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Ingestible Electronics for High Quality Gastric Neural Recordings

A. Gierlach, S. S. You, P. Schmidt, G. Selsing, I. Moon, K. Ishida, J. Jenkins, W. Abdalla M. Madani, S-Y. Yang, H-W. Huang, S. Owyang, A. Hayward, A. P. Chandrakasan, G. Traverso

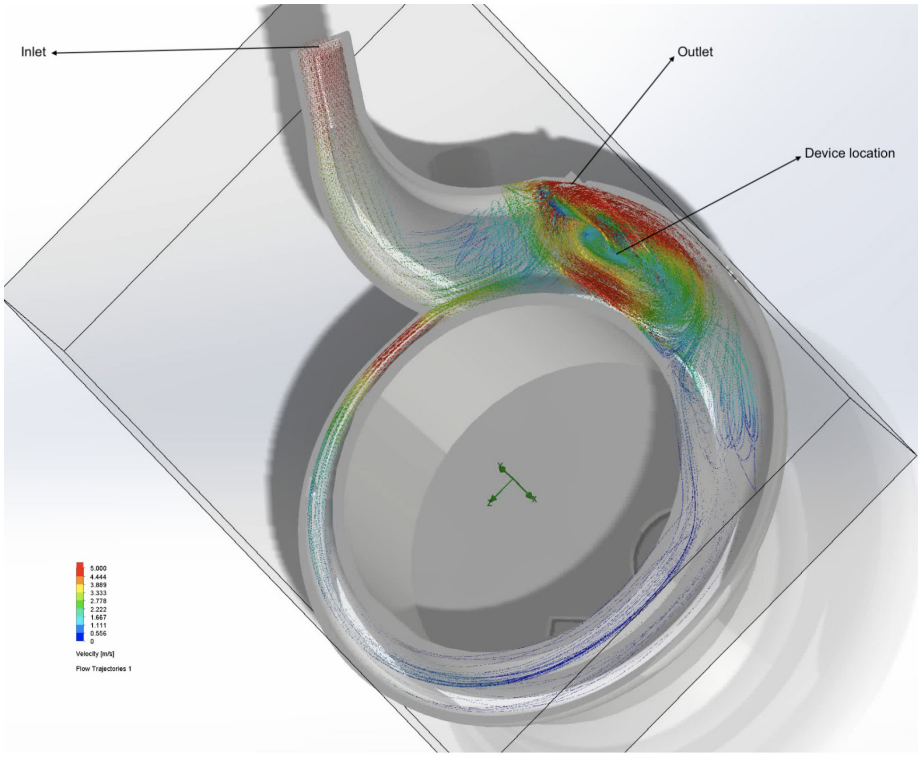
Recent advances in understanding gastrointestinal dysmotility, the gut-brain axis, and gastric stimulation therapies have highlighted the importance of the electrical signals that regulate the gastrointestinal (GI) tract. However, current tools that can measure these small, slowly oscillating potentials deep within the GI tract either involve acute, invasive procedures for high quality measurements or long-term cutaneous recordings that are highly attenuated and restrict patient movement. Here we introduce a non-invasive system for long term gastric recordings known as Multimodal Electrophysiology via Ingestible Gastric Untethered Tracking (MiGUT). Validated using the gold standard, MiGUT is able to record the gastric slow wave in-vivo in pigs, measure the expected response of prokinetic agents, while also directly observing signals from nearby organs such as the heart rate and respiratory rate. During multi-day measurements of freely-moving subjects, MiGUT measured changes in the slow wave during different behaviors and was not impacted by ingestion or high activity events. This work demonstrates new capabilities of ingestible devices, enabling long-term, at home, personalized diagnostics and detailed study of gastric electrophysiology algorithms.

Chamber Design and Airflow Optimization for E-nose Technology

M. Grande, C. Lopez Angeles, T. Palacios
Sponsorship: Universidad Politecnica de Madrid

Electronic nose (E-nose) technology has been explored for years. However, it has not yet achieved the digitization of the sense of smell with high accuracy. Various concepts of E-nose have been proposed, such as individual semiconductor-based sensors that respond to a certain chemical stimulus. However, their use has been limited due to variability on device-to-device performance resulting from nanofabrication processing. Moreover, when it comes to complex environments, such as the human breath, that involve many gases in low concentrations, a more robust and accurate sensing approach is needed. In this context, we are designing an E-nose system based on multiple graphene field-effect transistor (GFET) sensors arranged in an array. Each sensor chip is equipped with a thousand sensing units, aiming for enhanced precision in measurements.

These sensors, integrated with a printed circuit board system and an external computer, will enable the detection of biomarkers in exhaled breath. So far, we have achieved a good chemiresistive response of a metal nanoparticle functionalized graphene sensor to 10,000 ppm H_2, 100 ppm NH_3, 10 ppm H_2S, and 100 ppm NO_2 in dry air at room temperature. To optimize the performance, these devices are housed in a chamber design and engineered to ensure efficient airflow for detection. Furthermore, finite element modeling and simulations of airflow were utilized to enhance sensing module performance. This optimization was found through air recirculation and maximization of air volume in contact with the device. We found that chip performance is enhanced by creating localized vortices in the sample chamber. The air samples can be obtained either by exhaling into the chamber or by activating a vacuum extraction pump to capture ambient air. This research represents a significant step toward achieving a practical E-nose system for diverse applications, including disease diagnosis.



