acta phys. slov. 33 (1983), No. 4

DIELECTRIC ANISOTROPY OF NEMATIC LIQUID CRYSTALS AT CENTIMETER WAVELENGTHS

P. ŠÚRA[1]), Bratislava

The method of dielectric anisotropy measuring on five thermotropic liquid crystals in the K microwave band and the attained results are presented.

ДИЭЛЕКТРИЧЕСКАЯ АНИЗОТРОПИЯ НЕМАТИЧЕСКИХ ЖИДКИХ КРИСТАЛЛОВ В САНТИМЕТРОВОМ ДИАПАЗОНЕ МИКРОВОЛН

В работе указан метод измерения диэлектрической анизотропии пяти термотропных жидких металлов в К-диапазоне микроволн и приведены соответствующие результаты измерений.

I. INTRODUCTION

Dielectric anisotropy of liquid crystals is said to be a phenomenon, which is expressed in different values of the dielectric constant, measured in two significant directions, e.g. along the long molecular axis ($\varepsilon_{\parallel}$) and perpendicularly to this direction ($\varepsilon_{\perp}$). In other words, dielectric anisotropy is the difference $\varepsilon_a = \varepsilon_{\parallel} - \varepsilon_{\perp}$; it may have a positive and a negative sign and a value within the interval of $\langle -6, +41 \rangle$ [1], according to the structure of the material and the space arrangement of the molecule (the value of the angle between the long molecular axis and the direction of its dipole moment is decisive). The shown values are valid for static anisotropy: in alternating fields the dielectric relaxation appears (lag of the molecular reorientation after changes of the electric field) and a decrease of the values of $\varepsilon_{\parallel}$ and $\varepsilon_{\perp}$. In accordance with a strong nonspherical shape of the liquid crystal molecule there is a considerable difference between the hindering of the molecule along the long and the short axis: from this there follows a different dependence of $\varepsilon_{\parallel}$ and $\varepsilon_{\perp}$ on the frequency, as it is shown in Fig. 1 [2]. It will cause that ε_a can change more often the sign during the frequency variation from zero to optical frequencies. In the case of very high frequencies the orientational part of total polarization will vanish and ε_a will acquire some small positive values.

---

[1]) Katedra experimentálnej fyziky MFF UK, Mlynská dolina, 842 15 BRATISLAVA, Czechoslovakia.

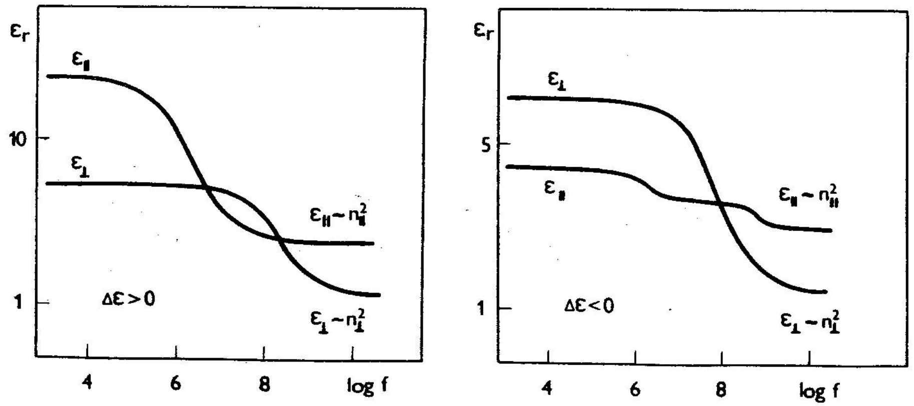


Fig. 1. Dependence $\varepsilon_\parallel$ and $\varepsilon_\perp$ on frequency.

II. METHOD

We have measured the dielectric anisotropy of the LC at the K microwave band, at the frequency of 26.5 GHz. The waveguide method, known from lit. [3] and modified according to [4] was used and the results were evaluated by a programming calculator. The basic arrangement of the measuring apparatus is shown in Fig. 2. It is a twin T-bridge arrangement, in which one of the opposite arms of the T-bridge is terminated by a waveguide with the measuring cell containing the investigated LC. The other opposite arm is terminated by a precision variable attenuator and a variable short with micrometer screw.

