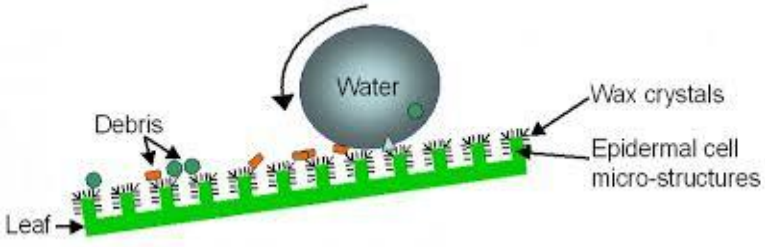
Effect of Varying Quantities of Carbon-Nanofibers on Superhydrophobicity

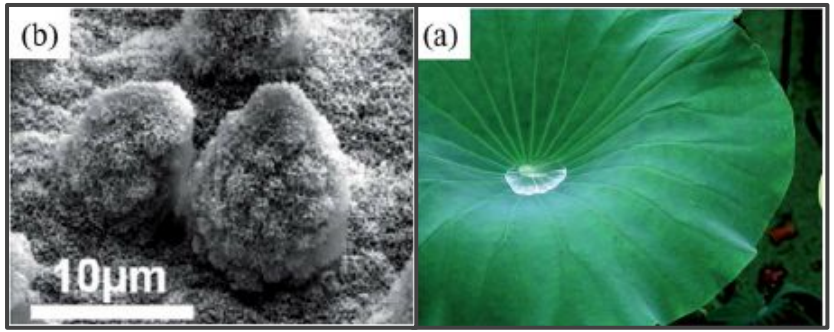
By Dhruv Modi

The Lotus-Effect

Water beads up on the surface of a plant creating a contact angle of over 150° due to hydrophobic nanostructures

Many plants display non-wetting and self-cleaning attributes.



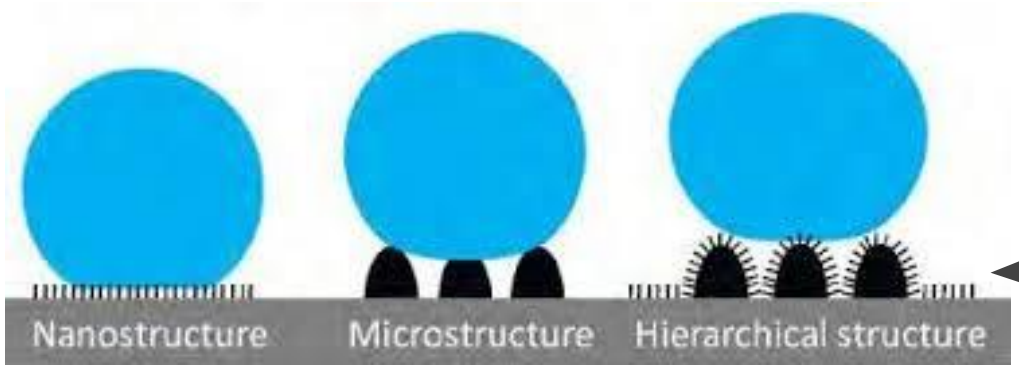


http://urban-gallery.net/txl/?page_id=3336
http://lotusrock.com/the-lotus-effect/

https://www.researchgate.net

What causes a surface to be superhydrophobic

Surface must be rough; Low surface energy



The double roughening of a surface, such as the morphology found on a lotus leaf, allows it to become superhydrophobic

