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## Liquid Crystals

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## Aliphatic polyimides as alignment layers for surface stabilized ferroelectric smectic C liquid crystal cells

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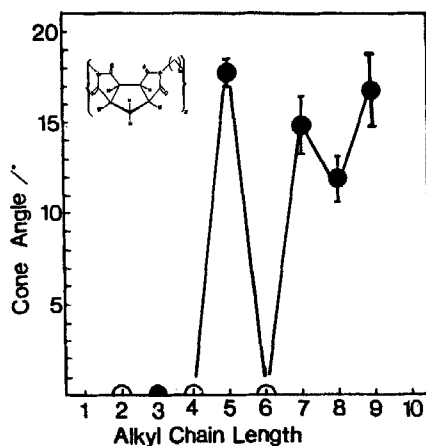
Eight aliphatic polyimides have been synthesized and tested as alignment layers for surface stabilized ferroelectric liquid crystals with a number of room temperature ferroelectric mixtures. The cone angles are used as a quantitative measure of the bistability obtained in these cells. The effect of the structure of the polyimides on the cone angles obtained is discussed. It is shown that the structure of the polymer alignment layer strongly influences the cone angle found between the relaxed states in a surface stabilized ferroelectric liquid crystal cell. Highly crystalline polymers give a larger cone angle than less crystalline homologues.

### 1. Introduction

The surface stabilized ferroelectric liquid crystal display (SSFLC) [1] provides the possibility of fast switching electro-optic elements and flat panel displays with a high information content. In addition to the fast switching, the bistability possible with the SSFLC is an attractive feature, and opens the possibility for an extremely high number of lines with multiplex drive. The bistability is a quality which has been difficult to achieve, and which seems to depend as much on the surface of the cells [2-4] as on the ferroelectric smectic phase.

The contrast between the two states in a bistable cell depends both on the dark state and the bright state transmission. The dark state transmission is largely dependent on the number of defects in the cell. This transmission can be easily made to lie below 0.5 percent by careful cell preparation together with correct polarizer orientation. Having minimized the dark state transmission, the transmission of the bright state will depend mostly on the angle between the director in the two stable states, the cone angle. We believe this angle to be a good way of quantifying the bistability as it disregards the effect of cell manufacturing technology which is often included when only contrasts are quoted.

We have previously used the angle between the two relaxed states as a measure of the bistability and found that this angle seems to depend on the crystallinity of the polymer used as alignment layer [5, 6]. For alkylaromatic polyimides with a flexible tetra-carboxylic acid moiety we found that both polyimides with an even number of carbon atoms in the alkyl chain and polyimides with an odd number of carbon atoms in the alkyl chain gave good results. For polyimides with a rigid tetra-carboxylic acid group and the C(alkyl)-N bonds collinear only those with an even number of carbon atoms in the alkyl chain gave good results. This can be explained using a simple picture in which the alkyl chains exist in their most out-stretched, all-trans conformation. For an odd number of carbon atoms the alkyl chains will be bent and there are difficulties in achieving good packing of the polymer chains comprising bent alkyl groups and linear aromatic segments. In contrast, an even number of carbon atoms



Cone angles found with polyimides synthesized from *cis,cis,cis,cis*-1,2,3,4-cyclopentane tetracarboxylic acid anhydride and different diamino alkanes as alignment layers in SSFLC cells as a function of alkyl chain length. Open symbols indicate that only focal conical alignment could be obtained.

gives linear alkyl groups and the packing of these with linear aromatic groups seems easy.

To test this simple model a series of polyimides with a bent tetra-carboxylic moiety was synthesized and tested as alignment layers for surface stabilised ferroelectric liquid crystal cells. The tetracarboxylic acid chosen is *cis,cis,cis,cis*-1,2,3,4-cyclopentane tetracarboxylic acid anhydride. The cyclopentane ring is almost flat, but the four carboxylic groups are on one side of the plane, thus the molecule as a whole is bent markedly. With the alkyl chain in an all *trans* conformation, which is usually found in crystals, there will be two differing situations depending on the number of carbon atoms in the alkyl chain. With an even number of atoms in the chain the cyclopentane moieties will be alternating above and below the axis along the chain, and the polymer as a whole will have a wave-like shape. With an odd number of atoms in the alkyl chain all the cyclopentane moieties are on the same side of the axis and the polymer as a whole will be closer to linearity. The structure of the polymer is shown in the figure.

## 2. Experimental

### 2.1. Synthesis and cell preparation

*cis,cis,cis,cis*-1,2,3,4-cyclopentane tetracarboxylic acid anhydride (Janssen Chimica), 1,2-diaminoethane, 1,3-diaminopropane, 1,4-diaminobutane, 1,5-diaminopentane, 1,6-diaminohexane, 1,7-diaminoheptane, 1,8-diaminooctane and 1,9-diaminononane (all from Aldrich) were used without further purification.

Equimolar amounts of the diamine and tetracarboxylic acid anhydride were reacted in dimethyl acetamide or dimethyl formamide at room temperature in a conventional manner [7].

### 2.2. Measurements

Our cell construction and experimental set-up for the electro-optic measurements has been described in detail in a previous communication [6]. Each polymer was tested

using ZLI-3774 (E. Merck) and one or more additional room temperature smectic C\* mixtures. All of them possess the isotropic–cholesteric–smectic A–smectic C\* phase sequence with a long pitch near the cholesteric–smectic A transition. All gave almost identical results for the cone angle in accordance with our previous results [6], thus only average values for the different experimental room temperature mixtures will be discussed.

### 3. Results and discussion

The cone angles found for the different members of the polyimide series are shown in the figure. As can be seen, there is a marked odd–even effect, for polymers with intermediate alkyl chain lengths. For this series, however, the polymers with an odd number of carbon atoms in the alkyl chain gives the best results, while even numbered alkyl chains were the best when the tetra-carboxylic acid moiety was linear.

Polyimides with two, four or six carbon atoms in the alkyl chain do not give well oriented samples, and focal conical textures are observed. The regularity of the odd–even effect is much less pronounced here than in the previously studied polyimide series [5]. In particular the polyimide with a three carbon alkyl chain gives a much poorer result than expected and no longer term bistability, while the polyimide with an eight carbon alkyl chain gives somewhat higher cone angles than expected. It seems clear that the flexibility of the alkyl chain plays an important part in the exact packing achieved and hence the crystallinity of the alignment layer. Thus although the importance of good crystallinity of the polyimides is shown, it is also clear that the prediction of the degree of crystallinity from the chemical structure of the polyimide is difficult.

### 4. Conclusions

It is shown that the structure of the polymer alignment layer will strongly influence the cone angle found between the relaxed states in an SSFLC cell. It is confirmed that highly crystalline polymers give a larger cone angle than less crystalline homologues.

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