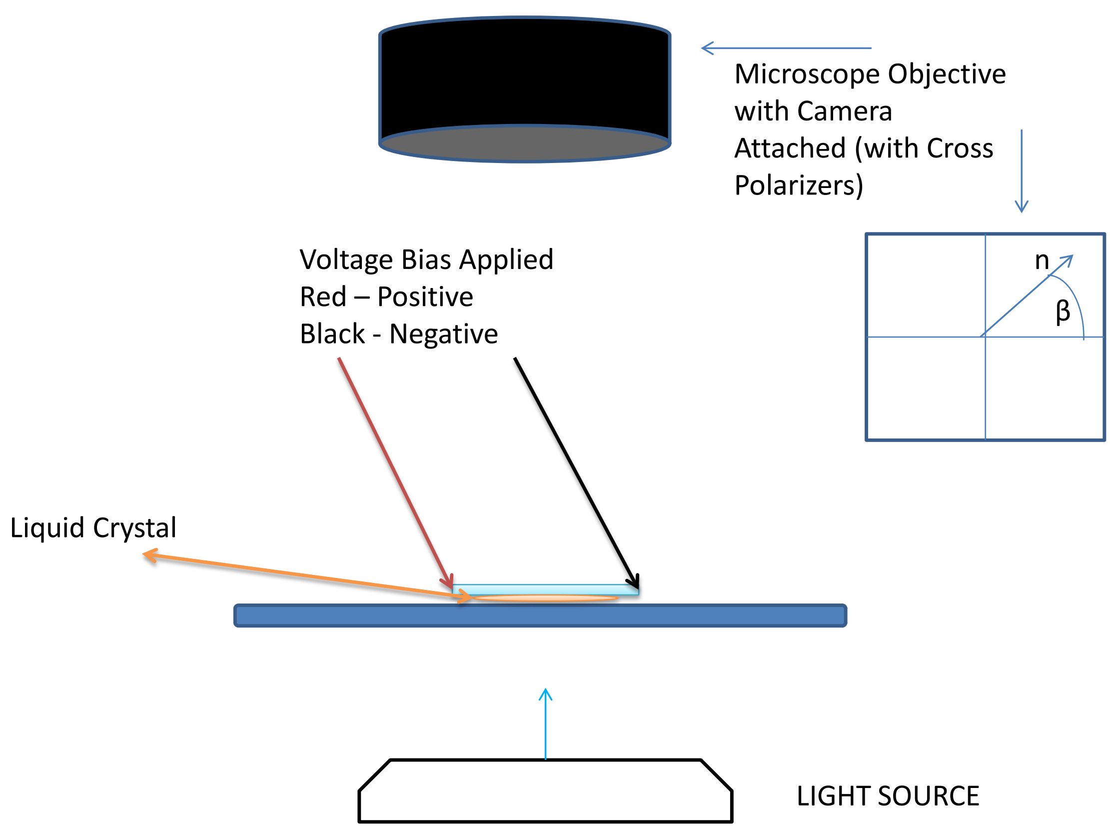
Flow Visualization Spring 2012
Benjamin Pacheco
4/6/2012

Team 2 –Thermotropic Liquid Crystal

For the team 2 assignment we decided to image a liquid crystal. In this case, the liquid crystal used was a synthetic thermotropic liquid crystal created in the laboratory. The few details were that molecule the liquid crystal consisted of was known as a banana molecule. The intent of the image was to visualize how a thermotropic liquid crystals phase depends on the temperature. This was accomplished by filling the thermotropic liquid crystal into the cell and raising the temperature up to 140˚C which is approximately when the liquid crystal reaches the phase Smectic APF. My image was taken several degrees lower at approximately 80˚C where the phase then becomes Smectic A. A voltage bias was then applied at this temperature and the banana molecules physically rotated which in turn gave the bright yellow/gold color seen in the image taken.

The experimental setup that was used can be referenced below in the following schematic.



Schematic 1

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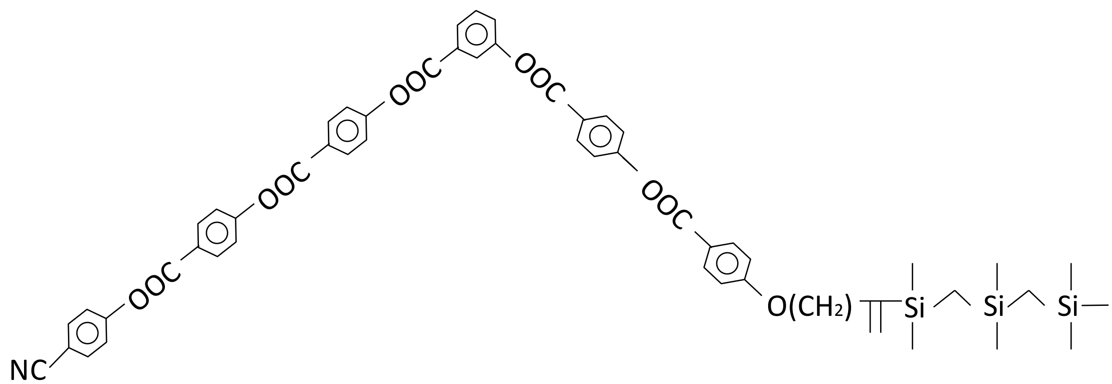