The balance of the TT bridge is indicated in the E-arm of the bridge by a sensitive microvoltmeter with a crystal detector. The components of the complex dielectric constant may be calculated from the measured attenuation and the shift of the variable short.

The measuring cell was tempered by electric heating or cooled by liquid nitrogen vapours, covering a temperature interval corresponding to the existence of

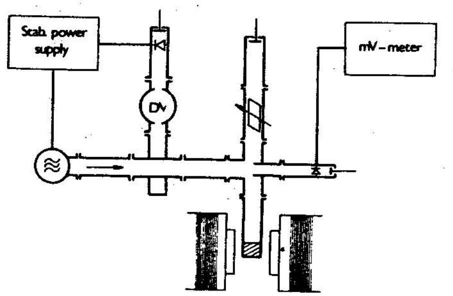


Fig. 2. Basic arrangement of the measuring apparatus.

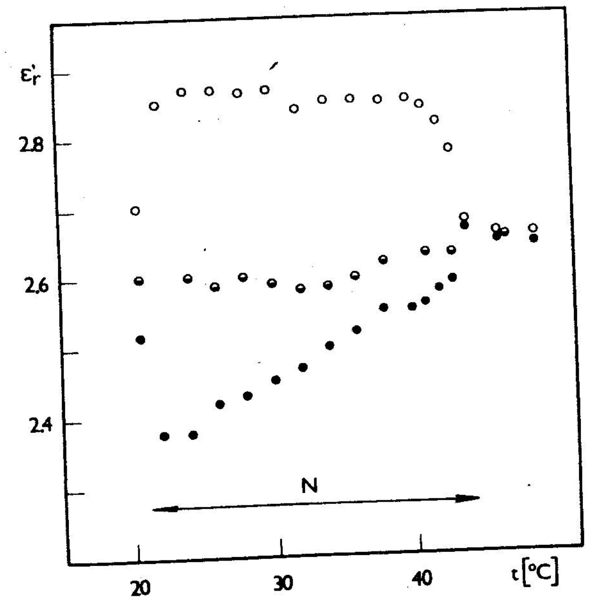


Fig. 3a. Temperature dependence of the real part of dielectric constant parallel (O) and perpendicular (●) to the long molecular axis and without orientation (O) for MBBA.

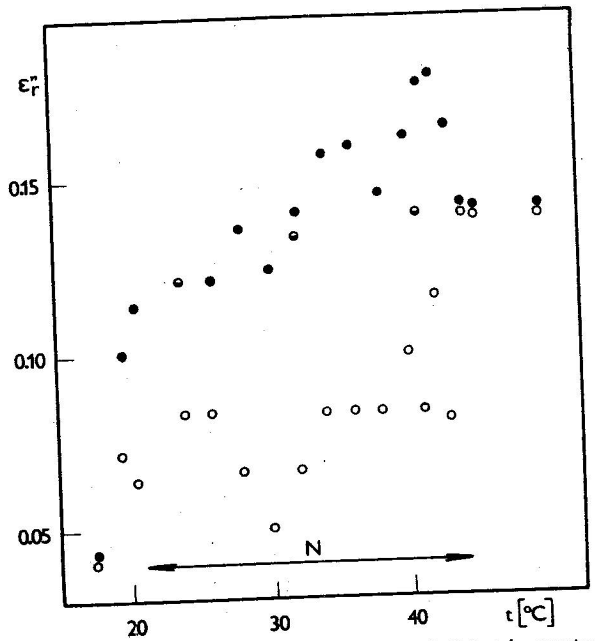


Fig. 3b. Temperature dependence of the imaginary part of dielectric constant parallel (O) and perpendicular (●) to the long molecular axis and without orientation (O) for MBBA.

