

REPORT DOCUMENTATION PAGE				Form Approved OMB No. 0704-0188	
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1. REPORT DATE (DD-MM-YYYY) July 2015		2. REPORT TYPE Briefing Charts		3. DATES COVERED (From - To) July 2015-August 2015	
4. TITLE AND SUBTITLE Effect of Surface Omniphobicity on Drying by Forced Convection (Briefing Charts)				5a. CONTRACT NUMBER In-House	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S) Madani Khan, Jeffrey Alston, Andrew Guenther				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Air Force Research Laboratory (AFMC) AFRL/RQR 5 Pollux Drive Edwards AFB, CA 93524-7048				8. PERFORMING ORGANIZATION REPORT NO.	
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES) Air Force Research Laboratory (AFMC) AFRL/RQR 5 Pollux Drive Edwards AFB CA 93524-7048				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S) AFRL-RQ-ED-VG-2015-313	
12. DISTRIBUTION / AVAILABILITY STATEMENT Distribution A: Approved for Public Release; Distribution Unlimited.					
13. SUPPLEMENTARY NOTES Briefing Charts presented at STAR Closing Conference; San Jose, CA; 7 August 2015. PA#15451.					
14. ABSTRACT Briefing Charts					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT SAR	18. NUMBER OF PAGES 26	19a. NAME OF RESPONSIBLE PERSON Kriss Vanderhyde
a. REPORT Unclassified	b. ABSTRACT Unclassified	c. THIS PAGE Unclassified			19b. TELEPHONE NO (include area code) 661-275-5429



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Effect of Surface Omniphobicity on Drying by Forced Convection

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STAR Program
August, 2015



Background



- **I am from Bangladesh.**
- **Education: The City College of New York**
- **Major: Chemistry; Minor: Education.**





Abstract



- **Low energy surfaces can strongly repel both oil and water. Recently these surfaces have been fabricated on various substrates including fabric, aluminum, stainless steel and many other materials. In this experiment we explore the use of low energy surface deposition on aluminum alloy, stainless steel and silicon substrates, to enhance the drying rate of liquids removed from the surface by forced convection. We control surface roughness by substrate abrasion and by the growth of Al_2O_3 nanograss to enhance liquid repellence by use of a hierarchical texture. Liquid repellence of the substrates is measured by contact angles of the probe liquids, water and hexadecane. Samples are mounted on a rigid stage constructed with a flat surface and a regulated air nozzle fixed to provide flow parallel to the substrate surface. The velocities of probe liquid droplets placed on the substrates are recorded via high-speed camera as they are moved by a constant air flow. It is shown that drops on omniphobic and superomniphobic surfaces move at increased velocity compared to untreated surfaces, and leave behind less residual liquid, resulting in a faster drying rate. 2-factor design of experiments (DOE) was implemented to explore the optimum conditions for a fast drying low energy surface. The use of DOE and the results of this experiment are merged into a lesson plan developed for 9th-12th grade students. These results will serve as examples low energy surfaces and their potential applications.**



Introduction



- **Explore the use of low energy surface deposition on aluminum alloy, stainless steel and silicon substrates, to enhance the drying rate of liquids removed from the surface by forced convection**
- **The velocities of probe liquid droplets placed on the substrates are recorded via high-speed camera as they are moved by a constant air flow**
- **2-factor design of experiments (DOE) is implemented to explore the optimum conditions for a fast drying low energy surface**



Application



- The application of this work can be used in rocket engines, rooftops, cars, umbrellas, tiles, oven, paint, or any kind of fabrics.





Design of Experiment (DOE)



- **Systematic method to determine the relationship between factors affecting a process and the output of that process.**
- **Why?**
 - Saves time
 - Lower cost
 - Reduce product material and labor complexity
 - Better design engineering
- **Accessibility**
 - Microsoft Excel or online software



