WHY SUPERHYDROPHOBIC SURFACES ARE SMART? A METHOD TO PREPARE A TYPE OF SHS AND HOW TO TEST THEM

I. Malavasi*, I. Bernagozzi, F. Villa, C. Antonini, M. Marengo*

MRG - MarengoResearchGroup
Department of Engineering, Università degli Studi di Bergamo, Viale Marconi 5, 24044 Dalmine (BG), Italy

* ileana.malavasi@unibg.it; *marco.marengo@unibg.it

Outlook

What are superhydrophobic surfaces

Industrial applications

Development of superhydrophobic surfaces

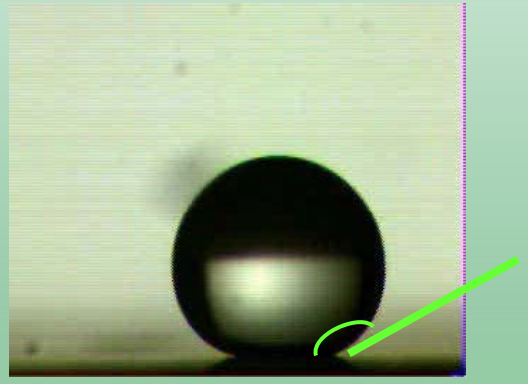
Surfaces characterisation

Results

Conclusions

What are superhydrophobic surfaces (1)

- Superhydrophobic surfaces (SHS) are surfaces characterized by **high liquid water repellency** and **low water adhesion**.
- To characterize the degree of wetting (or wettability), contact angles are typically used:
  - **advancing contact angles** (θ_A);
  - **receding contact angles** (θ_R).



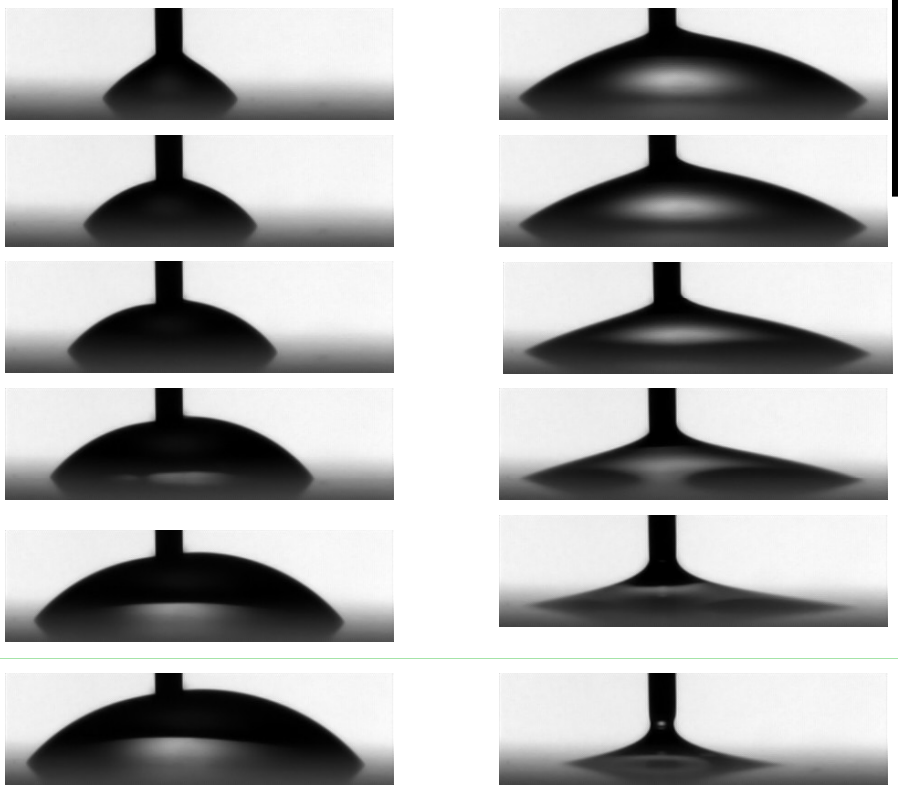
- Characteristic of lotus leaf, duck feathers, butterfly wings.

