NOVEL MATERIALS FOR BIOFILM INHIBITION

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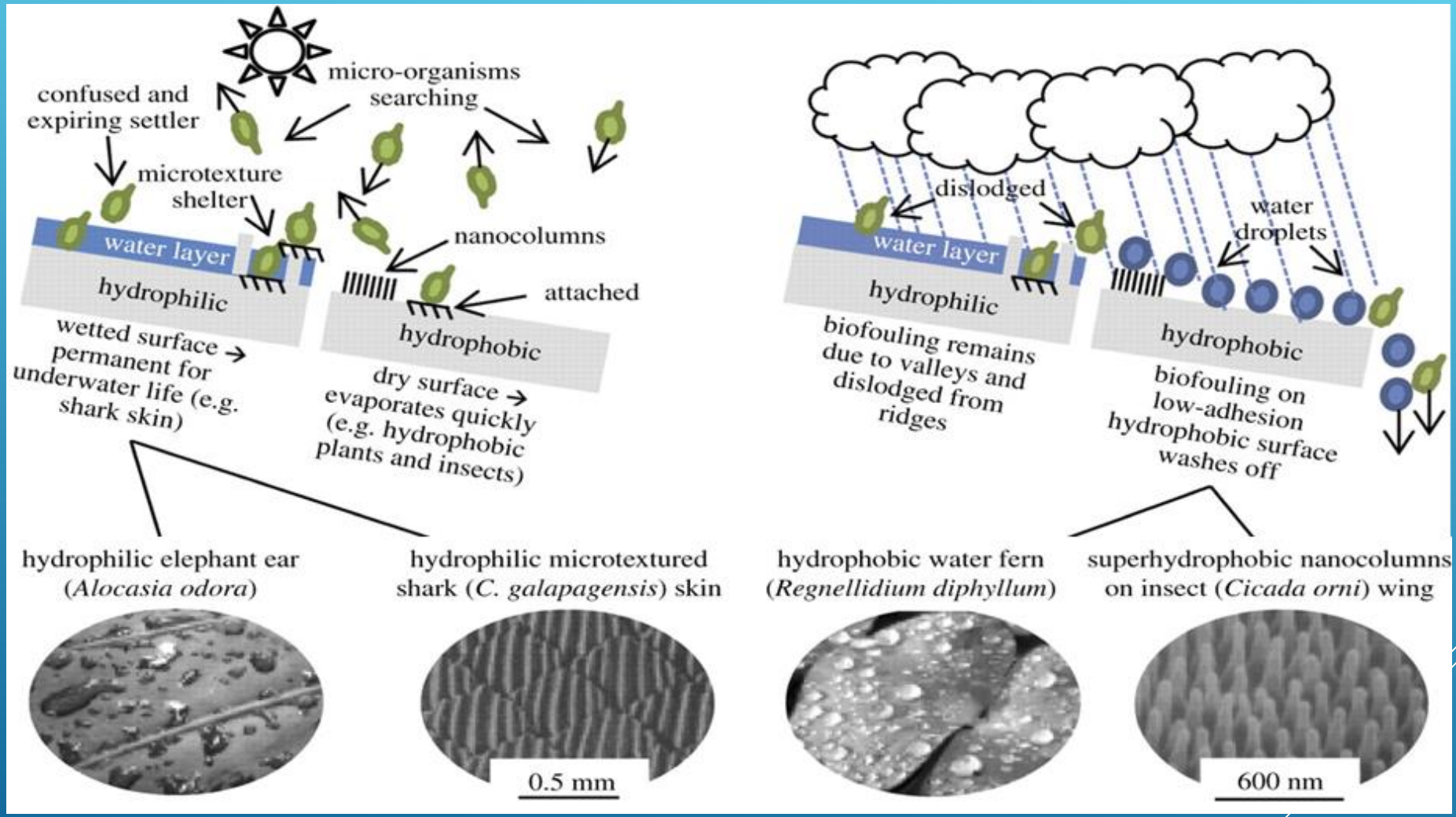
Introduction

