Superhydrophobic, Icephobic, and Photocatalytic Coatings for Concrete

Presenter:

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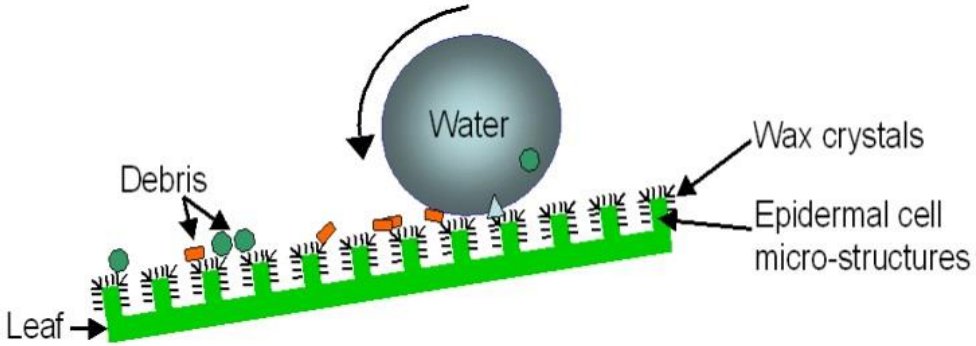
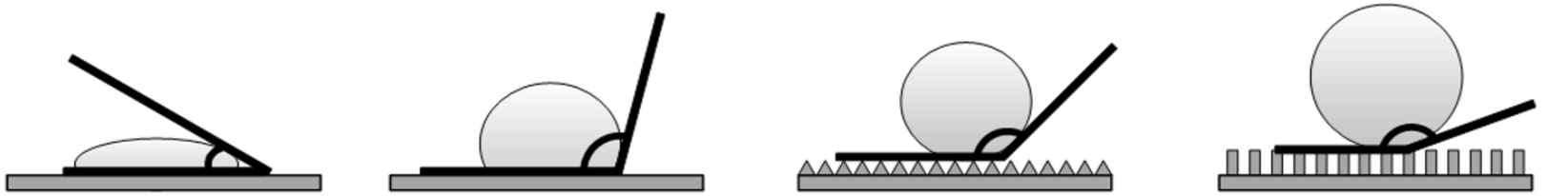
Hydrophobicity and photocatalysis

Hydrophobicity prevents water droplets from attaching and penetrating through the surface.

Photocatalytic property breaks down bio-organic material and nitrogen oxide (NOx) when exposed to light.





Hydrophilic surface	Hydrophobic surface	Overhydrophobic surface	Superhydrophobic surface
Θ < 30°	90° < Θ < 120°	120° < Θ < 150°	Θ > 150°
(standard concrete)	(concrete with PEHSO/PMHS)	(concrete with PEHSO/PMHS & micro particles)	(concrete with PEHSO/PMHS, micro & nano particles)

Why we care – durability performance

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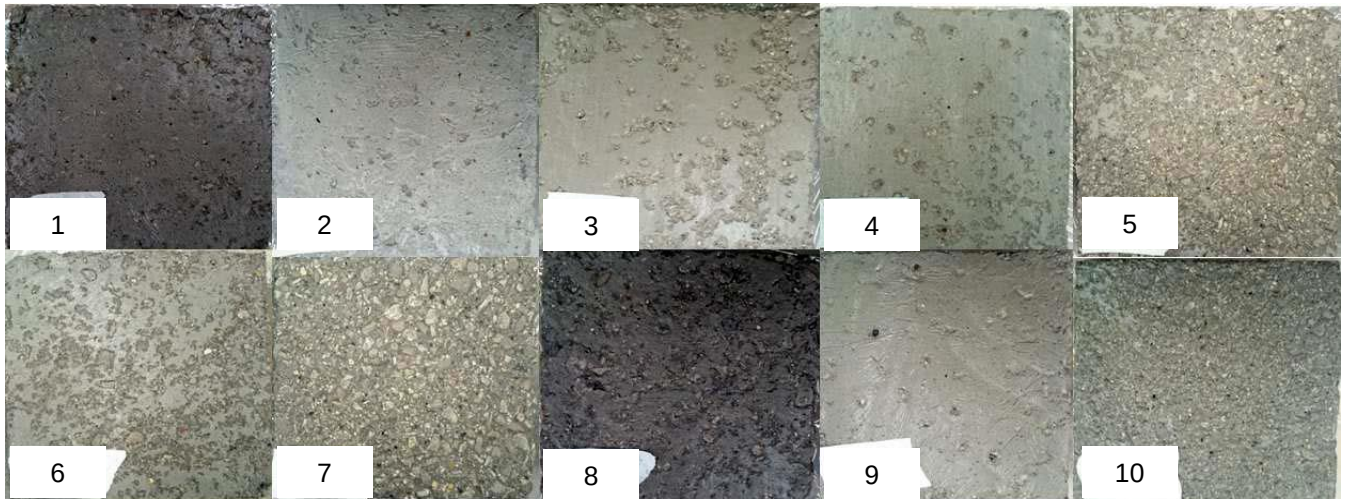
> Freeze-Thaw Performance:
DF > 92%

> The Surface Resistivity: of concrete was in the range of 25-200 kΩ.cm, which correlates to 100-1,000 Coulombs when tested for Rapid Chloride Permeability (ASTM C1202) and corresponds to concrete with a **Very Low Permeability**

