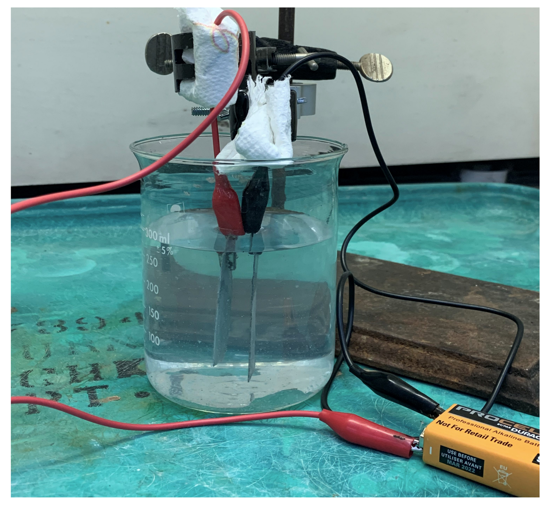

The Development of a Hydrophobic Surface Using Electrolytic Deposition and the Precipitation of Polymer Chains

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ABSTRACT

When referring to the Cassie-Baxter state, the correlation between the topography of the surface to the contact angle of the water droplet results in the surface's hydrophobicity. Water droplets have the greatest contact angle and lowest sliding angle when the surface has micro bumps that are further enhanced with non-polar nanofibers. A reduction treatment and an added layer of silicone were used to mimic this topography. Although the silicone layer faded the topography of the metal surface with heavy coating, it increased the mobility of the water droplet on the surface. The best outcome was 40 seconds for zinc, which had a contact angle of 126.35 and a sliding angle of 14.27, which supports the hypothesis; however, further development should be done regarding the precipitation of nano-fibers to maintain the created texture.

INTRODUCTION

Problem Corrosion of steel exposed to moisture despite much of it being Zinc plated continues to be a major problem.

Hydrophobicity
- The ability of a surface to resist wetting [1].

Surface energy
- Interfacial energy that attracts the liquid deposited on its surface [1].

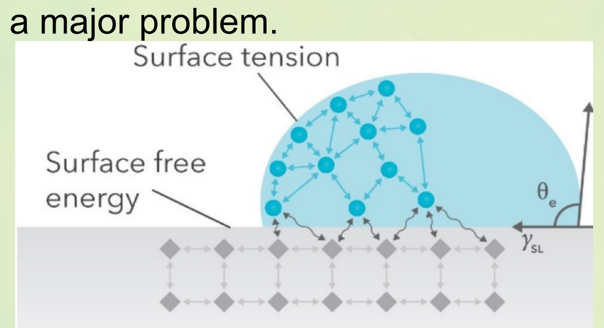
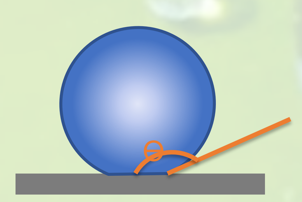


Figure 1. Illustration of intermolecular forces action on the water droplet https://www.nanoscience.com/

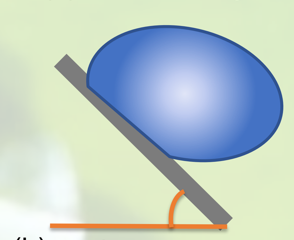
- Hydrophobic surfaces have low surface energy and the surface tension among the water molecule is greater than the attractions from the surface to the water [1].

Contact Angle
- The angle between the tangent line of water droplet to the surface [4].
- Surfaces are considered hydrophobic when the contact angle is at least 90°[4].



(a) Contact Angle

Angle Hysteresis (Sliding Angle)
- The angle in which the water droplet begins to roll off the surface [4].
- The lower the angle hysteresis, the more hydrophobic the surface is [4].



(b)Angle Hysteresis

Figure 3. Illustration of measurements

Young's Equation
- Shows equilibrium between the surface tension and surface free energy, which is represented by the contact angle [6].

$$\gamma_{SG} = \gamma_{SL} + \gamma_{LG} \cos\theta$$

Young- Dupré Equation
- Calculates the amount of work needed to pull the water droplet off of the surface, which is also equal to the work of adhesion of the surface to the water droplet [6].