◀Figure 1: SolidWorks simulation showing breath velocity trajectories. Breath vortices are shown specifically localized to enhance device performance and air profiles contact. Main vortex localizes where chip is placed; device design recirculates air.

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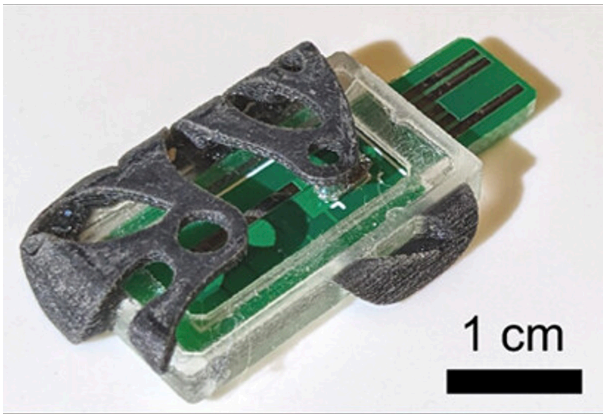
Additively Manufactured Electrospray Sources for Point-of-Care Mass Spectrometry

A. Kachkine, L. F. Velásquez-García
Sponsorship: Empiriko Corporation

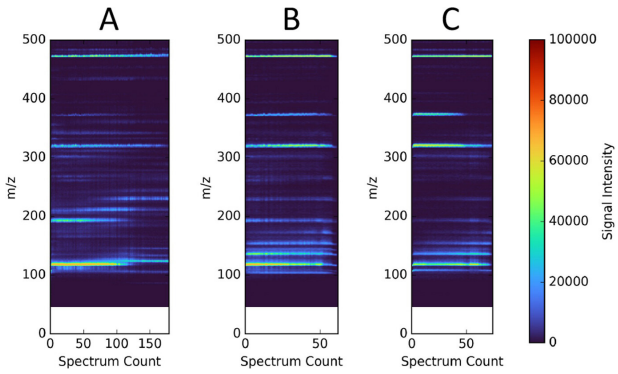
Clinical mass spectrometry of biological liquids, e.g., serum, allows fast and sensitive analysis of biological analytes. Mass spectrometry (MS) has yet to reach its full clinical potential. In particular, MS applications have been hindered by difficulties in constructing robust sample processing and ionization workflows, with existing methods requiring significant manual intervention.

Ionization of liquids is commonly attained via electrospray. The morphology of an electrospray emitter influences its performance. Internally fed emitters, i.e., capillaries, suffer from a variety of issues ranging from clogging to difficulty of integration; cleanroom microfabricated versions are expensive and time-consuming to make. Unfortunately, low-cost electrospray ionizers, e.g., paper spray, are often difficult to integrate into MS protocols.

This study focuses on the ionization step in standard MS protocols, concentrating on combining mainstream 3D printing technology and nanostructured surface treatments to achieve scalable manufacturing of high-precision hardware with automatable assembly. Each device comprises a digital microfluidic PCB, a soldered 3D-printed emitter made of SS 316L via binder jetting, covered by a conformal layer of hydrothermal ZnO nanowires, and an external 3D-printed casing (Figure 1). Using the 3D-printed ionizer, it was possible to detect pharmaceutical relevant compounds spiked in serum at a concentration of 1 µg/ml using various sol-vents (Figure 2).



▲ Figure 1: A 3D-printed ionizer for point-of-care MS.



▲ Figure 2: Time-series MS data from a 3D-printed ionizer using A) isopropanol, B) methanol, and C) acetonitrile as solvent. The sample included lisinopril, enalapril, clopidogrel, nicardipine, apixaban, atorvastatin, rosuvastatin, pravastatin, aspirin, and rivaroxaban.

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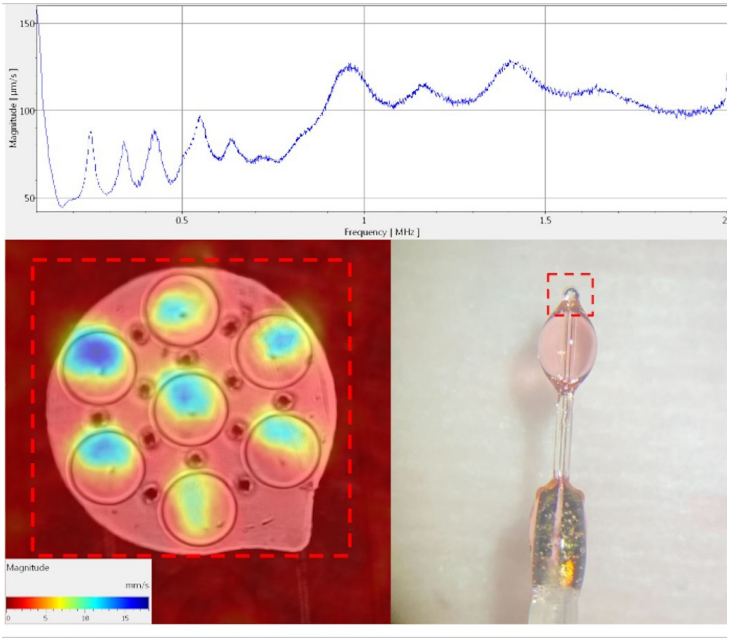
An Implantable Device for In-situ Ultrasound-enhanced Drug Delivery

J. F. Hou, S. B. Ornellas, M. O. G. Nayeem, C. Dagdeviren
Sponsorship: Media Lab Consortium Funding

Current intratumoral drug delivery strategies enable delivery of mRNA therapeutics but have poor tissue specificity and a need for repeated doses. Microfluidic devices enable targeted and controlled drug delivery, and ultrasonic cavitation has been used to reversibly modulate the permeability of tissue. A combined effect allows delivery of a drug payload to our target and enhanced penetration with an array of ultrasound transducers.

