

## Biomaterial Interfaces

### Room Ballroom BC - Session BI-ThP

#### Biomaterial Interfaces Poster Session

**BI-ThP-1 Antifouling Properties of Plastron Forming, Ultra-Porous, Superhydrophobic DCP- and PFPE-Based Coatings, Georg Friedrich Breilmann, Louisa Vogler, Onur Özcan, Axel Rosenhahn, Ruhr-University Bochum, Germany**

One key problem of humanity for several thousand years has been biofouling. It occurs on artificial surfaces by creating biofilms consisting of organic matter, such as proteins, lipids or bacteria within seconds after immersion into seawater.<sup>[1,2]</sup> In addition, macrofoulers, e.g. algae or barnacles can attach and form slimy layers on the surfaces.<sup>[3,4]</sup> Biofouling has several detrimental consequences such as higher greenhouse gas emissions during propulsion, transfer of invasive species, and an increased work required to maintain immersed surfaces, all affecting both economy and environment.<sup>[5]</sup> To combat the formation of biofouling we created superhydrophobic surfaces (SHSs), which form a protective air layer between water and the submersed surface, so called plastrons. Five ultra-porous SHSs with different porosities, three based on ethylene glycol dicyclopentenyl ether methacrylate and two based on perfluoropolyether urethane methacrylate, were prepared by introducing porogens during the polymerization process. The coatings were tested regarding their superhydrophobicity, plastron formation, and plastron longevity. The wettability was analyzed by static and dynamic water contact angle goniometry to determine the wetting hysteresis as important quantities that characterize the ability of the terminating molecules of the coatings to reorientate once in contact with water. In addition, the water sliding angle was determined as an important property characterizing superhydrophobicity. Furthermore, the plastron forming and retaining properties of these SHSs were characterized by the visual plastron coverage, and the antifouling performance (AF) was tested in static attachment assays using the diatom *Navicula perminuta*. Additionally, the AF performance was investigated for fully functional plastrons, plastrons that were maintained for seven days by joule heating, and coatings on which the plastron decayed during this period.

#### References

[1] R. T. Bachmann and R. G. J. Edyvean, *Biofilms*, 2005, **2**, 197–227. [2] A. J. Martín-Rodríguez, J. M. F. Babarro, F. Lahoz, M. Sansón, V. S. Martín, M. Norte and J. J. Fernández, *PLoS One*, 2015, **10**, 1–30. [3] C. E. Zobell and E. C. Allen, *J. Bacteriol.*, 1935, **29**, 239–251. [4] K. A. Dafforn, J. A. Lewis and E. L. Johnston, *Mar. Pollut. Bull.*, 2011, **62**, 453–465. [5] H. Qiu, K. Feng, A. Gapeeva, K. Meurisch, S. Kaps, X. Li, L. Yu, Y. K. Mishra, R. Adelung and M. Baum, *Prog. Polym. Sci.*, 2022, **127**, 101516.

**BI-ThP-2 Surface Sterilization by 260-280 nm Ultra-Violet C LEDs : Reducing the Probability of One Remaining Pathogen On A Surface to Less Than 10<sup>-6</sup> – a Reproducibility & Accuracy, Aarnav Sathish, Arizona State University, SiO2 Innovates LLC, Arizona State University; Nicole Herbots, University of Missouri Kansas City, Arizona State University, University of California Santa Cruz; Arjun Prabhu, Arizona State University; Anya Arun, SiO2 Innovates LLC; Zaid Abu-Salah, University of Missouri Kansas City, SiO2 Innovates LLC; Viraj Amin, University of Missouri Kansas City, SiO2 Innovates LLC, Arizona State University; Nachiket Rajinikanth, University of Missouri Kansas City, SiO2 Innovates LLC; Aditya Tyagi, SiO2 Innovates LLC; Yash Soni, SiO2 Innovates LLC, Arizona State University; Kush Patel, SiO2 Innovates LLC, Arizona State University, University of California Santa Cruz; Ashwin Suresh, SiO2 Innovates LLC, Arizona State University, University of Arizona; Shreyash Prakash, SiO2 Innovates LLC, Arizona State University; Nimith Gurijala, SiO2 Innovates LLC, Arizona State University, Washington University in St. Louis; Siddharth Jandhyala, SiO2 Innovates LLC, Arizona State University, Duke University; Arjun Sekar, SiO2 Innovates LLC, Northwestern University; Srivatsan Swaminathan, SiO2 Innovates LLC, Arizona State University, Ichan School of Medicine at Mount Sinai; Eric Culbertson, SiO2 Innovates LLC; Robert Culbertson, Arizona State University Antimicrobial resistance (AMR), hospital-acquired infections (HAI) and outbreaks are rising. 3M of AMR infections kill 50,000/y in the US and 1.3 M/ globally. AMR is projected to surpass cancer as the leading cause of death by 2050. Viral outbreaks now occur approximately every two years – twice as often as in the past 200 years: H1N1 (2009), MERS (2012), Ebola (2014), Zika (2015), and Covid (2019).**

