Biomaterial Interfaces Division
Room B117-119 - Session BI1+PS-MoM

Microbes and Fouling at Surfaces

Moderators: Kenan Fears, U.S. Naval Research Laboratory, **Sally M. McArthur**, Deakin University, Australia

8:20am **BI1+PS-MoM-1 Amphiphilic Coatings for Marine Low-Fouling Applications***, **Axel Rosenhahn**,* Ruhr University Bochum, Germany **INVITED**

Manmade materials in contact with ocean water become rapidly colonized by living matter like bacteria, diatoms, barnacles, or mussels. Increased fuel consumption, failure of devices, and substantial maintenance costs are among the penalties associated with marine biofouling. As the historical paradigm to combat fouling by biocide releasing coatings is increasingly challenged by legal restrictions, environmentally benign low-fouling materials for marine applications are intensively explored [1]. While several hydrophilic and hydrophobic materials show promising properties, their combination into amphiphilic coatings unites the best of the two worlds [2]. As hydrophilic compound, zwitterionic materials with different molecular architectures were developed and their structure-function relationship against different fouling organisms have been studied [3]. Amphiphilic coatings based on zwitterionic polymers have been designed and their anti-polyelectrolyte properties have been characterized by several methods including AFM and SPR. Their antifouling properties against a range of marine fouling species and in short term field exposures have been assessed and the results will be discussed under consideration of the interaction of the organic coatings with inorganic particulate matter in the ocean [4,5,6]. Based on the obtained data, design criteria for optimized zwitterionic building blocks for fouling-release technologies will be discussed.

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[2] S. Krishnan, C. Weiman, C. Ober, J. Materials Chemistry 2008, 18, 3405

[3] A. Laschewsky, A. Rosenhahn, Langmuir 2018, 35, 1056

[4] F. Koschitzki, R. Wanka, L. Sobota, J. Koc, H. Gardner, K.Z. Hunsucker, G.W. Swain, A. Rosenhahn, ACS Applied Materials & Interfaces 2020, 12(30), 134148

[5] J. Koc, E. Schönemann, R. Wanka, N. Aldred, A.S. Clare, H. Gardner, G.W. Swain, K. Hunsucker, A. Laschewsky, A. Rosenhahn, Biofouling 2020, 36(6), 646

[6] L. Schardt, A.M. Guajardo, J. Koc, J.L. Clarke, J.A. Finlay, A.S. Clare, H. Gardner, G.W. Swain, K. Hunsucker, A. Laschewsky, A. Rosenhahn Macromolecular Rapid Communications 2021, 43(12), 2100589

9:00am **BI1+PS-MoM-3 Bio-Informed Interface Design and Synthesis to Manipulate Microbial Behavior***, **Rong Yang**,* Cornell University **INVITED**

Biofilm is often considered detrimental, which needs to be minimized as it can cause infections and fouling in healthcare, food and water manufacturing, and underwater civil and military activities. Nevertheless, we also believe such naturally occurring biofilm can be desirable, upon appropriate programming via precise control over the surface they inhabit, as building blocks for self-actuated and self-repairing "living" coatings. To gain insight into the biointerface, research in the past two decades has unraveled the fundamental thermodynamics and hydrodynamics that have guided the design of numerous antifouling/antimicrobial surfaces. However, the biological effects of insoluble materials remain elusive. Recent advances in vacuum-based synthesis have enabled well-defined material properties at length scales relevant to microbes' biochemical and biophysical activities, enabling a bio-informed materials design approach. Motivated by the unmet needs for antifouling materials and living materials, our recent research has advanced our current understanding of the biointerface in three critical ways: (***i***) leveraging dynamic surface chain reorientation to achieve antifouling at the air-liquid-solid interface, the importance of which has been overlooked in past research; (***ii***) recognizing bacteria to be complex microorganisms with dynamic structure and metabolism and sophisticated chemical communication systems and leveraging the recent breakthroughs in microbiology to guide the design of bio-active polymer coatings; (***iii***) enabling living materials by performing polymerization directly on living organisms, which overcomes the limited tunability of the native microbial extracellular scaffolds and preserves the function and viability of coated organisms by avoiding harmful synthesis conditions. We seek to underscore the importance of understanding detailed microbe-material interactions and provide an outlook on extending the material-bacteria interactions beyond "kill or repel" towards signaling and control.

