NANOTECHNOLOGY TO IMPROVE THE PERFORMANCES OF HYDRODYNAMIC SURFACES

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EL HADJ DOGHECHE, LAURENT KEIRSBULCK., PHILIPPE CHAMPAGNE

OUTLINES

- INTRODUCTION (MARITIME INDUSTRY CHALLENGES)
- PROJECT STRATEGY
- SUPER-HYDROPHOBIC SURFACES (POTENTIAL SOLUTION, CONDITIONS & PUBLICATIONS)
- MARKET STUDIES
- PROPOSED SOLUTIONS
- ACHIEVEMENTS
- CONCLUSION

CONTEXTE

- CORROSION ($276 BILLION FOR USA/YAER = 3.1% OF USA GDP) *
- FOULING ($150 BILLION / YEAR 2020 GLOBE) **
- ENERGY
- ENVIRONMENT (2001, IMO CONVENTION PROHIBIT TBT) ***
- HYDRODYNAMIC PERFORMANCES

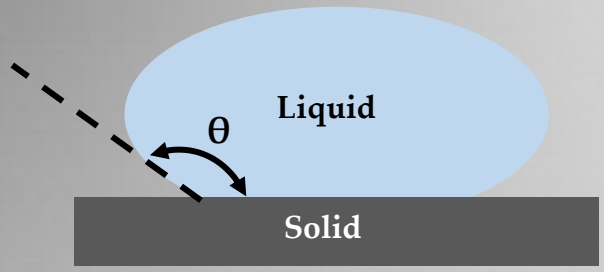
* J. H. P. GERHARDUS, “CORROSION COSTS AND PREVENTIVE STRATEGIES IN THE UNITED STATES,” NACE INT., PP. 3–11, 2002.

** C. HELLIO AND D. YEBRA, ADVANCES IN MARINE ANTIFOULING COATINGS AND TECHNOLOGIES. WOODHEAD PUBLISHING LIMITED, 2009.

*** TBT (TRIBUTYLTIN)

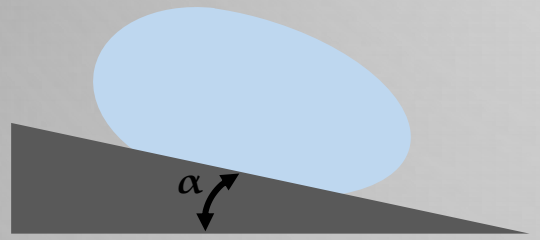
OBJECTIVE

- ENHANCE THE MARITIME SURFACES CHARACTERISTICS BY **SUPER HYDROPHOBIC** TREATMENT

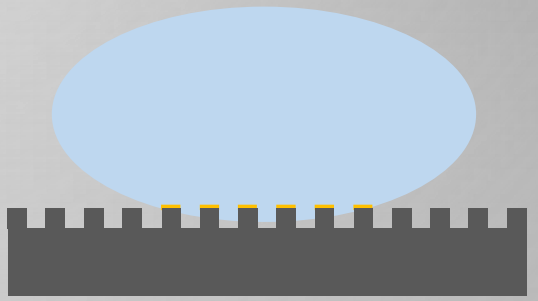


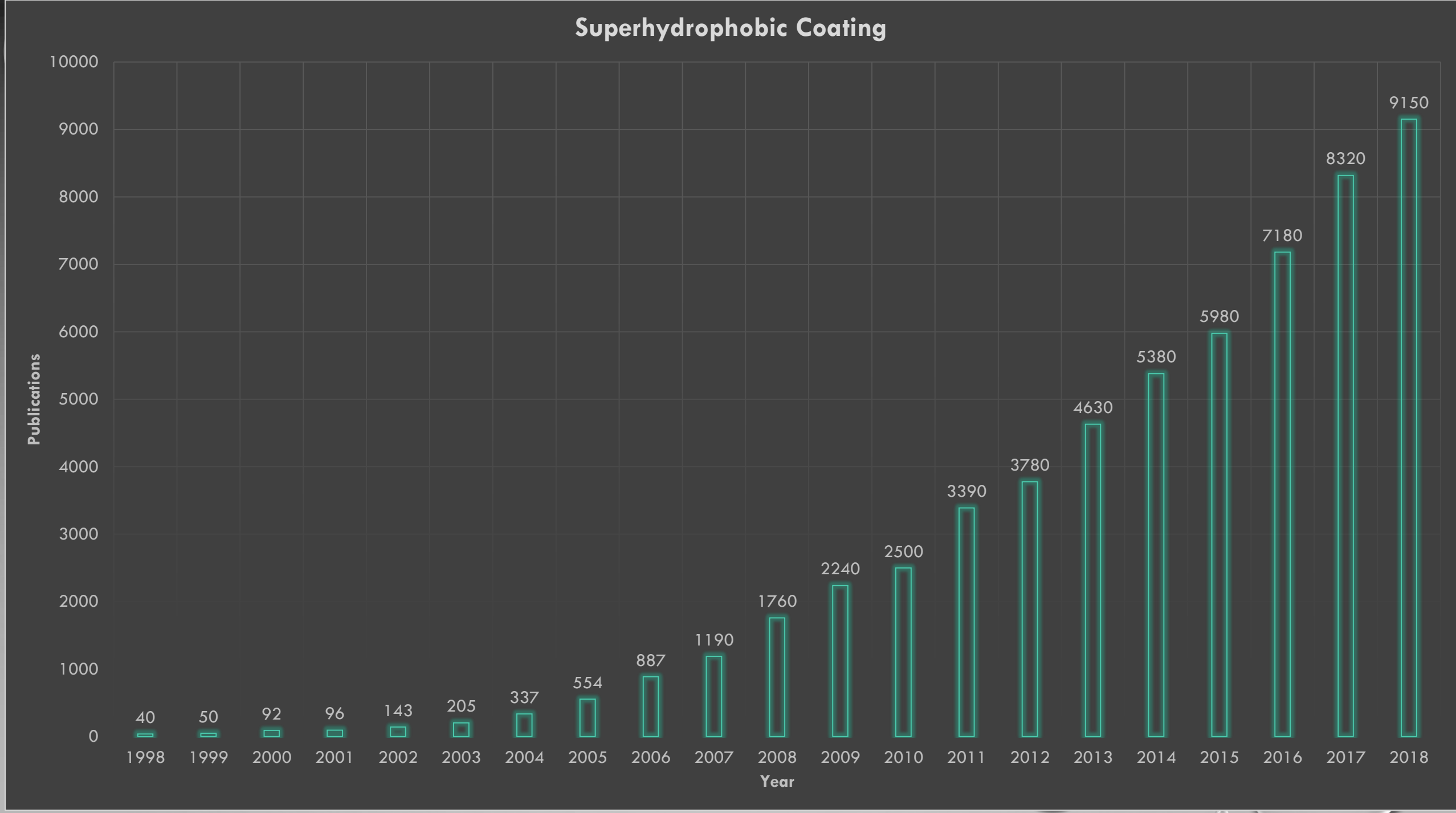
θ: Water Contact Angle (WCA)

- (**WCA**) (θ) ≥ **150°**
- Sliding Angle (**SA**) (α) ≤ **10°**



α: Sliding Angle (SA)




