Ion Gated Synaptic Transistors Based on Two-dimensional van der Waals Crystals with Tunable Diffusive Dynamics

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Neuromorphic computing represents an innovative technology that could perform intelligent and energy-efficient computation, whereas construction of neuromorphic systems requires bio-realistic synaptic elements with rich dynamics that can be tuned based on a robust mechanism. Here we demonstrate an ionic gating modulated synaptic transistor based on layered crystals of transitional metal dichalcogenides and phosphorus trichalcogenides, which have produced a diversity of short-term and long-term plasticity including EPSC, PPF, SRDP, dynamic filtering, etc., with remarkable linearity and symmetry as well as ultralow energy consumption of ~30 fJ/spike. Detailed transmission electron microscopy characterization and *ab initio* calculation revealed two-stage ionic gating effects, namely, surface adsorption and internal intercalation in the channel medium, causing different post-stimulation diffusive dynamics and thus accounting for the observed short-term and long-term plasticity, respectively. The synaptic activity can therefore be effectively manipulated by tailoring the ionic gating and consequent diffusion dynamics with varied thickness and structure of the van der Waals material as well as the number, duration, rate and polarity of gate stimulations, making present synaptic transistors intriguing candidates for low power neuromorphic systems.