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Quantifying Wicking in Functionlized Surfaces

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Quantifying Wicking in Functionalized Surfaces

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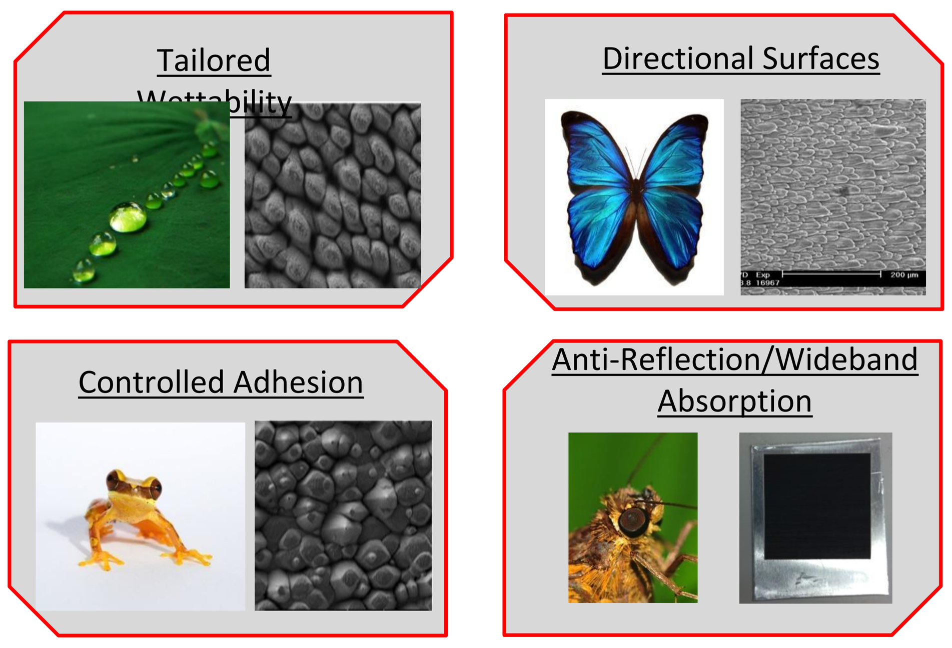
Motivation

Femtosecond Laser Surface Processing (FLSP) has the ability to functionalize metallic surfaces with self-organized micro/nanostructures mimicking nature:



Wicking Application

This experiment focuses on how water flows across the functionalized surface

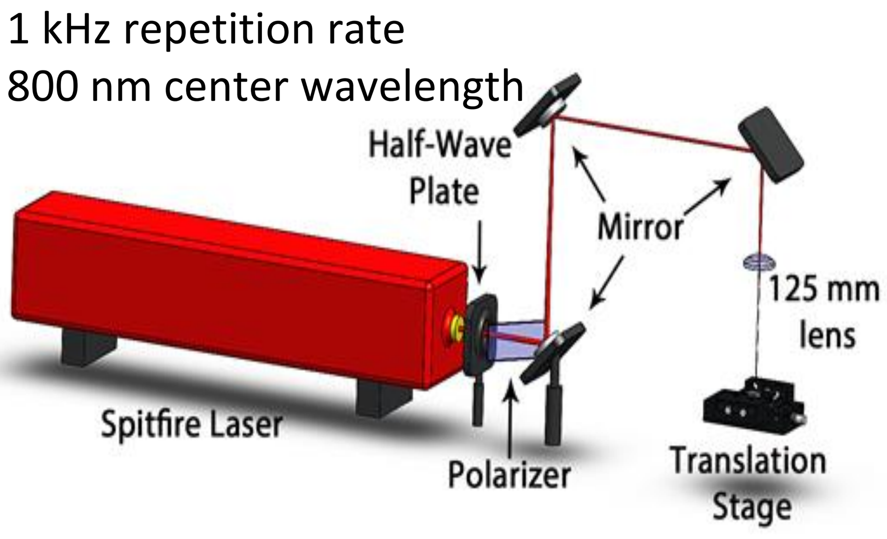
- Heat pipes
- Critical heat flux delay in boiling applications
- Deicing on plane wings

Many factors affect wickability, such as porosity and surface roughness. This experiment focuses on defining wickability as a parameter of the surface that captures all these factors.