In this work, we create a novel piezoelectric Micromachined Ultrasonic Transducer (pMUT) with a microfluidic channel for in-situ drug delivery. Our device is based on an array of lead-free potassium sodium niobate (KNN) thin films and is transfer-printed on a flexible SU-8 substrate. The biostable nature of our devices enables chronic and responsive delivery for the treatment of intracranial tumors, and our results highlight the microfabrication and early characterization of the device performance in-vitro.

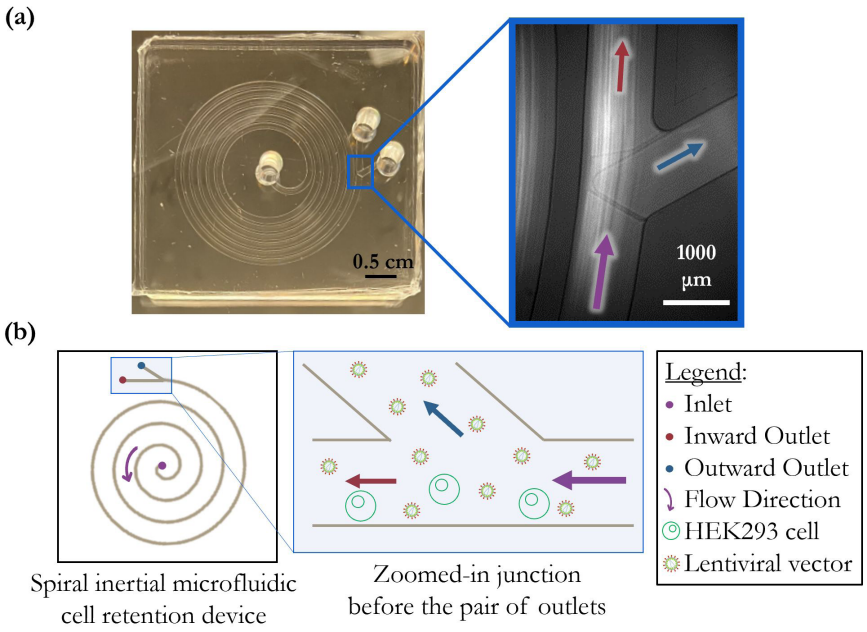


▲ Figure 1: Laser doppler vibrometer measurement of average velocity of transducer at various frequencies (top), Relative magnitude of velocity over the array (bottom left), Full scale device with water injected through the microfluidic channel (bottom right)

Continuous Lentiviral Vector Harvesting from HEK 293 Perfusion Culture using Spiral Inertial Microfluidic Technology

A. Bevacqua, F. Liu, D. H. Park, J. Chen, J. Han
Sponsorship: Food and Drug Administration (1R01FD007480-03) and NSF Graduate Research Fellowship

Lentiviral vectors are popular gene delivery tools used to create gene and cell therapies. With these therapies costing patients over $400,000 per dose, research to develop high-concentration, high-yield viral vector manufacturing strategies has a pivotal role in advancing therapy commercialization efforts and lowering costs. Viral vectors are manufactured in HEK 293 cell perfusion culture and a cell retention device is used to separate viral vectors from cells. Many membrane-based cell retention devices used in industry struggle to maintain high product recovery over long production runs. We used a spiral inertial microfluidic cell retention device to carry out high-recovery harvesting from perfusion culture. We achieved 7 days of continuous lentiviral vector production and harvesting with a peak, unconcentrated, functional titer of 10^8 transducing units/mL, with a high recovery throughout production. Advancing viral vector harvesting strategies will expand treatment accessibility.



▲ Figure 1: (a) The spiral inertial microfluidic device inertially focuses cells to the spiral's inward outlet (red arrow). (b) Viral vectors are continuously harvested through the outward outlet (blue arrow), since their motion is unbiased by inertial focusing.

Tracking Neurocognitive Decline via Abnormalities in Eye Movements Recorded on Mobile Devices

J. Koerner, V. Sze, C. G. Sodini, T. Heldt
Sponsorship: Aging Brain Initiative

The aging brain inevitably manifests in a decline of mental abilities. However, it is often difficult to discern age-related decline in neurocognitive performance from a decline due to neurodegenerative disease processes, especially early in the disease process when disease-modifying interventions are thought to be most effective. To this end, certain features of eye movements have been shown to be sensitive and specific markers of neurodegenerative disease progression. However, their quantitative measurements and assessments have hereto required dedicated staff time and high-end equipment and hence are only conducted during specialized neurological examinations. To close this diagnostic and clinical monitoring gap, this work proposes a novel approach for tracking neurocognitive decline in the elderly by transitioning eye movement measurements from high-end, specialized medical equipment to low-cost ubiquitous consumer electronics, such as smartphones or tablets. Specifically, our approach displays eye movement tasks on iPads and uses the integrated selfie-camera to record videos of subjects completing these tasks on a daily basis. From the recordings, we extract eye movement features, identify and track eye movement abnormalities, and correlate them with neurocognitive decline. Our approach promises to enable continual and personalized tracking of neurocognitive decline from home. This will dramatically increase the granularity of assessment, thereby assisting doctors to discern normal, age-related neurocognitive decline from that seen in neurodegenerative diseases and providing an avenue for the development of more effective treatment plans and helping advance research into new treatment strategies.