Superhydrophobic Coating
Publications
Year
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
40
50
92
96
143
205
337
554
887
1190
1760
2240
2500
3390
3780
4630
5380
5980
7180
8320
9150
1998
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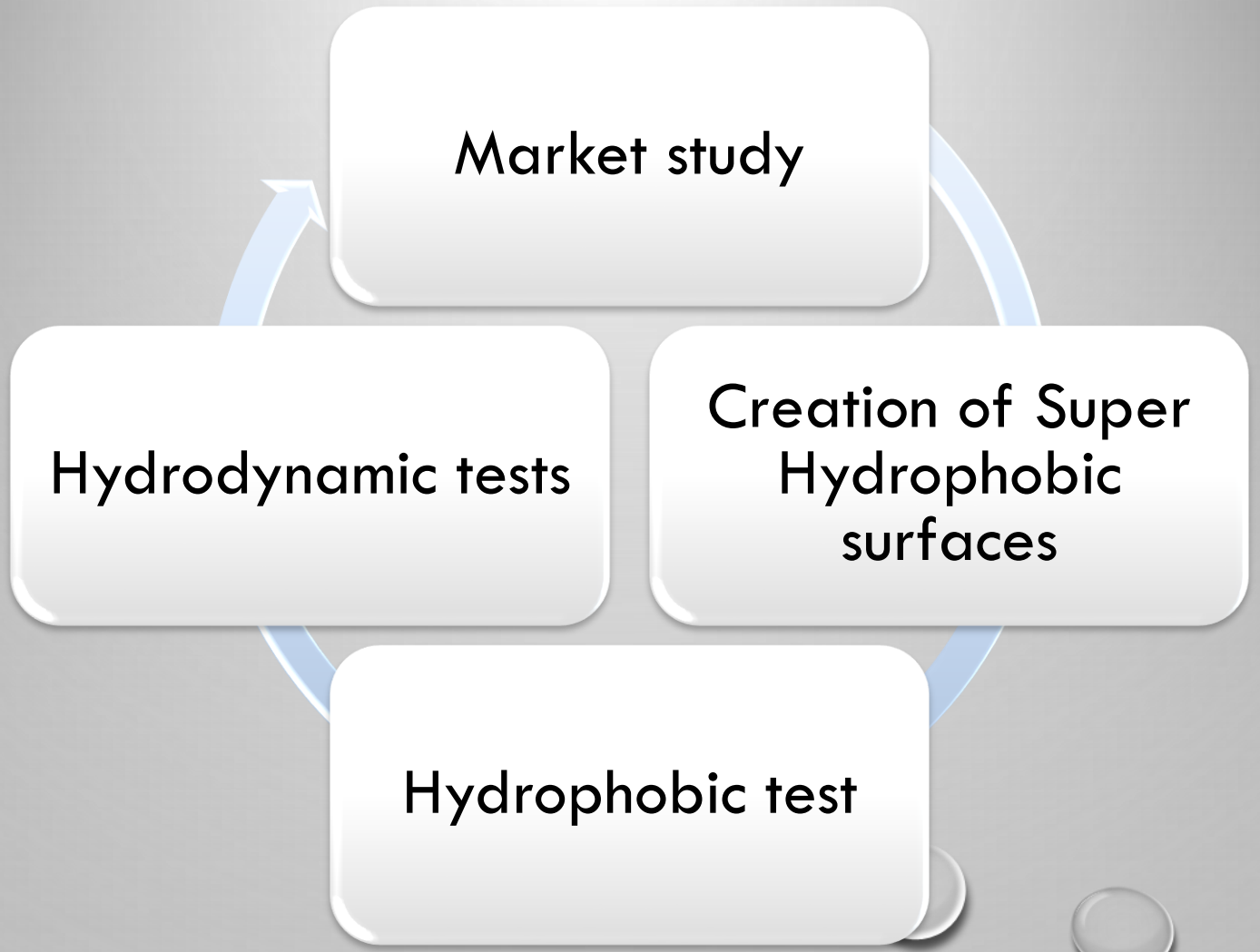
2018

STRATEGY


Market study
Creation of Super Hydrophobic surfaces
Hydrophobic test
Hydrodynamic tests

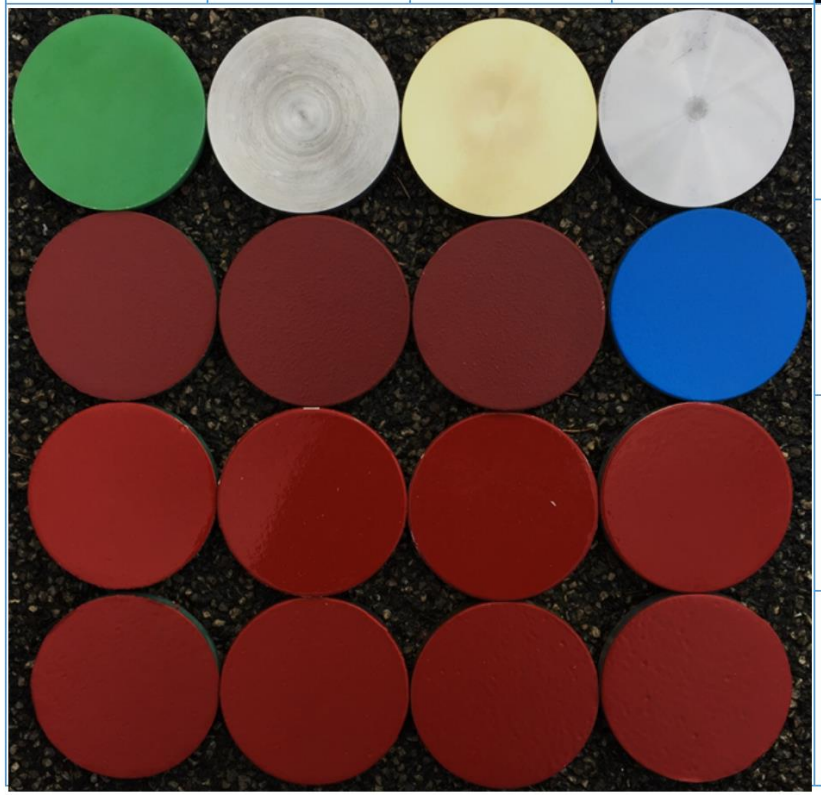
STRATEGY

Market study

Creation of Super Hydrophobic surfaces

Hydrophobic test

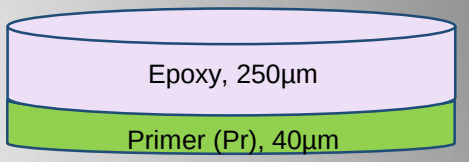
Hydrodynamic tests

Composite	Steel	Copper	Aluminum	Paint
				non
				Epoxy
				Silicone
				Classic

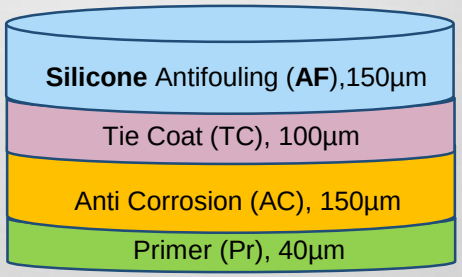
MARKET STUDIES

- WATER CONTACT ANGLE (**WCA**)
- SLIDING ANGLE (**SA**)
- SLIDING SPEED (**Vs**)
- SURFACE MORPHOLOGY
- ENERGY-DISPERSIVE X-RAY (**EDX**)
- SURFACE TENSION (**ST**)
- SURFACE ROUGHNESS (**RA**)

