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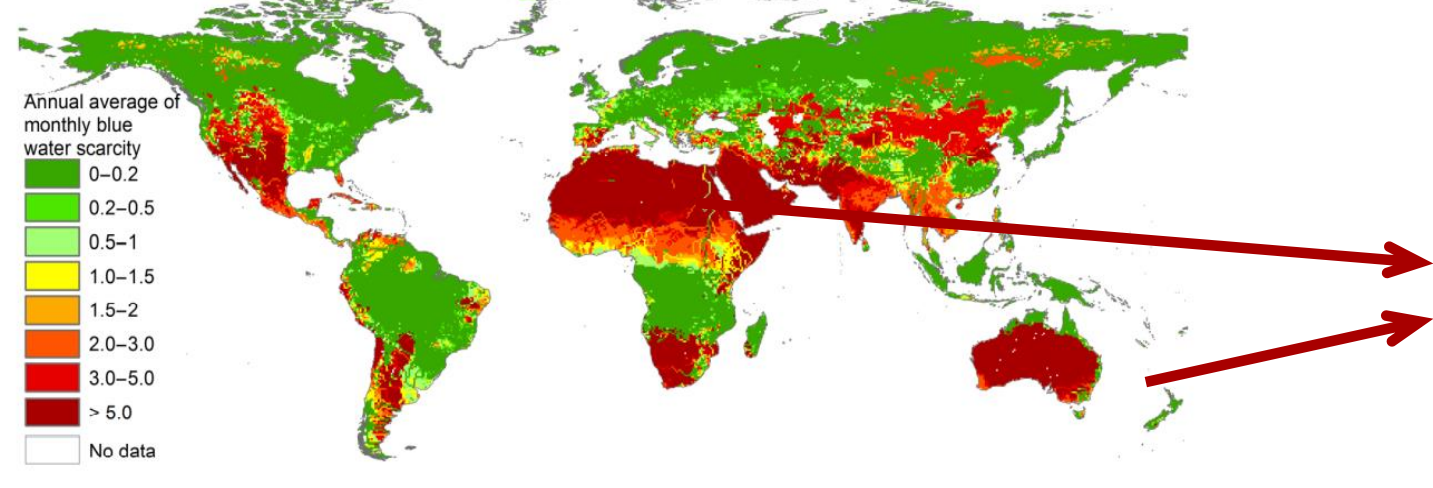
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Controlled Wettability of Mixed Surfaces for Enhanced Water Harvesting

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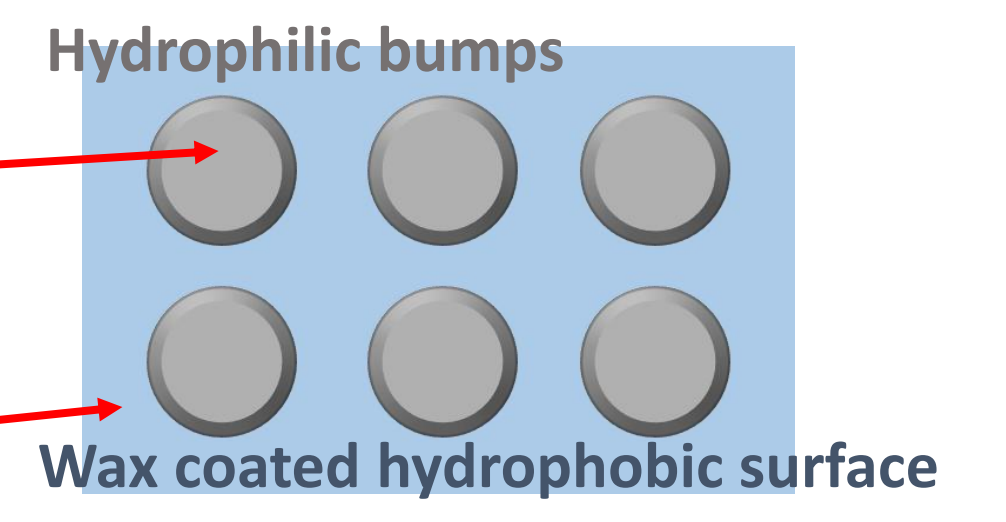
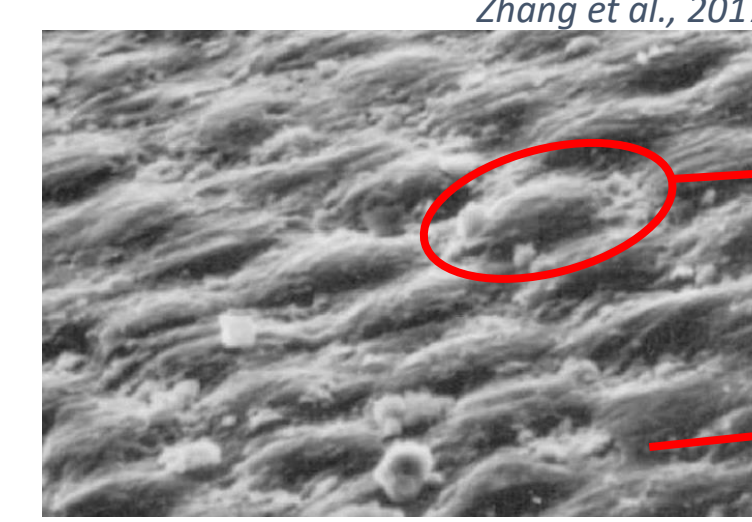
Introduction & Problem Statement

Two-thirds of the world's population face at least one month of water shortage a year. Many water harvesting techniques have been proposed to quench the world's thirst, such as seawater desalination and rainwater harvesting. Nevertheless, these techniques are expensive and insufficient to address water shortage worldwide.



Namib desert beetle inspiring humans to harvest water

To survive in the arid wilderness, the Namib desert beetles for instance, collect water droplets from fog and dew on their backs. In fact, the rough, bumpy surface of their backs incorporates alternating wax-coated regions, making them hydrophobic and hydrophilic non-waxy regions.



