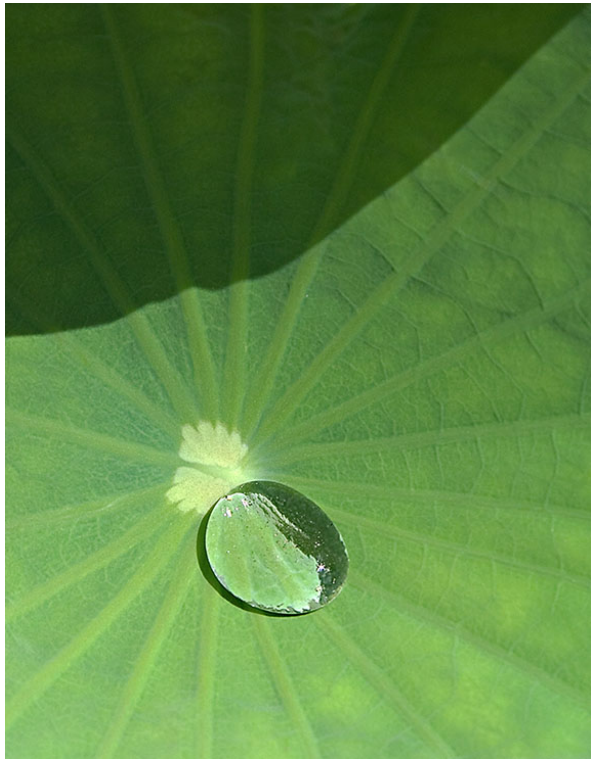
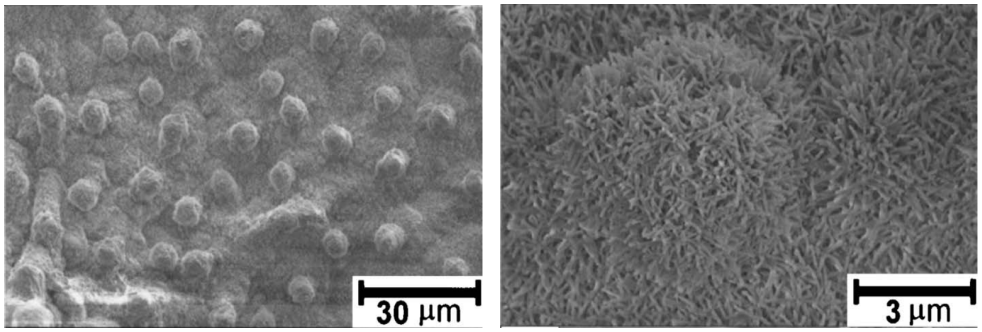
Superhydrophobic Surfaces

Nature-Inspired Superhydrophobic Surfaces



A water droplet beads up on a lotus leaf due to the hydrophobic nanostructures

Double roughening of a hydrophobic surface, on the submicron and nanometer scale, creates superhydrophobicity!



SEM images of lotus leaf surface

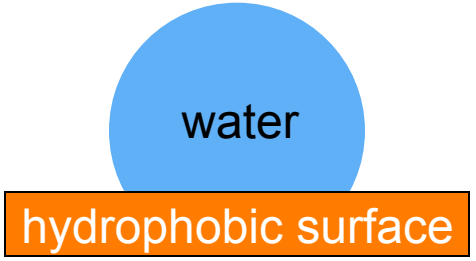
http://www.pbase.com/yvesr

Cheng, Y. T., *et. al. Applied Physics Letters* **2005,** 87, 194112.

Hydrophobic/Hydrophilic/Superhdyrophobic

Hydrophobic Surfaces: "Water-fearing surface"
Water tries to minimize contact with surface.

