SB08.08.01
A Comprehensive 3D FEM Model of Excitable Tissue and Capacitive Electrode Interface Aleksandar Opančar, Anja Mioković, Nikola Habek and Vedran Derek; Department of Physics, Faculty of Science, University of Zagreb, Croatia

The interface of excitable cells and stimulation or recording electrodes is essential for bioelectronic applications. Parameters such as the electrode impedance and capacitance, interface electrochemistry, surface structuring and long term in vivo stability have been thoroughly studied. However, in many applications, especially clinical ones, only trivial electrode geometries are used, resulting in increased charge density thresholds. Using optimized electrode geometries and stimulation protocols may overall be more effective, especially in the case of implanted bioelectronic devices with limited current generation capabilities.
For highly localized target specific electrostimulation, electrode design and stimulation protocol are crucial parameters to consider. We consider multiple planar and 3D electrode configurations for stimulating excitable cells and tissues, and different stimulation protocols using pulsed and modulated current. A comprehensive finite element method (FEM) model encompassing realistic capacitive photo-electrode (organic electrolytic photocapacitor – OEPC) and tissue model is made in COMSOL Multiphysics® software. Electrodes are characterized by their contact electrical properties, contact capacitance and contact resistance, while the OEPC is characterized by its equivalent circuit model. Realistic cell membranes and action potential propagation are implemented using the Hodgkin–Huxley model which can be tailored to a specific cell type.
We show that using the optimized electrode configuration enables multifold current density enhancement at the targeted stimulation area which enables effective cell and tissue excitation while minimising the residual effect on the surrounding tissue. Our numerical findings are validated in vitro using cortical neuron cell cultures and mouse brain slices.

SB08.08.02
Passivation Strategies for Enhanced BioFET Performance and Stability in Ionic Solutions Faris M. Albarghouthi, Nicholas Williams, Joseph Andrews, Shiheng Lu, Jay Doherty, Steven Noyce and Aaron D. Franklin; Duke University, United States

Increasing demand for personalized medicine has led to a surge of research into electronic biosensing approaches, particularly those involving the use of a field-effect transistor (FET) as the transduction element in ion-sensitive FET-like structures. While electrical biosensors adhere to many of the tenets of the so-called "ideal biosensor," one limitation that could hinder their success in a solution-gated setup is gate leakage. As electrical devices become immersed in solution (such as physiological liquid), improper passivation of the components results in electrical current leaking between the BioFET and the solution, thus compromising the transduction signal and preventing sensitive biological detection. Focus in the field has been on singular demonstration of BioFET applications, yet there is no consensus on device design and passivation strategy, which leads to difficulty comparing results between reports that ostensibly investigate similar phenomena, particularly with regards to gate leakage.
In this work, we investigate various passivation strategies for printed, solution-gated carbon nanotube (CNT) BioFETs. Contact-only photoresist passivation is investigated alongside whole-device dielectric passivation, particularly in the context of gate leakage reduction, long-term device stability, and wafer-scale device yield. We find that while optimized photoresist-only and dielectric-only passivation both result in high-quality BioFETs, the combination of the two – coating the contacts with a photoresist then the entire device with a dielectric – results in highly consistent performance, with more than 90% of tested devices displaying nA-level gate leakage with on/off-current ratios greater than 10^3 in solution. The photoresist+dielectric strategy also results in the best stability over 500 testing cycles, demonstrating robust performance on a timescale exceeding that required for most biomolecular binding reactions to occur. Finally, we show that the addition of a polyethylene glycol (PEG) polymer layer, which reduces non-specific protein adsorption and increases Debye length, has no significant impact on device performance both in initial device metrics and after long-term cycling when polymerized on these passivation structures. Ultimately, these results help pave the path toward the development of a truly high-yield, sensitive, stable, and robust electrical biosensing platform.

SB08.08.03
Electrical Transduction of Prothrombin Time Using Printed Nanoparticle-Based Sensors Brittani L. Carroll, Nicholas X. Williams, Jay Doherty, Steven Noyce and Aaron D. Franklin; Duke University, United States

Heart failure affects over 6.4 million people in the United States alone, with over 550,000 new cases emerging annually. Ventricular assist devices (VADs) have become a popular means of long-term care; yet, due to their thrombogenic nature, patients are frequently prescribed anticoagulation medication (e.g., warfarin). To ensure dosages remain in the therapeutic window for this strong anticoagulation drug, periodic blood-based testing (every 1-4 weeks) is required to measure patients' prothrombin time/international normalized ratio (PT/INR), which reflect the clotting tendency of blood and hence the extent of anticoagulation. This frequent, clinic-based monitoring of PT/INR is cumbersome and costly; thus, an at-home monitoring system to ensure adequate coagulation times would be transformative for those on warfarin therapy.
Although point-of-care (POC) coagulometers are commercially available and have been demonstrated to reduce the burden on both patients and the healthcare system, only a small percentage of VAD patients perform POC self-testing. Current POC coagulometers and reagent cartridges are high cost, which limits insurance coverage, and are inconsistent in device performance. Therefore, there is a need for an alternative device that offers an at-home and portable measurement of PT/INR that is low-cost, accurate, and user friendly. In this work, a fully printed POC PT/INR test using electrical transduction is demonstrated. In order to create a low-cost device, an inexpensive testing platform was designed, which consists of aerosol jet printed silver nanoparticle electrodes. The functionality of the device was demonstrated in whole blood derived from both animal and human subjects. Given the necessity of a robust sensor, identical clotting times were measured on both a ridged and a flexible substrate tested under bending strain. In addition, a handheld sensor with low-cost electronics was designed and shown to have a measurement accurate to within a standard deviation of the costly, stationary, computer-based testing system. Finally, to improve upon the accuracy of developed handheld devices, multiple sensing modalities were combined to incorporate on-chip calibration for the impedimetric coagulometer. Taken together, these results lay the groundwork for fully printed impedimetric sensors, which address the unmet need for a low-cost, robust, POC device, potentially improving outcomes for VAD patients by early detection of aberrations in PT/INR.

SB08.08.04
Detecting Cancer Biomarkers Electrically Using Single-Molecule Techniques for Future Liquid Biopsy Applications—Understanding Bioelectronics Fingerprints at the Nucleic Acid Bioelectronic Interface Keshani G. Pattiya Arachchillage, Subrata Chandra, Jordan Ventura, Sarah Currier, Steven Ayoub and Juan Artes Vivancos; University of Massachusetts Lowell, United States

Cancer is one of the most frequent causes of death globally and kills more than 8 million people per year.[1] Early diagnosed cancers are relatively easier to treat and cure. Cancer biomarkers, such as circulating free tumor nucleic acids (ctNA), are promising for detecting cancers early.[2,3] There are various techniques to screen cancers and liquid biopsy is one of them.[2] This is a promising approach since it is used to diagnose tumor-specific biomarkers non-invasively.[2] Detecting ctNA in body fluids is challenging, because of the low ctNA concentration and the low frequency of mutations compared to wild-type sequences.[2] Nanotechnology bioelectronics methods can help to address this challenge. In particular, the Scanning Tunneling Microscopic (STM)-assisted break junctions method (STM-BJ)[4] has recently allowed the first demonstration of detection and identification of RNA from E.Coli via single-molecule conductance.[5] This is an ideal new method for liquid biopsy bioelectronics since it is non-invasive, highly sensitive, and specific.