Dielectric Analysis of Carbon Nanotube Doped Nematic Liquid Crystals

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1. Introduction

Liquid Crystals (LCs) play an import role in everyday technology, particular for their uses in display devices. They can be viewed as long, rod-like molecules, and can exhibit a number of interesting **mesophases** — phases which are intermediate between the crystalline solid and isotropic liquid. The mesophase that we are interested in is the **nematic** phase, which is described as having orientational order, but no positional order[1] (Figure 1).

Carbon nanotubes (CNTs) have been shown to improve some of the electro-optic properties of liquid crystals,[2,3] in particular reducing the **Fréedericksz transition** critical voltage[4] (Figure 2). The aim of this research is to better understand the impact of carbon nanotubes on the electrical behavior of liquid crystals using **dielectric analysis**. This approach measures the response of the liquid crystal polarization to an oscillating electric field.

2. Experimental Methods

The liquid crystal chosen for study was **5CB** (4-pentyl-4'-cyanobiphenyl, shown in Figure 3) due to the high dielectric anisotropy and the fact that it is nematic at room temperature.

Liquid crystals were inserted into indium tin oxide (ITO) glass cells via capillary action. The cells had an active area of ~1.29 cm^2 and a nominal thickness of 10 μm (Figure 4). Cells were connected to an Agilent 4284A Precision LCR meter for dielectric testing at room temperature.

The voltage across the cell ranged from 50 mV to 10 V, and the electric field oscillation frequencies ranged from 20 Hz to 1 MHz. The capacitance and dissipation factor were measured, and from those measurements the complex dielectric permittivity could be found. Samples were tested with no CNTs (neat), and with 0.01 wt.% or 1.00 wt.% of multi-walled carbon nanotubes.

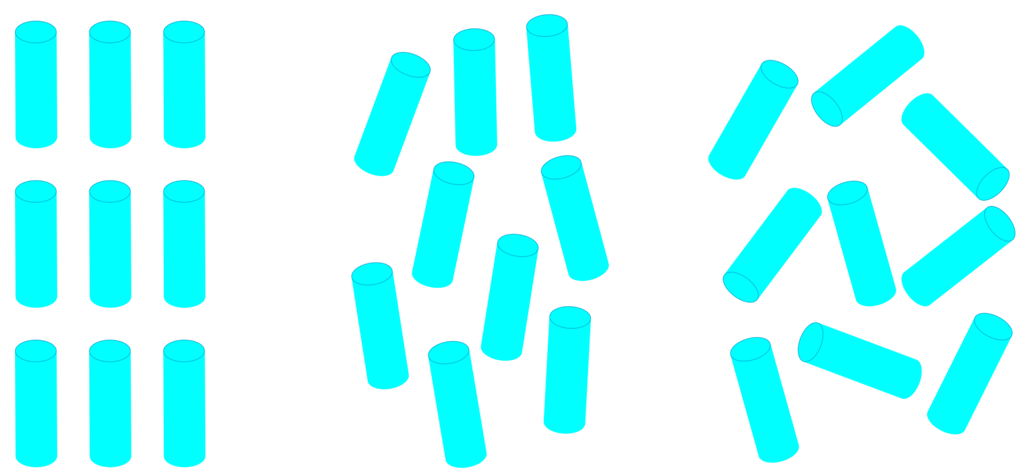

Figure 1. Comparison of three liquid crystal phases: crystalline solid (**left**); nematic liquid crystal (**center**); and isotropic liquid (**right**).

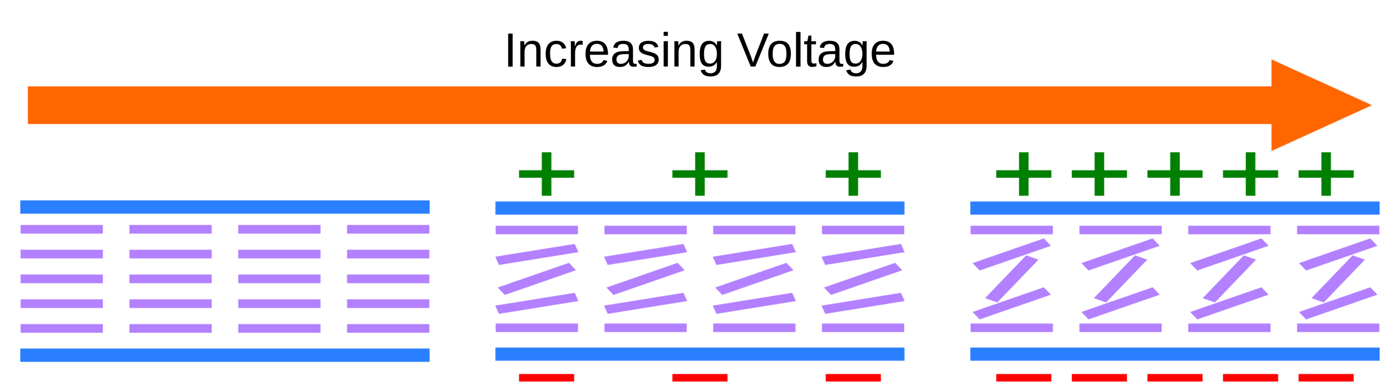

Figure 2. Increasing the voltage causes a distortion in the liquid crystal alignment. The point at which this deformation occurs is the **Fréedericksz transition**.