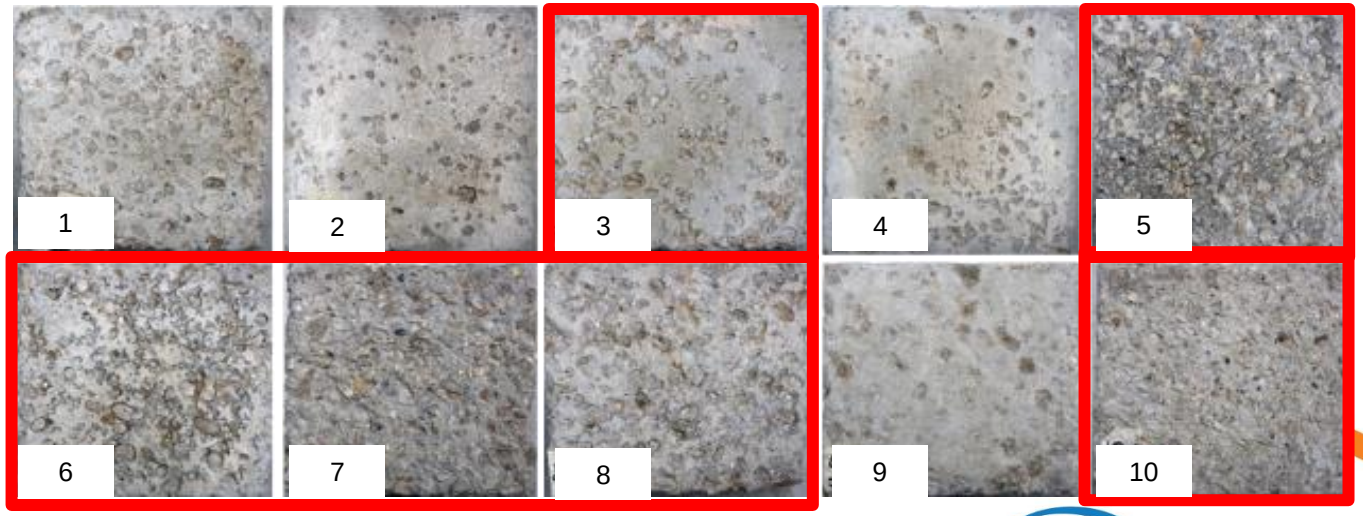
> Salt-Scaling:

After 10 cycles



Sample #	ID
1	L-M
2	L-H
3	L-M-C30
4	L-H-C30
5	L-M-F15
6	L-H-F15
7	L-M-F30
8	L-H-F30
9	L-M- C15-F15
10	L-H-C15-F15

After 50 cycles

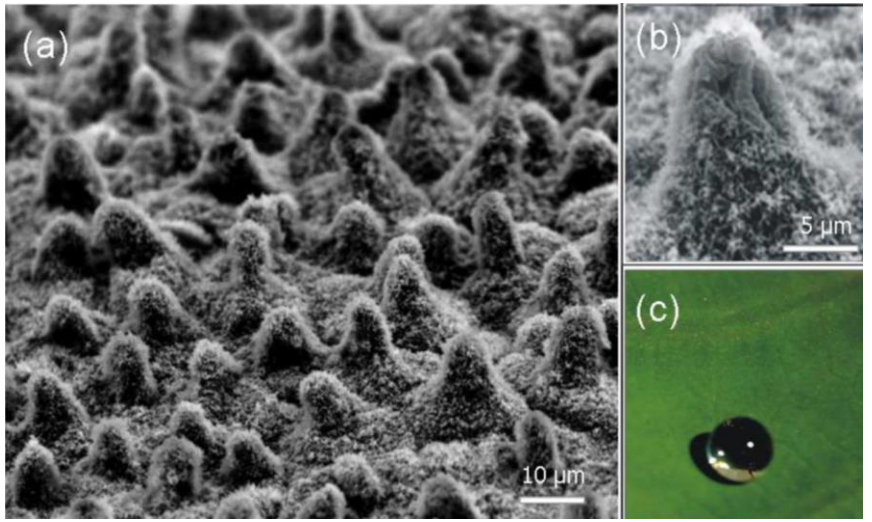


Weight loss after 50 cycles >1%

Coating envisioning

Our research was designed to demonstrate:

- protection mechanisms of TiO_2/ZnO-phosphate micro-texture patterns coated by silicone-organic compounds mimicking Lotus leaf effect
- the pathways to produce cement-based materials with ultimate durability and additional performance characteristics: *superhydrophobic, icephobic, anticorrosive, photocatalytic, and, even, antibacterial.*

