Physically Transient Resistive Memory by Solution-processed Magnesium Oxide on Flexible Substrate

Fang Song[*], Jing Sun[*], Hong Wang[*], Xiaohua. Ma[#], Yue Hao[#]

[*] School of Advanced Materials and Nanotechnology, Xidian University, No.2 Taibai South Road, 710071 Xi'an, China (songfang0912@163.com)
[#] School of Microelectronics, Xidian University, No.2 Taibai South Road, 710071 Xi'an, China

Abstract

Transient RRAM devices are very attractive in information security applications and eco-friendly electronics owing to the triggered failure and degradation characteristics by external stimulus such as bio-fluids and water. With the development of flexible electronics, it is innovative to realize the conformal integration of transient RRAM devices with flexible substrates for practical applications. The biomaterial-based transient RRAM devices showed good flexibility while suffered poor electrical performance. The inorganic based transient RRAM devices always need high vacuum process which is not compatible with low coat technology for flexible electronics. As a consequence, the solution process is highly desirable in flexible applications owing to its unique advantages, such as simplicity, low cost fabrication processes, and the potential for large-area fabrication. Therefore, the development of high-performance solution processed transient memory devices has great potential in low-cost flexible memory systems, wearable devices and bio-integrated electronics.

In this work, we propose physically transient resistive switching devices based on solution-processed MgO films, in which the insulation layer MgO is fabricated by spin-coating process. The MgO precursor solution was prepared by dissolving magnesium nitrate hydrate ($Mg(NO_3)_2$ $6H_2O$, Sigma Aldrich) in 2-methoxyethanol (2-ME, Sigma Aldrich). The precursor was spin-coated on the oxygen-plasma-treated substrate, followed by pre-annealing at 150 ℃ for 30 min and post-annealing at 250 ℃ for 2 h. The solution-based MgO RRAM devices exhibit reproducible and robust resistive switching performance under a compliance current of 10^{-4} A with the cell strcuture of Mg/MgO/W. Good endurance and retention behaviors demonstrate the stable performance of the devices.

The dissolution rates of solution-processed MgO films in DI water at room temperature (RT) and in phosphate-buffered saline (PBS, 0.01 M, PH 7.4) at 37 ℃ were estimated to be 0.058 nm/s and 0.146 nm/s, respectively. The resistive switching behaviors of solution-processed MgO RRAM became unstable after immersed in DI water for 4 min and finally failed while immersing for 6 min at RT. In addition, the MgO transient memory devices are transferred to flexible PDMS substrate by water-assisted transfer printing method. The rapid separation between the memory devices and silicon oxide substrate by water-assisted peeling-off process protected the transient devices from long time hydrolyzing and etching, which is critical to complete the transfer printing process. The transferred memory devices were attached to cylinders with different radius to perform the bending tests. None of any noticeable degradation is observed at the bending radius of 3 mm, which exhibits great potential in flexible and biocompatible electronics.