Stochastic Regulator with Estimation Filter Implementable Using Bio/Nano Chemistry and Useful for "Intelligent Design"

J. M. Protz, A. Jain, A. Y.-H. Lee
Sponsorship: Protz Lab Group and the former BioMolecular Nanodevices, LLC

Signal processing using polymers has been a focus of the authors for two decades and has recently become of greater interest at MIT. Their present effort explores chemical and biological implementation of a stochastic linear regulator. It builds on a conceptual reaction mixture considered by the performer two years ago: "PROM" -type "junk DNA" in a plasmid transcribes into mRNA strands that are attacked by exonucleases coded for in a "BIOS" region of said plasmid; the activity of the nucleases depends jointly on the species of nucleotide being removed and on peptides pulled from polypeptides present alongside the plasmid; this causes the mix of surviving mRNA to depend on the polypeptide composition; the surviving mRNA reverse-transcribes into DNA that overwrites partly a "RAM" region of coding DNA in the plasmid, evolving it from a "prior estimate" of the environmental state to an "updated estimate" of the environmental state; said DNA expresses phenotypically as "actuator" proteins that are assembled by ribosomes from the free peptides and that "actuate" the surrounding environment; separately, a "sensor" reaction uses proteases and environmentally-sensitive peptide ligation reactions to recycle used "actuator" proteins back into free peptides that are then assembled into the aforementioned "sensor measurement" -storing polypeptides. One period of this cycle represents one update interval for an estimation filter. If implemented in a cell or organism, with the "sensor measurement" -storing polypeptides doubling as, e.g., a yolk, the lifetime of one cell or organism could constitute one update cycle of a stochastic regulator implemented by way of a cell line, organism family line, or society. Progress of the effort may allow the engineering of cell lines that evolve themselves and their environment deterministically and robustly according to "intelligent design" and may also explain the existence of aging, death, reproduction, and variable life expectancy.

Engineering High-throughput Electrokinetic Filtration for Nucleic Acid Enrichment

M.Cui, E.M. Wynne, J. Han
Sponsorship: U.S. Food and Drug Administration (FDA, 1R01FD007226-01)

Rapid and reliable ultralow-abundance molecular detection is of great interest in biomedical research and clinical trial. Quantitative polymerase chain reaction, a widely used nucleic acid quantification method, has multiple inherent issues, including tedious sample preparation, non-specific amplification, limited detection range, etc. Besides, there is no existing amplification method for protein, which restricts the development of protein-based diagnosis. Thus, there is a critical unmet need for a universal amplification or preconcentration of molecules.

Previously, our group developed a high-throughput electrokinetic filtration for biomolecule concentration. Although the flow rate is extremely high, the sample recovery rate is only 40% - 60%. Furthermore, the optimization of this concentrator is complicated because the device is not designed for microscopy. Herein, we propose a microscopic version of high throughput concentrator. This device allows imaging of concentration region, which provides a quantitative assessment of device performance. With the assistance of microscopy, we optimized the device, including minimizing downstream pore size on cation exchange membranes (CEMs) to ~150 μm in diameter to effectively generate ion depletion zones (IDZs), inserting ~35 μm porous polyethylene (PE) in front of IDZs to increase the electric intensity, adding ~25 μm porous filter paper near IDZs to compress instability of vortex. The operating flow rate can also be easily determined by downstream imaging. In summary, the microscopic device provides not only straightforward assessments of concentration but also operation at a high flow rate.

We used fluorescent-tagged DNA (ssDNA-647) in 0.1X phosphate buffer saline to test the performance of the device. With the assist of microscopic device, a flow rate up to 50 μL/min is achieved without significant leakage at 50 V. A 1 mL sample can be concentrated to a final volume of 50 μL, with a concentration factor of 20. We will further test the concentration performance of protein and bacteria.

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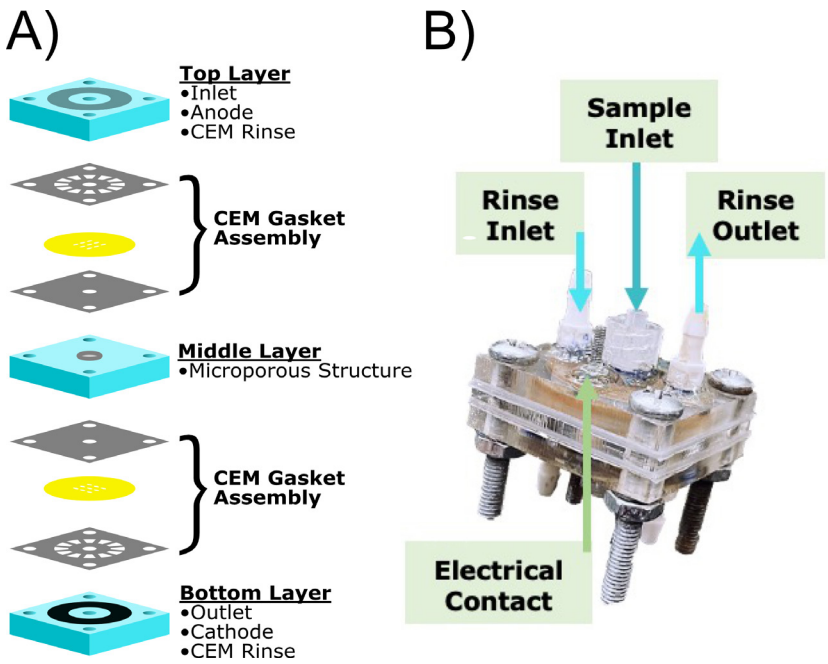
High Throughput Electrokinetic Concentrator with Polydopamine DNA Capture Substrate