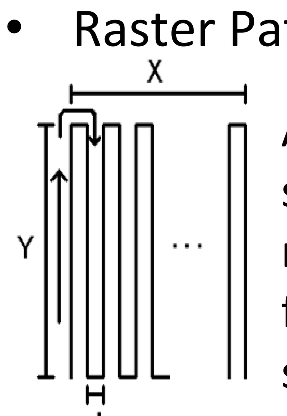
Nano and Microstructure Fabrication

Machining Process

- Spectra-Physics Spitfire Laser
  - 50 fs
  - 1 mJ maximum pulse energy
  - 1 kHz repetition rate
  - 800 nm center wavelength



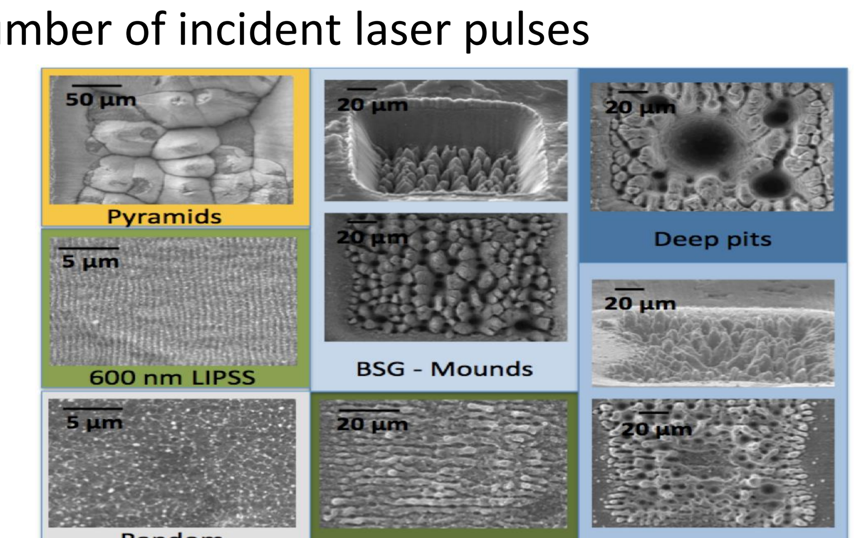
- Raster Path On Sample



As the laser moves across the surface, it causes nanoparticle redeposition and surface fluid flow that create micro and nano-structures

- Range of Structures

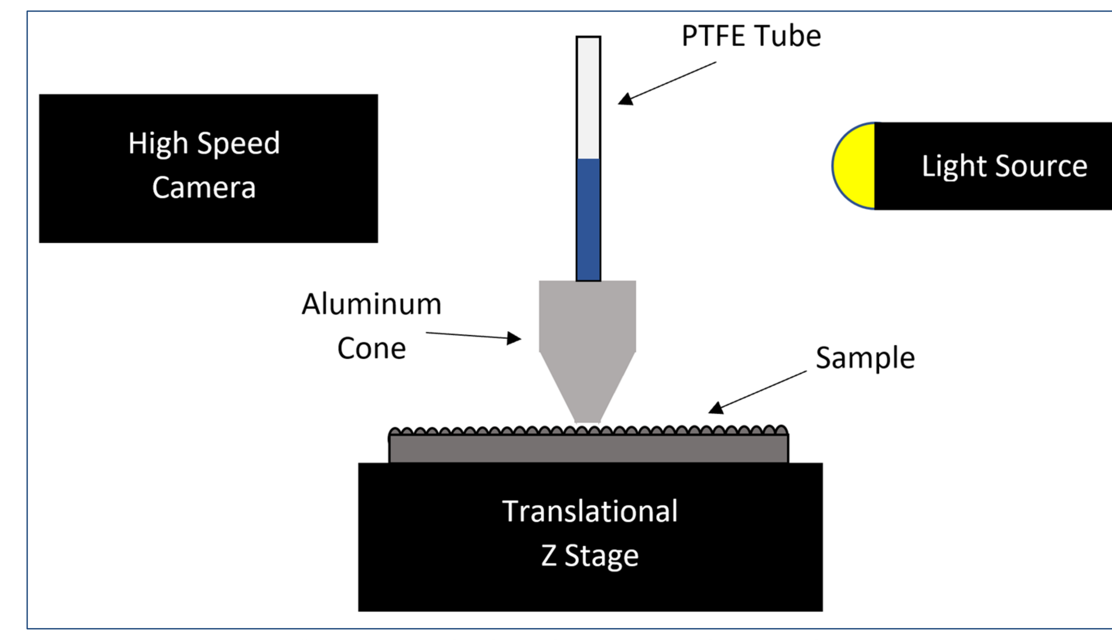
A variety of structures can be created through the control of laser fluence and number of incident laser pulses



