Gate-Tunable Neuromorphic Electronics Enabled by 2D Materials

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The exponentially improving performance of digital computers has recently slowed due to the speed and power consumption issues resulting from the von Neumann bottleneck. In contrast, neuromorphic computing aims to circumvent these limitations by spatially co-locating logic and memory in a manner analogous to biological neuronal networks [1]. Beyond reducing power consumption, neuromorphic devices provide efficient architectures for image recognition, machine learning, and artificial intelligence [2]. This talk will explore how 2D nanoelectronic materials enable gate-tunable neuromorphic devices [3]. For example, by utilizing self-aligned, atomically thin heterojunctions, dual-gated Gaussian transistors have been realized, which show tunable anti-ambipolarity for artificial neurons, competitive learning, spiking circuits, and mixed-kernel support vector machines [4]. In addition, field-driven defect motion in polycrystalline monolayer MoS_2 enables gate-tunable memristive phenomena that serve as the basis of hybrid memristor/transistor devices (i.e., 'memtransistors' [5]) that concurrently provide logic and data storage functions [6]. The planar geometry of memtransistors further allows multiple contacts and dual gating that mimic the behavior of biological systems such as heterosynaptic responses [7]. Moreover, control over polycrystalline grain structure enhances the tunability of potentiation and depression, which enables unsupervised continuous learning in spiking neural networks [8]. Overall, this work introduces foundational circuit elements for neuromorphic computing by utilizing the unique quantum characteristics of 2D nanoelectronic materials [9].

References

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Figures

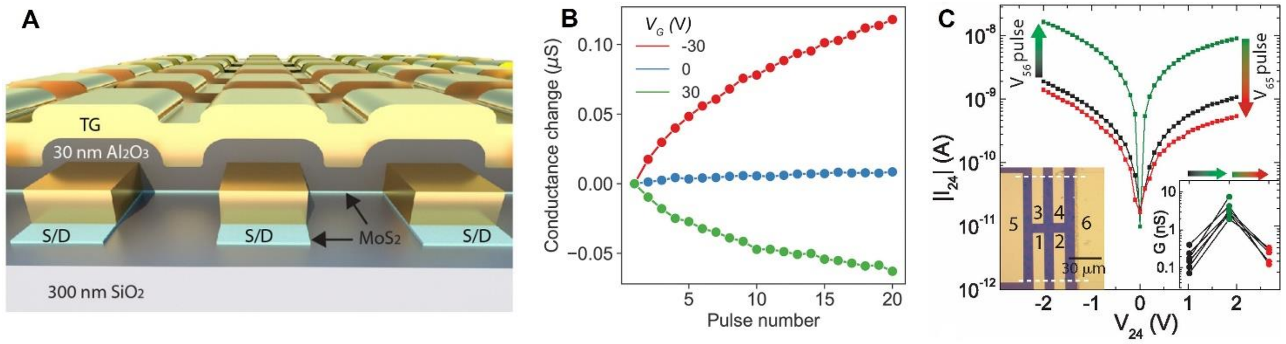

Figure 1: (A) Schematic of a dual-gated 2D memtransistor crossbar array. Adapted from Ref. 7. (B) The unipolar synaptic response of 2D memtransistors can be tuned from potentiation to depression as a function of the gate bias. Adapted from Ref. 8. (C) Multi-terminal 2D memtransistors show heterosynaptic responses between orthogonal contacts. Adapted from Ref. 5.