Thesis goal: to develop a surface mimicking the properties of the desert beetle's back for the purpose of collecting water from fog and condensing water from dew

Prepared Mixed Samples

1) Lithography + Fluorine Plasma

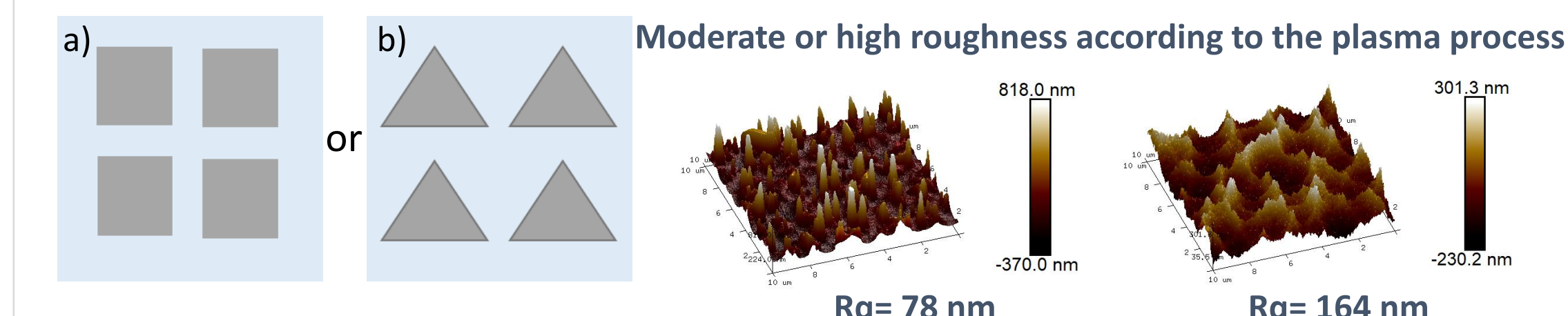
Triangles with base lengths ranging from 10 to 100 μm. Hydrophobic zones are fluorinated OrmoComp polymer.



a) Hydrophilic triangles in a hydrophobic background
Or b) Hydrophobic triangles in a hydrophilic background

2) SU-8 polymer treated with fluorine plasma + Al deposition

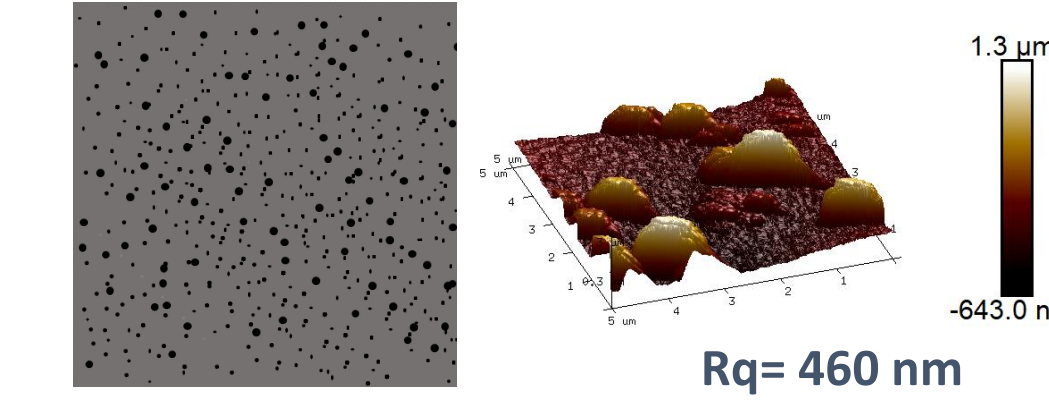
Squares with a side length of 210 μm and triangles with a base length of 300 μm.



a) Hydrophilic Al squares in a hydrophobic background
Or b) Hydrophilic Al triangles in a hydrophobic background

3) Nanocomposite + plasma

Al nanoparticles in a hydrophobic SU-8 matrix.



Very Rough Surface due of the topography

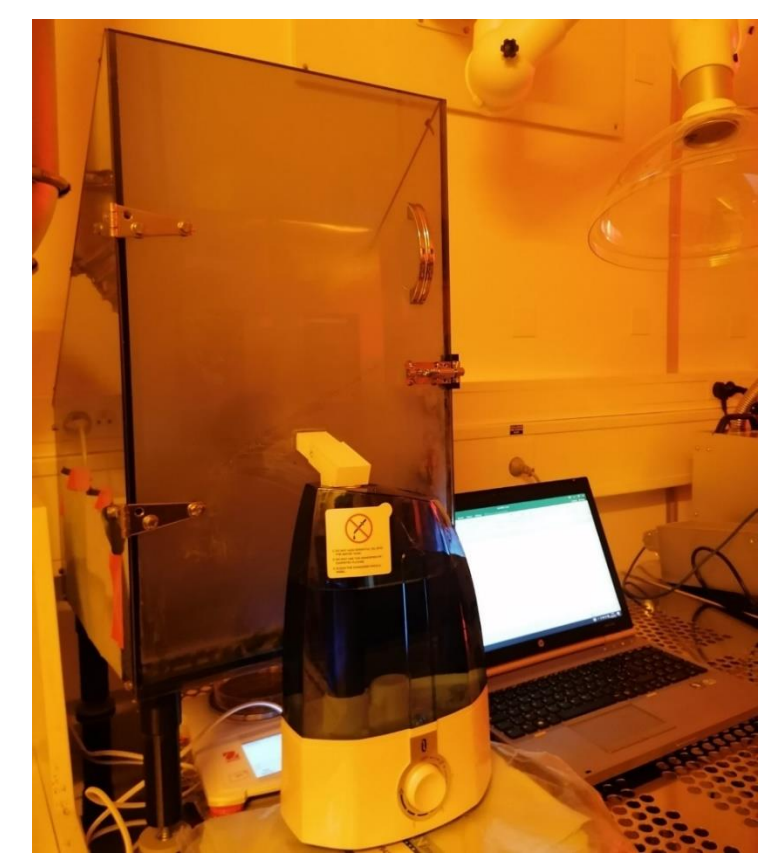
Homogeneous reference samples

Hydrophilic	Hydrophobic
Plasma-treated Si or Plasma-Treated Al Coated on Si	Plasma-treated SU-8 or OrmoComp coated on Si

