Advancements in biomimetic antimicrobial nanostructures: unravelling mechanisms, engineering applications, and theoretical insights

Prof., Prasad Yarlagadda University of Southern Queensland, Queensland, Australia, Queensland University of Technology, Queensland, Australia (presenter)
Dr Asha Mathew,University of Southern Queensland, Queensland, Australia, Queensland University of Technology, Queensland, Australia
Dr Amal Senevirathne, Queensland University of Technology, Queensland, Australia
Dr Dimuthu Herath, University of Southern Queensland, Queensland, Australia

Abstract

Statement of the Problem: Antibacterial nanostructured surfaces (NSSs) have been established as a promising nanotechnology to manage biofilms, as they physically inactivate bacteria and other microorganisms through direct contact and cell envelope damage, without the need for disinfectants or antibiotics which promote resistance. This technology derives from mimicking the naturally occurring NSS such as those found on the wings of cicadas or dragon flies. Since 2016, Prof Prasad Yarlagadda's group is working on developing nanomaterials with antibacterial properties. Natural nanostructures are found in distinct configurations: ordered patterns on cicada wings and random arrangements on dragonfly wings. We achieved significant milestones by fabricating both types of nanostructures on diverse substrates including titanium, stainless steel, aluminium, and polymers. By exploring advanced techniques like electron beam lithography, reactive ion etching, wet etching and hydrothermal etching the group has mastered methodologies to fabricate both organized and random nanostructures. Over the past decade, the research in antibacterial NSS has diverged with surfaces demonstrating a notable variation in BE; ranging from 5% to 99% suggesting that there are important yet overlooked factors influencing bacterial cell death and hence, attempts to correlate all known parameters to BE has been unsuccessful. This diversity in research makes it impossible to unravel a generalized the actual mechanism of cell death on NSSs. As depicted in graphical abstract, our current research uses a combination of theoretical analysis, computer simulations, artificial intelligence, and experimental investigations to elucidate the underlying molecular mechanisms and the complex relationship with NSS properties to provide guidelines for the engineering of NSS with enhanced BE for each material.

Conclusion & Significance: This exciting line of research will provide a mechanistic, molecular-level understanding of the interplay between bacterial cell mechanics and physiological responses, which ultimately underpins NSS antibacterial behaviour but has remained elusive to date.

Image

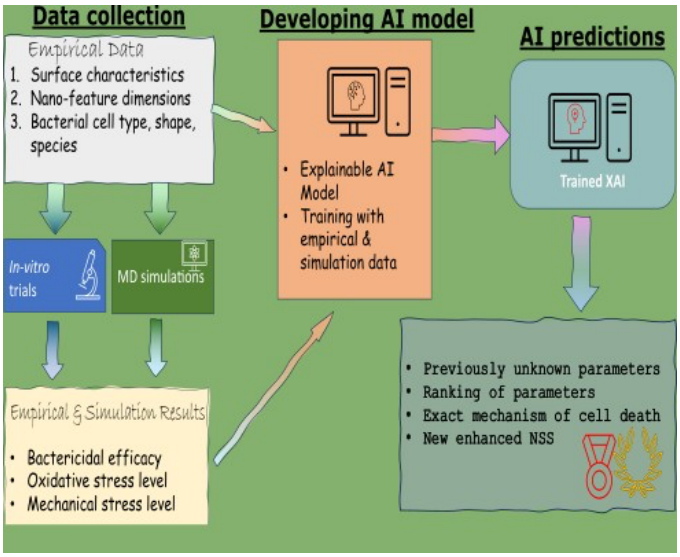

Figure 1. The hybrid model approach to enhance the reliability and effectiveness of antibacterial NSSs.

Recent publications:

1. Senevirathne, S. W.M.A.I Shantha, Mathew, Asha, Toh, Yi Chin, & Yarlagadda, Prasad K.D.V. (2023) Nanoscale Advances, 5(23), pp. 6458-6472.
2. Kumara, S. P.S.N. Buddhika Sampath, Senevirathne, S. W.M. Amal Ishantha, Mathew, Asha, Bray, Laura, Mirkhalaf, Mohammad, & Yarlagadda, Prasad K.D.V. (2023) Nanomaterials, 13(20), Article number: 2799.
3. Mathew, Asha, Hasan, Jafar, Singamneni, Sarat, & Yarlagadda, Prasad K.D.V. (2023) Advanced Engineering Materials, 25(8), Article number: 2201306.
4. Islam, Majedul, Aldawsari, Falah Sahal S., & Yarlagadda, Prasad K.D.V. (2023)
5. Senevirathne, S. W.M.A. Ishantha, Mathew, Asha, Toh, Yi Chin, & Yarlagadda, Prasad K.D.V. (2022) ACS Omega, 7(45), pp. 41711-41722.

Photograph

Biography

Prof. Prasad KDV Yarlagadda worked in industry and university over 38years. He is distinguished graduate of IIT Bombay and refined his expertise in manufacturing through extensive experience across India, Hong Kong, Papua New Guinea, and Singapore before establishing himself in Australia. Currently serving as Dean (Engineering) at the University of Southern Queensland, he previously held positions at Queensland University of Technology as Professor in Smart Systems and Domain Leader: Medical Devices. Throughout his career, Prof. Yarlagadda advanced manufacturing engineering globally, fostering collaborations with institutions such as City University of Hong Kong, Nanyang Technological University, and various Indian universities. He is also an advisor of various international government organizations and professional societies. His academic expertise is evident in securing over $18M in funding, supervising 60+ higher degree research students, and publishing 600+ peer-reviewed articles. Few of his recognitions include the Prestigious Great Honour Award from the Polish Academy of Sciences and the Order of Australia Medal. His dedication to engineering education earned him the title of VAJRA Professor from the Government of India and Principal Fellow of the Higher Education Academy, UK. In 2020, he secured the Australian Advanced Materials Award, cementing his legacy as a pioneering figure in manufacturing engineering and a leader of global higher education.

Email: y.prasad@unisq.edu.au