E. M. Wynne, M. Cui, J. Han
Sponsorship: SMART CAMP

Technologies such as next-generation sequencing are able to detect small amounts of genetic material, making low abundance detection of pathogens a possibility. These technologies can only process volumes on the scale of tens of microliters at time, limiting the utility of these methods when trying to process large volumes such as liters of bioreactor supernatant. Electrokinetic concentration devices could elevate these sensing technologies by reducing large sample volumes to a scale more compatible with these technologies.

We demonstrate an EK concentration device operating at flowrates up to 50 microliters per minute, and characterize the performance when adjusting voltage, flowrate, and buffer composition. Our device uses an electric field to focus DNA into a region with a polydopamine (PDA) coated substrate that binds DNA. We demonstrate that applying a chelating agent to PDA releases the DNA such that it can quantified by methods other than fluorescence microscopy. This work expands the utility of EK concentration devices and presents a semi-continuous method for DNA enrichment in contrast to existing batch methods.



▲ Figure 1: A) A blown up schematic of the electrokinetic concentration device. B) A photograph of the device fully assembled.

Electrophoretic Quality Assessment of Adeno-associated Virus (AAV) by Microfluidic Ion Concentration Polarization

Y. Park, M. Cui, J. Han
Sponsorship: U.S. Food and Drug Administration (FDA, 1R01FD007226-01) and Singapore MIT Alliance for Research and Technology, CAMP IRG.

Adeno-associated virus (AAV) is widely used as a viral vector in gene therapies as well as genetic manipulation of various cells. The demand for high-quality AAVs is increasing alongside the growth of gene therapy. Still, there is a critical lack of reliable tools to assess the general quality of AAV capsids produced in biomanufacturing. However, AAV manufacturing in HEK293 always produces a very impure population, where only <30% of produced AAV particles typically have all the genes that make the particle functional in vivo [1]. Moreover, a large number of them are partially filled with genes that are not functional but have the potential to be immunogenic in vivo [2]. Therefore, detecting and potentially removing empty and partially filled AAV capsids is an important quality-control step in AAV biomanufacturing. This study tried to address this critical challenge by introducing a microfluidic device with the ion concentration polarization (ICP) effect. The ICP effect-based microfluidic device is fabricated based on previous research utilizing Nafion resin solution to make cation exchange membranes [3]. The device was tested using a reference AAV capsid to differentiate fully packed AAVs from empty AAV samples. The result was analyzed and quantified based on fluorescence intensity values of labeled AAV. The technique used in this study was able to distinguish a 5% content difference in each empty AAV composition ratio, suggesting a potential to be used as a tool for quantitative analysis in various studies like purification of particles with a similar size but different electric charge.

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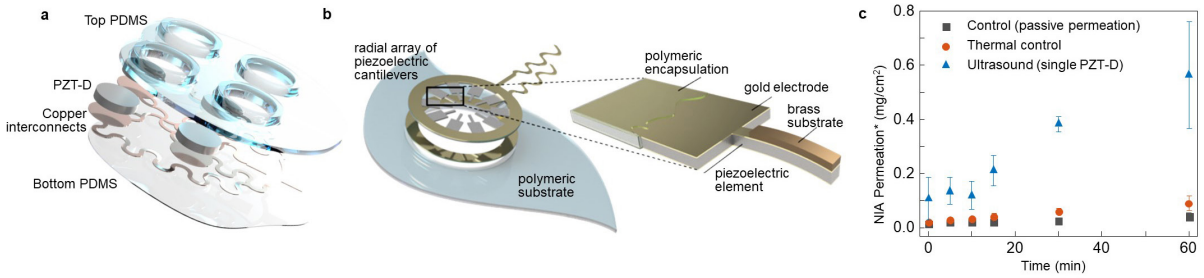
A Conformable Ultrasound Patch for Cavitation Enhanced Transdermal Cosmeceutical Delivery

A. Shah, C. Yu, N. Md Osman Goni, C. Marcus, C. Dagdeviren, A. Kumar-Bhayadiya
Sponsorship: MIT Media Lab Consortium, K.Lisa Yang Bionics Fellowship (AS, 2021-22), MIT Presidential Fellowship (AS, 2023-24), NSF CAREER: (Grant No. 2044688), 3M Non-Tenured Faculty Award, NSF (Grant No. s1905252).

Growing interest in skin health necessitates an effective method for enhancing the transdermal absorption of therapeutic cosmeceuticals such as niacinamide (122 $gmol^{-1}$). The challenge arises due to the limited permeation of such small-molecule drugs (<500 $gmol^{-1}$) through the stratum corneum barrier. We report a conformable ultrasound patch (cUSP) that employs intermediate-frequency sonophoresis to improve the transdermal transport of niacinamide. The cUSP, featuring bulk piezoelectric transducers within a soft elastomer, creates localized cavitation pockets (0.8 cm^2, 1 mm deep). Multiphysics simulations, acoustic spectrum analysis, and high-speed videography characterize transducer deflection, acoustic pressure fields, and cavitation bubble dynamics. In vitro testing on porcine skin demonstrates a 26.2-fold increase in niacinamide transport with a 10-minute ultrasound application. To further enhance portability, we propose miniaturizing the transducer footprint using piezoelectric unimorph cantilever structures to create a seamless conformable interface for patients suffering from skin conditions and premature skin aging.