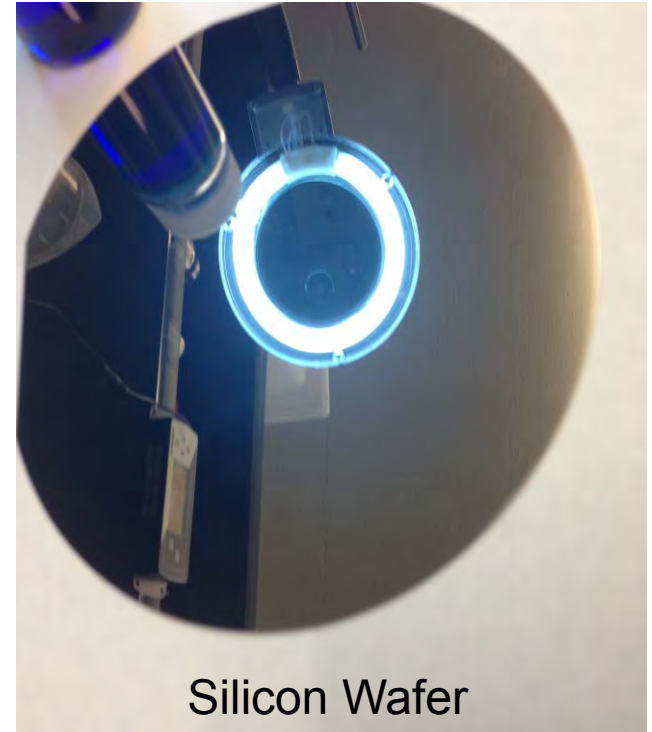
Substrates



Stainless Steel



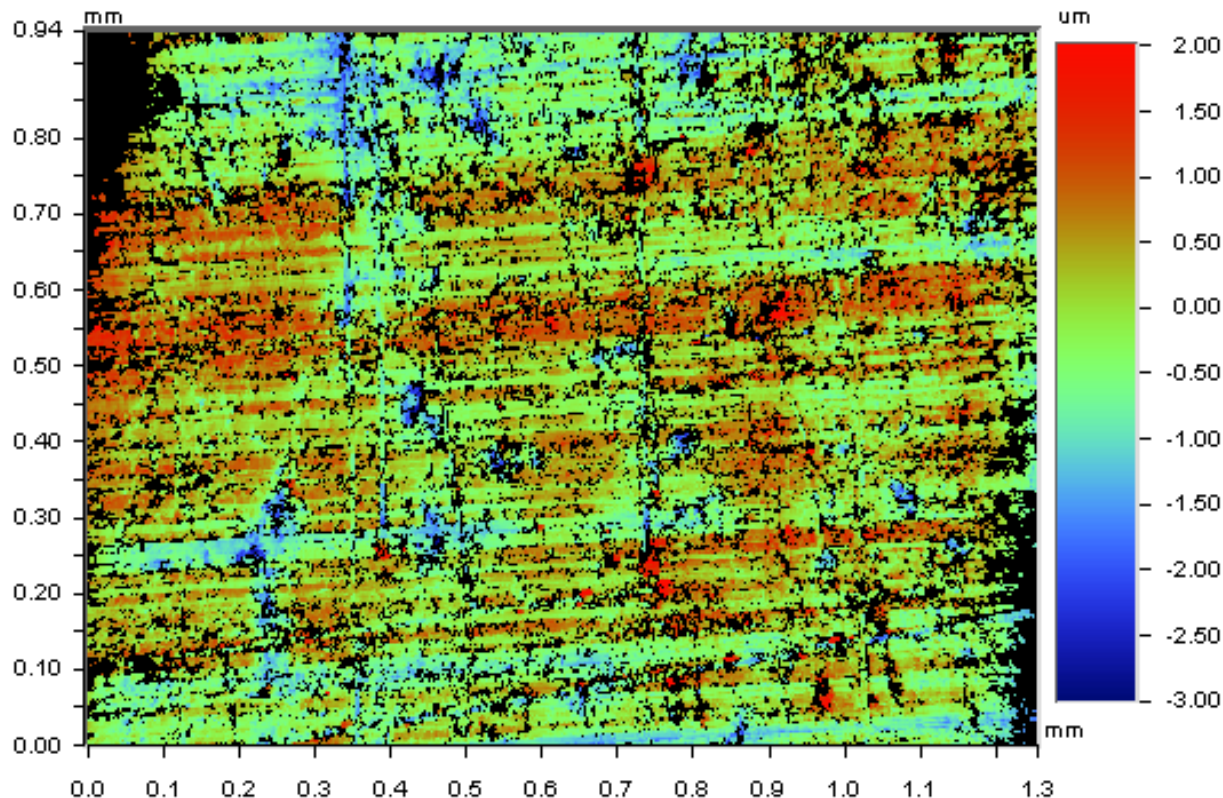
Aluminum



Silicon Wafer



Roughness Values



Roughened Surface Crossly Sanded with Grit Size 2000

R_a -Roughness Average (499.97nm)