Using Volume Flow Rate to Quantify Wicking

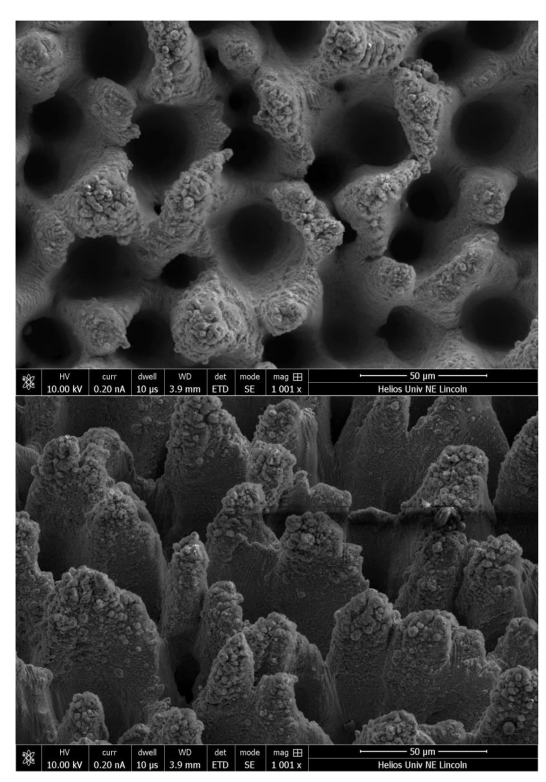
Experimental Setup

- A PTFE plastic tube with an inner diameter of 500 micrometers is capped with an aluminum cone. PTFE was bonded to the surface of the cone with vapor deposition to limit any changes in surface. The cone's inner diameter is the same as the tube, and allows the water to flow out with minimal contact resistance from the tip.
- Diameters of 250 and 750 micrometers were also tested. The volume flow rates were compared to determine if the tube diameter impacts the wicking rate.



View of Setup with the Photron High Speed Camera

- Back lighting from a directional LED allows the Photron high speed camera to observe the descent of the meniscus in the tube. A second camera was used to monitor consistent distances between the cone tip and sample.
- After various tests, it was determined that the initial height of the meniscus does not affect the volume flow rate, so the initial amount of water in the tube was chosen so that the meniscus could be seen by the camera..



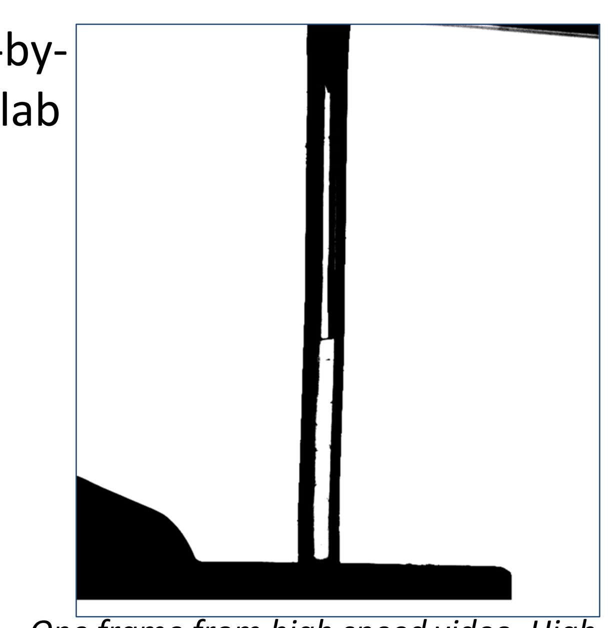
SEM images of the sample surfaces. The top one is perpendicular, magnification 1001 x while the bottom is angled at 1001 x.

Meniscus Motion

Each high-speed video was converted into frame-by-frame pictures that could be analyzed with a Matlab code to track the meniscus motion.

Meniscus height was converted into volume, and the volume flow could then be plotted as a function of time.

Multiple methods have been developed to quantify a wicking rate. However, this method demonstrates the most repeatable and measurable results for the initial flow rate.



One frame from high speed video. High contrast is used to locate meniscus.