https://en.wikipedia.org/wiki/Ultrahydrophobicity

Difference Between Hydrophobic and Hydrophilic Surfaces

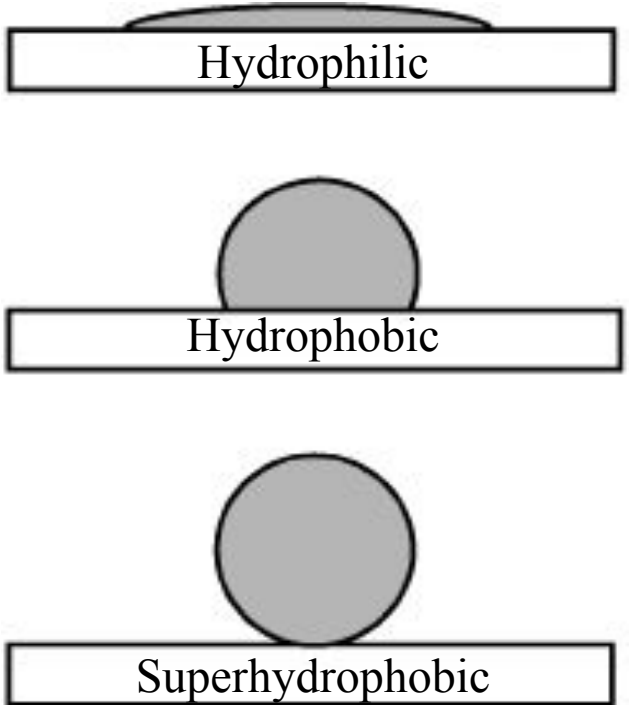
Hydrophilic Surface - Tendency to attract water; "water-loving"

Examples: Glass, Paper

Hydrophobic Surface - Tendency to repel water; "water-fearing"

Examples: Teflon, Oils

Superhydrophobic Surface - hydrophobic surface with nanostructures

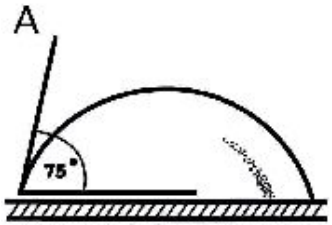


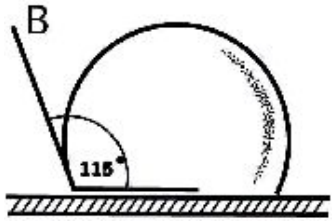
https://www.researchgate.net

Surface Type Measured Using Contact Angle

Determined by contact angle of a drop of water on the surface

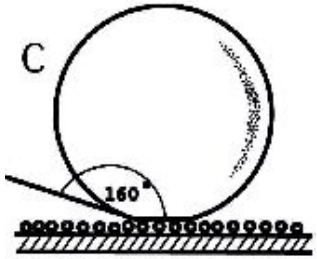
A hydrophilic surface has a contact angle under 90°; Water lays flat on the surface and has a high roll-off angle