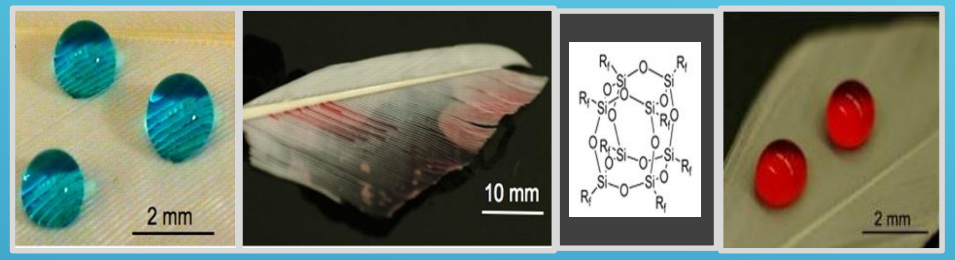
- Microbial contamination onboard the International Space Station (ISS) continues to pose significant mission risks, both in terms of crew health and functionality of mechanical systems.
- This project seeks to examine two types of novel materials coatings which discourage or eliminate biofilm formation through different mechanisms. Omniphobic surfaces display contact angles greater than 150° with essentially all liquids, including water, oils, alcohols, acids, bases, and blood.
- Phosphorylcholine (PC)-treated surfaces are highly hydrophilic, attracting water to form a water barrier that resists protein and cell adhesion.
- Both demonstrate great promise for inhibition of biofilm formation and water transportation in microgravity environments.

Background

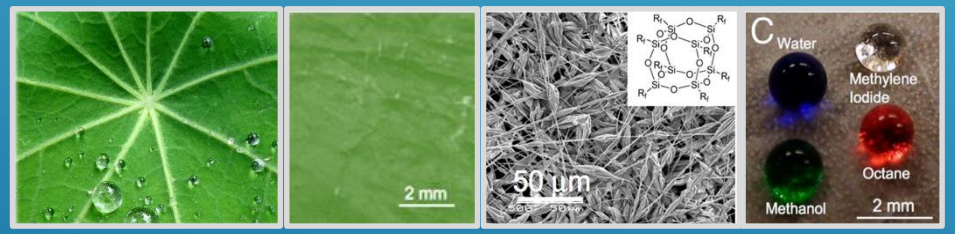

micro-organisms searching
confused and expiring settler
microtexture shelter
water layer
hydrophilic
nanocolumns
attached
hydrophobic
wetted surface → permanent for underwater life (e.g. shark skin)
dry surface → evaporates quickly (e.g. hydrophobic plants and insects)
dislodged
water droplets
water layer
hydrophilic
hydrophobic
biofouling remains due to valleys and dislodged from ridges
biofouling on low-adhesion hydrophobic surface washes off
hydrophilic elephant ear (Alocasia odora)
hydrophilic microtextured shark (C. galapagensis) skin
hydrophobic water fern (Regnellidium diphyllum)
superhydrophobic nanocolumns on insect (Cicada orni) wing
0.5 mm
600 nm

- Biofilm formation requires microbes finding suitable location to settle
- PC treated hydrophilic surface: water film results in confused and expiring organism.
- Omniphobic surface reduces fluid contact with surface, thereby reducing biofilm attachment locations and making solution biocide more effective

Omniphobic coatings



Duck feather repels water (blue), but not oil (red). Surface become omniphobic after dip-coated in a solution of fluorodecyl POSS.

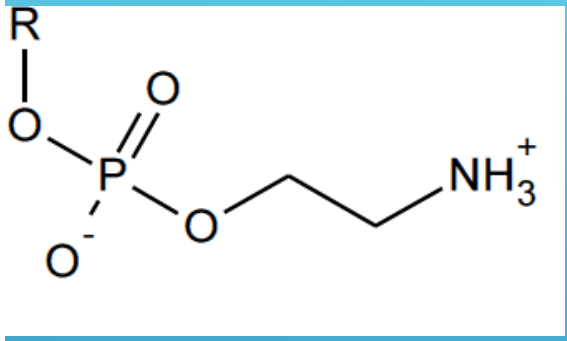


Lotus leaves repel water, but not octane. Surface becomes omniphobic after being covered with electrospun fibers (beads-on-strings morphology) of PMMA + 44 wt% fluorodecyl POSS.

Two omniphobic coatings, including the beads-on-strings, were prepared on 5 substrates:

- Inconel 718
- Stainless steel
- Titanium
- Polycarbonate
- Teflon

Hydrophilic coatings



- Phosphorylcholine is a zwitterionic, highly-polar head group; it attracts water to form a barrier that resists protein and cell adhesion.
- Hydrophilic coating process features vacuum plasma cleaning and activation steps before the coating the substrates with a PC-treated polymer.