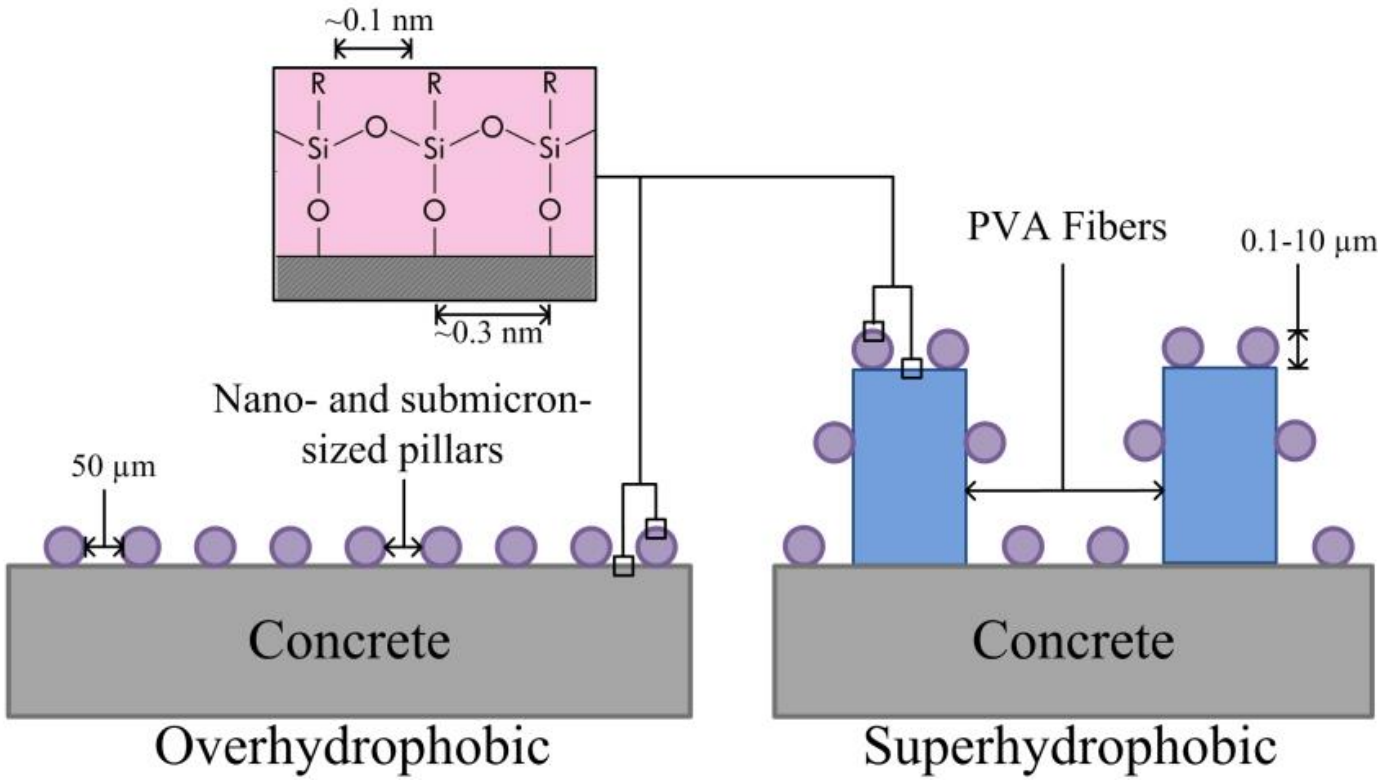


We propose two approaches: Single layer (2) and double layer (1 and 2 combined), based on:

(1) inorganic polymer bonded to the substrate to impose the hierarchical surface roughness

(2) an interpenetrating layer of zero-VOC hydrogen siloxane emulsion forming the crystallization barriers

