SURFACE TENSION OF HYDROGEN FILLED DROPS B EFORE AND AFTER CURING

Monyuddam Chheang, Middlesex Community College

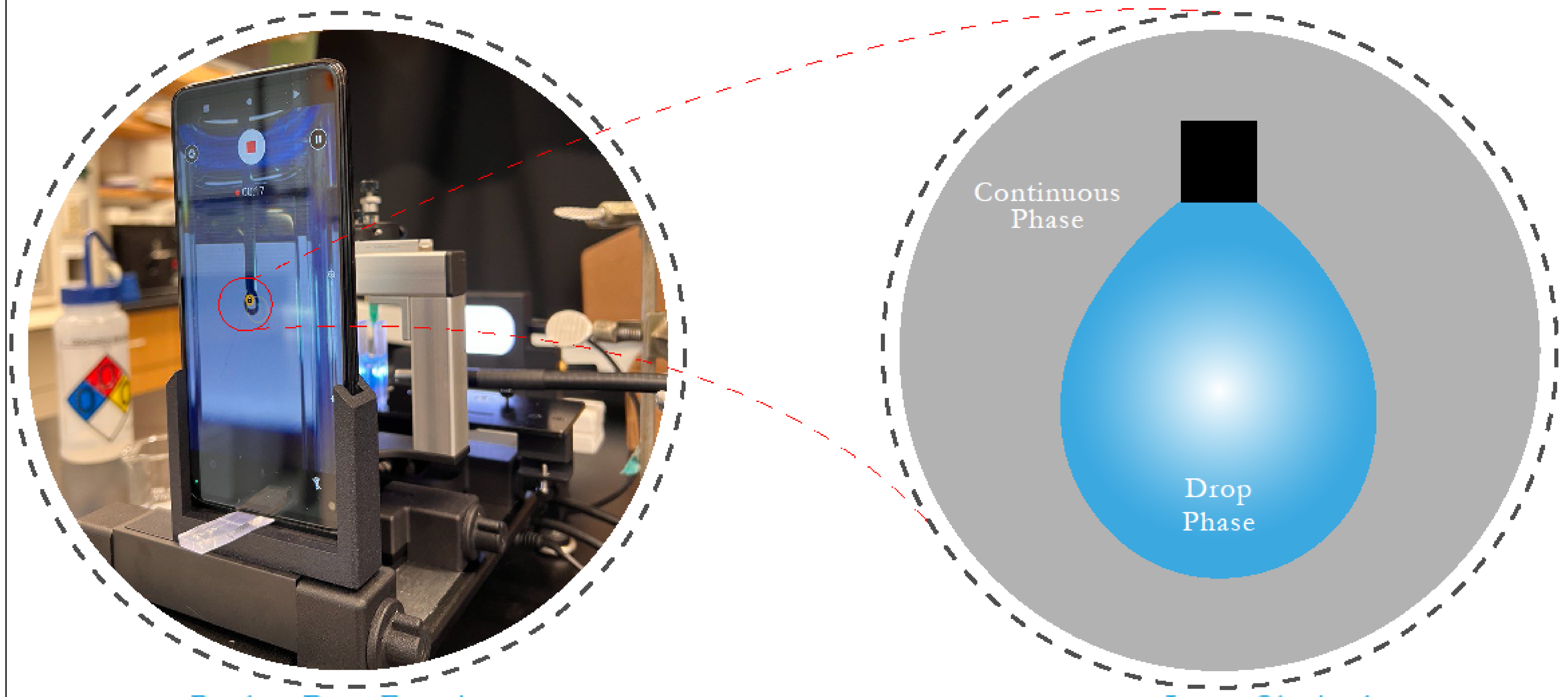
Sabrina M. Marnoto, PhD Candidate, Northeastern University

Prof. Sara M. Hashmi, Complex Fluids Lab, Northeastern University

Northeastern University College of Engineering

Northeastern University Center for STEM Education

Abstract & Background-Pendent Drop



Pendant Drop Experiment   Image Obtained

The pendant drop method is a widely utilized technique to measure the surface tension of liquids. This method involves analyzing the shape of a drop hanging from a blunt ended needle, on the verge of detachment. In our experiment, we employed Polyethylene Glycol Diacrylate (PEGDA) in water as the drop phase and mineral oil as the continuous phase. Due to their immiscibility, these phases do not form a homogeneous mixture, allowing us to measure the surface tension.

