The Effects of Multi-Walled Carbon Nanotubes on the Pretilt Angle of a Nematic Liquid Crystal

Matthew Sheffield, Rajarati Basu, and Charles Rosenblatt

Department of Physics, Case Western Reserve University, Cleveland, OH 44106 USA

Abstract

We examine whether the presence of multi-walled carbon nanotubes (CNT) in the nematic liquid crystal pentylenecyanobiphenyl (5CB) affects the pretilt angle associated with the liquid crystal. Here, pretilt angle is defined as the angle between the normal to the substrate and the liquid crystal director. We control the pretilt angle by coating a substrate with a polyamic acid, baking the substrate at a temperature slightly higher than recommended by the manufacturer, and rubbing the resulting polyimide with a fabric at different rubbing strengths. The increased baking temperature results in an expansion of the polyimide’s backbone and partially removes the side chains, which produce competing easy axes for the liquid crystal alignment. The rubbing preferentially aligns the backbone as well as creates a slightly tilted side chain. The pretilt angle is controlled by varying the rubbing strength. Pretilt angle was measured using a HeNe laser setup containing two crossed polarizers. The Babinet-Soleil compensation device was used to measure the retardation of the sample cells at various positions along the cell (each position corresponds to a different rubbing strength), from which the pretilt angle was extracted. Results appear to indicate that the LC-CNT has a slightly lower pretilt angle than 5CB. Also, the results suggest that the CNT causes a slower rate of increase in the pretilt angle as a function of rubbing strength.

Carbon Nanotubes and Liquid Crystals

Liquid Crystals (LC) are a unique phase of matter that exists in between the 3D structure of a solid and the perfectly random, isotropic state of a liquid. Thus, LCs exist in a variety of phases, of varying orders of alignment. In this experiment, we used the LC 4-Cyano-4-pentylphenyl (5CB).

Carbon nanotubes are essentially rolled up sheets of graphene (a single layer of graphite). Each graphene piece has a benzenetype structure made up of solely carbon atoms. Some liquid crystals also contain benzene rings and this leads to a CNT-LC interaction known as n stacking, where the benzene rings of the LC stack on top of the benzenes rings of the CNT forming a bond on the order of ~2eV. This bond does not affect the LC director, as the CNT itself tends to align with the orientation of the LC [2].

Gradienly Rubbed Cell Construction

The cell is composed of two Indium-Tin Oxide (ITO) coated glass slides, which allow for an electric field to be applied across the cell. Each slide has a layer of SE1211 polymer applied by spin-coating at 3000 rpm for 10 seconds. The slides are then pre-baked for 30 minutes at 80 °C and then over-baked at 200 °C for 50 minutes. This over-baking process weakens the side chains of the polymer, decreasing the normal homotropic tendencies of SE1211. We then rub each slide by translating it at a constant velocity under a rubbing cloth cylinder rotating at a fixed speed v.

We varied the rubbing strength in each cell by positioning the slides at a calculable angle in order to impart a gradient in the rubbing strength along the slide. The slides are arranged in an antiparallel configuration to ensure the alignment angle. We divided each cell into two halves: one half has plain 5CB and the other half has 5CB with 0.05% concentration by weight of multi-walled CNT. This dual-sided cell design ensured that the only factor affecting the pretilt of the LC is the CNTs.

Results and Discussion

As the rubbing strength is increased in the cell we see a marked increase in the pretilt angle in both the plain liquid crystal and the CNT-LC mixture, as is to be expected [1]. Present data suggests that the presence of CNTs may cause a slight decrease in the pretilt angle of 5CB. Additionally, the CNT-LC mixture data appears to indicate that the CNTs slow down the rate of increase in the pretilt angle as a function of rubbing strength. Because this experiment was done with only one percentage of CNT in the liquid crystal, more work is currently underway to repeat this experiment with various concentrations of CNT to ensure the validity of these results.

References


Experimental Setup

In this setup, a polarized HeNe laser passes through a polarizer crossed 90 degrees with an analyzer in order to maximize the sample cell’s signal. The sample and the Babinet-Soleil compensator are rotated to be 45 degrees with respect to the polarizer and analyzer. This creates a change in the birefringence of the sample and ensures that the compensator matches that change.

The Babinet-Soleil Compensator is a device that can impart a user-defined retardation to a laser beam. It consists of two birefringent plates of equal thickness with perpendicular ordinary and extraordinary refractive indices. One of the plates is divided into two wedges, and one of these wedges is then controlled by the user. This allows the user to control the effective thickness of the second plate and therefore the resulting retardation applied to the laser. By placing the compensator in the sample’s path, we can effectively cancel the retardation of the sample. The retardation of the compensator is then the retardation of the sample, from which the pretilt angle can be extracted.

A signal generator is used to apply an AC signal across the sample cell, and is used only to ensure only one period of retardation is present in the cell. This is an important step because the compensator can only indicate a 2π retardation in the signal, while the period of the sample cell’s retardation is only limited by the length of the cell and its inherent birefringence.