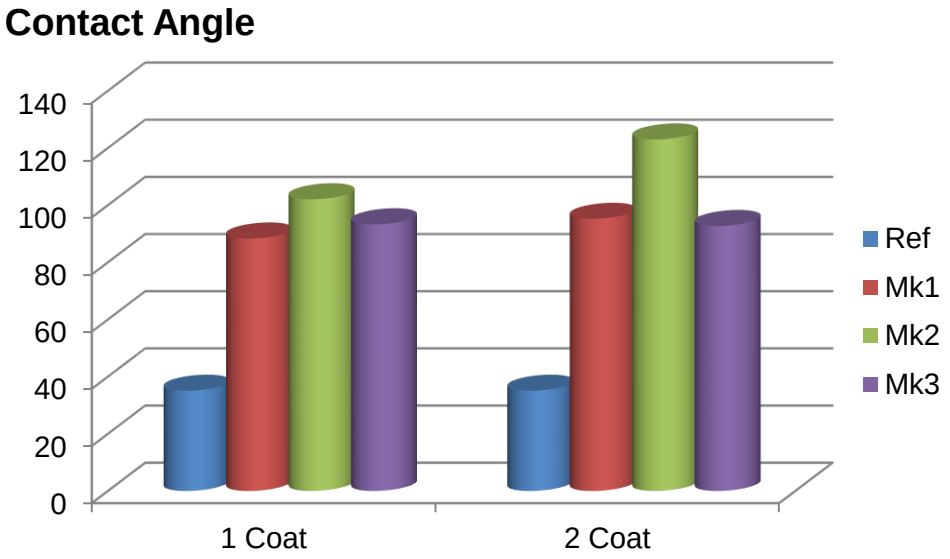
Single layer approach



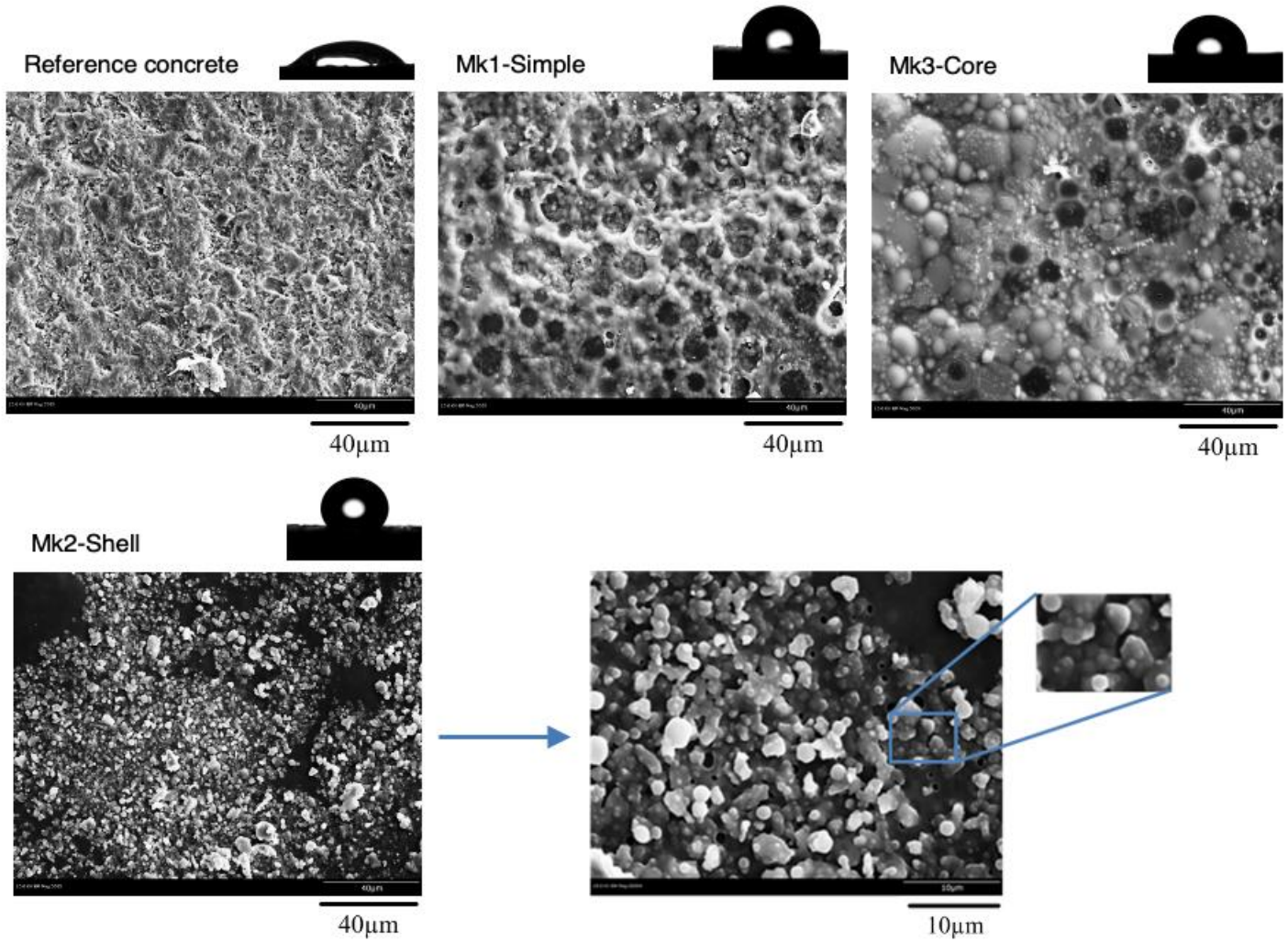
Hydrophobic and superhydrophobic surfaces

Hydrophobic materials tested	Contact angle
• Phenyltrimethoxysilane	85
• n-Octyltriethoxysilane	76
• Sodium methyl siliconate	103
• Methyltrimethoxysilane	80
• t-Butyltrimethoxysilane	88
• Tetraethoxysilane	82
• UWM mixtures	118-155
• UWM mix MK2	131

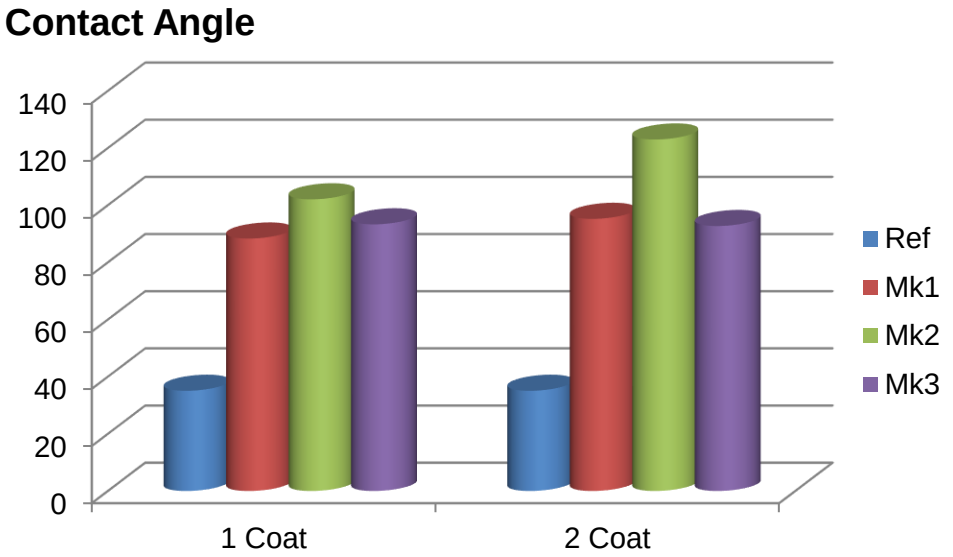
The contact angle of mortar specimens with single- and double- hydrophobic coating:



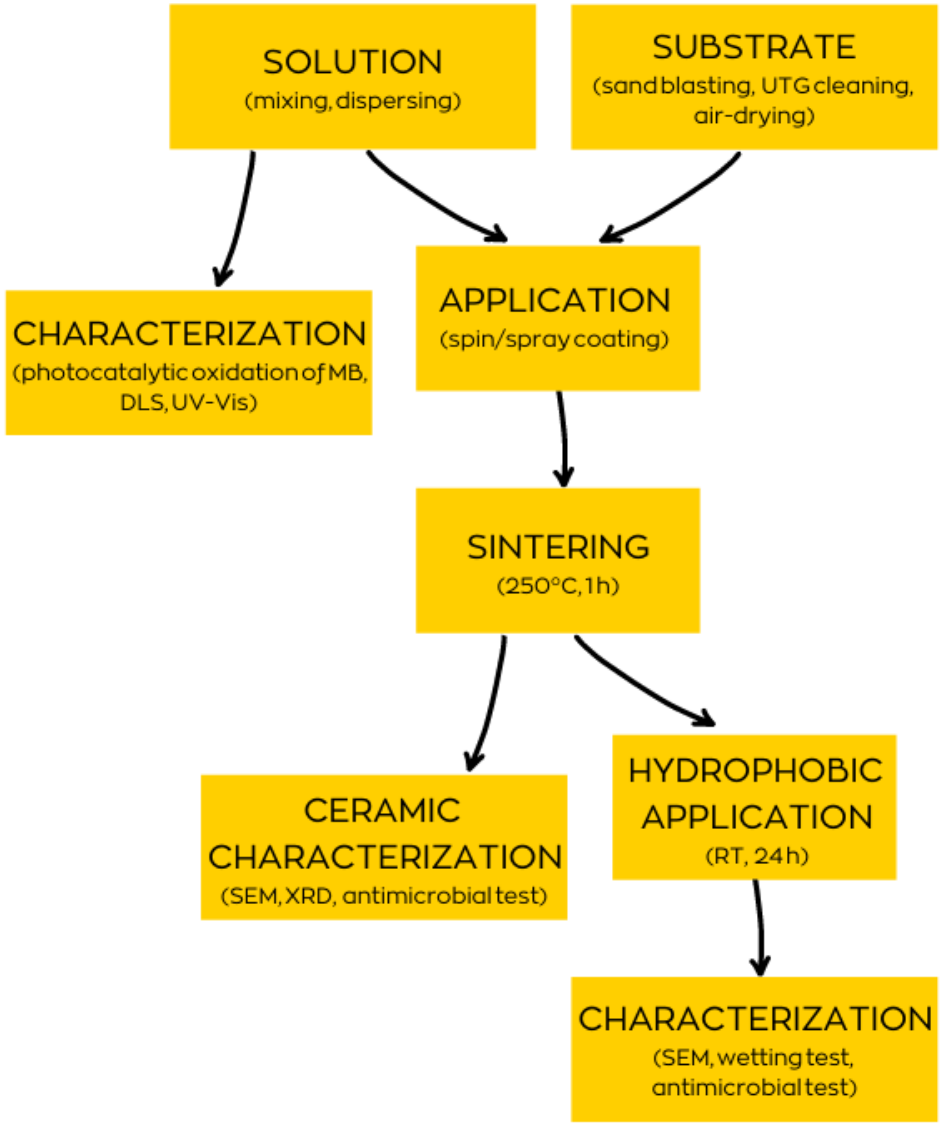
Hydrophobic and superhydrophobic surfaces



The contact angle of mortar specimens with single- and double- hydrophobic coating:

