Supporting Information

Analog Memristors Based on Thickening/Thinning of Ag Nanofilaments in Amorphous Manganite Thin Films

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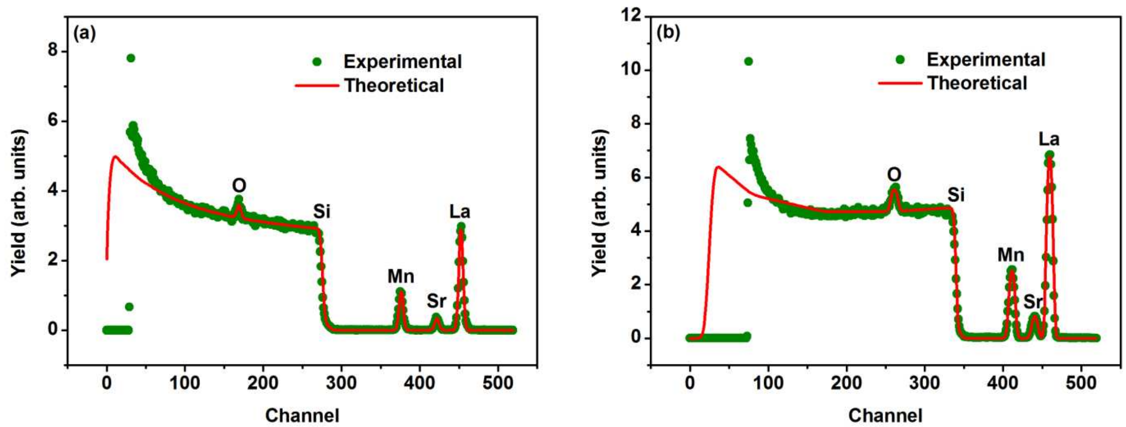

Figure S1. Rutherford backscattering spectrometry (RBS) analysis of the LSMO thin films deposited by RF magnetron sputtering in an atmosphere consisting of 80% argon and 20% oxygen, and the temperature of the substrate was 50°C. The chemical composition of the a-LSMO films was determined as $La_{0.79}Sr_{0.21}MnO_3$ with few oxygen vacancies. RBS spectra are acquired at a backscattering angle of 160° (a) and a grazing angle of 107° (b) using a 2.275 MeV He^{++} ion beam.

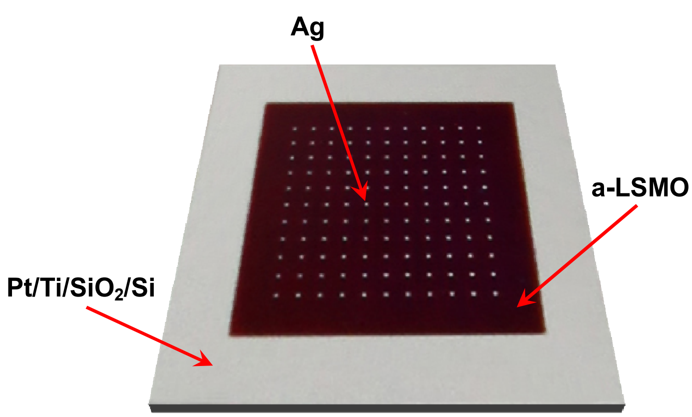

Figure S2. The photograph of the a-LSMO-based memristor. There are 121 memristor cells in total on the device. The layered structure consisted of Ag (100 nm)/a-LSMO (20 nm)/Pt (150 nm)/Ti (50 nm)/SiO_2 (500 nm)/Si.

