SuperHydrophobic Surfaces

Surface Coating

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Background

The influence of roughness on water repellency was studied long before the appearance of the Lotus Effect term and can be understood on a sound thermodynamic basis.

The wetting of a solid with water, with air as the surrounding medium, is dependent on the relationship between the interfacial tensions of water/air, water/solid and solid/air. The ratio between these tensions determines the contact angle of a water droplet on a given surface and is described by the Young's equation. If a droplet is applied to a solid surface, it will wet the surface to a certain degree. If the contact angle is less than 90 degrees the surface is hydrophilic, if the surface is greater than 90 degrees it is hydrophobic. The wetting depends on the ratio between the energy necessary for the enlargement of the surface and the gain of energy due to adsorption. At equilibrium, the energy of the system is minimized.

$$\cos \theta_Y = \frac{\gamma_{SV} - \gamma_{SL}}{\gamma_{LV}}$$

where θ_Y is called the Young's contact angle, γ_{SL}, γ_{SV}, and γ_{LV} are the interfacial energies per unit area of the solid-liquid (SL), solid-vapor (SV), and liquid-vapor (LV) interfaces, respectively. According to Young's equation, the maximum contact angle can be attained by lowering the surface energy of a flat surface.

The Young's equation can only be applied to a smooth and homogeneous surface. On rough solid surfaces Wenzel recognized that Young's equation does not to rough surfaces. He indicated that the roughness of the surface, and therefore the actual surface area, affects the surface wetting properties. He modified Young's equation as follows:

$$\cos \theta_W = r \frac{\gamma_{SV} - \gamma_{SL}}{\gamma_{LV}} = r \cos \theta_Y$$

In this equation, θ_W is called the Wenzel contact angle, r is the roughness factor, which is defined as the ratio of the actual area of a rough surface to the geometric projected area. Since r is always larger than 1, when the surface roughness increases, the hydrophilicity for hydrophilic surface ($0<\theta_Y<\pi/2$) increases and the hydrophobicity for hydrophobic surface ($\pi/2<\theta_Y<\pi$) increases. Wenzel's equation is called homogeneous wetting, however, the Wenzel's equation can only be applied to homogenous rough surfaces.

It is recognized that water spreading does not occur on a lotus plant surfaces, but instead forms a spherical droplet. The contact angle θ_c at a heterogeneous surface can be described by the Cassie's equation as follows:

$$\cos\theta_c = \Gamma f \cos\theta + f - 1$$

Where f is the remaining area fraction of the liquid-solid interface and Γ is the roughness factor of the wet area. According to Cassie's equation, when f decrease the water contact angle of hydrophobic surface will increase. Therefore the roughness ratio also affects the wetting properties of a heterogeneous rough surface.

The objective of this project is to determine if a Lotus Effect surface can withstand its superhydrophobicity when exposed to an increase of temperature. The Lotus Effect represents the replication of superhydrophobicity and self-cleaning properties of natural lotus leaves on artificial surfaces.

Sample Preparation

First, the substance used for the surface coating was prepared. Because polymers will degrade under UV exposure, UV stabilizers were used so the developing coating will have UV stability. To prepare the surface coating polybutadiene (PB), UV-3346 light stabilizer, UV-5411PA light absorber, (BLS 1944) were acquired. Next 0.4 gram and 1 gram of UV-3346, UV-5411PA, and BLS 1944 were placed in a glass container. Next 20 grams of polybutadiene where placed in each glass container and mixed. While the substances were mixing 12 miscroscope slides were prepared for the surface coating. The mixture was then applied evenly on top of the slides. Next each slide was placed on the spin coater for 45 seconds. Then the slides were placed in the vacuum oven for 1 minute. The thin films were then etched with SF_6 plasma for 5 minutes.

The next day the before treatment contact angle were measured. After the contact angles were measured the slides were placed in the oven for thermal treatment (150^{o}C, 60 minutes). Then the after treatment contact angles were measured.