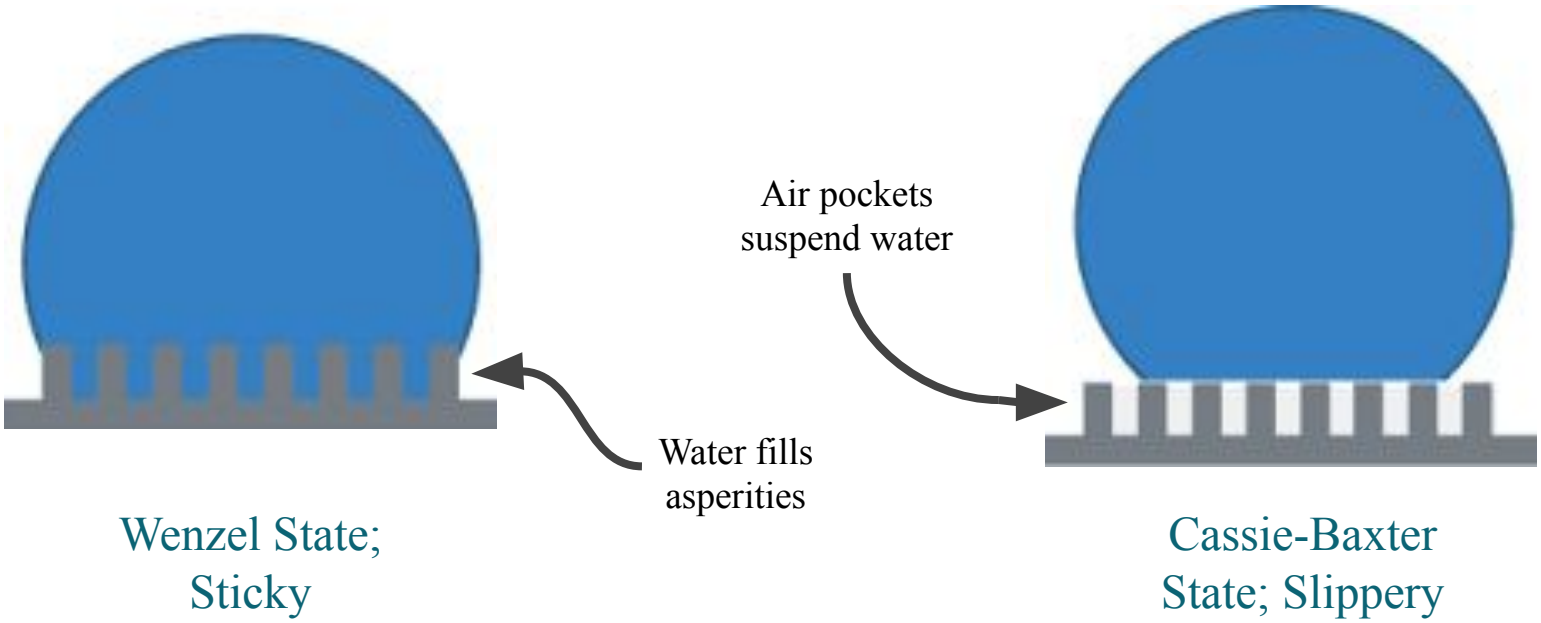
A hydrophobic surface has a contact angle above 90°; Water slightly beads up on the surface and has a moderately low roll-off angle

A superhydrophobic surface has a contact angle above 140°; Water beads up on the surface and has a roll-off angle less than 5°



http://wwn.inhs.illinois.edu/~rakitov/function.ht

Cassie-Baxter and Wenzel Models



http://iopscience.iop.org/article/10.1088/1742-5468/2011/06/P06013

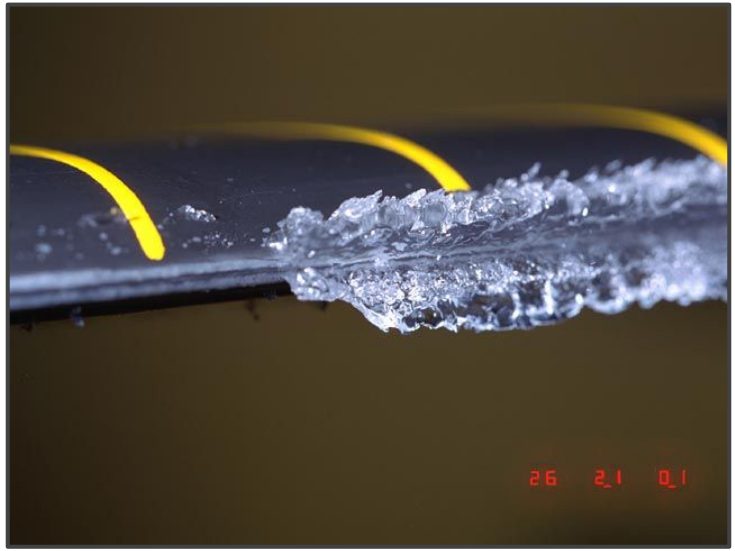
Applications

Anti-Icing (planes, wind turbines)

Less water friction = more efficient

Windows (self cleaning and water resistant)

