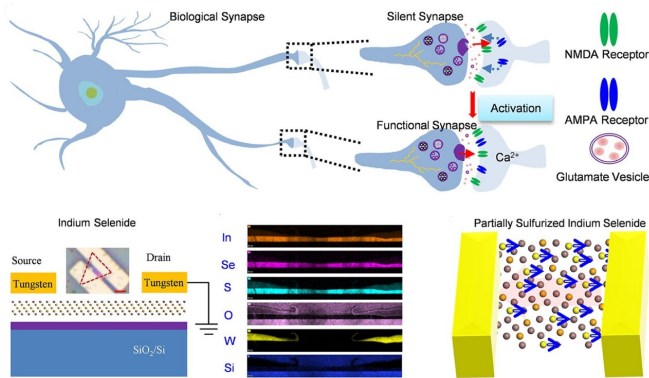


Developing an ultra-scalable artificial synapse

23 December 2021



Brain-inspired device used for integrating both silent and functional synapses. Credit: SUTD

A research team, led by Assistant Professor Desmond Loke from the Singapore University of Technology and Design (SUTD), has developed a new type of artificial synapse based on two-dimensional (2D) materials for highly scalable brain-inspired computing.

Brain-inspired computing, which mimics how the human brain functions, has drawn significant scientific attention because of its uses in artificial intelligence functions and low energy consumption. For brain-inspired computing to work, synapses remembering the connections between two neurons are necessary, like [human brains](#).

In developing brains, synapses can be grouped into functional synapses and silent synapses. For functional synapses, the synapses are active, while for silent synapses, the synapses are inactive under normal conditions. And, when silent synapses are activated, they can help to optimize the connections between neurons. However, as artificial synapses built on [digital circuits](#) typically occupy large spaces, there are usually limitations in terms of hardware efficiency and costs. As the

human brain contains about a hundred trillion synapses, it is necessary to improve the hardware cost in order to apply it to smart portable devices and internet-of things (IoT).

To tackle this issue, the SUTD research team mimicked behaviors of functional and silent synapses using 2D materials. Additionally, this artificial synapse demonstrates for the first time that it can be implemented with the same [device](#) that functions as both functional and silent synapses.

Assistant Prof Loke mentioned that this work can dramatically reduce the hardware costs by replacing functional and silent synapses that were based on complex digital circuits with a single device. "We have demonstrated that functional and silent synapses can be implemented using a [single device](#)."

"By integrating functional and silent synapses into the same device using ultrathin 2D materials, the hardware cost of artificial synapses will significantly decrease, which will drive the commercialization of brain-inspired hardware," added Assistant Prof Loke.

From the viewpoint of neurobiology, silent synapses would not generate excitatory behavior when presynaptic neurons receive continuous stimuli because they contain N-methyl-D-aspartate (NMDA) receptors, but they lack the alpha-amino-3-hydroxy-5-methyl-4-isoxazole-propionic-acid (AMPA) receptors. However, silent synapses can be activated to become functional synapses that respond to stimulations upon the insertion of AMPA receptors after consecutive stimulations.

Inspired by the biological mechanism for silent synapse activation through the insertion of AMPA receptors, transformations from silent synapses to functional synapses in devices can be achieved by introducing sulfur anions in 2D indium selenide material systems. The sulfur anions in indium

selenide can migrate under an electric field and exhibit functional synaptic plasticity. This device, based on a fully sulfurized type of system, show obvious memristive behavior at room temperature, which can be used to implement functional synapses. The activation of silent [synapses](#) can be demonstrated using a partially sulfurized type of system by modifying the temperature.

This research was published in *ACS Applied Materials & Interfaces*.

More information: Song Hao et al, Activating Silent Synapses in Sulfurized Indium Selenide for Neuromorphic Computing, *ACS Applied Materials & Interfaces* (2021). [DOI: 10.1021/acsami.1c19062](https://doi.org/10.1021/acsami.1c19062)

Provided by Singapore University of Technology and Design

APA citation: Developing an ultra-scalable artificial synapse (2021, December 23) retrieved 26 May 2022 from <https://techxplore.com/news/2021-12-ultra-scalable-artificial-synapse.html>

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