Table 1. Composition of Coatings

	Name	Amount of grams	Amount of Polybutadiene	Mixture
1	BLS 1944	0.4 g	20.0 g	20g PB + 0.4g of 1944
2	BLS 1944	1.0 g	20.0 g	20g PB + 1.0g of 1944
3	UV-3346	0.4 g	20.0 g	20g PB + 0.4g of UV-3346
4	UV-3346	1.0 g	20.0 g	20g PB + 1.0g of UV-3346
5	UV-5411PA	0.4 g	20.0 g	20g PB + 0.4g of UV-5411PA
6	UV-5411PA	1.0 g	20.0 g	20g PB + 1.0g of UV-5411PA

Measurement Tools and Techniques Used

- **Glass Containers**

The glass containers were used to hold the chemical substance used to make the surface coating.

- **Microscopic Slides**

The microscopic slides were used to spread the surface coating on top, so the contact angle could be measured.

- **Scale**

The scale was used to place accurate amounts of the chemical substance into each glass container.

❖ Dropper and Wooden stirrer

The dropper and wooden stirrer were used to transfer the substance to the glass bottles, also the dropper was used to apply the surface coating onto the slides.

❖ Spin Coater

The spin coater was used to spread the surface coating onto the microscopic slide evenly by acting as a vacuum while spinning the slide around.

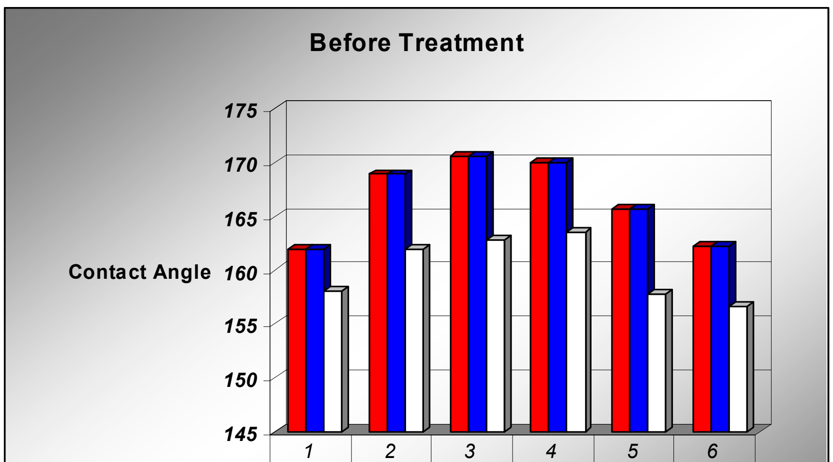
❖ Thermal Oven

The thermal oven was used to apply thermal treatment to the slides.

❖ Goniometer

The goniometer was used to measure the contact angle

Experimental Results



	1	2	3	4	5	6
Series1	162	168.9	170.5	170	165.7	162.2
Series2	162	168.9	170.5	170	165.7	162.2
Series3	158	161.9	162.8	163.5	157.8	156.6

