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Determination of K_i (i = 1–3) and μ_j (j = 2–6) in 5CB by observing the angular dependence of Rayleigh line spectral widths

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Using Parodi's relation, all of the Leslie viscosity coefficients, except μ_1, together with the Frank elastic constants have been measured successfully by the photon correlation spectroscopy of Rayleigh scattered light. The values so determined are in good agreement with those previously determined from shear flow experiments by Chmielewski and by Skarp *et al.* The polar angle dependence of mode 1 spectral width is proposed as a novel method for the measurement of μ_1 and for the experimental confirmation of Parodi's relation.

1. Introduction

Since the pioneering work by the Orsay Liquid Crystal Group [1–4], many Rayleigh light scattering experiments have been made to determine the Frank elastic constants and Leslie viscosity coefficients [5–26]. As far as we know, however, no one has been successful in determining all of the Leslie viscosity coefficients precisely by the Rayleigh light scattering method. One reason for this failure is the lack of accuracy in the elastic constant ratios, K_1/K_2 and K_3/K_2, obtained from the scattering angle dependence of the intensity [20, 21, 23].

In this work, we use photon correlation spectroscopy and accurately measure the spectral widths to obtain not only the ratios of the viscosity coefficients and the elastic constants, μ_i/K_ns, but also the ratios of the elastic constants, K_n/K_ms. Depolarized scattering geometries were used to measure η_{splay}/K_1, which greatly improve the accuracy; the inaccuracy in η_{splay}/K_1 has been another obstacle [23, 27].

We then determine the twist elastic constant K_2 by observing the scattered light intensity or spectral widths as a function of an applied electric field [25, 26]. Thus, using Parodi's relation, all of the Leslie viscosity coefficients, except μ_1, are successfully measured by the Rayleigh light scattering method; the values so determined are in good agreement with those previously determined from shear flow experiments by Chmielewski [28] and by Skarp *et al.* [29]. Finally, a novel method is proposed for the determination of μ_1 and for the experimental confirmation of Parodi's relation: the polar angle dependence of the mode 1 spectral width, which can be performed by cell rotation about the optic axis. The importance of this has already been insisted in the intensity measurement [27].

2. Experimental procedures

The experimental set up for photon correlation spectroscopy and the preparation of sample cells have already been described in the previous paper [23]. The material, 4-n-pentyl-4′-cyanobiphenyl (5CB), was supplied by Merck Japan Limited; it was used without further purification. To illustrate the accuracy of our measurement, figure 1 shows an observed homodyne signal in linear and logarithmic scales.

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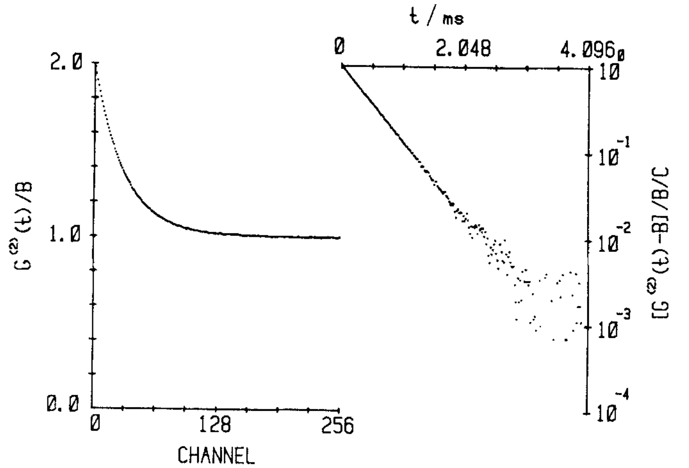

Figure 1. Example of an observed autocorrelation function.

The determination procedure is as follows

(1) η_{splay}/K_1, η_{twist}/K_2 and η_{bend}/K_3 were obtained by using the scattering geometries with a pure single deformation summarized in figure 2. The accuracy of η_{splay}/K_1 was greatly improved because the (O–E) and (E–O) depolarizations were used instead of the (E–E) polarization, as is clearly seen by comparing figure 3 with the corresponding figure 4 of [23]. Here, E and O refer to extraordinary and ordinary, respectively, and the first letter in parenthesis shows the state of polarization of the incident light and the second shows that of the scattered light.

