

Dielectric behaviour of cholesteryl oleyl carbonate and cholesteryl linoleate in dilute solutions of CCl_4 at a single microwave frequency

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Received 16 May 1995, accepted 1 August 1995

Abstract : In order to study the dielectric behaviour of isolated molecules, measurements of dielectric parameters permittivity (ϵ') and loss (ϵ''), have been made on cholesteryl oleyl carbonate and cholesteryl linoleate in dilute solutions of CCl_4 at a single microwave frequency of 4.0 GHz at 30°C. The results indicated that the dielectric relaxation time (τ) is larger for longer molecule cholesteryl oleyl carbonate (52.2 ps) compared to that for cholesteryl linoleate (45.2 ps), as expected

Keywords : Cholesteryl liquid crystals, dielectric properties

PACS No. : 77 84.Nh

Cholesteryl liquid crystals find commercial use in both twisted nematic (TN) and guest host (GH) electrooptic displays and also in many thermographic applications [1–3]. Understanding of the dielectric behaviour of liquid crystal continues to provide a considerable research challenge. The dilute solutions of polar substance in non-polar solvent allows the solute molecule to be examined in a quasi-isolated state and the behaviour is relatively less affected by the dipolar field. In the present work, we have reported the dielectric behaviour of cholesteryl oleyl carbonate and cholesteryl linoleate in dilute solutions of CCl_4 at a single microwave frequency of 4.0 GHz and at room temperature 30°C. The two cholesteric liquid crystals were procured from M/S Eastman Kodak Co. and were used without further purification.

Four dilute concentrations having weight fractions less than 0.04 were prepared with each liquid crystal and the measurements were made at 30°C. The coaxial line bench set up

is shown in Figure 1. A gold plated co-axial line of 30 cm in length, was used as a liquid cell. A teflon plug was used to support the central conductor and to allow for a vertical

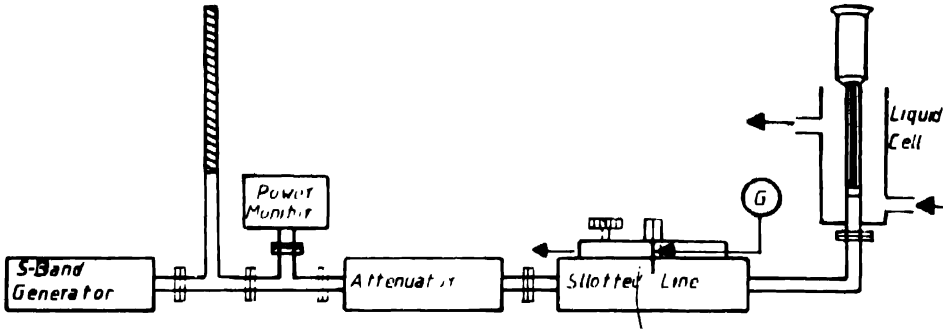


Figure 1. Experimental arrangement of S-band set up

column of the liquid, which was terminated by a movable short circuiting plunger. The length of the liquid column in the cell could be adjusted to an accuracy of 0.001 cm by means of a micrometer plunger drive. I N 21 crystals were used for detection. The temperature was maintained within $\pm 0.5^\circ$ by circulating water around the cell by a thermostat-type NBE.

The inverse VSWR (ρ_n) were determined for each concentration of the two liquid crystals for different liquid lengths by measuring the width ΔX_n at double minimum power points at $n\lambda_d/2$, for $n = 0, 1, 2, 3, 4$ and 5 and using the relations :

$$\rho_n = \frac{\pi}{2} \cdot \Delta x_n$$

The value of ρ_n were then corrected for the approximations involved in deriving the above relation [4] and ρ_c (corrected) are obtained.

The values of ϵ' and ϵ'' were calculated from the equations :

$$\epsilon' = \left(\frac{\lambda_0}{\lambda_c} \right)^2 + \left(\frac{\lambda_0}{\lambda_d} \right)^2$$

and
$$\epsilon'' = \frac{2}{\pi} \left(\frac{\lambda_0}{\lambda_d} \right)^2 \left(\frac{\lambda_g}{\lambda_d} \right) \cdot \frac{d\rho_c}{dn}$$

For coaxial bench (at 4.0 GHz), $\lambda_c = \infty$ and $\lambda_g = \lambda_0$ so that

$$\epsilon' = \left(\frac{\lambda_0}{\lambda_d} \right)^2 \tag{1}$$

and
$$\epsilon'' = \frac{2}{\pi} \left(\frac{\lambda_0}{\lambda_d} \right)^3 \frac{d\rho_c}{dn} \tag{2}$$

Here ρ_c is the corrected inverse VSWR which takes into account the contributions from the losses in the wave guide walls and the imperfection of the short in the measured values of the inverse VSWR.