We use PEGDA because it is relevant in various applications, including tissue engineering, regenerative medicine, and drug delivery. In our experiment, we vary PEGDA concentrations in water and measure the surface tension. Because PEGDA is a polymer, it can adsorb to the water-oil interface to lower surface tension. Additionally, we shine UV light on the drop phase to investigate the dynamics of curing under UV light exposure over time. By taking videos of the drop after UV light exposure, we investigate the dynamics of the polymer-curing process and the minimum UV dosage required.

We use a combination of image analysis, including Open Drop and custom-written codes in Python to measure both drop shape and the change in drop shape over time.

Theory

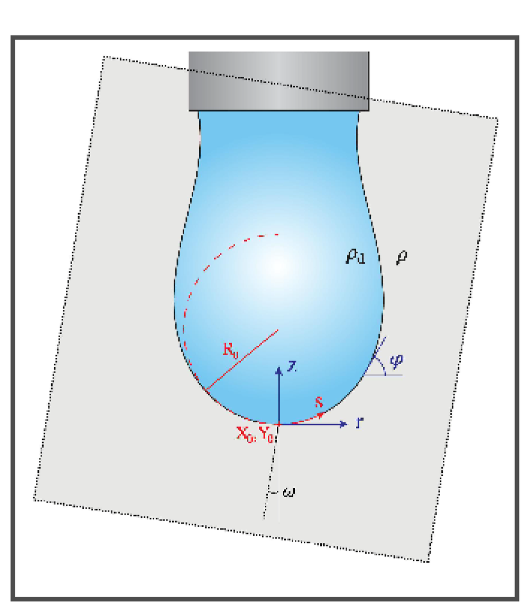


Figure 1

The Young-Laplace equation is used to calculate the surface tension from the shape of the static drop. The left hand side of the equation below depends on the surface tension and the drop shape. The drop shape is written in terms of the two radii of curvature, R1 and R2. The right hand side of the equation is the Laplace pressure, or, the pressure difference between the inside and outside of the drop.

$$\gamma\left(\frac{1}{R_1}+\frac{1}{R_2}\right)=\Delta P \equiv \Delta P_0 - \Delta\rho\, gz$$

- $\Delta\rho$: Density difference
- g : Gravitational acceleration constant
- ΔP : Laplace pressure across the interface
- γ : Surface tension
- R_1 & R_2 : Sadius of curvature of the drops