(2) K_1/K_2 was determined by the van der Meulen–Zijlstra method [12–14] using the mixed mode scattering geometries with $q_\parallel = 0$ summarized in figure 2.

(3) The mode 2 spectral width is given by

$$\Gamma_2 = \frac{(K_3/K_2)q_\parallel^2 + q_\perp^2}{(\gamma_1/K_2) - \dfrac{q_\parallel^2}{aq_\perp^2 + cq_\parallel^2}}, \tag{1}$$

where

$$a = K_2\eta_a/\mu_2^2, \qquad c = K_2\eta_c/\mu_2^2,$$

$$\eta_a = \mu_4/2, \qquad \eta_c = (-\mu_2 + \mu_4 + \mu_5)/2,$$

$$\eta_{\text{twist}} = \gamma_1, \qquad \eta_{\text{bend}} = \gamma_1 - \mu_2^2/\eta_c,$$

and

$$\gamma_1 = -\mu_2 + \mu_3.$$

Since

$$\frac{1}{c} = \frac{\eta_{\text{twist}}}{K_2} - \frac{\eta_{\text{bend}}}{K_3}\frac{K_3}{K_2},$$

equation (1) contains two independent unknown parameters, K_3/K_2 and $a = \eta_a K_2/\mu_2^2$. Hence two parameter fitting to equation (1) of the observed scattering angular