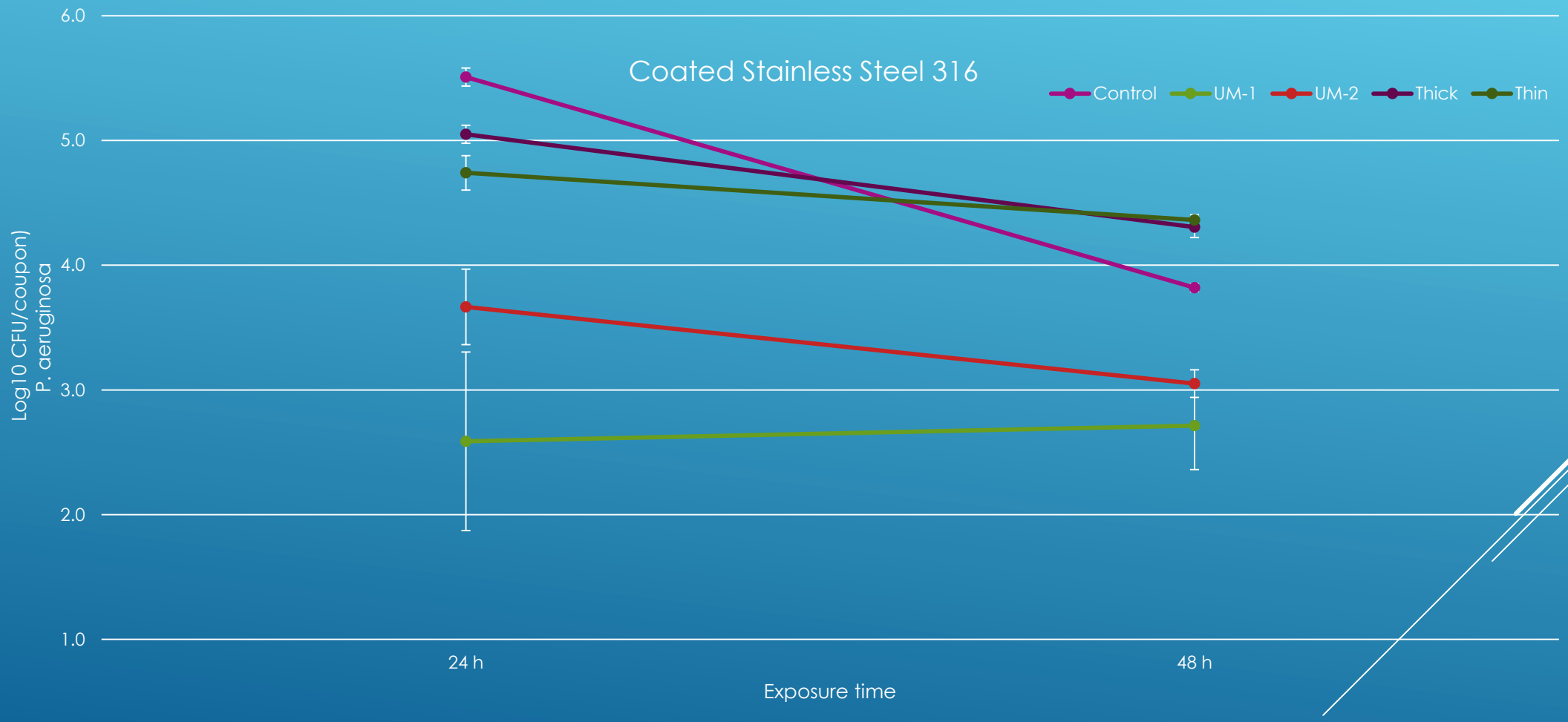
Table 1 reflects the surface property change in each steps, and the final formation of a hydrophilic coating. Contact angle change in each steps reflects the changes of surface properties from hydrophobic to hydrophilic.

Contact Angle	Before	Activation	Coating	Post Dip
Inconel 718	83°	<10°	50°	8 ± 4°
Stainless Steel	74°	<10°	54°	26 ± 5°
Titanium	75°	<10°	53°	13 ± 8°
Polycarbonate	89°	19°	56°	51 ± 2°
Teflon	115°	48°	57°	30 ± 9°