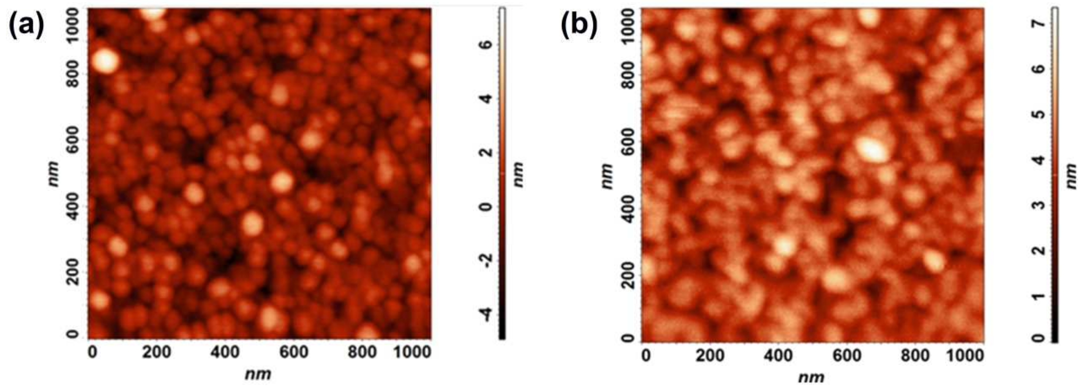

Figure S3. (a) AFM images of the substrate Pt/Ti/SiO_2/Si. RMS=1.31 nm. (b) AFM images of LSMO films deposited on the Pt/Ti/SiO_2/Si substrate under 50 W for 20 min at near room temperature. RMS=0.83 nm. From AFM images, it can be seen that the surface structure of the LSMO film resembles that of the substrate, indicating the film is very thin and amorphous, from another point of view.

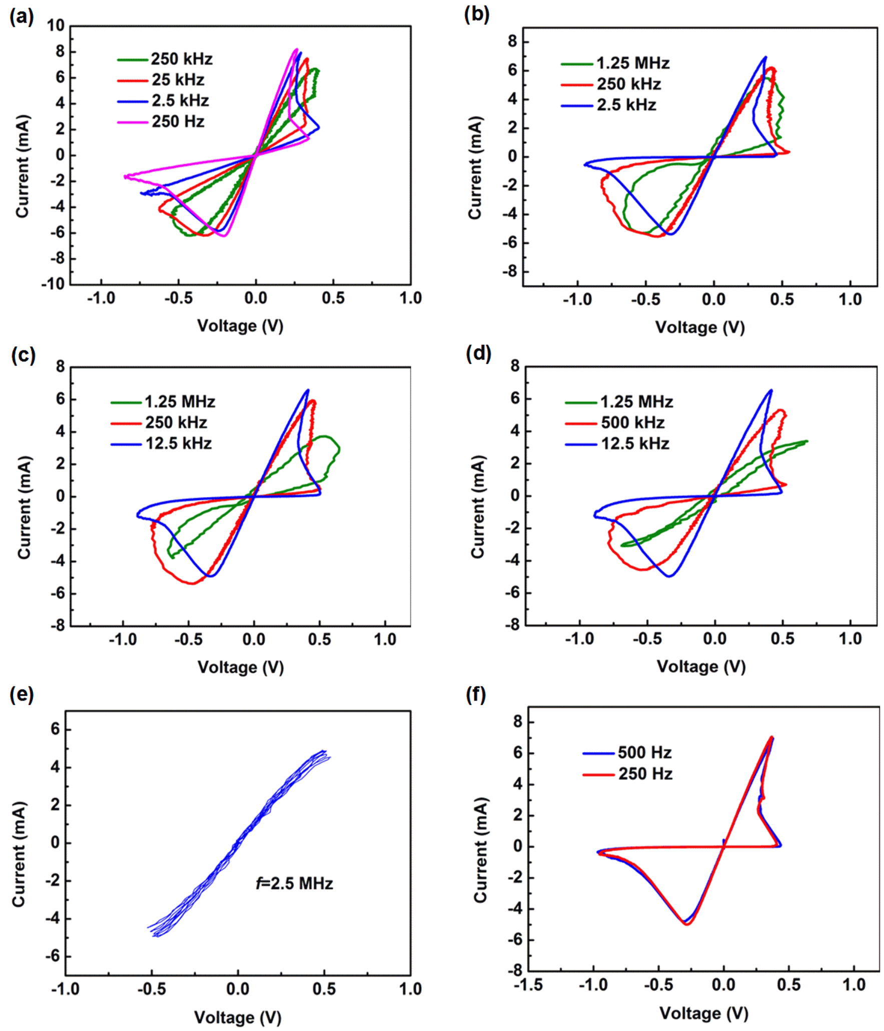

Figure S4. Pinched hysteresis loops of different Ag/a-LSMO/Pt memristor cells measured at various frequencies: (a) 250 kHz, 25 kHz, 2.5 kHz and 250 Hz; (b) 1.25 MHz, 250 kHz and 2.5 kHz; (c) 1.25 MHz, 250 kHz and 12.5 kHz; (d) 1.25 MHz, 500 kHz and 12.5 kHz. (e) Five successive pinched hysteresis loops measured at 2.5 MHz. (f) Pinched hysteresis loops measured at 500 Hz and 250 Hz. The area enclosed by the pinched hysteresis loop shrinks with increasing frequency of the forcing voltage. When the frequency increases to 2.5 MHz, the pinched hysteresis loops degenerate to almost straight lines. When the frequency reduces to 500 Hz, the area enclosed by the pinched hysteresis loops changes insignificantly with the frequency further decreasing.