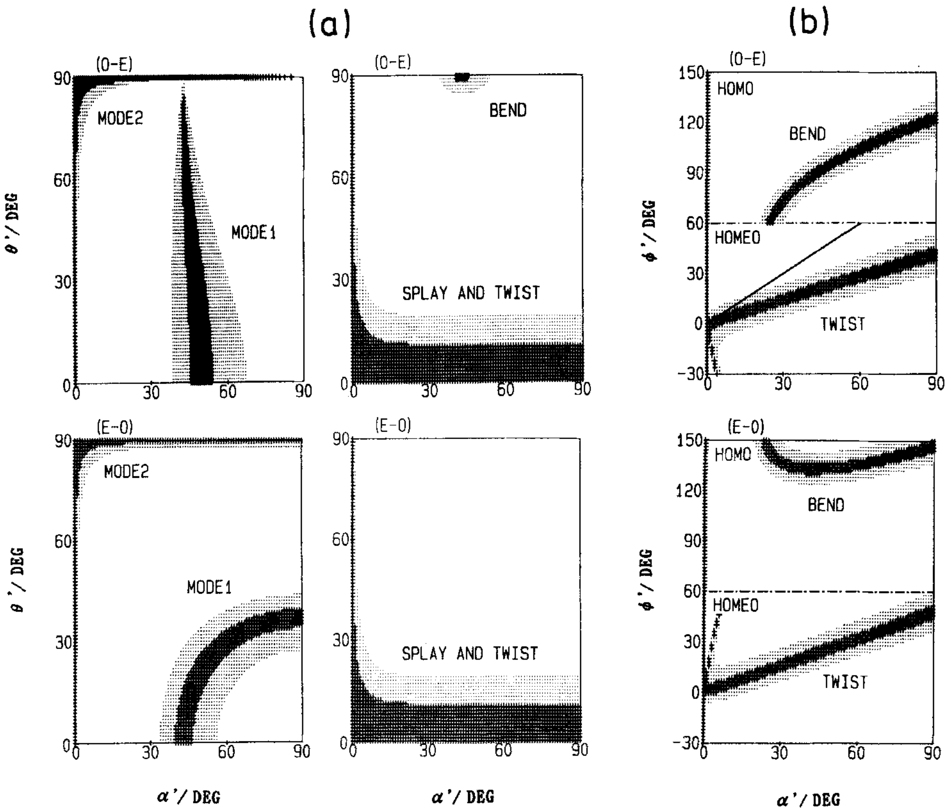

Figure 2. Maps drawn in (a) the (θ', ϕ' = 90°, α') space and (b) the (θ' = 90°, ϕ', α') space where at least one of $(G_1/G_2)^2$, $(G_2/G_1)^2$, $(q_\parallel/q_\perp)^2$ and $(q_\perp/q_\parallel)^2$ becomes negligibly small; darkly and lightly hatched regions indicate less than 10^{-3} and 10^{-2}, respectively. Here, θ' and ϕ' are polar and azimuthal angles defining the director orientation. α' is the scattering angle. The primes indicate the angles observed outside the medium. G_1 and G_2 are geometrical parameters defined in equation (17) of [27]. The reduced temperature $(T_{NI} - T)$ is 5°C.

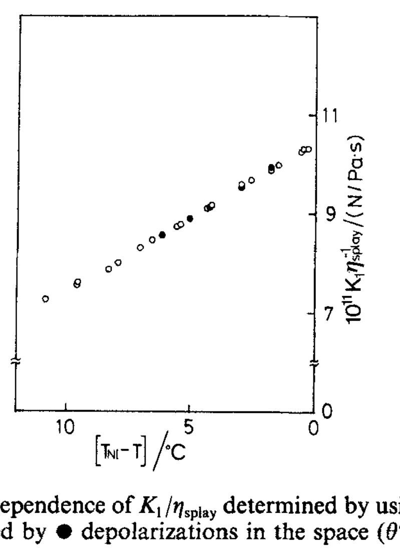

Figure 3. The temperature dependence of K_1/η_{splay} determined by using (O–E) indicated by ○ and (E–O) denoted by ● depolarizations in the space (θ' = 0, ϕ' = 0, α').

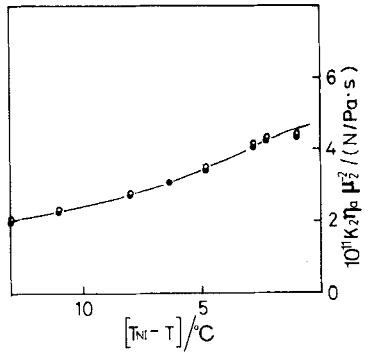

Figure 4. The temperature dependence of $K_2\eta_a/\mu_2^2$; ● and ○ indicate (E–O) and (O–E) depolarizations, respectively.

dependence of Γ_2, allows us to determine K_3/K_2 and $a = K_2\eta_a/\mu_2^2$ as illustrated in figure 4.

(4) The mode 1 spectral width is given by

$$\Gamma_1 = \frac{(K_3/K_2)q_\parallel^2 + (K_1/K_2)q_\perp^2}{(\gamma_1/K_2) - \dfrac{\{(\mu_3/\mu_2)q_\perp^2 - q_\parallel^2\}^2}{bq_\perp^4 + dq_\perp^2 q_\parallel^2 + cq_\parallel^4}}, \tag{2}$$

where

$$b = K_2\eta_b/\mu_2^2, \qquad d = K_2\eta_d/\mu_2^2$$

$$\eta_b = (\mu_3 + \mu_4 + \mu_6)/2, \quad \eta_d = (\mu_1 + \mu_3 + \mu_4 + \mu_5)/2,$$

and

$$\eta_{\text{splay}} = \gamma_1 - \mu_3^2/\eta_b.$$

Since

$$\frac{1}{b} = \left(\frac{\mu_2}{\mu_3}\right)^2 \left(\frac{\eta_{\text{twist}}}{K_2} - \frac{\eta_{\text{splay}}}{K_1}\frac{K_1}{K_2}\right),$$

equation (2) contains two independent unknown parameters, μ_2/μ_3 and $d = K_2\eta_d/\mu_2^2$. Hence two parameter fitting to equation (2) of the measured polar and scattering angle dependence, in principle, allows us to determine μ_3/μ_2 and $d = K_2\eta_d/\mu_2^2$. Note that the depolarized scattering geometries can be used as shown in figure 2(*a*) [27].