Effective surface sterilization must be rapid, reliable, safe, easy-to-deploy, and low-cost to address these issues. Sterilization, as defined by the US FDA, the EU and the International Standard Organization (ISO) is reducing the ‘probability for a single viable microorganism to less than 10<sup>-6</sup>’, a Sterility Assurance Level (SAL) of 6. Accepted methods (vaporized hydrogen peroxide (VHP), Ethylene Oxide (ETO), gamma irradiation (g), or autoclaving) cannot be used in public and hospital spaces, due to environmental, time, materials, and energy costs.

UVC irradiation eradicates pathogens by breaking bonds in nucleic acid pairs in DNA/RNA in water disinfection (SAL = 3) via 253.7 nm UVC fluorescent tubes. This work investigates whether low-cost low power LEDs can sterilize surfaces rapidly and reliably using *Lactobacillus Acidophilus*. (*Lacto. A*) as test pathogen and 260-280 nm UVC LEDs arrayed in a 4 cm<sup>2</sup> square with a power density of 0.8 ± 0.04 mW/cm<sup>2</sup> at 1 cm via two experiments, A and B. Two sets of *Lacto. A* solutions are calibrated to a concentration of 1 × 10<sup>7</sup> and 2 × 10<sup>7</sup> Colony Forming Units (CFUs)/mL, and then serially diluted from 1.0 to 10<sup>-9</sup>. In A and B, three sets of 10 agar plates are inoculated. The control set, ‘No UVC’ is compared to 2 irradiated sets, ‘UVC1 and 2’. One half of the surface of each plate in UVC 1 and 2 is irradiated for 180 s, the other half left unirradiated.

Irradiation for 3 min yields an energy density of 144 ± 7 mJ/cm<sup>2</sup> on a 4 cm<sup>2</sup> square area with 2.5 × 10<sup>5</sup> CFUs/mL on the surface in A and 5 × 10<sup>5</sup> CFUs on the surface in B. In A, at a distance of 1.5 cm, 94 ± 1 CFUs are left on the UVC1 culture set and 9 ± 3 CFUs on the UVC2 culture set. Thus, an average of 52 CFUs remain after UVC irradiation. This yields an SAL of 4. In B, at a distance of 1cm, UVC irradiation leaves an average of 7.5 CFUs remaining. This yields an SAL of 5. Therefore, UVC LEDs irradiation can consistently reach SALs above 3. The energy density at 1 cm needs to be increased by a factor of 10 to achieve sterilization with a SAL of 6, thus to 1.4 ± 1 J/cm<sup>2</sup>. This can be achieved by increasing the UVC LED power density to 8 mW/cm<sup>2</sup>, or extending the duration of UVC exposure to 30 min.

**BI-ThP-3 Dynamic Bonding (Dybonding) in DPD for Simulating DNA Hybridization and Self-Assembly, Christina Bayard, Yaroslava Yingling, North Carolina State University**