Series 1: Static Contact Angle
Series 2: Advancing Angle
Series3: Receding Angle

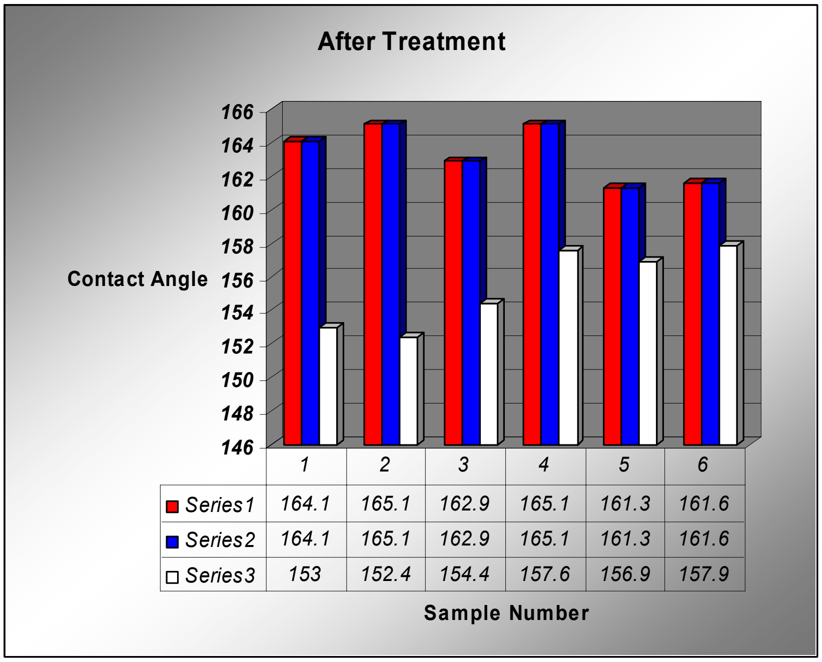
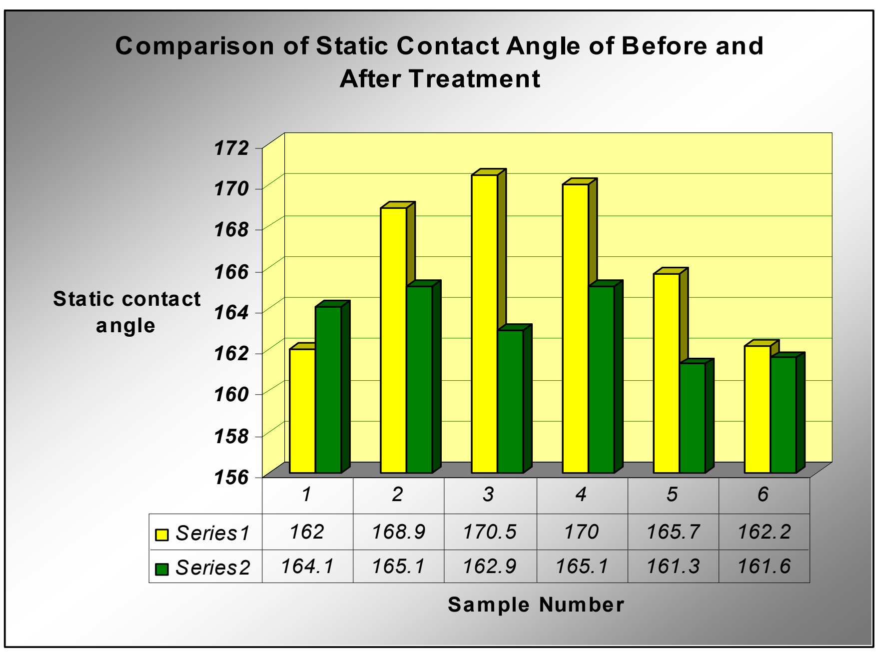
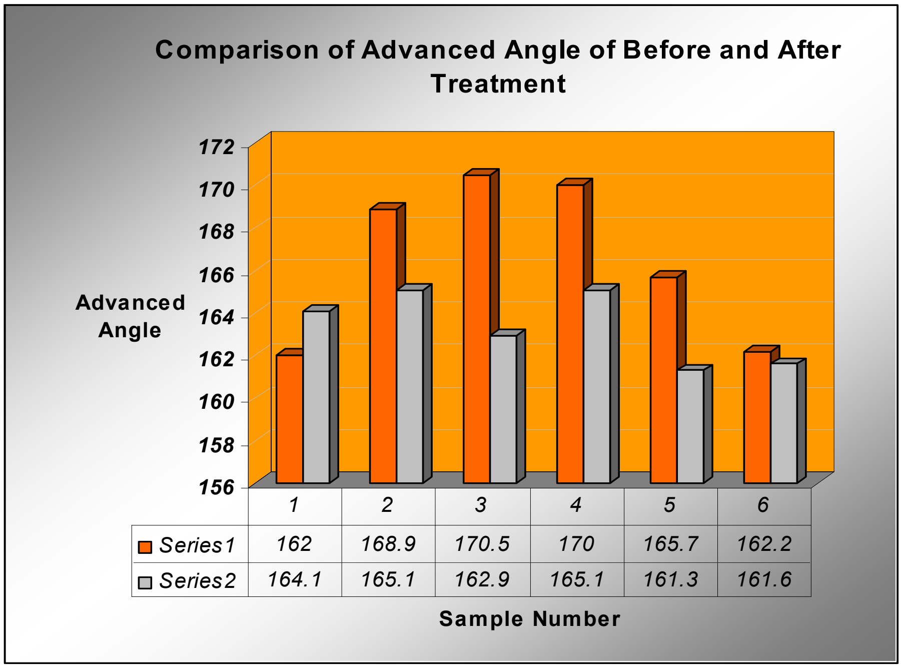


