small NANO MICRO

# Supporting Information

for *Small*, DOI: 10.1002/smll.202003964

## Adaptive Synaptic Memory via Lithium Ion Modulation in RRAM Devices

*Chih-Yang Lin, Jia Chen, Po-Hsun Chen, Ting-Chang Chang,* Yuting Wu, Jason K. Eshraghian, John Moon, Sangmin Yoo, Yu-Hsun Wang, Wen-Chung Chen, Zhi-Yang Wang, Hui-Chun Huang, Yi Li, Xiangshui Miao, Wei D. Lu, and Simon M. Sze*

Supporting Information

**Adaptive Synaptic Memory via Lithium Ion Modulation in RRAM devices**

*Chih-Yang Lin, Jia Chen, Po-Hsun Chen, Ting-Chang Chang*, Yuting Wu, Jason K. Eshraghian, John Moon, Sangmin Yoo, Yu-Hsun Wang, Wen-Chung Chen, Zhi-Yang Wang, Hui-Chun Huang, Yi Li, Xiangshui Miao, Wei D. Lu, and Simon M. Sze*

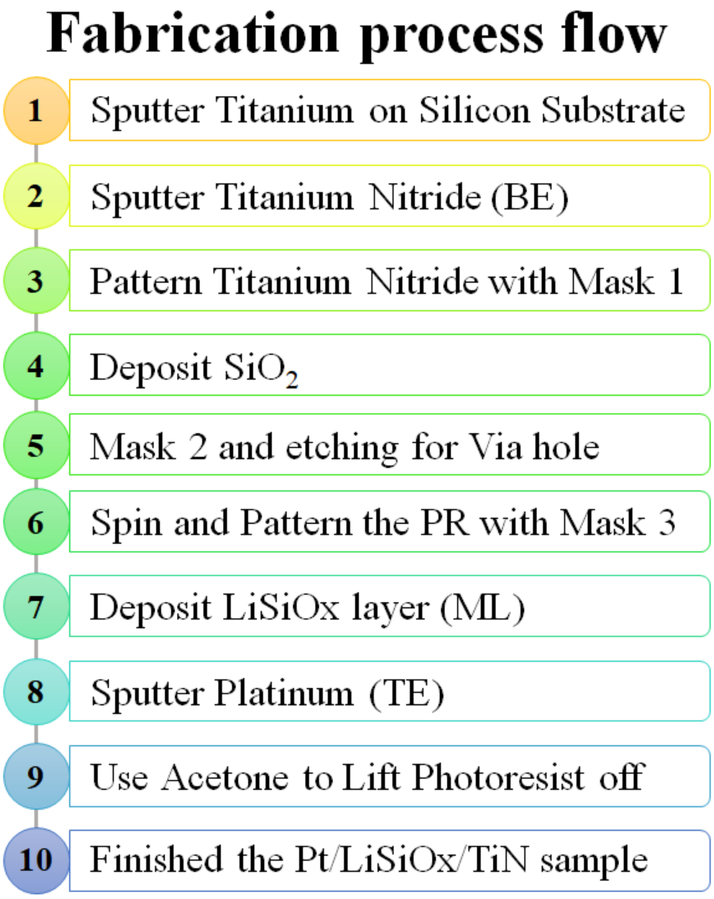


**Figure S1.** Detailed fabrication process flow of lithium ions doped RRAM device.

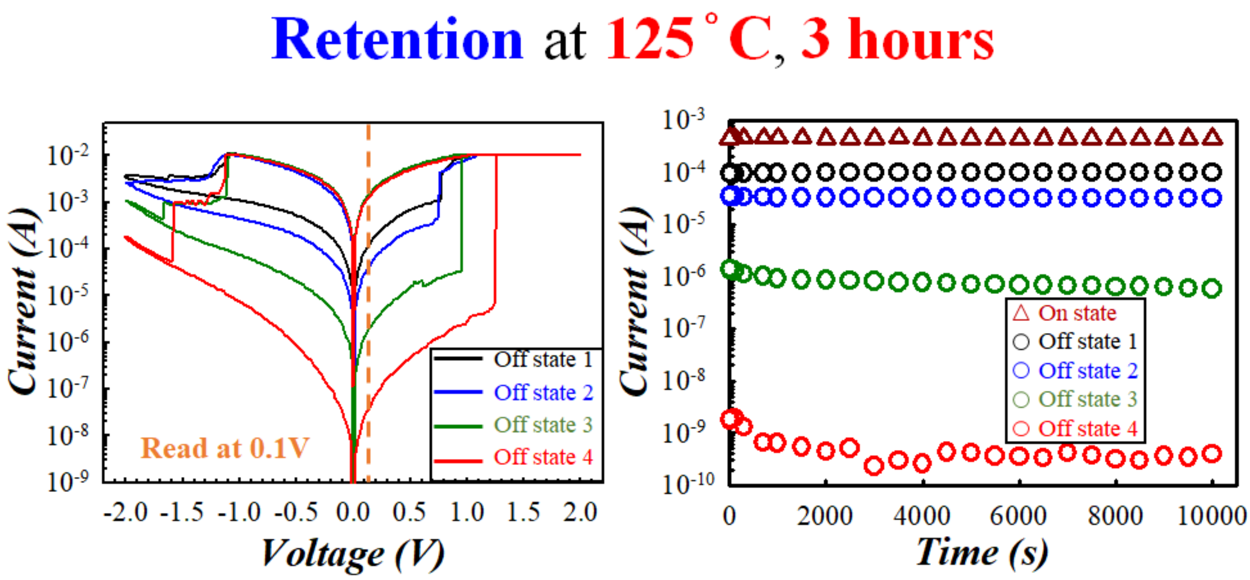