Many problems modeled using Dissipative Particle Dynamics (DPD) require the ability to simulate chemical reactions, such as polymerization, cross-linking, DNA hybridization, and ligand-receptor binding, to accurately capture mesoscale phenomena in soft and biological materials. However, standard DPD force fields are inherently non-reactive, limiting their applicability to systems where bond formation or chemical specificity plays a critical role. In this work, DPD was utilized to explore how initial conditions influence the formation of Quantum Dot (QD)-DNA assembled condensates, a system driven by DNA hybridization between QDs functionalized with complementary strands. To address the computational challenge posed by modeling reactive behavior with inherently non-reactive force fields, we implemented an internally developed method called dynamic bonding (dyBonding), deployable within the Large-scale Atomic/Molecular Massively Parallel Simulator (LAMMPS) simulation package. DyBonding enables selective, permanent bond formation based on distance and probabilistic rules between defined bead types. We further refined the approach to support directional, strand-specific bonding, allowing for complete DNA hybridization. This tailored approach offers a robust and efficient solution for modeling chemically reactive processes in DPD, expanding its applicability to a broader range of self-assembling and biofunctional systems. These novel methodologies substantially improve computational precision and expand the functionalities of widely used simulation packages such as LAMMPS. Enhanced understanding of nucleic acid interactions across multiple spatial and temporal scales enables the design of advanced materials for applications in drug delivery, therapeutics, and beyond.

**BI-ThP-4 Plasma Diagnostics for the Modification of Naturally Derived Biopolymers, Bethany Yashkus, Mollie Corbett, Joshua Blechle, Wilkes University**

Naturally derived biopolymers such as silk fibroin and chitosan show promise for use in biomedical devices due to their mechanical strength and slow degradation profile. Because these polymers are naturally hydrophobic, limitations in cell adhesion present challenges in applications that require short term degradation. To combat this, the surfaces of these materials are being altered using various inductively coupled plasma modification techniques. Surface analysis has shown that utilizing polymeric precursors with polar functionality, such as acrylic acid, can deposit a thin hydrophilic coating over the surface through plasma enhanced chemical vapor deposition (PECVD). Molecular precursors, such

as  $N_2$ , have also been used to alter hydrophilicity by introducing polar groups to the surface via plasma functionalization. In this work, acrylic acid treatments reduce the water contact angle (WCA) of silk fibroin from  $75^\circ$  to  $47^\circ$ , whereas nitrogen plasma treatments reduce WCAs from  $75^\circ$  to  $40^\circ$  for silk and  $95^\circ$  to  $25^\circ$  for chitosan.

To achieve a significant change in chitosan WCA, treating the sample for two minutes with a 25 mTorr, 115 W  $N_2$  plasma containing 10% Ar has proven effective. In addition, when the films are casted on glass slides, the observed WCA of the glass is highly correlated with the WCA of the biopolymer. This suggests a synergy between the film and the underlying material. Due to these complex relationships, predicting ideal treatment conditions is not possible. Because little is known about the mechanisms that drive these surface modifications, optical emission spectroscopy (OES) is being employed to observe gas phase species during treatments and make diagnostic calculations such as species densities and vibrational temperatures. By cataloguing the trends in plasma species behavior with and without the presence of the biopolymer, key mechanistic contributors can be identified. Such insights allow for fine procedural adjustments, ultimately leading not only to desired surface outcomes but to reproducible plasma conditions.

**BI-ThP-5 Effect of Surface Oxidation on Carbonic Anhydrase Immobilization on Graphene Oxide: A Molecular Dynamics Study, Merve Fedai, Albert Kwansa, Youngwoo Hwang, Jialong Shen, Sonja Salmon, Yaroslava Yingling, North Carolina State University**

Carbonic anhydrase (CA) enzymes, which catalyze the conversion of carbon dioxide ( $CO_2$ ) to bicarbonate ( $HCO_3^-$ ), are promising candidates for improving the efficiency of existing carbon capture processes. However, their natural forms often lack the stability needed to maintain high activity over extended periods, especially under harsh industrial conditions. Immobilizing enzymes on surfaces is a widely used strategy to improve their durability and reusability. Experimental studies have shown that surface attachment can help overcome stability limitations, provided that catalytic activity is preserved. Graphene (GRA) and graphene oxide (GO) are effective matrices for enzyme immobilization due to their simplicity as model surfaces, electrical conductivity, and tunable surface chemistry. To examine the molecular-level interactions of this biomaterial system, all-atom molecular dynamics (AMD) simulations were performed. CA was modeled in contact with both GRA and GO surfaces to evaluate how surface chemistry affects enzyme structure and function. Various GO surfaces were constructed with oxidation levels ranging from 0% to 68% in 5% increments using a custom-built workflow for a systematic investigation of how surface oxidation modulates enzyme-surface interactions and potentially influences catalytic behavior. The simulations showed that oxidized GO surfaces form stronger hydrogen bonds and electrostatic interactions with CA, which help maintain the enzyme's structure, particularly near the active site. In contrast, GRA surfaces exhibit weaker binding, which may offer less stabilization but create fewer barriers to  $CO_2$  diffusion. In addition to structural effects, the simulations revealed differences in  $CO_2$  diffusion into the enzyme's active site. While GO enhances structural stability, stronger interactions may slightly restrict substrate access. GRA, on the other hand, allows faster diffusion but provides less structural support. Previous work with a different biomolecule suggested that GO oxidation levels between 15–25% yielded the best performance for biomaterial applications. However, due to the greater rigidity of CA, it remains uncertain whether the same range leads to optimal interaction and activity. These findings demonstrate that biomolecule-specific surface oxidation levels can be tuned to optimize enzyme performance.