Water and oil separation



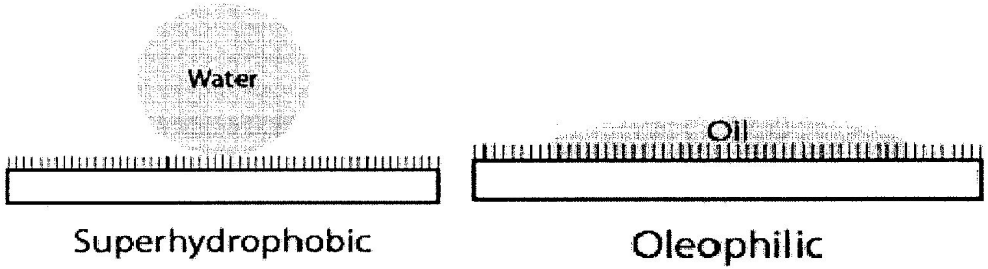
http://cr4.globalspec.com/blogentry/20722/Anti-Icing-Surfaces

Problem

Oil spills and chemical pollutants, wastewater byproducts

Synthesize surface to absorb oil and separate water

Carbon-Nanofibers (CNFs) used



https://www.hakaimagazine.com/article-long
https://www.google.com/patents/US20120223011

How to Prepare the Superhydrophobic Surfaces

Chemical Vapor Deposition (CVD)

Lithography

Vacuum Filtration

Variables

Independent - Amount of Carbon-Nanofibers

Dependent - Contact Angle of Water

Controls - Amount of ethanol, resting times, amount of water in droplet

Vacuum Filtration Process

Mixed different amounts Carbon-Nanofibers in 10 mL of ethanol

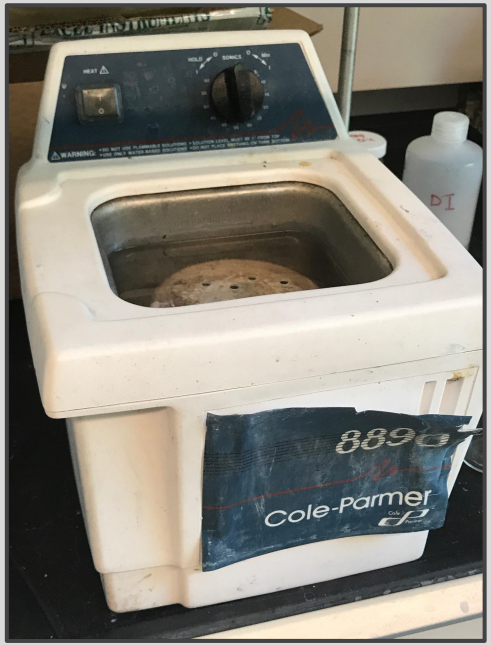
Used Sonicator to evenly distribute CNFs throughout solution; Dispersion time was 30 min

CNFs and ethanol were separated via a BDVF membrane in a vacuum filtration setup

Samples were left to dry for 30 minutes in ambient conditions

Contact angle of a drop of water droplet was measured on each sample using the contact angle measurement device

