MEMS and NEMS
Room 125 - Session MN1-TuA

Bio and Environmental MEMS

Moderators: Matthew Jordan, Sandia National Laboratories, **Yanan Wang**, University of Nebraska-Lincoln

2:15pm **MN1-TuA-1 Gaede-Langmuir Award Talk: Ingestible Technologies for Disease Assessment and Treatment in the Gastrointestinal Tract***, **Reza Ghodssi***[1], University of Maryland, College Park **INVITED**

MEMS and Microsystems have shown the potential to improve healthcare through advanced monitoring and treatment approaches among other applications. Microsystems, like wearable electronics, that interface with the body have been thoroughly explored in academic research and commercially. A rising field of research is the development of ingestible technologies to address gastrointestinal (GI) and related diseases. The GI tract is the only internal organ that can be non-invasively accessed, so it provides a gateway to analyze bodily processes and reach specific organ systems for treatment. Moreover, digestive diseases affect more than 40 million people in the US alone. My group's research focuses on the development of ingestible tools for diagnostics and treatment of gastrointestinal and systemic diseases. Embedded electronics and sensors enable analysis of critical biomarkers, like hydrogen sulfide (H_2S) and tissue impedance, while actuators allow sampling and drug delivery at precise locations in tissue for diagnostics and highly effective on-command treatment. In this talk, I will discuss current progress toward integrated capsule systems capable of biomarker sensing, localized actuated drug injection and intestinal sampling for further analysis.

2:45pm **MN1-TuA-3 Packaging Development with an Integrated Wireless System for an Electrochemical Cardiac Biosensor***, **Jorge Manrique Castro**,* The University of Texas at El Paso*; B. Walker, F. Kashem, S. Rajaraman,* University of Central Florida

Cardiovascular disease is one of the main causes of mortalities globally. It is of high importance to identify early conditions given by the analysis of biomarkers in blood such as troponin, D-Dimers and brain natriuretic peptide **[1]**. In order to capture information emanating from these biomarkers, BioMEMS technologies have emerged as solution for the development, and packaging of biosensors aimed for accurate diagnosis and prognosis of cardiac diseases **[2]**. Among them, wearable cardiac biosensors **[3]**, and point-of-care platforms **[4]** have been proposed.

Data collection, processing, and telemetry is a challenge due to limitations in power source, consumption, and range of operation accompanied by issues in biocompatibility, size, and hermeticity. There is also a lack of exploration in processing techniques for biocompatible materials to minimize wound infection; point-of-care immunosensors optimization to improve patient compliance; and continuous monitoring for making informed decisions in real-time to overcome any life threatening situation in the short and long term.

Here, we present the development of a cardiac microsystem for electrochemical sensing with wireless data extraction. Two workflows are presented: Packaging and system integration. Material processing for packaging was performed with multimodal and CO_2 lasers on fused silica. This material was selected due to its great biocompatibility, chemical and mechanical robustness, and its transparency to optical and RF signals **[5]**. **Fig. 1** details results from the laser micromachining process with different parametrization. After engraving a microcavity on fused silica quartz, laser confocal characterization was carried out to measure the 3D profile and surface roughness (**Fig. 2**). On the other hand, system integration started at the macrolevel with Arduino-based board (Elegoo Uno R3), bluetooth module (HC-05), and impedance converter board (EVAL-AD5933EBZ) as presented in **Fig. 3**. Miniaturization of the impedance board was implemented by extracting the AD5933 chip from the board (**Fig. 4**). It was connected and programmed using I^2C communication protocol and customized script **[6]**. To test impedance measurements, 1 kΩ resistor was used as device under test. Real, imaginary and magnitude impedance were collected and sent wirelessly to a remote laptop (**Fig. 5**).

Ongoing work exploring different techniques for etching glass are being studied. Miniaturization of the Arduino board and bluetooth module into a single microcontroller unit is in progress to reduce footprint. A flex circuit with an interdigitated electrode is conceived to be encapsulated within the fused silica cavity.

