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A high-performance MoS_2 synaptic device with floating gate engineering for Neuromorphic Computing

Understanding the complexities in the functioning of the human brain has been one of the foremost challenges in the field of neuroscience. A human brain is far superior to a traditional computer in terms of parallel processing and energy consumption. This is made possible by the unique computational architecture of the brain where processing and storage of data occurs simultaneously in the synapse. Thus, mimicking a synapse is of utmost importance towards achieving the goal of neuromorphic computing.

The human brain is a highly interconnected system with 10^{11} neurons and 10^{14} interconnections or synapses. Conventional silicon-based electronics suffer from short channel effects making it difficult to attain synaptic densities comparable to that in the human brain. However, two dimensional materials like molybdenum disulphide (MoS_2), graphene etc. demonstrate excellent gate coupling and negligible short channel effect making them an excellent candidate for synaptic devices. In this work, we demonstrate solid state synaptic transistors using MoS_2 floating gate memories. The MoS_2 channel, placed on a crystalline hexagonal boron nitride (hBN) dielectric with an extended floating gate architecture exhibits a subthreshold swing of 77 mV/decade maintained over four decades of drain current while exhibiting a highly tuneable hysteresis in the transfer characteristics. We exploit this charge tunnelling to realize synaptic devices with performance comparable to their electrochemical counterparts and successfully demonstrate various features of a biological synapse including pulsed potentiation and relaxation of channel conductance and spike time dependent plasticity (STDP). Our device returns acceptable energy efficiency figures and provides a robust platform based on ultrathin two-dimensional nanosheets for future neuromorphic applications.