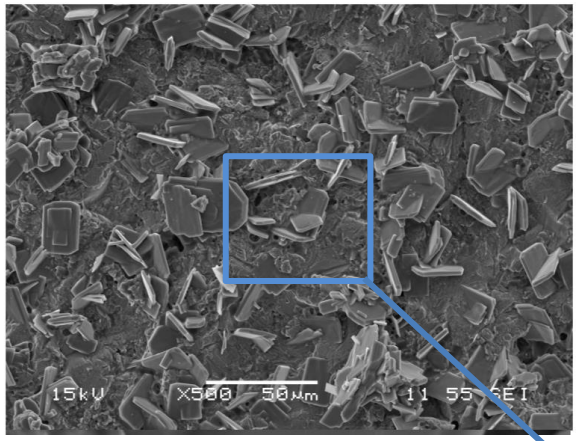


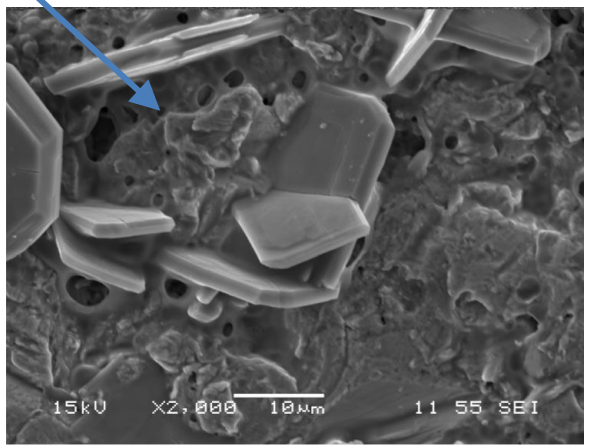
Double layer approach

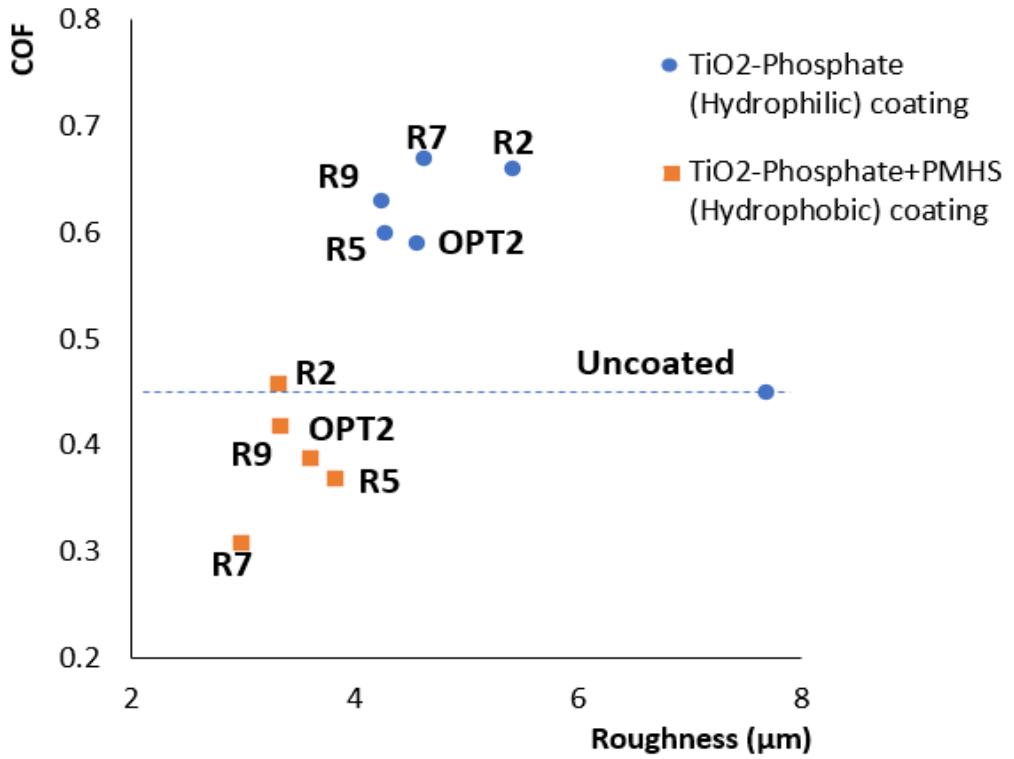


Texture and Friction

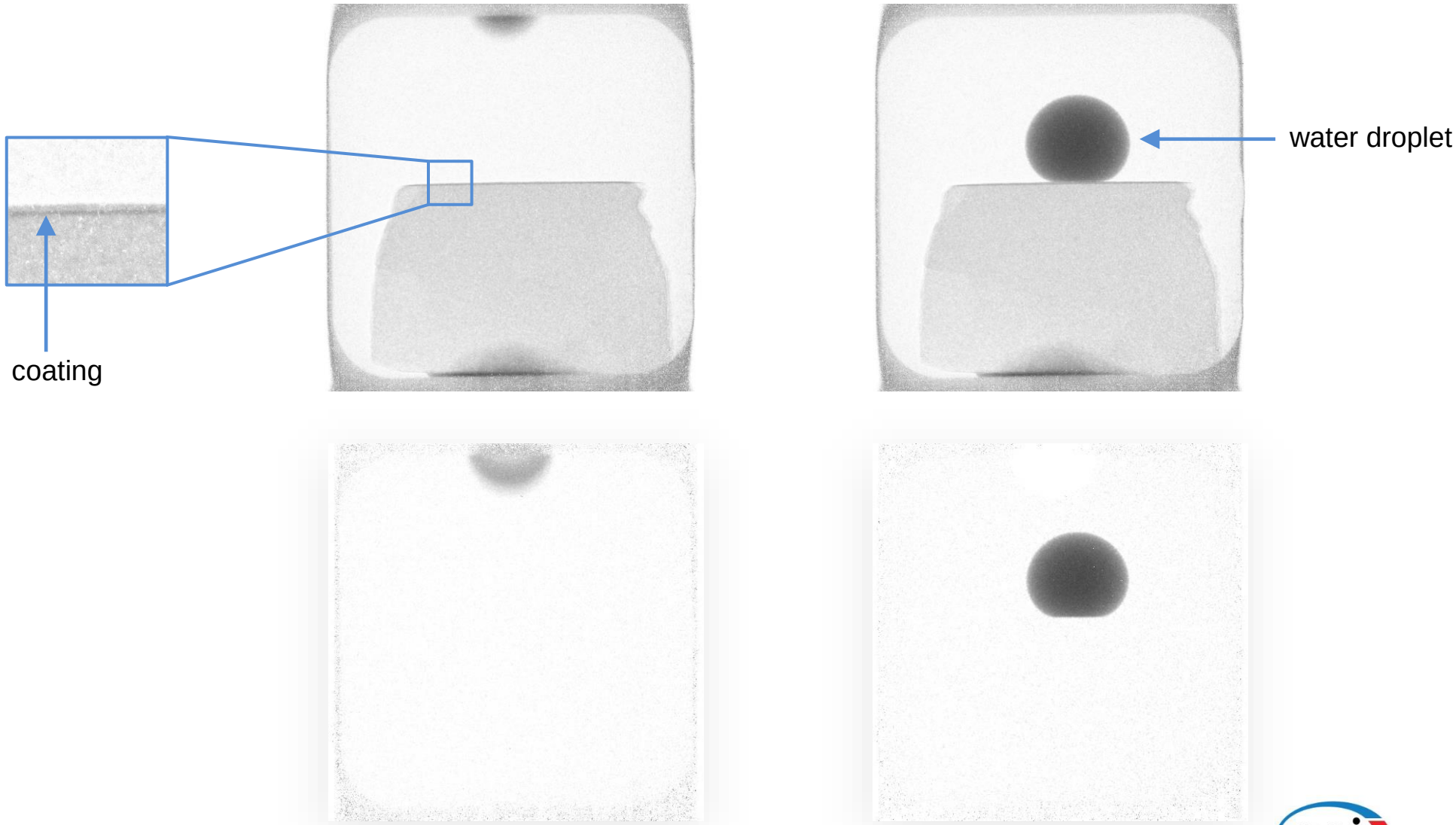
Engineering the micro-texture patterns based on TiO_2/ZnO-phosphate layer:







Impermeability evaluation - imaging with cold neutrons

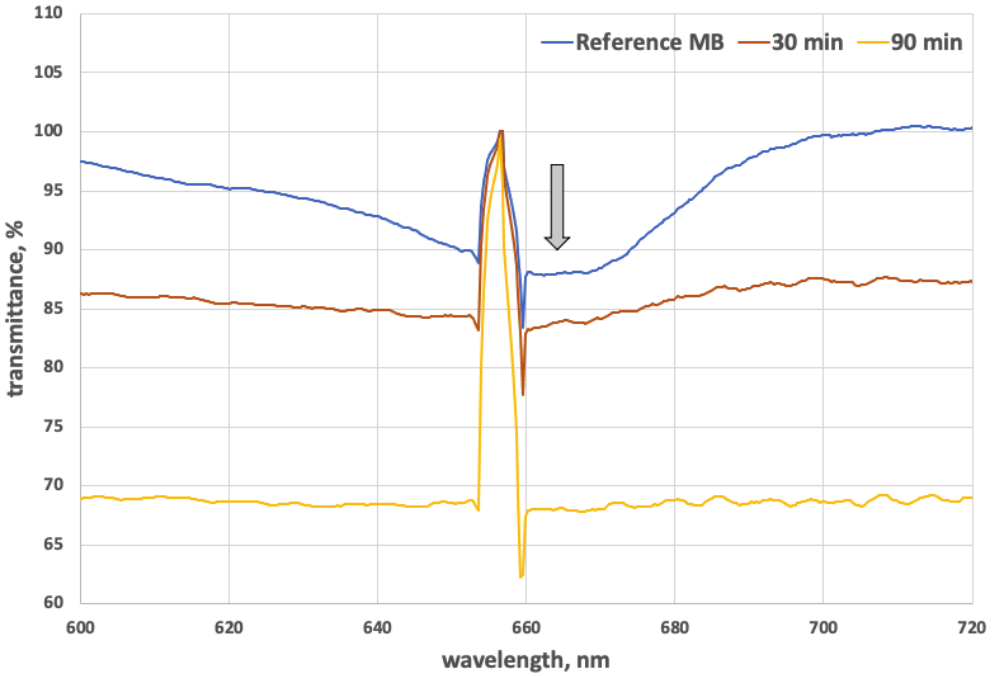


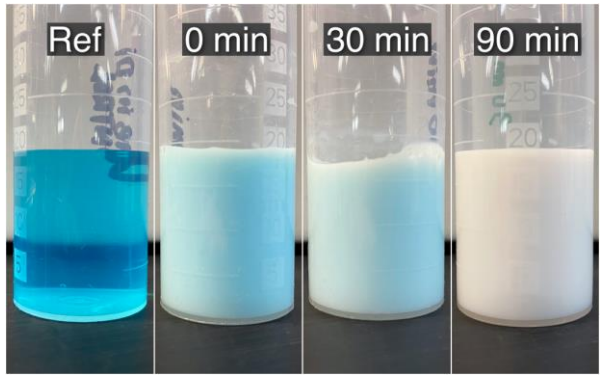
Towards extreme durability

at -15°C (5°F)

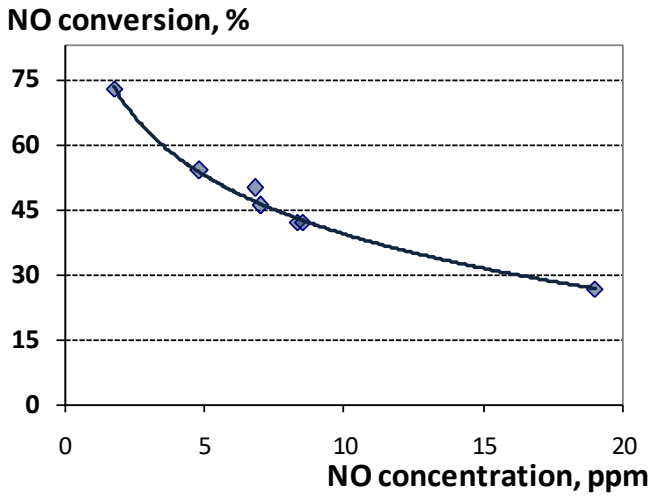
Photocatalytic degradation of Methylene Blue (MB)

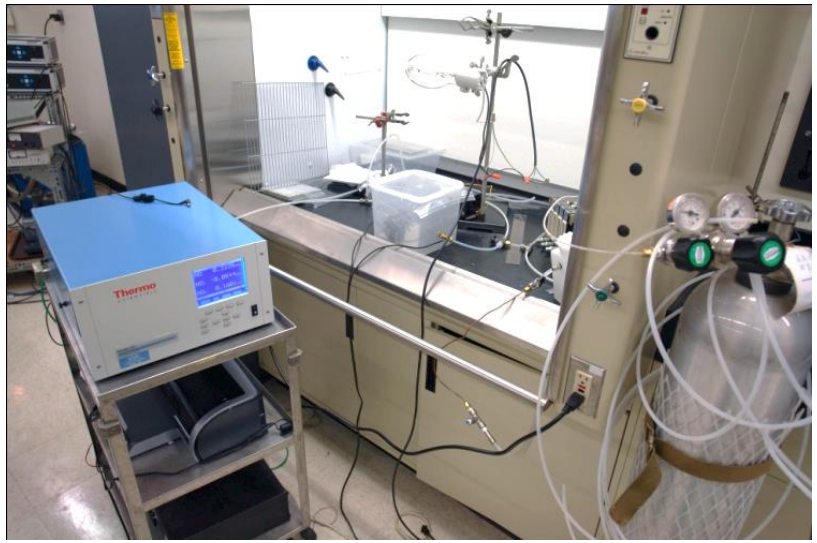
- kept in dark for 30 min to reach sorption-desorption equilibrium;
- visual observation can provide immediate understanding of efficiency of photocatalytic reaction;
- UV-Vis performed to determine transmittance of the obtained solutions.
- prior to UV-Vis, samples were centrifuged;
- at 663 nm wavelength maximum characteristic absorption of MB.