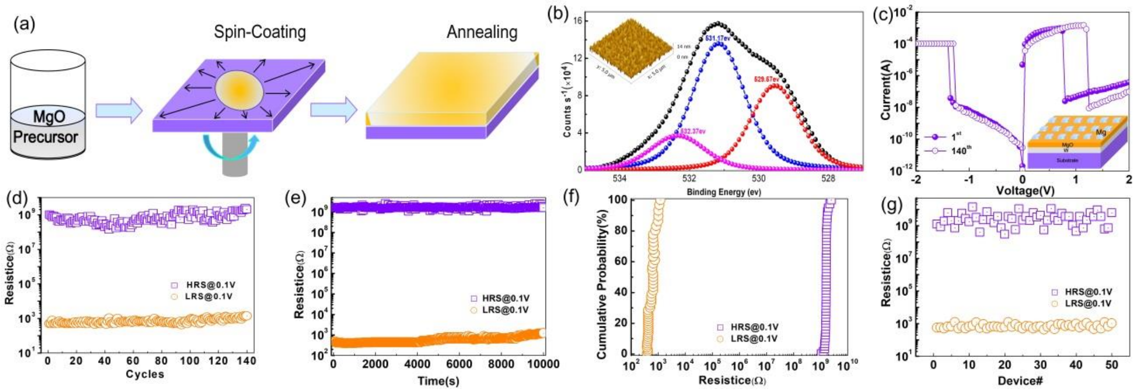

Figure 1: (a) Schematic diagrams of the fabrication procedure of MgO films. (b) XPS O1s spectra of the solution-processed MgO thin films annealed at 250 ℃.(c) Typical I-V curves,(d) Endurance characteristics, (e) Retention characteristics, (f) Cumulative probabilities and (g) Device to device distribution of HRS and LRS of the Mg/solution-processed MgO/W devices.

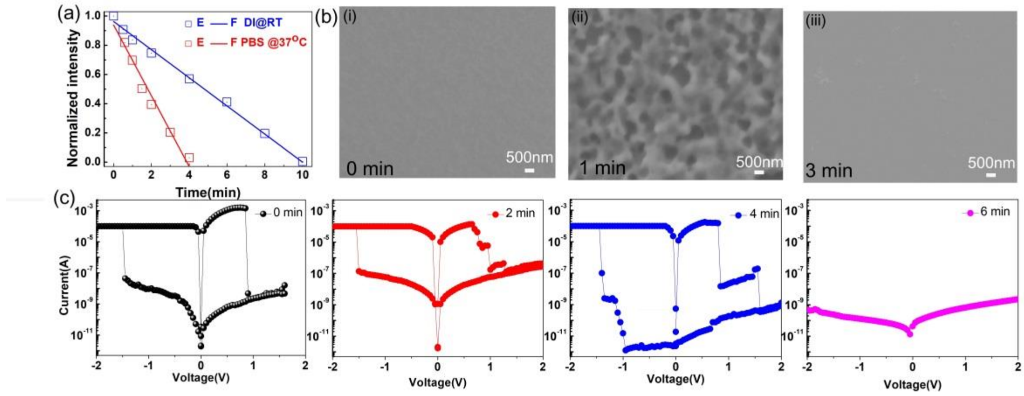

Figure 2: (a) Normalized EDS intensity and (b) SEM images of MgO/Cr films in PBS at 37 ℃. (c) Electrical characteristic of the memory devices at various immersing times in DI at RT.

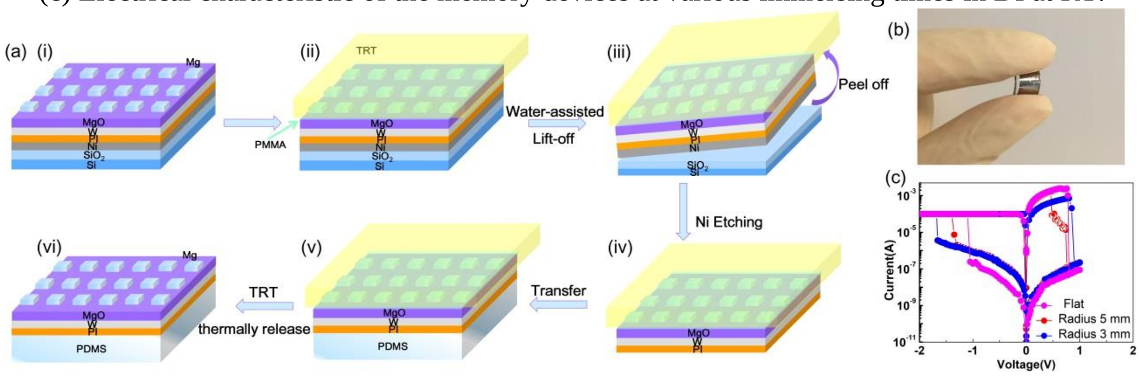

Figure 3: (a) Schematic diagrams of the WTP steps for transferring the transient memory devices to flexible substrate. (b)Transferred memory devices on the PDMS substrate. (c) Resistive switching characteristics of the flexible memory device with different bending radius.

References

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