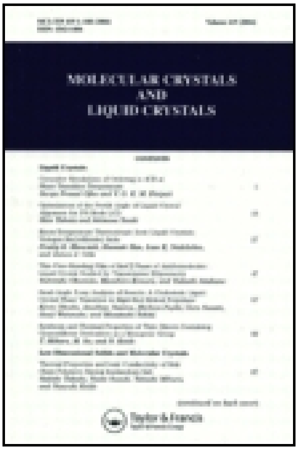

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Synthesis and Physical Properties of a Novel Difluoroterphenyl Ferroelectric Liquid Crystal with a Fluorine at the Chiral Centre

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Synthesis and Physical Properties of a Novel Difluoroterphenyl Ferroelectric Liquid Crystal with a Fluorine at the Chiral Centre

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This paper details the synthesis and mesomorphic properties of a novel SmC*-forming liquid crystalline compound with potential applications in fast-switching multi-component ferroelectric mixtures. The material (NG158) possesses a difluoro-substituted *p*-terphenyl core and a fluorine at the chiral centre. The spontaneous polarisation at frequencies of 20Hz and 50Hz, tilt angles and switching speeds, are also reported.

Keywords: Ferroelectric; mixtures; fluorine

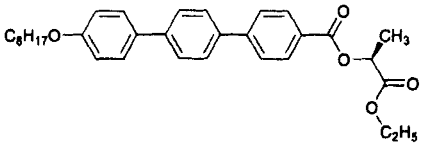
INTRODUCTION

Liquid crystals possessing the ferroelectric SmC* phase are being increasingly accepted as the materials of choice for the next generation of fast electro-optic devices[1]. These materials possess a number of attractive properties that make them particularly suitable for full-colour high-resolution display devices (fast response times, bistability, good contrast and excellent viewing angles)[2].

By far the most practical technique for obtaining materials with the most suitable properties, for use in any twisted nematic-based device, is the combining of individual liquid crystalline components to form mixtures[3]. In order to exploit the ferroelectric SmC* phase in a similar manner[4], individual materials with wide SmC* phases, good switching characteristics, low viscosities and a reasonably large spontaneous polarization are required.

Tailoring these mixtures to further enhance these properties, and moreover lower their viscosities, can be achieved by replacing individual components in present mixtures with those that have the more preferred properties.

Derivatives based on the *p*-terphenyl core, such as the material shown in Figure 1, have been widely used in both multi-component chiral and chiral-dopant mixtures[5].



K 127 SmC* 158.5 SmA* 180.2 I (°C)

FIGURE 1 An example of a *p*-terphenyl-based material used in ferroelectric mixtures

The aim of this work was to synthesize a novel liquid crystal NG158 (Figure 2), with a difluoro-substituted *p*-terphenyl core and a fluorine at the chiral centre, and to determine its suitability as a component for ferroelectric mixtures for use in electro-optic devices. The material is structurally tailored as a co-dopant for use with the low viscosity difluoroterphenyl hosts favoured for τV_{min} FLC mixtures[6]. It was postulated that the fluorine at the chiral centre would give the material a reasonably high spontaneous polarization. Tilt angles and switching speeds were also measured.

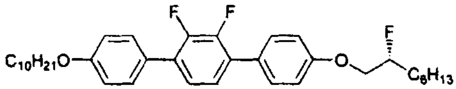
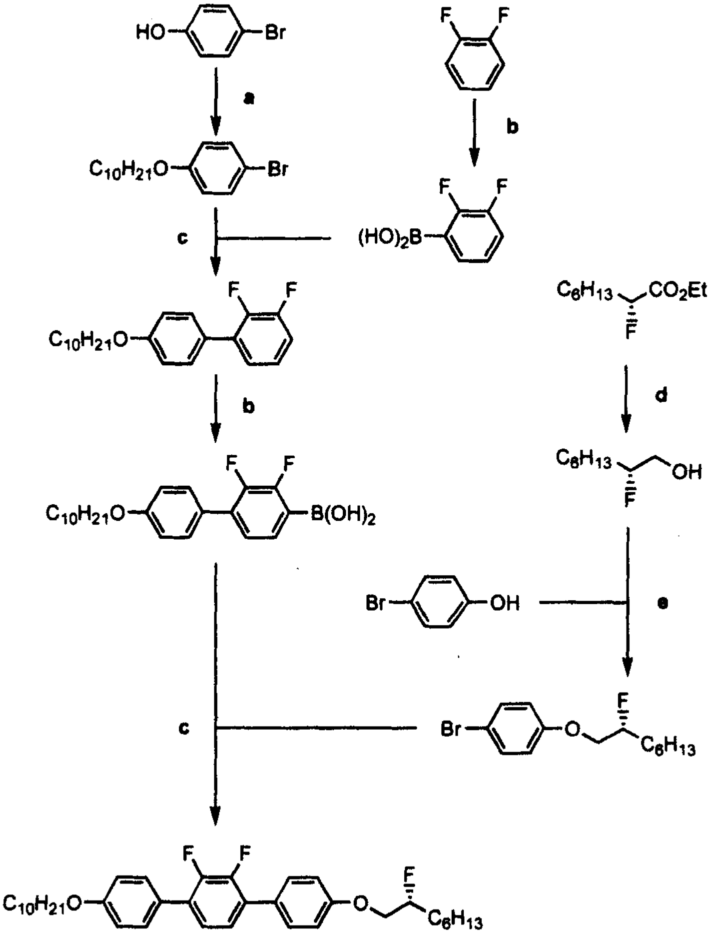


