Bio-inspired liquid-infused surfaces for reducing bacterial adhesion in catheters

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Self-Cleaning Surfaces

Cassie-Baxter State

Wenzel State

Barthlott and Neinhuis 1997 Planta 202 1-8
Nosonovsky 2011 Nature 477 412-413
Microorganisms: Adaptive Foulants

Friedlander et al. 2013, PNAS 110, 5624-5629
Bio-Inspired Slippery Surfaces

Bohn & Federle, 2004, PNAS 101, 14138-14143
Slippery Liquid-Infused Porous Surfaces (SLIPS)

1. Roughening
2. Functionalization
3. Lubricant Addition

Wong and Aizenberg et al., Nature 2011, 477, 443-447
Adv. Funct. Mat. 2014, 24, 6658-6667
Nanotech. 2013, 25, 014019
Nature Comm., 2013, 4, 2167-2177
Appl. Phys. Lett. 2013, 102, 231603
Nano Lett. 2013, 13, 1793-1799
Phys. Chem. CP 2012, 15, 581-585
ACS Nano 2012, 6, 6569-6577
Recipient: R&D 100
Award 2012
Start-up Company in 2014
In vitro bacterial resistance

E. coli, 48 hours

S. aureus, 48 hours

P. aeruginosa, 7 days

Epstein and Aizenberg et al., PNAS 2012 109:13182-13187
Liquid as a Physical Barrier

Static

Dynamic

Side View

Top View

Advanced Healthcare Materials 2017, 1600948
Customizable Platform Technology

Solid Material:
- Plastics
  - PET
  - PS
  - PVC
  - ...
- Metals
  - Steel
  - Titanium
  - Aluminum
  - ...
- Rubbers
  - Silicone
  - Fluoroelastomers
  - EP
  - ...
- Other
  - Glass
  - Enamel
  - Hydrogels
  - ...

Surface Functionalization:
- Intrinsic
- Added

Surface Structure:
- Micro Scale
- Nano Scale
- Flat
- Infused

Liquids:
- Pharmaceutical Grade
  - Perfluorodecalin
  - Perfluoroperhydrophenanthrene
  - Silicone oils
  - Others…

Advanced Materials 2018, 30, 1802724
Biofilm Resistance Under Laminar Flow

P. aeruginosa

Untreated

Liquid Surface

ACS Biomat. Sci. Eng. 2015, 1, 43-51
Treatment of Foley Catheters

**Silicone**

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<tr>
<th>Length</th>
<th>Cross-Section</th>
<th>Additional Cost</th>
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**Silicone-Coated Latex**

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<tr>
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Biofilms on Foley Catheters

*P. aeruginosa*

**Liquid Surface**

**Untreated**

Liquid Surface Untreated

Absorbance

- 24 hrs
- 48 hrs
- 168 hrs

*p = 0.00*

**Liquid Surface**

*Untreated*
Rethinking our approach: Physics Working for Us

3-Phase Contact

Chemistry of Materials 2015, 27, 1792-1800

Advanced Healthcare Materials 2017, 1600948
Spontaneous Biofilm Stripping

Coated Catheter Piece

Stain Biofilm

Liquid Surface

Biofilm
Rethinking our approach: Physics Working for Us

Diffusion

Surface liquid replenishment

ACS Appl. Mat. Int. 2014, 6, 13299-13307
Vascular systems for continuous resistance

ACS Appl. Mat. Int. 2014, 6, 13299-13307
Rethinking our approach: Physics Working for Us

Liquids as Solvents
Summary

• Bio-inspired slippery liquid surfaces

A *non-solid* paradigm shift in anti-biofouling materials and interfaces

• Resist bacterial adhesion

• Straightforward application to catheters

• Potential platform for new approach to anti-adhesive surfaces
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