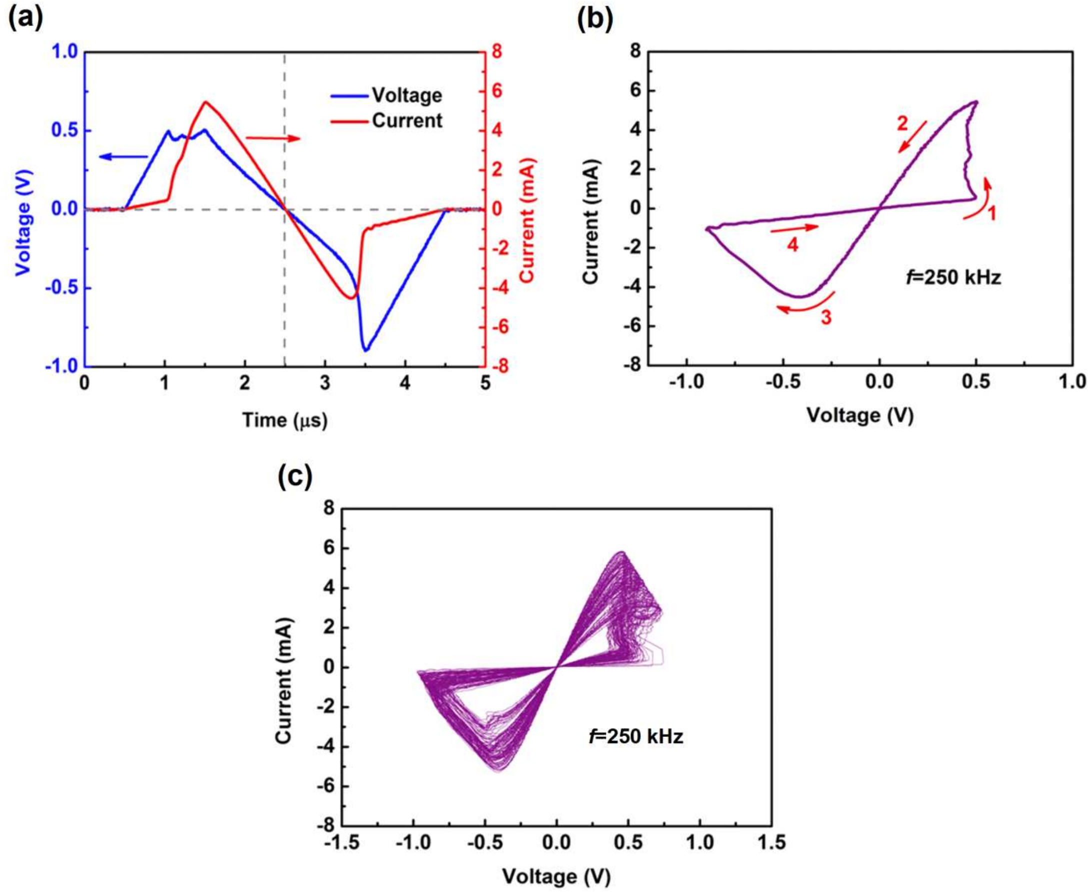

Figure S5. (a) The applied triangular-waveform voltage pulse and the resulting current as a function of time for an Ag/a-LSMO/Pt memristor cell. The magnitude of the applied voltage pulse is 1 V and the period is 4 μs with a 10-mA CC. (b) The *I*-*V* hysteresis loop corresponding to the curves in (a). (c) One hundred sequential *I*-*V* hysteresis curves measured at 250 kHz. The memristive performances have no obvious degradation after 100 repeating pulse *I*-*V* cycles. The result indicates that Ag/a-LSMO/Pt memristors are highly reliable and reproducible.