**Figure S2.** The retention results under 125°C ambient temperatures.

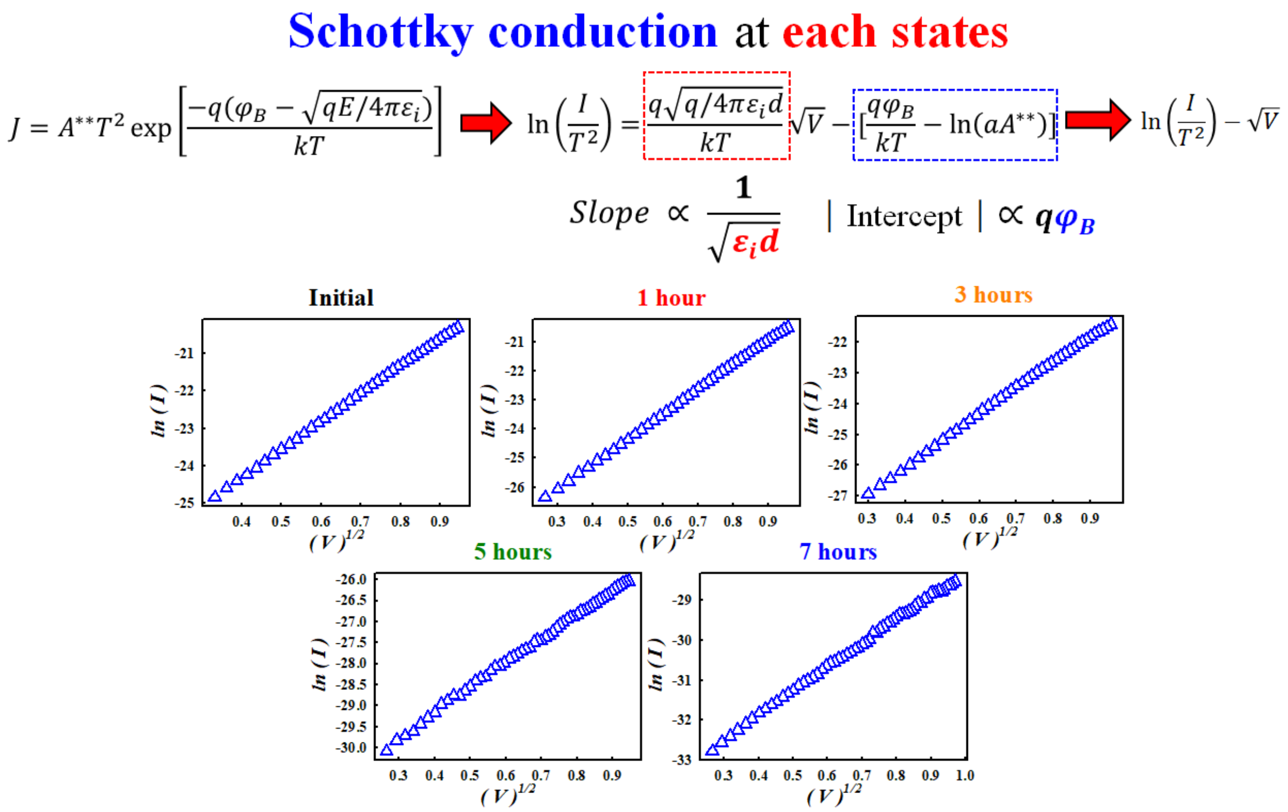


**Figure S3.** Fitting results of Schottky conduction in each state at varying times.

The experimental process uses a signal generator to generate two relatively identical waveforms. The pulses were only applied to the TiN BE. Our waveforms were all 500 ns pulse widths and 0.8 V amplitudes for the set process. Measurement results under these conditions are provided in **Figure S4**. The time interval between the two pulses is used to observe the difference from the initial resistance state. We perform resistance readings by first measuring the initial resistance value, and waiting until the 1st pulse is finished before re-reading the post-spike resistance value. Once the 2nd pulse is completed, the resistance is read-out immediately after once more. This