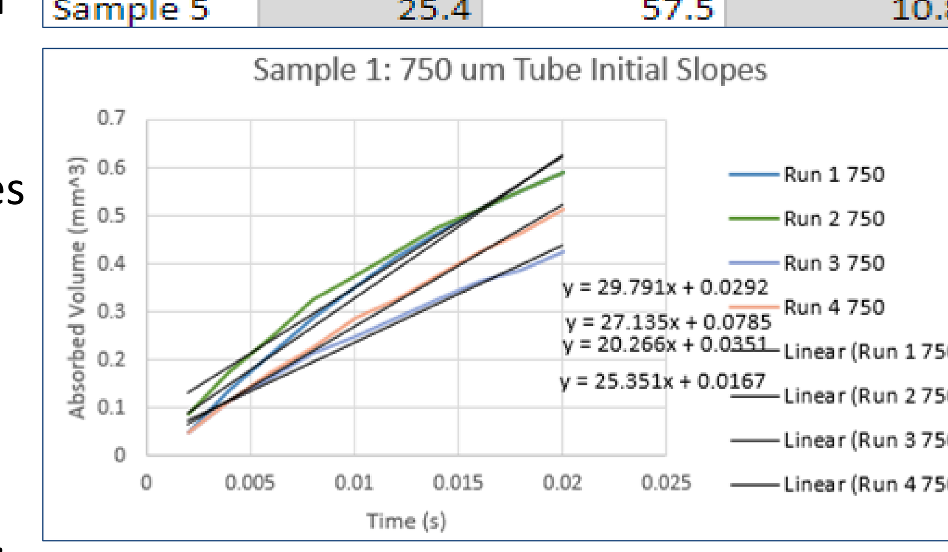
Results and Conclusions

Results

The initial volume flow rate is considered as the linearized slope of the first 0.02 s of the flow. The graph on the right shows data for four runs of sample 1 using the 750 um tube. The average of the four runs (25.6 mm^3/s) is shown in the table on the right. This average was then divided by the circumference of the tip to determine a wicking rate as a function of the surface. Similar methods were used for both tips and samples.

From the table to the right, it is clear that the wicking rates are comparable between the two tips for both samples, and the larger values for the 750 um tube are thought to be because the larger tube leads to less resistance from capillary forces.

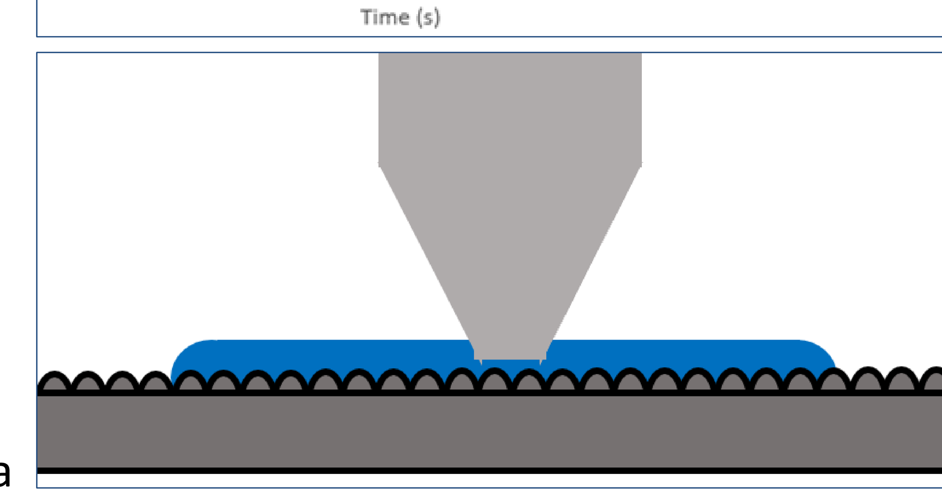
500 um Tip	Flow Rate (mm^3/s)	Wicking Flux (mm/s)	Wicking Rate (mm^2/s)
Sample 1	15.6	79.5	9.9
Sample 5	13.5	68.6	8.6
750 um Tip	Flow Rate (mm^3/s)	Wicking Flux (mm/s)	Wicking Rate mm^2/s
Sample 1	25.6	58	10.9
Sample 5	25.4	57.5	10.8



Conclusions

From the table, it can be seen that dividing by the circumference instead of the area has given comparable wicking rates between tube diameters. This implies that the volume flow rate is directly related to a wicking parameter of the surface, and does not depend on the tube size used for testing. However, there are still differences from capillary forces.

Previous wicking experiments have relied on a 500 micrometer tube diameter and divided by the area. But tube size leads to drastic changes in the wicking flux and changes from capillary forces. An ideal wicking parameter would not depend on the testing device, but would solely be a function of the surface.



Surface flooding is when fluid flows over the tops of the structures rather than wicking through

Since tubes with larger openings have lower capillary forces, they also do not hold water, so new setup is being explored that will provide a constant flow rate to the functionalized surface. This setup will observe the surface to find the flow rate at which it floods, and use that value divided by the circumference of the tube as the wicking rate.

Acknowledgements

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