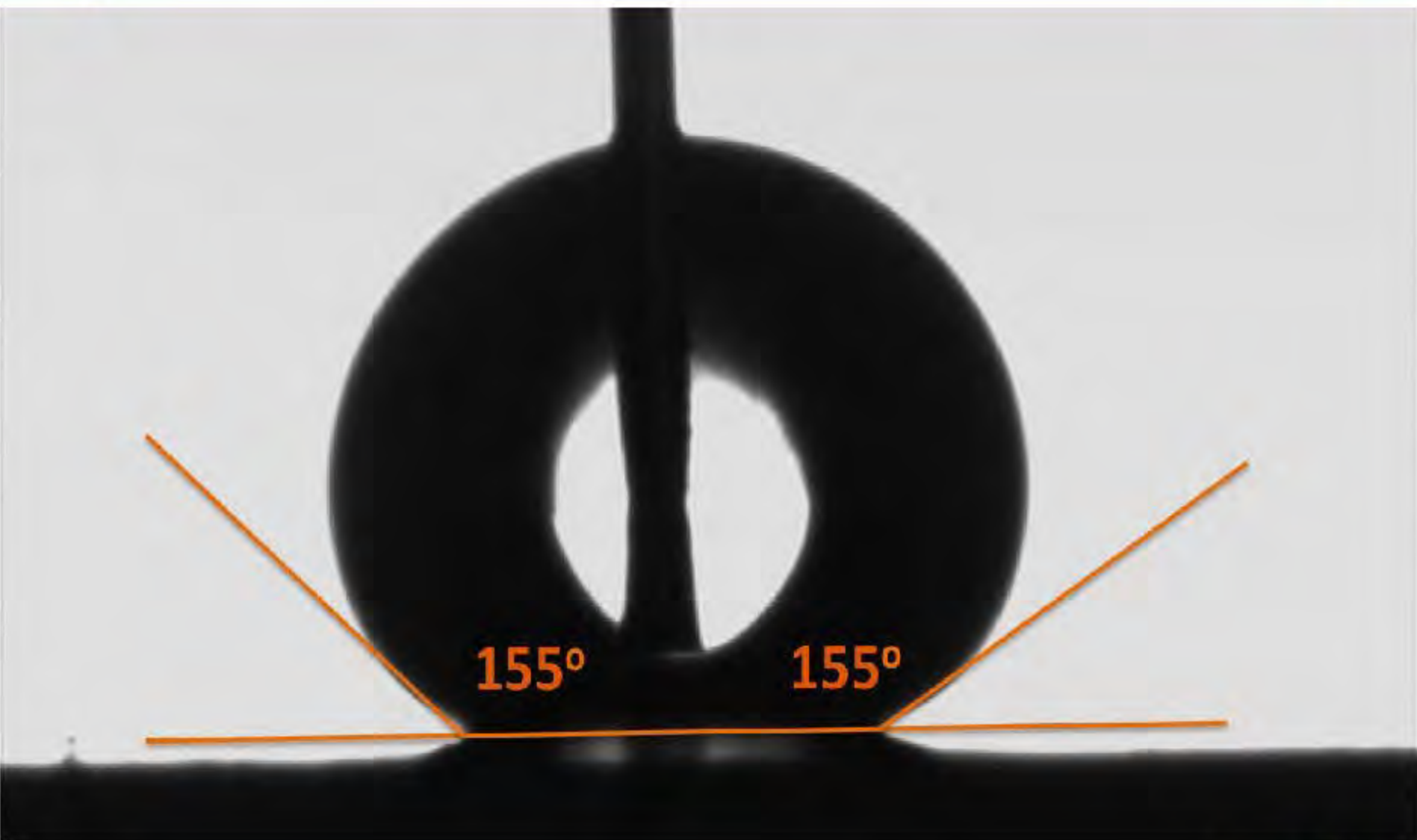
R_q - Root Mean Square (624.58 nm)

S_m - Surface Material Volume (26.36 nm³/nm²)

S_v - Surface Void Volume (66.06 nm³/nm²)