(5) The twist elastic constant K_2 was determined by observing the scattered light intensity or spectral width as a function of an applied electric field [26].

3. Results and discussion

Since the experimental setup we used was not suitable to measure the polar dependence of the spectral width, we could not perform procedure (4). Instead, we assumed Parodi's relation

$$\mu_2 + \mu_3 = -\mu_5 + \mu_6.$$

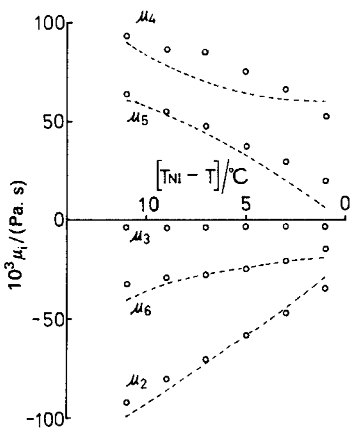

Figure 5. The temperature dependence of the Leslie viscosity coefficients μ_i (i = 2–6) determined in this work indicated by ○, compared with the data (except μ_3) from shear flow experiments by Chmielewski [28] represented by the broken line.

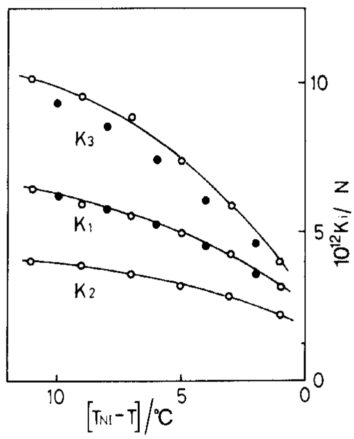

Figure 6. The temperature dependence of the Frank elastic constants K_i (i = 1–3) where a rather large disagreement exists between the data of K_3 determined in this work indicated by ○ and in the intensity measurement of scattering angle dependence represented by ● [27].

Thus, all of the Leslie viscosity coefficients except μ_1, together with the Frank elastic constants were determined as shown in figures 5 and 6. The viscosity coefficients μ_2, μ_4, μ_5 and μ_6 so determined are in good agreement with those previously obtained by Chmielewski [28] using a shear flow method. Figure 7 shows the ratio μ_3/μ_2 so determined together with that previously obtained by Skarp *et al.* using a shear flow method [29]; the agreement is rather good. The elastic constant K_3/K_2 is systematically higher than that obtained from the intensity measurement of the scattering angle dependence [27], resulting in a higher K_3 as shown in figure 6, although the agreement is almost equally close for K_1/K_2. The reason may be that the intensity measurement of the scattering angle dependence has a low reliability. Actually, figure 1 in [27] shows a larger data scatter and a larger systematic error for K_3/K_2 than for K_1/K_2. Detailed measurements and full discussions will be reported shortly.

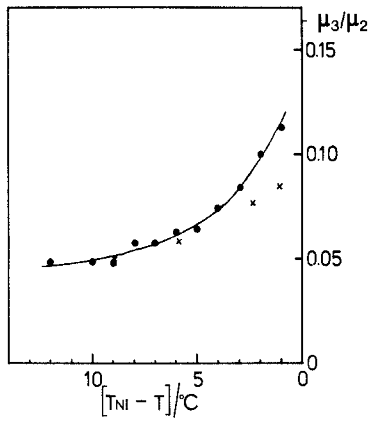

Figure 7. The temperature dependence of μ_3/μ_2 determined in this work indicated by ●, compared with the data from shear flow experiments by Skarp *et al.* [29] represented by x.