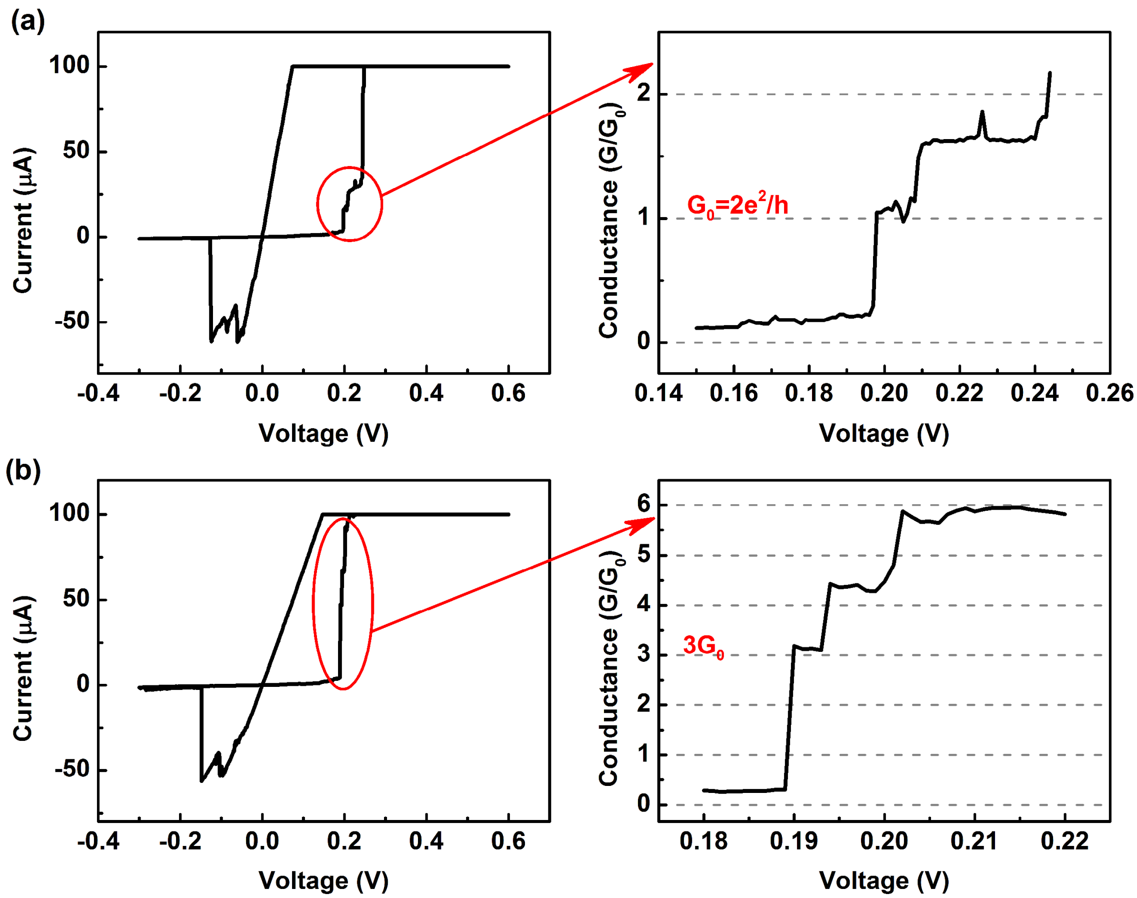

Figure S6. (a), (b) Two examples of multiple current jumps we found during the set processes under quasi-static voltage sweep. G_0=$2e^2/h$=78 μS=1/(12.9 kΩ), where e represents the charge of an electron and h is Planck constant.