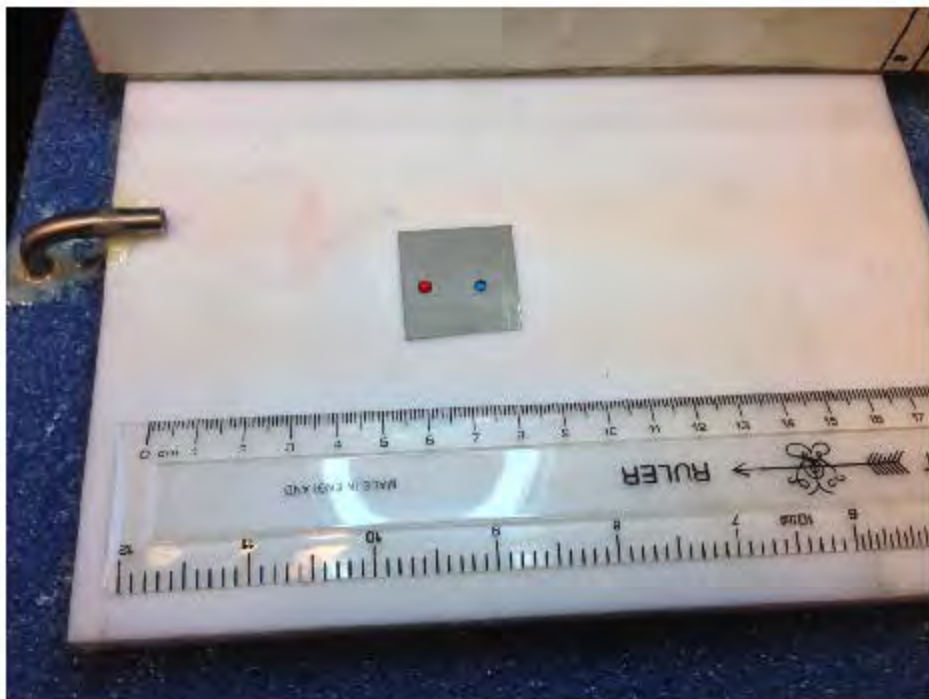


Contact Angle



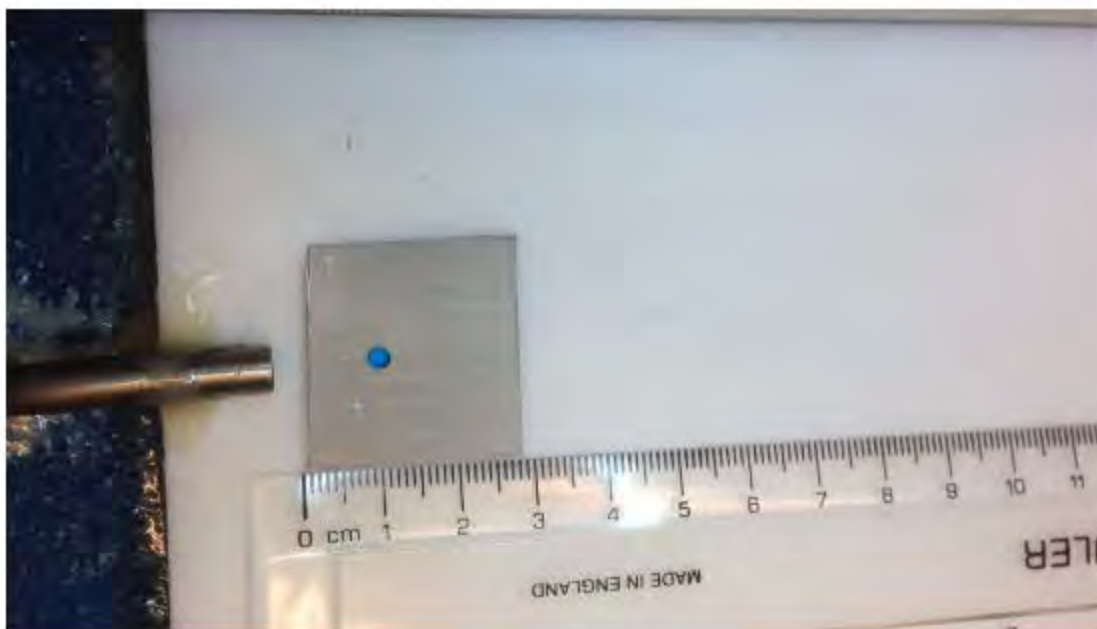


Gas-Flow System





High-speed Video

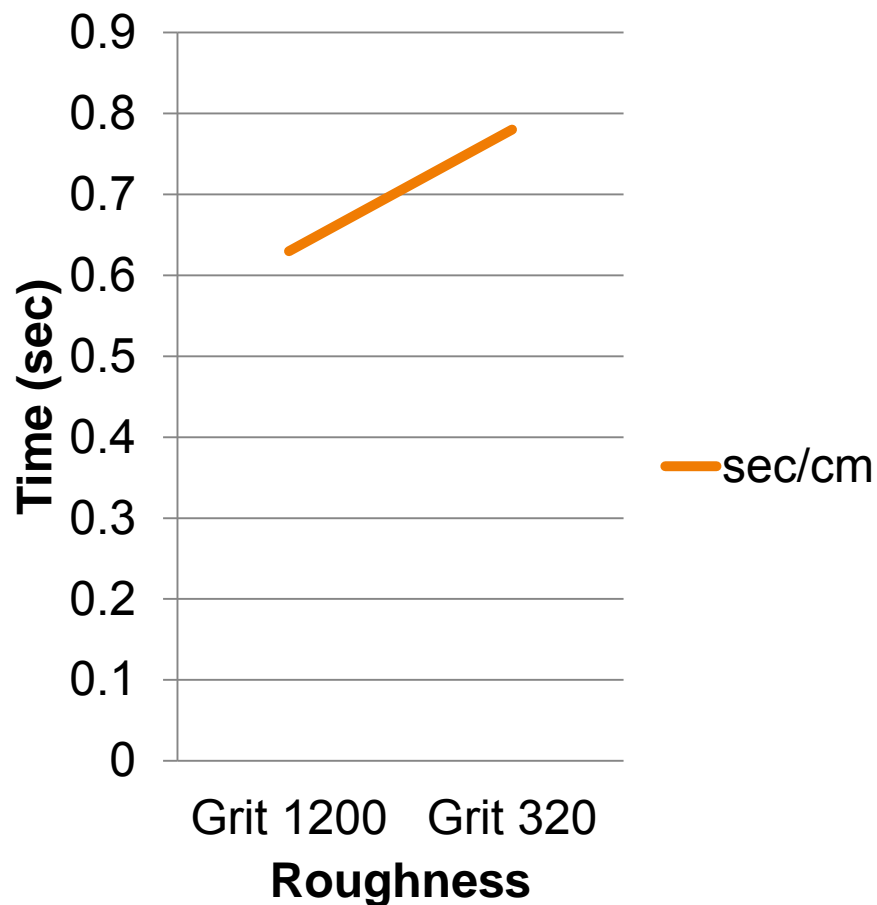




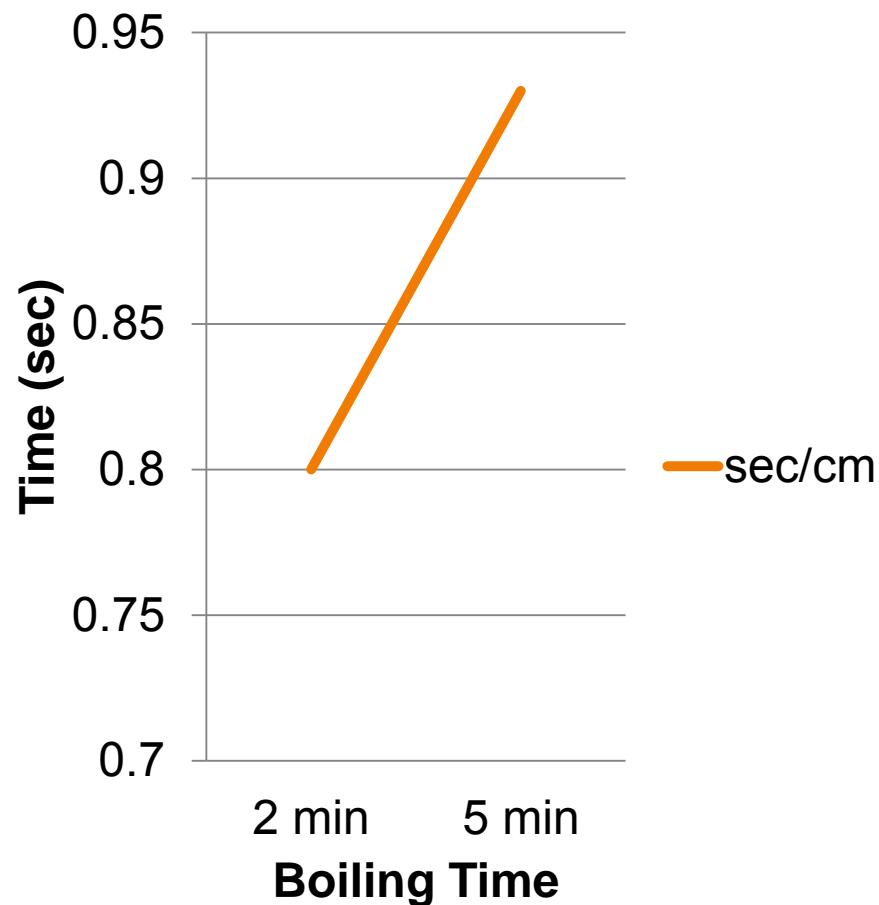
Result



Roughness vs. Drying Time



Boiling Time vs. Drying Time





Conclusion



- **Lower roughness leads to faster drying time.**
- **An irregular surface can cause pinning regardless of silanization and contact angle, which disturbs the trend of hysteresis.**
- **Higher boiling time leads to faster drying time.**
- **Water has a faster drying rate than hexadecane.**



Lesson Plan



- **This lesson plan is directed for 9th-12th grade students.**
- **Reading about ice-cream.**
- **Learning to make ice-cream through a DOE optimization.**
- **The three factors are different weight percent of salt per ice, fat content in dairy and shaking time.**
- **Measured output will be rating and average of different ice-creams.**



Future Work



- **Different type of liquids**
- **Durability**
- **Using the optimization from DOE to further explore factors.**





Acknowledgement



- Funding and support was received by the STAR program and thank you to the AFRL for a great research experience. Thank you to Dr. Jeffrey Alston and Dr. Andrew Guenther for all their guidance and encouragement throughout this the project. And a special thanks to my fellow STAR student: Nicholas Rubel.





Questions?

