Non-volatile Resistive Switching in Nanocrystalline MoS_2 with Vertically Aligned Layers Enabled by Mobile Ions

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Two-dimensional (2D) layered materials are capable of providing bio-realistic ionic interactions that are needed for realizing energy-efficient artificial neural networks to emulate the functioning of the human brain[1]. Molybdenum disulfide (MoS_2) is a layered 2D transition metal dichalcogenide (TMD) material which is gaining considerable attention recently for exhibiting a memristive effect. However, the mechanism and origin of the effect still remains unclear. In this work, we provide experimental demonstrations on the presence and origin of a nonvolatile and bipolar resistive switching (RS) in nanocrystalline MoS_2 with vertically aligned layers (Figs. 1a and 1b). Electrical characterization results reveal that the RS process is forming-free and also has a stable endurance for at least 140 DC switching cycles and state-retention for at least 2500 s (Figs. 1c and 1d). Controlled switching tests carried out in ambient and vacuum conditions suggest that the observed RS is enabled by hydroxyl ions (OH^-) [2] that originate possibly from catalytic splitting of adsorbed water molecules in MoS_2 [3]. Experimental observations in combination with analytical simulations further suggest that the electric field-driven movements of the mobile OH^- ions along the vertical MoS_2 layers influence the energy barrier at the Si/MoS_2 interface [4]. The observed ion-based plasticity may be exploited in ionic-electronic devices based on TMDs and other 2D materials for memristive applications. Furthermore, the device fabrication process used in this work is fully scalable and semiconductor production compatible. This enables integration of such novel 2D materials-based memristors into existing Si technology for future neuromorphic applications.

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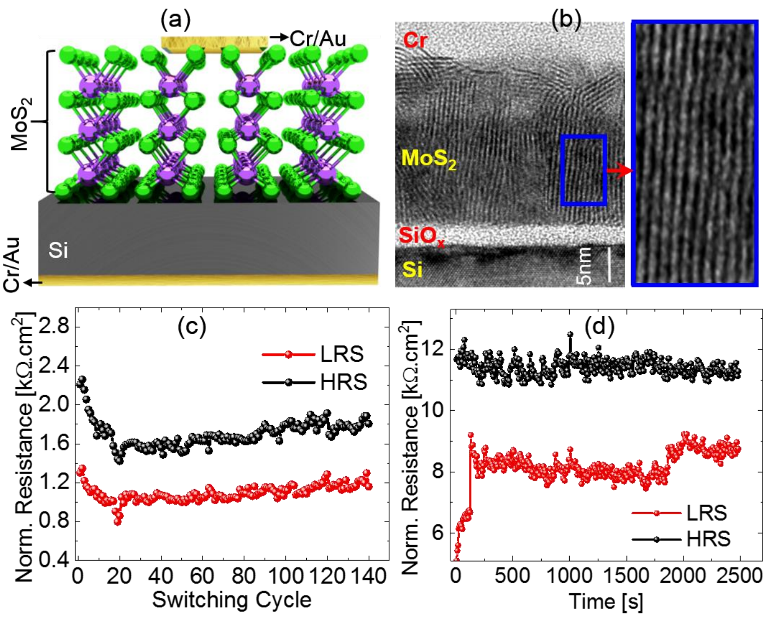

Figure 1: (a) Schematic diagram showing the structure of the investigated memristor device based on MoS_2 with vertically aligned layers and (b) a TEM cross-section image of the device structure revealing the nanocrystalline MoS_2 film with vertically aligned layers. Electrical characterizations of the present devices in ambient conditions indicating a resistive switching performance with stable: (c) endurance for at least 140 DC switching cycles and (d) state-retention for at least 2500 seconds.