$$W_{ls} = \sigma_l(1 + \cos\theta)$$

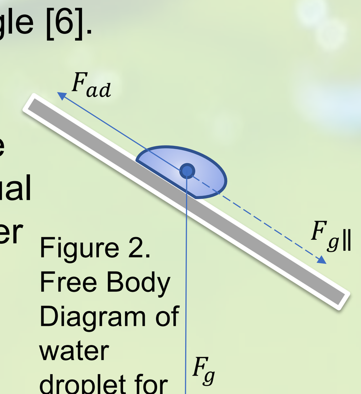


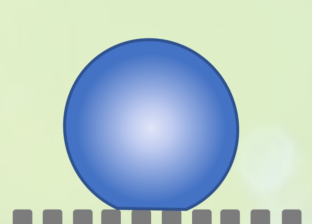
Figure 2. Free Body Diagram of water droplet for force of adesion

Force of Adhesion
- Calculates the amount of force needed for the droplet to be pulled from the surface [6].

$$mg\sin\theta = F_{ad}$$

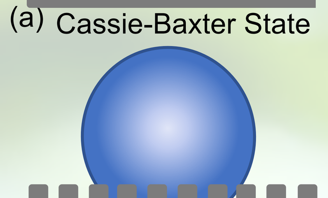
Cassie Baxter and Wenzel States
- These states depict the shape of water droplets in non-ideal surfaces (heterogeneous surface) [2].
- Uniformed micro bumps with nanofibers on these micro bumps create either one of these states [3].

Cassie Baxter State
- The water droplet will only contact the tips of the bumps, creating air pockets below the droplet [3].



(a) Cassie-Baxter State

Wenzel State
- Occurs when the droplet wets through the whole surface area of the micro bumps. No air pockets are created [2].



(b) Wenzel State

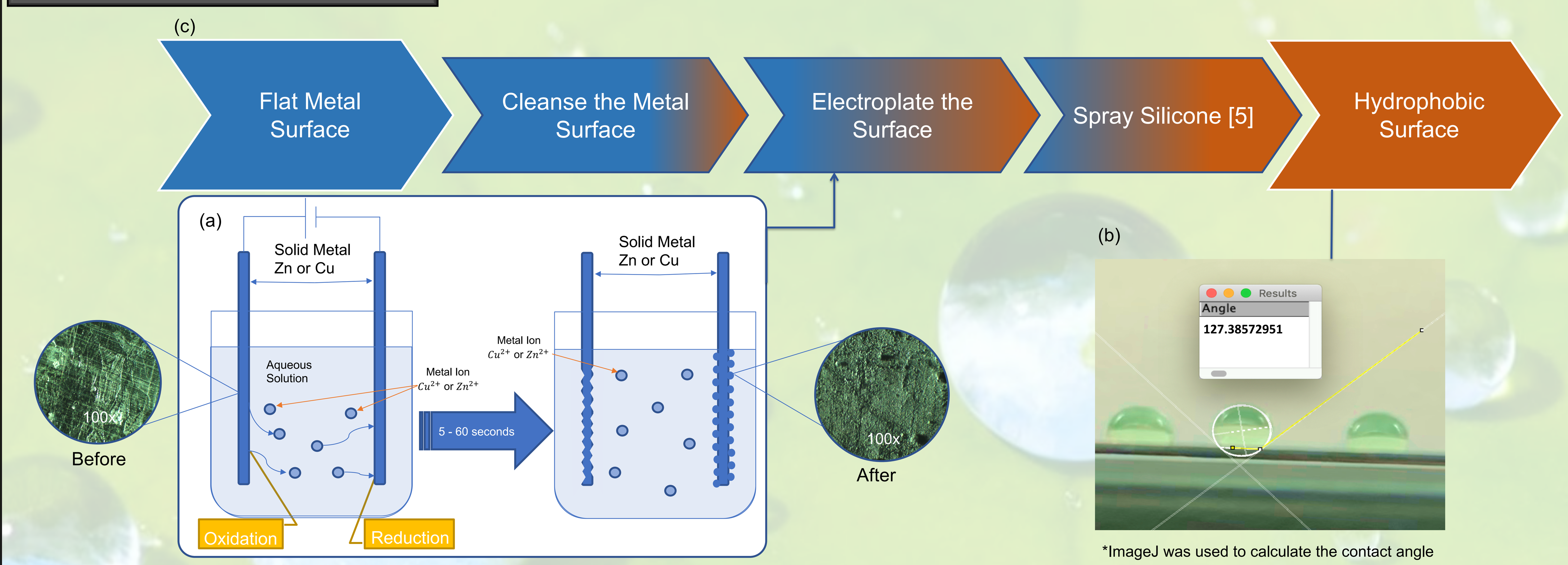
Figure 4. Illustration of states of water droplets

