The Society of Rheology
K12 Outreach Activities

Science is FUN!

The Lotus Effect - Part 2

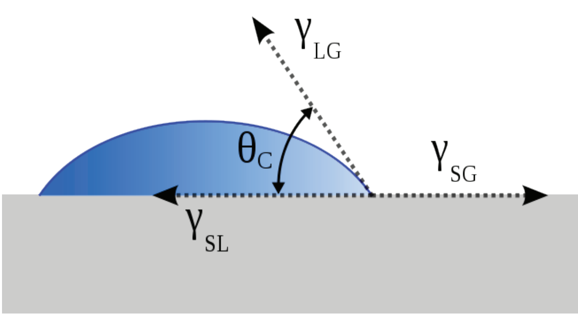
In nature, you can find plants, insects and animals that have evolved with some incredible adaptations for surviving in their natural habitat. Take for example the lotus plant. The lotus grows in swamps where dirt and mud can get on its leaves blocking out the sun making it harder to grow through photosynthesis. Not a problem!. The leaves of the lotus plant have evolved to be naturally self-cleaning. Scientists classify lotus leaves as *superhydrophobic* surfaces meaning that water beads up on the surface of the plant and moves freely with almost no resistance. When it rains, the raindrops roll down along the lotus leaves collecting any dirt or mud in their path. The lotus leaf has been mimicked by scientists and engineers to create self-cleaning surfaces and stain resistant clothes, but it has also been used to stop ice formation, reduce bacteria growth and even reduce the drag of boats moving through water. Here we will make our own *superhydrophobic* surfaces that mimic the properties of the lotus leaf.

What you will need to get started

- Regular sand and “Magic” sand
- Two shallow pans/plates/dishes
- Two cups and two spoons
- Water
- Paper towels for cleanup

What does superhydrophic mean?

- Liquids and solids interact through surface tension, γ, and contact angle, θ
- If water likes a surface it will spread, the contact angle is small, $\theta < 90^o$, and the surface is hydrophilic
- If water dislikes a surface, the contact angle is large, $\theta > 90^o$, and the surface is hydrophobic
- If water really dislikes a surface, it beads up like a sphere and its contact angle approaches, $\theta = 180^o$.
- This is *superhydrophbic*. This is a lotus leaf.



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Let's experiment!

The incredible properties of the lotus leaf come from a combination of chemistry which makes the surface hydrophobic and roughness. In part 1 of this demo we added roughness to a hydrophobic surface. Here we will add make an already rough surface or sand hydrophobobic. We will make it "Magic."

1. Cover the bottom of one pan with regular sand and the other with magic sand.

2. Place a small drop of water on the regular sand and the magic sand
   - What happens in each? What does the drop look like in each dish? Is it flat? Is it a sphere? Is it a hemisphere? Does the drop stick or slide on the sand when you tilt pan?

3. Now shake the pan of magic sand.
   - What does the drop do? Is this superhydrophobic surface better or worse than the sanded Teflon?

4. Now fill two cups with water. Pour reglar sand in one cup and magic sand in the other.
   - What happens in each case? Does the magic sand get wet? Congratulations, you have just created an inverted sandcastle.

5. Use a spoon and bring the magic sand to the surface
   - What happens? Is it wet or dry? Touch it.

6. Gently sprinkle some sand on the surface of the water to create a film. Slowly push your finger under water through the sand raft and retract it
   - Why does th sand float? Does your finger get wet? Is it magic? No. It's science!!!

Magic Sand

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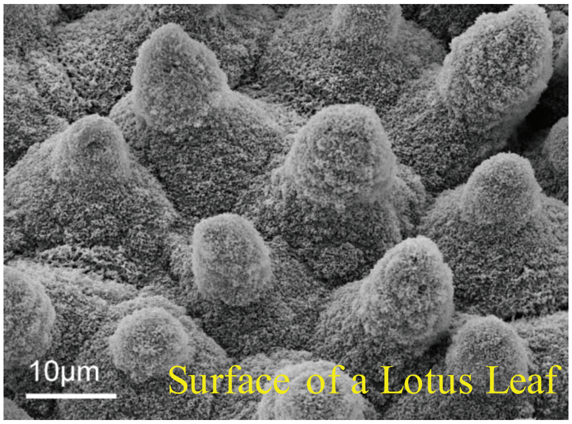
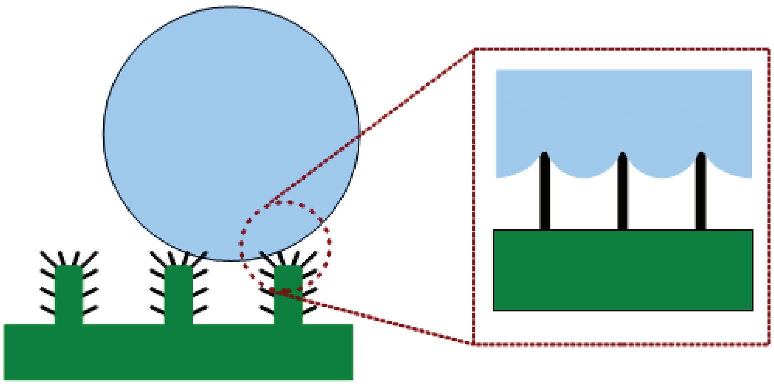
How does it work?

The surface of the lotus leaf is covered by 10μm wide bumps which are coated by waxy crystals that are even smaller and extremely hydrophobic. Even without the surface bumps, a surface coated with just the crystals would be extremely hydrophobic. By adding the micron sized bumps, the surface becomes superhydrophobic.



The bumps serve a very important purpose. The water does not wet the entire surface of the leaf, but instead it only makes contact with the very tops of the bumps trapping air between the drop and the surface. This trapped air is what gives the surface its incredible properties. The contact angle between water and air is $\theta = 180^{o}$. the more air that is trapped, the larger the contact angle and the more mobile the drops become.



When you put the magic sand under water, air is trapped between the grains of sand just as it is between the features of the lotus leaf. That's why you can see it shimmer underwater. It is also why it sticks together to form an underwater sand castle. The surface tension of the water is the glue that holds the sand particles together.

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