30°. In this paper we show that these methods can be combined to give alignment coatings in which the tilt angle of the director to the surface can be controlled to be anywhere within the range 0° to 45°.

METHOD

The controlled tilt alignment may be accomplished in two different ways. The coating may be produced by simultaneously evaporating from two different sources S_1 and S_2 as shown in fig 1.

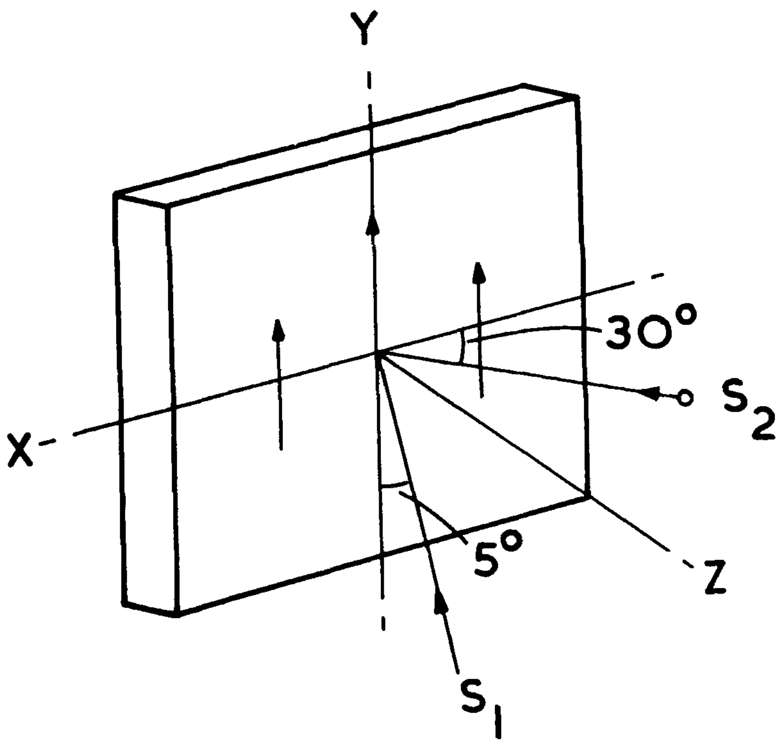
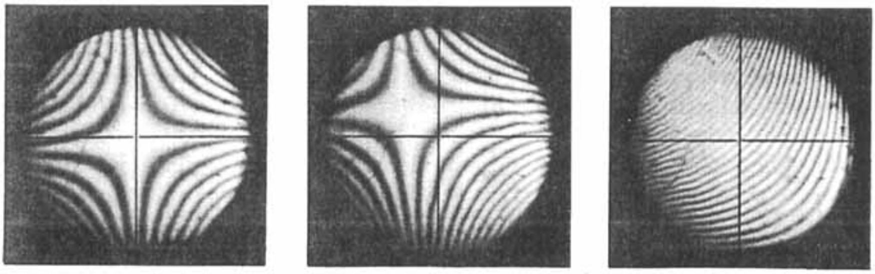


FIGURE 1. The geometric arrangement used in the simultaneous and sequential evaporation methods. S_1 and S_2 are the two sources used to evaporate silicon monoxide onto the substrate to give controlably, tilted, homogeneous alignment of the liquid crystal director parallel to the Y-axis.

The tilt is controlled by the relative amounts of the coating originating from the two sources and this may be effected by controlling the boat currents, the times of evaporation or the source to substrate distances. In the second method the coating is produced by first evaporating a coating from S_2 at an angle of about 30° to the substrate and then evaporating a second layer of SiO from S_1 at an angle of about 5° to the substrate. The methods of tilt control are the same as in the first case.

Our experiments were carried out in a vacuum system at a pressure of $<10^{-5}$ Torr with a 21" x 12" diameter bell jar containing two separate molybdenum boats located in the base in the appropriate positions. The heating currents through the boats were separately controllable and the distance of the substrate from the two sources was about 9 inches. The substrate was mounted on a specially made jig and was not deliberately heated in any way. The thickness of a number of coatings was measured and found to be of the order of 400 Å. The coated substrates were then assembled into 100 µm thick, parallel aligned cells filled with the nematic liquid crystal mixture E3* and examined in a Vickers polarising miscroscope with a conoscopic attachment. The surface tilt was estimated by noting the amount of displacement of the conoscopic figure from the centre of the field of view. The objective magnification was 40X.



(a) (b) (c)

FIGURE 2. Conoscopic figures obtained from 100 µm thick parallel aligned cells containing E3 and assembled using 100Ω/□ 'Hyviz' substrates evaporated with silicon monoxide at 5° and 30° incidence from S_1 and S_2 for 4 mins simultaneously. The boat currents were: a)S_1 - 100A; S_2 - 110A. b)S_1 - 105A; S_2 - 110A. c)S_1 - 110A; S_2 - 110A.

* Obtained from BDH Ltd, Poole, Dorset, UK.

