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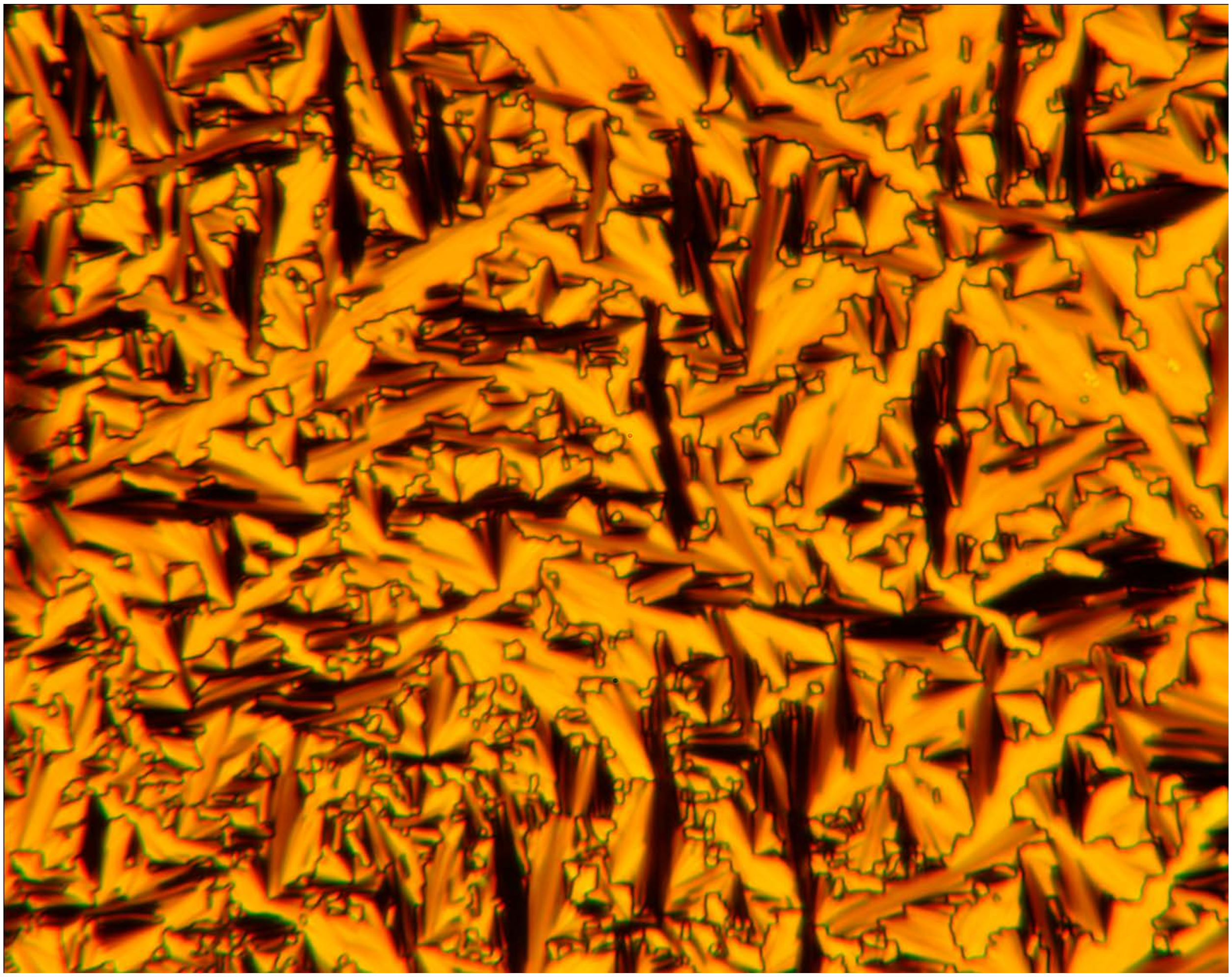
Team Assignment #2



Purpose of Image

For team project 2, my team decided to study the "physics" of fluid flow. To pursue this goal, we wandered around the physics building until someone agreed to teach us something about liquid crystals. This person was a professional research associate by the name of Renfan Shao, who works in the Clark group in the physics department at CU Boulder. In fact, Renfan even allowed us to make our own sample and take pictures with a microscope! So, for this project, we wanted to capture something cutting-edge and unique. In fact, we were able to capture something unique – the phase changing phenomena of liquid crystals.

Background and Apparatus

Liquid crystals are an interesting phenomenon to discuss in a fluid visualization class. However, since they fall on the spectrum somewhere between crystalline solid and liquid, they are definitely relevant. They possess many fluidic properties – the ability to flow, formation of droplets, and the inability to support shear stresses [1]. They also exhibit the optical, electrical, and magnetic properties of crystals [1]. Although we typically think of matter as being only solid, liquid, or gas, this is clearly not always the case (think mayonnaise). Liquid crystals do exhibit solid behavior below a certain temperature and liquid behavior above a certain temperature, but also have distinct phases in between [2]. Liquid crystals have other distinguishing characteristics – a rigid, rod-like long axis and strong dipoles [2]. Electric dipoles result when one end of a molecule has a net positive charge and the other end has a net negative end. When an electric field is applied, the molecules will orient their axis along the direction of the field.