PURPOSE

This research is designed to develop a cost efficient, hydrophobic surface through the electrolytic deposition of metal particles and the precipitation of a silicone layer.
- To verify the enhancement of hydrophobicity with silicone coating
- To find the optimal time of plating

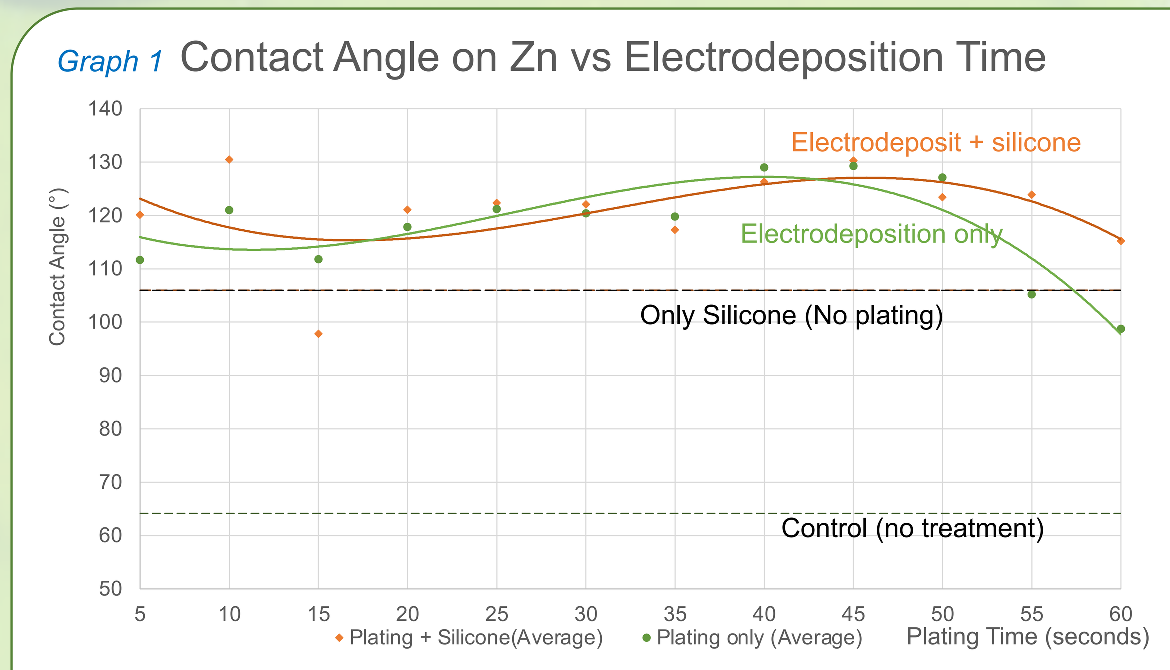
Hypothesis Rapid electrodeposition on metal surfaces can develop surfaces that have contact angles over 90 degrees and sliding angles below 30 degrees by imparting micro-bumps that achieve a *Cassie-Baxter State*. Hydrophobicity of metal surfaces can be further enhanced by precipitation of silicone polymers.