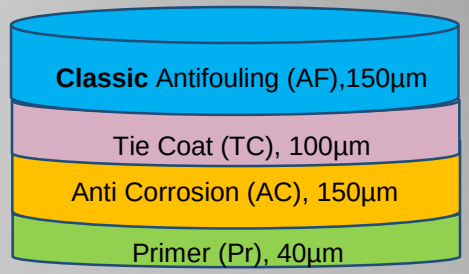
configuration of paint layers



Epoxy
paint system



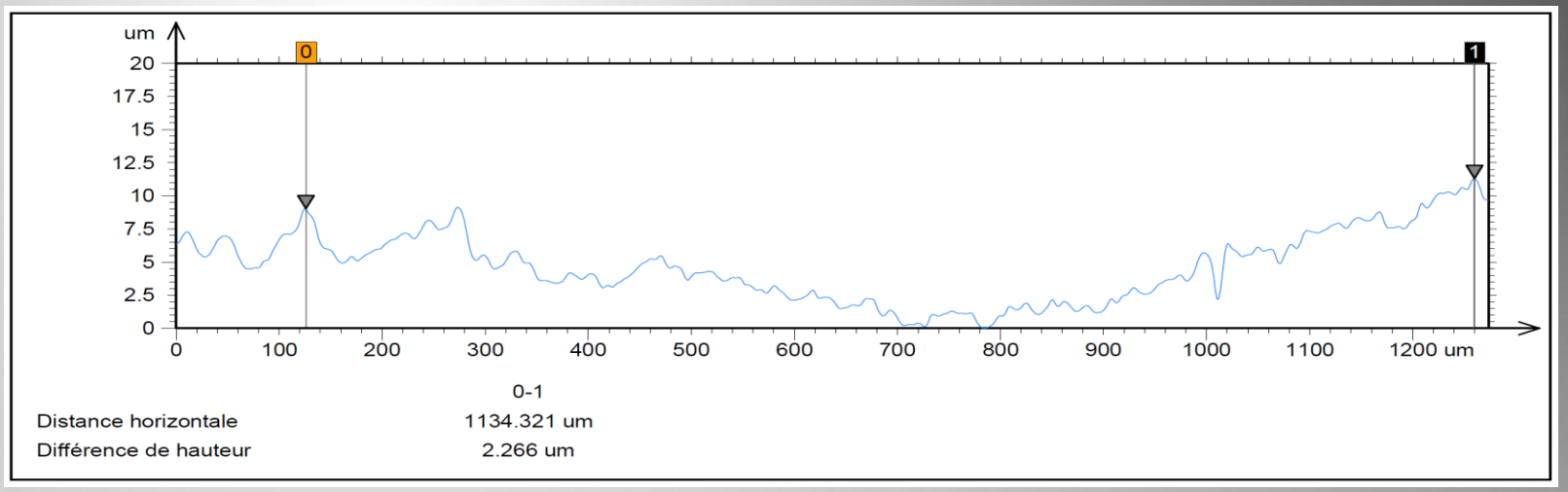
Silicone A.F.
paint system



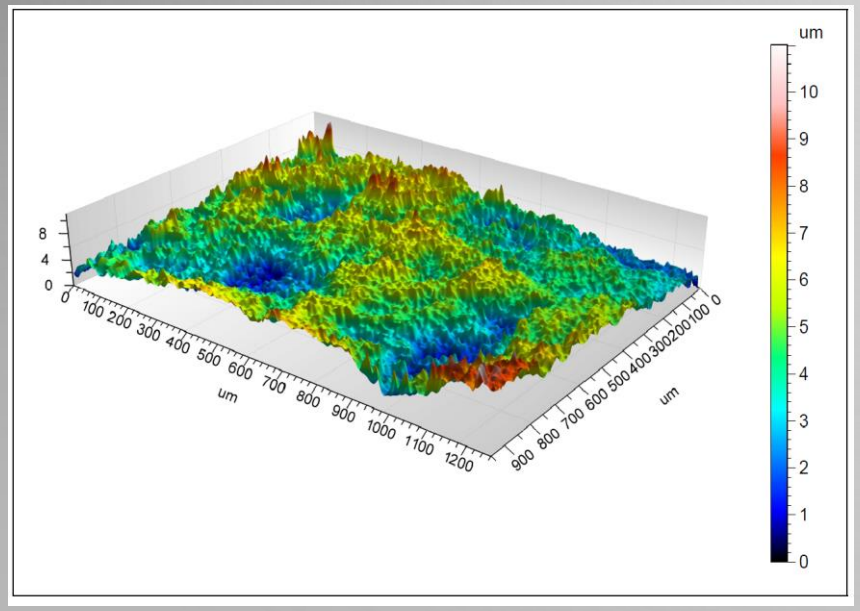
Classic A.F.
paint system

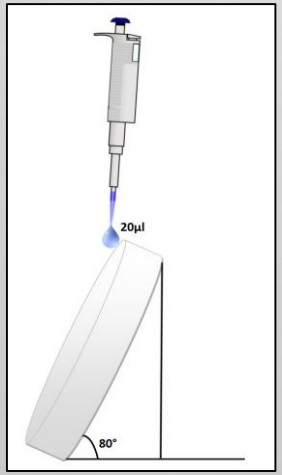
EPOXY PAINT

Surface morphology



Confocal microscopy





Vs = 0.23 m/s

EDx

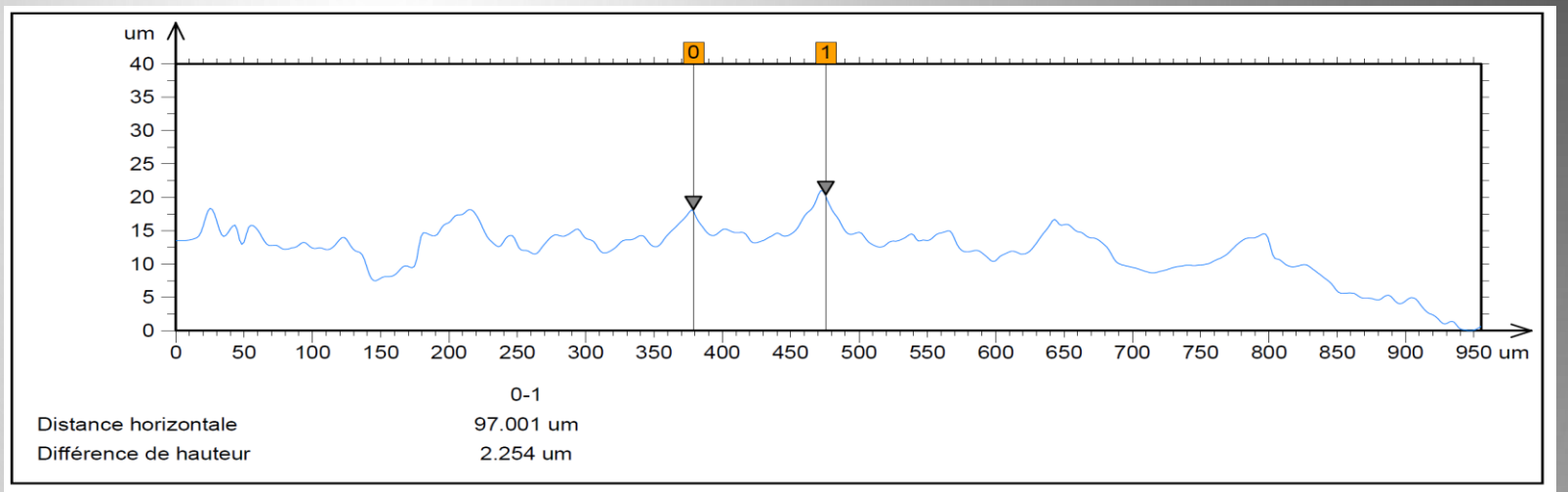
Element	Weight %	Atom %
Al	0.28	0.42
S	1.12	1.43
Mg	2.03	3.42
Si	3.40	4.95
Cl	8.91	10.27
Fe	10.68	7.81
O	13.00	33.19
Zn	24.21	15.13
Cu	36.37	23.38
Total	100.00	100.00

WCA = 85°
SA = 36°
ST= 43 (mJ.m-^{2})

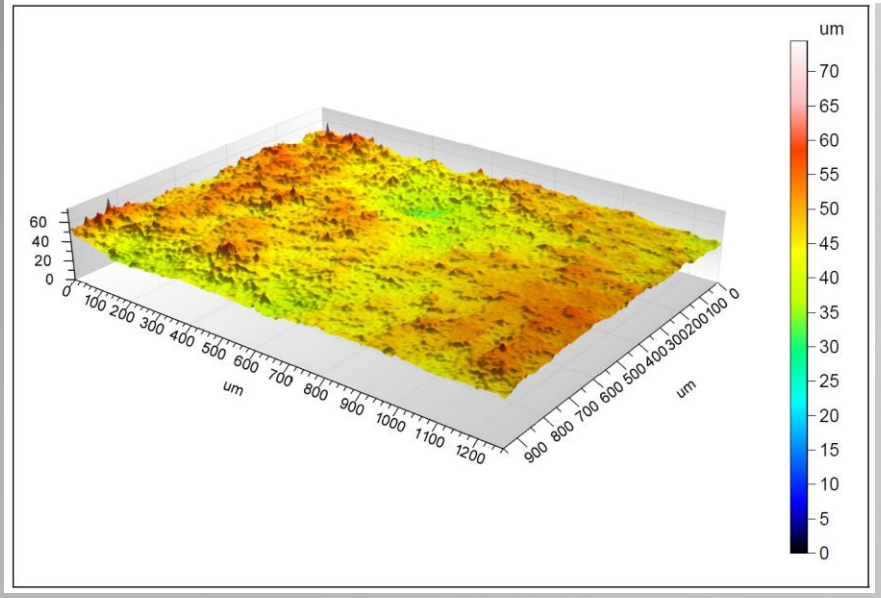
Ra = 373 (nm)

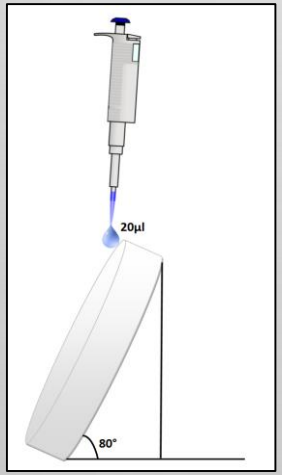
CLASSIC A.F. PAINT

Surface morphology



Confocal microscopy





EDx

Element	Weight %	Atom %
Ca	0.70	0.47
Cl	1.69	1.30
Fe	6.55	3.20
S	7.73	6.59
Mg	10.15	11.41
Si	19.86	19.31
Ba	22.09	4.39
O	31.23	53.32
Total	100.00	100.00

WCA = 84°

SA = 37°

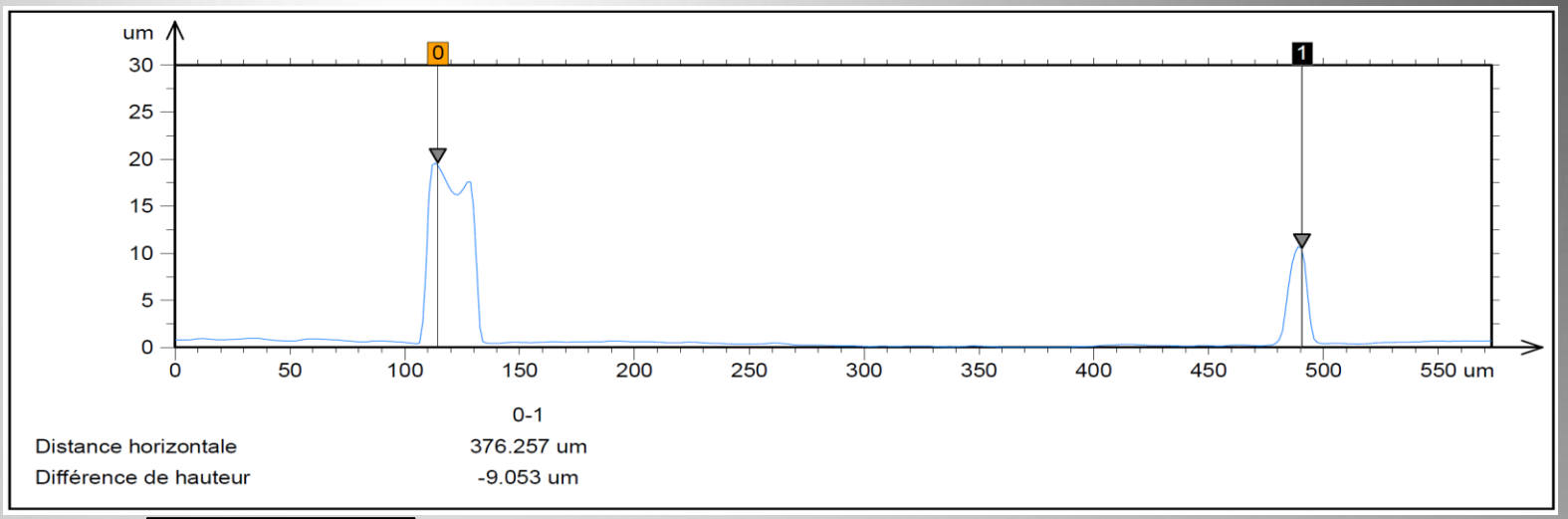
ST= 43 (mJ.m-^{2})