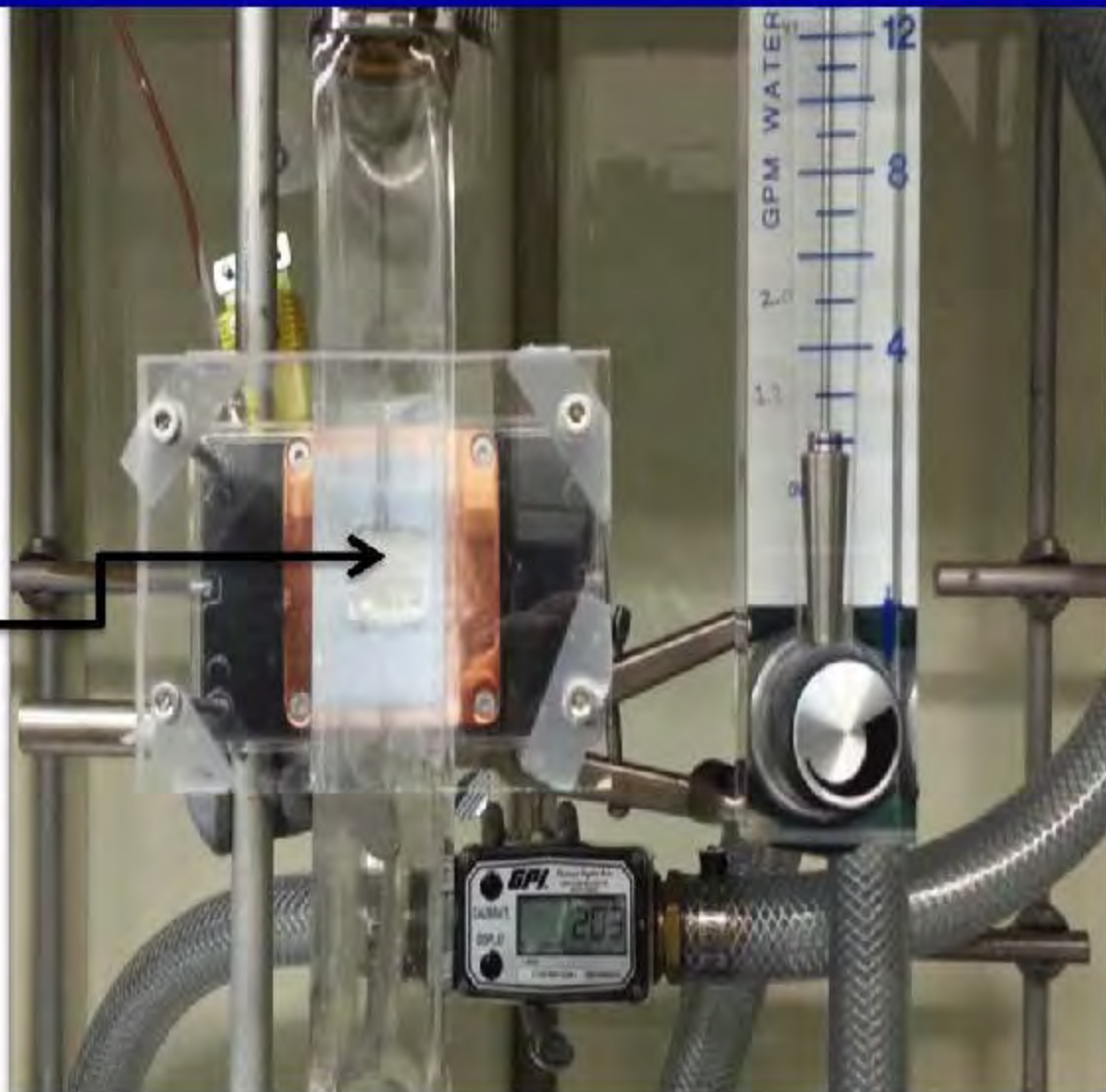




Flow System



Al Substrate



Flow Cell



Creating Reentrant Surface



Before Sanding





After Sanding



Micro-scale