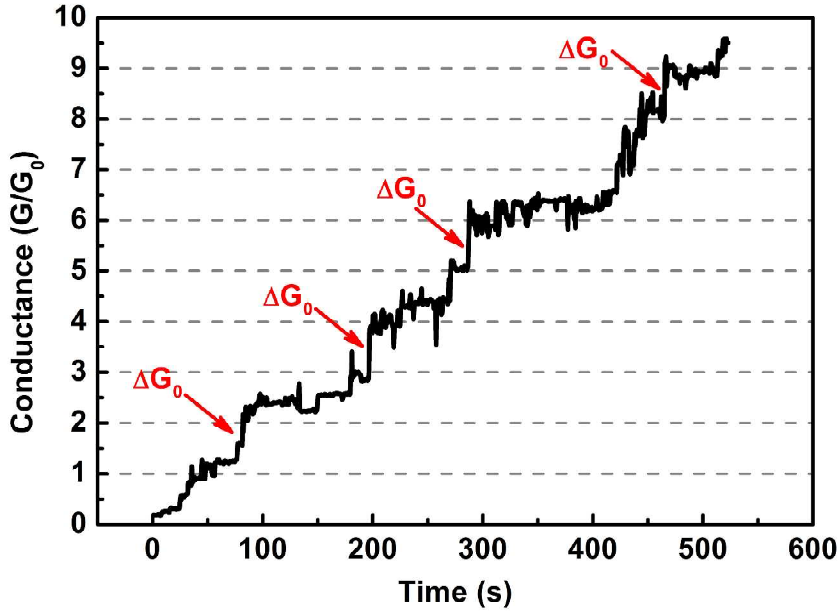

Figure S7. Analysis of quantized memristor conductance by sweeping the current. The current is increased stepwise from 1 to 100 μA at 100 nA and 0.5 s per step. Four abrupt conductance changes can be clearly observed, each followed by a stable conductance plateau. Besides, most of the the changes in conductance occurr at integer multiples of G_0.

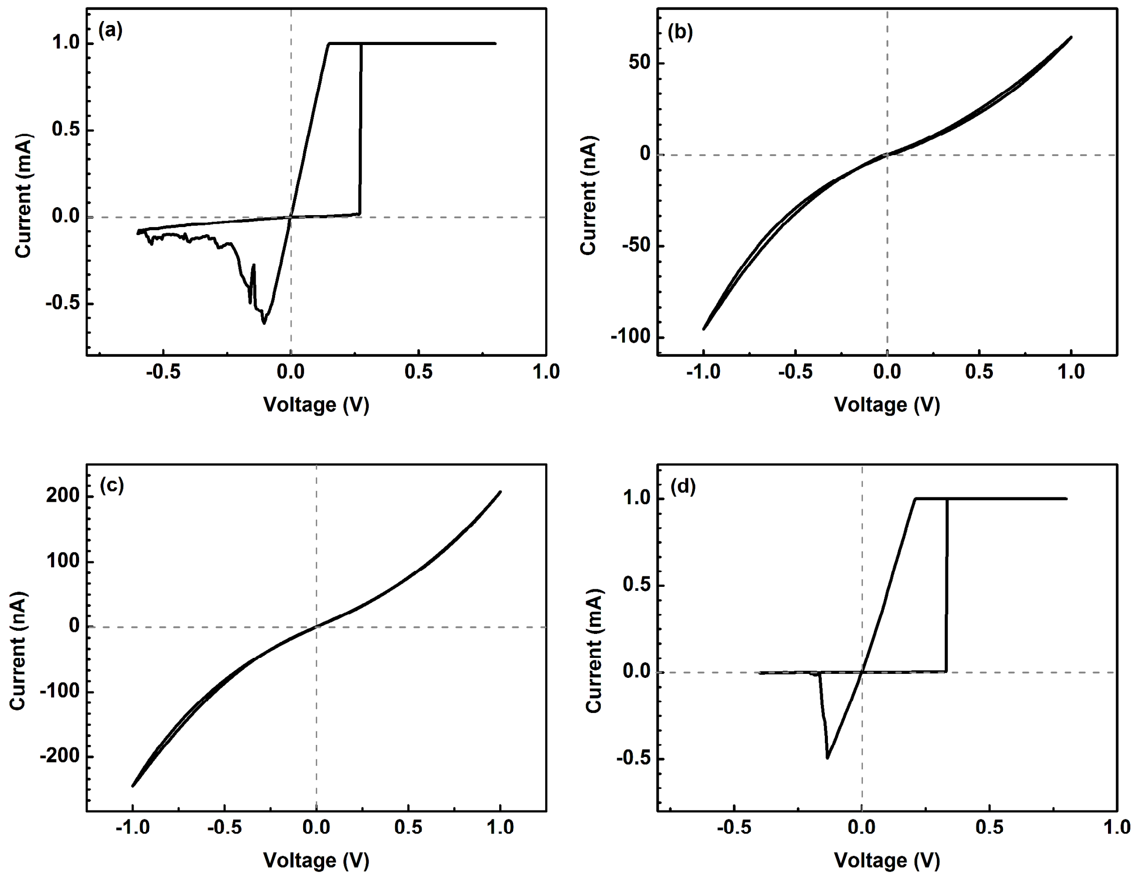

Figure S8. *I-V* cycles of the a-LSMO-based memristor cell using Pt as the BE material and (a) Ag, (b) Pt, (c) Au, (d) Cu as the TE materials, respectively. Only the memristor using Ag or Cu as the TE materials exhibited memristive properties.