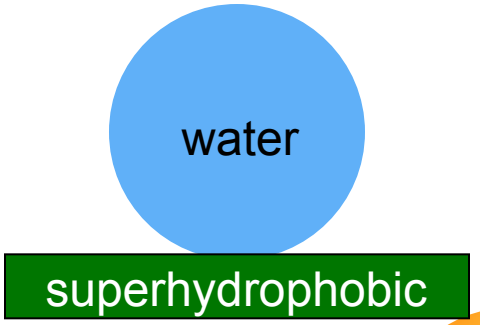
Examples: Teflon, oily surfaces



Hydrophilic Surfaces: "Water-loving surface"
Water tries to maximize contact with surface.

Examples: Glass, rusted metal surfaces

Superhydrophobic Surfaces: Hydrophobic surface having nano-scale roughness.

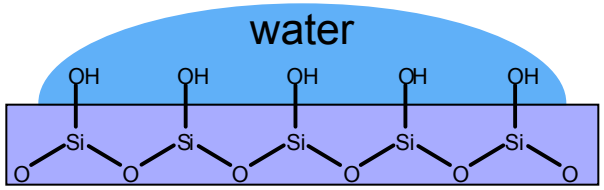


Why Do Surfaces Attract or Repel Water?

Remember, the “Like dissolves like” principle!

- Intermolecular interactions are:
  - Hydrogen bonding
  - Dipole-dipole interactions
  - Van der Waals forces

Example 1

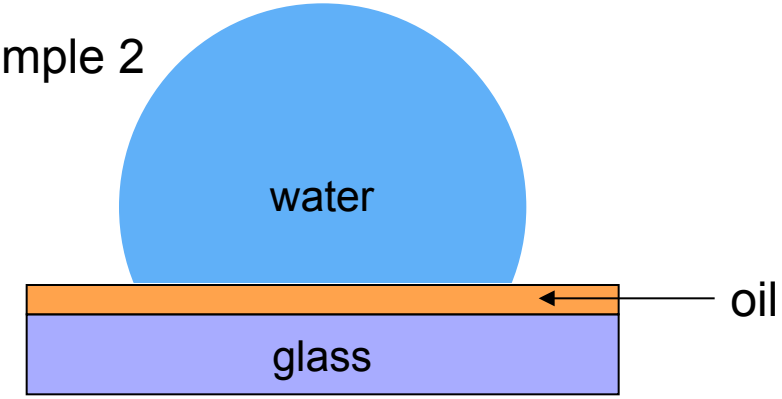


Glass surface

1. Hydrogen bonding
2. Dipole-dipole interactions
3. Van der Waals forces

} Attraction

Example 2



Oil coated surface

1. Van der Waals forces

} Repulsion

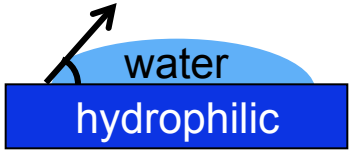
How to Classify a Surface

Liquid-surface interactions and surface texture determine droplet shape!

Contact angle: A way to measure liquid-surface interactions.

Hydrophilic surface:

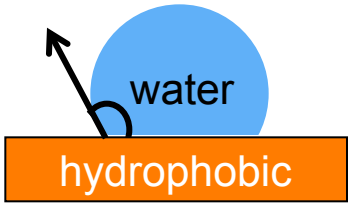
- Surfaces with a contact angle $\theta_c < 90°$
- Water spreads out on surface



θ_c = Contact angle

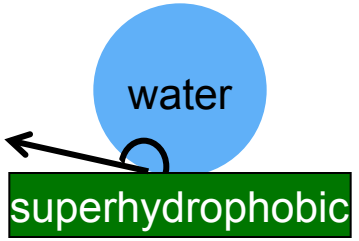
Hydrophobic surface:

- Surfaces with a contact angle $\theta_c > 90°$
- Water beads-up on the surface



Superhydrophobic surfaces:

