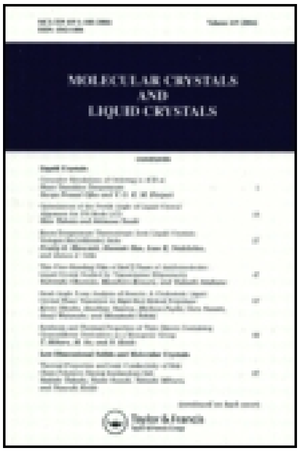

Molecular Crystals and Liquid Crystals
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/gmcl16

Voltage Dependence of the Capacitance of a Twisted Nematic Liquid Crystal Layer

E P Raynes [a], R J A Tough [a] & K A Davies [a]
[a] Royal Signals and Radar Establishment, Worcs., Malvern, WR14 3PS, U.K.
Version of record first published: 19 Apr 2011.

Mol. Cryst. Liq. Cryst. Vol. 56 (Letters), pp. 63-68
0140-6566/79/5602-0063$04.50/0

VOLTAGE DEPENDENCE OF THE CAPACITANCE OF A TWISTED NEMATIC LIQUID CRYSTAL LAYER

E P RAYNES, R J A TOUGH and K A DAVIES
Royal Signals and Radar Establishment, Malvern, Worcs.
WR14 3PS, U.K.

(Submitted for publication July 10, 1979)

INTRODUCTION

The magnetic field dependence of the capacitance of a twisted nematic layer has been analysed by Shtrikman et al[1] who found only moderate agreement between their theory and the experimental results of Gerritsma et al[2]. Here we investigate the voltage dependence of the capacitance of a twisted nematic liquid crystal layer just above threshold and present experimental results obtained over a range of temperatures with the nematic mixture E7. Agreement between theory and experiment is satisfactory at all temperatures.

THEORY

The director configuration in a twisted nematic layer across which there is a potential difference is determined by the requirement that the elastic and electric free energies of the liquid crystal be minimized[3,4]. An aligned layer of a nematic sample with positive dielectric anisotropy and zero surface tilt shows a well defined Freedericksz transition voltage Vc. We have calculated the linear variation of the capacitance of the sample with voltage just above this threshold from linearized solutions of Deuling's equations[3], and for a layer with a total twist angle Φ and zero surface tilt we find that

$$\frac{C - C_{\perp}}{C_{\perp}} = \frac{2\gamma v}{F(k) + \gamma} + O(v^2) \quad . \qquad (1)$$

$C_{\perp}$ and C are respectively the capacitances of the undistorted twisted layer and of the layer distorted by an

	General Case	Parallel layer ($\phi = 0^\circ$)	Twisted layer ($\phi = 90^\circ$)
$\frac{\epsilon_0(\epsilon_\parallel - \epsilon_\perp)V_c^2}{\pi^2}$	$k_{11} + \left(\frac{\phi}{180}\right)^2 (k_{33} - 2k_{22})$	k_{11}	$k_{11} + \frac{1}{4}(k_{33} - 2k_{22})$
$F(k)$ $k_{11} \neq k_{22} \neq k_{33}$	$\frac{k_{33} + (\frac{\phi}{180})^2 (k_{33} - k_{22} - \frac{k_{33}^2}{k_{22}})}{k_{11} + (\frac{\phi}{180})^2 (k_{33} - 2k_{22})}$	$\frac{k_{33}}{k_{11}}$	$\frac{5k_{33} - k_{22} - k_{33}^2/k_{22}}{4k_{11} + k_{33} - 2k_{22}}$
$F(k)$ $k_{11} \neq k_{33} = 2k_{22}$	$\left(1 - \frac{3}{2}(\frac{\phi}{180})^2\right) \frac{k_{33}}{k_{11}}$	$\frac{k_{33}}{k_{11}}$	$\frac{5k_{33}}{8k_{11}}$
$F(k)$ $k_{11} = k_{22} = k_{33}$	1	1	1

TABLE 1 Vc and F(k) for a general total twist angle ϕ, and for the special cases of parallel ($\phi = 0^\circ$) and twisted ($\phi = 90^\circ$) alignment.

applied voltage $V > Vc$, $v = (V-Vc)/Vc$ and $\gamma = (\epsilon_{\parallel} - \epsilon_{\perp})/\epsilon_{\perp}$ where $\epsilon_{\parallel}$, $\epsilon_{\perp}$ are the parallel and perpendicular components of the electric permittivity of the sample. Vc and F(k) are given in Table 1 for a variety of twist angles and elastic constant ratios. We see that our result reduces to that of Gruler et al[5] when $\phi = 0$ and that in the one constant approximation ($k_{11} = k_{22} = k_{33}$) F(k) is independent of ϕ. When $k_{33} = 2k_{22}$ (as is more or less the case for many nematic materials) the Freedericksz transition voltage for the layer is independent of ϕ and the initial slope of the capacitance-voltage curve of the layer increases with its total twist. Finally we note that the expression of Shtrikman et al[1] for the linear variation of the capacitance of a 90° twisted nematic layer with an applied magnetic field $H > H_c$, the Freedericksz threshold field, can be retrieved from (1) by setting $\phi = 90^{\circ}$ and $\gamma = 0$ in the denominator and interpreting v as $(H-H_c)/H_c$.

