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An Analysis of the Wickability and Profilometry of Samples

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Background:

This semester I was assigned the role of assisting in a boiling experiment, where the heat flux of an aluminum disc was recorded through a boiling chamber. More samples were then coated with a lubricant and then retested to see if there was an impact on their heat flux. The flow of heat through an object, more commonly known as heat flux, is a material property of all objects and has many factors contributing to its magnitude. This semester, I isolated two of these properties, wickability and profilometry, and investigated each one in order to determine how each factor plays a role in the recorded heat flux values for the samples. A sample's wickability refers to its ability to transfer moisture about its surface. A higher wickability allows for a greater sustained heat flux, due to the moisture being more rapidly absorbed onto the heated surface and then vaporizing. Profilometry is the measurement of the roughness of a surface. We wanted to see a close-up view of the surfaces of the samples to detect the thickness of the deposited copper sulfate layer and its role in the samples' heat flux. This factor's contribution to the heat flux is slightly more complicated, but in general, a surface with more grooves can support a higher heat flux because liquid can flow into the grooves more easily and continue to vaporize. However, the copper sulfate layer also acts as a slight barrier, requiring the heat to flow into it before moving into the water. Understanding these two properties of the samples that we investigated would allow us to have a clearer view on the data that we obtained from them, and ultimately, a better understanding of any anomalies that we observed upon analysis of the data.

Object:

The object of these experiments is to determine quantitative graphs of a surface's wickability and profilometry from raw data. I designed a setup to measure the wickability of these surfaces and I will use a profilometer to record the roughness on each of them. Having both measurements will tell us more about how their heat fluxes relate and will guide our understanding of the results that we obtained.

Experimental Setup:

For the wickability experiment (Figure 1), I filled a syringe needle with DI water and waited for the water to drip out enough until the surface tension overcame the gravitational effects of the water (i.e. there was some water remaining in the syringe, and a small meniscus forming at the tip of the needle). My setup then allowed for me to place the sample in a mobile platform and secure the syringe against a plate so that the tip was pointing down (see Figure 3). As soon as I was ready to begin the testing for the sample, I would turn a knob to raise the sample up to the needle, and as soon as I observed water draining onto the sample, I would stop raising it. While that was taking place, I used an Edgertronic high speed camera to film the syringe and observe the water level falling. I repeated this test for 3 trials of each sample, moving the needle to contact that sample at a different position each trial. I then used the hi speed videos to measure the rate at which the water level was falling in order to create a line plot of the change in the water's volume as a function of time.

For the profilometry experiment, I deposited a very thin (0.5 microns) layer of parylene on each one in order to stabilize the copper sulfate deposition on them. I then placed each sample under the profilometer and recorded 6 readings for each one. I had labeled each sample with cardinal directions, so I know exactly where each reading took place. I used a 16 mm long scan to record diagonal measurements across the diameter of each sample (see Figure 2).

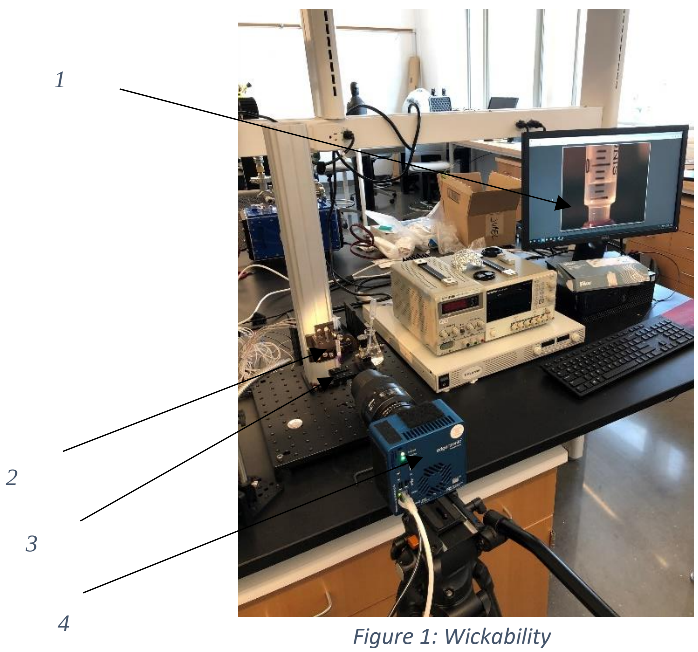


Figure 1: Wickability experimental setup

List of Equipment:

1. Computer screen displaying live feed of high-speed camera
2. Edgertronic high speed camera
3. Mobile platform where sample is placed
4. Securely held syringe filled partly with DI water