The results obtained on 100Ω/□ 'Hyviz'* transparent electrode coatings can be seen, for small tilt angles < 15°, in fig 2 for simultaneous evaporations at different boat currents and in fig 3 for sequential evaporations at 30° and 5° for different times of evaporation.

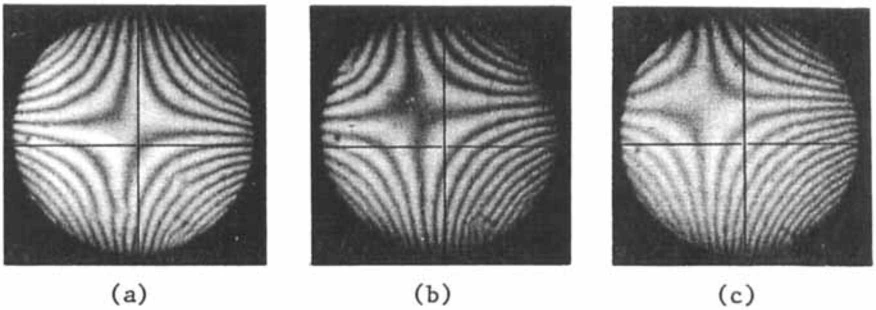


FIGURE 3. Conoscopic figures obtained from 100 μm thick, parallel aligned cells containing E3 and assembled using 100Ω/□ 'Hyviz' substrates evaporated sequentially with silicon monoxide at 30° and 5° incidence from S_2 and S_1 at boat currents of 100A. The times of evaporation were: a)S_2-4 mins, S_1-0.5 mins b) S_2-4 mins; S_1-1 min. c) S_2-4 mins, S_1-2 mins.

The centre of symmetry of the conoscopic figure moves from the centre of the field of view corresponding to the different evaporation conditions. Movement of the centre of symmetry to the perimeter of the field of view corresponds to a tilt angle of about 15° to 20°. Similar controlled tilt alignments can also be obtained on glass surfaces and these are shown in fig 4 for a cell comprised of etched plates of 'Hyviz' evaporated sequentially at 30° and at 5° for 3 mins and 2 mins respectively at a boat current of 100A. It can be seen that there is only a very slight change of tilt angle in going from a glass substrate to a tin oxide/indium oxide coated glass substrate. Large tilt angles up to ~45° have also been obtained using longer evaporation times or higher boat currents for the 5° source.

* Obtained from Triplex Ltd, Kings Norton, Birmingham, UK

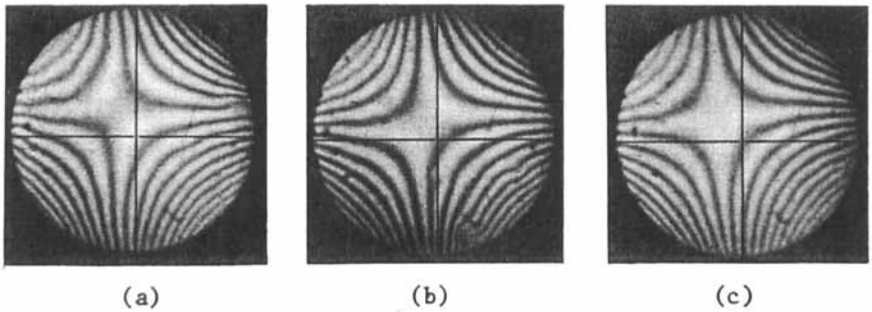


FIGURE 4. Conoscopic figures obtained from 100 μm thick, parallel aligned cells containing E3 and assembled using etched 100Ω/□ 'Hyviz' substrates evaporated sequentially with silicon monoxide at 30° and 5° incidence from S_2 and S_1 at boat currents of 100A for times of 3 mins (S_2) and 2 mins (S_1). The combinations of substrate surfaces were: a) glass and glass. b) glass and 'Hyviz'. c) 'Hyviz' and 'Hyviz'

DISCUSSION

These methods enable the production of homogeneously aligned liquid crystal layers with controllable surface tilts. They are quite repeatable and offer simple methods of achieving the controlled small tilts desirable in devices to give symmetrical viewing angles, sharper electrical thresholds, greater multiplexing capability and faster turn-off times. The sequential method is particularly attractive since only one source need be used and a much larger source to substrate distance is then possible thus reducing the angle subtended at the source by the substrate. This method has the advantage that since only one source may be used, the substrate can be rotated and altered in tilt relative to the source between the two sequential evaporations so that the single source occupies positions corresponding to S_2 and S_1 in the two evaporations. This may be accomplished, without bringing the bell jar up to atmospheric pressure, by means of an actuating mechanism or wires entering the vacuum chamber through appropriate seals. These methods should be of use in the manufacture of twisted nematic display devices and should allow a significant improvement in the optical properties of these.

CONCLUSIONS

We have demonstrated two distinct methods which allow parallel homogeneous alignment of liquid crystals to be obtained with a controllable tilt angle and we believe this to be of significance in producing improved twisted nematic display devices and shutters.

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