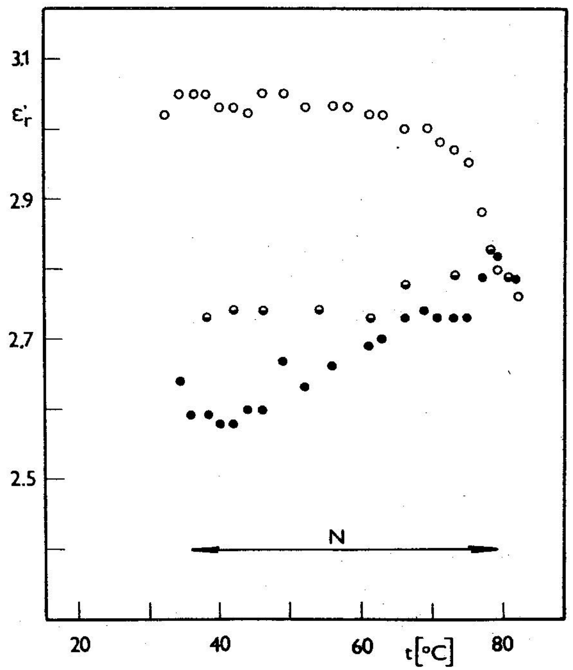


Fig. 4a. The same dependence as in Fig. 3a for EBBA.

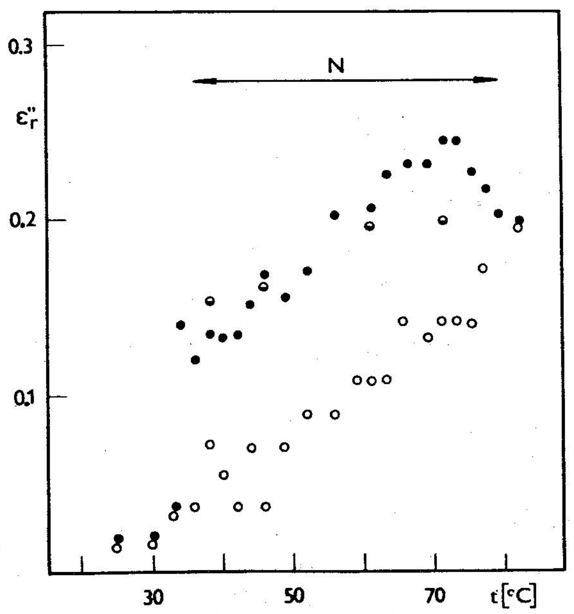
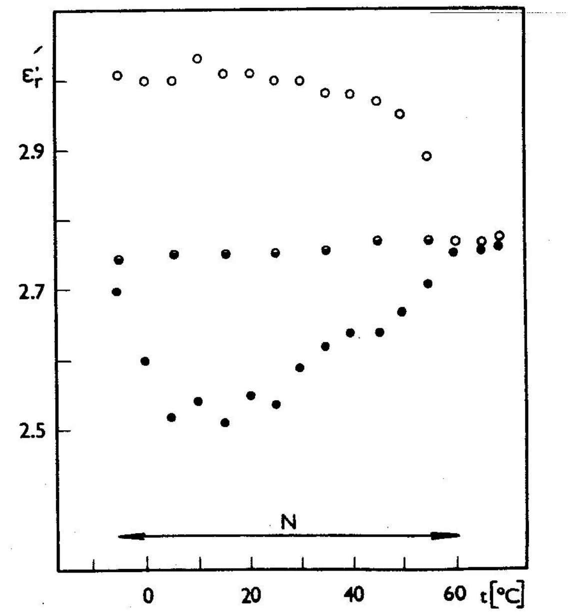


Fig. 4b. The same dependence as in Fig. 3b for EBBA.

Fig. 5a. The same dependence as in Fig. 3a for MBBA + EBBA 1 : 1.



