Researchers target silicon chips for biomolecular devices

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Arizona State University researchers in the Ira A. Fulton School of Engineering are key contributors to an $11.7 million, multicollaborative Defense Advanced Research Project Agency research project developing novel hybrid biomolecular nanodevices and systems for potential application as biosensors in areas such as disease detection, pharmaceutical drug-testing, drug-delivery systems and health monitoring.

Hybrid biomolecular devices involve interfacing biological matter with electronic circuitry to create a silicon chip that can interpret and convert molecular changes into real-time digital information.

Stephen Goodnick, a professor of electrical engineering, and Trevor Thornton, also a professor of electrical engineering and director of the Center for Solid State Electronics at ASU, are leading the university's efforts.

The multi-institutional grant, part of the Engineered Bio-Molecular Nano-Devices/Systems (MOLDICE) Program within DARPA' s Defense Sciences Office, involves researchers from Rush Medical Hospital in Chicago and six other partner universities: UCLA, Texas A&M, the University of Florida, the University of Utah, Rush Medical, Oxford University and the Max Planck Polymer Institute in Mainz, Germany. ASU's share in the grant is $1.7 million, which is one of the largest portions.

The DARPA grant is being conducted in two phases. Phase I, completed recently, has yielded significant results from the ASU side, Goodnick says.

Goodnick and Thornton have integrated an artificial cell membrane into a silicon chip. The chip contains integrated electrodes that measure the ion current flowing in solution from one side of the membrane to the other, through a single protein channel inserted into the membrane.

Quantifying sodium and potassium ion transport properties and structure in a cell wall is of particular importance, because it helps in identifying protein structure, including mutations that can affect the cell's function.

The pharmaceutical industry is especially interested in this type of process, because channel proteins are noted for their unique ability to react to different types of drugs. Biomolecular devices can help provide valuable electrophysiological feedback that warns researchers of potential side effects of new drugs that are being tested.

The ion channel measurements, demonstrated by Goodnick and Thornton, represent the first such measurements performed in a silicon platform.

"Potential applications include use of this structure as a biosensor, where ion-channel proteins bind to specific target biological agents, hence changing the electrical behavior of the channel," Goodnick says.

This was the primary application funded by DARPA, he adds.

Other applications include traditional uses of ion-channel measurements in drug testing, where ion channels and the patch clamp measurement technique are used to study the response of channels that are targeted by specific drugs, such as those regulating the heart. The patch clamp

measurement requires a number of complex instruments and is a traditional laboratory-scale technique used for measuring ionic currents through channels.

“Effectively, we have demonstrated that we can perform patch clamp measurements on a chip, leading to the possibility of lower noise and substantial reduction in size for a portable device,” Goodnick says.

As with any new process, one of the biggest hurdles that researchers faced was the interface between the biological and non-biological world.

“Processes compatible with semiconductor processing are not generally amenable to biological systems,” he says.

In particular, getting a lipid bilayer (the component of cell walls) to adhere to a substrate required a special process that was developed at ASU. This process helped to make the chip surface hydrophobic, or water repellent, to attach the bilayer.

Phase II, which will integrate ASU’s work with the research of other partners, will involve prototyping a complete system in the form of a handheld ion-channel biosensor that can be tested in a microfluidic array system.

Goodnick believes that biomolecular devices essentially are fueling much of the research being conducted in the information technology arena today.

“Such devices are expected to appear increasingly in health-monitoring applications, where implanted bionano devices monitor drug delivery and predict epileptic or heart attacks, while transmitting information externally or taking remedial actions to prevent such attacks,” he says. “Bionanoelectronics also hold the potential for new types of electronic

devices for computing and information processing based on biological principles."

Thornton explains the usefulness of this type of sensor in the context of the recent controversy surrounding the recall of Vioxx, a prescription painkiller developed by Merck Pharmaceuticals.

"Despite stringent FDA testing, when Vioxx was finally released on the market, it caused fatal heart attacks in a small percentage of the population," he says. "The reason for this was that Vioxx interfered with the ion channel proteins that controlled the beating of the heart. As a result of this, all new medications have to be screened against such interactions with ion channel proteins. Currently, this screening is done in a very laborious manner. Our chip promises to help automate the process."

Source: ASU

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