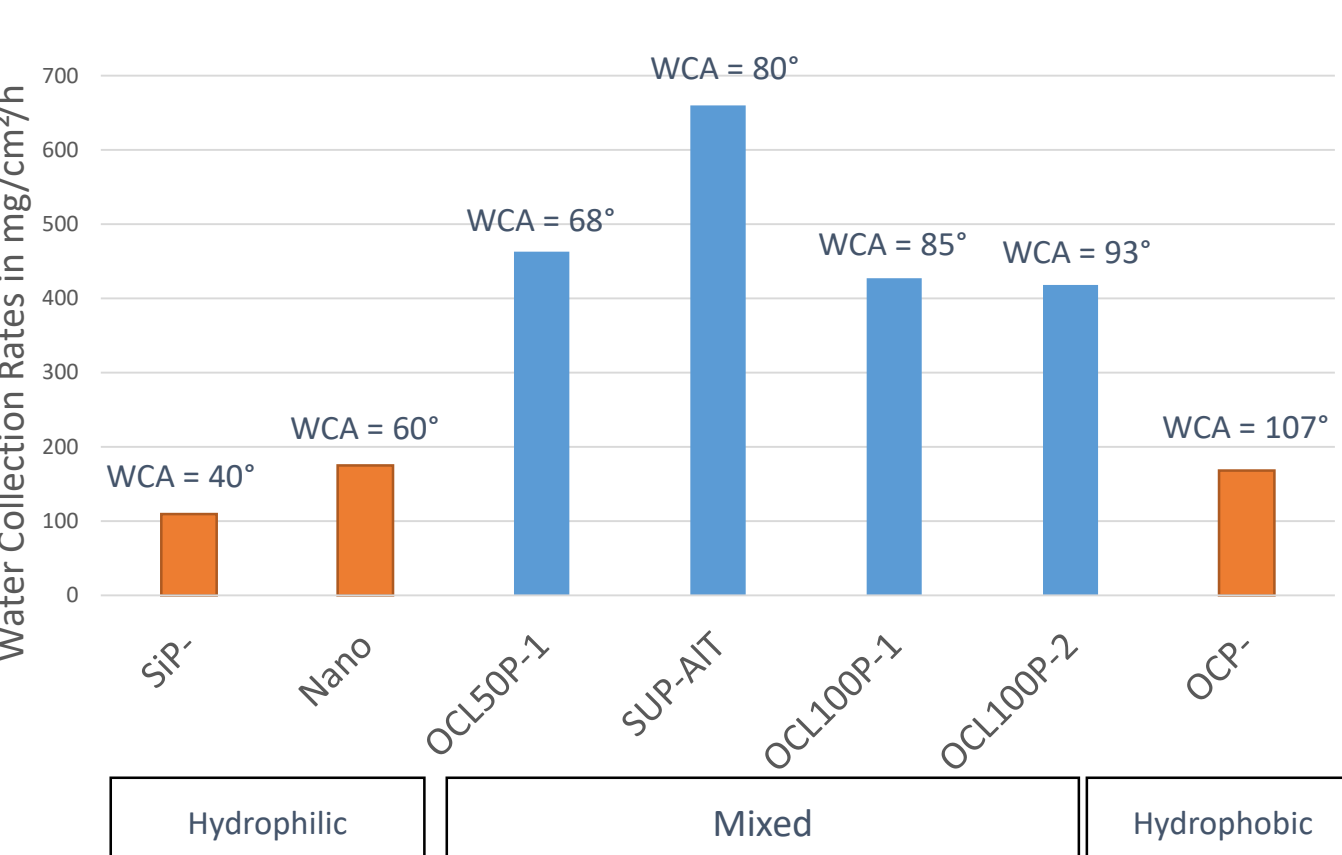
Water Collection Tests

Tests were done at room temperature with a commercial humidifier that delivers a fog around 150 mL/h, raising the humidity inside the chamber above 90%

Water Collection Setup



Water Collection Results



Mixed samples collect more water than homogeneous samples. The sample with the highest water collection has a rougher surface and different chemistry than others, with greater hydrophobic-hydrophilic angle differences.