FIGURE 2 NG158

RESULTS AND DISCUSSION

Synthesis

The compound was prepared according to the synthesis outlined in Scheme 1.



NG158

Reactions and reagents used in the preparation of NG158:

a...$CH_3(CH_2)_9Br$, Na_2CO_3, acetone.
b...i) nBuLi, THF, -76 °C, ii) $B(OMe)_3$, -76 °C, iii) 10% HCl.
c...$Pd(PPh_3)_4$, 2M Na_2CO_3, MTBE.
d...$LiAlH_4$, THF.
e...DEAD, PPh_3, Et_2O.

SCHEME 1

Mesomorphic Properties

The transition temperatures of the material were determined by optical microscopy and verified by DSC. The phase sequence of the material is as follows;-

K 88.6 SmC* 144.1 SmA* 154.9 N* 157.3 BPI 157.8 I (°C)

The material possesses the greater part of preferred phase sequence on cooling for alignment in a display device (N* - SmA* - SmC*). No ordered phases (SmI*, SmF* etc.) were observed in the material; this was more-than-likely due to the inhibiting steric effect of the lateral fluorines on the central phenyl ring.

The photographs below (Figures 3 and 4) show two of the textures observed on cooling from the isotropic liquid;

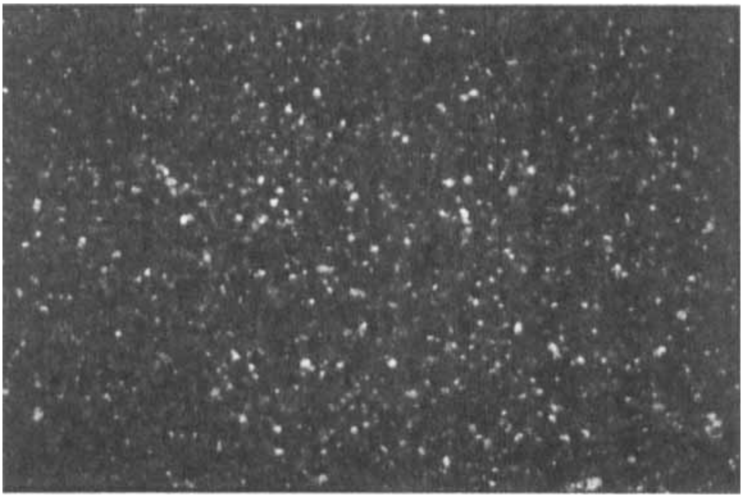


FIGURE 3 Blue Phase I (157.5°C)

(See Color Plate X at the back of this issue)

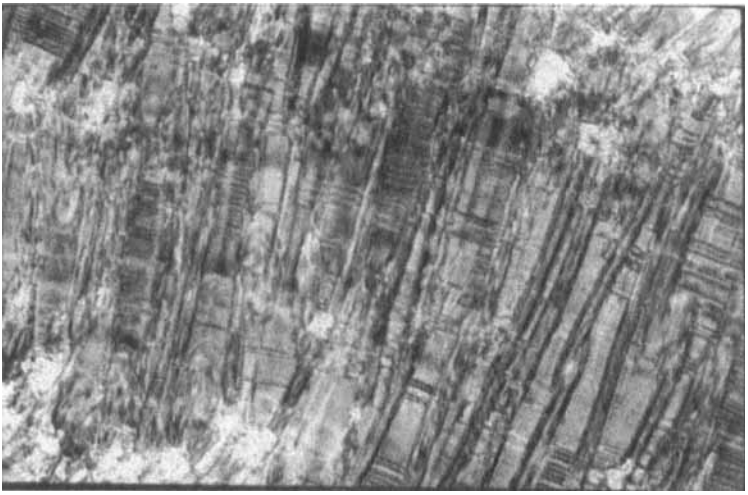


FIGURE 4 Smectic C* (120°C)
(See Color Plate XI at the back of this issue)

Physical Measurements

The spontaneous polarization (P_s) of the compound was measured at switching frequencies of 20Hz and 50Hz under an applied triangular-wave AC field of ±50V (±10Vμm^{-1}). The cells used were standard Linkam cells (5μm thick, 0.81cm^2 area, ITO-coated, antiparallel-aligned). The change in observed tilt angles of the material, from the temperature at which the P_s is detected (on cooling from the SmA* phase), is also shown in Figure 5.