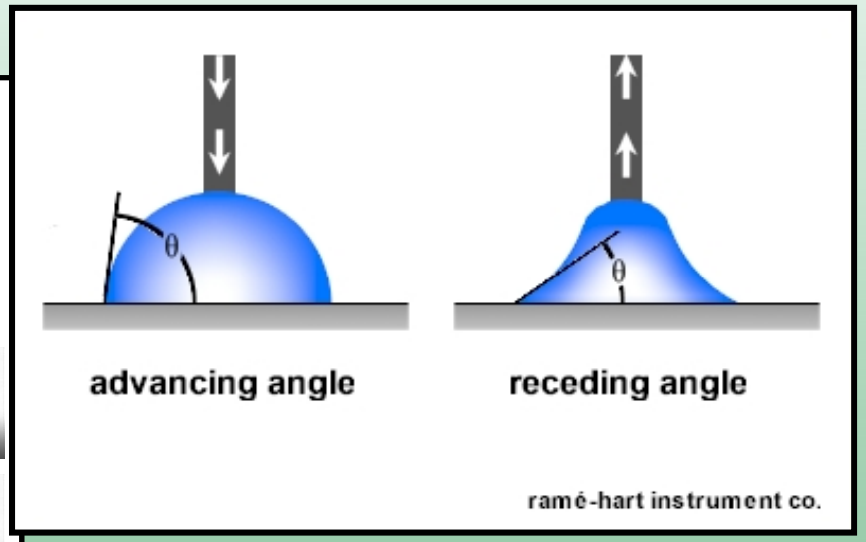
What are superhydrophobic surfaces (2)

SESSILE DROP METHOD

Contact angle measurement

θ_A advancing (drop inflation) | **θ_R receding (drop deflation)**





- θ_A and θ_R provide an indication of the drop mobility, which is related to their difference, the so-called **contact angle hysteresis**, $\Delta\theta = \theta_A - \theta_R$.
- **Superhydrophobic surfaces**: **θ_A >150°** (or **θ_R >135°)** and **$\Delta\theta$ <10°.**

What are superhydrophobic surfaces (3)

