U.S. Department of Health and Human Services
NIH News
National Institutes of Health

National Institute of Neurological Disorders and Stroke (NINDS)

National Institute of Biomedical Imaging and Bioengineering (NIBIB)

Embargoed for Release
Sunday, April 18, 2010
1 p.m. EDT

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A Brain-Recording Device that Melts into Place

Scientists have developed a brain implant that essentially melts into place, snugly fitting to the brain’s surface. The technology could pave the way for better devices to monitor and control seizures, and to transmit signals from the brain past damaged parts of the spinal cord.

"These implants have the potential to maximize the contact between electrodes and brain tissue, while minimizing damage to the brain. They could provide a platform for a range of devices with applications in epilepsy, spinal cord injuries and other neurological disorders," said Walter Koroshetz, M.D., deputy director of the National Institute of Neurological Disorders and Stroke (NINDS), part of the National Institutes of Health.

The study, published in Nature Materials, shows that the ultrathin flexible implants, made partly from silk, can record brain activity more faithfully than thicker implants embedded with similar electronics.

The simplest devices for recording from the brain are needle-like electrodes that can penetrate deep into brain tissue. More state-of-the-art devices, called micro-electrode arrays, consist of dozens of semi-flexible wire electrodes, usually fixed to rigid silicon grids that do not conform to the brain's shape.

In people with epilepsy, the arrays could be used to detect when seizures first begin, and deliver pulses to shut the seizures down. In people with spinal cord injuries, the technology has promise for reading complex signals in the brain that direct movement, and routing those signals to healthy muscles or prosthetic devices.

"The focus of our study was to make ultrathin arrays that conform to the complex shape of the brain, and limit the amount of tissue damage and inflammation," said Brian Litt, M.D., an author on the study and an associate professor of neurology at the University of Pennsylvania School of Medicine in Philadelphia. The silk-based implants developed by Dr. Litt and his colleagues can hug the brain like shrink wrap, collapsing into its grooves and stretching over its rounded surfaces.

The implants contain metal electrodes that are 500 microns thick, or about five times the thickness of a human hair. The absence of sharp electrodes and rigid surfaces should improve safety, with less damage to brain tissue. Also, the implants’ ability to mold to the brain's surface could provide better stability; the brain sometimes shifts in the skull and the implant could move with it. Finally, by spreading across the brain, the implants have the potential to capture the activity of large networks of brain cells, Dr. Litt said.

Besides its flexibility, silk was chosen as the base material because it is durable enough to undergo patterning of thin metal traces for electrodes and other electronics. It can also be engineered to avoid inflammatory reactions, and to dissolve at controlled time points, from almost immediately after implantation to years later. The electrode arrays can be printed onto layers of polyimide (a type of plastic) and silk, which can then be positioned on the brain.

To make and test the silk-based implants, Dr. Litt collaborated with scientists at the University of Illinois in Urbana-Champaign and at Tufts University outside Boston. John Rogers, Ph.D., a professor of materials science and engineering at the University of Illinois, invented the flexible electronics. David Kaplan, Ph.D., and Fiorenzo Omenetto, Ph.D., professors of biomedical engineering at Tufts, engineered the tissue-compatible silk. Dr. Litt used the electronics and silk technology to design the implants, which were fabricated at the University of Illinois.

Recently, the team described a flexible silicon device for recording from the heart and detecting an abnormal heartbeat.

In the current study, the researchers approached the design of a brain implant by first optimizing the mechanics of silk films and their ability to hug the brain. They tested electrode arrays of varying thickness on complex objects, brain models and ultimately in the brains of living, anesthetized animals.

The arrays consisted of 30 electrodes in a 5x6 pattern on an ultrathin layer of polyimide – with or without a silk base. These experiments led to the development of an array with a mesh base of polyimide and silk that dissolves once it makes contact with the brain — so that the array ends up tightly hugging the brain.

Next, they tested the ability of these implants to record the animals' brain activity. By recording signals from the brain's visual center in response to visual stimulation, they found that the ultrathin polyimide-silk arrays captured more robust signals compared to thicker implants.

In the future, the researchers hope to design implants that are more densely packed with electrodes to achieve higher resolution recordings.

"It may also be possible to compress the silk-based implants and deliver them to the brain, through a catheter, in forms that are instrumented with a range of high performance, active electronic components," Dr. Rogers said.

Neural electrode array wrapped onto a model of the brain. The wrapping process occurs spontaneously, driven by dissolution of a thin, supporting substrate of silk.

The study received support from NINDS, NIH's National Institute of Biomedical Imaging and Bioengineering (NIBIB), the U.S. Department of Energy's Division of Materials Sciences, the U.S. Army, the Defense Advanced Research Projects Agency (DARPA), and the Klingenstein Foundation.

NINDS (www.ninds.nih.gov) is the nation's leading funder of research on the brain and nervous system. The NINDS mission is to reduce the burden of neurological disease — a burden borne by every age group, by every segment of society, by people all over the world.

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Reference:

Kim, D-H et al. "Dissolvable Films of Silk Fibroin for Ultrathin Conformal Bio-Integrated Electronics." Nature Materials, published online April 18, 2010.

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