Biomaterial Interfaces Division
Room Ballroom A - Session BI-TuP
Biomaterial Interfaces Poster Session

BI-TuP-2 Direct Detection of COVID-19 Oligonucleotides Through Formation of Nanoparticle Satellite Conjugates, ***Hannah Umoeka**, A. Martinez, C. Afzulpurkar, M. Sharma, S. Talasila, T. Nguyen, D. Singh, I. Shortt, E. La Plante, S. Koh,* The University of Texas at Arlington

Polymerase chain reaction (PCR) and reverse transcription polymerase chain reaction (RT-PCR) have been the gold standards for accurately detecting specific oligonucleotide sequences of various pathogens such as COVID-19. However, considering the hour-long thermal cycling of PCR and RT-PCR, as well as the requirement of lab space and trained personnel, it would be beneficial to have a method that enables a rapid and point-of-care detection of a specific sequence of oligonucleotides. Here we present an approach in which a specific COVID-19 sequence is directly and rapidly detected on a small Si substrate (<1 cm^2) without any amplification. As a target oligonucleotide, we used the 67-mer DNA having the same sequence as the complementary DNA that the current CDC approved COVID-19 RT-PCR test is targeting. The target oligonucleotide is sandwiched between a capture Au nanoparticle (*C*-AuNP) and a detection Au nanoparticle (*D*-AuNP), to produce a nanoparticle satellite conjugate, where a *C*-AuNP is a 50 nm Au nanoparticle on which 20-mer capture DNA (*C*-DNA) is immobilized and a *D*-AuNP is a 30 nm Au nanoparticle on which 18-mer detection DNA (*D*-DNA) is immobilized. *C*-DNA is complementary to a portion of the target oligonucleotide while *D*-DNA is complementary to the other portion of the target oligonucleotide. The nanoparticle satellite conjugates are detected by electrically contacting the *C*-AuNP to one electrode and the *D*-AuNP to the other electrode, where an electrical current is produced when a voltage is applied between the two electrodes. The nanoparticle satellite conjugates were controllably placed on exact substrate positions using the electrostatic funneling (*Nano Lett*., Vol.7, 439-445, 2007) and self-limiting single-nanoparticle placement (*Langmuir*, Vol.37, 11961-11977, 2021; *Appl. Phys. Lett.*, Vol.93, 073110, 2008), with self-assembled monolayers (SAMs) of 16-mercaptohexadecanoicacid and 3-aminopropyltriethoxysilane providing the electrostatic guiding structure. The total hybridization time for the assay was 10 minutes for 5 nM target COVID-19 oligonucleotides and optimization for higher sensitivity is currently underway. Our approach can be used for detection of any oligonucleotide sequence. For example, this method enabled detection of anthrax oligonucleotides by adequately changing the *C*-DNA and *D*-DNA sequences. This work was supported by the National Science Foundation (ECCS-2031770, DMR-2122128, CMMI-1463451, and CMMI-2143159).

BI-TuP-3 Study of Catechol Reaction Mechanisms, *J. Appenroth, **Laura L. E. Mears**, A. Celebi, M. Valtiner,* Vienna University of Technology, Austria

Redox-active catechols, in particular *L*-DOPA and dopamine, are found in many adhesive biological systems. For exmple, in marine mussels *L*-DOPA containing byssus threads are shown to adhere to different substrates in harsh saline environments. Their oxidation and reduction can be driven both by pH changes and electrochemistry. While various models have been proposed, the exact reaction paths of these catechols remain a topic of discussion.

First, we will present new insights gained on the dynamics and redox activity of catechols in aqueous solution. Their reaction paths and products were studied using electrochemistry, UV-vis and NMR spectroscopy and the results are compared to DFT based ab initio thermodynamics. To characterize the energy change during binding/unbinding events of catechols, we then show bond rupture experiments of single catechol molecules against gold surfaces using AFM and Optical Tweezers.