Critical Volume of droplet departure

Theoretical Volume

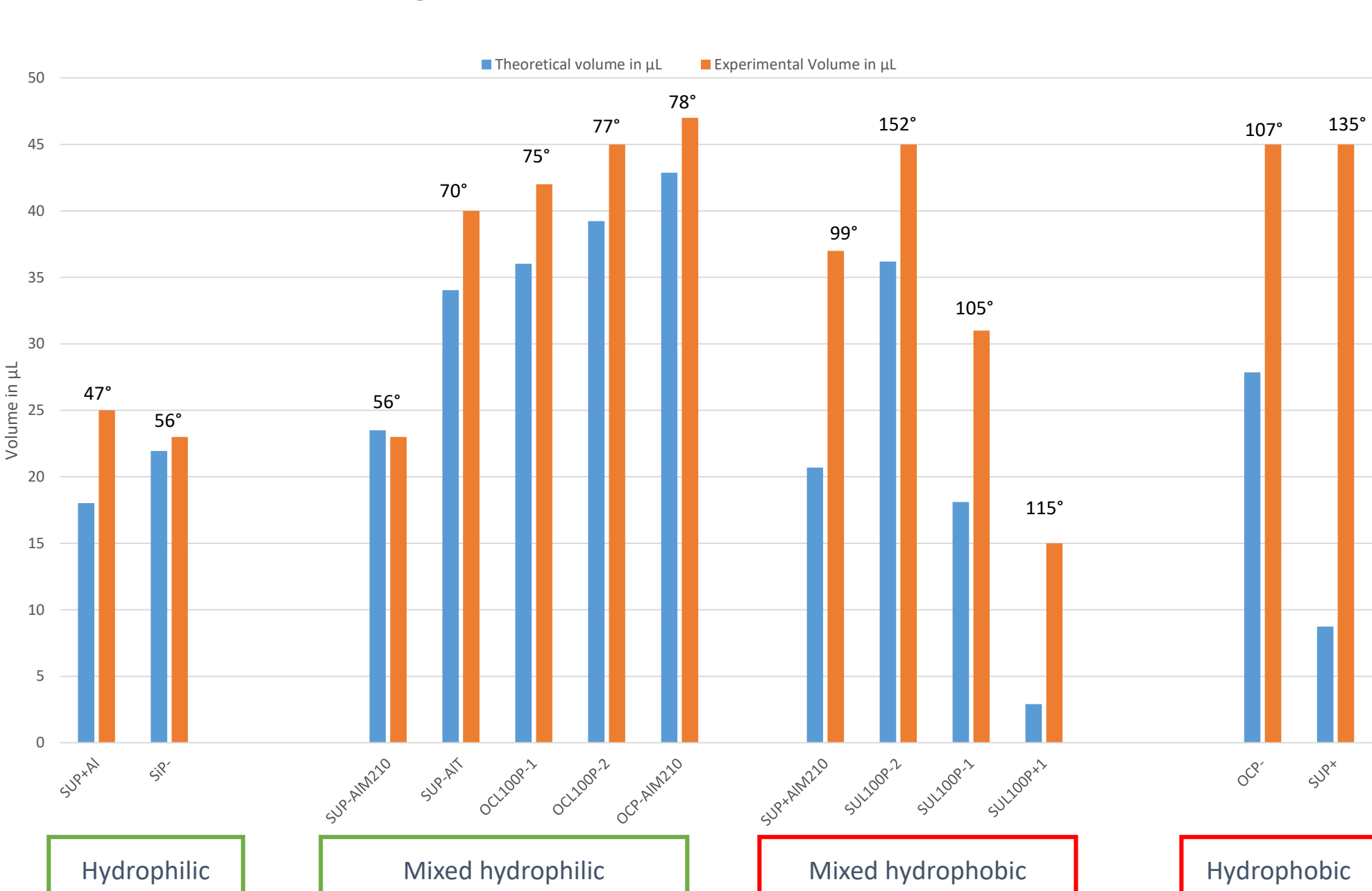
$$r_{max} = \left(\frac{6c(\cos\theta_r - \cos\theta_a)\sin\theta}{\pi(2-3\cos\theta + \cos^3\theta)} \frac{\sigma}{\rho g} \right)^{\frac{1}{2}}$$

$$\rightarrow V = \pi \cdot r_{max}^3 \left(\frac{2-3\cos\theta + \cos^3\theta}{3} \right)$$