Schematic 2 (Banana Thermotropic Molecule)

Initially, the experimental apparatus was setup by the Post-Doc Renfan Shao. The key goal was to get a picture of one of the specific liquid crystal phases. For this experiment, the liquid crystal was allowed to cool back down to 80˚C so I could take a picture of it in the Smectic A phase. The voltage bias that was applied to the liquid crystal to give it a brighter yellow/gold color was roughly about 10mV. Once the conditions were set I used a Nikon camera supplied by the lab connected to the microscope. The magnification used for the experiment was set to 50x.

The physics of the individual nanoparticles themselves are rather complicated and require multiple layers of quantum mechanics as well as a copious amount of boundary conditions. Due to this reason when studying a liquid crystal there are easier steps to be taken to measure the liquid crystal as whole and use the optical properties of light to simplify the actual flows occurring. For this reason the calculation of transmission of wavelengths of light can be used to measure the actual thickness of the liquid crystal at a given color (wavelength).

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$$T = \sin(2\beta)^2 * \sin(\delta/2)^2$$ [1]

Where phase perturbation is $\delta = \frac{2\pi * \Delta n * d}{\lambda}$, where Δn is the index of refraction of the liquid crystal which is approximately equal to 0.25, d is the thickness of the liquid crystal at that point and λ is the wavelength. β will also equal the angle of the director n in the cross polarizers . In our case the value is 45˚. For example one can now see that the violet (λ = 580) was transmitted at near 100 percent so we can then put this value in for T and solve for d which comes out to be roughly 9µm thick. Then with this we can compare the light and dark spots on the pattern of the liquid crystal to determine how the nanoparticles orientation relates to the thickness. This can be done by previously knowing the liquid crystal is Smectic A and the dark spots are particles horizontally aligned where as the brightest spots are particles oriented in a 45˚ angle counter clockwise from that horizontal.

The most crucial part of visualization happened to be not only the lighting but the right temperature to physically see the changes within the liquid crystal. Next the only way to physically visualize the direction of the liquid crystal and orientation depended on the direction of the cross polarizers and director of each liquid crystal molecule. This difference in the direction of the molecules end up creating what we see as light and dark spots in the liquid crystal and sometimes form streaks that look like boundary lines in the thermotropic liquid crystal. More so the dark spots are not absence of liquid crystal but are in fact a difference of orientation being seen through cross polarizers. This visualization can be seen in schematic number 1.

The size of the image was roughly taken in the field of view of ~500x500um and a few mm from the lens objective of the microscope. This micro-sized image was taken at 50x magnification and the flow of the liquid crystal was rather slow and time consuming. In order to capture this flow a Nikon D5000 camera was used. The camera was used by the program SPOT running on the computer, which allowed alteration in exposure, and post-processing to allow for maximum clarity and color of the image. The resulting image was 4288 x 2848 pixels with an exposure time of 0.25sec. More so the ISO of 200 was used to capture the flow without blur. Overall, once the photo was taken the levels were adjusted to give an overall brighter picture with more saturated colors.

Overall, the image was ideal for showing how thermotropic liquid crystals work and how their phases are temperature dependent. Not only that it was able to show how the fluid flow changes with time and temperature; as well as a voltage bias. It revealed that in fact the thermotropic crystal is in question does make a Smectic A phase at 80˚C as is clarified by the data sheet the liquid crystal came with. The applied voltage was also able to tell us that the molecules will rotate under the bias creating a phase shift of color in the visible wavelength of light. My intent was overall fulfilled but I would like to improve on the visualizing different types of crystals that will permit chiral behavior as well as maybe homeotropic alignment. In the future I would like to investigate crystals that perhaps react with different waves of light in order to create structures within the cell.

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[1] S Chandrasekhar, *Liquid Crystals* (Cambridge [England]; New York, NY, USA: Cambridge University Press, 1992).

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Sources:

Renfan Shao – Professional Research Assistant

Schematic 2 – Jennie Jorgenson

Chandrasekhar, S. *Liquid Crystals*. Cambridge [England]; New York, NY, USA: Cambridge University Press, 1992.