By combining these methods we are able to shed new light on the redox active behaviour of catechols.

BI-TuP-6 Direct Observation of Focal Adhesion by Nanoendoscopy-AFM in Live Cells, ***Alam Mohammad Shahidul**, T. Shirokawa, T. Ichikawa, K. Miyazawa, k. Miyata, T. Fukuma,* Kanazawa University, Japan

Cells are the basic building units of all living organisms. It is essential to visualize the cell structures and their dynamics at the subcellular level to understand the mechanisms of basic cellular functions. Despite the enormous efforts, there are still many things that remain underexplored about this basic unit of life. Direct imaging of such nanostructures and their dynamics inside living cells has been a great challenge. Traditional approaches including tear down the cell into various components, which may distort its natural behavior. Moreover, many nanoscale dynamics are not yet visible because of the limited resolution. Therefore, we have developed nanoendoscopy-AFM (Atomic Force Microscopy), a label-free, non-harmful imaging technique that allows us to see the intracellular structures of a living cell without breaking it apart. A long ultrathin nanoprobe is inserted into living cells to perform 2D and 3D imaging by AFM. We can visualize intra-cellular structures ranging from whole-cell to unsupported actin fibers. Further, we proved that such an imaging method based on ultrathin nanoprobes does not significantly affect cell viability. Our next aim is to investigate focal adhesions (FA) in living cells that play a crucial role in cell motility. Multiple proteins (paxillin, integrin, vinculin, etc.) form this dynamic nanostructure, which mechanically connects intracellular actin bundles to the extracellular substrate. However, it remains elusive due to the difficulties of its direct observation. We are succeeded in the direct imaging of focal adhesion in a living cell with an originally developed nanoprobe. In the future, we want to study the dynamic behavior of FAs along with TIRF microscopy which will have a significant influence on cell biology and medical sciences.

BI-TuP-8 pH Responsive Functionally Graded Nano-Composites Coatings for Studying Hepatocellular Carcinoma Cellular Behaviour, ***Juhi Jaiswal**, M. Dhayal,* Indian Institute of Technology (Banaras Hindu University), India

In the present study, a process has been developed for metal-polymer coatings on tissue culture plastic surfaces through an in-situ reduction process by chitosan. The reduction of the metal compound by chitosan was performed, thereby exploring the role of different functional moieties of chitosan in the reduction process at acidic and basic pH. Time-dependent reduction kinetics for different chitosan concentrations by monitoring the in-situ reduction of nanometal assemblies (< 10 nm) at the polymeric surface has been demonstrated to understand the role of chitosan amine and hydroxyl functional moieties in the reduction process. The FTIR spectra were used to quantify the relative change in nitrogen and oxygen atom-containing functionalities in nano-composites. ^{1}H NMR spectra of the nanocomposite were further used to identify a relative change in the corresponding peak during the interaction of different molecules in functionally graded composites. A uniform distribution of less than 10 nm nanoparticles was confirmed by TEM image analysis of composite metal-polymer coatings on a copper grid. The UV-Visible spectroscopic analysis confirmed the obtainability of tunable size, density, and functionality in composite films. XRD analysis of nanocomposite coatings confirmed the presence of nanoparticles having two (111) and (200) crystal plans. In-vitro cell viability and proliferation analysis for the HepG2 cell line was performed. These coatings can be used to develop active biomaterial for cancer therapeutics because of the existence of composite in two forms, gel and sol directed by environmental pH.

