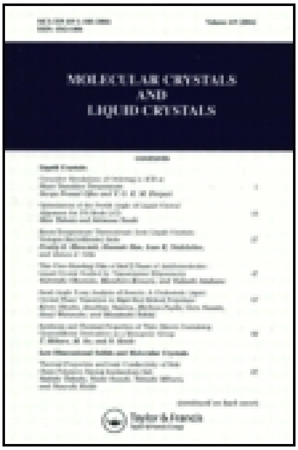

Molecular Crystals and Liquid Crystals
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/gmcl16

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To cite this article: P. A. Breddels & J. C. H. Mulkens (1987): The Determination of the Frank Elastic Constant for Twist Deformation of 4′-n-pentyl-4-cyanobiphenyl (5CB) Using a Conoscope, Molecular Crystals and Liquid Crystals, 147:1, 107-112

To link to this article: http://dx.doi.org/10.1080/00268948708084628

Mol. Cryst. Liq. Cryst., 1987, Vol. 147, pp. 107–112
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Printed in the United States of America

The Determination of the Frank Elastic Constant for Twist Deformation of 4′-*n*-pentyl-4-cyanobiphenyl (5CB) Using a Conoscope

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(*Received October 8, 1986; in final form November 19, 1986*)

The Frank elastic constant for twist deformation k_{22}, has been determined as a function of temperature for 5CB and compared with values cited in literature. The results, together with the values of the elastic constants for splay, k_{11}, and bend, k_{33}, which have been measured recently by Bradshaw *et al.* and the values for k_{11}/k_{22} and k_{33}/k_{22} as found by Hara *et al.* suggest that the values of Karat and Madhusudana (corrected by Bunning *et al.*) are somewhat too low.

Keywords: elastic constants, 5CB, conoscope

Measurements of the elastic constants of nematic liquid crystals have occupied numerous researchers[1–7] for many years and continue to do so. Interest in these elastic constants largely comes from the fact that they appreciably influence important display properties such as the threshold voltage, the steepness of the electro-optical characteristic[8] and the hysteresis width in the recently discovered supertwisted birefringence effect.[9,10] The reason why many reports are still concerned with the elastic constants of well-known materials like 5CB[1–4, 11–14] is that the measurements are far from being trivial.

Recently Bradshaw *et al.*[12] presented an extensive report on the bend and splay elastic constants of two homologous series of nematic compounds (comprising 5CB), using and comparing an electrical field (capacitive detection) and magnetic field (optical detection) deformation. As a very confident outcome they found the same results for k_{11} and k_{33} of 5CB with both measurement methods. However, no such report, to our knowledge, exists regarding k_{22} and relatively few (largely diverging) data are available.[3,4,13]

In order to measure the twist elastic constant we have built a conoscope which we use in combination with a magnet. A cell with a planar homogeneous director configuration oriented with the director (optical axis) perpendicular both to the magnetic field and the optical axis of the conoscope gives an interference figure consisting of four (or more) equilateral hyperbolas.[15,16] From the rotation of the interference figure as a function of the applied field, the Freedericksz transition for twist deformation can be obtained.[16] This Freedericksz transition is given by $H_F = \pi/d\ \sqrt{k_{22}/\Delta\chi}$, where d is the thickness of the layer and $\Delta\chi$ the anisotropy of magnetic volume susceptibility. Furthermore the set-up enabled us to determine the rotational viscosity, γ_1, by switching a magnetic field and following the rotation of the interference figure with time. A more detailed description of the set-up will be presented elsewhere.

In order to test our equipment we determined k_{22} and γ_1 of 5CB as a function of temperature. The 5CB was obtained from Merck and used without further purification. The nematic-isotropic transition temperature was 35.2°C. In order to compare our results with those of other authors we present the measurements on a relative scale, i.e. $(T_{NI} - T)$, where T is the temperature in degrees Kelvin. Thicknesses of our cells were determined interferometrically and were typically $100 \pm 1\mu$m. The $\Delta\chi$ values were obtained by the Faraday-Curie method. The relative error of these measurements we estimated at $< 1\%$.

In Figure 1 a typical example of the rotation angle δ of the interference figure is depicted as a function of the applied field. The slow onset of rotation below the critical field, H_F (obtained by a fitting procedure), is due to a non-perfect alignment of the director with respect to the field. This has been accounted for in the numerical fitting procedure.[16]

Figure 2 gives the anisotropy of magnetic mass susceptibility, $\Delta\chi^{(m)}$, versus temperature as measured in our laboratory and as presented in literature. Our results are in good agreement with those of Buka and de Jeu[17] and differ somewhat from those of Bunning *et al.*[4,18] and Sherrell and Crellin.[19] In order to calculate the volume susceptibility we used the density measurements of Dunmur and Miller.[20]

Our results for k_{22} as a function of temperature are given in Figure 3. Numerical values are summed up in Table I. In the figure we have