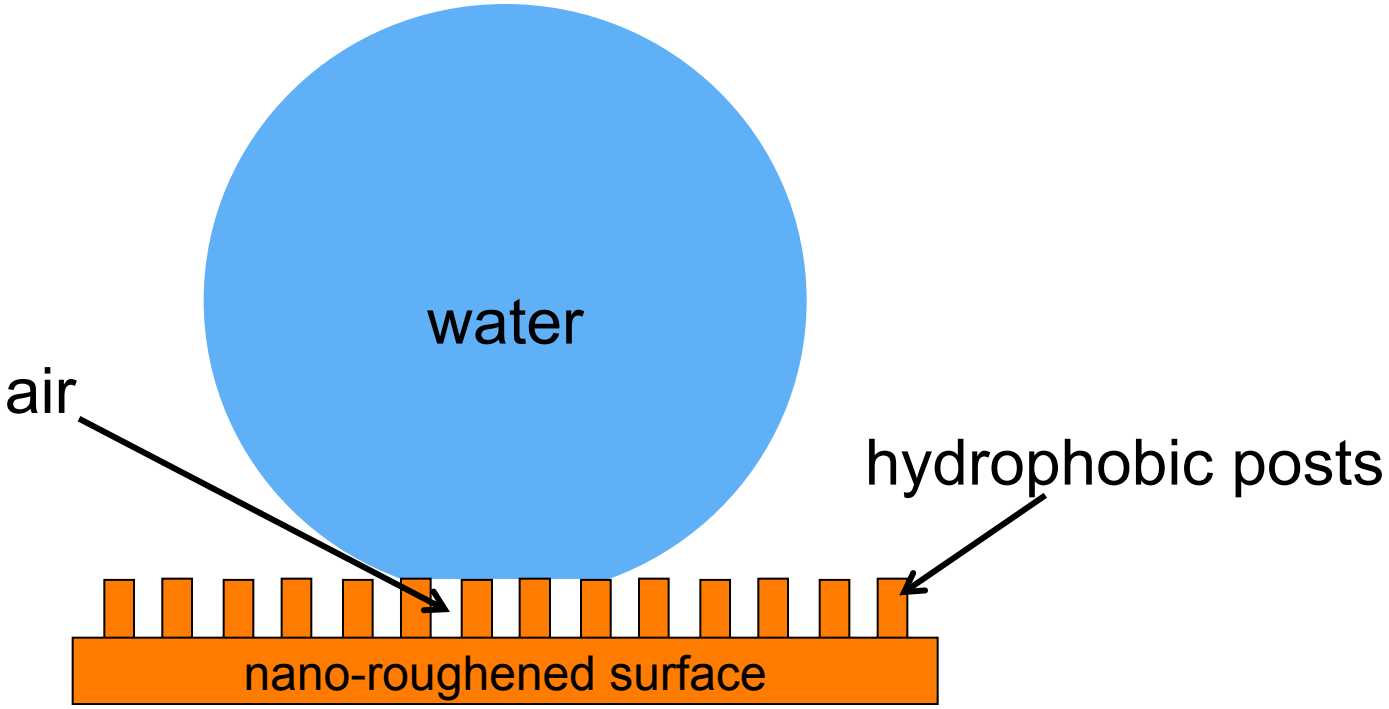
- Surfaces with a contact angle $\theta_c > 150°$
- Water is highly beaded (repelled)



Making Superhydrophobic Surfaces

Nano-roughness creates superhydrophobic surfaces

- Lower water-solid contact area
- Water perched on hydrophobic posts containing trapped air
- Result: high contact angle



