Thin Film Drainage Caused by Surface Tension Gradients

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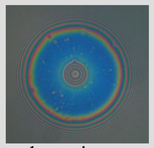
INTRODUCTION



Millions of adults suffer from dry eye each year. The problem is the lack of knowledge on the catalyst to thin film drainage over a curved surface. In certain instances, the drainage of the liquid is interrupted by a unique distribution of surface tension. These flows are called Marangoni flows (pictured right).

The driving force behind Marangoni flows is either evaporation and gravity, or evaporation and liquid composition (Fanton & Cazabat, 1997). It is unknown which combination of forces is dominant over the other. Research backing the phenomena that takes place as film drains in Marangoni flows is currently limited.

RESEARCH METHODOLOGIES

June 2016

Begin Working in Lab

The **true experimental** methodology was also used in my research as I spent a lot of time in a lab. In this lab, I designed experiments that fostered environments for Marangoni flows to take place. **Correlational methodologies** were vital to my study because in order to understand Marangoni flows, I needed to understand how different variables interact with each other.

Aug. 2017

Discovery of Minimal Thermal Gradients

Using a thermal camera while conducting experiments, my mentor and I noticed an almost uniform temperature taking place across the surface of the Marangoni flow which proved that the driving force to our Marangoni flows was liquid composition.

Sept. 2017

Application of Computer Science

My data collection tool was a **database** where blocks of experimental data were stored. I have programmed an application that analyzes and summarizes my experiments. It uses a database that is linked to my software, and then analyzes numerous relationships between experiments and is then capable of normalizing unique trials of experiments.

Feb. 2018

Scaling Research to Real Life Applications

The lab and I look to applying what we learned about the drainage of tear film to the human eye--more specifically, to helping prevent dry eye and even creating better contact lenses. We are in the early stages of runnning experiments relating to human eyes.

DISCUSSION, ANALYSIS, AND EVALUATION

It was clear that liquid composition was the main driving force behind my facete of Marangoni flows. Figure 1 details a liquid with two components (I and II). Component I is more volatile, so it evaporates at a quicker rate than Component II. This creates a concentration gradient on the surface, which features a higher ratio of component II to component I. Component II has a greater surface tension than Component I, so the areas with a concentration gradient also form a surface tension gradient. A Marangoni flow is then able to develop due to an instability of liquid surface tension.

The rate at which these surface tensions develop is characterized by the impurity fraction. This fraction represents the ratio between the two differing liquids mention in Figure 1. The effect of the impurity fraction upon the velocity of the Marangoni flow is shown in Figure 2.

The first graph in Figure 3 displays the volume of liquid within the various experimental trials at different times. Software developed by Hunter North allows individuals to easily normalize experimental trials into a single line (second graph in figure 3), thus proving that a function can be developed to predict Marangoni flows.

DATA AND FINIDNGS

Figure 1. Liquid Composition Breakdown. Liquid Composition proves to be the driving force behind our Marangoni flows

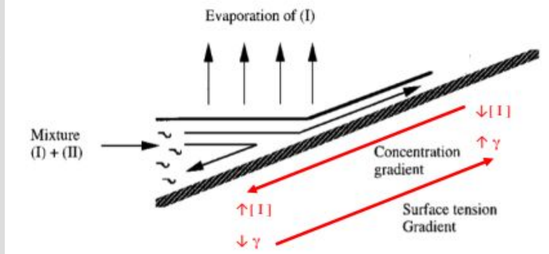


Figure 2. Predicting Marangoni Patterns. Velocity of Marangoni flow is a function of the liquids impurity fraction as well as several other liquid characteristics

$$V = \left[\frac{\Delta\gamma\varphi(1-\varphi)E}{2\mu}\right]^{1/2}$$

$\mu = viscosity$
$E = evaporation\ velocity$
$\varphi = impurity\ volume\ fraction$
$\Delta\gamma = surface\ tension\ difference$

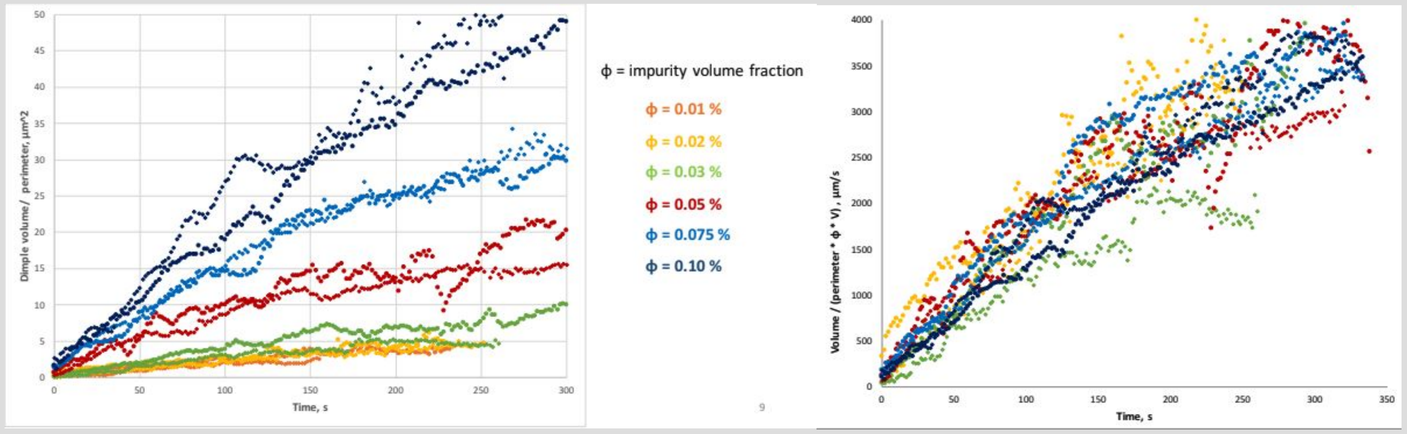


Figure 3. Normalization of Marangoni Flows. This is the Pre and Post Normalization of different trials of Marangoni flows.

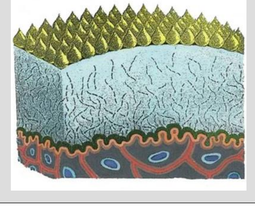
CONCLUSIONS, IMPLICATIONS, AND NEXT STEPS

The results of this experiment categorize Marangoni flows to be driven by liquid composition. Establishing this process allowed my mentor and me to move onto the next step in our research: the impact of liquid characteristics upon Marangoni flows.

After understanding the effects of each characteristic of a solution upon Marangoni flows, we came to the equation in Figure 2.

Upon the conclusion of our research, we refocused on our preceding research areas: analyzing the components of tear film (pictured below) and the drainage of tear film (Marangoni flows). Next, I will go through numerous sources that include information on human tear film, specifically its composition. After developing a good understanding of the matter, my mentor and I will begin developing a new experimental setup that is fitted to observe a human eye. We can test the differences between tear film drainage on eyes with and without contact lenses.

Ultimately, our research has added numerous pieces of information to the limited field of research around Marangoni flows. Furthermore, we are one step closer to understanding and modeling the drainage of a human eye (tear film). With this model, doctors will be able to better treat eye conditions such as dry eye, and contact manufacturers will be able to develop contact lenses that minimize discomfort.



ACKNOWLEDGEMENTS / REFERENCES

Special thanks to Gerald Fuller, Marianna Hakim-Rodriguez, and the rest of the chemical engineering lab for making this project possible.

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