**BI-ThP-7 Differential Detection of Viral and Bacterial Infections by Macroscopic Epi-Fluorescence Combining DNA and RNA Specific Stains, Nithish Prakash, Sudharshini Ram, David Guo, Arizona State University / SiO2 Innovates LLC / InnovaBug LLC / Microbe Lab-On-Chip LLC; Viraj Amin, SiO2 Innovates LLC / InnovaBug LLC / University of Missouri - Kansas City (School of Medicine) / Microbe Lab-On-Chip LLC; Arya Saravanan, Sriram Rajesh, Nila Kathiravan, Arizona State University / SiO2 Innovates LLC / InnovaBug LLC / Microbe Lab-On-Chip LLC; Robert J. Culbertson, Arizona State University; Eric J. Culbertson, SiO2 Innovates LLC / Microbe Lab-On-Chip LLC; Nicole Herbots, Arizona State University / SiO2 Innovates LLC / InnovaBug LLC**

Six viral outbreaks in the last 15 years increased the need for viral detection at a triage level to contain these outbreaks. Standard viral diagnostics with rapid antigen testing yield ~58% False Negatives (FNs), and plaque assays take days to weeks for results. Annually, misdiagnosed infections cost hospitals \$4.6 Billion, and antimicrobial resistance results in 35,000 deaths.

This work aims to reduce misdiagnoses to <10%, the gold standard, in detecting viral infections in 0.1mL of biofluids - blood, urine, etc. One fluorescent stain for bacterial DNA and one for viral RNA are combined to detect and distinguish bacterial and viral infections using Macroscopic DNA/RNA Epifluorescence (MaDRE). These stains were used with flattened drops on a *super hydrophilic* strip with ~1.5 mm diameter, 100  $\mu$ m thin film, and surface area of ~1.8  $cm^2$ , in order to prototype a low-cost, hand-held Small Blood Volume Diagnostic (SBVD) device, ViroBug™.

$7 \times 10^{10}$  Colony Forming Units (CFU)/mL of a benign virus, *T4 Bacteriophage*, are serially diluted into 10 solutions. 0.5 mL of each of the 10 dilutions ( $1.0$ ,  $10^{-1}$ ,  $10^{-2}$ ... $10^{-9}$ ) is combined in a 1:1 ratio of undiluted  $7 \times 10^{10}$  CFUs/mL benign *E. Coli* bacteria host cells. As a control, each T4 : *E. Coli* mix is tested via plaque assays. Six identical 0.1 mL drops of each T4 : *E. Coli* mix are applied onto test strips. 0.1 mL of safe green DNA-specific fluorescent dye is applied to the drops and photographed under 470 nm of blue light. Third, 0.1mL of safe red RNA-specific fluorescent dye is added to be fluoresced and imaged.

The ratio of green bacterial fluorescence ( $R_G$ ) over blue illumination ( $R_B$ ) and the ratio of red viral fluorescence ( $R_R$ ) over green bacterial fluorescence ( $R_G$ ) are calculated via a self-built app, FastRGB™. Raw ratios  $R_G/R_B$  and  $R_R/R_G$  are calibrated with background fluorescence to reduce photo-detector error, yielding  $R_{GNet}$  and  $R_{RNet}$ .