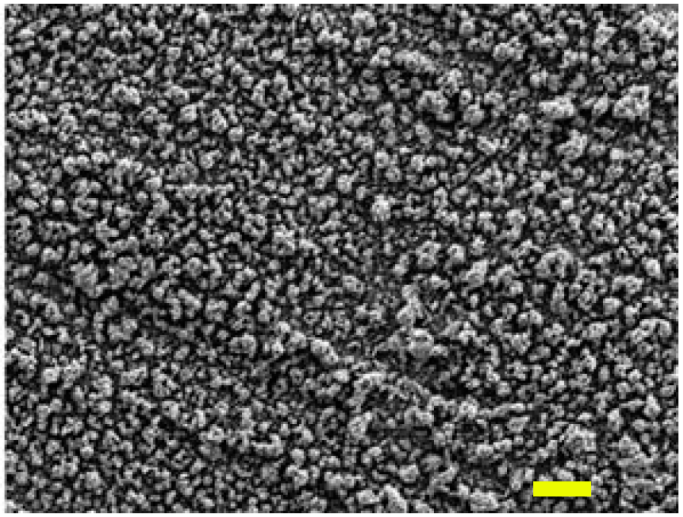
Lab-constructed Superhydrophobic Surface

1. Fabricate nano-roughened silver surface

$$Cu^{0} + 2AgNO_{3\,(aq)} \rightleftharpoons Cu(NO_3)_{2\,(aq)} + 2Ag^{0}$$

Electroless Galvanic Deposition

Nano-roughened silver surface



SEM image of silver deposited on copper. Scale bar = 1μm

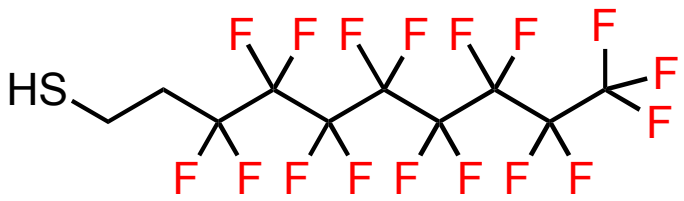
- Islands 150–300 nm in size
- 150–300 nm between islands
- 50–100 nm clusters of silver atoms on islands

Larmour, I. *et al.*, Angew. Chem. Int. Ed. **2007**, 46, 1710-1712.

Constructing the Superhydrophobic Surface

Surface prep process:

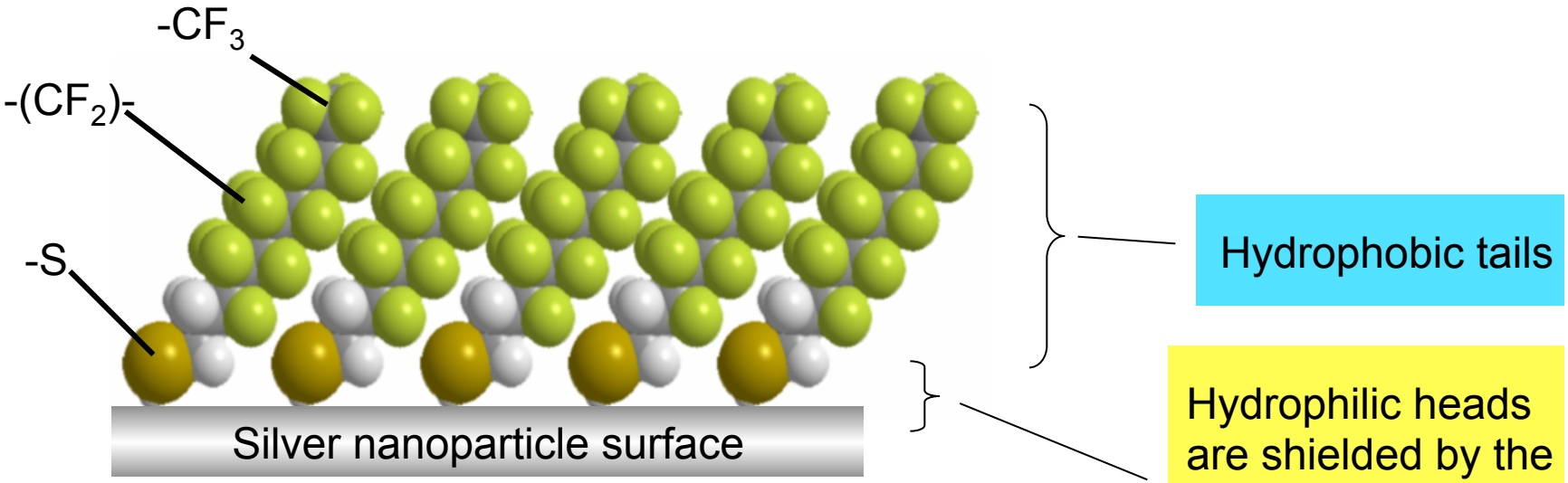
1. Dip Cu, in a solution of silver nitrate ($AgNO_{3)}$.
2. Dip silver coated surface in heptadecafluoro-1-decanethiol (HDFT) or 11-mercapto-1-undecanol (MUO) solution.