The type of liquid crystal used in this image was a banana (or bent-core) liquid crystal. The name of the crystal becomes clearer upon inspection of the molecular structure, as shown in **Figure 1**. In this case, the most important information to be gleaned from the chemical formula is the shape, which results in the aforementioned properties of liquid crystals. When an external

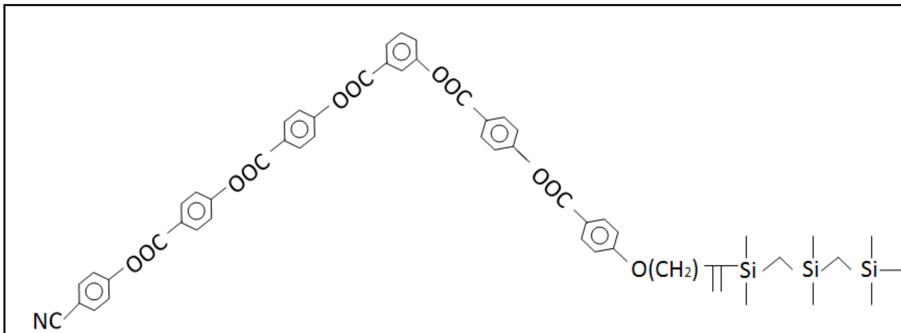


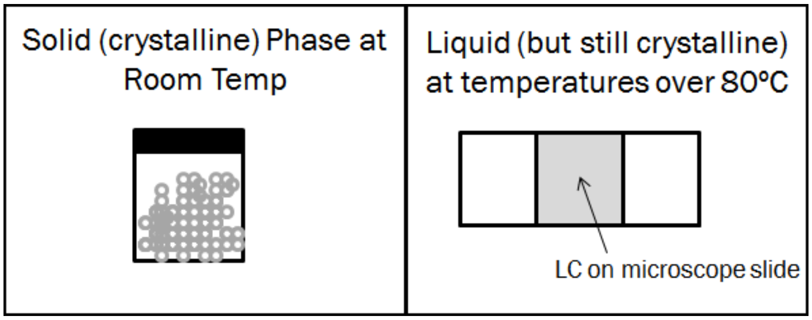
Figure 1: The molecular structure of a banana-shaped liquid crystal.

field is applied to banana-shaped liquid crystals, the molecules undergo rotation about their long axis and a color change is observed [3].

However, we still need to discuss another important aspect of liquid crystals – phase changes. Every crystal has a characteristic phase diagram, or distinct temperatures at which the substances changes phase or orientation. In this case, the substance transforms from a visible solid to a clear liquid at 80°C. As the temperature increases above 80°, the substance visibly changes crystal structure as well at 120° and 140°. The final phase change occurs at 160°C, which is called the isotropic temperature. Isotropic liquids reversibly exhibit completely liquid phase behavior (ie, no crystals) [4]. Basically, above the isotropic temperature, the crystalline order is disrupted so much that the fluid now behaves more like a liquid [4]. However, the isotropic process is reversible, meaning that decreasing the temperature will recrystallize the solution [4].

Now that we have discussed the background necessary to understand the physics of the issues, I will introduce the apparatus used. First, we heated the solid molecule (shown in **Figures 1** and **2**) above its isotropic temperature. Next, we placed the liquid substance near two "sandwiched" microscope slides. Capillary action along a small channel "pulled" the liquid between the two microscope slides. Finally, we placed the microscope slide on the microscope itself. The microscope was equipped with a temperature control and a voltage source. I took the first photograph, while the liquid crystal was still at room temperature from transport to the microscope. Due to magnification, the image is a few micrometers in size (see next section for details). Since the scenario I captured was below 80°C, the substance was in a disordered crystal form. The difference between the appearance of crystals at room temperature and above the isotropic temperature is shown in **Figure 2**.

Figure 2: Difference in physical appearance between solid and isotropic liquid crystals.



Visualization Techniques

The visualization technique was a simple microscope with strategically placed camera to capture the image displayed by the microscope. The microscope magnified the image by 1000x. Therefore, the microscope slide was about 2 cm in size (2 x 10^-2 m) and the image must have been on the order of 2 micrometers (2 x 10^-6 m). Ambient lighting was used. It is important to note that a polarized microscope was used. Polarized microscopes use polarized light to capture the optical properties of liquid crystals [5]. In this case, the sample interacts strongly with the polarized light which lends greater contrast between the sample and the background [5].