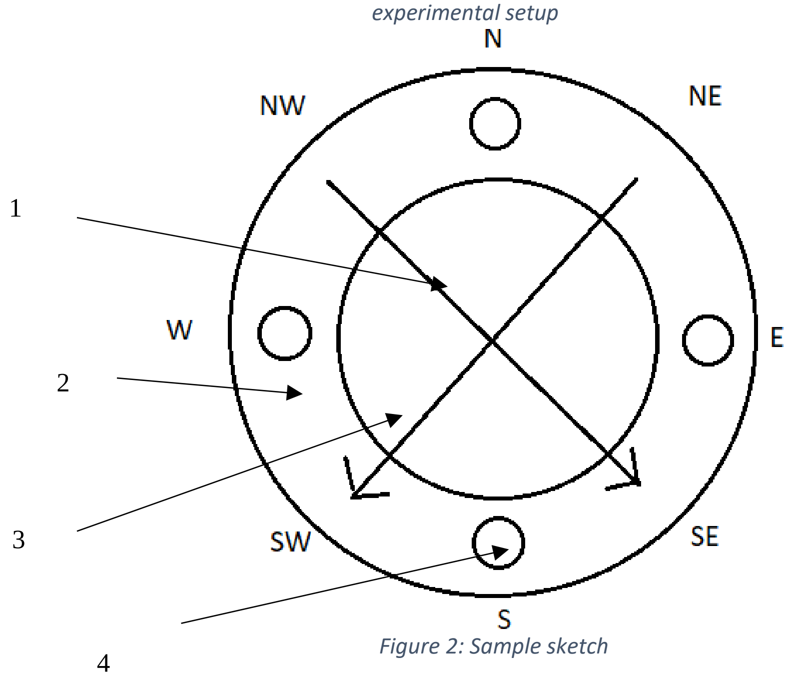


Figure 2: Sample sketch

List of elements:

1. Arrow representing path of profilometry needle
2. Raw aluminum of sample
3. Copper sulfate layer on sample
4. Hole (1 of 4) used to grab and transport sample

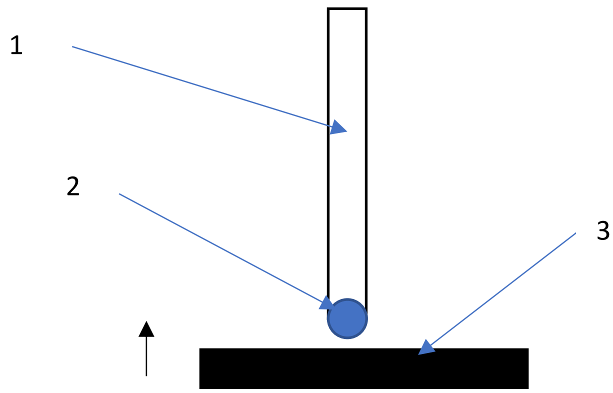


Figure 3: Close up sketch of wickability experiment

List of elements:

1. Needle filled with water
2. Meniscus at tip of needle
3. Aluminum sample

Black arrow indicates direction of platform movement

Experimental Results:

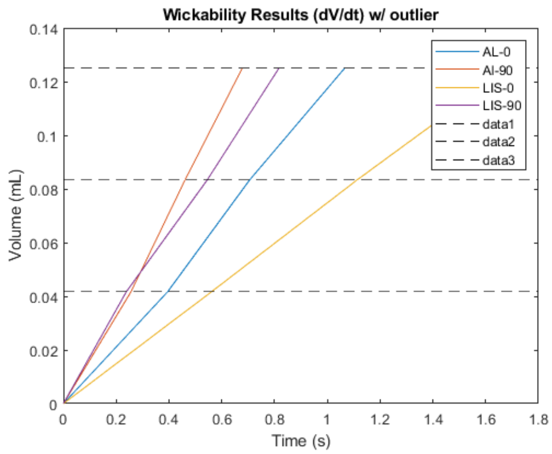
For the wickability experiment, I recorded videos for 3 different points on each sample and recorded the rate at which the water level fell as soon as the needle contacted the sample (Figure 3). A faster rate corresponds to a more wickable surface. Two of the samples had been coated with Krytox oil. Of those two, one had been used in a boiling experiment where the sample was oriented 0^{o} relative to the ground (disc was parallel to the ground), and the other was oriented 90^{o} relative to the ground (perpendicular to the ground). The same orientations applied to the two non-coated samples. I used the volume measurements on the syringe to record the volume, and the number of frames it took for the water level to fall to a certain height to record the time. Table 1 displays the data for each of the 12 samples. The “Al” or “LIS” represents whether or not the tested sample contained the Krytox oil (“Al” means no oil”). The “90” or “0” represents the angle at which the sample was oriented in the boiling chamber, and the final integer “1-3” represents the trial number for the corresponding sample. Because the camera was filmed at a frame rate of 249 frames per second, each frame equates to 1/249 seconds in real time. I used these values and MATLAB to determine plots of each change in volume as a function of time seen in Graph 1. Upon viewing the results in Table 1, an outlier is present in the third row of the first column of data. Therefore, I included a second graph (Graph 2) that includes all the data except for that outlier value.