Experimental Volume

The volume of droplets that leave the surface when it is tilted at 90°

Theoretical vs experimental Volume

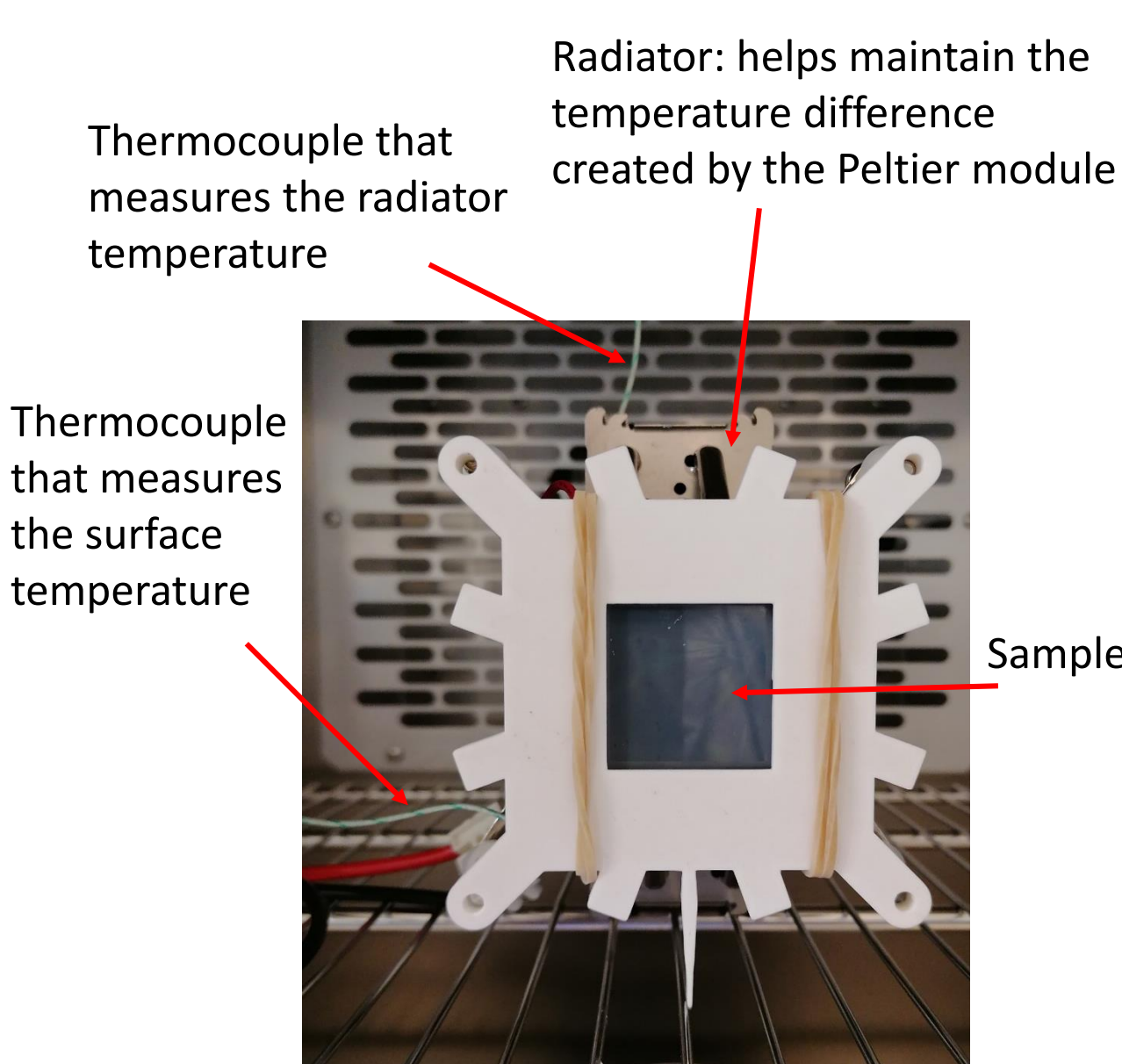


- Low departure volumes for hydrophilic samples with WCA < 60°.
- Greater departure volumes for samples with WCA > 60° because droplets grow before falling.
- Disagreement between theoretical and experimental volumes is observed in samples with WCA > 90° due to a significant contact angle hysteresis (CAH).

Water condensation tests

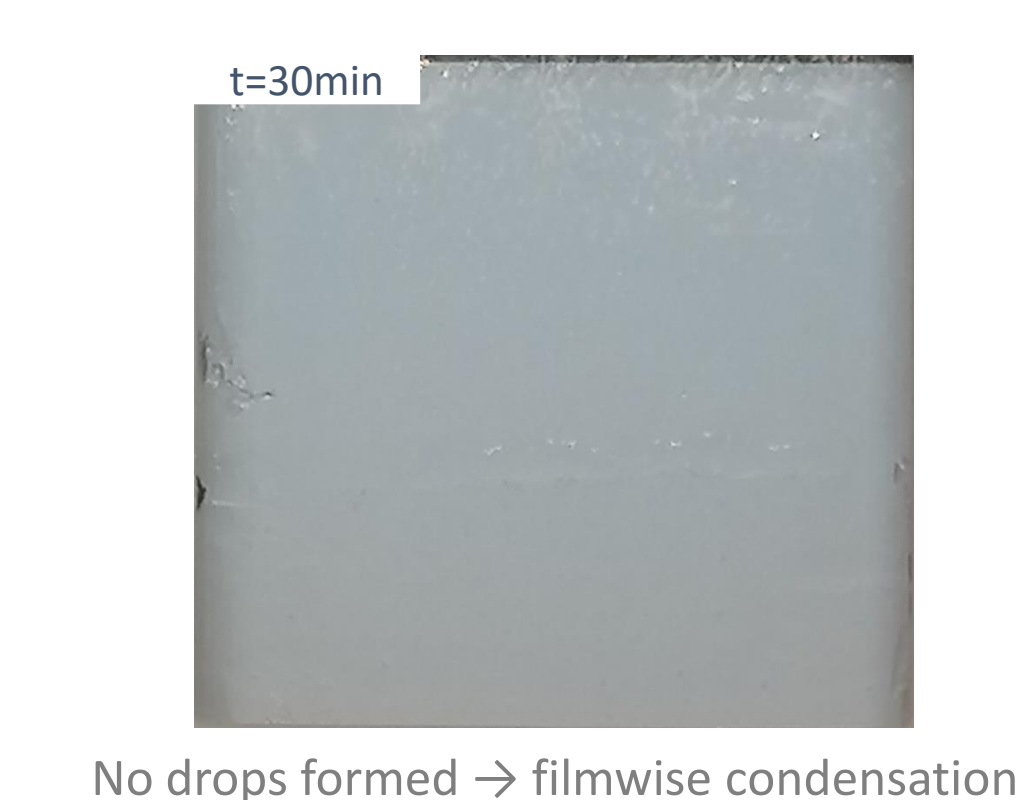
Water Condensation Setup

- Experiments were conducted in a controlled environment at 298K and 90% humidity.
- Samples fixed on a Peltier device → ΔT between the water dew point (296.2 K) and the sample's surface (288 K)
- All samples measured 3.5 cm x 3.5 cm

