ADVANCED MATERIALS

Supporting Information

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Observation of Conductance Quantization in Oxide-Based Resistive Switching Memory

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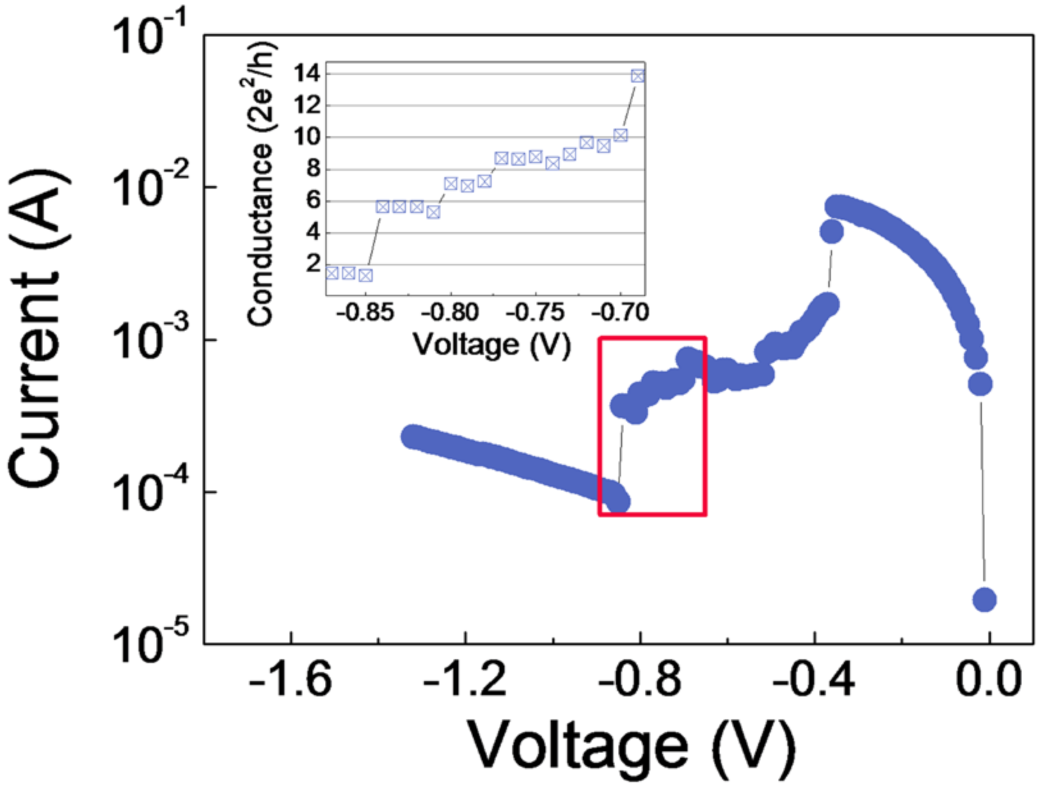

Figure S1. *I-V* curve of a Nb/ZnO/Pt device in the Reset process. Inset: corresponding *G-V* curve showing apparent quantized conductance behaviors.