Ra = 923 (nm)

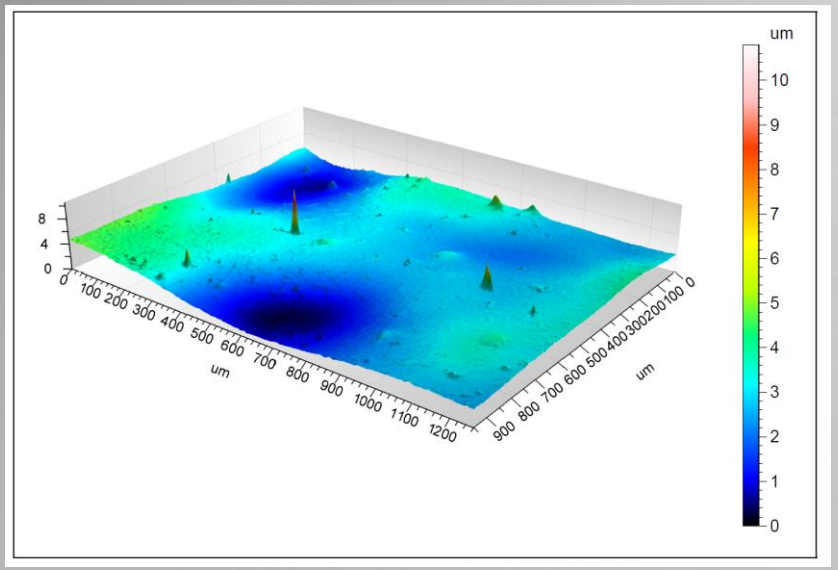
Vs = 0.16 m/s

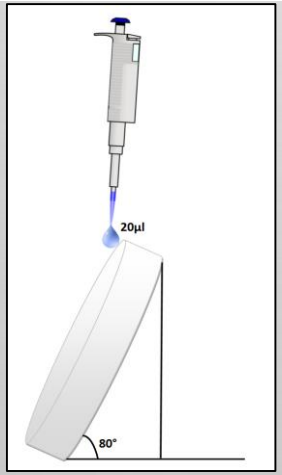
SILICONE A.F. PAINT

Surface morphology



Confocal microscopy





EDx

Element	Weight %	Atom %
Fe	2.43	0.99
O	33.22	47.07
Si	64.35	51.95
Total	100.00	100.00

WCA = 101°

SA = 16°

ST= 23 (mJ.m-²)

Ra = 121 (nm)

Vs = 0.3 m/s

MARKET STUDIES

WCA = 101°
SA = 16°
ST= 23 (mJ.m-²)
SS = 0.3 m/s

Silicone A.F.
paint system
75€/L

WCA = 84°
SA = 37°
ST= 34 (mJ.m-²)
SS = 0.16 m/s

WCA = 85°
SA = 36°
ST= 43 (mJ.m-²)
SS = 0.23 m/s

Classic A.F
paint system
40€/L

Epoxy
paint system
25€/L

Lotus Leaf : WCA=153.4°,SS = 0.32 m/s

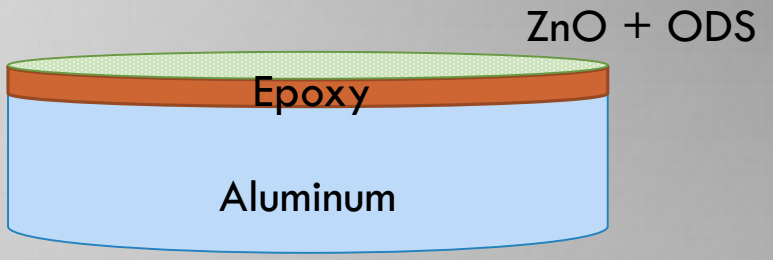
STRATEGY

Market study

Creation of Super Hydrophobic surfaces

Hydrophobic test

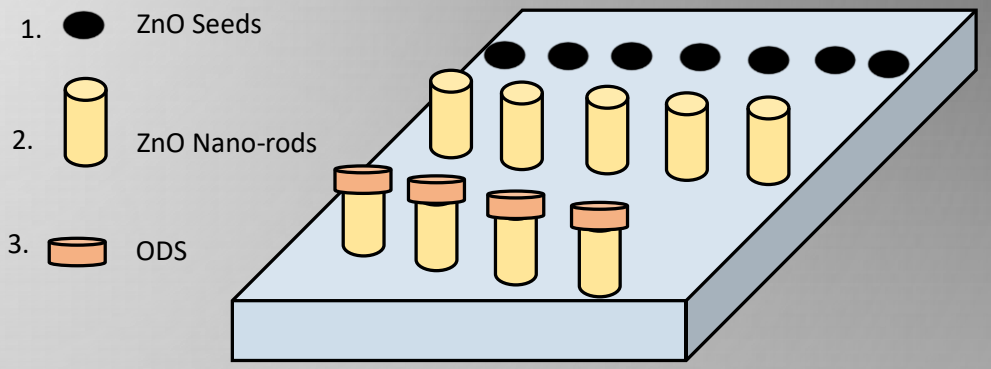
Hydrodynamic tests



PROPOSED SOLUTIONS

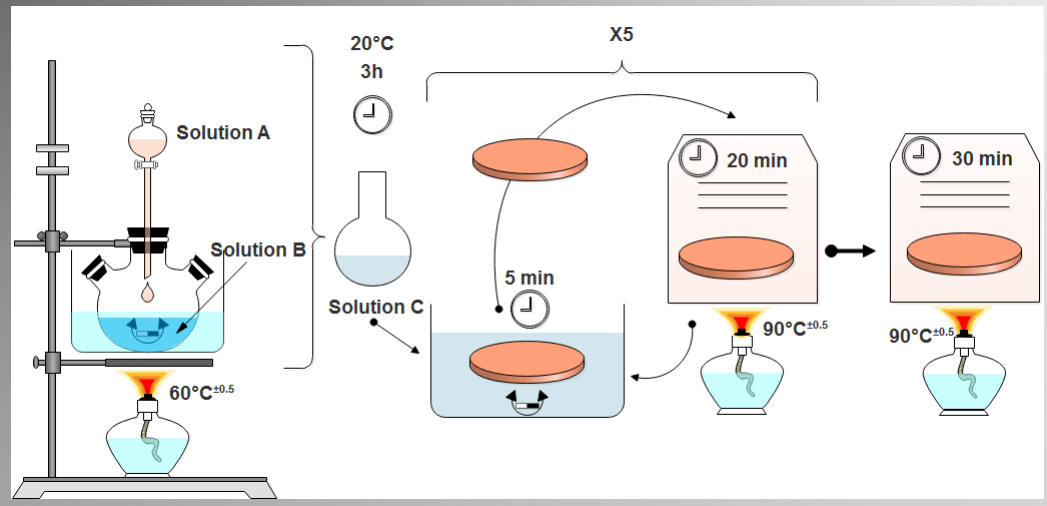
Create **Super-Hydrophobic** Surfaces from Nanotechnology Process

1. **ZnO NRS** nanorods by Hydrothermal process (antibacterial, simple fabrication & green material: most popular solution studied (0.5 M Paper 2007-2017)
2. reduce **surface energy** ODS (OctaDecyltrimethoxySilane)