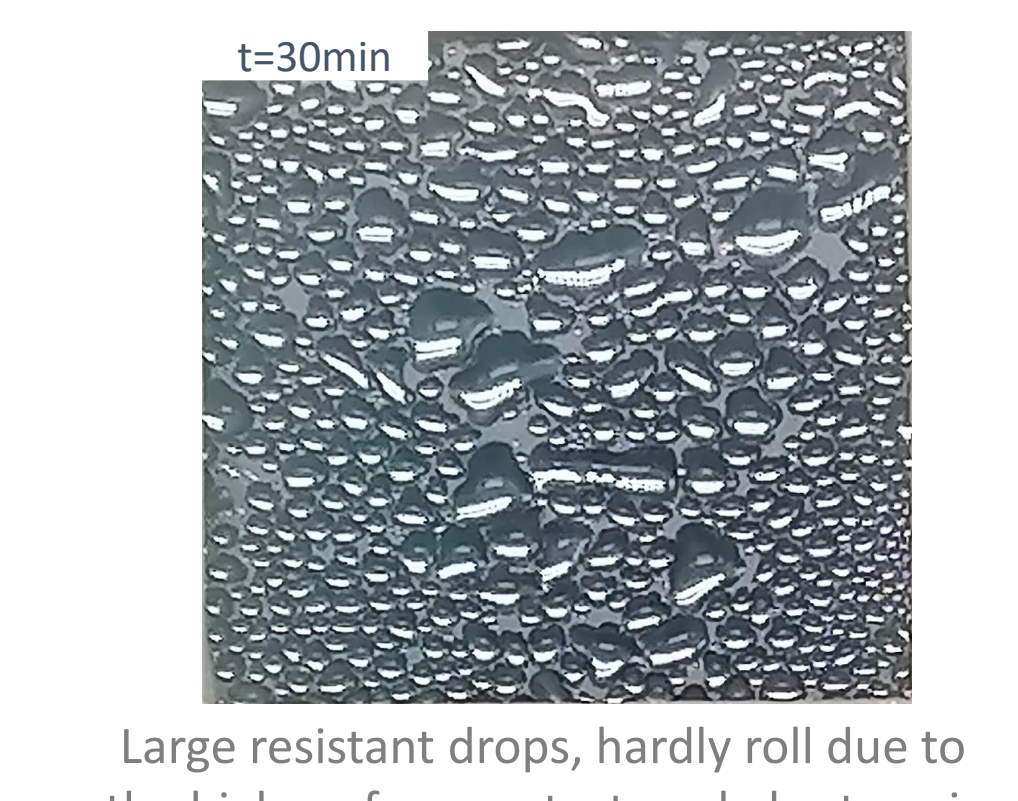


Results

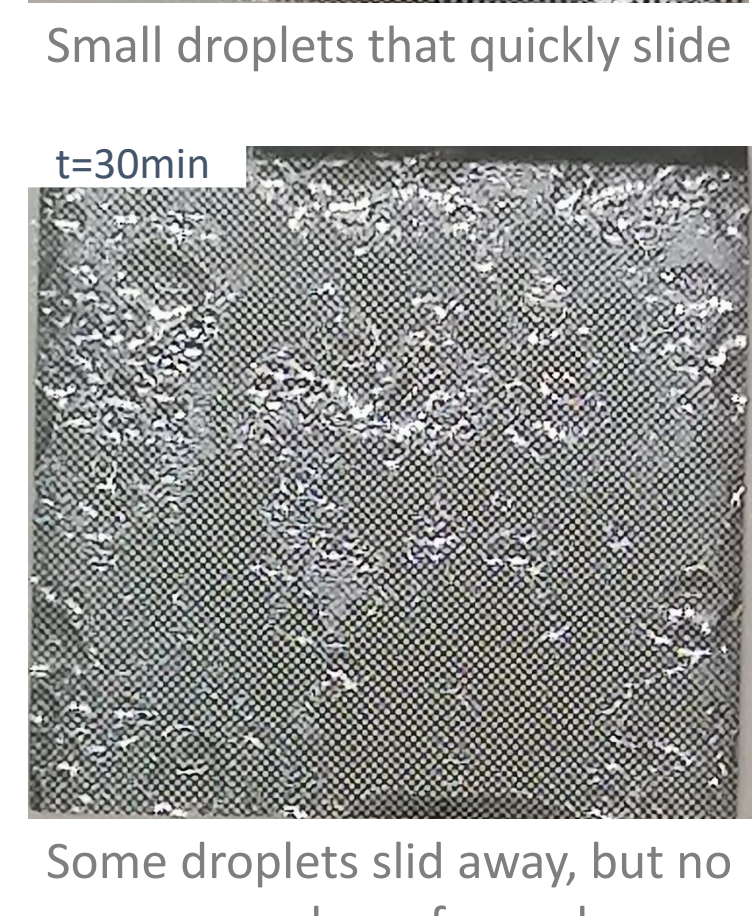
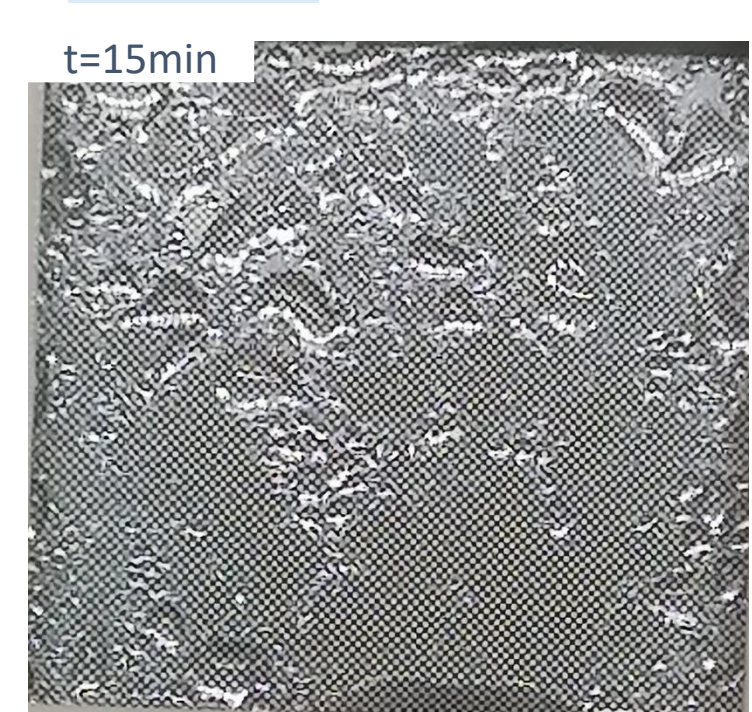
Superhydrophilic Surface, WCA < 10°