Frames to deposit 0.025 mL

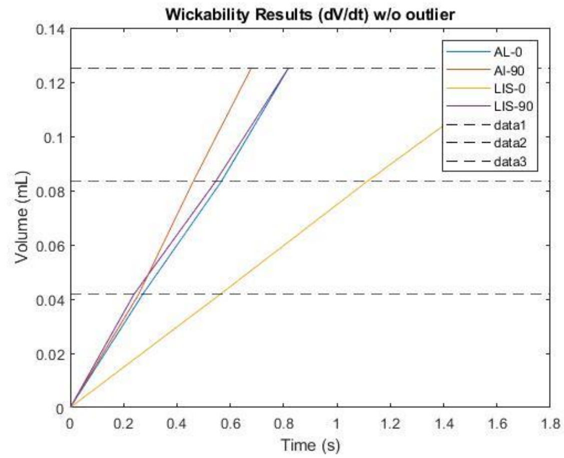
Al_O_1	Al_90_1	LIS_0_1	LIS_90_1
199	233	509	182
Al_0_2	Al_90_2	LIS_0_2	LIS_90_2
208	201	426	260
Al_0_3	Al_90_3	LIS_0_3	LIS_90_3
389*	241	328	168

Table 1
**data outlier*

Figure 4: Screenshot of high speed video showing water level falling

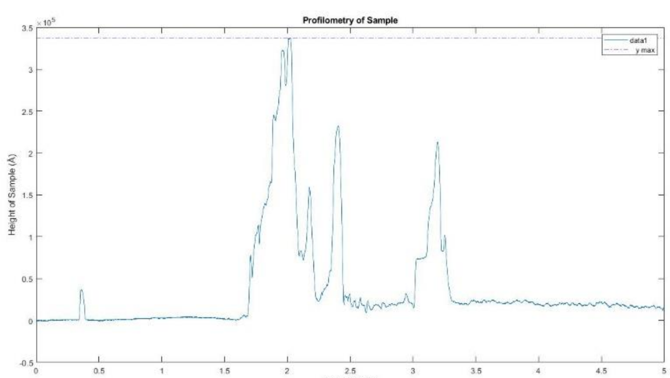


Graph 1



Graph 2

For the profilometry experiment, I only was able to test an individual sample, as I am currently working through processing more data. I took a scan of 5 mm, beginning in the pure aluminum section of the sample and ending in the region of copper sulfate deposition (see Figure 5). Using MATLAB, I made a graph of the data and plotted it (Graph 3).



Graph 3

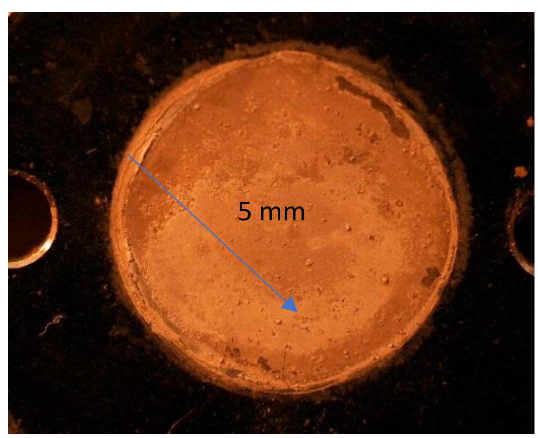


Figure 5: Close up image of Al_0 sample. Arrow traces the 5 mm long path of the profilometer needle.

Data Analysis:

The two wickability graphs show similar results. The Al_90 sample has the largest slope and an average wickability of 0.036889 mL/s, and therefore has the highest wickability, while the LIS_0 sample has the smallest slope and an average wickability of 0.014786 mL/s, and therefore has a low wickability. However, the two plots in the middle, along with the Al_90 plot show very similar results that are likely within their own percent error, so no conclusive evidence can be made about those plots. Although these results are approximately what we expected, more evidence is needed to further prove or disproof these claims. The major source of error includes the fact that if the platform with the sample was raised too high before stopping (i.e. it was not stopped early enough), then perhaps the water was blocked from flowing out of the needle, resulting in a very low wickability reading. Therefore, the responsibility is placed onto the investigator, and they must ensure that the platform stops its ascent as soon as water begins flowing from the needle (see Figure 6).

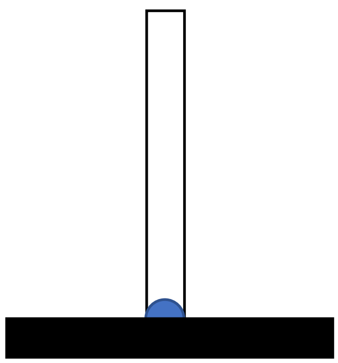


Figure 6: Illustrated cause of error showing water unable to flow out of the needle

For the profilometry experiment, it appears that the border of the deposition holds the most thickness of about 3.4 x 10^5 Å, and eventually it evens out to about 0.25 x 10^5Å. As with the wickability experiments, much more data, including plots of other samples, is needed to prove/disprove any discrepancies.

Future Experiments:

Recently, I’ve taken 24 more videos for the wickability experiment, and completed the profilometry testing for all the samples, totaling 24 readings. I am currently working on processing this data, and I expect that by the beginning of next year, I will have completed the results for these experiments.