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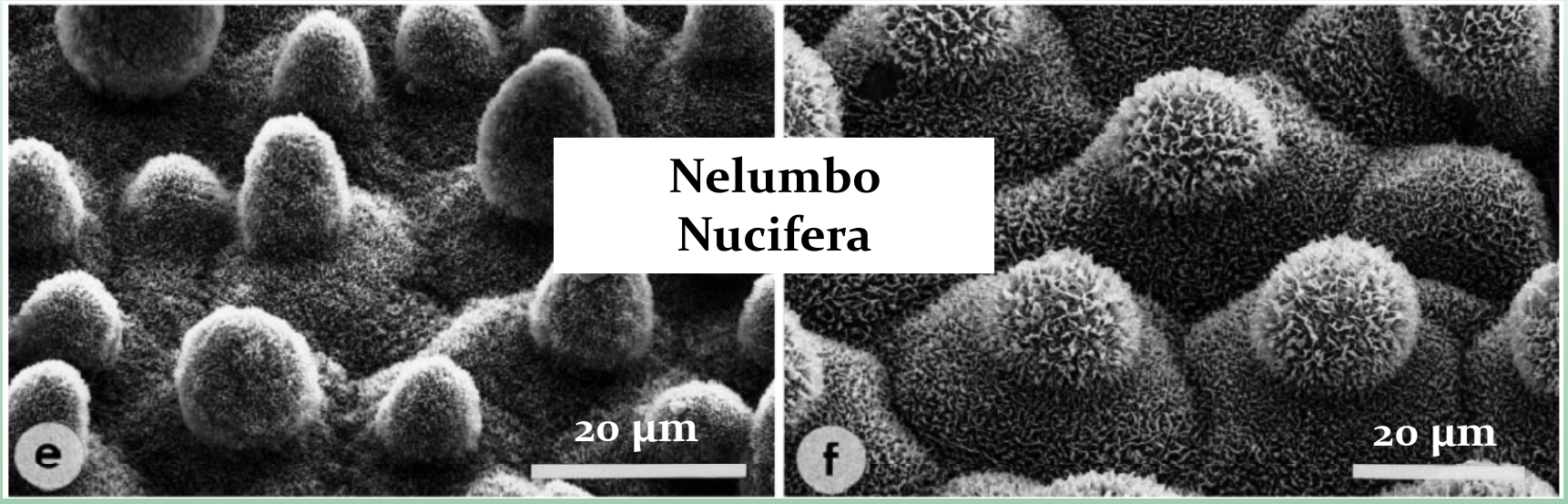
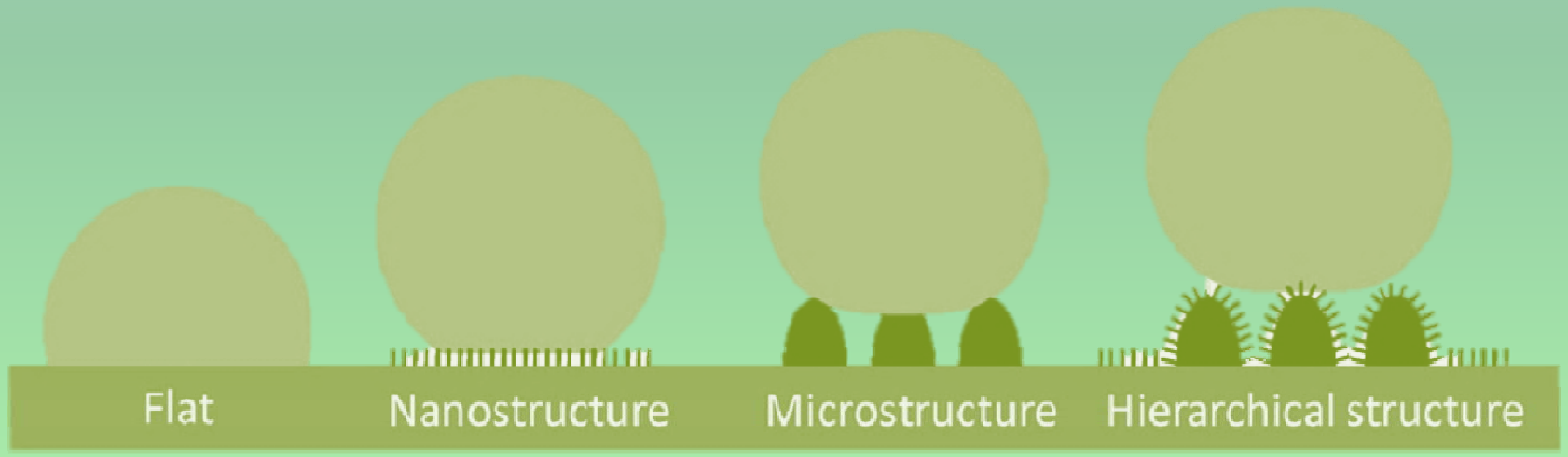


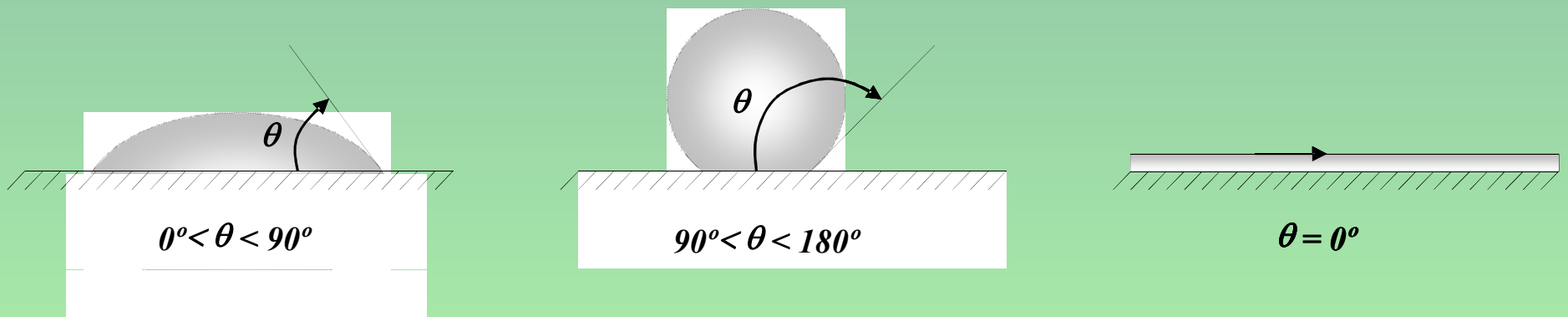


What are superhydrophobic surfaces (4)

Young's equation :

$$\gamma_{SG} = \gamma_{SL} + \gamma_{LG} * \cos\theta$$

where: θ = contact angle;
γ_{SG} = solid–vapor interfacial energy;
γ_{SL} = solid–liquid interfacial energy;
γ_{LG} = liquid–vapor interfacial energy.