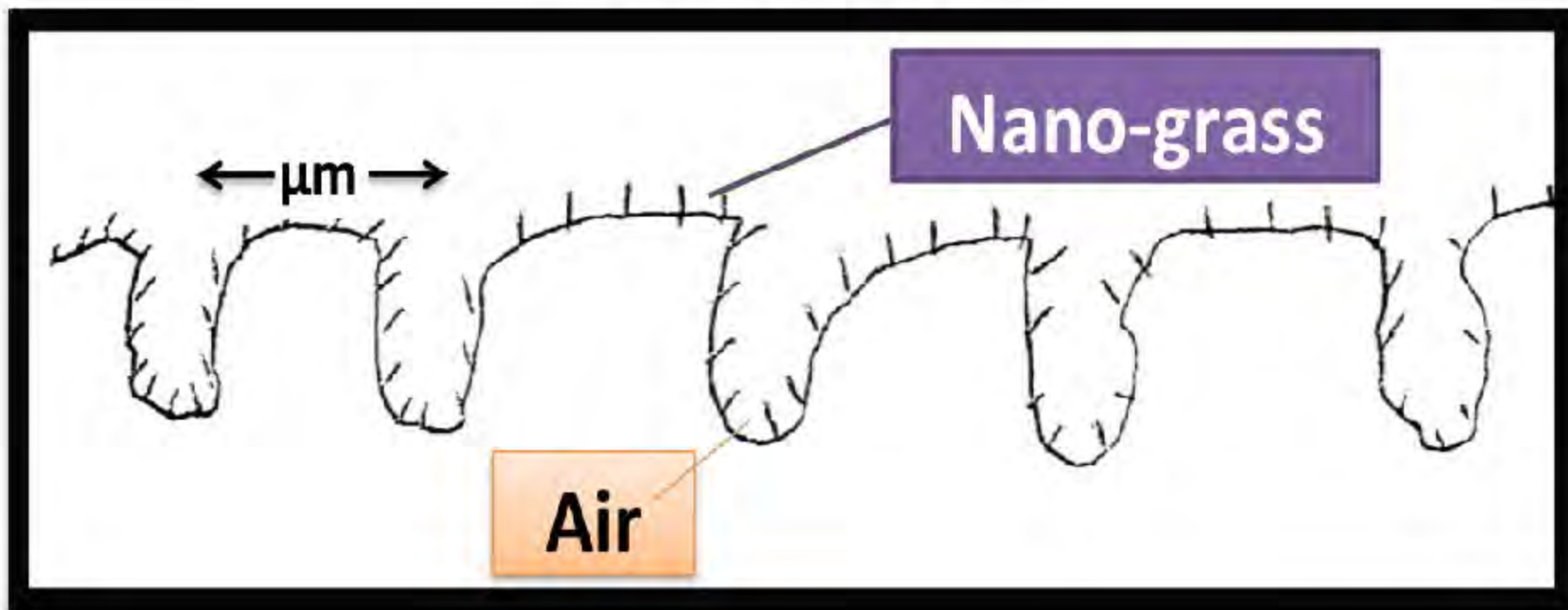




Nano-grass Growth

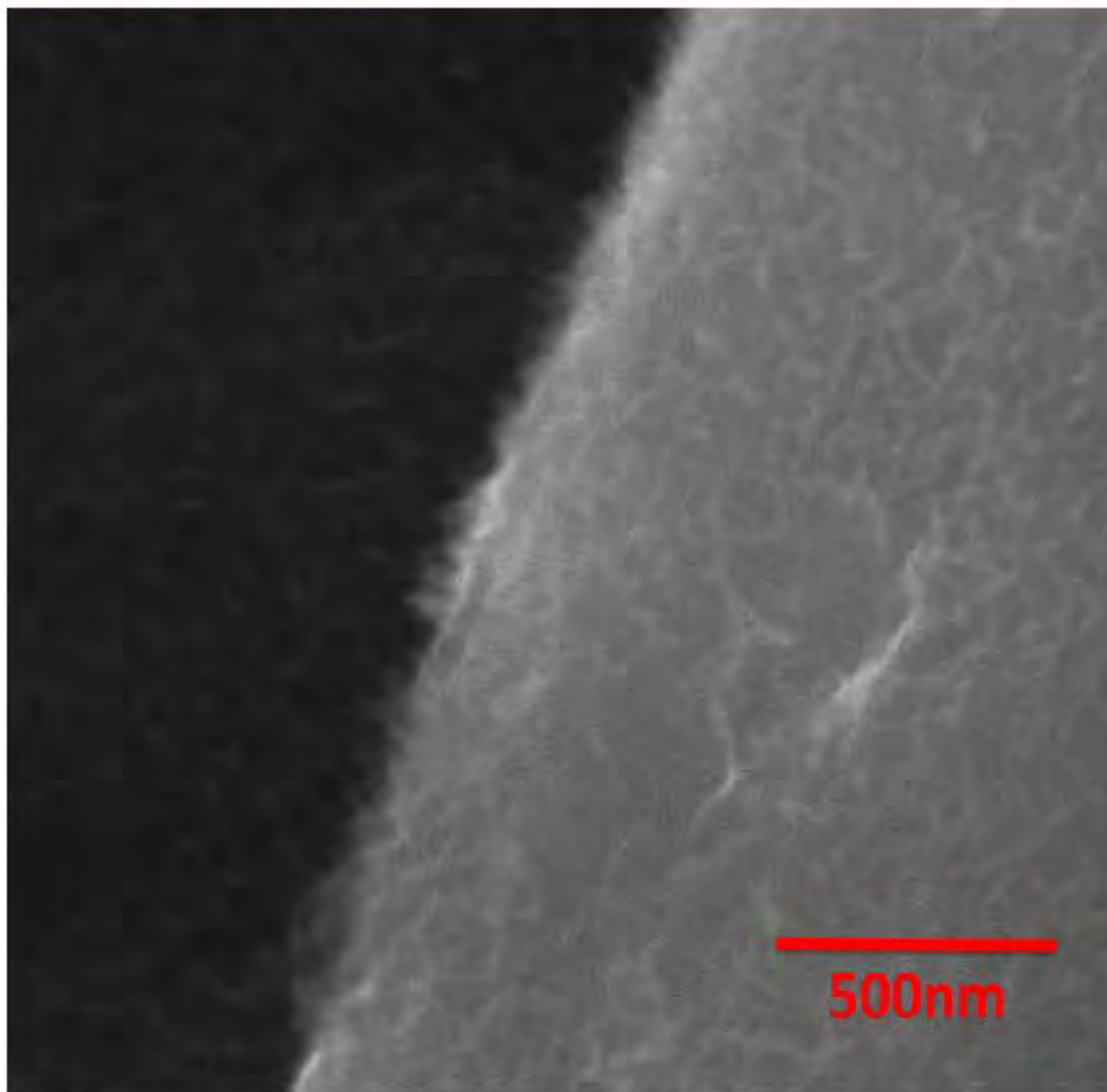


Nano-scale





SEM Image

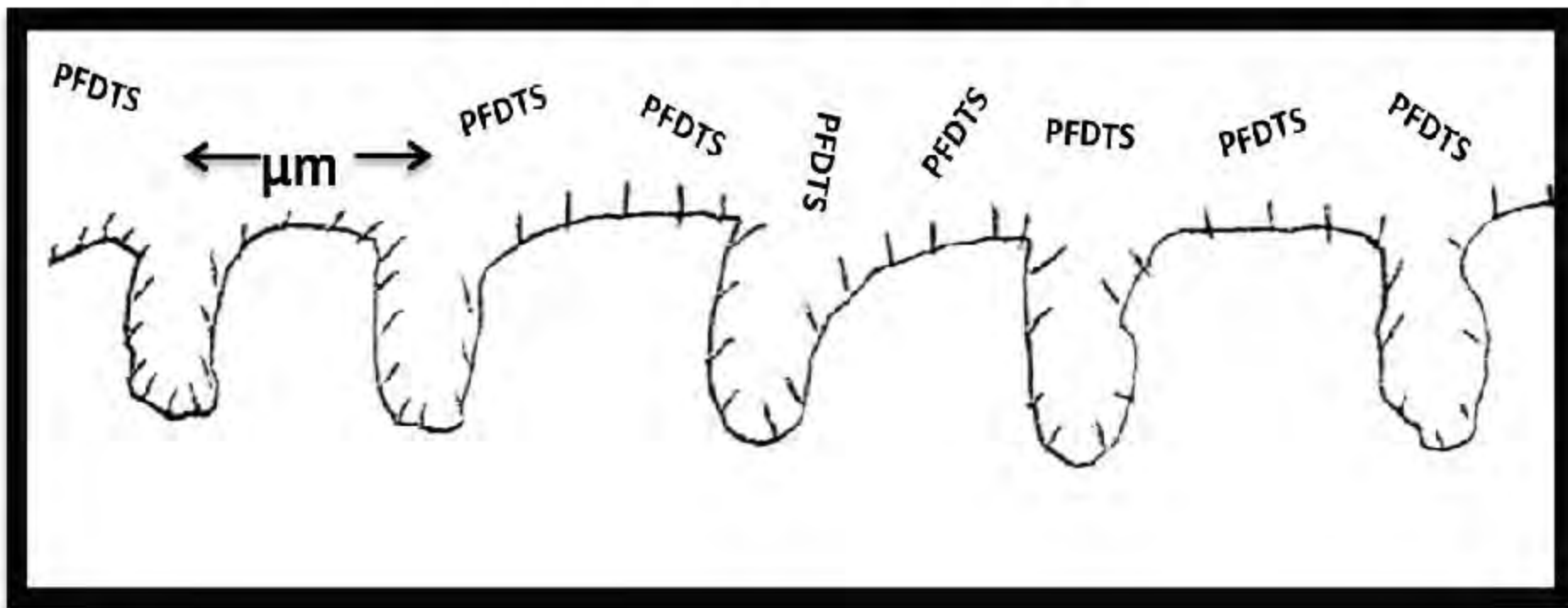