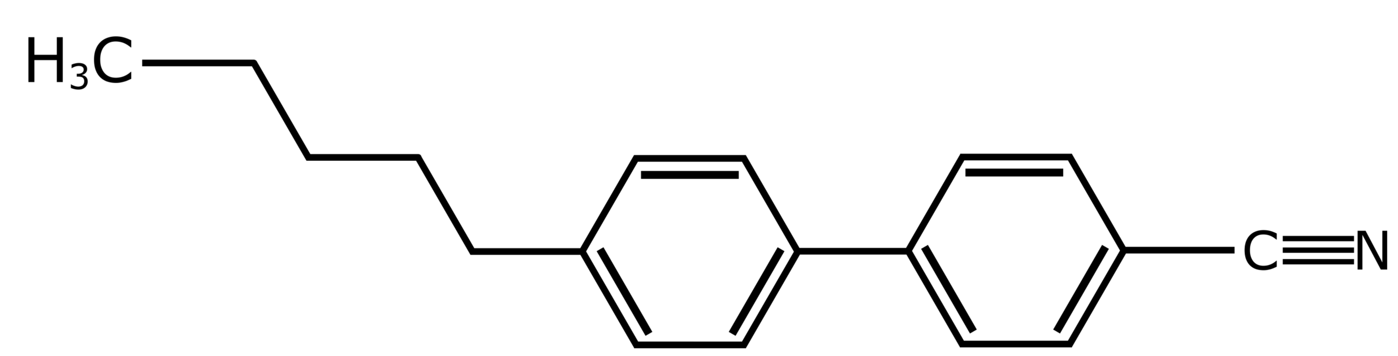

Figure 3. The chemical structure of 5CB. The two phenyl groups are responsible for many of the interesting dielectric properties of 5CB

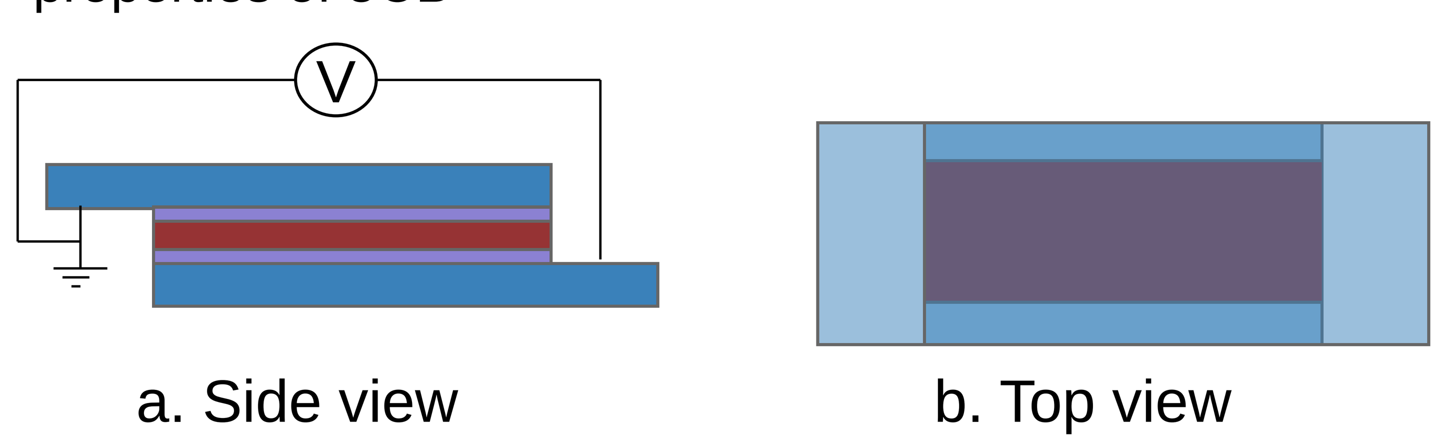

Figure 4. Sketch of the filled ITO glass cell, from the side (a) and from the top (b), showing the liquid crystals (maroon), ITO glass (blue), polyimide alignment layer (purple), and spacer (light blue). Electrodes are connected to the overhanging edges as shown in (a).