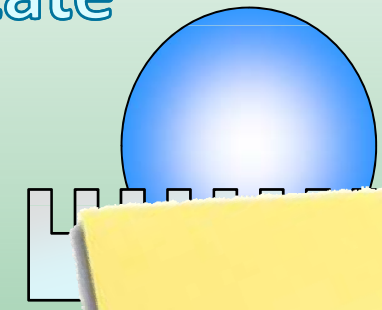


What are superhydrophobic surfaces (5)

Wetting regimes for rough surfaces.

1. Wenzel state

Homogeneous wetting



$\cos\theta^* = r\cos\theta$

where:

apparent contact angle ;
ughness ratio.;
ung contact angle.

2. Cassie–Baxt

Heterogeneous wetting

+ f - 1

rent contact angle;
ness ratio of the wet

of solid surface area wet
area;
ntact angle;

θ* = θ*(topography, roughness, chemistry)

3. Transition state

Industrial applications

- Mitigation of the ice formation (aerospace, offshore platforms, power lines, wind turbines).
- Resistance to the growth of micro-organisms (antifouling properties) → application as protective coatings on marine vessels, submarines and oil platforms.
- Prevention of contamination and oxidation → corrosion and fouling.
- To repel water, dust, and dirt → easy-clean surfaces.
- Reduction of friction and pressure drops in pipes.

UNTREATED ALUMINUM	SUPERHYDROPHOBIC COATING

Example of ice accretion during icing wind tunnel (IWC) tests. Only the central part of the leading edge is heated. Application of SHS in the leading edge area entail a significant reduction of required heating power (approximately 80% compared to metallic sample) to avoid ice accretion.

Development of superhydrophobic surfaces (1)

- focus on **roughness + chemical modification**
- not coating, but **grafting** on aluminum (strong bond)

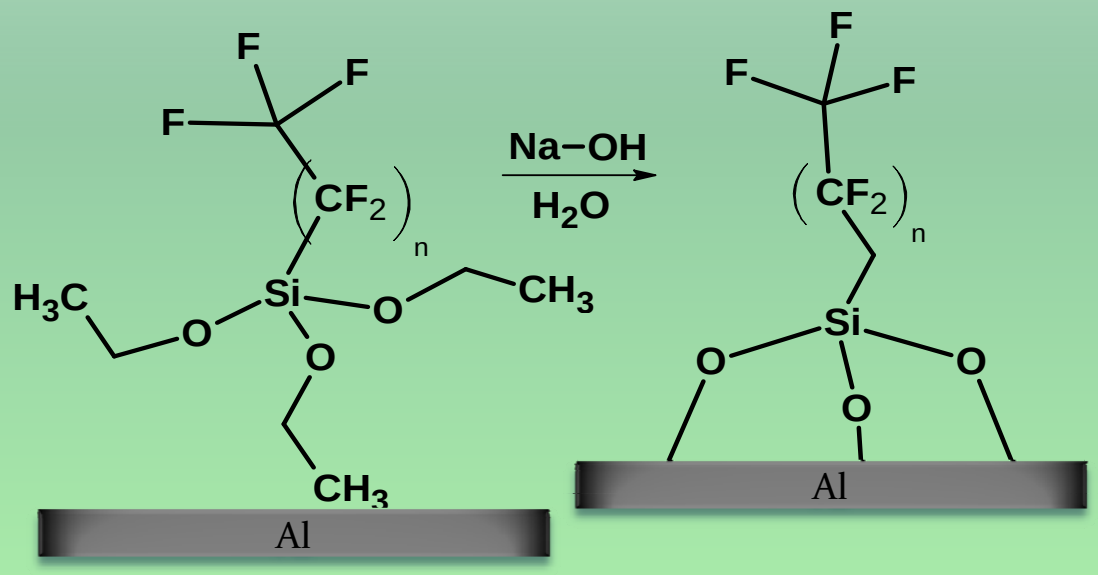
Development of superhydrophobic surfaces (2)