EXPERIMENT

The capacitance voltage curves of a 25μm thick twisted nematic layer aligned by 100 Å of SiO evaporated at 30° incidence have been measured at a variety of temperatures using a previously described technique[3]. The threshold voltage and slope at threshold of each curve were determined by inspection, bearing in mind the problems inherent in this procedure when it is applied to the capacitance voltage curve of an untwisted layer[3]. Twisted layers thinner than 25μm show a poorly defined threshold. k_{11}, k_{33}, $\epsilon_{\parallel}$ and $\epsilon_{\perp}$ were found by analysing the capacitance voltage curve of a zero tilt, parallel aligned layer, $\epsilon_{\parallel}$ being determined by Meyerhoffer's extrapolation procedure[7] and k_{11} and k_{33} by use of a two parameter, non-linear least squares fitting programme. k_{22} was then calculated from the threshold voltage of the twisted layer. It is estimated that the errors in the measurements are 1% in γ, 2% in k_{11}, 10% in k_{22} and 5% in k_{33}.

Measurements were made on the commercial mixture E7 which comprises the following (by weight)

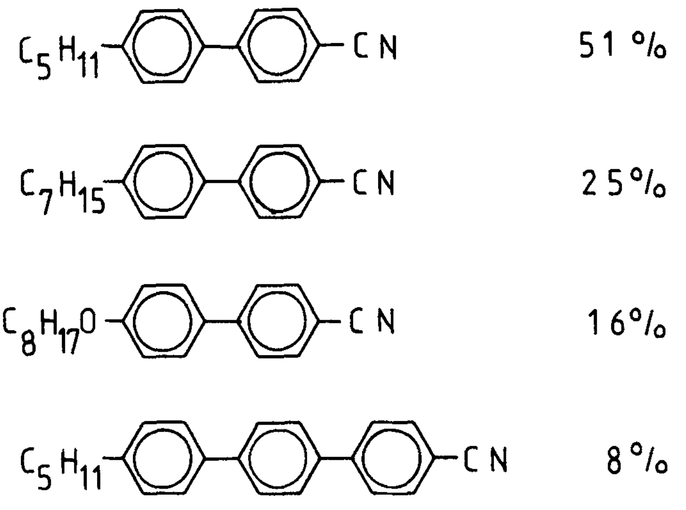

Table 2 shows the measured elastic constants and permittivities of E7 over the temperature range 1°C to 55°C while Table 3 compares the corresponding experimental and calculated

T(°C)	$\epsilon_\parallel$	$\epsilon_\perp$	k_{11}	k_{22}	k_{33}
1	20.41	4.83	14.6	11.0	25.9
10	20.06	4.97	13.3	9.9	23.0
20	19.54	5.17	11.7	8.8	19.5
30	18.98	5.43	10.1	7.3	16.2
40	18.16	5.80	8.2	5.9	12.3
50	16.97	6.41	5.8	4.4	8.2
55	15.83	7.00	4.0	3.2	5.5

TABLE 2 Permittivities and elastic constants of E7. The elastic constants are presented in units of 10^{-12} newtons. E7 clears over the temperature range 58°C to 60°C.

$T(^{\circ}C)$	$\frac{C - C_{\perp}}{C_{\perp}(V-V_c)}$	
	Observed (volts^{-1})	Calculated (volts^{-1})
1	1.48	1.47
10	1.51	1.51
20	1.53	1.54
30	1.59	1.58
40	1.61	1.62
50	1.70	1.64
55	1.69	1.61

TABLE 3 Observed and calculated initial slopes of the capacitance voltage curves of a 25μm twisted ($\phi = 90^{\circ}$) layer of E7.

slopes of the capacitance voltage curve of a twisted layer of E7. The agreement between theory and experiment is quite satisfactory and justifies the accuracy quoted for the elastic constants and permittivities.

ACKNOWLEDGEMENTS

We wish to thank BDH Chemicals Ltd for supplying the E7. This letter is published by permission of the Controller, HMSO.

REFERENCES

1. S Shtrikman, E P Wohlfarth and Y Wand, Phys. Lett., 37A, 369 (1971).

2. C J Gerritsma, W D de Jeu and P van Zanten, Phys. Lett., 36A, 389 (1971).

3. H J Deuling, Mol. Cryst. Liq. Cryst. 27, 81 (1974).

4. C Fraser, J. Phys. A11, 1439 (1978).

5. H Gruler, T J Scheffer and G Meier, Z. Naturforsch, 27A, 966 (1972).

6. R J A Tough and E P Raynes, Mol. Cryst. Liq. Cryst. Letters, in press.

7. D Meyerhoffer, J. Appl. Phys. 46, 5084, (1975).