Superhydrophobic and omniphobic, slippery surfaces to prevent bacterial surface attachment

Presenter: Benjamin Hatton, University of Toronto, Toronto, Canada
Co-Authors:Tak-Sing Wong, Penn State; Joanna Aizenberg, Harvard University

Recent years have shown a development in non-wetting, 'superhydrophobic' surfaces, which can resist the wetting of liquids (typically aqueous) by mechanism known as the Cassie-Baxter effect. A rough, hydrophobic surface causes the liquid interface to be stuck at the tips of the rough surface features, and an air layer is maintained underneath. This type of surface – often seen in plant leaves such as the lotus, insects such as the water strider, and many bird feathers – can be very stable against wetting, and sometimes even for liquids with relatively low surface tension (i.e.; alcohols). However, these surfaces often 'fail' (become fully wetted) after some time, or due to surface defects, or exposure to surfactants. Therefore, efforts to use such materials to prevent the formation of bacterial biofilms (or marine biofouling) have generally been unsuccessful. Once full wetting of the surface features occurs, the non-wetting, Cassie-Baxter state does not (typically) return, and the bacteria can easily populate the surface to produce a highly-adherent biofilm.

Most recently, however, our lab (Harvard University, School of Engineering and Applied Sciences) has developed a novel 'omniphobic' surface that is highly-resistant to the wetting of any liquid, even very low surface tension, and over extended periods of time [1]. This material, known as a Slippery Liquid-Infused Porous Surface (SLIPS), incorporates a thin layer of lubricant around the rough microstructure of the substrate surface, which is energetically stable (has a strong chemical affinity for the surface) and is immiscible to other contacting liquids. Therefore, other liquids – including an aqueous medium, containing bacteria – in contact with this surface can only 'see' this smooth, stable lubricant layer, and there is very little opportunity to develop a physical adhesion. As a result, bacteria grown in contact with SLIPS materials cannot adhere, and there is insignificant biofilm growth even after an extended time. For example, *Pseudomonas aeruginosa* was cultured for 7 d under static and flow conditions, but a SLIPS material (incorporating a perfluorocarbon lubricant) remained 99.6% (by area) without bacterial attachment, compared to a fluorinated polymer control (PTFE).

Herein we show results for the antimicrobial properties of superhydrophobic materials, and show that SLIPS-based anti-biofilm surfaces can be highly effective to prevent bacterial adhesion, and also stable in submerged and extreme environments. They are low-cost, passive, simple to manufacture, and can be formed on arbitrary surfaces. We anticipate that these approaches could enable a broad range of anti-biofilm solutions in clinical and industrial environment.

[1] T. S. Wong, S. H. Kang, S. K. Y. Tang, E. J. Smythe, B. D. Hatton, A. Grinthal, J. Aizenberg, Bioinspired self-repairing slippery surfaces with pressure-stable omniphobicity. *Nature* **477**, 443 (2011).
[2] A. K. Epstein, T. S. Wong, R. A. Belisle, E. M. Boggs, J. Aizenberg, Liquid-infused structured surfaces with exceptional anti-biofouling performance. *Proceedings of the National Academy of Sciences* **109**, 13182 (2012).