Researchers fabricate logic gates based on neuristors made of 2D materials

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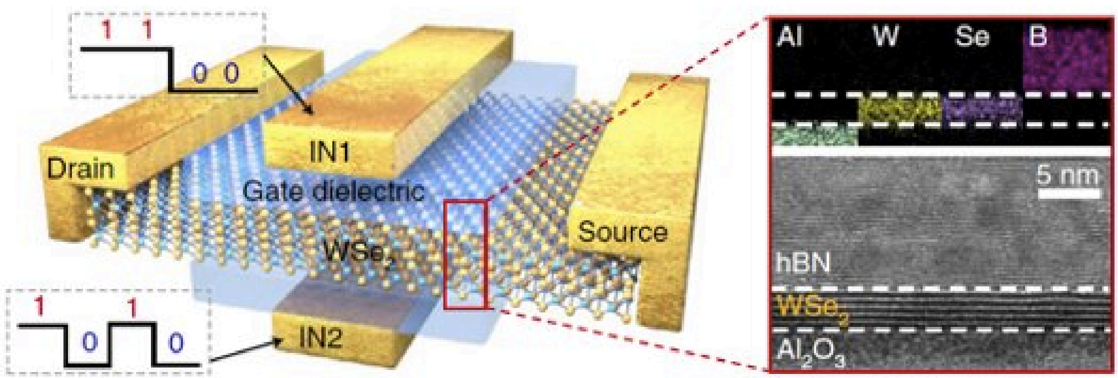

Figure 1. Schematic of the neuristor.

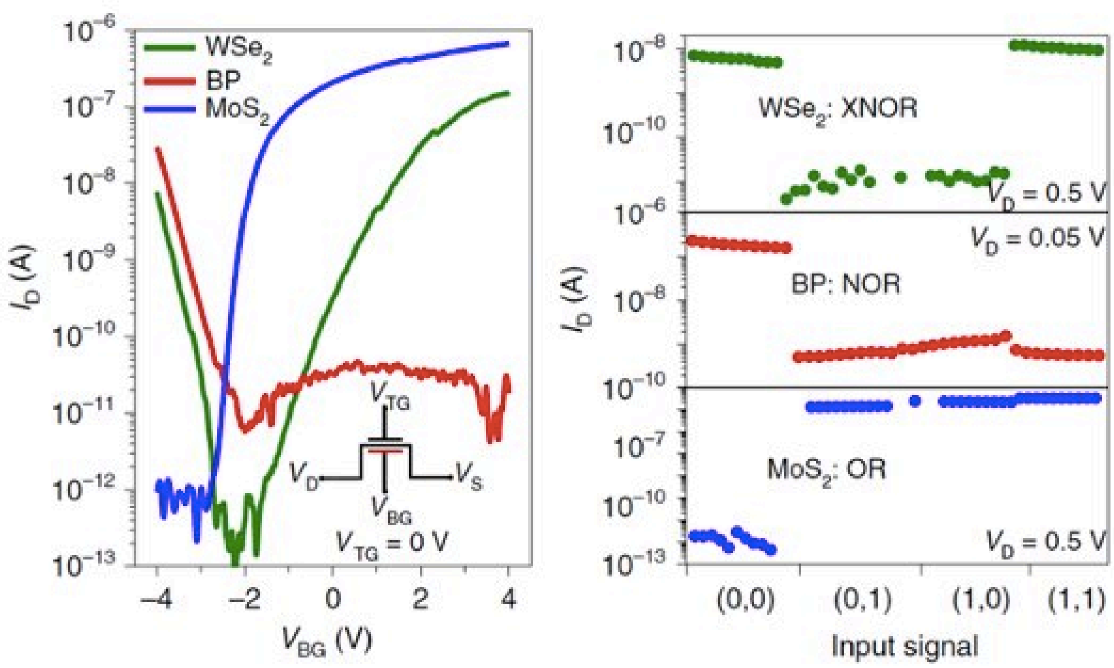

Figure 2. Neuristors with different polarities for different logic operations.

Credit: Chen et al.

Individual neurons in the human brain can efficiently perform so-called Boolean operations; a type of algebraic operations that include union, subtraction and intersection. Computing systems that emulate biological neurons, such as neuromorphic computing systems, however, typically require several devices to complete these operations.

Researchers at Fudan University and the Chinese Academy of Sciences recently developed neuristors based on two-dimensional (2D) materials that can perform logic operations individually, without the need for multiple devices. These neuristors, presented in a paper published in *Nature Electronics*, could enable the development of better performing bioinspired computing systems.

"In our previous work, we proposed a high-area-efficiency 2D transistor architecture that can realize photoswitching logic computing in a single cell," Peng Zhou, one of the researchers who carried out the study, told TechXplore. "The proposed transistor performs linear logic computing including OR and AND operations efficiently, but remains insufficient to realize nonlinear logic computing such as XOR and XNOR operations."

Recent research findings suggest that a single human neuron is capable of nonlinear logic operations. The main objective of the study carried out by Zhou and his colleagues was to design a single electronic device that can mimic this nonlinear logic computing ability of individual neurons in the human brain.

"Our neuristors for logic gates were designed with a dual-gate structure, employing 2D materials as channel materials," Zhou said. "Specially, we used different polarities of 2D materials including ambipolar-type, n- and p-type features in the neuristor to generate different logic operations. Therefore, one neuristor can function as one logic gate."

To evaluate the device they designed and confirm its feasibility, Zhou and his colleagues fabricated logic half-adder and parity-checker circuits using a WSe_2 neuristor and a MoS_2 neuristor in a two-transistor two-resistor configuration. They found that the resulting circuits offered an area saving of 78% compared to circuits with a more conventional design utilizing MoS_2 gates.

"We demonstrated nonlinear logic operation by fully utilizing the ambipolar-type feature of 2D materials, hence the neuristors with different polarities can mimic the logic computing ability of a single human neuron for high-efficiency computing," Zhou said. "The feasibility of these neuristors was further validated by using them to demonstrate a small footprint logic half-adder and high-efficiency binary neural network."

In a series of simulations where they ran a binary neural network based on a 3D XNOR array, the logic circuits created by the researchers achieved an energy efficiency of 622.35 tera-operations per second per watt and a power consumption of 7.31 mW. In the future, the neuristor and logic gates designed by this team of researchers could thus be used to develop neuromorphic computing chips that are smaller, more efficient and consume less power.

"We demonstrate the logic library based on 2D materials with different polarities, such as MoS_2, WSe_2 and BP, and different neuristors generate different logic operations," Zhou said. "As a next step, we want to add the memory layer into the neuristor architecture, so that the polarity can be switched by the memory operations instead of materials type, which means that one neuristor would generate different logic operations."

More information: Logic gates based on neuristors made from two-dimensional materials. *Nature Electronics*(2021). DOI: 10.1038/s41928-021-00591-z.

Small footprint transistor architecture for photoswitching logic and in situ memory. *Nature Nanotechnology*(2019). DOI: 10.1038/s41565-019-0462-6.

Dendritic action potentials and computation in human layer 2/3 cortical neurons. *Science*(2020). DOI: 10.1126/science.aax6239.