is done because the resistance states are different at each time, and the weight update, Δw, is used to observe the memory change between the post-set condition and the original resistance value. To not affect the experimental process, we read the resistance state using a small subthreshold DC voltage (300mV) and use the obtained voltage-current diagram to calculate the change in resistance. For PPF experiments, the initial state was always the highest resistance state, controlled by a 3 V pulse waveform to complete switch the LiSiOx device off.

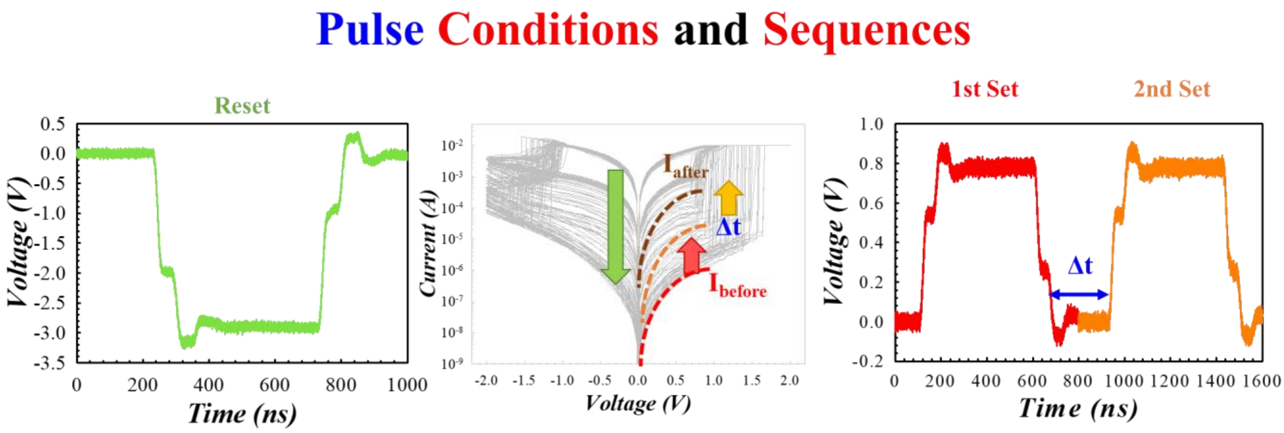


**Figure S4.** Pulse conditions and sequences.

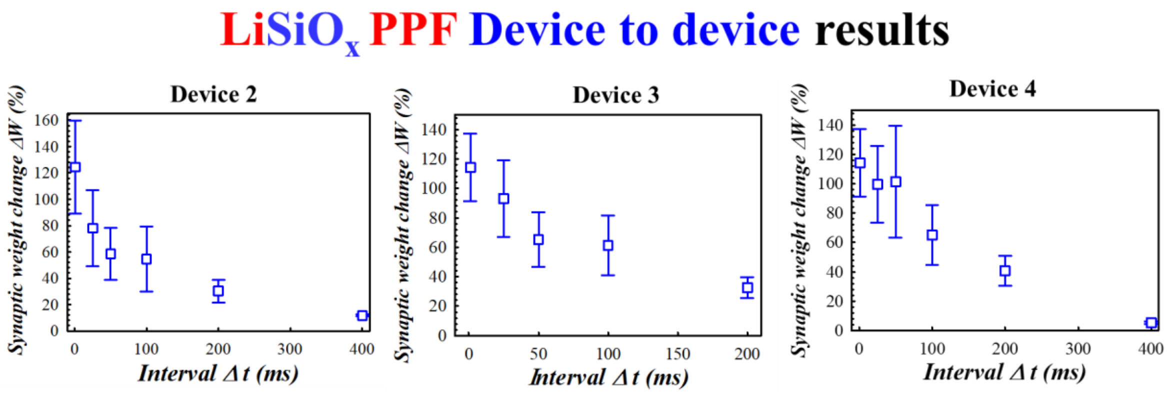


**Figure S5.** PPF cycle-to-cycle variation across three additional devices.

[1] P. A. Salin, M. Scanziani, R. C. Malenka, R. A. Nicoll, Proc. Natl. Acad. Sci. U.S.A. **1996**, 93, 23, 13304.