Sonicator



The sonicator vibrates, evenly distributing the CNFs throughout the solution

The dispersion time was 30 minutes

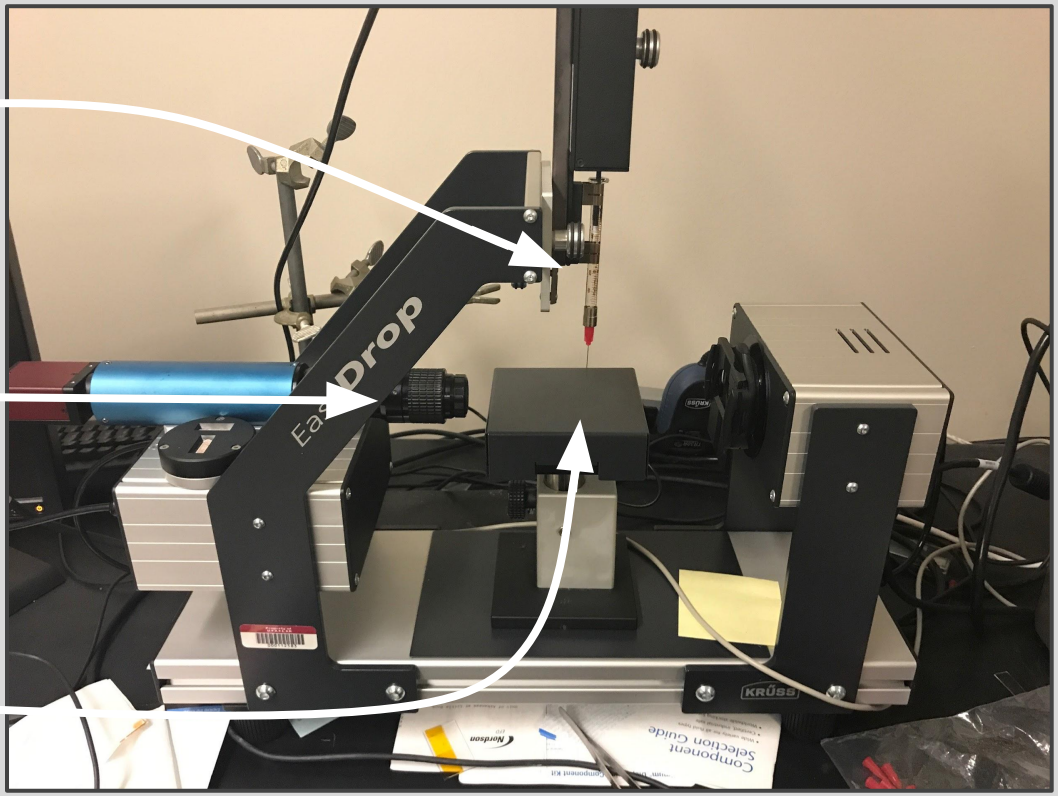
Vacuum Filtration Setup

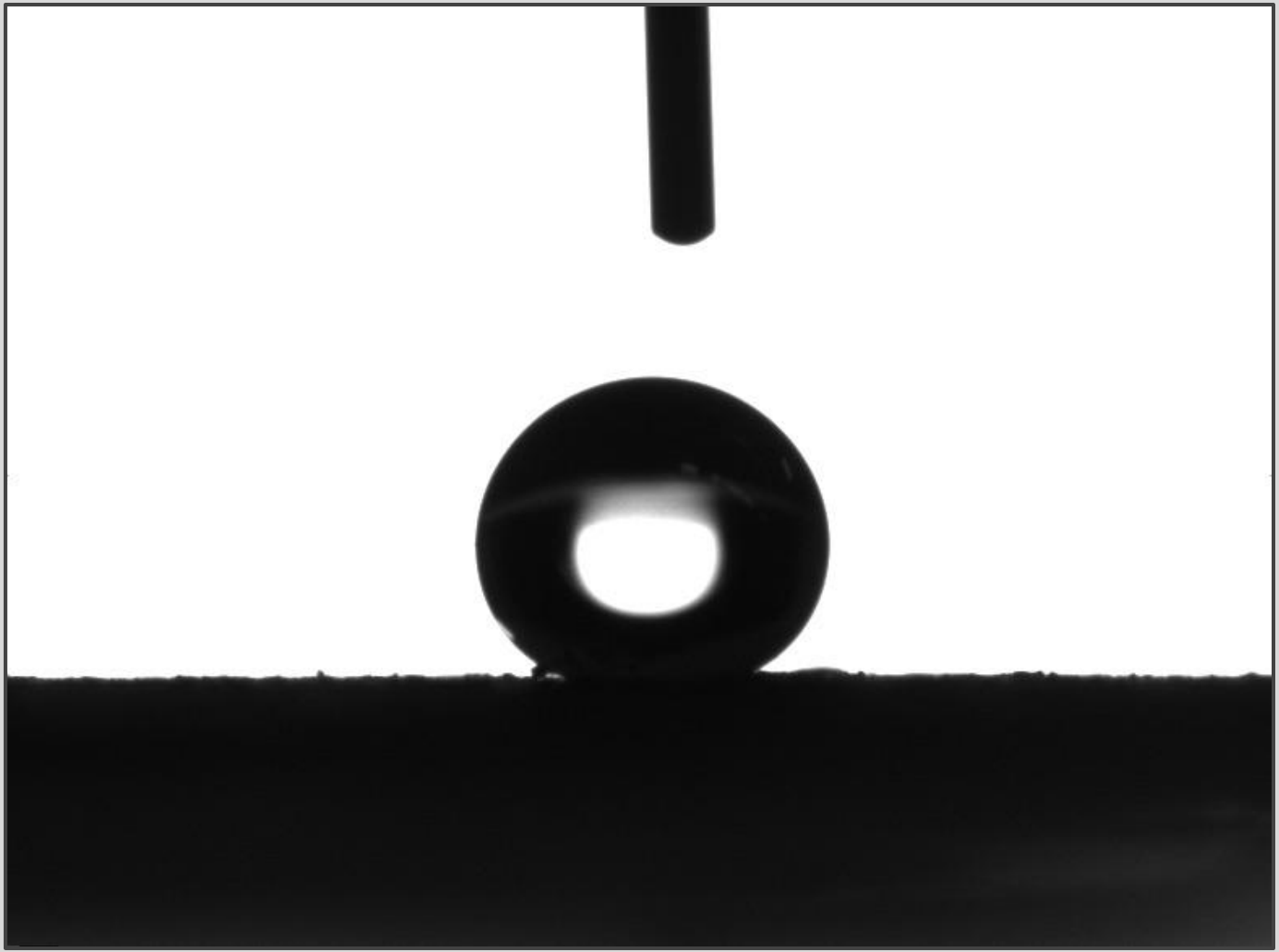
The ethanol/CNF mixture is poured through the top

