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.[1,2] In addition, macrofoulers, e.g. algae or barnacles can attach and form slimy layers on the surfaces.[3,4] 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.[5] 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 methacrylateand 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

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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^{-6} – 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^{-6}*, 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^2 square with a power density of 0.8 ± 0.04 mW/cm^2 at 1 cm via two experiments, A and B. Two sets of *Lacto. A.* solutions are calibrated to a concentration of 1 x 10^7 and 2 x 10^7 Colony Forming Units (CFUs)/mL, and then serially diluted from 1.0 to 10^{-9}. 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^2 on a 4 cm^2 square area with 2.5 x 10^5 CFUs/mL on the surface in A and 5 x 10^5 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 ± J/cm^2. This can be achieved by increasing the UVC LED power density to 8 mW/cm^2, 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° to 47°, whereas nitrogen plasma treatments reduce WCAs from 75° to 40° for silk and 95° to 25° 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-6 Macroscopic DNA/RNA Epi-Fluorescence (MaDRE) for Differentiated Detection of Bacterial, Viral and Fungal in Small Fluid Volume Diagnostic (Sfvd) Device: InnovaBugTM, ***David Guo**,* InnovaBug LLC/SiO2 Innovates LLC/ViroBug LLC/College of Medicine, Drexel University/College of Medicine, University of Arizona*; Nithish Prakash,* InnovaBug LLC/SiO2 Innovates LLC/ViroBug LLC*; Sudharshini Ram, Arya Saravaran,* InnovaBug LLC/SiO2 Innovates LLC/ViroBug LLC/BacteroBug LLC*; Nila Kathivaran,* InnovaBug LLC/SiO2 Innovates LLC/ViroBug LLC*; Sriram Rajesh,* InnovaBug LLC/SiO2 Innovates LLC/ViroBug LLC/BacteroBug LLC*; Jonathan Guo,* InnovaBug LLC/SiO2 Innovates LLC/ViroBug LLC*; Robert Culbertson,* Department of Physics, Arizona State University*; Eric Culbertson,* InnovaBug LLC/SiO2 Innovates LLC/ViroBug LLC/BacteroBug LLC*; Nicole Herbots,* Arizona State University/InnovaBug LLC/SiO2 Innovates LLC/ViroBug LLC/BacteroBug LLC

The 21st century has seen 8 viral outbreaks, 5 due to new viruses. Better, faster, more accurate detection of viral infections is needed via low cost, fast, Small Fluid Volume Diagnostic (SFVD) devices that can be mass produced. Macroscopic DNA/RNA Epifluorescence (MaDRE) is here investigated to quickly and accurately detect viral infections and differentiate them from bacteria and fungi, before virus specific tests are available.

Detecting viral infections rapidly and reliably by differentiating viruses from bacteria and fungi can limit outbreaks where it is most needed in ER's, hospitals, and refugee camps.

In 2025, diagnostics for viral infections use Polymerase Chain Reaction (PCR) and virus-specific antigens but are not reliable. Covid-19 PCR swabs yield ~ 40% False Negatives (FN), ~ 50% False Positives (FP), and require 3 days and advanced labs to be performed. Covid Rapid Antigen tests yield 66% FNs and 40% FPs in asymptomatic individuals.

MaDRE is a new approach for detection of pathogens, via safe fluorescence microscopy stains inducing large scale fluorescence on 0.1 mL drops flattened into thin films. It is investigated here to prototype a new hand-held SFVD device, InnovaBug™, to detect and differentiate the 3 pathogen groups - bacteria, viruses, and fungi. This approach combines MaDRE stains, one specific to bacterial DNA, BacteroBug™, to viral RNA, ViroBug™, and to hydrophobins, FungiBug™, in drops of saliva, blood serum, urine, etc.

MaDRE in drops flattened into films is studied via calibrated pathogens solutions, using standard day-long plaque assays as controls. MaDRE's accuracy is measured by sampling four 0.1 mL drops of each solution. Reproducibility is measured by comparing MaDRE in 3 independent labs.

Strips are engineered to be tested within the same handheld analyzer, InnovaBug™, akin to a glucometer. For example, ViroBug™ test strips detect viral infections by combining 2 MaDRE stains and an RGB color analysis app.

Drops are applied on the test strip with 0.1 mL of a safe green and red DNA/RNA fluorophores, after lab-on-chip filters out blood and tissue cells. Blue light illuminates drops and yields red to green fluorescence ratio $R_{Red/Green}$ ($R_{R/G}$) in ≤ 30 min via the analyzer, and a smartphone for imaging and computing $R_{R/G}$. RRG detects viral loads ranging between 1 - 300 M Colony Forming Units/mL.

Results show MaDRE detects viruses quantitatively in 0.1 mL drops applied to ViroBug™ test strips, whose surface is engineered to be super-hydrophilic and can be analyzed in the InnovaBug™ SFVD analyzer. The InnovaBug™ analyzer prototypes and test strips are being optimized as small hand-held devices to be tested in triage situations.

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 µm 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 x 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 x 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 ± 0.3 with a relative error e of ± 7%. When T4 is diluted to 10^{-9}, R_{GNet} increases to 12 ± 2.6, with a bacterial load of 5 x 10^8 CFUs/mL with e of ±33%. Meanwhile, R_{RNet} decreases from 1.8 ± 0.2 for 5 x 10^8 CFUs/mL for 1.0 T4 Phage to 1.3 ± 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.

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