Electrical-field manipulated reversible switching between 1T and 2H phase in vertically aligned $MoSe_2$ via ion intercalation: a synapse-mimicking memristor

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Abstract

In this work, reversible resistance switchings were demonstrated in vertical aligned molybdenum diselenide ($MoSe_2$) thin films based on the electric-field induced phase change between the 1T and 2H geometry assisted by the metal ion intercalation. In horizontal Cu/$MoSe_2$/Au devices, this electric-field induced phase switching exhibits a great endurance of more than 100 cycles, high stability of more than 10,000 seconds under retention, and an on/off ratio of about 900%.

Judging by the changes of binding energy and the interlayer distance observed from the pseudo-operando scanning photoemission spectroscopy (SPEM) operated in TLS BL09A, NSRRC, and in-house transmission electron microscopy (TEM), once an applied positive bias was applied in a Cu/$MoSe_2$/Au device where the pristine $MoSe_2$ exhibits a 1T-geometry, the external electric field drives active copper ions intercalated into vertical $MoSe_2$ lamellar structures via a $CuSe_x$ intermediate layer and introduces atomic rearrangements from intrinsic 1T phase into 2H phase. On the contrary, the negative bias activates the *RESET* process and results in a phase change back to the 1T geometry. Since the 1T- and 2H-$MoSe_2$ exhibits metallic and semiconductive feature, respectively, the reversible phase change is considered as the origin of the resistance switching. Furthermore, based on the non-filament nature, multiple resistance levels together with an analog potentiation behavior was successfully achieved, allowing the device to emulate synaptic potentiation and depression behaviors.

Keywords - memristor, synapse, 1T-$MoSe_2$, Cu intercalation, phase change, scanning photoemission spectroscopy