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Getting nanowires on the brain

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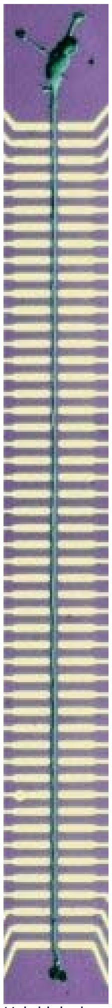
Researchers from Harvard University, US, have linked nanowire field-effect transistors to neurones, cells found in the brain and nervous system that create and transmit electrical signals. As well as offering the potential for hybrid biological/electronic devices and interfaces to neural prosthetics, the technique could provide high-resolution information about electrical signals in the brain.

"The truly exciting – and new – aspect of this work is that using multiplexed nanowire devices we were able to measure, elicit and modulate neuronal signals, with high spatial resolution and in real-time, at both the single axon and single dendrite level of individual neurones simultaneously," Charles Lieber told *nanotechweb.org*. "Thus we have demonstrated multiple inputs and outputs, or 'artificial synapses', to a single neurone for the first time."


Hybrid device

Lieber and colleagues connected silicon nanowire devices to parts of the neurone cell known as the axon and dendrites. "The key concepts are based on the unique and natural size-scale match between the nanowire transistors and neuronal projections – axons and dendrites – that allow for very different interfaces than previously possible to access in whole cell level interfaces with microfabricated structures," said Lieber.

To make the connections, the team first created an assembly of oriented p- and/or n-type silicon nanowires. Next they added metal contacts passivated with silicon nitride so that they were able to withstand the environment needed to culture cells (37°C and high ionic strength).

The researchers grew neurones in the desired locations by patterning polylysine onto square regions roughly 30 µn; across and onto 2 µm wide lines intersecting the squares. The polylysine selectively promoted neural growth and also served as an adhesion agent between the cell and the chip surface.

When a cell suspension was added and incubated for an hour before washing, cells remained on the square polylysine-coated areas. Incubation for four to eight days then encouraged axons or dendrites to grow along the intersecting polylysine-covered lines so that they connected with the nanowire devices.

"These structures can allow us to measure the speed and shape of a signal as it propagates through an axon or dendrite, and moreover we can use the nanowires as inputs to inhibit or totally turn off signal propagation in a highly local and precise manner," said Lieber. "We have demonstrated the incorporation of up to 50 devices with a pitch as low as 150 nm along a single axon, allowing for the mapping of signals at resolutions exceeding available methods, while at the same time allowing us to manipulate these signals."

The researchers say they showed that both devices and neurones could survive in culture for at least two weeks. They were also able to prepare virtually any patterned structure they wanted.

Now the team is pursuing studies in four areas: studying and manipulating signal propagation in neuronal networks; building sophisticated interfaces between the brain and external neural prosthetics; real-time cellular assays useful for drug discovery and other applications; and creating hybrid circuits that couple the strengths of digital nanoelectronic and biological computing components.

"We are currently quite excited about and pursuing studies in the above four areas through, for example, increasing the level of integration of both nanowires and neurones to create and study networks and hybrid circuits," said Lieber.

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The researchers reported their work in *Science*.

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