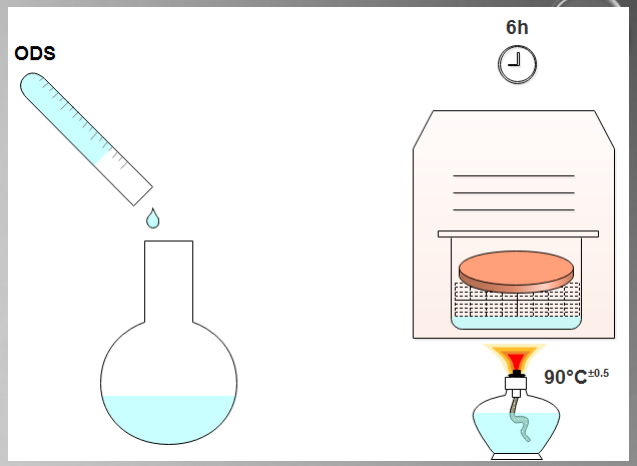


PROTOCOL

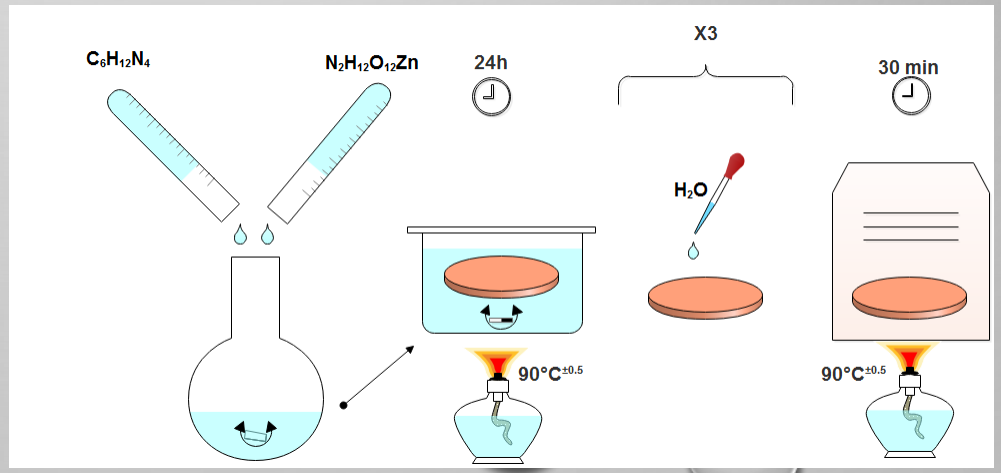
1. ZnO seeds



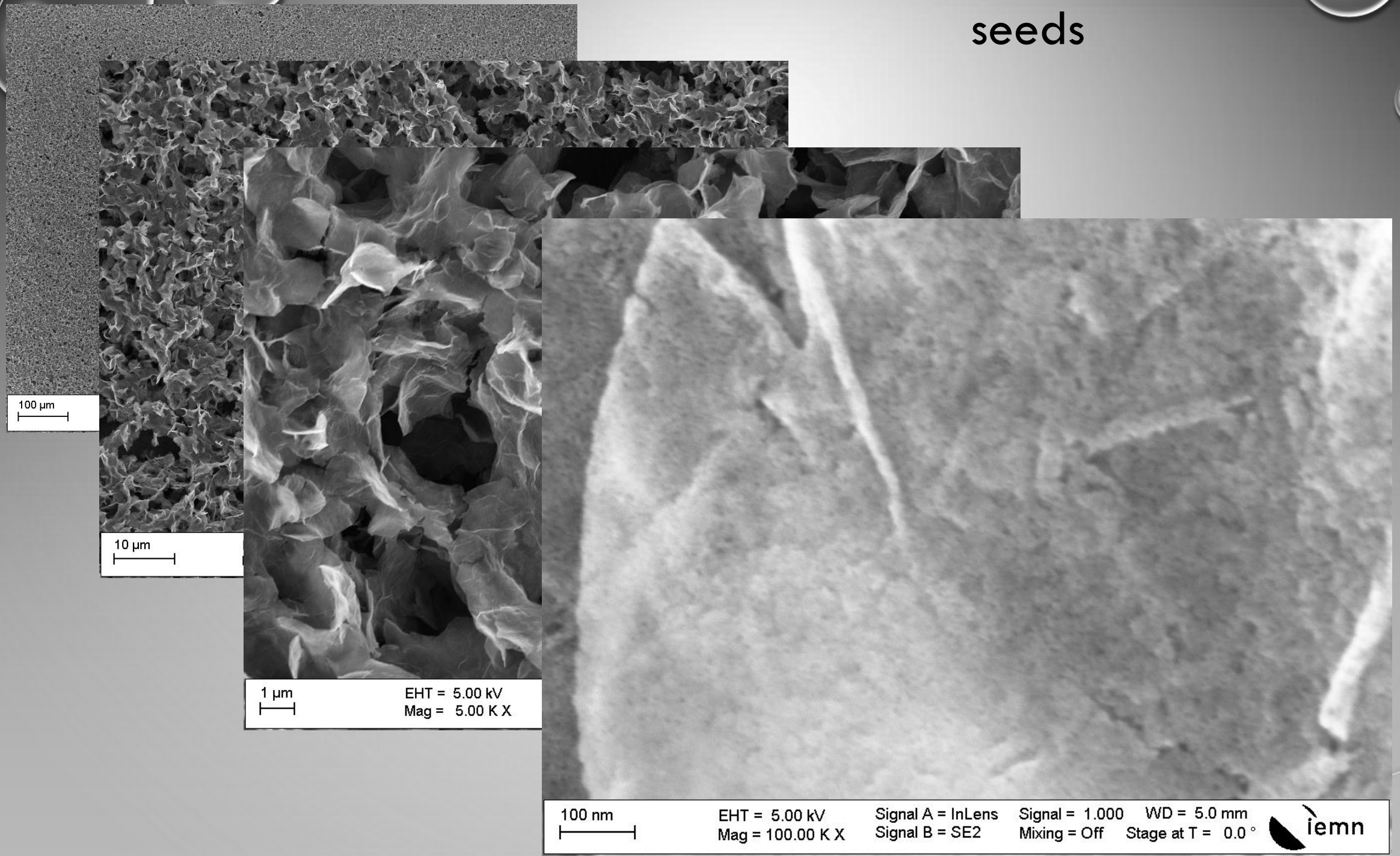
3. ODS



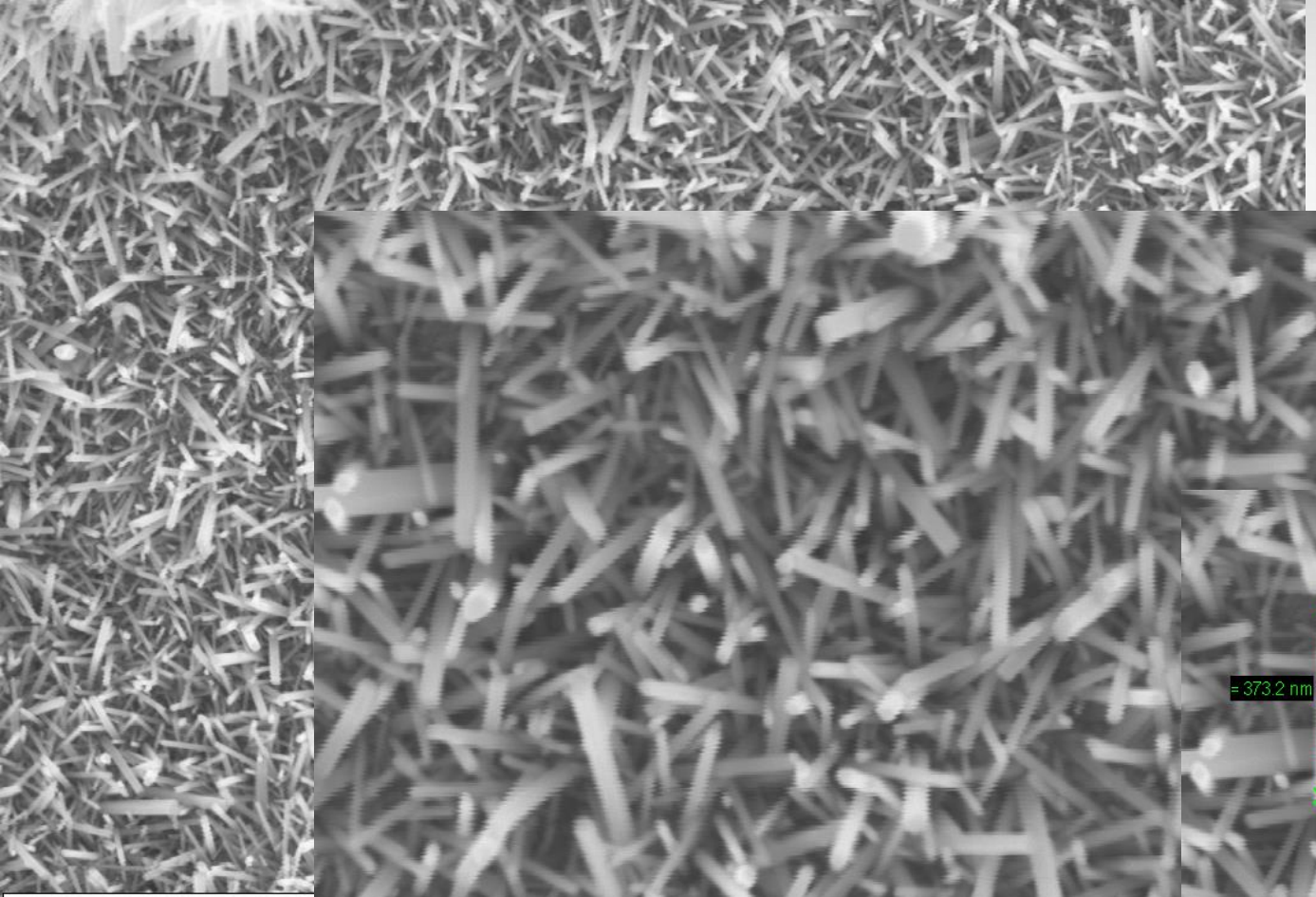
2. ZnO NRs



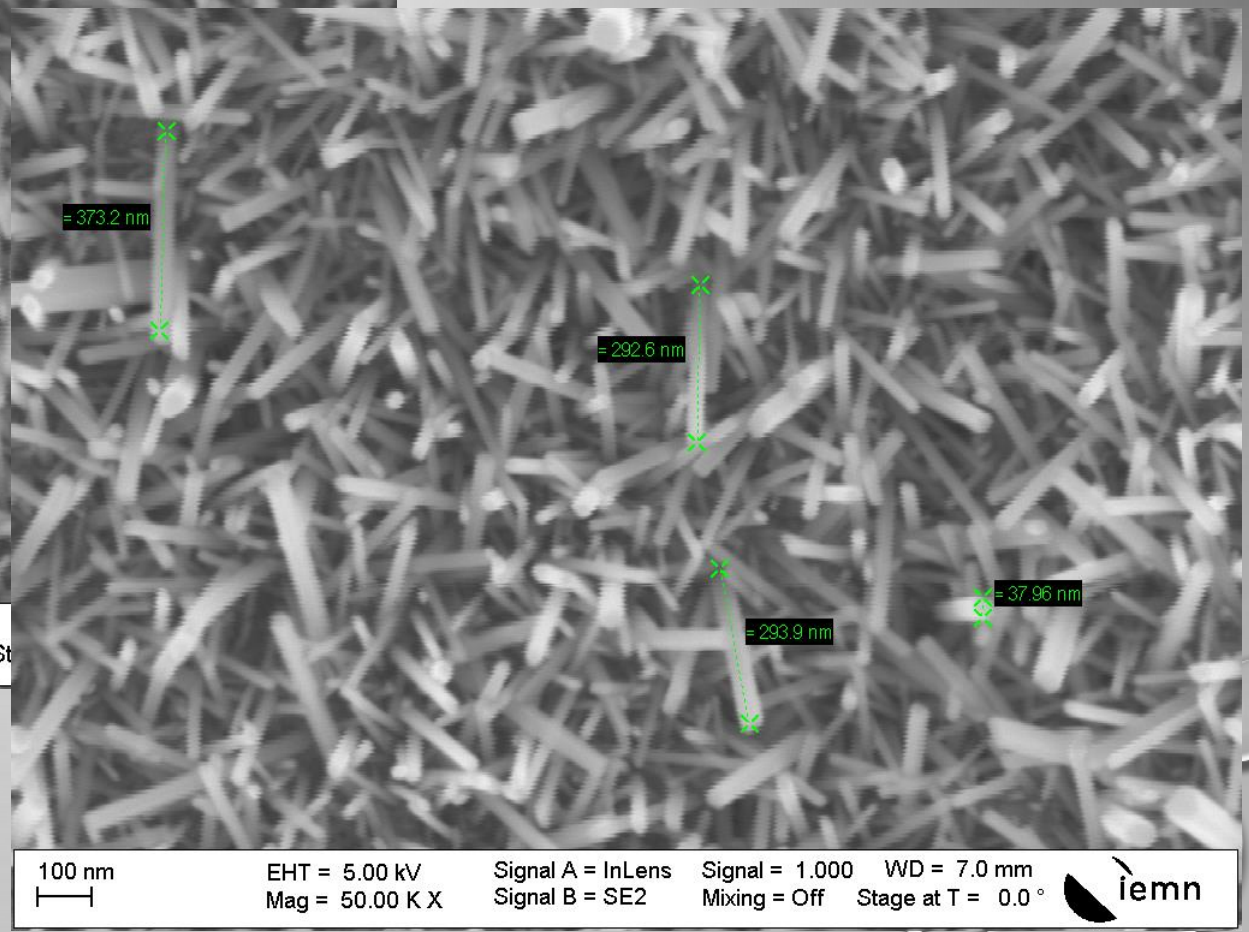
seeds


100 µm
10 µm
1 µm
EHT = 5.00 kV
Mag = 5.00 K X
100 nm
EHT = 5.00 kV
Mag = 100.00 K X
Signal A = InLens
Signal B = SE2
Signal = 1.000
