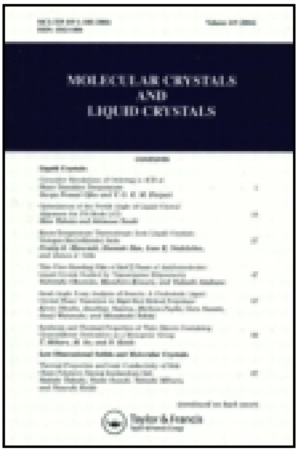

Molecular Crystals and Liquid Crystals Science and Technology. Section A. Molecular Crystals and Liquid Crystals
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/gmcl19

Investigation of Surface Torsional Anchoring Energy for Pure Nematic Liquid Crystals

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To cite this article: Sun Ruipeng , Huang Ximin , Jiang Min , Ma Kai , Wang Zongkai , Jing Hai , Yuan Jianfeng & Jin Changfeng (1995): Investigation of Surface Torsional Anchoring Energy for Pure Nematic Liquid Crystals, Molecular Crystals and Liquid Crystals Science and Technology. Section A. Molecular Crystals and Liquid Crystals, 265:1, 335-340

To link to this article: http://dx.doi.org/10.1080/10587259508041704

Mol. Cryst. Liq. Cryst. 1995, Vol. 265, pp. 335–340
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INVESTIGATION OF SURFACE TORSIONAL ANCHORING ENERGY FOR PURE NEMATIC LIQUID CRYSTALS

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Abstract By measuring the actual twist angle in the twist nematic liquid crystal cell and the surface torsional angle between the rubbing direction and the liquid crystal director at the substrate boundary, a new measuring method of the surface torsional anchoring energy for pure nematic liquid crystals has been given. The relation between the surface anchoring energy and the rubbing strength was studied. The intermolecular interaction between the polymer and liquid crystal is considered very important for the alignment of liquid crystals.

INTRODUCTION

The surface alignment of the nematic liquid crystal molecules on a treated substrate is an important and inevitable process for preparing experimental samples and practical devices. Rubbing is a simple method to obtain homogeneous alignment of liquid crystals. The investigation for the mechanism of the liquid crystal molecules orientation has always fascinated a lot of scientists,in which the surface anchoring energy is a key parameter in their studies[1,2]. This paper has given a new method of measuring the surface torsional anchoring energy of pure nematic liquid crystals without chiral materials,and studied the relation between the surface anchoring energy and the rubbing strength .

THEORY

Accoding to Frank elastic theory a liquid crystal is an elastic fluid and the state of the even and consistent alignment of the liquid crystal molecules is the state of the minimum of the bulk energy, that is the most stable state of liquid crystals. When the rubbing directions on the both substrats in the cell have a cross angle each other, the nematic liquid crystals injected in the cell also form a twist structure by the surface anchoring force. If the surface anchoring strength is weak, the direction of the surface orientation of liquid crystals deviates from the rubbing direction due to a spontaneous twisting elastic power of nematic liquid crystals. This deviated angle is determined by the balance between the twisting elastic power and the torsional anchoring energy, and from this angle the torsional anchoring energy can be calculated using the elastic theory.

In the twist liquid crystal cell, the free energy per unit area is obtained by the sum of the bulk elastic energy f_b and the surface energy f_s as follows:

$$f=f_b+2f_s \qquad (1)$$

where

$$f_b=(1/2)K_{22}(\Psi_a/d)^2d \qquad (2)$$

$$f_s=(1/2)E_T\sin^2\varphi_s \qquad (3)$$

Here, K_{22} is the elastic constant. d is the cell gap, E_T is the torsional anchoring energy, φ_s is the deviation of the director at the surface from the rubbing direction, Ψ_a is the actual twist angle of the director in the cell. The relation between Ψ_a and φ_s can be expressed by the following equation:

$$2\varphi_s=\Psi_r-\Psi_a \qquad (4)$$

where Ψ_r is the angle between the two rubbing directions on the both substrats.

The director orientation in the cell is obtained by minimizing of f, or $\partial f / \partial \varphi_s = 0$, which gives the torque balance equation as:

$$K_{22}(\Psi_a / d) = (1/2) E_T \sin 2\varphi_s \qquad (5)$$

From this equation the surface torsional energy can be expressed as:

$$E_T = (2K_{22}\Psi_a)/[d \sin(\Psi_r - \Psi_a)] \qquad (6)$$

Eq.(6) indicats that E_T can be measured if the cell gap, the actual twist angle and the angle between the rubbing directions in the cell are known.

