

PhD PROJECT PROPOSAL

PhD PROJECT TITLE

The roles of nanotopography and vibration on controlling long-term bacterial adhesion

PhD SUPERVISORY TEAM

Principal Supervisor

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PhD PROJECT DETAILS

Project abstract

All organisms respond to vibration, and bacteria are no exception. It is well established that external vibration can affect bacterial phenotypes, including surface adhesion, proliferation and virulence. However, the question how bacteria perceive large scale and local nanoscale vibration cues from their environment, and how they integrate and translate this information to result in altered bacterial physiology on a molecular level, remains unanswered. In an unprecedented interdisciplinary approach combining cutting-edge techniques and tools from nanotechnology, acoustics and microbiology, this project aims explore how sub- and supracellular vibrational stimuli are perceived and processed by bacteria and if vibration and nanoscale topography can act in synergy to induce superior anti-bacterial properties.

Application of Topology

The main research goal of this project is to understand how bacterial adhesion is affected by nanoscale vibration cues. Our principal objective is to discover which nanofeatures and vibrational characteristics influence the adhesion of different types of bacteria, through the use of surface engineering technologies to fabricate well-defined dynamics of vibration on nanostructured surface materials.

DETAILED PROJECT DESCRIPTION

Please submit the details of the proposed project here. Information on the details required in this section can be found in the guidance below in point 3. Max. 1000 words including figures, diagrams and references.

Bacteria have propensity to colonize abiotic surfaces, resulting in the formation of structured, multicellular communities known as biofilms. Biofilms are often responsible for human infections (e.g. on implants and urinary catheters), contamination of processed products such as food, clogging of pipes, reduction of heat transfer in heat exchangers and cooling towers and fouling of ship hulls causing increased fluid resistance and fuel

consumption. Since they adversely affect so many human activities, prevention or eradication of biofilms has been a topic of intensive research over the past decades. Although progress has been made, strategies are still subject to limitations in terms of their long-term resistance to bacterial adhesion. For example, chemical antimicrobials can generate multidrug-resistant bacteria, with potentially devastating consequences for animal and human health.

Consequently, there is an urgent need for new strategies to prevent bacterial attachment to abiotic surfaces. Recent studies demonstrated that bacteria respond to mechanical stimuli, including the unique dynamic loading regimes induced by vibration, by modulating phenotypes such as surface adhesion, proliferation and virulence.[1-4] Furthermore, previous studies have provided evidence that man-made nanostructured surfaces, which also exist in nature, have a direct influence on bacterial cell attachment.[5] However, such nanostructures behave as static interfaces. Thus, the question arises concerning the significance of providing such nanostructured surfaces with vibration to influence bacterial adhesion. In this line of reasoning, the project aims explore how sub- and supracellular vibrational stimuli are perceived and processed by bacteria and if vibration and nanoscale topography can act in synergy to induce superior anti-bacterial properties. We will construct and characterise dynamic solid biointerfaces that act as resonators. These surfaces will possess features from the micrometre to the nanometre scale-such structured surfaces are known to influence bacterial adhesion. The effect of different structures and vibrational regimes on bacterial adhesion will be tested.

Nanostructures will be created using soft lithography replica molding and the nanostructures will be characterised for morphology, composition and wettability using atomic force microscopy, scanning electron microscopy, energy dispersive X-ray spectroscopy and contact angle. Bacterial adhesion will be analysed using standard microbiology techniques as well as microscopy (confocal laser scanning microscopy, Raman confocal microscopy, atomic force microscopy).

This understanding will allow development of next generation surfaces that prevent the attachment of bacteria, which could be used to make products such as: urinary catheters that are resistant to colonisation and therefore reduce infections in hospitals; antimicrobial surfaces for food processing to prevent spoilage or contamination of food; and industrial equipment that resists bacterial attachment, which would increase process efficiency.

The project will be supervised by Professor Paula Mendes with expertise on nanotechnology and biointeractions and Dr Tim Overton with expertise on microbial physiology and bacterial biofilms, both located in the School of Chemical Engineering.

A degree in Engineering, Chemistry, Material Sciences, Physics or Biology is required.

(1) Hazan, Z.; Zumeris, J.; Jacob, H.; Raskin, H.; Kratysh, G.; Vishnia, M.; Dror, N.; Barliya, T.; Mandel, M.; Lavie, G. Effective prevention of microbial biofilm formation on medical devices by low-energy surface acoustic waves. *Antimicrob. Agents Chemother.* 2006, 50, 4144-4152.

- (2) Paces, W. R.; Holmes, H. R.; Vlasisavljevich, E.; Snyder, K. L.; Tan, E. L.; Rajachar, R. M.; Ong, K. G. Application of sub-micrometer vibrations to mitigate bacterial adhesion. *J. Funct. Biomater.* 2014, 5, 15-26.
- (3) Murphy, M. F.; Edwards, T.; Hobbs, G.; Shepherd, J.; Bezombes, F. Acoustic vibration can enhance bacterial biofilm formation. *J. Biosci. Bioeng.* 2016, 122, 765-770.
- (4) Robertson, S. N.; Campsie, P.; Childs, P. G.; Madsen, F.; Donnelly, H.; Henriquez, F. L.; Mackay, W. G.; Salmeron-Sanchez, M.; Tsimbouri, M. P.; Williams, C.; Dalby, M. J.; Reid, S. Control of cell behaviour through nanovibrational stimulation: nanokicking. *Philos. Trans. R. Soc. A-Math. Phys. Eng. Sci.* 2018, 376, 21.
- (5) Michalska, M.; Gambacorta, F.; Divan, R.; Aranson, I. S.; Sokolov, A.; Noiro, P.; Laible, P. D. Tuning antimicrobial properties of biomimetic nanopatterned surfaces. *Nanoscale* 2018, 10, 6639-6650.