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ELECTRONIC DEVICES

Making multi-terminal memtransistors

“Our memtransistor combines the non-volatility of a memristor with the gate tunability of a transistor”

A memristor is a non-volatile circuit component with an electrical resistance that varies depending on the charge that has previously flowed through the device. This memory effect has prompted their use in resistive random-access memory and multi-bit data storage. In the future, it is envisaged that memristors may be used in neuromorphic computing architectures. However, neuromorphic computing requires multi-terminal devices resembling the many synapses of the brain and until now, fabricating memristors with more than two terminals has been challenging.

Now, writing in *Nature*, Mark Hersam and colleagues report a multi-terminal hybrid memristor and transistor — namely, a memtransistor — that mimics the multiple synapses in neurons. “Our memtransistor combines the non-volatility of a memristor with the gate tunability of a transistor,” says Hersam.

The active part of the memtransistor is a polycrystalline monolayer of MoS_2 that is grown by chemical vapour deposition on a SiO_2/Si substrate. The monolayer forms the channel within a typical field-effect transistor arrangement. “Thus far, we have demonstrated seven terminals — six terminals in direct contact with the MoS_2 channel and a seventh gate terminal — but additional terminals should be achievable using higher resolution lithography,” explains Hersam.

The electrical characteristics of the device can be tuned by applying a gate potential, with this gate tunability observed over four orders of magnitude. The devices also have large switching ratios with high cycling endurance. In addition, the multiple terminals enable gate-tunable heterosynaptic functionality, which is not possible with two-terminal devices. “More specifically, the conductance between a pair of floating electrodes (pre-synaptic and post-synaptic neurons) can be varied by an order of magnitude by applying voltage pulses to the modulatory terminals,” explains Hersam.

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The memtransistor can also assist with the study of defect kinetics in 2D materials. Using techniques such as scanning probe microscopy, cryogenic charge transport measurements and device modelling, it is concluded that the movement of defects in MoS_2 drives the switching in memtransistors. This is a consequence of the dependence of the height of the Schottky barrier on defect motion. “Having established the connection between defect motion and device characteristics, we can now use charge transport measurements to study defect kinetics in other 2D materials,” says Hersam.

The Northwestern team now aim to make smaller and faster memtransistors with lower operating voltages and more efficient neuromorphic computation. “We are also exploring the integration of memtransistors into more complicated circuits that are suitable for non-volatile memory and advanced neuromorphic architectures,” concludes Hersam.

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ORIGINAL ARTICLE Sangwan, V. K. et al. Multi-terminal memtransistors from polycrystalline monolayer molybdenum disulfide. *Nature* **554**, 500–504 (2018)