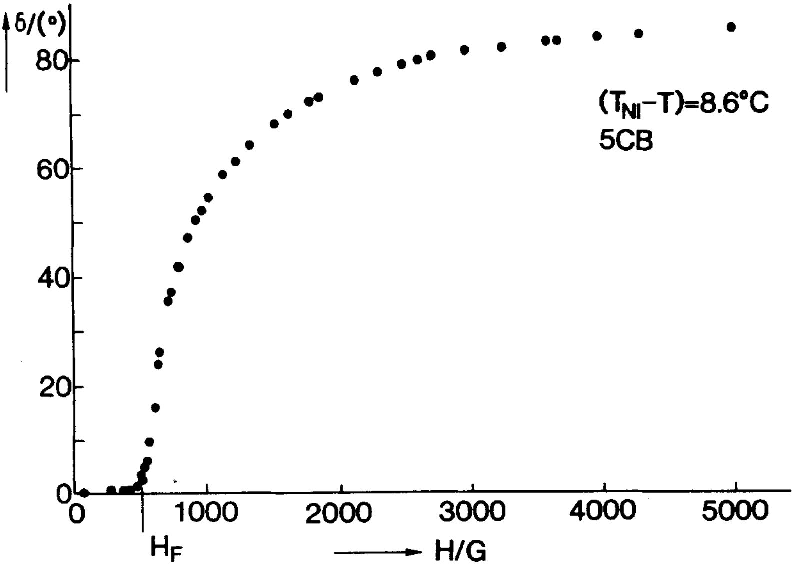

FIGURE 1 The rotation angle, δ, of the conoscopic interference figure as a function of the applied magnetic field. H_F denotes the Freedericksz transition.

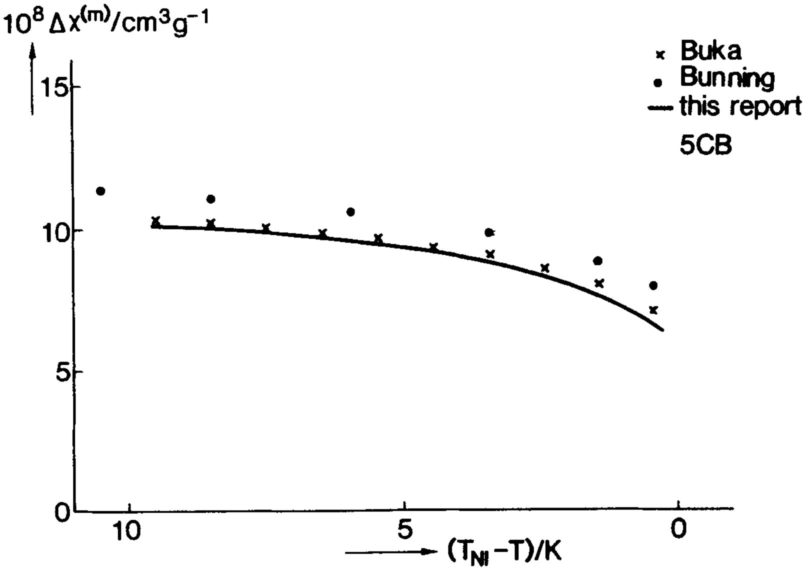

FIGURE 2 The anisotropy of the magnetic mass susceptibility, $\Delta\chi^{(m)}$, as a function of temperature.

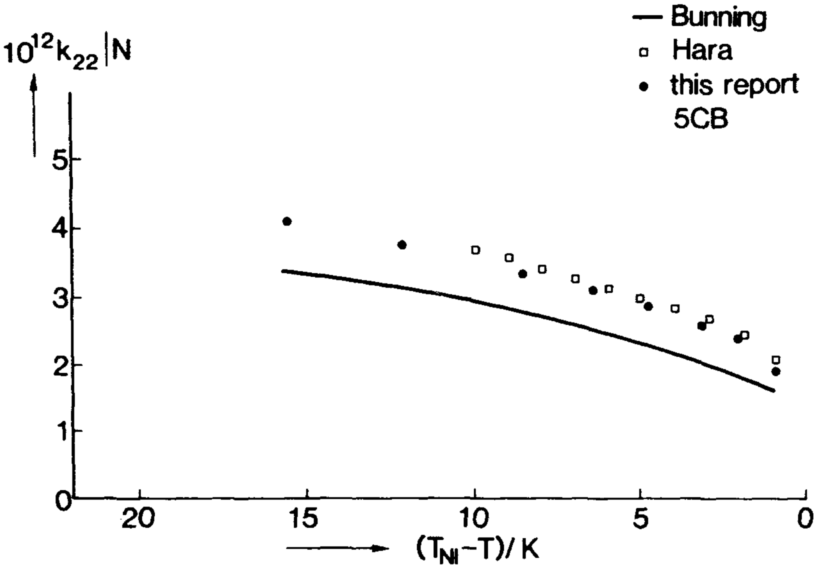

FIGURE 3 The twist elastic constant, k_{22}, as a function of temperature.

inserted the values of k_{22} as obtained by Bunning *et al.*[4] by correction of the values of Karat and Madhusudana.[3] We also calculated values for k_{22} from the data on k_{11}/k_{22} and k_{33}/k_{22} by Hara *et al.*[2] through inserting the values of k_{11} and k_{33} as measured by Bradshaw *et al.*,[12] which seems reasonable in view of the above-mentioned arguments (identical results for magnetic and electric deformations). These values have also been drawn. As can be seen from this figure the values thus obtained for k_{22} are in good agreement with our results and