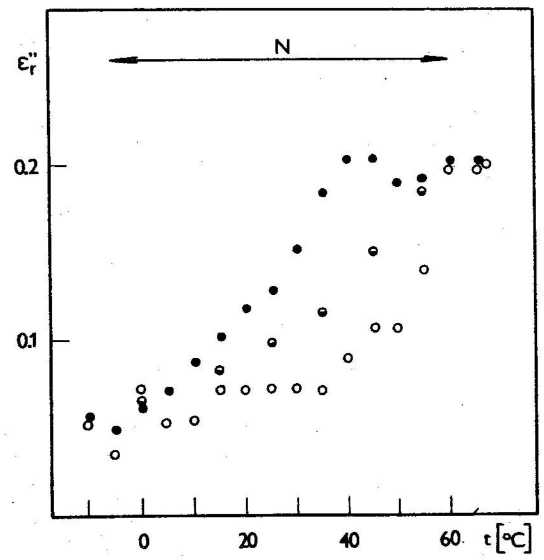


Fig. 5b. The same dependence as in Fig. 3b for MBBA + EBBA 1 : 1.

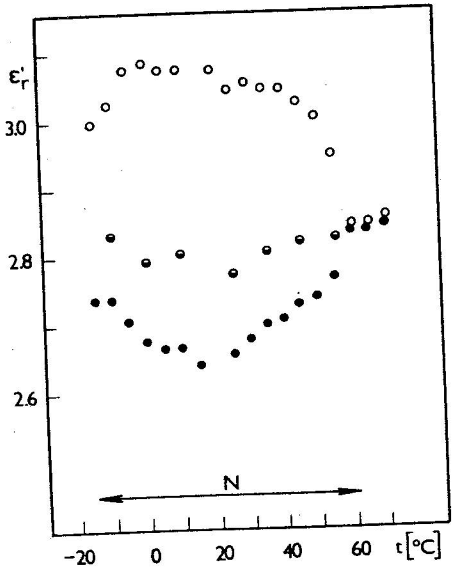


Fig. 6a. The same dependence as in Fig. 3a for NP8A fy Merck.

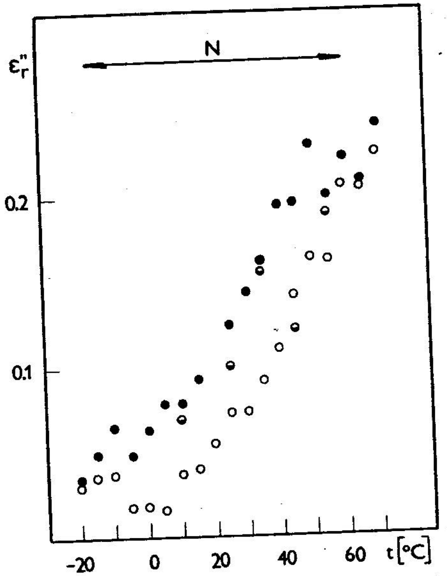


Fig. 6b. The same dependence as in Fig. 3b for NP8A fy Merck.

a mesophase. As a transducer of temperature a silicon diode fed from the source of a constant current was used; the signal for the digital voltmeter which indicates the temperature in Celsius and for the stabilizer which enables a pre-choice required temperature was derived from the voltage in the conducting direction.

The orientation of the liquid crystal was performed by the magnetic field of an electromagnet, which can rotate in an arbitrary direction with respect to the direction of the electric component of the microwave field. The induction of the used field ($B = 0.225$ T) was sufficient for a reliable orientation of all the nematic samples, the crystal K-24 in the smectic region was not oriented even by the doubling of the given field. Before being measured each sample was warmed up above the temperature of the phase transition from the mesophase to the isotropic liquid and the temperature dependence of the dielectric constant was measured at decreasing temperature (this direction of the temperature variation is necessary for creating the mesophase in monotropic liquid crystals). The sample was alternately reoriented during the measuring, i.e. $\varepsilon_{\parallel}$ and $\varepsilon_{\perp}$ were measured simultaneously at each temperature.

The described procedure was not used for the smectic phase of K-24, which must be heated above the mesophase temperature for each measured value.