3:00pm **MN1-TuA-4 Self-Powered, Eco-Friendly, and Edible UV Sensors for Food Packaging Applications***, **Pouya Borjian**, M. Chimerad, P. Pathak, H. Cho,* University of Central Florida

We present a novel self-powered ultraviolet (UV) sensor based on non-toxic and edible materials. UV radiation can play an important role in food spoilage. Prolonged exposure to UV can lead to the degradation of different nutrients such as vitamins in the food. Proper control and monitoring UV exposure levels are crucial to minimizing food spoilage and maintaining food quality throughout production and distribution. Although there are some sensors available in the food industry for detecting UV radiation, many of them are fabricated using toxic or harmful materials. Additionally, most of these sensors require external power sources to perform. In this work, a flexible UV sensor was developed based on a non-toxic and edible ethyl cellulose (EC) substrate coated with gold interdigitated electrodes using sputtering. The interdigitated electrodes were incorporated with an algae-based electrolyte and safe-to-eat zinc oxide (ZnO) nanoparticles as a UV-absorbent material. The formation of ZnO nanoparticles was characterized using scanning electron microscopy (SEM). Moreover, the optical response of the EC coated with the ZnO layer showed an absorbance edge around 370 nm compared to a bare EC film. The photocurrent response of the sensor was tested at various bias voltage and zero bias. At zero bias, the fabricated UV sensor displayed repeatable and steady photocurrent responses. In conclusion, a self-powered UV sensor was successfully demonstrated utilizing sustainable materials certified for food-grade applications.

3:15pm **MN1-TuA-5 Inkjet Printing of $AgNO_3$ inks With Solvent-Selective Morphologies on Liquid Crystal Polymer Substrates***, L. Murthy, **Christian Zorman**, A. Hess-Dunning,* Case Western Reserve University

Inkjet printing offers unique prototyping and customization advantages for microfabricated biosensors, in particular sensors printed on flexible substrates. Electrochemical biosensors exhibit analyte sensitivities that increase with total exposed sensor area; therefore, rough or porous electrode structures with high specific surface areas are desirable for maximizing analyte sensitivity. In this work, we explored the properties of inkjet printed silver structures from plasma-reduced silver nitrate inks on liquid crystal polymer (LCP) substrates. LCP is an attractive substrate material for biosensing applications due to its biocompatibility, low moisture absorption and mechanical flexibility. Unfortunately, high quality printing of microscale structures on LCP can be challenging. We evaluated the pattern fidelity, conductivity, and surface morphology of silver nitrate in monoethylene glycol (mono-EG) and triethylene glycol (tri-EG) ink solvents in terms of their use in electrochemical sensors for measuring hydrogen peroxide concentration.

Inks were prepared by dissolving silver nitrate in a mono-EG/water or tri-EG/water solution. LCP substrates were prepared by cleaning the substrate surface with appropriate solvents and then exposing the substrates to a low power oxygen plasma. Structures were printed on the LCP substrates using a Dimatix inkjet printer. The substrates were then exposed to a low-pressure argon plasma to reduce the dissociated silver cations and form elemental silver.

We found that the ink solvent had a strong influence on all measured parameters. While the mono-EG ink demonstrated good print fidelity on LCP, the tri-EG ink displayed either excessively hydrophobic or excessively hydrophilic behavior, leading to poor print fidelity. Silver structures printed from the tri-EG inks displayed a sheet resistivity three order of magnitude higher than structures printed using mono-EG inks. Scanning electron microscope images indicated that silver structures from the mono-EG inks were dense and flat, while those from tri-EG inks had a rough surface morphology. As no single ink could meet the requirements for the hydrogen peroxide sensor, we developed a bilayer approach in which the interconnect and base contact pads were printed from the mono-EG ink and a sensing electrode consisted of a tri-EG/mono-EG bilayer. Compared to the smooth Ag from mono-EG inks alone, the addition of the rough Ag coating from the tri-EG improved the electrochemical sensitivity to hydrogen peroxide by a factor of 3.6. The bilayer approach allowed for leveraging the advantageous characteristics of both ink types for improving sensor characteristics.

[1] **Gaede-Langmuir Award Winner**

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