The membrane is placed in the middle; gathers CNFs

The ethanol collects at the bottom, leaving the CNFs on the surface of the membrane

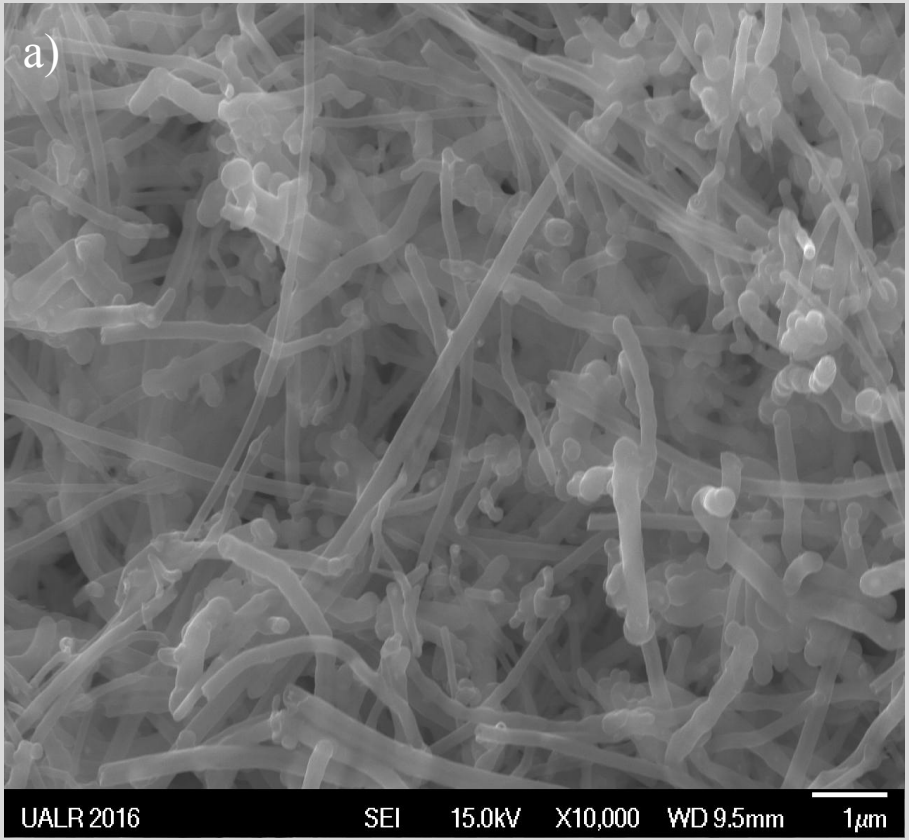
Contact Angle Measurement Device

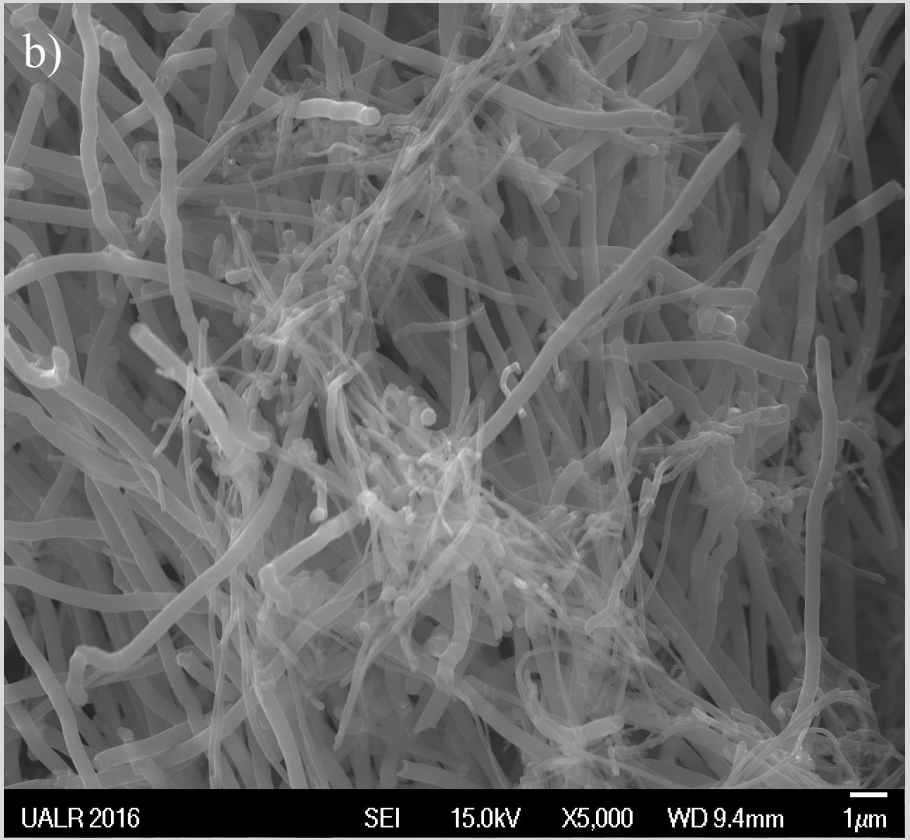




Super Hydrophobic Surface - 2mg CNFs 155°

SEM Images of Superhydrophobic Surfaces with CNFs Based Coating



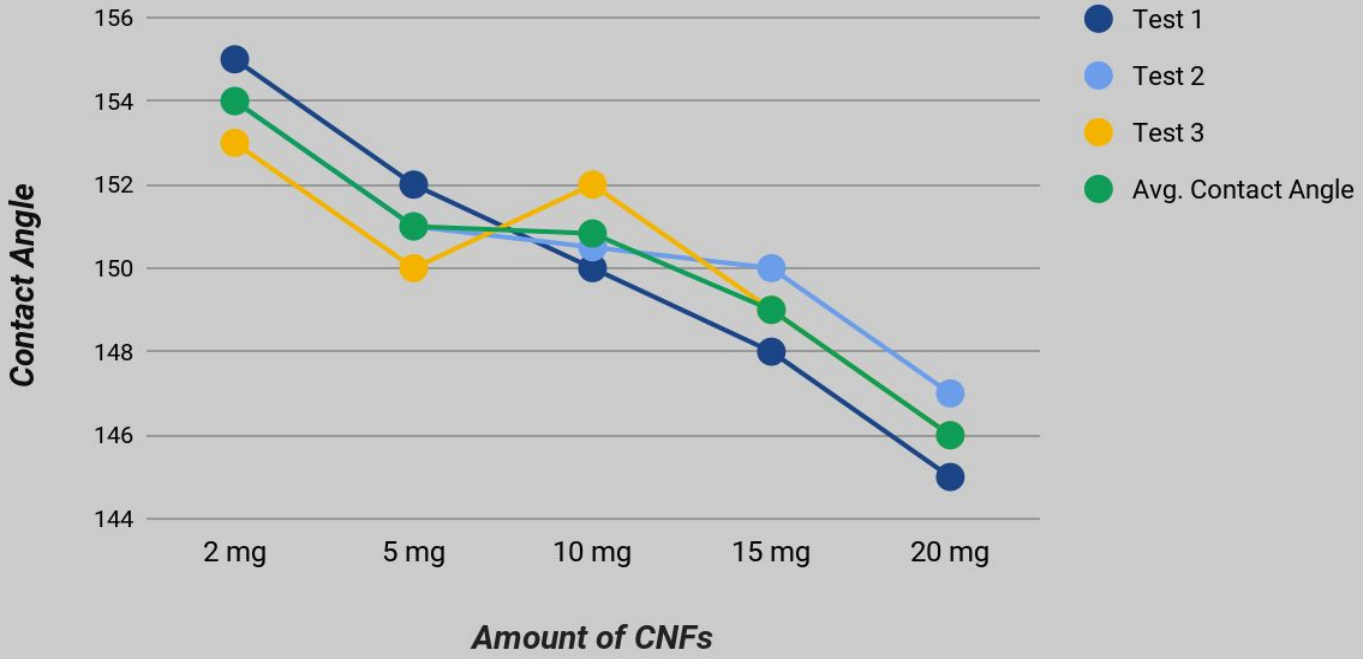


SEM images of carbon-nanofibers: a) high magnification b) low magnification

Contact Angle of Surfaces with Varying Amounts of Carbon-Nanofibers

Amount of CNFs in solution	2mg	5mg	10mg	15mg	20mg
Test 1	155°	152°	150°	148°	145°
Test 2	154°	151°	150.5°	150°	147°
Test 3	153°	150°	152°	149°	146°
Avg. Contact Angle	154°	151°	150.83°	149°	146°

Contact Angle of Surfaces with Varying Amounts of Carbon-Nanofibers



ANOVA Test

	1	2	3	4	5	Total
N	3	3	3	3	3	15
$\sum X$	462	453	452.5	447	438	2252.5
Mean	154	151	150.8333	149	146	150.1667
$\sum X^2$	71150	68405	68254.25	66605	63950	338364.25
Std.Dev.	1	1	1.0408	1	1	2.8515

p-value = 0.000032
(significant at $p < 0.05$)

f-ratio value = 25.492
(variance in data)

Results

Wettability of carbon nanofibers base coatings are changed based on the amount of CNFs in the solution

↑ Carbon-Nanofiber amount = ↓ Contact Angle
(decreases superhydrophobicity)

ANOVA Test further proves correlation

Conclusion

Fabricated superhydrophobic CNF based coating on a Polyvinylidene (BVDF) membrane using simple and affordable techniques.

Used inexpensive raw materials such as CNFs

Created superhydrophobic surfaces with contact angle up to 155°

CNF based coating is oleophilic (oil-attractive)

It can absorb many types of oils like hexadecane and petroleum hydrocarbons immediately

This coating can be used in oil-water separation applications

Acknowledgements

Thank You for Listening!

Questions?