Figure1. Static, Advancing and Receding Contact Angles of Samples 1-6

Data Analysis





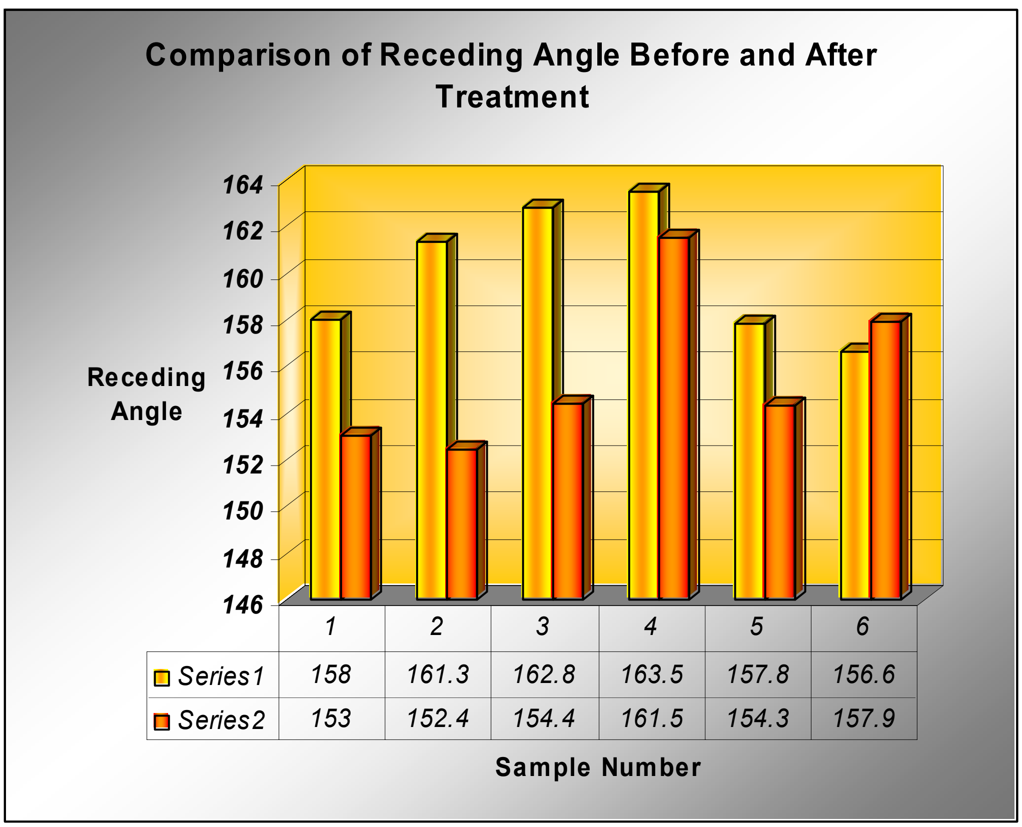


Figure 2. Comparison or static, advancing and receding contact angle before and after thermal treatment (Series 1: Before Treatment Series 2: After Treatment)

The data doesn't show any significant difference in the contact angles before and after the thermal treatment.

Conclusion and Discussion

In this paper, Young's equation, Wenzel's equation, Cassie's Equation, and Lotus Effect surfaces were discussed. The data in this paper shows a comparison of the contact angles of the samples before treatment and after treatment. The data shows that the thermal treatment had little effect on the samples. It can be concluded from the data that there is little difference in the contact angle before and after the thermal treatment.

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