3. Results

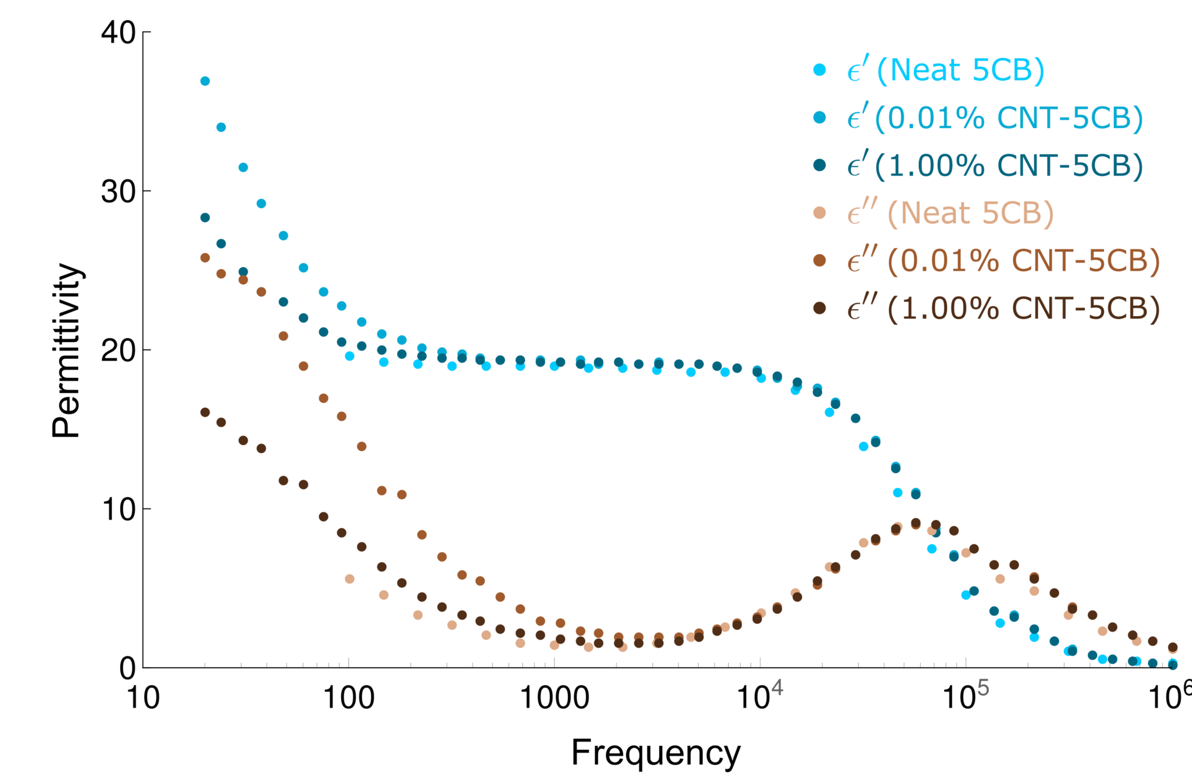

Figure 5. Measurements of the complex permittivity at 10 volts, far above the critical voltage, show a clear relaxation process occurring at around 20 kHz, where the real permittivity (blue symbols) decreases and the imaginary part (brown symbols) shows a peak. Significant differences can be seen between the neat and doped 5CB in the low frequency region where ionic conductivity occurs (f < 1kHz).

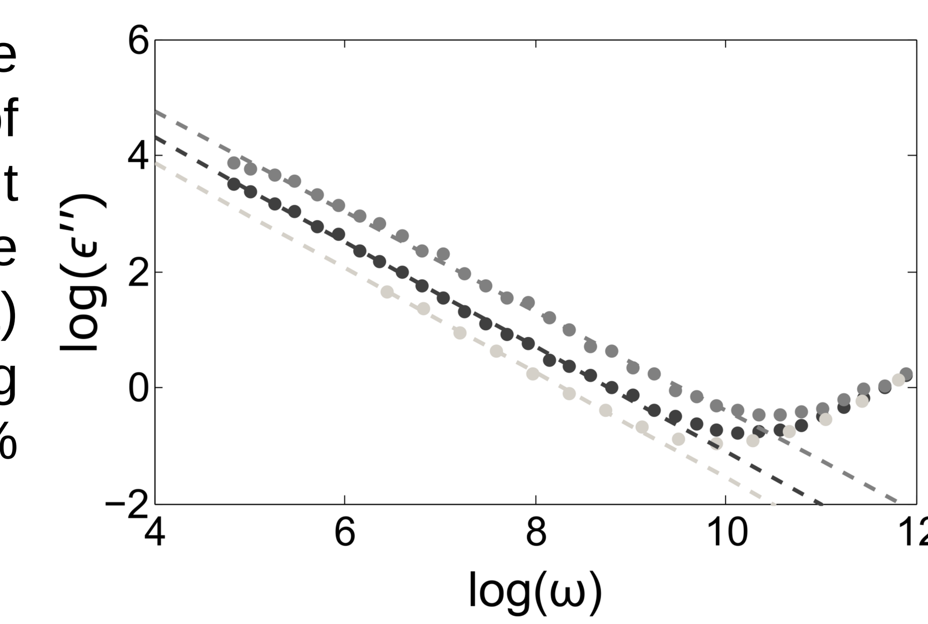

Figure 6. Plotting the log of the imaginary permittivity vs. the log of frequency gives information about the conductance. There is a notable difference between the neat (light) samples, and those containing carbon nanotubes at 0.01 wt.% (medium), or 1.00 wt.% (dark).

4. Conclusions

- The addition of carbon nanotubes has a strong impact on the low-frequency dielectric properties where ionic conductivity dominates the polarization.
- Analysis of low frequency characteristics indicate that CNTs increase the conductivity of the liquid crystals, but leave the ohmic response fairly constant.

5. Acknowledgements

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6. References

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