BI-TuP-9 'Plasmoresistor' Device – Electronic Transduction of Plasmon Signals for Highly Sensitive Detection of Biomolecules, ***Corbin Feit**,* University of Central Florida*; P. Rathi, S. Singamaneni,* Washington University, St. Louis*; P. Banerjee,* University of Central Florida

Sensing of biomolecules with plasmonic nanoparticles has become the "gold standard" for lab-on-a-chip devices. Observing changes to localized surface plasmon resonance (LSPR) frequency of nanoparticles provides label-free, real-time measurements without the need for chromophores or fluorophores. When a molecular binding event occurs on a plasmonic nanoparticle, the change of the local dielectric environment leads to a shift in the LSPR frequency. This optical shift in LSPR is measured via optical spectroscopy techniques such as UV-Vis or Raman spectroscopy. However, challenges to miniaturization and hardware portability remain, making point-of-care diagnostics harder to achieve.

Therefore, in this work, we present detailed results of a "plasmoresistor" sensor that monitors the photocurrent generated by hot electrons emitted from plasmonic gold nanorods. This device overcomes the limitations that arise from the above described, state-of-the-art optical readout technologies. Upon excitation of the LSPR, hot electrons are generated, transferred, and conducted through a vicinal ZnO film. Thus, the change in photocurrent (i.e., resistance) performs the sensing action. Nanoscale engineering involving area-selective atomic layer deposition is required to deposit a conductive and optically transparent ZnO, while keeping viable plasmonic nanostructured surfaces exposed for conjugation with the biomarkers.

This transformative plasmoresistor device is expected to pave the way for highly sensitive plasmonic sensors that operate through electrical

detection. The use of expensive, bulky and labor-intensive instrumentation will become obsolete.

BI-TuP-10 Hemoglobin-Bound Iron Fraction In Thin Films Rapidly Solidified From 100µL Drops Measured By Extended X-ray Absorption Fine Structure (EXAFS)*, **Arjun Sekar**, A. Suresh, R. Rane, A. Thinakaran,* Arizona State University*; J. Bischoff,* Simon Fraser University, Canada*; N. Herbots,* Arizona State University*; K. Kavanagh,* Simon Fraser University, Canada

Iron (Fe) bound to Hemoglobin in blood is key to detection of anemia. Blood diagnostics(BD) via High Performance Liquid Chromatography(HPLC) require significant volumes of blood per test (8-10 mL). Such volumes lead to Hospital Acquired Anemia in a large fraction of patients(74%) [1]. Conducting BD on smaller volumes is a pressing need for modern medicine.

Recent ongoing developments of X-ray synchrotron sources and detectors with higher X-ray intensities are now making possible investigating direct EXAFS analysis on smaller blood volumes.

In this work, we use hyper-hydrophilic coatings to rapidly solidify blood drops(10-250 µL) [2], making solid state analysis feasible. Our process yields flat, Homogeneous Thin Solid Films (HTSF) in minutes without coagulation. HTSFs are sufficiently uniform, over analyzed areas (~ 5 mm^2) such that the Fe composition can be measured with an accuracy of ± 10% using conventional solid-state techniques such as X-ray Fluorescence (XRF) and Ion Beam Analysis. This is unlike conventional Dried Blood Spots(DBS). DBS are non-uniform and exhibit high fracture rates followed by detachment. In addition, Fe-rich Red Blood Cells(RBC) migrate to the periphery of DBS, while no such phase separation occurs in HTSFs [2]

We have confirmed that our process to solidify blood drops into HTSF does not modify the bonding of Fe in hemoglobin by carrying out Extended X-ray Absorption Fine Structure (EXAFS) directly on such HTSFs.

Hemoglobin is a *globular* protein, which means it folds into a spherical shape, defining bonding lengths and species surrounding Fe. Hemoglobin consists of four *heme* groups, each with an Fe bound to a *histidine* residue via N. In each *heme*, Fe is bound directly to four N nearest neighbors within a plane, with a 5th nearest neighbor and a 6th N atom. EXAFS has been reported for measurements on concentrated hemoglobin separated from whole blood and has detected oxidized Fe in hemoglobin, matching results from HPLC [3]. We carried out EXAFS at the Canadian Light Source (CLS) using fluorescence detection near the Fe absorption edge (7.126 to 7.8 keV). Our EXAFS spectra on small volume HTSF blood share similarities to previous reports on hemoglobin and consistently measure the expected Fe-N bond length of 1.97±0.02 Å [3].