9:40am **BI1+PS-MoM-5 Using Flow-Cells to Culture Microbial Biofilms for Improved Secondary Ion Mass Spectral Imaging***, **Yuchen Zhang**,* Oak Ridge National Laboratory, USA*; X. Yu,* Oak Ridge National Laboratory

Bacterial biofilms are a main player in organic processing in the environment. Therefore, characterization and understanding of the biofilm interactions with groundwater and soil components is important in deepening our knowledge in the biosphere and rhizosphere. We present two approaches to prepare the bacterial biofilms suitable for time-of-flight secondary ion mass spectrometry (ToF-SIMS). *Shewanella* MR-1 was used as the model bacteria biofilm due to their known traits in subsurface, surface, and soil microbiology. A mixture of silica, alumina, and iron oxide was used as the model soil system. In the static culture, the bacteria were inoculated in a multi-well cell culture dish at their log phase. Then minerals were added to the culturing well. The mixture of the bacteria biofilms and minerals were scratched off carefully and deposited onto the clean silicon (Si) wafers before ToF-SIMS analysis. Second, we used a microfluidic cell to culture biofilms. We made a modification of the system for analysis at the liquid vacuum interface (SALVI) microfluidics for biofilm attachment in the growth and detection chamber. The mineral components were mixed to the growth media at a ratio of 1:1 by volume as nutrients to support the biofilm's growth. During static culturing, a series of Si wafers were used to capture the temporal progression of the biofilms and the soil components over days. In dynamic cultures, effluents were collected onto clean Si substrates. The time intervals were chosen based on the growth curve of the strain. Distinctive fatty acids peaks of *Shewanella* biofilms, such as myristic acid (m/z^- 227, $C_{14}H_{27}O_2^-$), palmitic acid (m/z^- 255, $C_{16}H_{31}O_2^-$), and arachidic acid (m/z^- 311, $C_{20}H_{39}O_2^-$), and the biomarker riboflavin peak (m/z^- 241, $C_{12}H_9N_4O_2^-$) are observed in the dynamic results. In contrast, the static results do not provide as much information. This finding indicates that static culture is not optimal for studying biofilms using ToF-SIMS. Our results demonstrate that sample preparation is quite critical in microanalysis of bacteria biofilms, specifically in surface analysis like ToF-SIMS. The microfluidic growth chamber is more flexible in microbial culture and media tuning, both are important in simulating a variety of conditions to understand microbes and soil interactions at the microscale. Additionally, characteristic signals of biofilms are not buried under the mineral components in the dynamic setup, which is imperative in understanding the role of biofilms in soil aggregation and bioremediation occurring at the microbial interface.

10:00am **BI1+PS-MoM-6 Role of Microbial Biofilms in the Settlement of Macrofoulers on Antifouling Marine Coatings***, **Sara Tuck**, M. Kardish,* US Naval Research Laboratory*; B. Orihuela,* Duke University*; G. Vora,* US Naval Research Laboratory*; D. Rittschof, K. Franz,* Duke University*; K. Fears,* US Naval Research Laboratory

Accumulation of biofouling on submerged surfaces is a foundational problem for maritime transport and human health. Biofouling build-up increases the drag coefficient, fuel consumption, exhaust emissions, and operational costs. Traditionally, biofouling is inhibited by the application of antifouling coatings, the most popular of which, contain copper. Copper-based antifouling coatings can contain up to ~75% CuO, by weight, in attempt to release sufficient levels of copper to deter the settlement of fouling organisms. Despite these high loadings, the efficacy of these antifouling coatings has been declining with the emergence and spread of copper tolerant species. Microbial communities resistant to copper have been found to form mature biofilms on these coatings, which could be altering the interfacial properties to create more favorable conditions for the settlement of a broader biofouling community. To gain an understanding of the mechanisms responsible for the loss in antifouling performance, coated and uncoated polyvinyl chloride panels were submerged at estuarine and marine field test sites and microbial communities were harvested. Collected biofouling communities were cultured and individual species were collected and identified. Copper tolerance was assessed by re-exposing cells to copper-containing coatings and traditional antimicrobial assays to determine susceptibility to an array of biocides. Finally, resistant biofilms were formed on marine coatings to assess the effect of their presence on the settlement of acorn barnacle larvae.

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