The material showed excellent alignment on cooling from the N* phase to SmA* phase under an applied square-wave AC field of ±90V *(±18Vμm^{-1}) at switching frequency of 100Hz.*

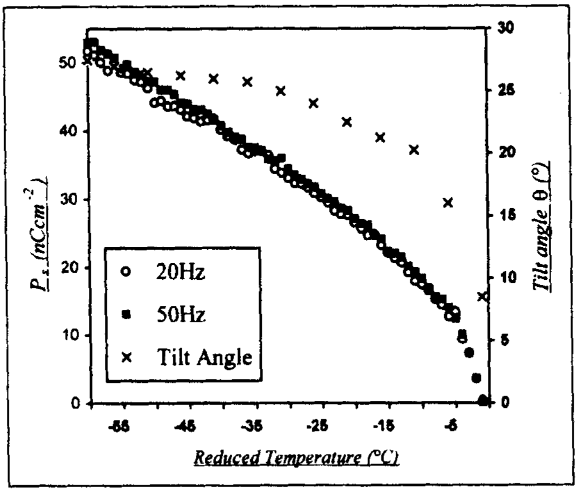


FIGURE 5　P_s (at 20Hz and 50Hz) and observed tilt angle of NG158

The material has a maximum P_s of approximately 50nC cm^{-2}, and a maximum tilt angle of 28.5°. The value of the P_s increases with observed tilt angle although the material showed a tilt angle of approximately 10° before the P_s was detected. This was due to electroclinic (soft-mode) switching in the SmA* phase. The P_s measured at 50Hz is slightly higher than that measured at 20Hz; this may be due to increased saturated switching taking place at 50Hz in comparison to 20Hz.

Figure 6 shows the triangular-wave response of the material at 90°C, at a switching frequency of 20Hz. The first plot is the input triangular-wave, the second is the detected electrical response from the cell; ferroelectric switching is clearly visible.

FIGURE 6 Triangular-wave response at 90° C (±50V at 20Hz)

The energy-minimised molecular model below (Figure 7) shows the fluorine at the chiral centre forms an angle of approximately 90° with the lateral fluorines on the central phenyl ring. The combination of the molecular dipole at the chiral centre due to the fluorine, with the lateral dipole associated with the di-fluorinated core may account for a reasonable value for the P_s of the material, given that the material does not possess any ester linkages.

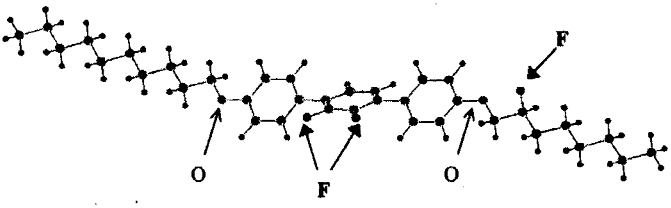


FIGURE 7 Energy-minimised molecular model of NG158 (COSMIC force field)

Table 1 shows the switching speeds of the material, obtained by shining a red laser (734nm) at a photodetector through a cell of the liquid crystal, switched under an applied square wave of ±50V at 50Hz. The material showed very fast response times, this indicates that the material possesses a low viscosity, also due to the absence of any ester functional groups. This suggests that the difluoroterphenyl core, in combination with a fluorine at the chiral centre and ether linkages between the core and the alkyl chains, are potentially useful in the preparation of suitable ferroelectric SmC* components.

Temperature (°C)	Switching Speed
140	6.8 μs
130	8.0 μs
120	8.4 μs
110	9.2 μs
100	11.6 μs
90	13.2 μs

TABLE 1 Switching speeds of NG158 at different temperatures.

CONCLUSIONS

A novel difluoroterphenyl ferroelectric SmC*-forming liquid crystal, with a fluorine at the chiral centre, has been synthesized and its physical properties investigated. A postulated trade-off between Ps and viscosity, as reflected by the moderate P_s but very fast switching times, is achieved by using a material with a difluoroterphenyl core and a fluorine at the chiral centre. The viscosity is reduced by the absence of any ester groups in the material. The material may then be suitable as a component for tailoring fast-switching ferroelectric mixtures for display devices. The rotational viscosity and mixture studies of the material will be reported in a future paper.

Acknowledgements

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