- Al samples
  - Grinded with sandpaper 500, 800 and 1000
    - Mixture of NaOH 0.1M + FAS (fluoroalkyl silane) 0.01M in water
      - Ultrasonic bath for 30 min (reaction time)
        - Rinsed in pure water and dried in air

✓ NaOH: etching

✓ Ultrasouns: additional erosion + agitation and simultaneous heating of the solution

✓ FAS: hydrophobicity



Surfaces characterisation (1)

* **Static measures**:

evaluation of the contact angle

SHS: θ_A >150° and $\Delta\theta$<10° ($\Delta\theta = \theta_A - \theta_R$)

* **Dynamic measures**

normal and oblique impacts

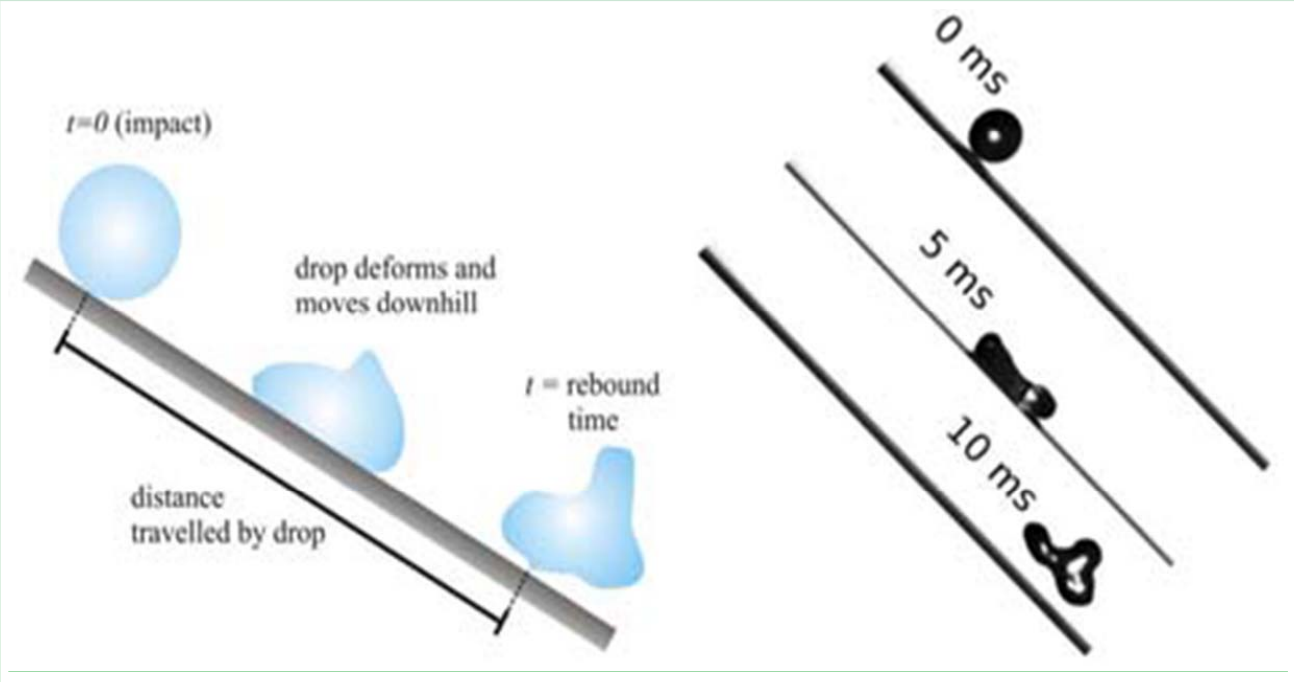
Experimental conditions: impact speed in the range 0.8<V<4.1 m/s and constant drop diameter D0=2.55 mm.

Images of drop impact are recorded using a highspeed camera.

Images are analyzed to identify the drop impact outcome (rebound or deposition).

Surfaces characterisation (2)

Target surface can be inclined from from 0° (horizontal impact) until 80°.



Schematic of drop impact on a tilted surface (left) and an experimental image of water drop impact on tilted surface (D0=2.55 mm, V=1.65 m/s, α=45°, frame per second=1010) (right).

Transition from Cassie-Baxter to Wenzel state is used to explain why a drop remains stuck on the surface after impact, unable to rebound, in case of the so called SHS.