Low Surface Energy



Low Surface Energy

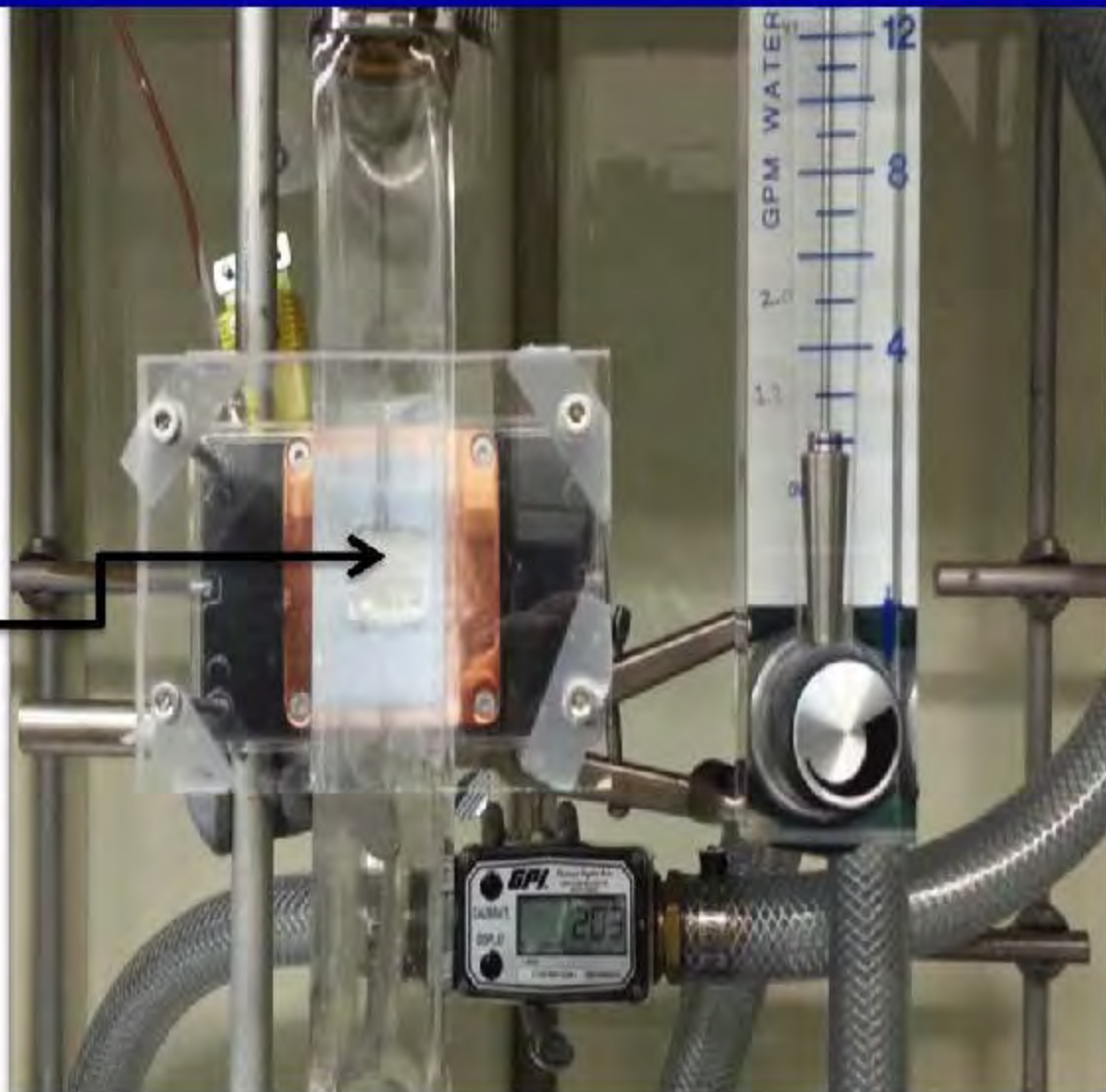




Flow System



Al Substrate



Flow Cell



Trapping Plastron



Dry



Under Water