▲ Figure 1: Simplified schematic, (not to scale) of the (a) bulk and (b) unimorph embodiments of the cUSP interface. (c) In vitro skin permeation results obtained with the bulk interface demonstrating a 19.2-fold enhancement in the total of niacinamide delivered in 60 minutes after 10 minutes of ultrasound application.

Ultrasound-based Detection and Sizing of Emboli: Toward Safer ECMO

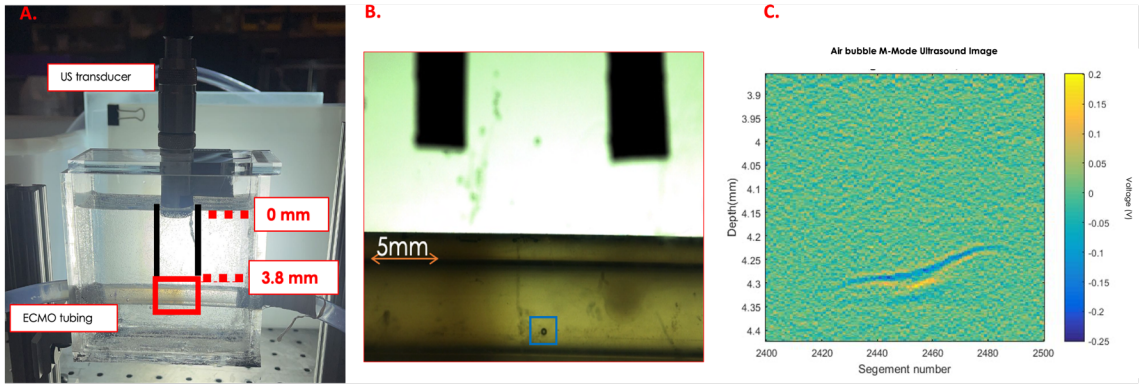
I. Romero, S. M. Imaduddin, T. Heldt, L. Bourouiba
Sponsorship: Boston Children's Hospital Anaesthesia Foundation

Extracorporeal membrane oxygenation (ECMO) is an extreme life-support mechanism designed to aid individuals whose lungs or heart is not functioning properly in oxygenating their blood. This process continuously pumps blood through an external device that adds oxygen and removes carbon dioxide.

However, ECMO comes with certain risks, including the potential formation of emboli, which can be either solid, such as blood clots, or gaseous, like air bubbles. Such emboli can lead to tissue damage through ischemia and may result in stroke or pulmonary obstruction, posing a substantial challenge in critical care. The detection and prevention of such emboli remain major technological challenges.

We aim to tackle this problem by leveraging ultrasonography. For that, we are collaborating closely with colleagues at Boston Children's Hospital and established a laboratory-based simulation system to replicate the clinical ECMO environment. We developed a data acquisition system for time-synchronized recording of ultrasound imaging and high-speed videography. This dual imaging approach allows for ground-truth recording of the emboli injected into this system. Finally, we have developed algorithms to analyze the recordings. By using signal processing techniques, we can detect, count, and size the emboli, thus paving the way for safer ECMO.

Future work will focus on improving the laboratory setting by using real blood clots and refining the algorithm to differentiate between solid and gaseous emboli. Additionally, expanding the application of these technologies to other forms of extracorporeal support systems will also be a priority, potentially broadening the impact of our work across different domains of critical care.



▲ Figure 1: A. Laboratory-based ultrasound data collection: Ultrasound transducer positioned perpendicular to the ECMO tube, with liquid flowing from left to right. B. High-speed videography for ground truth: Camera aligned with the ultrasound's focus area, capturing a 460-micrometer air bubble. C. Ultrasound imaging of the same air bubble: Air bubble represented in a color-scaled plot of segment number versus depth versus voltage.

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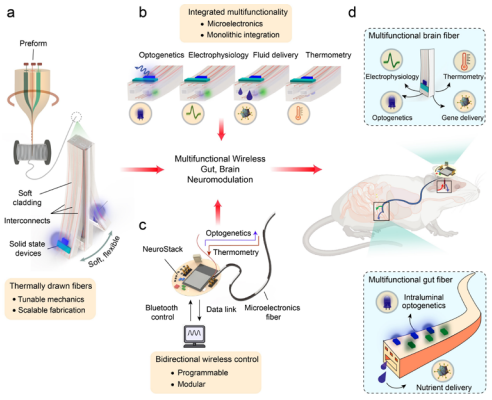
Multifunctional Microelectronic Fibers Enable Wireless Modulation of Gut-brain Axis

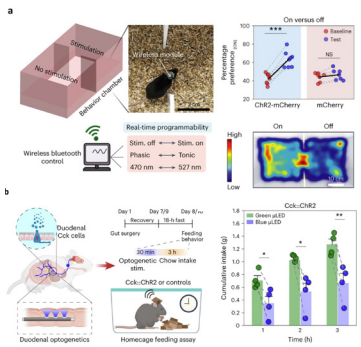
A. Sahasrabudhe, P. Anikeeva

The body's peripheral organs are in a constant bidirectional cross talk with the brain, generating a cognitive map of the body's physiological state, which is vital for survival. This is exemplified by the gut-brain communication, wherein hormonally and neurally mediated signals emerging from the abdominal viscera transduce metabolic information to the brain to maintain energy homeostasis. Although these internally arising gut-to-brain sensory cues are consciously imperceptible, they have been shown to influence neurocognitive processes such as motivation and affect. However, probing and understanding critical brain-body circuits in behaving animal models presents a neurotechnological challenge due to contrasting design criteria imposed on implantable devices by drastic anatomical differences between the skull-encased brain tissue and mobile, delicate peripheral organs.

