Effect of Carbon Nanotubes on Chirality in Liquid Crystals

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Abstract

Carbon nanotubes (CNTs) were added to a liquid crystal (LC) that exhibits a layered Smectic A phase and a tilted Smectic C phase. An electric field $E$ was applied parallel to the layers in the Smectic A phase, causing the molecules to tilt an angle $\theta$ with the director. Such a tilt only occurs when chirality is present. The presence of this electroclinic effect in the CNT and achiral LC mixture indicates that the CNTs transmitted chirality to the liquid crystal.

Introduction

There are three types of CNTs: armchair, zigzag, and chiral. The nanotubes used in this experiment include all three types.

• CNTs dispersed in a liquid crystal will adopt the long range orientational order of the liquid crystal.

• LCs are substances that have properties of both liquids and solids. Liquid crystals have three distinct phases: nematic, Smectic A, and Smectic C.

• A liquid crystal is chiral when the mirror image of the molecule cannot be superimposed on the molecule.

• The similar chemical architectures of the LC and CNT molecules allow the molecules to anchor at the surface due to $\pi - \pi$ electron stacking.

• As a result of the anchoring energy, the director of the liquid crystal is along the axis of the nanotube.

• The electroclinic effect is a sensitive measurement of chirality. If there is no chirality, there is no electroclinic effect. If there is chirality, the tilt angle $\theta$ is directly proportional to the electric field $E$, as shown in the equation:

$$\theta = \frac{\kappa E}{\Delta}$$(1)

where $\kappa$ is the electroclinic coefficient, given by

$$\kappa = \frac{k(T - T_{AC})}{\pi}$$

Method

The cells used in this experiment were made using Indium Tin Oxide (ITO) coated glass spool coated with the alignment polymer RN1175, manufactured by Nissan Chemicals. The glass was then rubbed and placed together, separated by 2 $\mu$m mylar spacers, in an antiparallel configuration. The LC-CNT mixture was made by dispersing the nanotubes in acetone, then shaking them in a vortex mixer for 15 minutes and sonicating them for 2 hours. The cell was filled in the nematic phase, then cooled to the Smectic A phase, where it was kept throughout the experiment. The set-up shown in Figure 6 allows for the measurement of the AC intensity and the DC intensity, which can be used to find the tilt angle by $\theta = 1/c/l$.

\[\theta = \frac{E}{c/l}\]

\[\text{Figure 8 (left): The inverse electroclinic coefficient as a function of } T - T_{AC}, \text{with a } \pi \text{ - Smectic C* transition temperature } T_{AC}\star.\]

\[\text{Figure 7 (above): The tilt angle as a function of electric field for pure } 8S5 \text{ (a) and } 8S5 \text{ with CNTs (b) at different temperatures. The temperatures are given as } T = T_{AC}\star \text{ where } T_{AC}\star = 56°C.\]

SSS and Carbon Nanotubes

8S5 is an achiral (non-chiral) liquid crystal. The experiment was run using both pure 8S5 and 8S5 with 0.058 wt% multi-walled carbon nanotubes, with an electric field applied at frequency $f = 1$ kHz. The results are shown in Figures 7 and 8.

\[\text{Figure 9: A comparison of the results with the unwashed CNTs, the CNTs washed in acetone, and the CNTs washed in toluene.}\]

Could this be the result of an artifact?

These results show that the CNTs transferred chirality to the liquid crystal. The exact cause of this is unknown, as the nanotube sample should have an equal amount of left-handed chiral and right-handed chiral nanotubes. One possible cause is the presence of a chiral artifact in the nanotube. However, chemical analysis by the manufacturer revealed no chiral impurities. Also, purification methods were used in the lab. The CNTs were placed in acetone, spun in a centrifuge, and drained of the acetone. The same procedure was repeated with toluene. Both samples produced similar results to the nanotubes that were not subjected to these procedures. Based on this data, it appears that the chirality is not the result of an artifact, but is from the nanotubes themselves.

Conclusions

Though pure 8S5 is not chiral, the 8S5 and carbon nanotube mixture exhibited the behavior of a chiral liquid crystal. This demonstrates that the nanotubes transferred some chirality to the LC. The exact cause of these chirality is unknown. However, it is known that the chirality comes from the nanotubes themselves, and not from any chiral impurities in the CNTs. The analysis provided by the manufacturer did not reveal any chiral artifacts. In addition, purification methods, such as dissolving the CNTs in acetone and in toluene, were used in the lab. Experiments performed with the purified CNTs yielded the same results. Future work will focus on finding a cause for the chirality in the nanotubes.

References


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