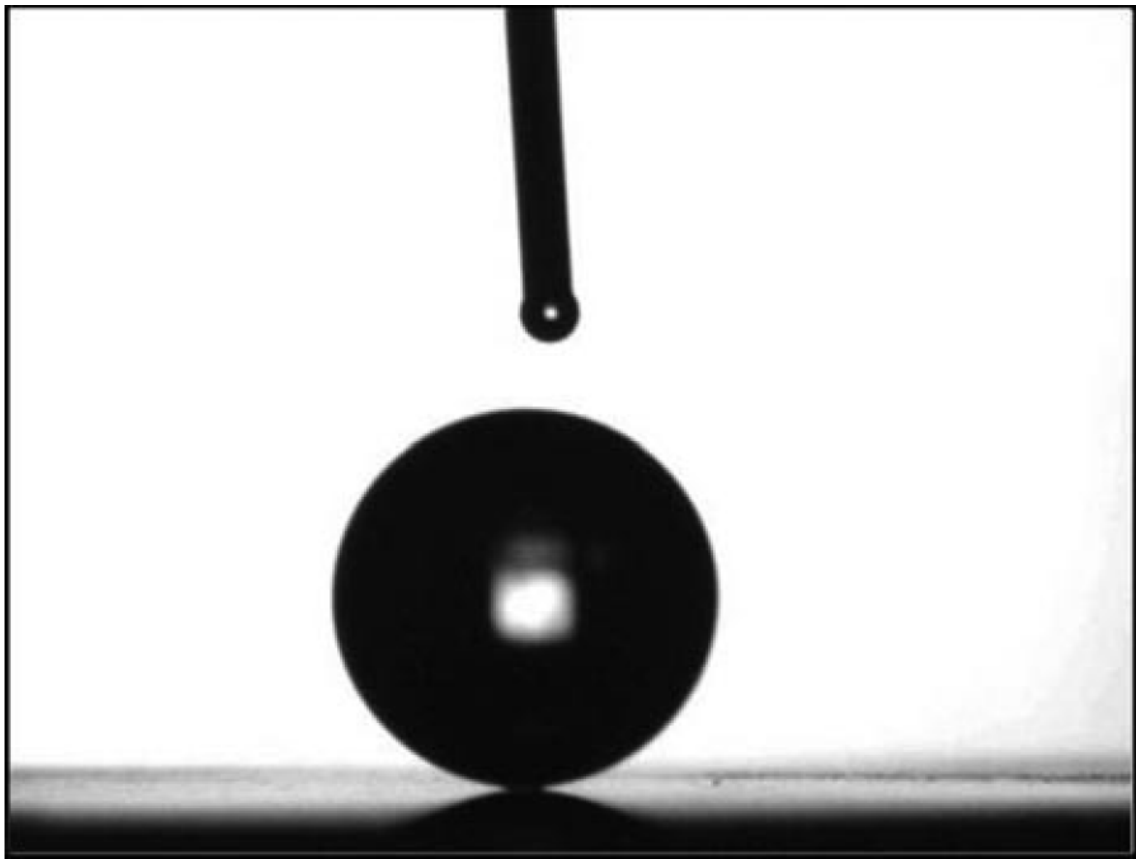
HDFT

MUO

HDFT Self-assembled monolayer:

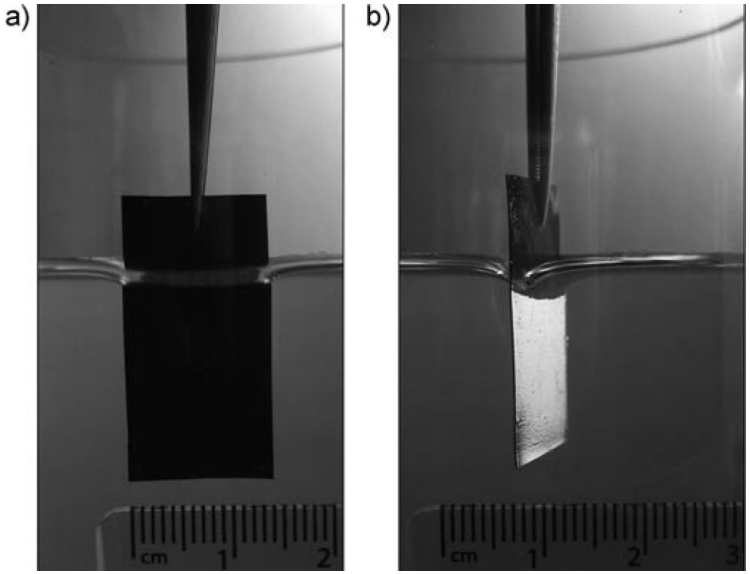


HDFT Surface Properties



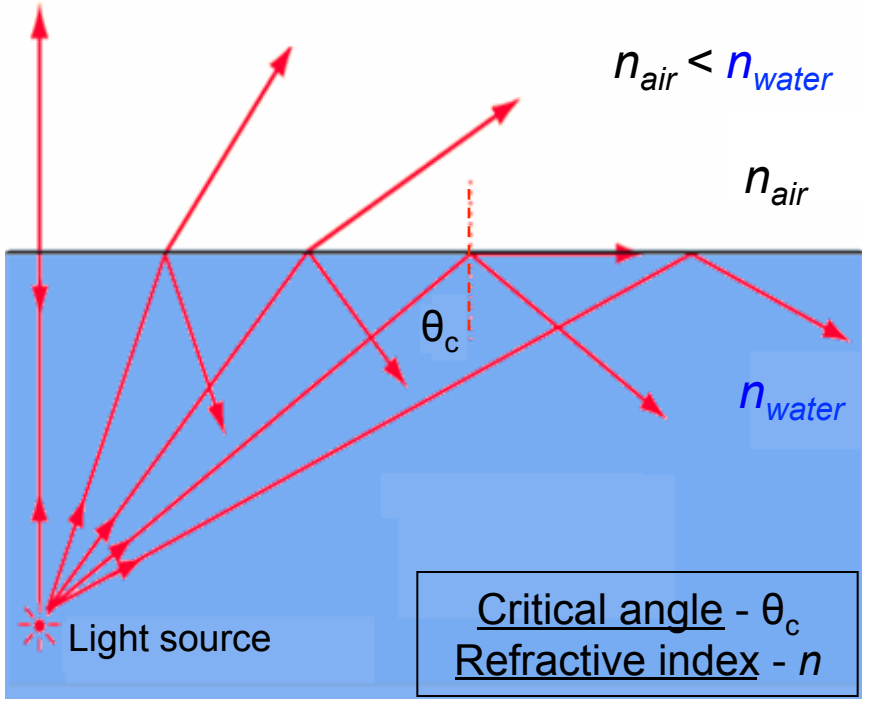
- This is the surface students make; the contact angle is nearly 180°!
- The “roll-off” angle of water droplets is LESS than 1°, so good luck trying to get it to stay in one place!