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References

[1] Orsay Liquid Crystal Group, 1969, *J. chem. Phys.*, **51**, 816.
[2] Orsay Liquid Crystal Group, 1969, *Phys. Rev. Lett.*, **22**, 1361.
[3] Orsay Liquid Crystal Group, 1970, *Liquid Crystals and Ordered Fluids*, Vol. 1, edited by J. F. Johnson and R. S. Porter (Plenum Press), p. 447.
[4] Orsay Liquid Crystal Group, 1971, *Molec. Crystals liq. Crystals*, **13**, 187.
[5] Haller, I., and Litster, J. D., 1970, *Phys. Rev. Lett.*, **25**, 1550.
[6] Haller, I., and Litster, J. D., 1971, *Molec. Crystals liq. Crystals*, **12**, 27.
[7] Schaetzing, R., and Litster, J. D., 1979, *Advances in Liquid Crystals*, Vol. 4, edited by G. H. Brown (Academic Press), p. 147.
[8] Fellner, H., Franklin, W., and Christensen, S., 1975, *Phys. Rev.* A, **1**, 1440.
[9] Van Eck, D. C., and Westera, W., 1977, *Molec. Crystals liq. Crystals*, **38**, 319.
[10] Van Eck, D. C., and Perdeck, M., 1978, *Molec. Crystals liq. Crystals Lett.*, **49**, 39.
[11] Van Eck, D. C., and Zijlstra, R. J. J., 1980, *J. Phys., Paris*, **41**, 351.
[12] Van der Meulen, J. P., and Zijlstra, R. J. J., 1982, *J. Phys., Paris*, **43**, 411.
[13] Van der Meulen, J. P., and Zijlstra, R. J. J., 1984, *J. Phys., Paris*, **45**, 1347.
[14] Van der Meulen, J. P., and Zijlstra, R. J. J., 1984, *J. Phys., Paris*, **45**, 1627.
[15] Usui, H., Takezoe, H., Fukuda, A., and Kuze, E., 1979, *Jap. J. appl. Phys.*, **18**, 1599.
[16] Akiyama, R., Saito, Y., Fukuda, A., Kuze, E., and Goto, N., 1980, *Jap. J. appl. Phys.*, **19**, 1937.
[17] Akiyama, R., Hasegawa, M., Fukuda, A., and Kuze, E., 1981, *Jap. J. appl. Phys.*, **20**, 2019.
[18] Akiyama, R., Abe, S., Fukuda, A., and Kuze, E., 1982, *Jap. J. appl. Phys.*, **21**, L266.
[19] Akiyama, R., Tomida, K., Endo, Y., Murooka, H., Fukuda, A., and Kuze, E., 1983, *Jap. J. appl. Phys.*, **22**, L769.
[20] Hara, M., Hirakata, J., Toyooka, T., Takezoe, H., and Fukuda, A., 1985, *Molec. Crystals liq. Crystals*, **122**, 161.
[21] Akiyama, R., Tomida, K., Fukuda, A., and Kuze, E., 1986, *Jap. J. appl. Phys.*, **25**, 769.
[22] Toyooka, T., Hirakata, J., Chen, G.-P., Takezoe, H., and Fukuda, A., 1987, *Second Asia Pacific Physics Conference (Proceedings of the 2nd Asia-Pacific Physics Conference, Bangalore*, India, 1986) (World Scientific Publishing Co.), p. 1064.
[23] Hirakata, J., Chen, G.-P., Toyooka, T., Kawamoto, S., Takezoe, H., and Fukuda, A., 1986, *Jap. J. appl. Phys.*, **25**, L607.
[24] Langevin, D., and Bouchiat, M. A., 1975, *J. Phys., Paris*, **36**, C1-197.
[25] Coles, H. J., and Sefton, C. M., 1985, *Molec. Crystals liq. Crystals Lett.*, **1**, 151.

[26] TOYOOKA, T., CHEN, G., TAKEZOE, H., and FUKUDA, A., 1987, *Jap. J. appl. Phys.*, **26**, 1959.
[27] CHEN, G.-P., TAKEZOE, H., and FUKUDA, A., 1989, *Jap. J. appl. Phys.*, **28**, 56.
[28] CHMIELEWSKI, A. G., 1986, *Molec. Crystals liq. Crystals*, **132**, 339.
[29] SKARP, K., LAGERWALL, S. T., and STEBLER, B., 1980, *Molec. Crystals liq. Crystals*, **60**, 215.