Z2 - Dielectric Anisotropy of Nematic Liquid Crystals

Physics Laboratory II
Faculty of Physics, Astronomy and Applied Computer Science, Jagiellonian University

Liquid crystals are materials which, for appropriate values of temperature and pressure, exhibit at the same time the typical properties of liquids as well as of solid crystals. Thanks to their unique properties they are used for example in displays, computer screens or television sets. In the experiment performed during this lab the dielectric anisotropy of selected liquid crystals is measured. Molecules of a liquid crystal, contained between the plates of a parallel-plate capacitor, are aligned by a strong magnetic field, the change of molecules' orientation causes then the significant change of the capacitance. In this experiment the temperature dependence of the anisotropy of liquid crystals is measured and their microscopic parameters are determined according to the Maier-Meier's model.

Preparatory questions

1. Dielectric material in an electric field, the construction of a parallel-plate capacitor [1].
2. Relation between microscopic properties and macroscopic dielectric permittivity, the Onsager's and Fröhlich-Kirkwood's local field models [2, 3].
3. Liquid crystal - macroscopic properties and microscopic structure [2, 3, 4].
4. Classification of liquid crystalline phases [2].
5. Anisotropy of the physical properties of liquid crystals [2, 3, 4].
6. Maier-Meier's local field model for liquid crystals [3].

References [2-4] available in lab-manual (you have to sign-in).

Computational assignments

1. The parallel-plate capacitor was filled with two substances with dielectric permittivities equal to $\varepsilon_1 = 2.28$ and $\varepsilon_2 = 25.3$. The measured capacities of the capacitor are equal to $C_1 = 88.9pF$ and $C_2 = 0.881nF$, respectively. Calculate the capacity after filling this capacitor with a substance with the permittivity equal to 15.75.
2. Calculate the coefficients of a linear regression by minimizing the function $g(a,) = \sum_{i=1}^{n}(y_i - (ax_i + b))^2$.

Apparatus and materials

Experimental set-up for measurement of the principal components of the dielectric permittivity of nematics (Fig.1) consists of:

1. electromagnet,
2. LCR meter,
3. parallel-plate capacitors filled with liquid crystalline samples,
4. direct current source of the sample's furnace,
5. electronic thermometer.

Experiment

1. Qualitative observation of the liquid crystalline sample in a strong static magnetic field.
2. Heating the sample to the isotropic liquid phase.
3. Measurement of the liquid crystal-filled capacitor's permittivity every 0.5/degree C during cooling.
4. Change of the capacitor's orientation with respect to the direction of a magnetic field and heating the sample up to the same temperature as in 2.
5. Measurement of the liquid crystal-filled capacitor's permittivity in the same way as in 3.

Data analysis

1. Use the calibration data to calculate the values of the dielectric permittivity of the liquid crystal from the measured capacities.
2. Plot the temperature dependence of the dielectric permittivity for both orientations of the capacitor with respect to a magnetic field.
3. Determine the clearing temperature from the plot.
4. Fit the Maier-Meier's model to both branches of $\varepsilon(T)$ dependence. Use as fitting parameters the Fröhlich-Kirkwood's correlation factor given by the formula $g = g_0 + \Delta T g_t$ and β angle between the molecular long axis and the dipole moment vector.

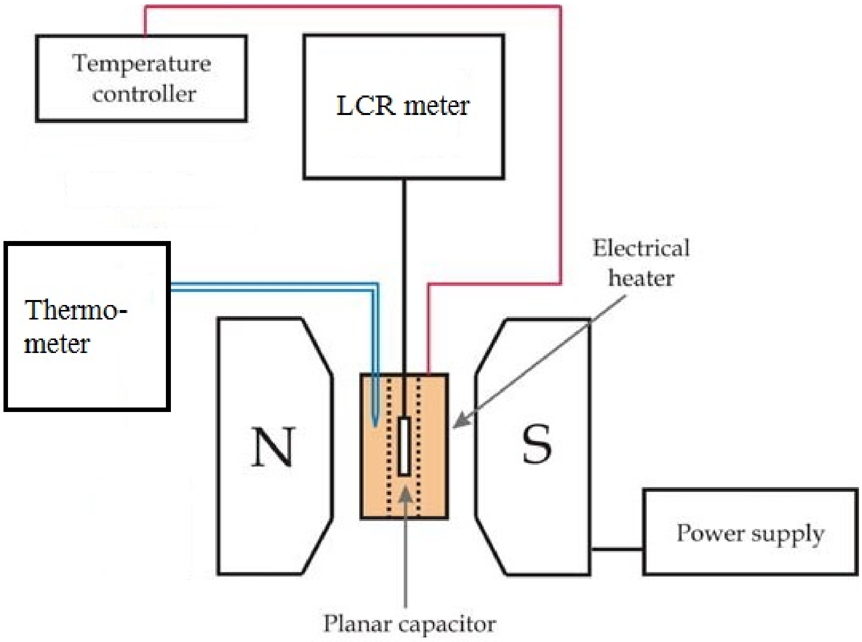

Figure 1: Experimental set-up.

Safety rules

1. The electromagnet produces a very strong magnetic field. Be careful and do not approach with metal items as well as watches.
2. The current in the coils must be slowly reduced to zero before switching off the electromagnet.

References

[1] Any university handbooks on electricity and magnetism e.g. E.M. Purcell, D.J. Morrin *Electricity and magnetism.*

[2] S. Urban, *Dielectric relaxation processes in calamitic liquid crystals. Influence of temperature and pressure*, in *Dielectric Properties of Liquid Crystals*, edited by Z. Galewski and L. Sobczyk, Transworld Research Network, Kerala, India, 2007, ch. 10, pp. 255-262.

[3] S. Urban, J. Kędzierski, and R. Dąbrowski, *Anaslysis of the dielectric anisotropy of typical nematics with the aid of the Maier-Meier equations*, *Z. Naturforsch*, 2000, 55a, 449-456.

[4] S. Urban, *Static dielectric properties of nematics* in *Physical Properties of Liquid Crystals: Nematics*, edited by D. Dunmur, A. Fukuda and G. Luckhurst, 2001, EMIS Datareviews Series, ch. 6.1.