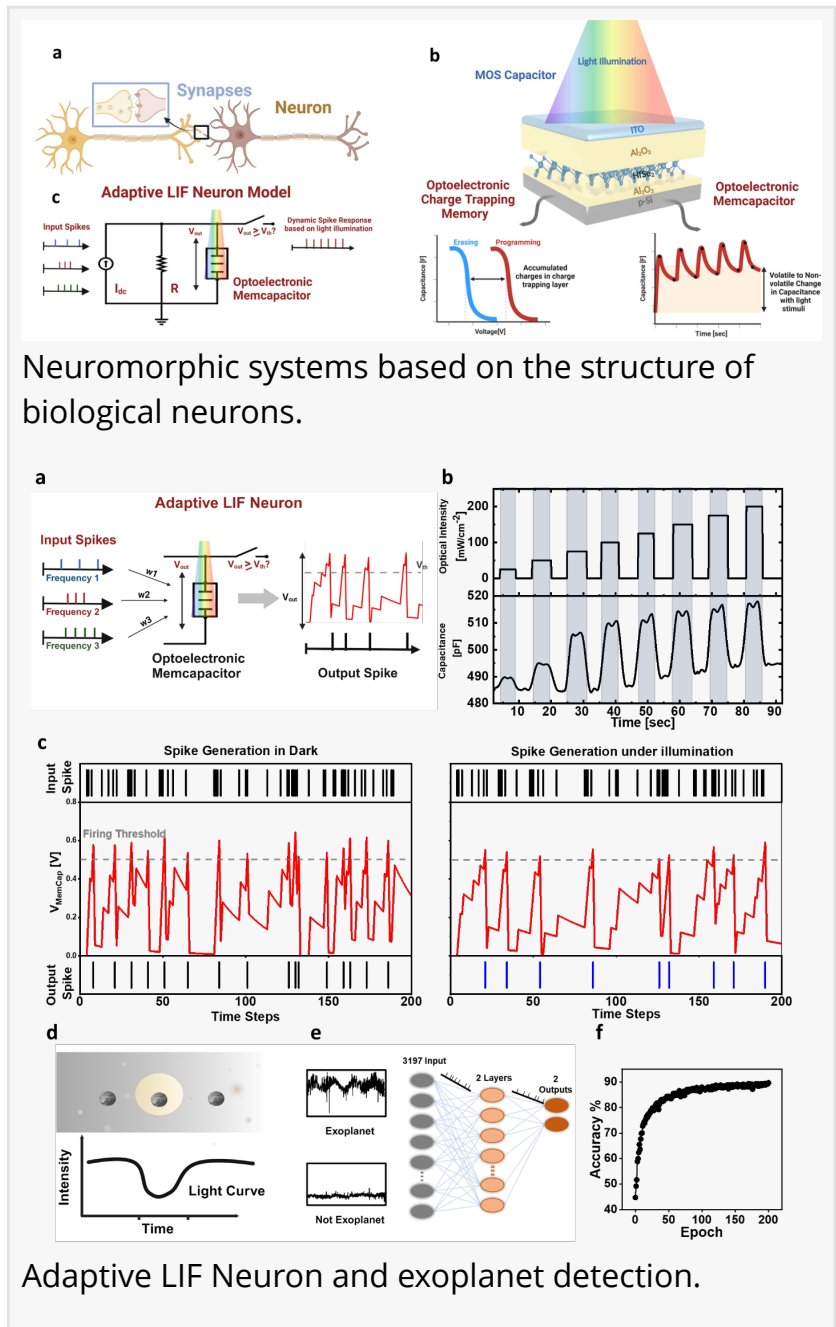


From Light Sensing to Adaptive Learning: Reconfigurable Memcapacitive Devices in Neuromorphic Computing

GA, UNITED STATES, January 6, 2025 /EINPresswire.com/ -- Researchers at KAUST, Saudi Arabia, have made significant strides in neuromorphic computing by developing a reconfigurable metal-oxide-semiconductor capacitor (MOSCaps), demonstrating optoelectronic synaptic features and memcapacitive behavior. These devices can perform stimulus-associated learning and exhibit tunable volatility, enabling transitions from light sensing to optical data-retention. Integrated into a leaky integrate-and-fire neuron model, the MOSCaps show potential for dynamically adjusting firing patterns based on light stimuli, with applications in exoplanet detection towards more adaptive and energy-efficient systems.