Inspired by nerve fibers, we design a soft, flexible polymer fiber-based organ-brain neurotechnology. To match the inherent signaling complexity of the nervous system, we envisaged probes that integrate multiple functionalities yet retain a miniature device footprint to facilitate chronic bio-integration. To create a multifunctional and multi-organ neurotechnology, we combine the scalability and rapid customization of fiber drawing with the functional sophistication of solid-state microdevices (Figure 1a). We produce hundreds of meters of flexible polymer filamentary probes integrating microscale light-emitting devices, thermal sensors, microelectrodes, and microfluidic channels (Figure 1b). The ability to process thermoplastic elastomers with the same route enables deterministic tunability of device mechanics and allows probes of target deep-brain structures and/or regions of the murine intestine (Figure 1d, e). We design a lightweight and modular wireless control circuit, NeuroStack, that offers bidirectional wireless control and real-time programmability of in-fiber microdevices and an intuitive user interface (Figure 1c). The brain fibers offer gene delivery for cell-type specific optogenetic neuromodulation, single-neuron recordings, thermometry, and tetherless control of the mesolimbic reward pathway (Figure 2a). The soft gut fibers grant access to anatomically challenging, delicate intestinal lumen, allowing intraluminal optofluidic control of sensory epithelial cells that guide feeding behaviors (Figure 2b). We discover that optogenetic stimulation of vagal afferents from the intestinal lumen drives reward behavior in untethered mice. These illustrative applications foreshadow widespread use of wireless multifunctional microelectronic fibers to study the roles of specific cells in bidirectional communication between peripheral organs and the brain. This will empower the field of interoception, paving the way for mechanistically guided improved autonomic neuromodulation therapies.



▲Figure 1: Schematic illustration of microelectronics-integrated multifunctional fibers that enable wireless modulation of brain and gut neural circuits.



▲Figure 2: (a) Wireless brain devices allow modulation of neural circuits in deep brain reward structures as tested in real-time place preference assay in transgenic mice; (b) Wireless gut devices allow modulation of eneteroendocrine cells that signal satiety through hormone release in small intestine of mice as tested in acute feeding assay. devices allow modulation of eneteroendocrine cells that signal satiety through hormone release in small intestine of mice as tested in acute feeding assay.

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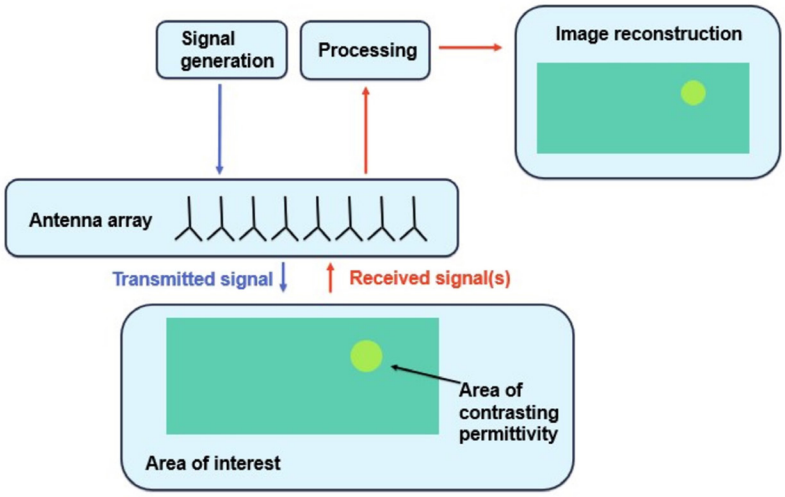
Miniaturization and Integration of Medical Microwave Imaging Systems

M. St. Cyr, A. Zarrasvand, N. Reiskarimian
Sponsorship: Draper Scholars

Microwave imaging (MWI) is an imaging modality of importance to numerous medical applications. Changes within the body are directly correlated to changing dielectric properties that correspond to different responses to an applied electric field. Thus, by sending a microwave signal into the body and detecting the transmitted and reflected signals from multiple locations surrounding the area of interest, an image can be reconstructed that demonstrates physiological changes. MWI is identified as a potential new harmless and noninvasive imaging modality for medical spaces such as tumor detection.

MWI requires sensitive and reliable electronics. Signal generators, transmitters, and receivers are some of the components needed to realize an MWI system. Early research on microwave imaging has used highly dependable off-the-shelf electronics; however, these electronics are often very bulky and unspecified to the application of MWI. By developing integrated circuits for MWI, we can make systems cheaper, smaller, and easier to operate. Such characteristics are necessary for continuous monitoring of conditions inside the body and overall higher accessibility to healthcare.

This work will design integrated circuits specifically for MWI. The goal is for these circuits to occupy a much smaller footprint than current electronic solutions, without compromising image quality. This work begins with understanding the challenges and tradeoffs that exist within off-the-shelf electronic systems through system level design exploration. After understanding the metrics in the electronic system that correlate with image quality, we will design circuit topologies to fit the exact specifications required.