Acknowledgements: CLS, NSERC, MatthewNewville

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BI-TuP-12 Detecting Shared Touch Surface Contamination with a Deep Learning-Enhanced Smartphone and Nanopatterned Material System*, **Ainslie Allen**, J. Andle, O. Biswas,* University of Maine*; R. Perry,* VEMI Lab*; S. Yasaei Sekeh, C. Howell,* University of Maine

Shared-touch surfaces can transmit diseases when not cleaned properly. Some methods of surface contamination detection exist, but nearly none are immediately accessible, hands-free, and do not require specialized equipment. This work is focused on building a deep-learning driven, smartphone-based system that interacts with nanopatterned surface appliques and identifies contamination on a surface. We used a nanopatterned material that acts as a diffraction grating and measured the difference in the refracted light pattern when the material was clean and when it was contaminated. Unlike nearly all other applications of nanopatterned diffraction gratings, our applique material is mass-produced by a Maine paper company, making it both able to be applied over large areas and affordable. The light diffracting off our nanopatterned material resulted in bright rainbows which changed significantly in intensity, length, and color composition, as measured with a standard smartphone camera, when the surface was contaminated with oil. Using this system, we were able to detect oil contamination down to a volume of 0.1µL over a surface area of 64cm2 when the data were processed manually. We then trained a convolutional neural network (CNN), ResNet 50, to detect these differences. The network was able to detect contamination at an even lower volume of 0.0001 µL over a surface area of 64cm2. Training the CNN on the collected data improved the detection performance by over 100%. Additionally, by changing the angle of the smartphone and the light source, we were able to effectively scan the surface to search for areas of contamination and under ambient light conditions, making it more applicable to use in everyday life. Adding the angle and light features into the CNN method provides extra information to the neural network and leads to a robust learning process. Together, the results demonstrate that a deep-learning-enhanced nanopatterned material system can detect general surface contamination, which may help identify potentially infectious contamination on shared touch surfaces.

BI-TuP-13 Smartphone Enabled Micro/ Nano Microscopy for Biomedical Sensing*, M. Sami,* Rutgers University*; **Umer Hassan**,* Rutgers, The State University of New Jersey

Biomarker quantification finds many applications in disease diagnostics. Detecting biomarkers require developing technologies with micro-nano sensing resolutions to enable their specific identification. Here, we report a 3D printed, portable, fluorescent microscopy system to image micro/ nano particles for biomedical applications. The 3D printed microscopy system houses an excitation source (laser diode/ LED), optical filters and lenses to achieve desired optical resolutions. The images can be taken by using a regular smartphone camera. A sample slot is housed within the platform to place the desired biological samples e.g., microparticles, or fluorescently tagged blood cells. We tested the setup using blood samples from patients at Robert Wood Johnson Hospital. We imaged leukocytes stained with nuclear stain using the platform and tested them with control microscopy instrument. We found a strong correlation between the two platforms with $R^2$of 0.99. Further, we developed a machine learning model based on artificial neural networks (ANN) to count the microparticles and blood cells in the captured images.

Lens of smaller focal lengths allow the improvement in achieving higher resolution. Further, excitation methods can also be varied for improved particles imaging performance. For sub-micron and nanoparticles imaging, we explored multiple microscopy imaging modalities including perpendicular, parallel, and slanted. We found that slanted imaging methodology where laser diode exposes the samples at various angles allows higher imaging quality and improves the nanoparticles sensing resolution and accuracy. Our system is versatile and interoperable between multiple smartphones. We tested its imaging capability using iPhone XR, Samsung Galaxy S9, Samsung Ultra S21, and Nokia Lumia. This setup can be translated for different biomarkers (e.g., cells, proteins, etc.) quantification and developing associated diagnostic products.

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