METHOD

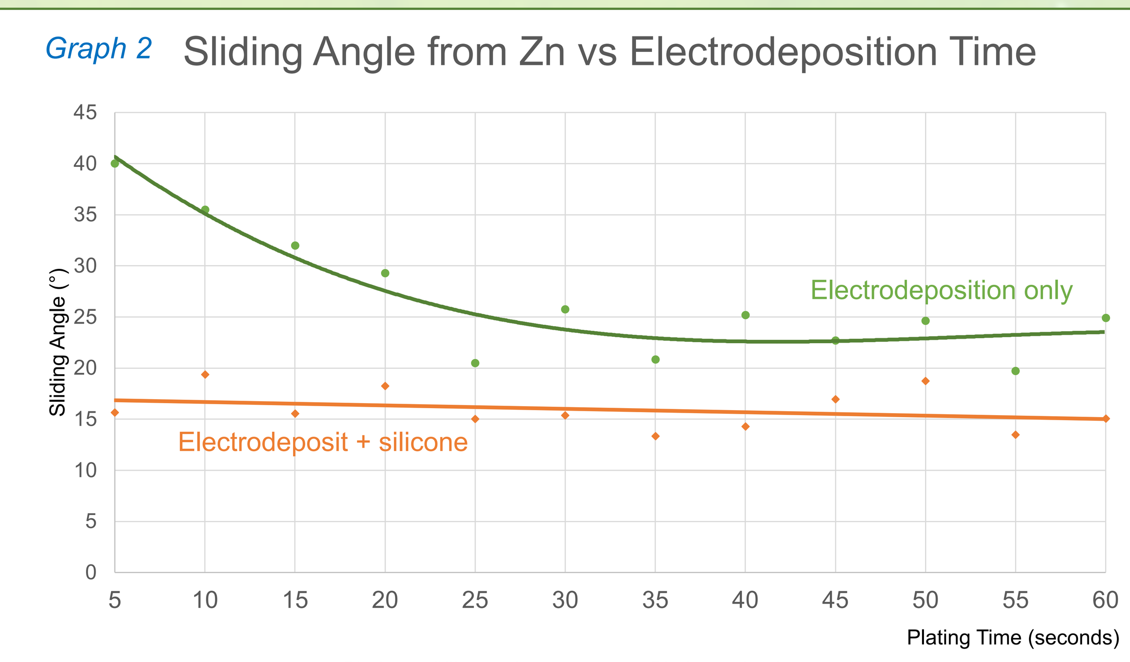


*ImageJ was used to calculate the contact angle

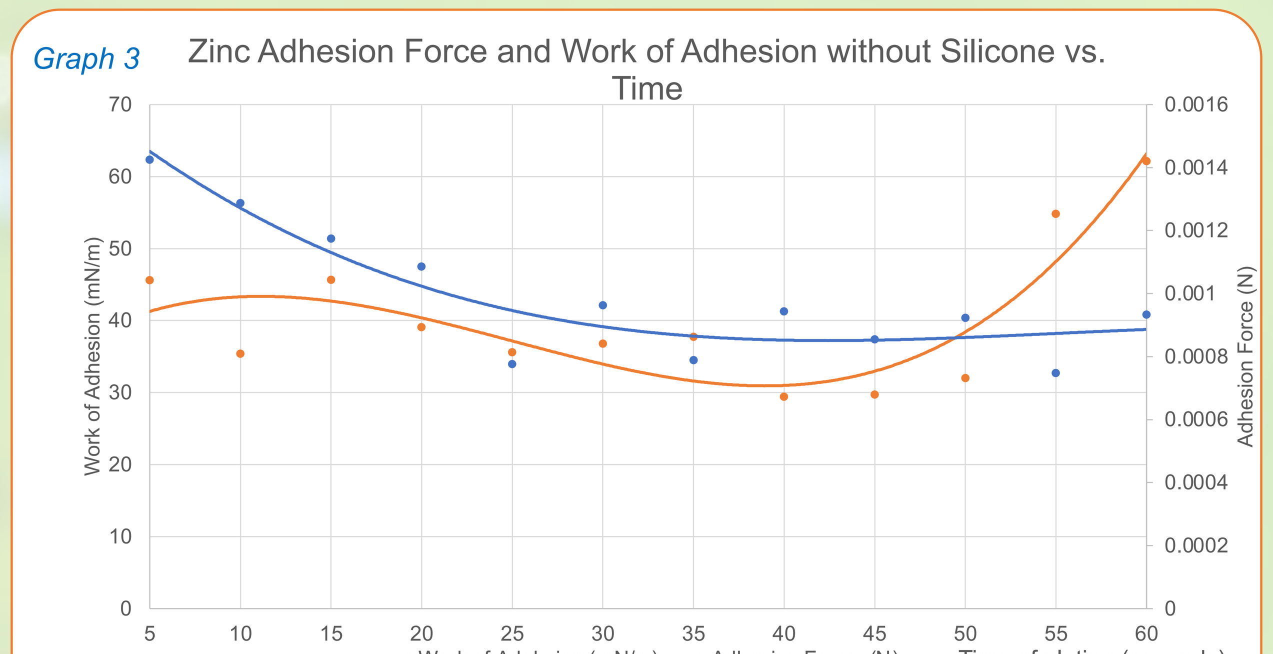
RESULTS



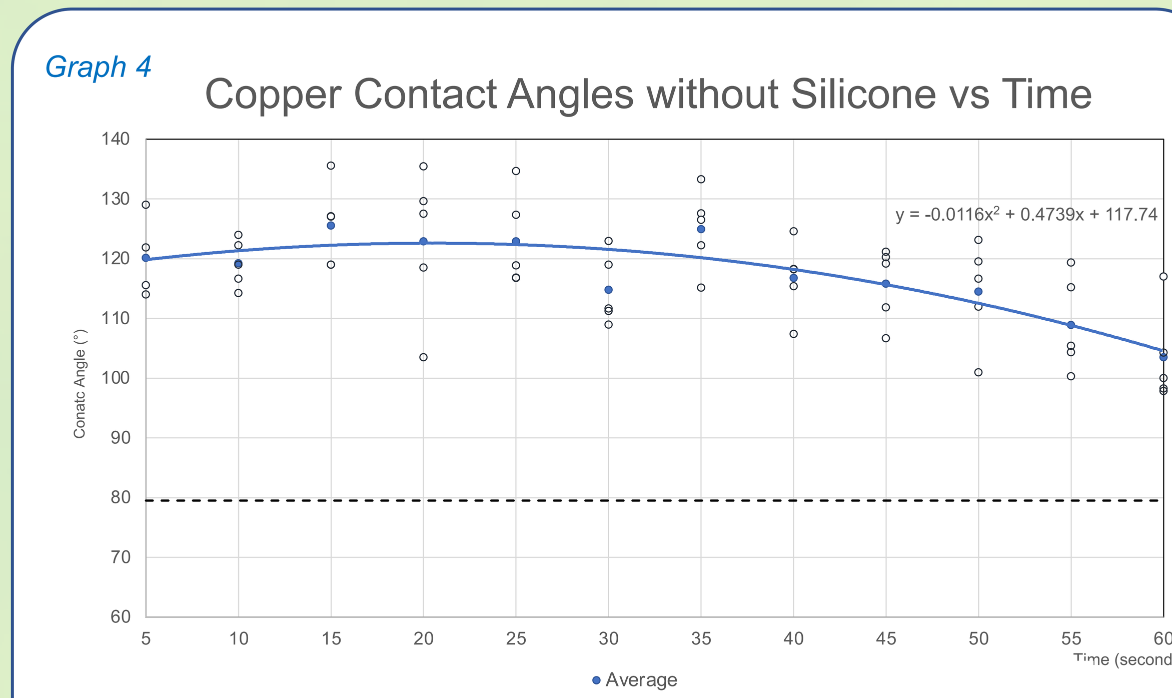
Graph 1. Zn-plated steel samples were electroplated with Zn at 9V for 5 to 60 seconds, rinsed, dried, and measured for contact angle, then exposed to silicone in xylene, dried, and remeasured for contact angle.



Zn-plated steel samples were electrodeposited with Zn at 9V for 5 to 60 seconds, rinsed, dried, coated with water droplets and angled until water ran off completely. They were then exposed to silicone in xylene, dried, and remeasured for sliding angle.



Adhesion force and work of adhesion were calculated from the contact angles and sliding angles using the following equations:
Adhesion Force: $mg\sin\theta = F_{ad}$
Work of Adhesion: $W_{ls} = \sigma_l(1 + \cos\theta)$ - Young-Dupré equation
The ratio between work of adhesion and adhesion force is 32005.7125.



Cu- plated steel samples were electroplated with Cu at 9V for 5 to 60 seconds, rinsed, dried, and measured for contact angle.

CONCLUSIONS

- Metal surfaces can develop hydrophobic properties by rapid electroplating that deposits metal as micro-bumps, which prevent water from penetrating between the bumps of the treated metal surface, creating a Cassie-Baxter State.
- Both the contact angle and the sliding angle were measured for Zinc surfaces electroplated with additional Zinc. The result showed that hydrophobicity depended on the time of electrodeposition. With 5 seconds, there was a major increase of contact angle from the untreated surface, and this increase peaked at 40 seconds.
- Additionally, this surface treatment was also successful with Copper, but there is a different optimal plating time. It could be concluded that this trend would also shown in other metals as well.
- The additional precipitation of silicone from a dilute xylene solution provided very little increase in contact angle, but lowered the sliding angle. Additionally, there was no water residue left on the surface after the treatment with silicone.

DISCUSSION

- By calculating Work of Adhesion and Force of Adhesion, the hydrophobicity of the surface can be seen. Since the Work of Adhesion and Force of Adhesion both have a general decrease, these calculations verify the trends in our data. Additionally, a relationship between contact angle and sliding angle is derived.
- By developing a water repellent metal surfaces, the surfaces are more corrosion resistant. In bridges that cross bodies of water, epoxy/waxy coating is used to prevent the surface from corroding away. However, after a few years, this epoxy must be removed, and the surface must be recoated. [7] With the development of an electroplated metal surface, the surface does not have to rely on an additional source for protection, and this protective layer does not have to be replaced.

FUTURE WORK

- A different method should be used to guarantee that the silicone layer is a monolayer and the geometry is ideal. One way of achieving this could be by following the Langmuir Blodgett method.
- Different industrial metals should be tested to find the general trend for different metals.

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