Transformational research combines solid-state and biological components

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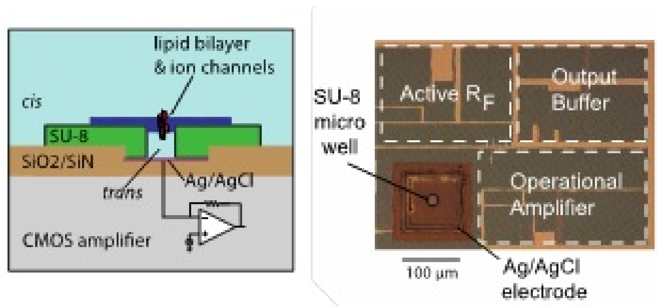

This illustration shows the direct interface between an ion-channel protein and a solid-state amplifier on the surface of an integrated circuit chip. Columbia University researchers have won a $1 million Keck Award for transformational research that combines solid-state and biological components. Electrical Engineering Professor Ken Shepard is among the pioneers in the development of engineered solid-state systems interfaced to biological systems; he has developed many new techniques for interfacing CMOS integrated circuits with biological materials. Credit: Columbia Engineering

An interdisciplinary team of researchers from Columbia University, led by Ken Shepard, professor of electrical engineering and biomedical engineering at Columbia Engineering and including Virginia W. Cornish, Helena Rubinstein Professor of Chemistry, and Lars Dietrich, assistant professor of biological sciences, has won a prestigious $1 million three-year grant from the W. M. Keck Foundation to advance their research in combining biological components with solid-state electronics, creating new systems that exploit the advantages of both.

"Winning this generous Keck grant is critical to moving our research forward," says Shepard, whose group has a long history in developing solid-state interfaces to biological and biomolecular systems.

"Just in the short-term, this work has the potential to impact many biotechnology applications seeking to replace fluorescence-based diagnostics with electronic ones."

The team is leveraging the tremendous sophistication and economies of scale present in modern microelectronics based on complementary metal-oxide-semiconductor (CMOS) technology. This is the core technology behind the integrated circuits that power computing and communications devices. Despite its overwhelming success, CMOS solid-state electronics is incapable of replicating certain functions natural to living systems, such as the senses of taste and smell and the use of biochemical energy sources. Living systems achieve this functionality with their own version of electronics based on lipid membranes and ion channels, which act as a kind of "biological transistor." In this project, the team will combine these biological electronic devices with CMOS to create new systems not possible with either technology alone. The ultimate goal of this work could be autonomous hybrid "cells" that could exist as probes in living organisms.

"Modularity exists in both the biological and solid-state domains, thus enabling components to be easily reassembled to change functionality," says Cornish, whose group has carried out pioneering work in synthetic biology with an emphasis on directed evolution. "The engineered interaction of the heterogeneous biological with the simple, but massively integrable and robust solid-state enables new capabilities not possible with either material system alone."

Shepard's lab is among the pioneers in the development of engineered solid-state systems interfaced to biological systems. Shepard has developed many new techniques for interfacing CMOS integrated circuits with biological materials. In recent work, his team has designed custom CMOS amplifiers engineered to operate with biomolecular systems. This close integration has allowed these systems to be studied with sub-microsecond temporal resolution.

"The fact that revolutionary improvements in the quality of electrophysiological interfaces can come from custom CMOS integrated circuit design motivates development of a whole new class of engineered systems that are based on the integration we are proposing here," he adds.

Lars Dietrich's research group brings essential expertise to the team in understanding the general principles underlying bacterial signaling and the role of this signaling in community behavior. Shepard and Dietrich are already collaborating on using CMOS electronics to study and control the behavior of bacterial biofilms. Bacterial colonies will constitute an important multicellular biological environment in which the hybrid systems developed here will interact.

"Creating hybrid engineered integrated systems that exploit the unique advantages of both biological and solid-state components is endlessly exciting," Shepard says. "Columbia is an exciting place to pursue this kind of interdisciplinary research, and the new Northwest Corner Building has been a tremendous catalyst for these collaborations."

Provided by Columbia University

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