Brain-Inspired Plasticity and Cognitive Learning in Iontronic Memtransistors of 2D Molybdenum Disulfide

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Neuromorphic hardware that emulates the adaptive plasticity of biological synapses is crucial for realizing energy-efficient cognitive learning.[1-2] Here, we demonstrate iontronic memtransistors (IMT) based on two-dimensional molybdenum disulfide (2D MoS_2), which exhibit stable n-type characteristics with a memory window of about 0.88 V, analogous channel conductance modulation, and an ON/OFF ratio of about 10^3. The devices function reliably as non-volatile resistive memories, with endurance over 2000 cycles and multi-state retention exceeding 10^3 s. Impedance spectroscopy reveals slow ionic migration and dipolar relaxation that evolve into purely electronic transport, highlighting the mixed ionic-electronic dynamics underpinning device operation.[3] Using pulse programming of varied amplitude and duration, we realize essential synaptic functions, including paired-pulse facilitation and depression, potentiation-depression dynamics, Hebbian learning, and Atkinson-Shiffrin-type memory behaviour, with an energy consumption as low as ~300 fJ per event and response times approaching 1 μs. Beyond these, the memtransistors mimic higher-order brain functions, such as Pavlovian associative conditioning and logic operations (AND, OR). These results establish 2D MoS_2 iontronic memtransistors as a promising platform for brain-inspired plasticity and energy-efficient neuromorphic computing.

1. Kudithipudi, D.; et al. *Nature, 637* (8047), 801-812, 2025.
2. Mehonic, A.; et al. *APL Materials*, 12 (10), 109201, 2024.
3. Xu, K.; Fullerton-Shirey, S. K., *2D Materials*, *12* (2), 023003, 2025.