Results

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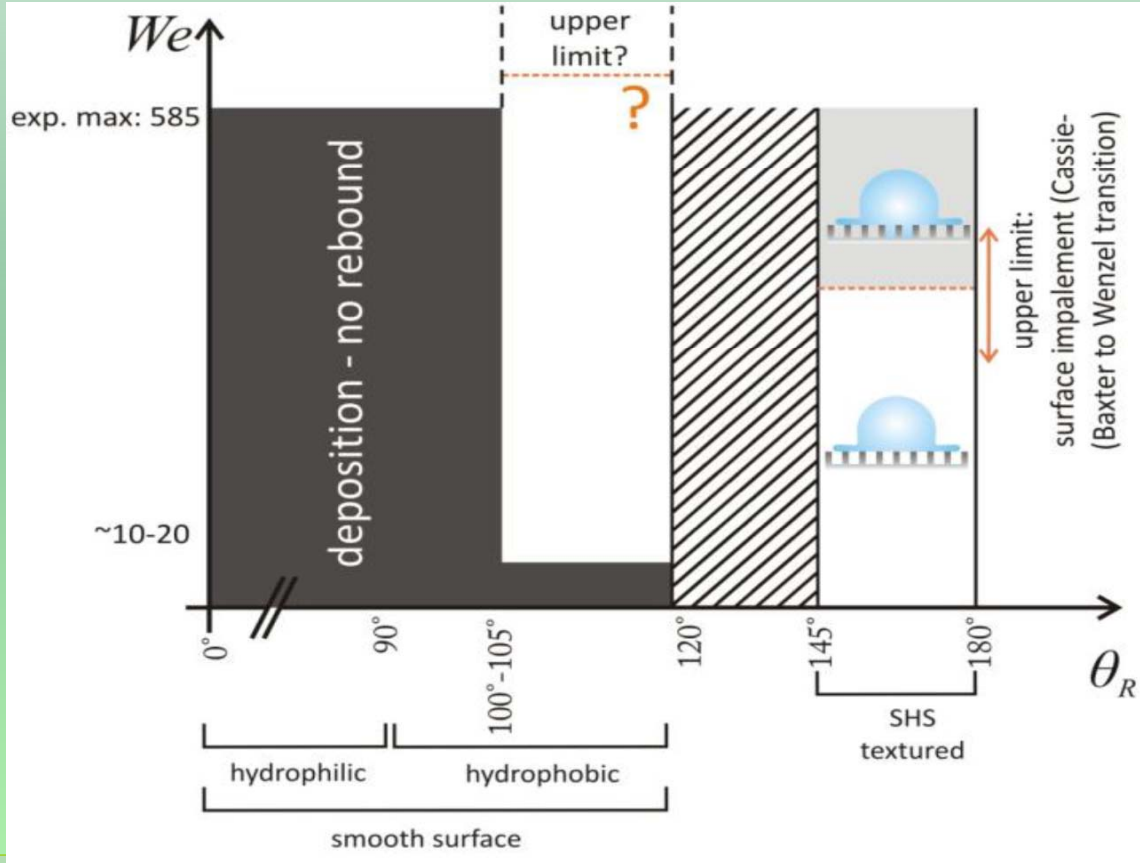
Surface	θ_A [°]	θ_R[°]	$\Delta\theta$ [°]	Rebound time (normal impact)
SHS-FAS	169	161	8	10-12 ms

Static and dynamic wettability properties of SHS-FAS.

** We= $(\rho v^2 d)/\sigma$, where ρ is the density of the fluid, v is the velocity of the fluid, d is the droplet diameter and σ is the surface tension of the fluid.*



Schematic rebound map for water drops impacting normally on a surface, plotted on the We—θ_R plane.

Conclusions

- SHS-FAS are characterized by a θ_A greater than 160° and $\Delta\theta$ lower than 10°.
- Rebound time was found to be independent from impact speed on SHS in agreement with Quéré and co-workers.
- Rebound always occurs on tilted SHS-FAS.
- The increasing of the tilt angle generally facilitates drop shedding and reduces drop rebound time.
- During our drop impact tests no transition from Cassie-Baxter to Wenzel state, in the range of Weber number $21<We<552$, were observed.

Thank you for your attention!

Ing. Ileana Malavasi
Via Galvani 2, 24044 Dalmine (BG) – Italy
ileana.malavasi@unibg.it
+39 035 205 2067