Scalable Lateral MoS_2-Based Memristor Arrays for Neuromorphic Applications

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Neuromorphic computing integrates both memory and computation in a parallel and event-driven architecture that minimises data movement and enables concurrent processing, thereby addressing the von Neumann bottleneck [1]. To implement such functionality in electronic hardware, a single memristive device has demonstrated synaptic behavior and low-power switching [2], but scaling these devices into reliable, high-density arrays remains a major challenge. In crossbar architectures, the large active area created by electrode overlap makes the device highly sensitive to defects and thickness variations in the active materials, driving device-to-device variability [3]. Meanwhile, two-dimensional (2D) materials have attracted considerable interest as active layers for neuromorphic electronics due to their material properties. Atomically thin geometry, tunable bandgap, and defect-free surface offer advantages, such as reduced power consumption, and fast response time [4–6]. Despite these promising attributes, the practical realisation of large-scale 2D material-based memristor arrays remains limited. These constraints highlight the need for alternative device architectures and fabrication strategies that can exploit the advantages of 2D materials. In this work, we demonstrate a lateral MoS_2-based memristor array fabricated using a nanogap electrode patterning technique known as adhesion lithography (a-Lith). Unlike crossbar structures, our lateral configuration confines the active region to the 15 nm, relaxing material-quality requirements and significantly reducing device variability across the array. The coplanar nanogap electrodes are Au and Al separated by 15 nm, beginning with patterned Al, self-assembled monolayer (SAM) treatment, deposition of a global Au/Al stack, and selective removal of the Au layer using an adhesive film [7]. A subsequent lithography and Al etching step isolates individual memristive cells. Bilayer MoS_2 is synthesized through a two-step process: atomic layer deposition of MoO_3 on Si/SiO_2 wafer, followed by sulfurisation via annealing in hydrogen sulfide (H_2S), whereby the MoO_3 is converted to MoS_2 [8]. The resulting MoS_2 film is characterised using Raman spectroscopy and transferred onto the nanogap structures using a 2% polystyrene/toluene solution. The memristive devices in a 2×2 array exhibits resistive switching under a low compliance current of 1 μA and emulate short-term synaptic plasticity. In the floating scheme, unselected cells experience state disruption from sneak-path currents. When using the V/2 scheme, the states of the unselected cells are unaffected. Overall, these results highlight the promise of 2D materials-based lateral memristive devices for neuromorphic devices, offering stable synaptic behavior, and reduced variability for complex neural network systems.

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