The actual twist angle and the cell gap may be measured by experiments which had been described by Dr. A. Lien[3,4] used Jones optical propagation matrix. Fig.1 clearly illustrated the theoretical relation among E_T, Ψ_r, and φ_s

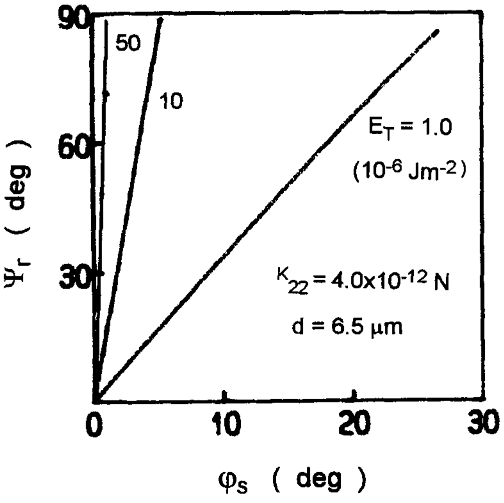

Fig.1 The theoretical relation among E_T, Ψ_r, and φ_s .

EXPERIMENT

In the experiments liquid crystal 5CB was used and the alignment is polyimide (which was suplied by Changchun Institute of Applied Chemistry, Chinese Academy of Sciences). The experimental cells were prepared 90° TN cells ($\Psi_r=\pi/2$). The measuring system of the twist angle and the cell gap was illustrated in the references [3] and [4]. The rubbing strength parameter $\mathfrak{R}$ was expressed as following:

$$\mathfrak{R} = Nlrn/(60v)-1 \qquad (7)$$

where l, N, r, n, and v stand for the depth of the distorted portion of the fabric on a rubbing machine, the repeated times of the rubbing, the radius of the drum, the rotation rate of the drum, the translating velocity of the substrate, respectively.

RESULT AND DISCUSSION

Changing the rubbing strength, using eq.(6), we measured the surface

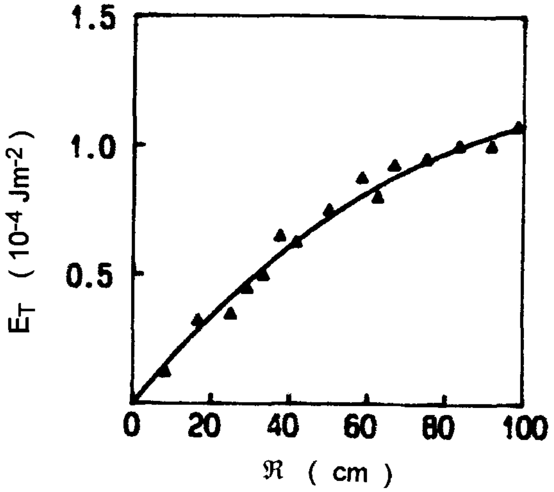

Fig.2 The relation between E_T and $\mathfrak{R}$

anchoring energy E_T. Fig.2 shows the experimental result. It indicate the surface torsional anchoring energy is increased with increasing the rubbing strength. The value of E_T can be reached to 1.1×10^{-4} Jm^{-2} at $\Re = 100$ cm.

Based on the above experimental results, the intermolecular interaction strength between the polymer and liquid crystal[5] is considered more important for the alignment of liquid crystals on the rubbed surfaces. With increasing the rubbing strength, the orientational degrees of the polymer chains along the rubbing direction is raised and the polar direction of the ionic groups of the polymer draws up in better order, so that the surface anchoring energy is also increased. When the orientation of the polymer chains are consistent, the intermolecular interaction between the polymer and liquid crystal is the largest and it means that the surface anchoring energy is the largest at the same time, which doesn't change with increasing rubbing strength. The experimental results are difficult to explain by the microgrooves theory which given calculated results are two orders less than the experimental results of the surface anchoring energy[6].

CONCLUSIONS

The paper has given a new measuring method of the surface torsional anchoring energy for pure nematic liquid crystals. Using this method, the relation between the surface torsional anchoring energy and the rubbing strength was given. It indicates, for polyimide, the surface torsional anchoring energy is increased with increasing the rubbing strength and it may be reached to 1.1×10^{-4} Jm^{-2} when rubbing is the most strong. The intermolecular interaction between the polymer and liquid crystal is considered more important for the alignment of liquid crystals on the rubbed surfaces.

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