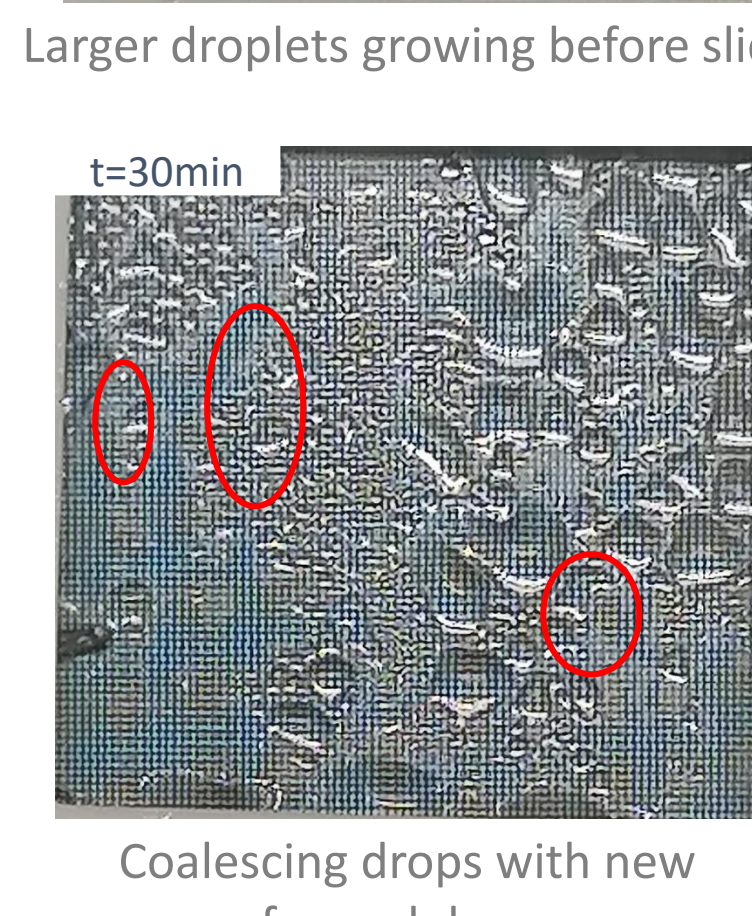
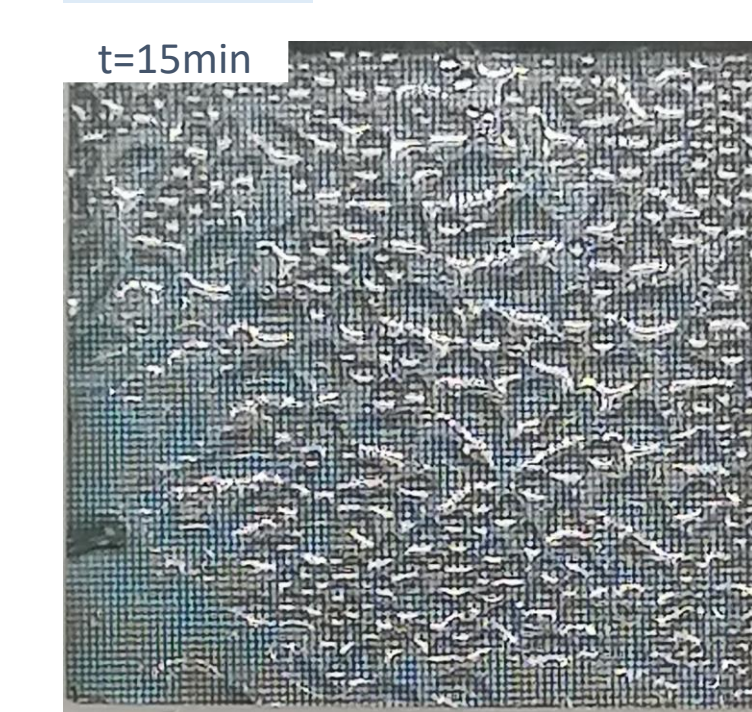
Hydrophobic Surface, WCA = 130°



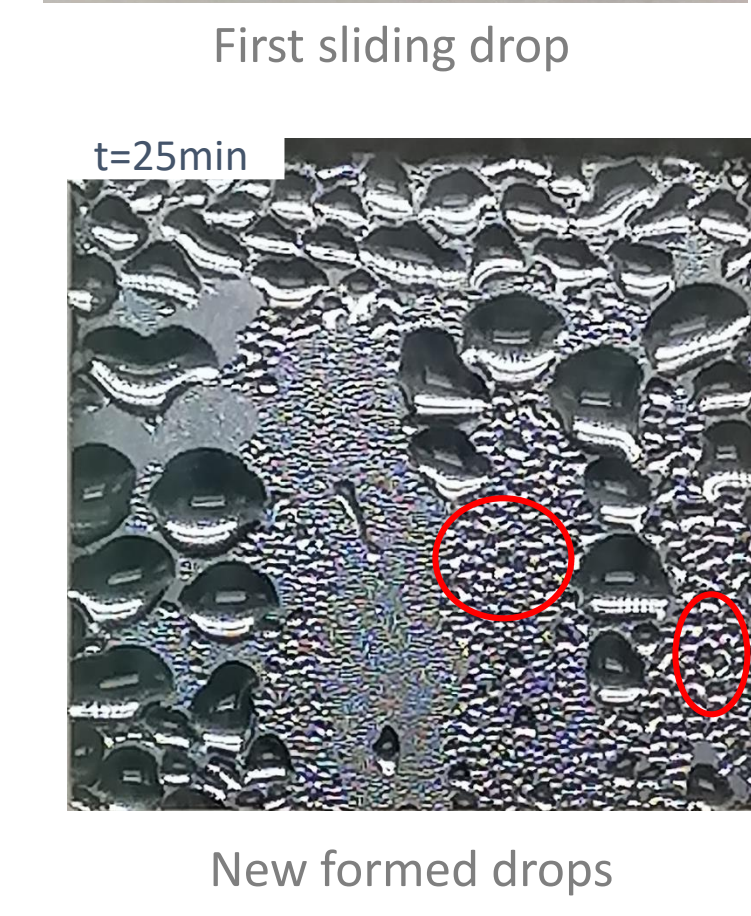
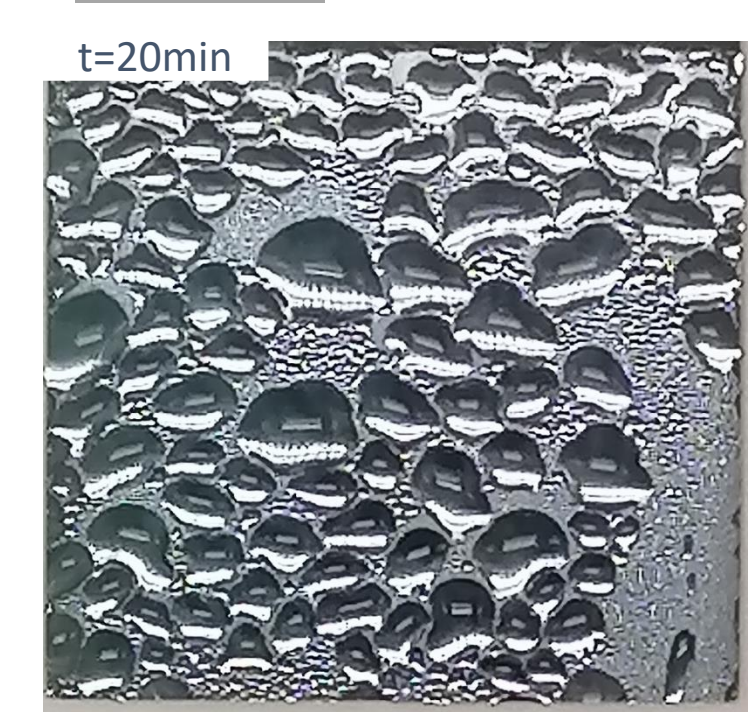
WCA = 77°
Rq = 78 nm
Side = 210 μm