After analyzing 80 drops,  $R_{GNet}$  is  $4.5 \pm 0.3$  with a relative error  $e$  of  $\pm 7\%$ . When T4 is diluted to  $10^{-9}$ ,  $R_{GNet}$  increases to  $12 \pm 2.6$ , with a bacterial load of  $5 \times 10^8$  CFUs/mL with  $e$  of  $\pm 33\%$ . Meanwhile,  $R_{RNet}$  decreases from  $1.8 \pm 0.2$  for  $5 \times 10^8$  CFUs/mL for 1.0 T4 Phage to  $1.3 \pm 0.06$  for 50 CFUs/mL at  $10^{-9}$  T4 Phage dilution.

$R_{GNet}$  correlation with T4 load is 0.94 while  $R_{RNet}$  correlation is 0.96. Bacterial fluorescence ( $R_{GNet}$ ), indicative of host cell survival, increases with decreasing viral load. Across 80 drops, 2 were identified as outliers, yielding an error rate of 2.5%. ViroBug™ produces rapid and accurate diagnoses using biofluid samples, fluorescent dyes, and automated color analysis.

**BI-ThP-8 Laser-Induced Graphene Coated Wearable Smart Textile Electrodes for Biopotentials Signal Monitoring, C M Vidhya, Yogita Maithani, Sakshi Kapoor, J P Singh, Indian Institute of Technology Delhi, India**

This work describes how to produce a functional nanomaterial using laser induced graphene (LIG) and use it for biomedical applications. Laser induced graphene was manufactured using the low-cost single-step process, laser ablation of polyimide, a commercial polymer. The formation of LIG on PI sheet and other carbonaceous materials has been widely explored meanwhile the characteristics of laser induced graphene has been less explored in its ability to form a stable dispersion. In this work, the characterizations of the LIG in forming a stable dispersion in low boiling solvent was investigated which is both nontoxic and environmentally friendly. The conductivity of the dispersion obtained was better than reduced graphene oxide and comparable to the graphene. The synthesised LIG was used to form a conductive smart textile for the monitoring of biopotentials like electrocardiogram and electromyogram. After successive coating of the graphene dispersion on the cotton fabric to make it conductive, the sheet resistance of the resulting fabric dropped to 3% of its initial value. The laser-induced graphene (LIG) cotton dry electrodes thus manufactured are comparable to Ag/AgCl wet electrodes in terms of the skin-to-electrode impedance, measuring between 78.0 and 7.2 k $\Omega$  for the frequency between 40 Hz and 1 kHz. The LIG cotton electrode displayed a signal-to-noise ratio of 20.17 dB. Due to its comfort, simplicity, and good performance over a longer period of time, the textile electrode coated with the functional material appears suited for medical applications.

**BI-ThP-9 Impact of Marine Biocides on Early Biofilm Community Development, Kailey Richard, Naval Research Laboratory; Sara Tuck, Kenan Fears, Naval Research Laboratory, USA**

Biofouling, the accumulation of unwanted flora and fauna on submerged assets, is an ongoing challenge within the maritime industry. Biofouling build-up increases fuel consumption, drag coefficients, and operational costs in addition to facilitating the transfer of environmental and pathogenic bacteria from one location to another. Antifouling coatings are the typical method for biofouling control with copper being the main constituent. In biological systems, copper is tightly regulated and, to exploit this, some antifouling coatings contain high amounts of copper (I) oxide. Despite these high loadings, the efficacy of these coatings is rapidly declining with the emergence and spread of copper tolerant species. Microbial communities have been found to form dense communities on

# Thursday Evening, September 25, 2025

these high copper loaded coatings suggesting resistance and speculated to lay the foundation for subsequent fouling. Therefore, new alternatives are being used to combat this. To gain an understanding of the mechanisms responsible for the loss of antifouling performance, coated and uncoated polyvinyl chloride panels were deployed at field sites to harvest early biofilms. From these collections, we isolated, cultured, and identified bacterial species. Biocide tolerance profiles were developed by re-exposing individual colonies to four different biocides on microdiluted agar and broth solutions.