Methodology

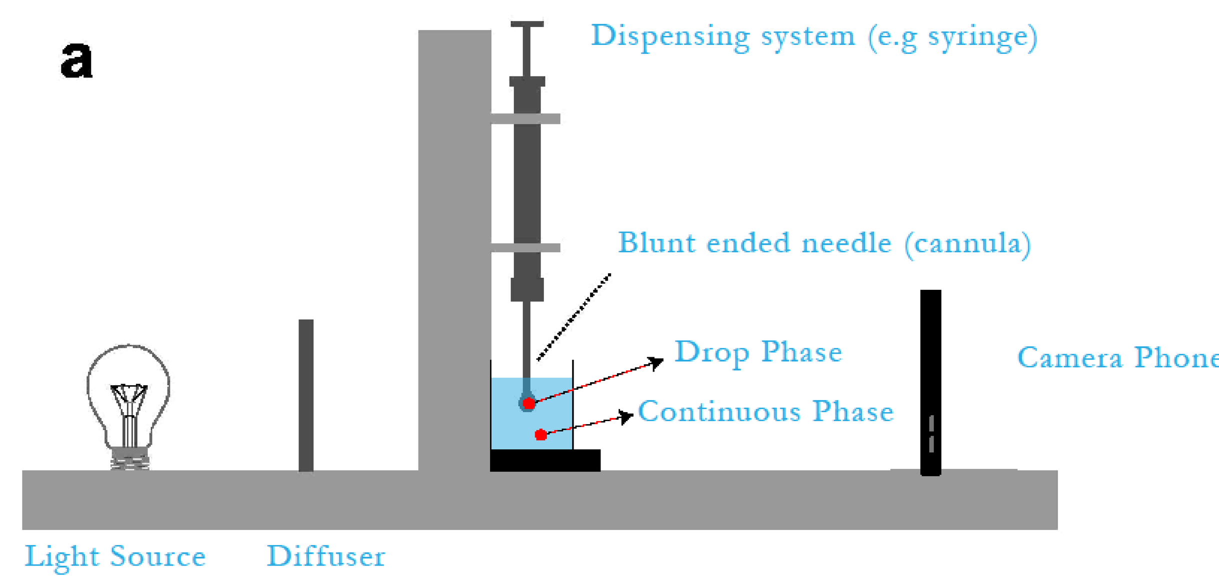


Figure 2

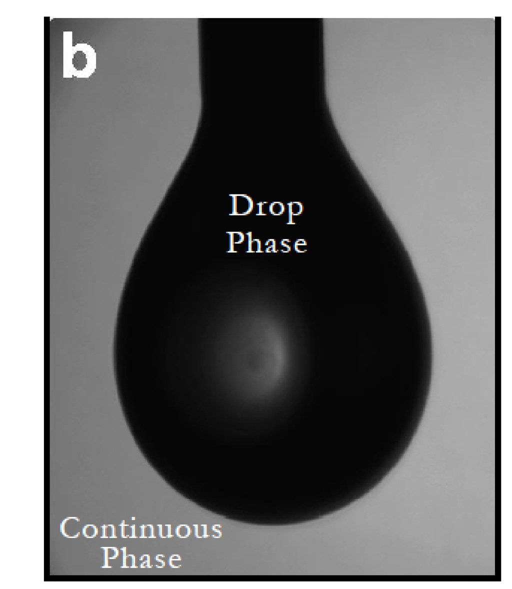


Figure 3

Pendant Drop

Drops are formed by storing the drop phase in a syringe and shaping it to hang from a blunt-ended needle before detaching, while the continuous phase was placed in a beaker. The drops are illuminated using white light from behind, and images captured with a phone camera. Image analysis on each drop measures the drop shape. An application from DropLab uses the Young Laplace equation to analyze the shape and provide surface tension measurements. The analysis requires inputs such as gravity, density difference, and the needle size. The pictures are exported and stored in systematically named folders to avoid data loss. Once all the pictures were collected, the OpenDrop application was used to analyze the images and measure surface tension, providing the final values needed for the research. This methodical approach ensured comprehensive data analysis and accurate result. We measure surface tension of water drops with added polymer, PEGDA.

UV Light

PEGDA polymer can form a gel when illuminated with UV light. Therefore, in this setup, aUV light generator is positioned on one side, allowing direct exposure of the drop to the UV light. The light intensity isadjusted using a knob, ranging from 1 to 5, to observe how the drop's shape changes over time after exposure. Additionally, Python is utilized to analyze the droplet shape over time and determine the time required to cure the drop. The UV light exposure time is in turn used to calculate the UV energy dosage needed to cure the drop.

Curing the Polymer Drop with UV Light

Figure 4

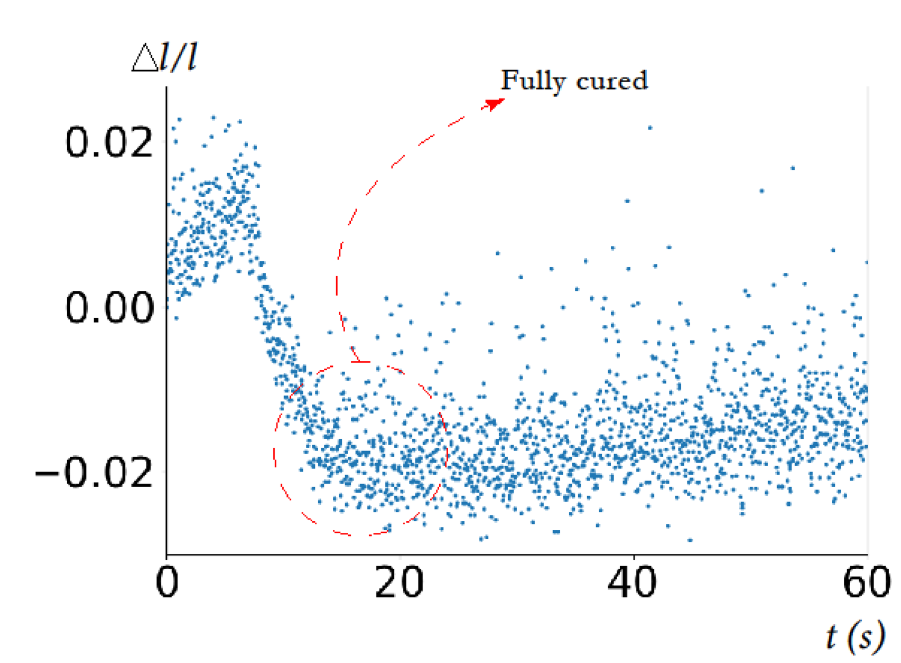


Figure 4 shows an image of a drop. The green contour line measures the drop perimeter, l. The plot shows the change in perimeter over time. After ~8 seconds, the perimeter decreases abruptly. It reaches a plateau at ~12 seconds.