Traditional computing systems struggle with dynamic adaptation and suffer from the separation of sensing, processing, and memory functions, leading to high energy consumption and latency. Neuromorphic computing offers a promising solution by mimicking biological neural networks, enabling faster, more energy-efficient, and adaptive data processing. By integrating sensing, computing, and memory functions within a single device, neuromorphic systems can overcome the limitations of traditional architectures. The implementation of



Adaptive LIF Neuron and exoplanet detection.

artificial neurons and synapses often involves materials with tunable electrical properties or optoelectronic devices, providing a flexible platform for developing innovative computing solutions.

In a new paper published in *Light Science & Applications*, a team of scientists, led by Professor Nazek El-Atab from Smart, Advanced Memory devices and Applications Lab (SAMA), Computer Electrical Mathematical Science and Engineering Division, King Abdullah University of Science and Technology (KAUST), Thuwal, Saudi Arabia, and co-workers have developed a MOSCap device using Hafnium diselenide ([HfSe2](#)) that replicates neuron-like adaptive behavior and memory retention. Their work advances the field of neuromorphic technology, which seeks to emulate the brain's highly efficient data processing and adaptive capabilities.

The researchers achieved this by integrating two-dimensional HfSe2 nanosheets into the MOSCap structure, enabling the device to sense and retain light information in both "charge trapping and memcapacitive behavior within the same MOSCap device, whose threshold voltage and capacitance vary based on the light intensity", noted by researchers. Electrical characterization tests demonstrated considerable memory window and robust memory retention, with the device maintaining its data stability under stressing conditions, such as high temperatures. "The memory window of the device remained above the failure threshold for 106 seconds at 60–80 °C," the researchers observed, highlighting its reliability in practical applications. The MOSCap also showed an ability to preserve data after removal of light stimuli, thanks to an efficient charge-trapping mechanism, which reinforces its potential for energy-efficient, optoelectronic non-volatile memories.

The MOSCap framework allows the device reconfigurability "the memcapacitor volatility tuning based on the biasing conditions, enabling the transition from volatile light sensing to non-volatile optical data retention" the scientists note. This marks a significant step in the evolution of neuromorphic devices, demonstrating optoelectronic synapse functions and enabling "stimulus-associated learning" where "the responsiveness of the device to light across the entire visible spectrum is notable," according to the KAUST team.

A key advantage of this innovation is its use of capacitive synapses, which operate in the charge domain. This leads to lower power consumption and reduced leakage currents compared to memristive synapses. The KAUST team notes that capacitive synapses allow for minimal static power use, potential 3D stacking, and decreased sneak-path current leakage, making them ideal for compact, high-density memory applications.

One particularly compelling application proposed by the researchers is the use of this adaptive MOSCap in astronomy, specifically in detecting exoplanets through changes in light intensity. By integrating the device into a leaky integrate-and-fire (LIF) neuron model, the team demonstrated that the MOSCap could alter firing patterns in response to light fluctuations—a method that could simplify the process of identifying exoplanets transiting distant stars. "These dynamic optoelectronic neurons showed exceptional capabilities for detecting exoplanets based on their

light intensity," the researchers highlighted, noting these neurons' integration into a spiking neural network (SNN).

The MOSCap device exhibits versatile functionality, making it a notable advancement in the field of neuromorphic technology. This breakthrough has the potential to inspire further innovations in the development of artificial systems that can respond to and learn from environmental stimuli as dynamically as biological neurons do.

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