Mixing = Off
WD = 5.0 mm
Stage at T = 0.0 °
iemn

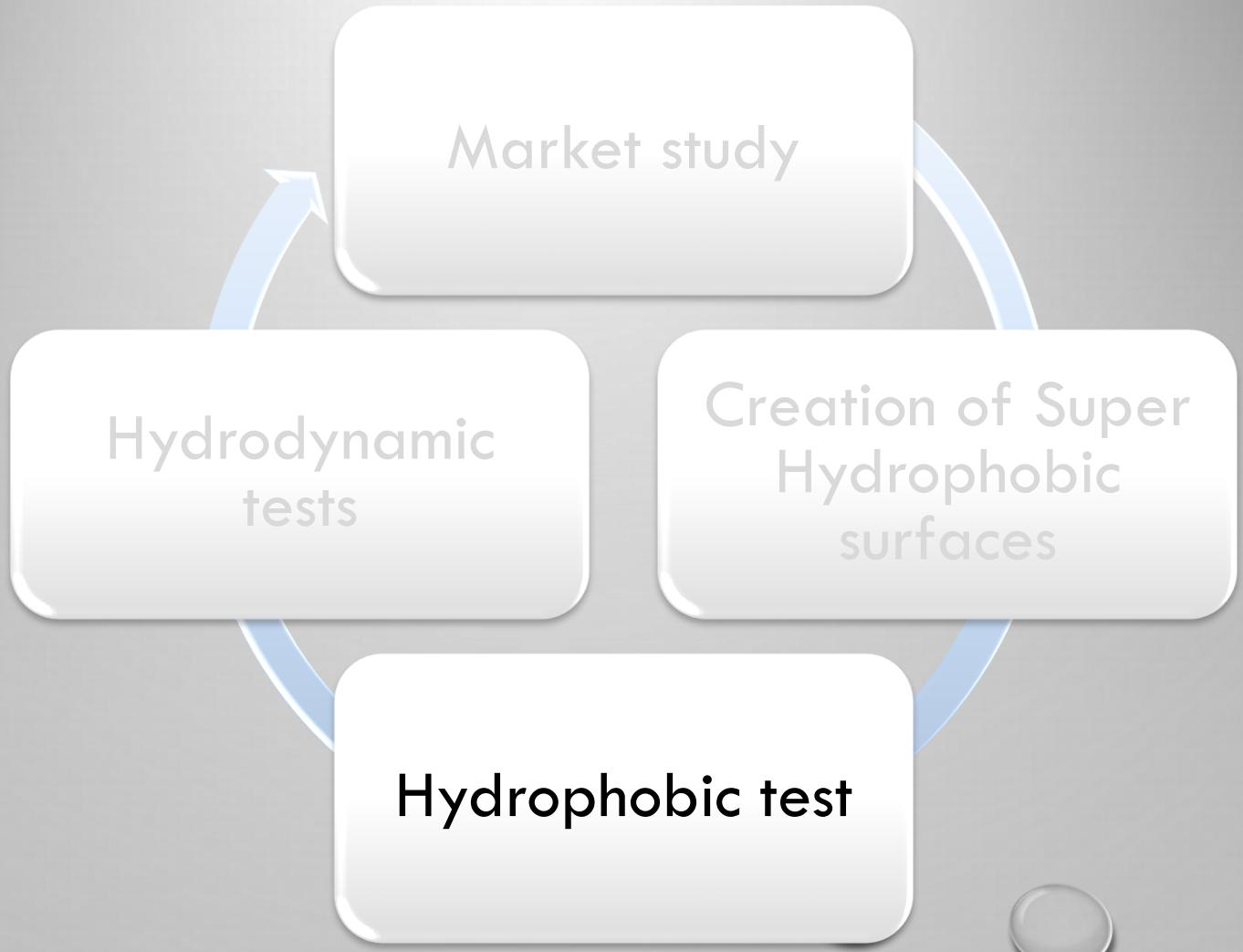
ZnO NRs


200 nm
EHT
Mag

100 nm
EHT = 5.00 kV
Mag = 50.00 K X
Signal A = InLens
Signal B = SE2
Signal = 1.000
Mixing = Off


= 373.2 nm
= 292.6 nm
= 293.9 nm
= 37.96 nm
100 nm
EHT = 5.00 kV
Mag = 50.00 K X
Signal A = InLens
Signal B = SE2
Signal = 1.000
Mixing = Off
WD = 7.0 mm
Stage at T = 0.0 °
iemn