Photographic Technique

Again, the field of vision was a few square micrometers. The microscope itself was placed a few millimeters from the sample. The camera was simply situated to capture the image seen in the microscope. The camera settings were f/60, ISO 800, and 1/160 sec. Some post-processing was done in Photoshop. I changed the contrast between the crystalline regions, and brightened it up a bit. I also played with the color curves to produce a “warmer” and more visually appealing color. There were also a couple distracting elements near the edges of the photo, so cropped out the far left and right sides of the original. **Figure 3** displays the ”pre- Photoshop” image.

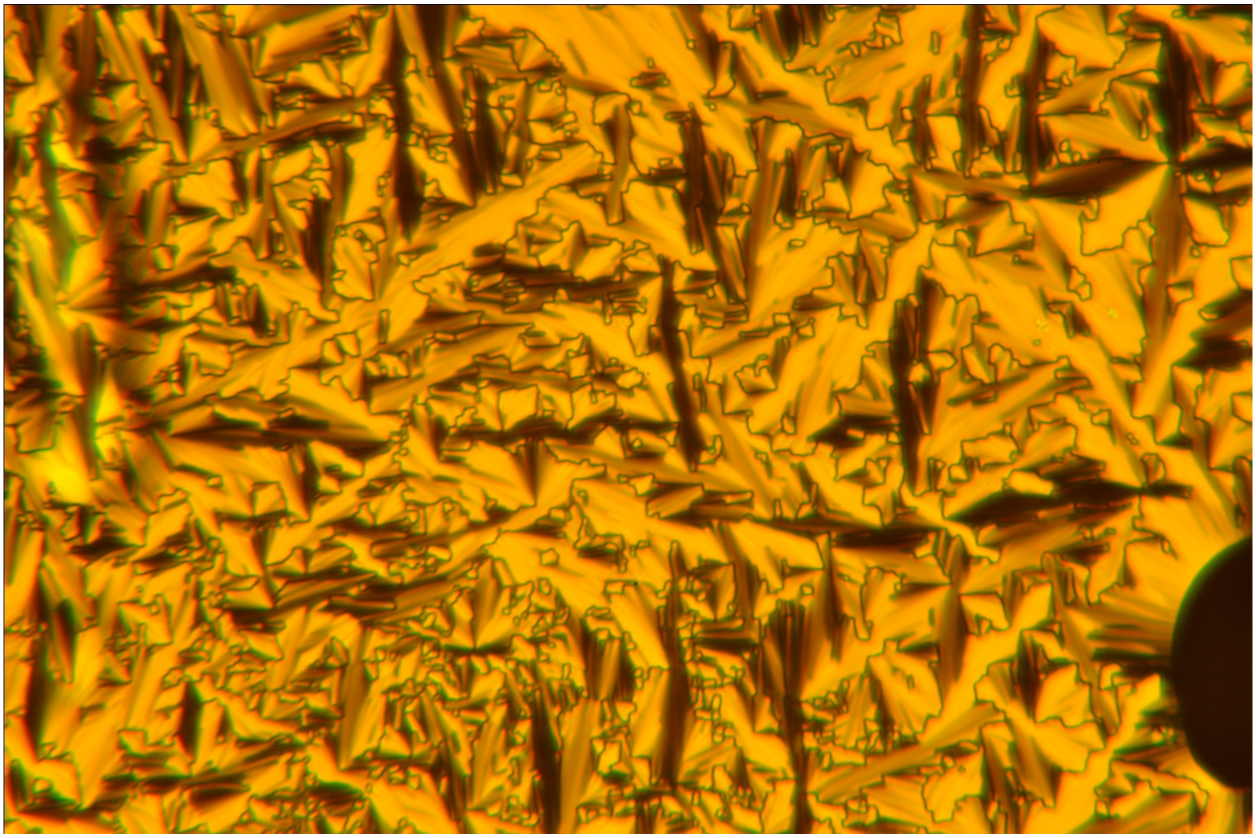


Figure 3: The “Pre-Photoshop” image.

References

[1] Stephen, M.J. and J.P. Straley. “The Physics of Liquid Crystals.” *Reviews of Modern Physics.* **46**(4). pp 618 – 701. October 1974.

[2] “Polymers and Liquid Crystals.” Case Western Reserve University. <http://plc.cwru.edu/tutorial/enhanced/files/lc/intro.htm>.

[3] Jakli, A., et al. “Uniform textures of smectic liquid-crystal phase formed by bent-core molecules.” *Physical Review Letters*. **57**(6). pp. 6737 – 6740. June 1998.

[4] Takashi, Kato. “Self-Assembly of Phase-Segregated Liquid Crystal Structures.” *Science*. Vol 295. pp. 2414-2416. March 2002.

[5] Olympus, *Basics of Polarizing Microscopy.* Accessed: May 2012 from <http://www.olympusamerica.com/files/seg_polar_basic_theory.pdf>.