TABLE I

Experimental data for 5CB

$(T_{NI}-T)/K$	$10^{12}K_{22}/N$	$\gamma_1/Pa\ s$
15.6	4.1	0.093
12.2	3.7	0.082
8.6	3.3	0.069
6.5	3.2	0.058
4.8	2.9	0.045
3.2	2.6	0.044
2.1	2.4	0.034
1.0	1.9	0.027
0.3	1.6	0.019

suggest that the previously reported values by Bunning *et al.*[4] are somewhat too low. Some remarks, however, need to be made. Since the anisotropy of volume susceptibility directly affects the determination of k_{22}, the differences in $\Delta\chi^{(m)}$ measurements have to be taken into consideration. If the $\Delta\chi^{(m)}$ values measured in our laboratory are too small (and then also those of Buka and de Jeu),[17] the calculated k_{22} values will become even larger. Consequently, the reverse will happen if the $\Delta\chi^{(m)}$ values of Bunning *et al.*[18] are too high, i.e. a further decrease of their k_{22} values. Thus, the discrepancy between the two sets of k_{22} versus temperature data cannot be simply explained by a trivial difference in the value of $\Delta\chi^{(m)}$. We also point out that Coles and Sefton[21] found higher k_{22} values as compared to those of Bunning *et al.*[4] These values, for unknown reasons, are slightly higher than ours.

Finally we remark that we have also determined the rotational viscosity, γ_1, as a function of temperature for 5CB. We found good agreement of γ_1 with values reported in literature,[22,23] confirming the reliability of our measurement system. The numerical values for γ_1 are given in Table I.

In conclusion we have presented new data on the (relatively little measured) twist elastic constant, k_{22}, of 5CB. Evidence has been given for somewhat higher values which is supported by measurements of Hara *et al.*

Acknowledgments

The authors wish to thank Dr. W. H. de Jeu for his advices on the building of the conoscope and G. J. M. Poodt for performing the susceptibility measurements.

References

1. M. J. Bradshaw, E. P. Raynes, J. D. Bunning and T. E. Faber, *J. Physique*, **46**, 1513 (1985).
2. M. Hara, J. Hirakata, T. Toyooka, H. Takezoe and A. Fukuda, *Mol. Cryst. Liq. Cryst.*, **122** 161 (1985).
3. P. P. Karat and N. V. Madhusudana, *Mol. Cryst. Liq. Cryst.*, **40** 239 (1977).
4. J. D. Bunning, T. E. Faber and P. L. Sherrell, *J. Physique*, **42**, 1175 (1981).
5. H. Gruler, T. J. Scheffer and G. Meier, *Z. Naturforsch*, **27a**, 966 (1972).
6. P. R. Gerber and M. Schadt, *Z. Naturforsch*, **35a**, 1036 (1980).
7. M. Schadt and P. R. Gerber, *Z. Naturforsch*, **37a**, 165 (1982).
8. G. Baur, *Proceedings SID*, Eurodisplay 1984 Paris, 49 (1984).
9. C. M. Waters, E. P. Raynes and V. Brimmell, *Mol. Cryst. Liq. Cryst.*, **123**, 303 (1985).
10. H. A. v. Sprang and P. A. Breddels, accepted for publication in *J. Appl. Phys.*

11. K. Skarp, S. T. Lagerwall and B. Stebler, *Mol. Cryst. Liq. Cryst.*, **60**, 215 (1980).
12. M. J. Bradshaw and E. P. Raynes, *Mol. Cryst. Liq. Cryst.*, **72**, 35 (1981).
13. H. Hakemi, E. F. Jagodzinski and D. B. DuPré, *J. Chem. Phys.*, **78**, 1513 (1983).
14. S. Faetti, M. Gatti, V. Palleschi and T. J. Sluckin, *Phys. Rev. Lett.*, **16**, 1681 (1985).
15. P. E. Cladis, *Phys. Rev. Lett.*, **28** 1629, (1972).
16. F. Leenhouts and A. J. Dekker, *J. Chem. Phys.*, **74**, 1956 (1981).
17. A. Buka and W. H. de Jeu, *J. Physique*, **43**, 361 (1982).
18. J. D. Bunning, D. A. Crellin and T. E. Faber, *Liq. Cryst.*, **1**, 37 (1986).
19. P. L. Sherrell and D. A. Crellin, *J. Physique*, **40**, C3-211 (1979).
20. D. A. Dummur and W. H. Miller, *J. Physique*, **40**, C3-141 (1979).
21. H. J. Coles and M. S. Sefton, *Mol. Cryst. Liq. Cryst. Letters*, **1**, (5), 151 (1985).
22. H. Kneppe, F. Schneider and N. K. Karma, *J. Chem. Phys.*, **77**, 3203 (1982).
23. W. W. Beens, Ph.D. thesis, University of Groningen, 1984.