Biodegradable and Flexible Threshold Switching Device for Secure Storage Application

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Abstract

Memristive devices based on transient materials are promising candidates for next-generation secure memory applications due to their ideal storage capability, desirable scalability and 3D integrated potential, which are capable of physically vanishing at prescribed times after achieving their target functions [1]. However, the sneak path currents in neighboring device have become a considerable barrier to achieve stable memristor arrays with high integration density [2]. To deal with such a problem, it is essential to develop a physically transient access device to switch the memory device on and off effectively. We introduce here a biodegradable threshold switching device with a cross-point structure of W/Ag/MgO/Ag/W stack, which exhibits high selectivity of 10^7, steep turn-on slope of < 8mV/dec and fast ON/OFF switch speed of 50/25 ns. To examine the dissolution characteristic of the threshold switching device for security applications, we performed transient experiment by soaking the device arrays in deionized water at room temperature. The selectivity of the transient device began to degenerate after soaking in deionized water for 4 min and triggered failure was finally completed after 8 min dissolution. Importantly, the water-assisted transfer printing technique was employed to transfer the threshold switching device arrays onto flexible polydimethylsiloxane (PDMS) substrate and water-soluble poly (vinyl alcohol) (PVA) substrate respectively, which depended on the infiltration of water between the hydrophilic Ni layer and SiO_2 layer. It was found that none of any noticeable degradation could be observed under a bending radius of 2 mm and the resulting system on PVA substrate finally disintegrated in deionized water within 30 min. In addition, a resistive switching device consisting of Mg/MgO/W stack was integrated with the threshold switching device vertically to build a one selector-one resistive swithing memory (1S1R) structure. It was obvious that the threshold switching device effectively controlled the magnitude of current of the 1S1R cell in the OFF state. To further confirm the feasibility of the 1S1R structure, the maximum array size of the system was calculated for an $N \times N$ crossbar array with the worst case read scheme. And the maximum array size of 10^7 Gb of the 1S1R cell could be guaranteed. This dissolvable threshold switching device could potentially be applied in neuromorphic engineering, wearable electronics and implantable electronics.

References :

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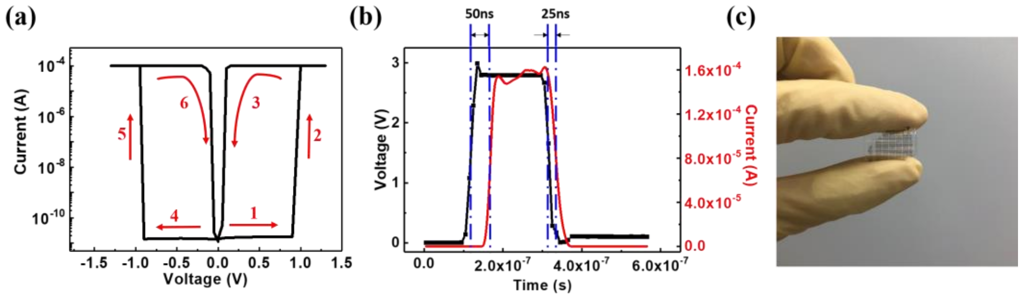

Figure 1. (a) DC I–V characteristic of the symmetric W/Ag/MgO/Ag/W selector device with a 10^{-4} A compliance current. (b) The threshold switching device transforms from HRS to LRS within 50 ns and returns to HRS within 25 ns. (c) Transferred threshold switching device arrays on PDMS substrate.

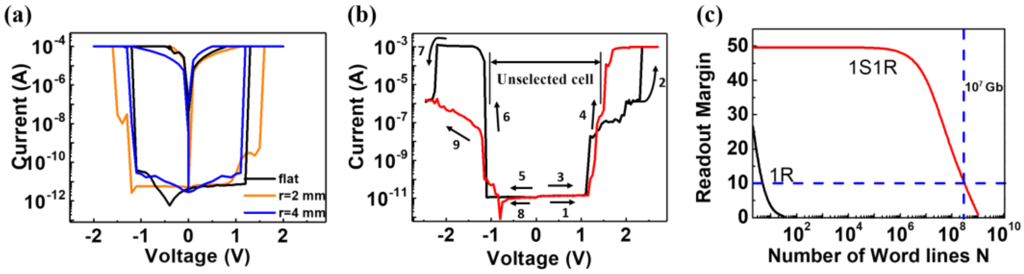

Figure 2. (a) Electrical characteristics of the flexible threshold switching device with various bending radius. (b) DC I–V curves of the vertically integrated 1S1R structure. (c) Simulated readout margin as a function of the number of the word lines for 1S1R cell in crosspoint array.

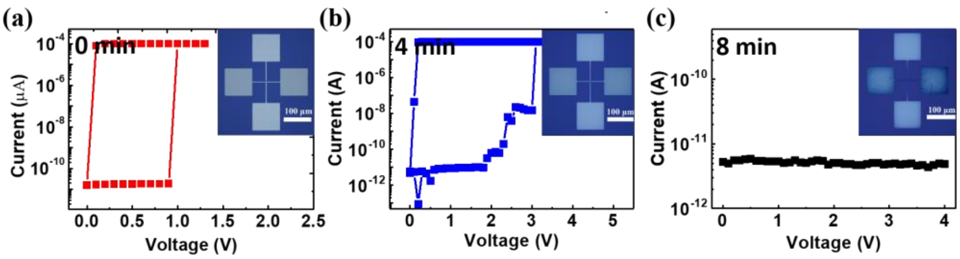

Figure 3. (a) Electrical characteristics of the threshold switching device after immersing in deionized water for (a) 0 min (b) 4 min (c) 8 min.

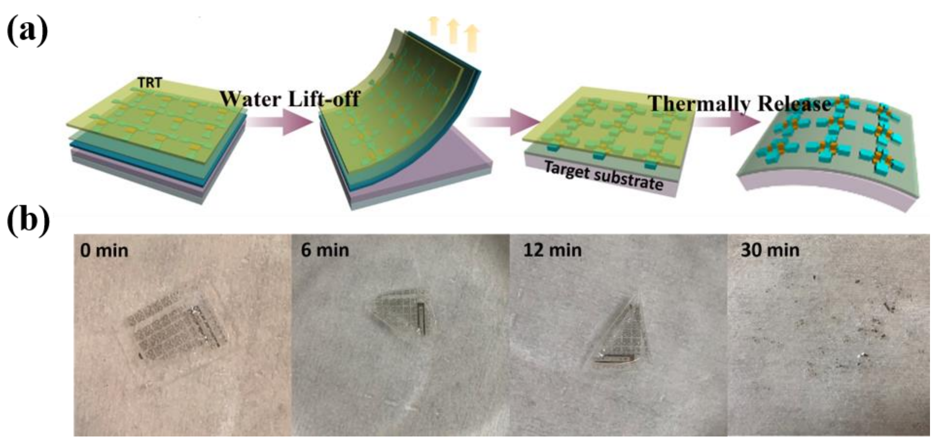

Figure 4. (a) The water-assisted transfer method used in the work. (b) Images showing the time sequence of transient behavior of the device arrays on PVA substrate in deionized water.