STRATEGY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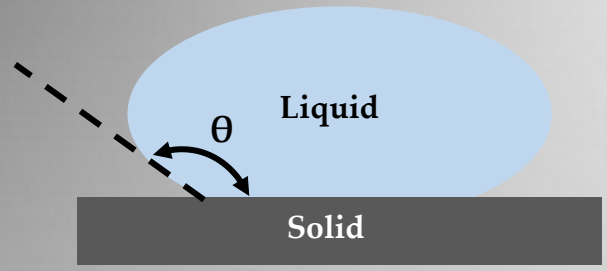
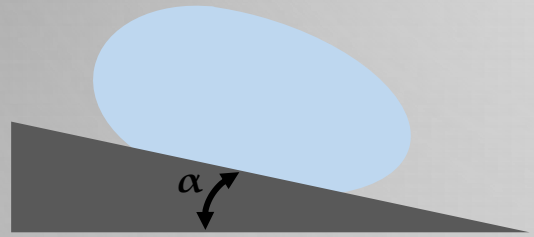
CHARACTERIZATION (WCA & SA)



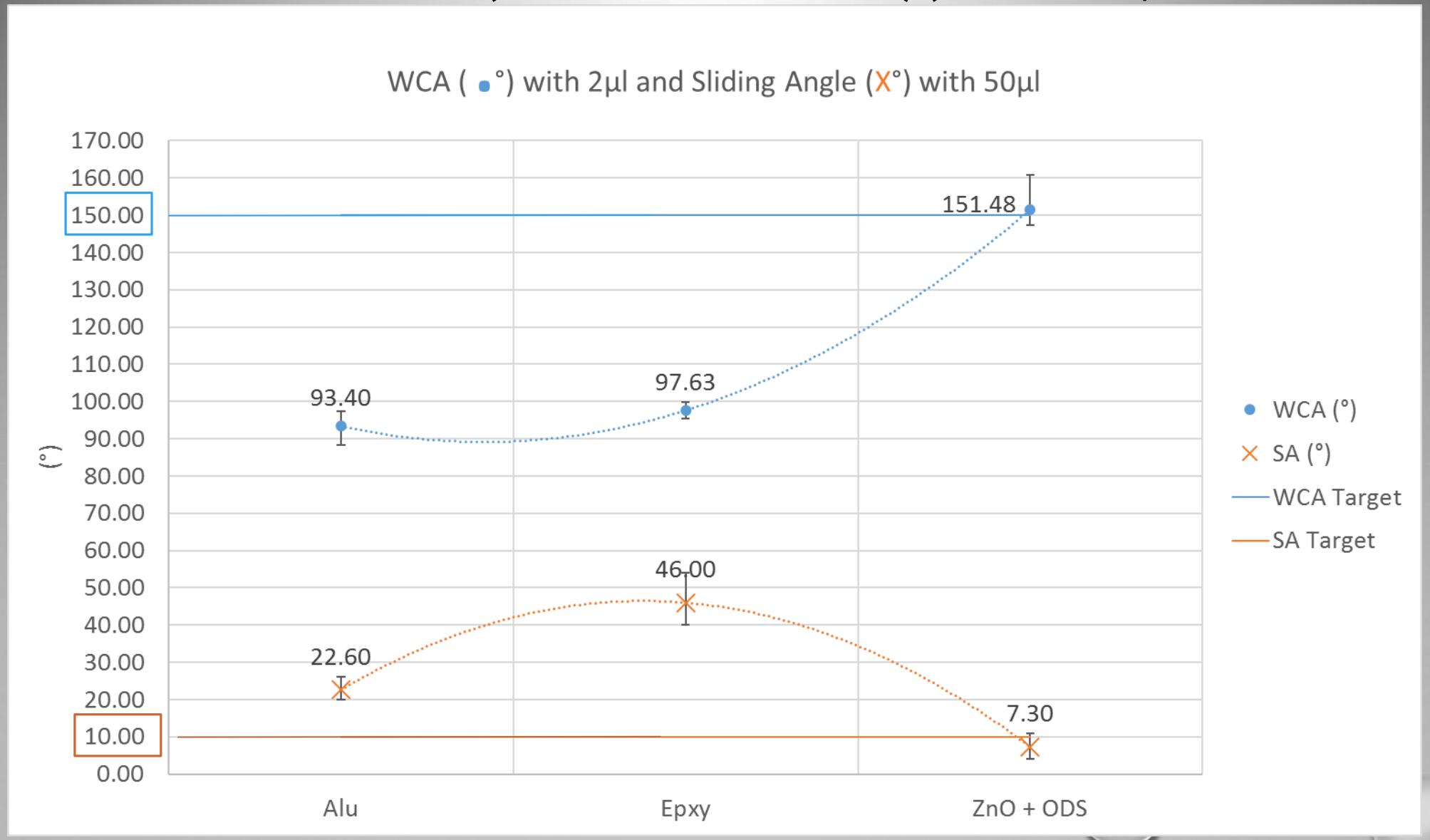
θ: Water Contact Angle (WCA)



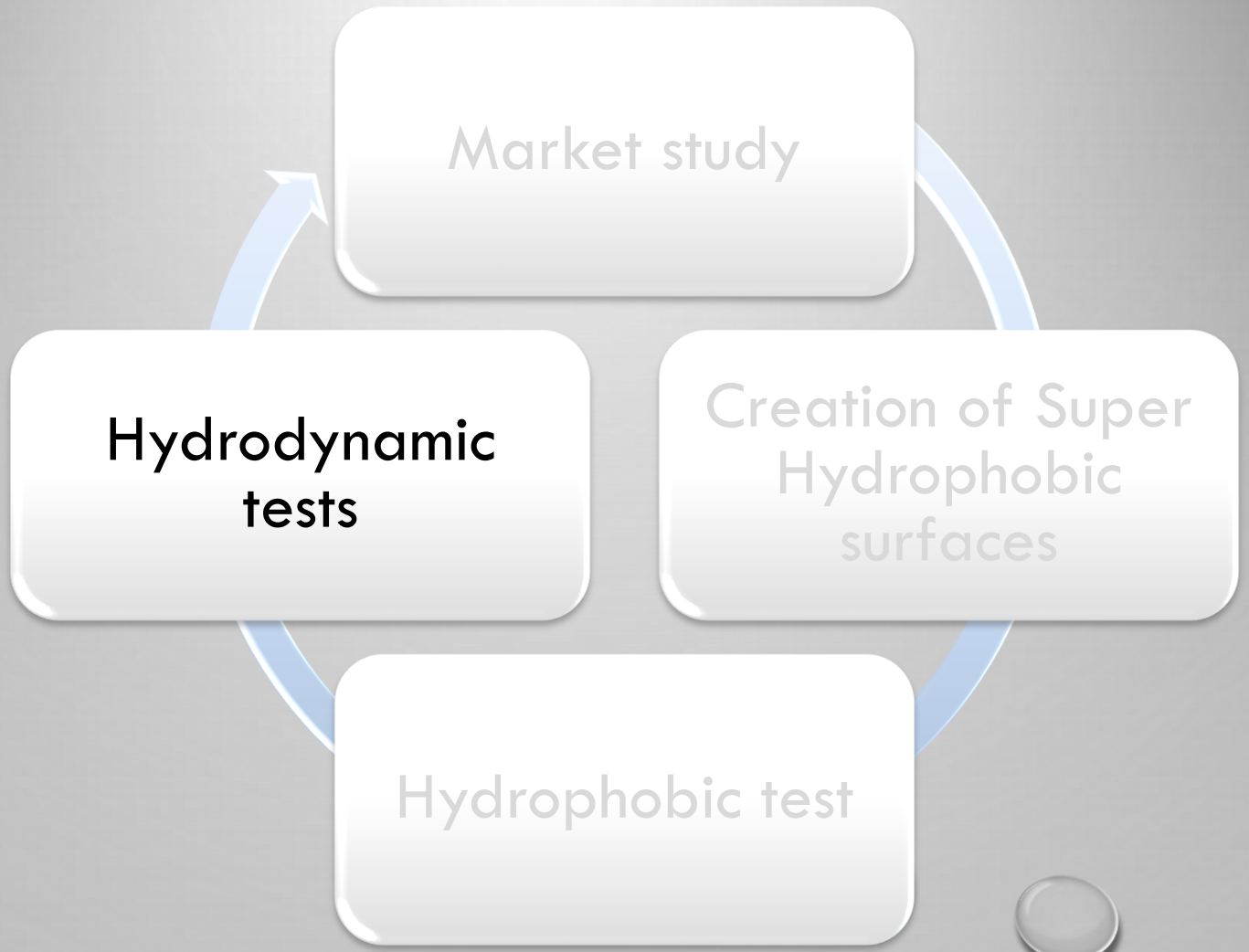
α: Sliding Angle (SA)

DSA25S, Kruss

CHARACTERIZATION (ALUMINIUM + EPOXY) (WCA & SA)