**BI-ThP-10 Impacts of Substrate Type on Barnacle Morphology Using Microcomputed Tomography, *Brittney Mitchell*, *Beatriz Orihuela*, Duke University; *Gary Dickinson*, The College of New Jersey; *Daniel Rittschof*, Duke University**

Barnacle biofouling poses significant environmental and economic challenges. A deeper understanding of the barnacle-substrate interface provides insights into barnacle physiology, adhesive performance and substrate contributions. Here, we leverage microcomputed tomography ( $\mu$ CT) to non-destructively characterize the interface and investigate how natural and engineered substrates influence barnacle morphology including adhesive plaque and plate development. Our reconstructions reveal that substrate topography affects barnacle morphology. Changes to the adhesive plaque and exoskeletal plates on planar surfaces and across surface boundaries suggest barnacle morphologies are responsive to some substrate chemistries. We find calcium containing substrates undergo corrosion and erosion, which we hypothesize is related to calcium uptake into barnacle exoskeletons. Overall, these findings underscore the morphological adaptability of barnacles in response to physical, topographic and chemical substrate properties. Insights into these interactions at the interface could help guide material selection and manufacturing in biofouling applications.

## Author Index

**Bold page numbers indicate presenter**

### — A —

Abu-Salah, Zaid: BI-ThP-2, 1  
Amin, Viraj: BI-ThP-2, 1; BI-ThP-7, 2  
Arun, Anya: BI-ThP-2, 1

### — B —

Bayard, Christina: BI-ThP-3, **1**  
Blechle, Joshua: BI-ThP-4, 1  
Breilmann, Georg Friedrich: BI-ThP-1, **1**

### — C —

Corbett, Mollie: BI-ThP-4, 1  
Culbertson, Eric: BI-ThP-2, 1  
Culbertson, Eric J.: BI-ThP-7, 2  
Culbertson, Robert: BI-ThP-2, 1  
Culbertson, Robert J.: BI-ThP-7, 2

### — D —

Dickinson, Gary: BI-ThP-10, 3

### — F —

Fears, Kenan: BI-ThP-9, 2  
Fedai, Merve: BI-ThP-5, **2**

### — G —

Guo, David: BI-ThP-7, 2  
Gurijala, Nimith: BI-ThP-2, 1

### — H —

Herbots, Nicole: BI-ThP-2, 1; BI-ThP-7, 2  
Hwang, Youngwoo: BI-ThP-5, 2

### — J —

Jandhyala, Siddharth: BI-ThP-2, 1

### — K —

Kapoor, Sakshi: BI-ThP-8, 2  
Kathiravan, Nila: BI-ThP-7, 2  
Kwansa, Albert: BI-ThP-5, 2

### — M —

Maithani, Yogita: BI-ThP-8, 2  
Mitchell, Brittny: BI-ThP-10, **3**

### — O —

Orihuela, Beatriz: BI-ThP-10, 3  
Özcan, Onur: BI-ThP-1, 1

### — P —

Patel, Kush: BI-ThP-2, 1  
Prabhu, Arjun: BI-ThP-2, 1  
Prakash, Nithish: BI-ThP-7, 2  
Prakash, Shreyash: BI-ThP-2, 1

### — R —

Rajesh, Sriram: BI-ThP-7, 2  
Rajinikanth, Nachiket: BI-ThP-2, 1

Ram, Sudharshini: BI-ThP-7, **2**  
Richard, Kailey: BI-ThP-9, **2**  
Rittschof, Daniel: BI-ThP-10, 3  
Rosenhahn, Axel: BI-ThP-1, 1

### — S —

Salmon, Sonja: BI-ThP-5, 2  
Saravanan, Arya: BI-ThP-7, 2  
Sathish, Aarnav: BI-ThP-2, **1**  
Sekar, Arjun: BI-ThP-2, 1  
Shen, Jialong: BI-ThP-5, 2  
Singh, J P: BI-ThP-8, 2  
Soni, Yash: BI-ThP-2, 1  
Suresh, Ashwin: BI-ThP-2, 1  
Swaminathan, Srivatsan: BI-ThP-2, 1

### — T —

Tuck, Sara: BI-ThP-9, 2  
Tyagi, Aditya: BI-ThP-2, 1

### — V —

Vidhya, C M: BI-ThP-8, **2**  
Vogler, Louisa: BI-ThP-1, 1

### — Y —

Yashkus, Bethany: BI-ThP-4, **1**  
Yingling, Yaroslava: BI-ThP-3, 1; BI-ThP-5, 2