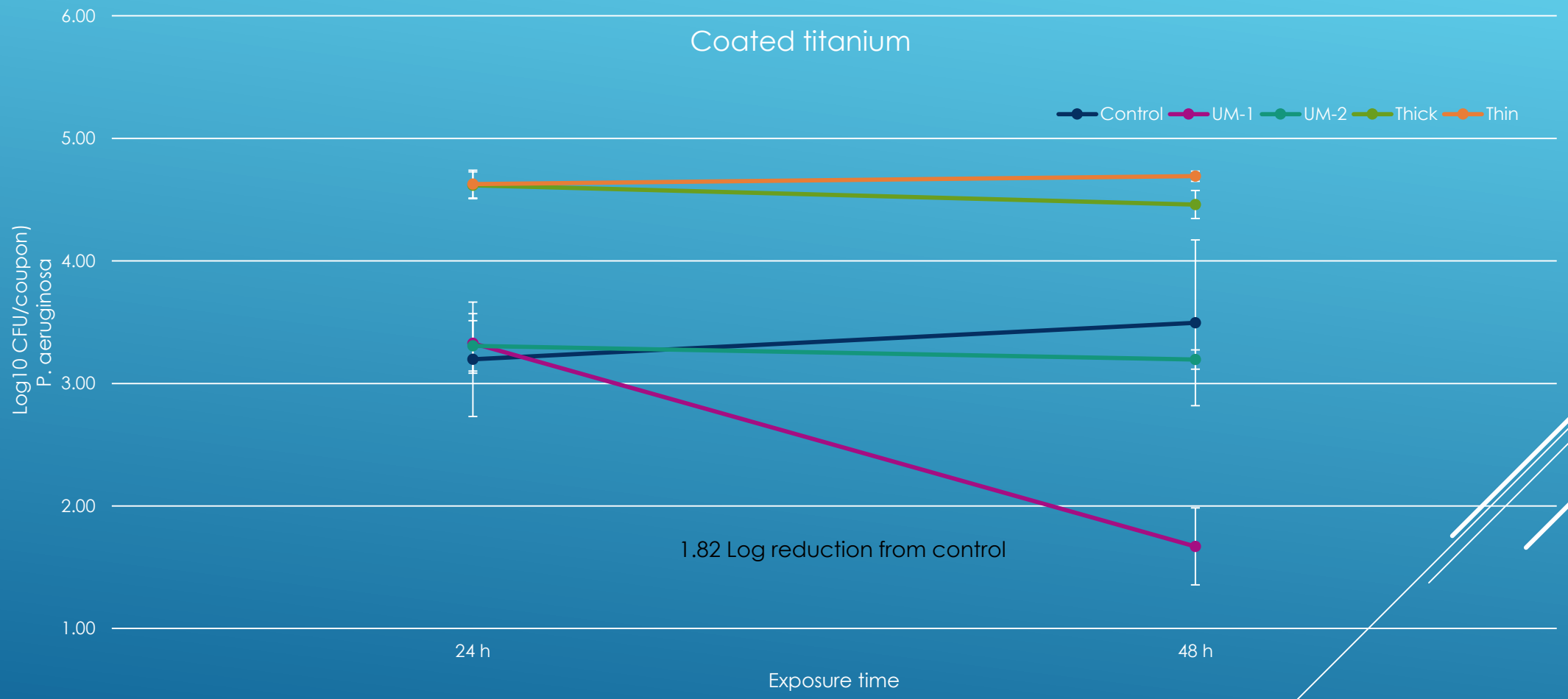
Project Overview

- Physical characterization and microbial testing of the omniphobic and PC-treated coatings are ongoing at KSC.
- The results will be used to further understand the affect of surface treatment on biofilm formation and provide insight to coating designed for more effective for biofilm prevention.
- Additional microbial testing is ongoing at UM on omniphobic coatings with novel active antibacterial agents.
- Initial results showed that biofilm prevention (*S. aureus col*, MRSA strain) can be achieved by incorporating an antibacterial agent.
- Parabolic flight testing is planned to understand the microgravity fluid dynamics with these treated surface (November 13, 2017).

Results


Coated Stainless Steel 316
Control
UM-1
UM-2
Thick
Thin
6.0
5.0
4.0
3.0
2.0
1.0
Log10 CFU/coupon)
P. aeruginosa
24 h
48 h
Exposure time

Results


Coated titanium
Control
UM-1
UM-2
Thick
Thin
6.00
5.00
4.00
3.00
2.00
1.00
Log10 CFU/coupon)
P. aeruginosa
1.82 Log reduction from control
24 h
48 h
Exposure time

CONCLUSIONS

- Omniphobic coatings prevent bacterial attachment for 48 hours.
- Hydrophilic coatings are ineffective in preventing bacterial attachment.
- Neither coating was effective when used with polycarbonate.

References

1. Tuteja, A., Choi, W., Mabry, J. M., McKinley, G. H.; Cohen, R. E. “Engineering robust omniphobic surfaces” *PNAS*, 105 (2008), 18200-18205
2. Lewis, A.L. “Phosphorylcholine-based polymers and their use in the prevention of biofouling” *Coll Sur B: BioInt*, 18 (2000), 261-275.

QUESTIONS?