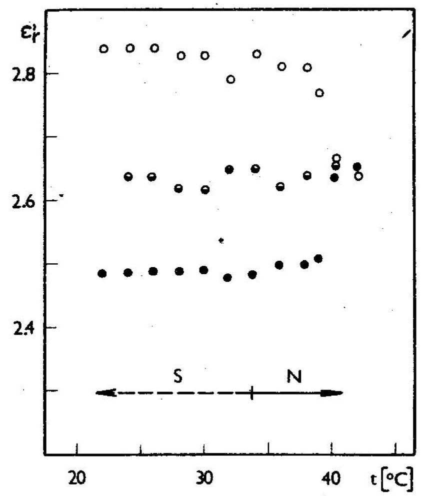


Fig. 7a. The same dependence as in Fig. 3a for K-24 fy BDH.

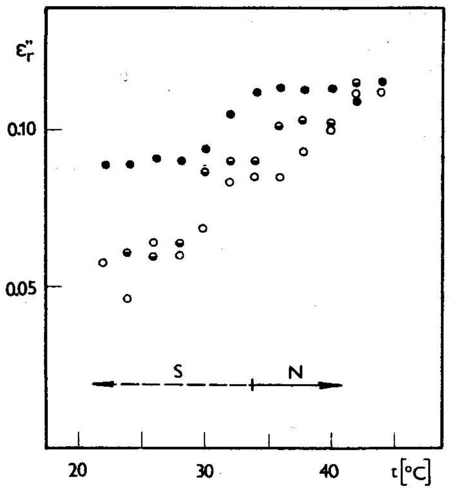


Fig. 7b. The same dependence as in Fig. 3b for K-24 fy BDH.

III. RESULTS

Three pure nematic liquid crystals EBBA, MBBA and NP8A (Merck), the mixture EBBA + MBBA 1:1 and the nematic — smectic A K-24 (BDH) were investigated. The samples were not purified and not adapted in any way before measurement. The measured results are shown in graphical form in Fig. 3 (MBBA), 4 (EBBA), 5 (MBBA + EBBA), 6 (NP8A) and 7 (K-24). By the sign $\overset{N}{\longleftrightarrow}$ or $\overset{S}{\longleftrightarrow}$ the temperature interval of the mesophase existence (known from lit.) is represented (N-nematic, S-smectic LC). The points, which correspond to the values of $\varepsilon_{\parallel}$ are marked in the graphs by a mark "○", to those of $\varepsilon_{\perp}$ there corresponds "●" and the mark "○" determines the dielectric constant of the unoriented material.

IV. DISCUSSION

From the measured values it may be concluded that the used microwave field frequency (26.5 GHz) is above the region of dielectric relaxation, i.e. it is higher than the reciprocal value of the relaxation times of molecular rotation along the long and the short axis. This is confirmed by considerably lower values of the real parts of the dielectric constant compared with the values at low frequencies known from catalogues and also by the positive sign of dielectric anisotropy of all the measured samples. The vanishing of the orientational part of the total polarizability of the molecules results in approaching the values of the real part of the dielectric constant to the square of the refractive index, as predicted in theory. The imaginar components of the dielectric constant of the investigated samples have an anisotropy with the negative sign. In the proximity of the phase transition point the shape of the curves from Fig. 3—7 confirms the existence of pre-transition effects [5].

The author is thankful to Dr. A. Tirpák for his reading of the text and for stimulating discussions.

REFERENCES

[1] *Židkije kristally*, in Russian. Ed.: S. I. Ždanova, Chimija, Moskva 1979.
[2] *Indikatornyje ustrojstva na židkich kristallach*, in Russian. Ed.: Z. J. Gotry, Moskva 1980.
[3] Roberts, S., Hippel, A. R.: J. Appl. Phys. *17* (1946), 610.
[4] Champlin, K. S., Armstrong, D. B., Guderson, P. D.: Proc. IEEE *52* (1964), 677.
[5] Adamczyk, A., Strugalski, Z.: *Ciekle kryzstaly*, Warszawa 1976.

Received March 9th, 1982