Ion Migration Studies in 2D Molybdenum Trioxide Thin Flake through Ionic Liquid Gating

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Ionic liquids (ILs) are well known for their ability to electrostatically enhance carrier densities and chemically dope thin film materials. The formation of an electric double layer can electrostatically induced charge carriers and/or intercalate ions in and out of the lattice which can induce a large change of the electronic, optical and magnetic properties of materials and even induce a change in the crystal structure. We present a systematic study of ionic liquid gating of exfoliated molybdenum trioxide devices and correlate the resultant electrical properties to the electrochemical doping via ion migration during the IL biasing process through ionic liquid. A nearly nine orders of magnitude modulation of the MoO_3 conductivity was obtained via ionic liquid gating where two types of ionic liquids are investigated – BMIM-Tf2N and LiClO4 – PEO. Notably rapid on/off switching can be realized through a lithium containing ionic liquid (LIL) whereas much slower modulation is induced via oxygen extraction/intercalation. Secondary ion mass spectrometry (SIMS) has been carried out to study the ion migration process. Results of short-pulse tests show the potential of these MoO_3 devices as neuromorphic computing elements.

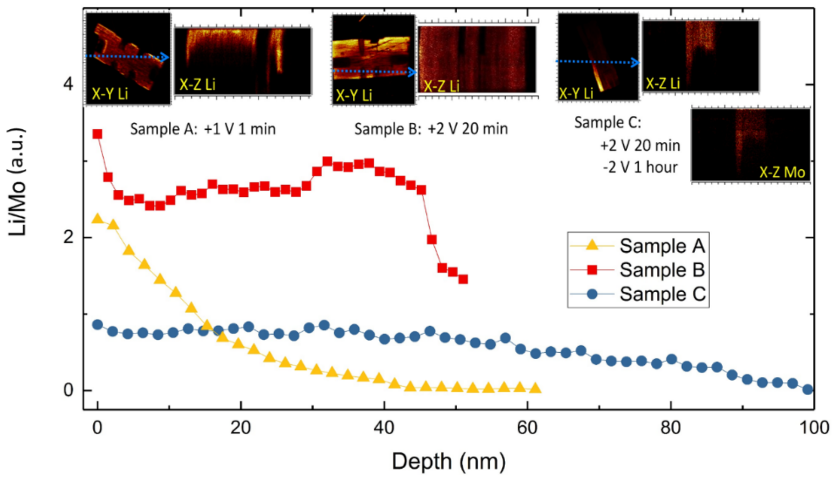

Figure 1: Quantitative analysis of the Li distribution along the depth of three devices after different LIL biasing process. Sample A was partially charged at +1 V for 1 minute; Sample B was charged at +2 V for 20 minutes; Sample C was initially charged at +2 V for 20 minutes, and then Li was extracted via a-2 V for 1 hour. The Li/Mo atom ratios was obtained from the intensity of 3D ion mapping images using SIMS. Thickness of Sample A, B and C is approximately 60 nm, 50 nm and 100 nm, respectively. Sample A is the same device presented in Fig. 4, with Li highly concentrated at the top surface of the sample. While other two devices exhibit comparatively uniform Li distribution along depth.

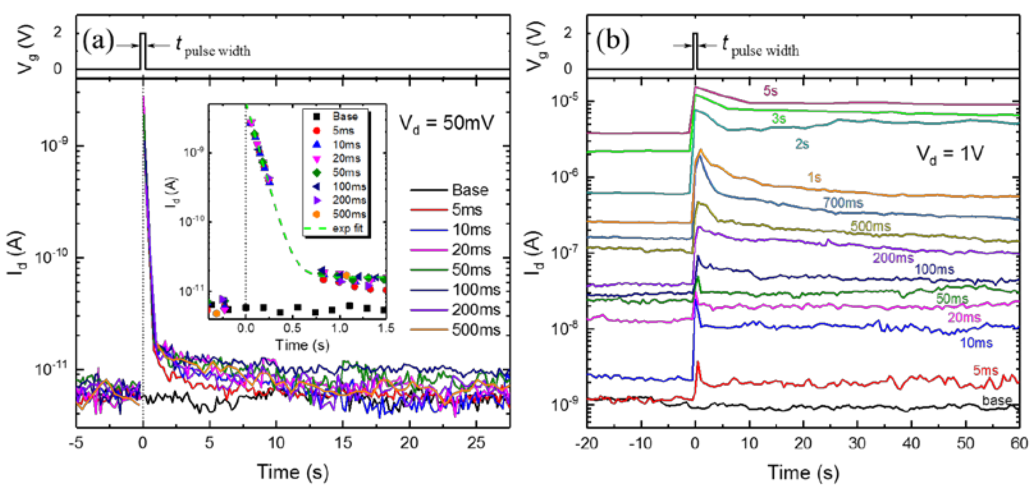

Figure 2: LIL short pulse measurement results under drain voltage of (a) 50 mV and (b) 1 V. 2V pulses through LIL side gate were applied on MoO3 devices sequentially with increasing pulse widths. With Vd = 50 mV drain voltage drain current increases instantly with the pulse and quickly decays; with an increased Vd at 1V, post-pulse drain current saturates at a higher compare to that measured before the pulse, leading to a long term change similar to a biological synaptic system. Inset in (a) zooms in a short time region near pulses, Id after different pulses follows the same exponential decay.