STRATEGY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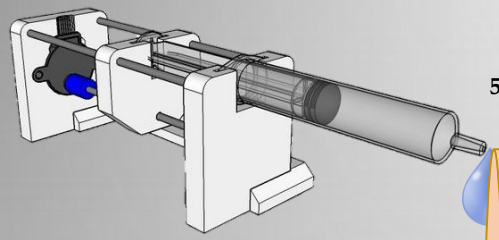
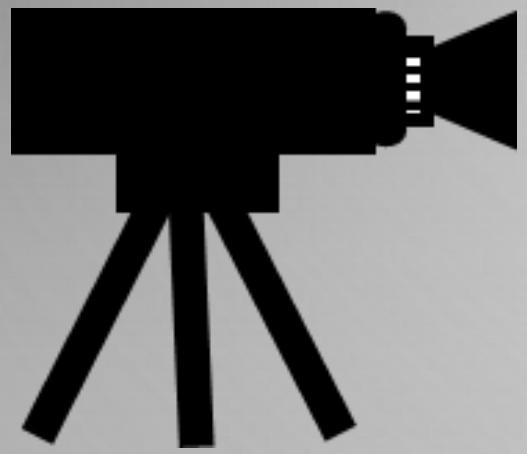
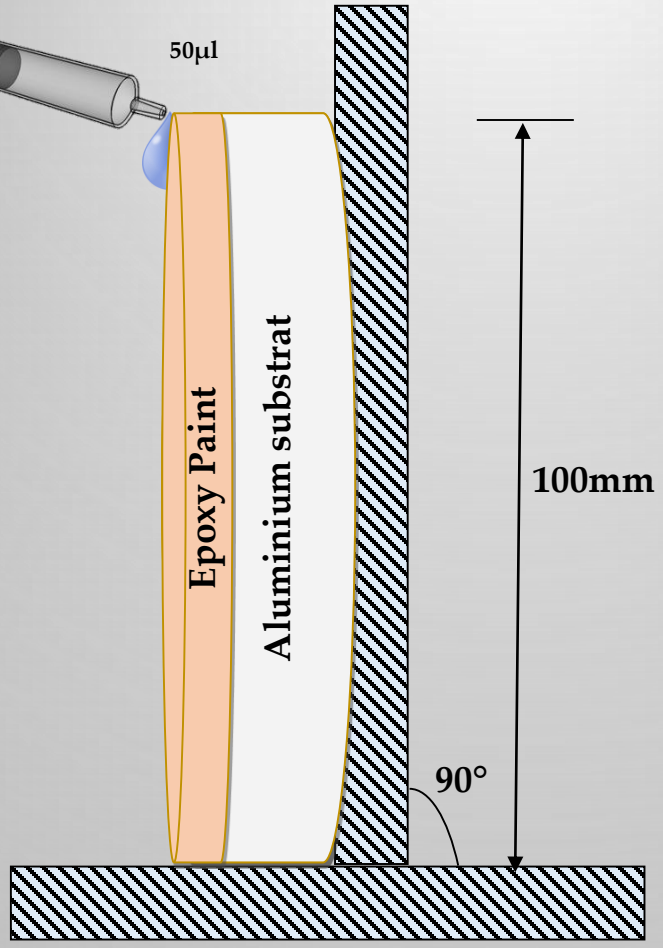
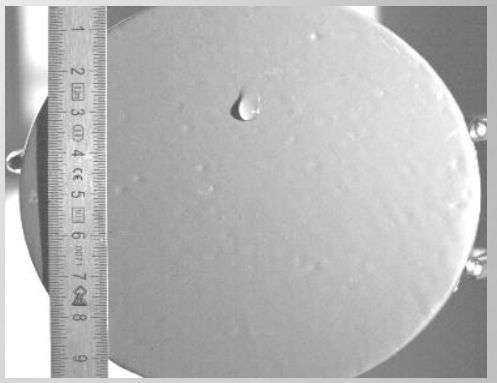
CHARACTERIZATION (SLIDING SPEED) (SS)



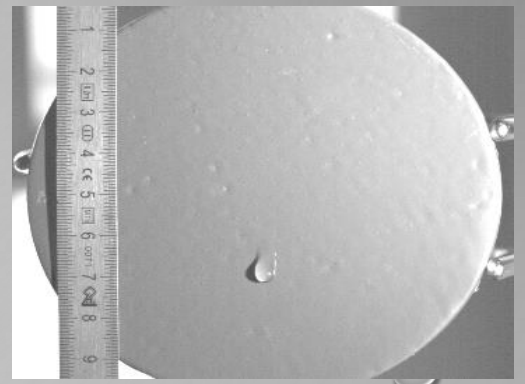




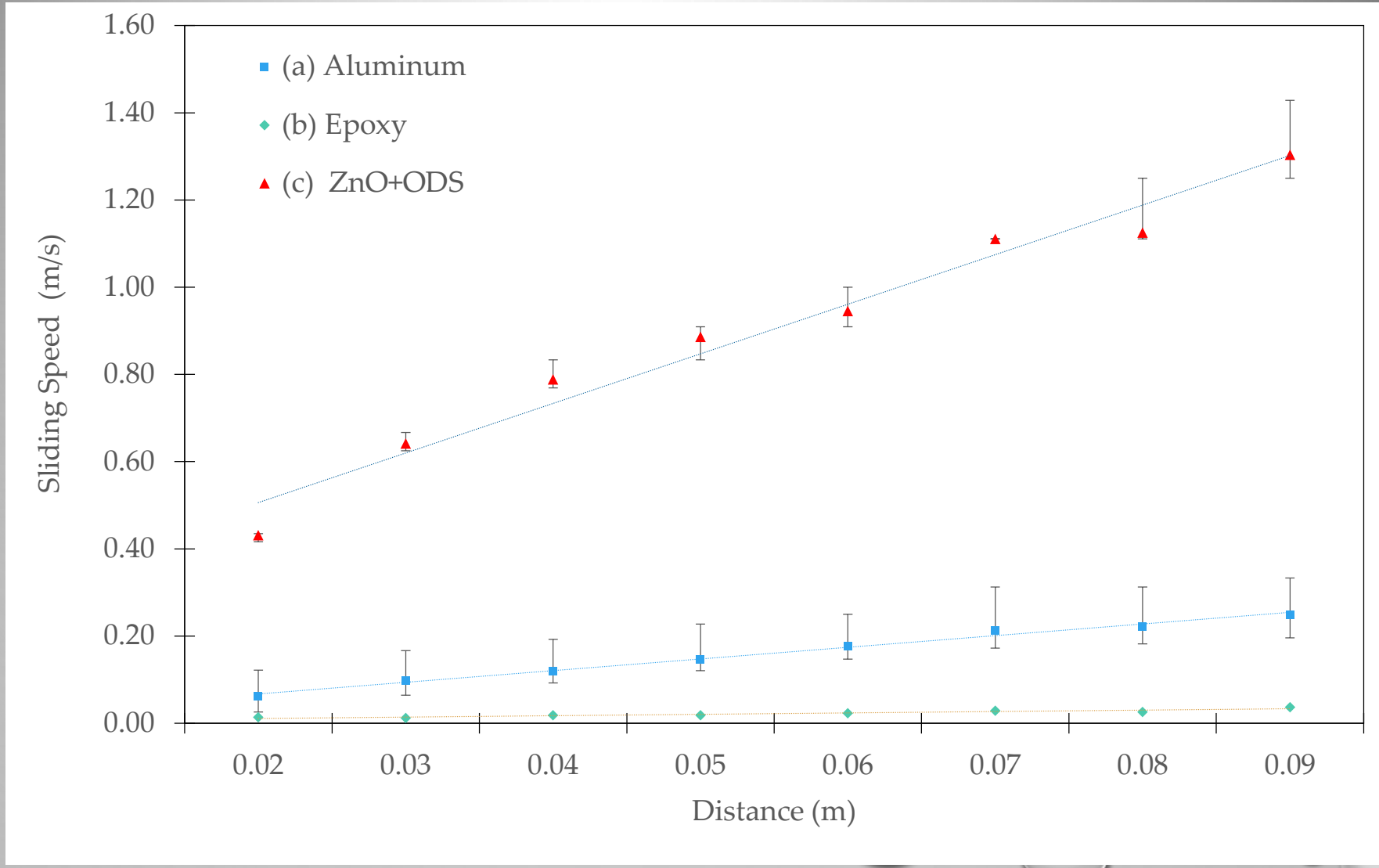
T= t



T= t + Δt



CHARACTERIZATION (ALUMINIUM + EPOXY) (SS)



CONCLUSION

- MARKET STUDY.
  - ✓ BEST WCA, SA & SLIDING SPEED (WCA +20%) (SA -55%) (VS +14%): **SILICONE PAINT**
- ACHIVEMENTS.
  - ✓ WCA >152°, SA < 7°
  - **PERSPECTIVES**:
    - APPLICATION NACA AIRFOIL

    - CHARACTERIZATIONS: FOULING, ANTIBACTERIAL, RESISTANCE & DURATION.