The accuracy of measurements for ϵ' and ϵ'' is $\pm 2\%$ and $\pm 5\%$ respectively.

The values of ρ_c as functions of n for different concentrations of cholesteryl oleyl carbonate and cholesteryl linoleate in dilute solutions of CCl_4 are given in Table 1. The straight line plots of ρ_c vs n yielded $d\rho_c/dn$. The values of ϵ' and ϵ'' obtained using eqs. (1) and (2), for the two mesogens at different concentrations are reported in Table 2.

Table 1. Corrected VS WR (ρ_c) as a function of n for different concentrations of cholesteric materials in dilute solutions of CCl_4 at 30°C and at 4.0 GHz

Concentration	$n \rightarrow 0$	1	2	3	4	5
Cholesteryl linoleate						
.0051	.0323	.0381	.0402	.0419	.0419	.0452
.0148	.0339	.0411	.0411	.0457	.0498	.0578
.0212	.0335	.0350	.0364	.0406	.0469	.0586
.0292	.0330	.0360	.0469	.0524	.0662	.0741
Cholesteryl oleyl carbonate						
.0143	.0335	.0419	.0436	.0398	.0356	.0486
.0209	.0368	.0369	.0423	.0465	.0473	.0478
.0299	.0364	.0452	.0452	.0461	.0423	.0436
.0391	.0373	.0377	.0436	.0436	.0482	.0524

Table 2. Measured values of ϵ' and ϵ'' for two cholesteric materials in dilute solutions of CCl_4 and 4.0 GHz and at 30°C

Cholesteryl oleyl carbonate			Cholesteryl linoleate		
Wt. fractions	ϵ'	ϵ''	Wt. fractions	ϵ'	ϵ''
0.0143	2.231	0.0037	0.0051	2.231	0.0035
0.0209	2.235	0.0053	0.0148	2.241	0.0093
0.0299	2.236	0.0065	0.0212	2.246	0.0151
0.0391	2.239	0.0081	0.0292	2.250	0.0176

Assuming that a single Debye type dispersion exists, the dielectric relaxation times (τ) at 30°C are obtained using Gopal Krishna expression [5]

$$X = m\gamma + C,$$

where
$$X = \frac{\epsilon' + \epsilon'' + \epsilon''^2 - 2}{\epsilon''^2 + (\epsilon' + 2)^2},$$

$$Y = \frac{3\epsilon''}{\epsilon''^2 + (\epsilon' + 2)^2}$$

and slope
$$m = \frac{1}{\omega\tau}.$$

Thus, the plot of X against Y will give a straight line with slope $(\omega\tau^{-1})$. Figure 2 shows the plots for two cholesteric liquid crystals and these are reasonably straight lines within the

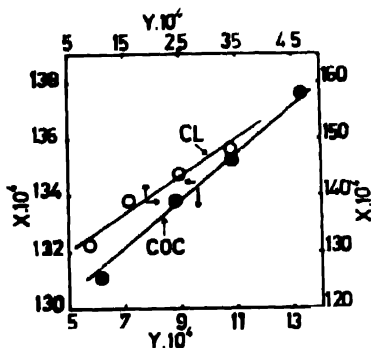


Figure 2. Plots to determine $\omega\tau$ for cholesteryl oleyl carbonate (COC) and cholesteryl linoleate (CL).

errors. From the slopes of lines, the dielectric relaxation times at 30°C are evaluated as 52.2 ps for cholesteryl oleyl carbonate and 45.2 ps for cholesteryl linoleate respectively. It can be seen that there is a reasonable agreement between the two relaxation times, indicating that the assumption concerning simple Debye type dispersion is justified. Further, the cholesteryl oleyl carbonate is a slightly longer molecule, it is expected to exhibit larger relaxation time, as observed in the present study.

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