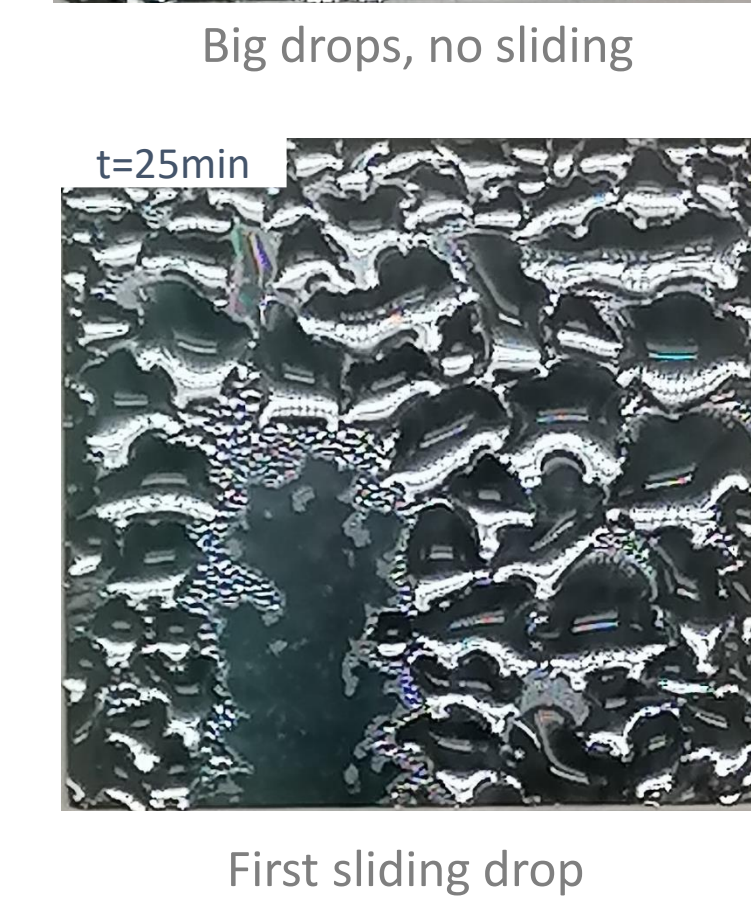
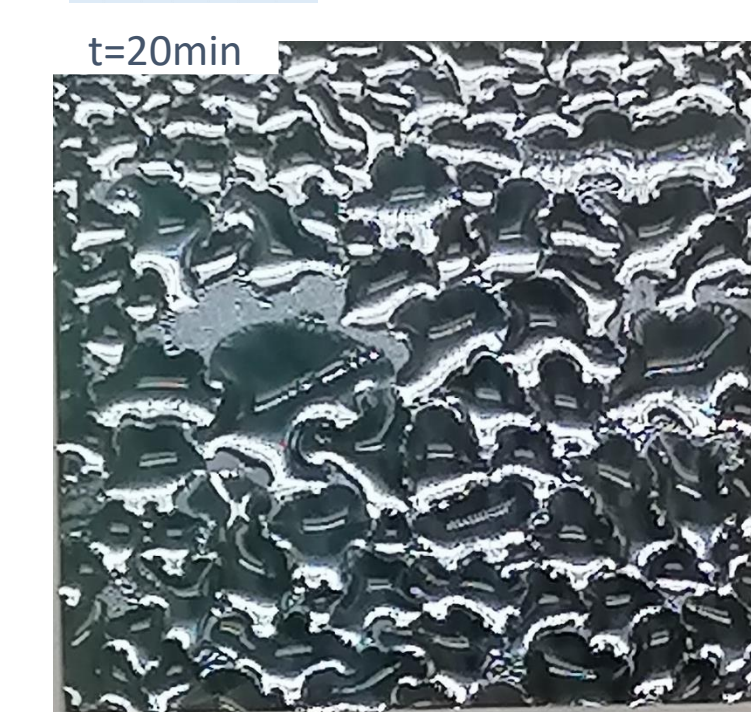
WCA = 99°
Rq = 164 nm
Side = 210 μm



WCA = 77°
Rq = 18 nm
Base = 100 μm



WCA = 87°
Rq = 18 nm
Base = 10 μm



Conclusions

- Ideal surfaces for collecting water differ from those ideal for condensing it.
- Surfaces with sliding but without filmwise condensation work best for condensation.
- Water collection and condensation depend on factors like patterns, pattern size, and surface roughness, not just the water contact angle.
- This research improves our understanding of water harvesting mechanisms for surface optimization.

Perspectives

Incorporating a quantitative measurement scale into the water condensation testing procedure to precisely quantify the volume of water collected from atmospheric dew deposition.

References

- Beysens, D. (2022). The Physics of Dew, Breath Figures and Dropwise Condensation (Vol. 994). Springer International Publishing. <https://doi.org/10.1007/978-3-030-90442-5>
- Kim, S., & Kim, K. J. (2011). Dropwise Condensation Modeling Suitable for Superhydrophobic Surfaces. Journal of Heat Transfer, 133(8), 081502. <https://doi.org/10.1115/1.4003742>
- Zhang, S., Huang, J., Chen, Z., & Lai, Y. (2017). Bioinspired Special Wettability Surfaces: From Fundamental Research to Water Harvesting Applications. Small, 13(3), 1602992. <https://doi.org/10.1002/sml.201602992>