This plateau, ~2% smaller than the orignial perimater, indicates the drop is fully cured. The light is placed 37.33 mm from the needle, and the minimum dosage is 133.5 mj/cm^2.

Surface Tension of Polymer-Filled Water Drop

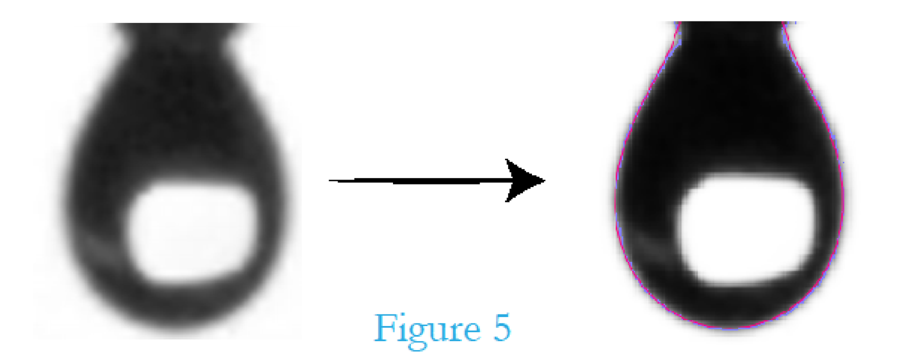


Figure 5

We use software called Open Drop to sharpen the images of each drop. Figure 5 shows a drop image before and after using Open Drop. Ten analyses are conducted for each solution, with subsequent calculation of an average value. Figure 6 shows the average surface tension as a function of PEGDA concentration. Surface tension decreases because the polymer can adsorb to the interface.

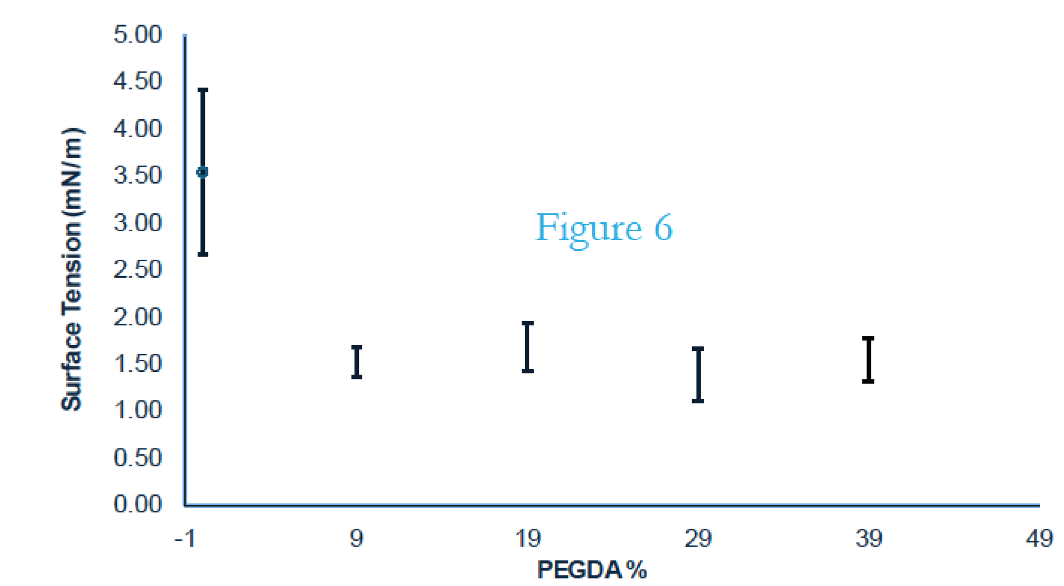


Figure 6

Acknowledgements

COMPLEX FLUIDS LAB

Dr. Sara Hashmi

(Assistant Professor-Chemical Engineering, Affiliated Faulty-Chemistry and Chemical Biology, Mechanical Industrial Engineering)

Sabrina Marnoto (PhD Candidate)

Barrett Smith (PhD Candidate)

Annabelle McGregor (REU Student)

GRANTS

NSF #2150417: REU-PATHWAYS |P.I C. Duggan

CENTER FOR STEM EDUCATION

Claire Duggan- Excutive Director

Jennifer Love- Associate Director

Nicolas Fuchs- Program Manager

Lauren De Sousa- Program Coordinator

NSF REU-Site: Research Experience for Undergraduate site to create "Pathways for community college students to enrich their education and carriers" -(REU -PATHWAYS)

This work was supported by the National Science Foundation Grant ##2150417