Deflecting damage: Flexible electronics aid brain injury research

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Flexible electronic membranes may overcome a longstanding dilemma faced by brain researchers: How to replicate injuries in the lab without destroying the electrodes that monitor how brain cells respond to physical trauma.

Developed by a team of engineers at Princeton University, Columbia University and the University of Cambridge, the membranes feature microelectrodes that are able to withstand the sudden stretching that is used to simulate severe head trauma. The systems could allow far more nuanced studies of brain injury than previously possible and may lead to better treatments in the minutes and hours immediately following the injury. The work also has implications for other areas of medicine, including next-generation prosthetics, as well as myriad industry and military applications.

"This is an immediate application of the electronics of the future," said Sigurd Wagner, a Princeton professor of electrical engineering. Wagner and former Princeton postdoctoral researcher Stephanie Lacour are part of a National Institutes of Health-funded project to develop flexible arrays of microelectrodes for brain research. Led by Barclay Morrison III, an assistant biomedical engineering professor at Columbia, members of the team will present their work at the April 9-13 conference of the Materials Research Society in San Francisco.

Existing techniques to study traumatic brain injury have been limited because it is almost impossible to insert an electrode into a cell to obtain a recording, remove the probe, injure the cell, and then reinsert the probe into the same cell, Morrison said. Because of this limitation, researchers rely on other surrogate markers of injury, such as cell death.

"In terms of traumatic brain injury, there can be a lot of functional damage to the brain in other ways than just killing a cell," Morrison said. "Neurons can still be alive, but not properly firing," which leads to problems ranging from comas to epilepsy.

These improperly functioning neurons can now be assessed by the electrodes in the stretchable membranes. After brain cells have been placed on the flexible surface and allowed to grow, the researchers measure their normal activity. The membrane is then suddenly stretched and returned to its original form. Having withstood the shock, the electrodes embedded in the membrane continue to monitor the cellular activity, providing a before and after picture of traumatic brain injury.

Future work will continue to refine these measurements and also attempt to obtain readings from cells during the injury events themselves, Morrison said. The flexible electrodes also can be used to provide electrical input to brain tissue and may one day be used to induce learning in brain cells damaged by trauma. This technology also has promising applications for the engineering of nervous, muscular and skeletal tissue. For instance, Morrison said, the electrodes could potentially be used to train heart tissue grown in the lab to contract appropriately when stimulated.

The new membranes build upon work done by Lacour during her time at Princeton in Wagner's lab. Lacour now is managing research in flexible electronics for neuroscience at the University of Cambridge in England. She has been recognized by Technology Review magazine, which named her to its 2006 list of 35 leading innovators under age 35.

Together, the engineers created the first working stretchable circuits by linking tiny pieces of traditional semiconductors mounted on a rubbery membrane with thin pieces of gold. Even when stretched, the circuits maintained their ability to conduct electricity.

Research on the flexible membranes also is likely to contribute to the longstanding challenge of connecting electronic devices to the human nervous system, Wagner said. Prosthetic devices, for example, could be coated with electronic "skin" that senses touch and temperature and sends that information back to the brain like any natural human limb.

"A basic problem with the interface between electronics and living tissue is that electronics are hard and tissues are soft," he said, noting that nerve cells quickly become irritated when in contact with the hard electrodes of today. The hope is that the devices of the future will flex with living tissue, maintaining a connection without damaging the human cells.

Source: Princeton University

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