Total Internal Reflections on Water Immersed HDFT Surfaces



A superhydrophobic copper plate in water viewed a) perpendicular to the surface and b) past the critical angle.

Some physics review!



$$\text{Snells Law: } n_{water}\sin(\theta_1) = n_{air}\sin(\theta_2)$$

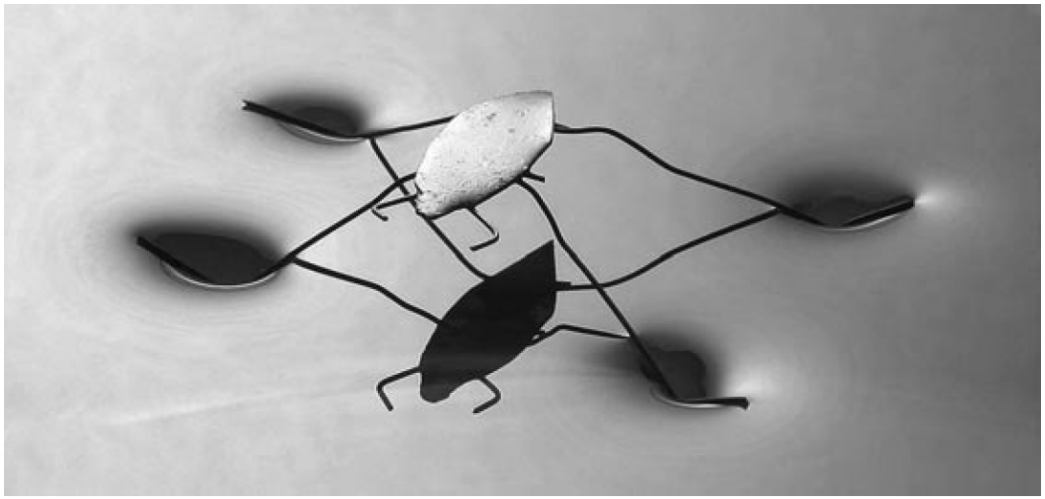
- Critical angle is 48.6°, identical to the internal reflection at a water/air interface

Total internal reflection and critical angle concept.

Larmour, I. *et al.*, Angew. Chem. Int. Ed. **2007**, 46, 1710-1712.

http://hyperphysics.phy-astr.gsu.edu

Gliding on Superhydrophobic Feet



- A “pond skater” replica (much heavier than a real one) can rest on the surface of water thanks to its superhydrophobic feet and the surface tension of water
- Real-life pond skaters possess similar nano-rough feet which are also hydrophobic!

- A live “pond skater” utilizing its superhydrophobic feet to rest on the surface of water

Applications – Real World

Spray-on UV blocker
(but still get tanned!)

New-age nonstick surfaces

Applications – Real World

Ultra-high efficiency windmills for cheaper “green” energy

Low water resistance for boats – racing / high speed applications

Super-hydrophobic Surfaces Procedure:

1. Place copper piece on a fresh paper towel. Using a piece of sandpaper, sand both sides of the copper until each surface is shiny.
2. Pick up the sanded copper with tweezers and rinse both sides with water for 5 seconds, followed by ethanol for 5 seconds.
3. Place the cleaned copper in silver nitrate solution and swirl solution containing the copper for 25 seconds.
4. Remove the copper with tweezers and rinse both sides with water for 5 seconds.
5. Dry both sides of copper with compressed air. Be careful not to blow too hard with the compressed air. The surface should look silvery-black.
6. Place the silver-coated copper pieces in the HDFT solution. Let both it soak in solution for at least 10 minutes.
9. After 10 minutes, take out the copper piece from the HDFT solution. Wash the piece with ethanol for 5 seconds and then dry it with compressed air.