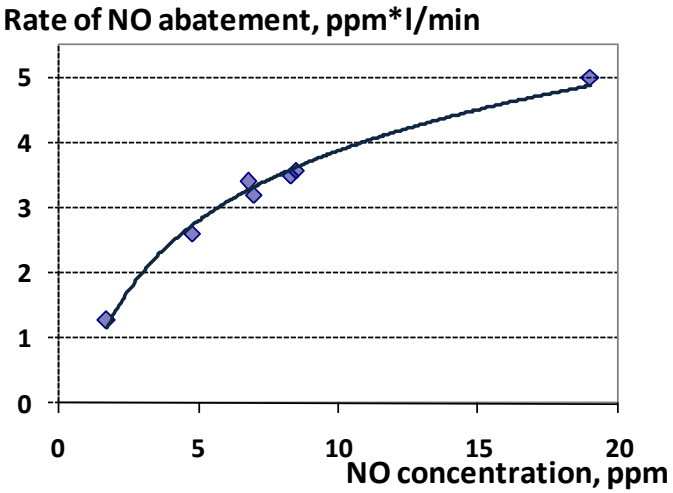




Depollution

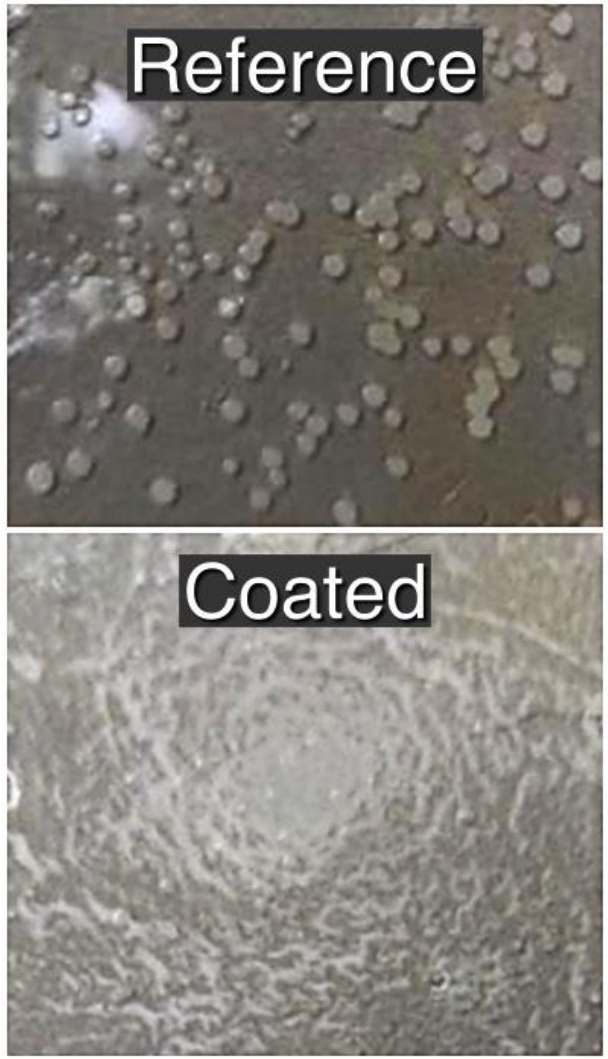






Antimicrobial efficacy

- specimens submerged in gel;
- E.coli strains (C41) placed on the top of the gel;
- incubated and irradiated with UV-C;
- colonies (“bubbles”) grew on reference, uncoated specimen;
- no colonies on coated specimen.



Conclusions

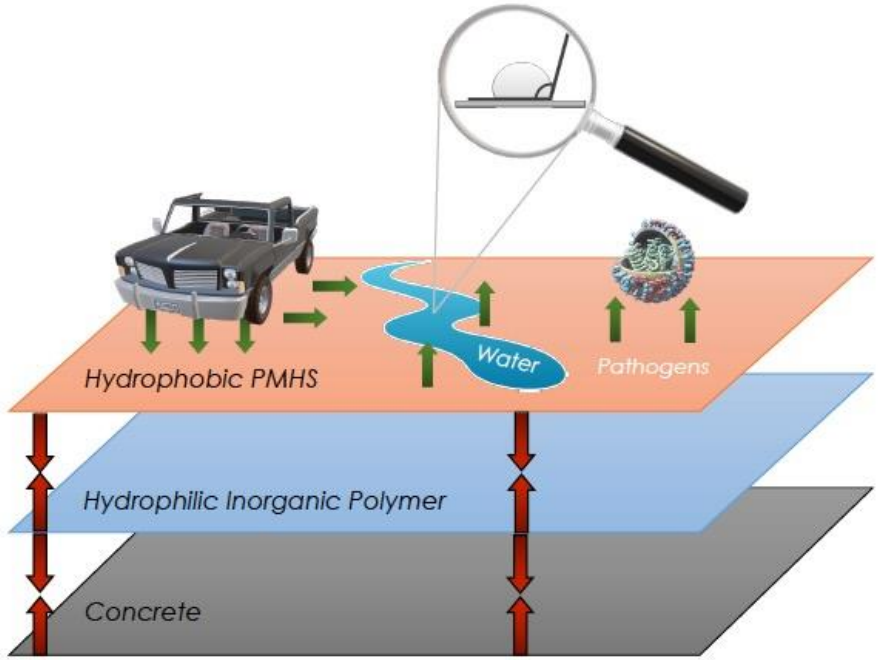
Discussed coatings can:

(1) hinder water transport through treated surfaces;

(2) reduce a tendency for ice accretion by disrupting crystallization process on engineered surface patterns;

(3) eliminate corrosion of reinforcement and loss of structural integrity when exposed to aggressive environments; and

(4) due to photocatalytic action, assure self-cleaning, improve the air and water quality in polluted urban zones.



This work can have a considerable impact on the efficiency and sustainability of the construction industry and the environment due to a reduction of CO_2 emissions associated with extended service life.

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