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FROM NATURE TO NDT

It has been over 15 years since I began my journey in nondestructive testing (NDT). In 2010, I started my PhD at the University at Buffalo, focusing on distributed sensor networks using guided ultrasound waves for structural health monitoring of pipelines and plate-like structures. Later, I joined General Electric (GE) in power system production, where I expanded my expertise in NDT. Working on composite material inspection, gas and steam turbine components, and in-service inspections across GE Power, Oil & Gas, and Aviation significantly enhanced my understanding of real-world NDT applications. Now, as an associate professor in the School of Manufacturing Systems and Networks at Arizona State University, I strive to transfer this industry experience to my students.

In 2017, I developed and taught an NDT course at New Mexico State University. I worked with students from civil, mechanical, industrial, and electrical engineering departments, creating an interdisciplinary learning environment. Securing funding to establish my research program was a challenge, motivating me to explore innovative ideas. In 2018, while watching a documentary [1] about aye-ayes with my then 4-year-old (and equally curious) son Daniel, I was captivated by their unique foraging behavior called “percussive foraging” or “tap-testing.” I immediately recognized the similarity between this and conventional tap-testing techniques used in NDT to identify hidden defects in materials. That night, I delved into the scientific literature on aye-ayes and learned more about how they naturally perform a process identical to what we do in NDT—using tapping techniques to detect cavities beneath the surface. However, unlike conventional NDT applied to engineered materials, aye-ayes detect deep cavities in far more complex natural structures, such as tree bark, with astonishing precision. This sparked my long-term research interest in bioinspired NDT.

Supported by the National Science Foundation [2], our research has uncovered key factors influencing the unique NDT process that aye-ayes use in their foraging behavior. While bioinspired research has significantly advanced fields such as robotics, materials science, and biology, a new frontier lies in examining entire biological processes—such as food foraging—as a model for detection, localization, sizing, and classification, much like the fundamental principles of NDT. By studying and mimicking these natural processes, we have the potential to pioneer new NDT methods or enhance existing techniques with greater sensitivity and reliability.

I am honored to be the guest editor of this special issue dedicated to the emerging field of bioinspired NDT, with the hope that this innovative approach to engineering solutions will drive advancements in inspection technologies, ensuring greater safety and reliability for our communities.

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RESEARCHERS DEVELOP NEW METHOD TO AMPLIFY BIOELECTRONIC SENSING

In a breakthrough that could transform bioelectronic sensing, an interdisciplinary team of researchers at Rice University (Houston, TX) has developed a new method to dramatically enhance the sensitivity of enzymatic and microbial fuel cells using organic electrochemical transistors (OECTs). The research was recently published in the journal *Device*.

The innovative approach amplifies electrical signals by three orders of magnitude and improves signal-to-noise ratios, potentially enabling the next generation of highly sensitive, low-power biosensors for health and environmental monitoring.

"We have demonstrated a simple yet powerful technique to amplify weak bioelectronic signals using OECTs, overcoming previous challenges in integrating fuel cells with electrochemical sensors," said corresponding author Rafael Verduzco, professor of chemical and biomolecular engineering and materials science and nanoengineering. "This method opens the door to more versatile and efficient biosensors that could be applied in medicine, environmental monitoring, and even wearable technology."

A lithographically patterned organic electrochemical transistor (OECT) device, used for measurement with enzymatic and microbial fuel cells. Researchers at Rice University are using OECTs to amplify weak bioelectronic signals.

Traditional biosensors rely on direct interactions between target biomolecules and the sensor device, which can pose limitations when the electrolyte environment is incompatible. This research circumvents that challenge by electronically coupling fuel cells with OECTs instead of introducing biomolecules directly into the sensor.

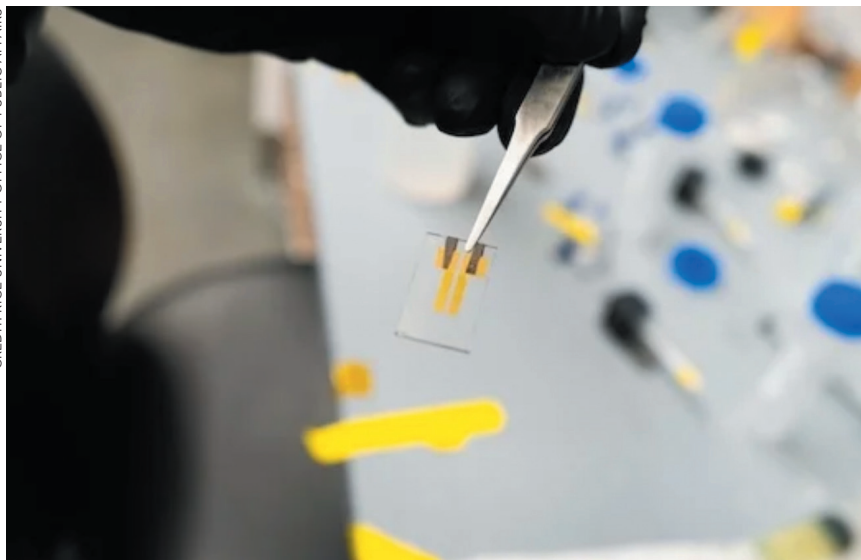
"One of the biggest hurdles in bioelectronic sensing has been designing systems that work in different chemical environments without compromising performance," said corresponding author Caroline Ajo-Franklin, professor of biosciences, director of the Rice Synthetic Biology Institute, and Cancer Prevention and Research Institute of Texas (CPRIT) Scholar. "By keeping the OECT and fuel cell separate, we ensured optimal conditions for both components while still achieving powerful signal amplification."

OECTs are thin-film transistors that operate in aqueous environments and have gained attention for their high sensitivity and low-voltage operation. For the study, the team integrated OECTs with two types of biofuel cells to enhance their performance. The first type, enzymatic fuel cells, utilize glucose dehydrogenase to catalyze glucose oxidation, generating electricity in the process. The second type, microbial fuel cells, rely on electroactive bacteria to metabolize organic substrates and produce current. The OECTs were coupled with the fuel cells in two different configurations: a cathode-gate configuration and an anode-gate configuration.

The researchers found that OECTs can amplify signals from enzymatic and microbial fuel cells by factors ranging from 1000 to 7000, depending on the configuration and fuel cell type. This amplification is significantly higher than traditional electrochemical amplification techniques, which typically achieve signal enhancements in the range of 10 to 100 stronger.

The team discovered that the cathode-gate configuration provided the best amplification, especially when using a specific polymer as the channel material. The anode-gate configuration also showed strong amplification but posed potential challenges at higher fuel cell currents, leading to irreversible degradation in some cases.

Along with boosting signal strength, the researchers found that OECTs reduced background noise, making measurements more precise. Traditional sensors can struggle with interference and weak signals, but the OECTs produced clearer, more reliable data.



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