▲ Figure 1: Overview of an MWI system.

Progress on an Implantable Microphone for Cochlear Implants

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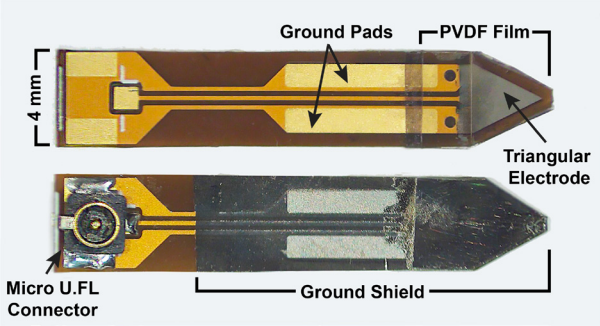
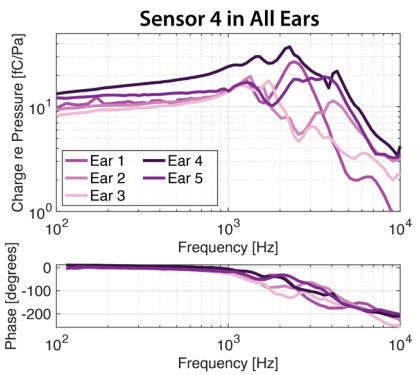
Cochlear implants are devices that can restore hearing loss to people with sensorineural hearing loss. Despite their name, cochlear implants rely on an external electret microphone which poses many lifestyle restrictions on the users. We present the fabrication and testing of an implantable microphone as an important step towards a totally implanted cochlear implant.

The piezoelectric microphone is made from titanium and thin film polyvinylidene fluoride (PVDF), is shaped like a triangular cantilever, and has a differential output. Figure 1 shows an image of the microphone sensor during and after fabrication. The microphone sensor is inserted through the facial recess and contacts the manubrium's umbo. We target the umbo because its uni-directional motion produces a well-represented sound signal. As the umbo moves, it displaces our piezoelectric sensor, resulting in a charge accumulation that we amplify with a custom differential charge amplifier.



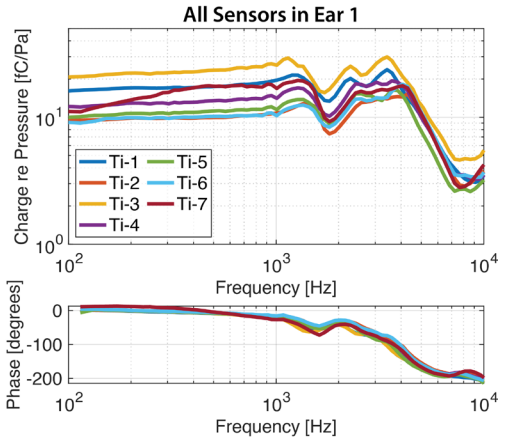
▲ Figure 1: A picture of two UmboMic sensors. The top sensor is partially fabricated; the triangular electrodes have been patterned, the flex PCB trimmed, and the PVDF layer adhered. It is missing the ground shield and U.FL connector which can be seen in the finished bottom sensor.



We use photolithography and thin film deposition to fabricate our sensors in a nano-microfabrication facility at the Massachusetts Institute of Technology. We have tested seven sensors at Mass Eye and Ear via bench testing and human cadaveric experimentation.

The eight sensors behave comparably during bench testing and in five distinct human cadaveric ears. Our microphones show a flat frequency response, high sensitivity, good linearity, and an equivalent input noise comparable to commercial hearing aid microphones. Figure 2 shows the frequency response of all seven sensors in a single ear, while Figure 3 shows the frequency response of a single sensor across five ears.

Our prototype demonstrates the feasibility of a PVDF-based microphone and is an important step towards developing a totally implantable cochlear implant.



▲ Figure 2: The frequency response of eight different microphones in a single ear. The y-axis shows the charge output of the microphone normalized by the pressure in the ear canal. Despite fabrication and implantation differences, the sensors have a very similar frequency response.

◀ Figure 3: The frequency response of a single sensor in five different ears. Despite anatomical differences between ears, the sensor has a similar frequency response across experiments.

Piezoelectric Single Crystal-Based Ultrasound Patch for Breast Imaging

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Sponsorship: NSF CAREER: Conformable Piezoelectrics for Soft Tissue Imaging (grant no. 2044688), NSF Graduate Research Fellowship Program under grant no. 2141064

Ultrasound is pivotal for breast cancer diagnosis, but challenges limit its integration with wearables, especially for large curvilinear organs. We've introduced a breakthrough: the cUSBr-Patch, a conformable ultrasound breast patch. This wearable offers standardized, reproducible image acquisition across the entire breast, reducing operator reliance and transducer compression. The honeycomb-shaped patch, guided by an easy-to-use tracker, enables large-area, deep scanning, and multiangle breast imaging. Using a piezoelectric crystal [Yb/Bi-PIN-PMN-PT], our in vitro and clinical trials achieved a contrast resolution of ~3 dB and axial/lateral resolutions of 0.25/1.0 mm at 30 mm depth. This allows the observation of small cysts (~0.3 cm) in the breast. Our technology provides a noninvasive method for real-time tracking of dynamic soft tissue changes, marking a significant advancement in ultrasound for breast tissue scanning within a compact wearable form.