Discussion on the superconductivity of Nb/ZnO/Pt devices

As is known, Nb is a superconductor with a superconducting transition temperature T_C of 9.3 K, while Zn and Pt wires are also superconductors but with much lower superconducting transition temperatures (< 1 K) [Nano Lett. 5 7 (2005)]. It is reasonable to attribute the sudden drop in the resistivity to the superconducting transition of Nb in the Nb/ZnO/Pt device at LRS. In order to clarify the contribution of Nb electrode to the superconductivity in the devices, two devices with different top electrode structures were fabricated, Cu (75 nm)/Nb (25 nm)/ZnO (80 nm)/Pt and Nb (75 nm)/Cu (25 nm)/ZnO (80 nm)/Pt. The diffusion of electrochemically active metals (*e.g.* Cu and Ag) into the oxide film and form local filaments and induce resistive switching behaviors are well known (Nano Lett. 9 1636 (2009)). As a result, in the Nb (75 nm)/Cu (25 nm)/ZnO (80 nm)/Pt device, the filaments should be composed of Cu, which will not indicate superconductivity in our measurement temperature range. On the other hand, if the observed superconducting behavior originates from the Nb electrode, we should observe similar superconducting behavior no matter the electrode structure. However, after Forming process with a compliance current of 100 μA, although the device showed a metal conducting behavior in the resistance-temperature curve, we didn't observe any obvious resistance drop at low temperatures for many measurements (See Figure S2). So it is natural to think that the contribution of Nb electrode to the superconductivity is very small. Moreover, according to our simple estimation, the resistance of Nb electrode is in the order of $\mu\Omega$. So the contribution Nb electrode to the superconductivity is very small. On the other hand, for the Cu (75 nm)/Nb (25 nm)/ZnO (80 nm)/Pt device after Forming process with the same current compliance level, the superconducting behavior at Nb superconducting temperature could still be detected although we reduced the thickness of Nb electrode, and the resistance drop is found to be around 3×10^{-3} Ω (See Figure 2d). As a result, it is reasonable to expect the superconductivity mainly originate from the Nb filaments, rather than the Nb electrode.

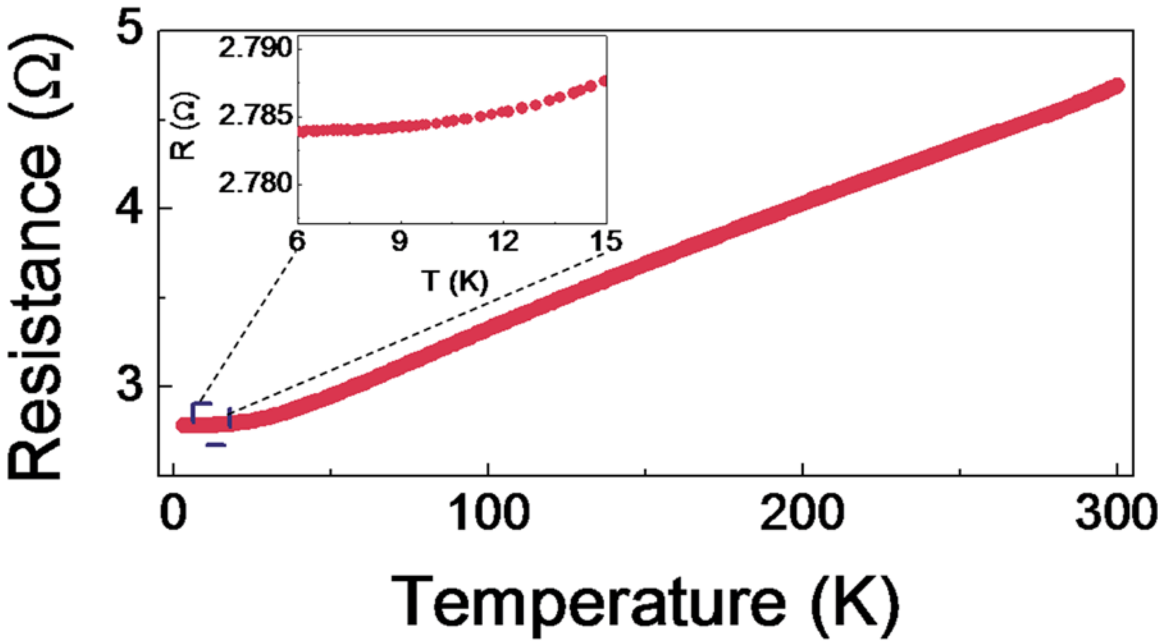

Figure S2. Temperature dependence of the resistance for a Nb (75 nm)/Cu (25 nm)/ZnO (80 nm)/Pt device at LRS. Inset: Zoomed-in curve showing a temperature range from 6 to 15 K.

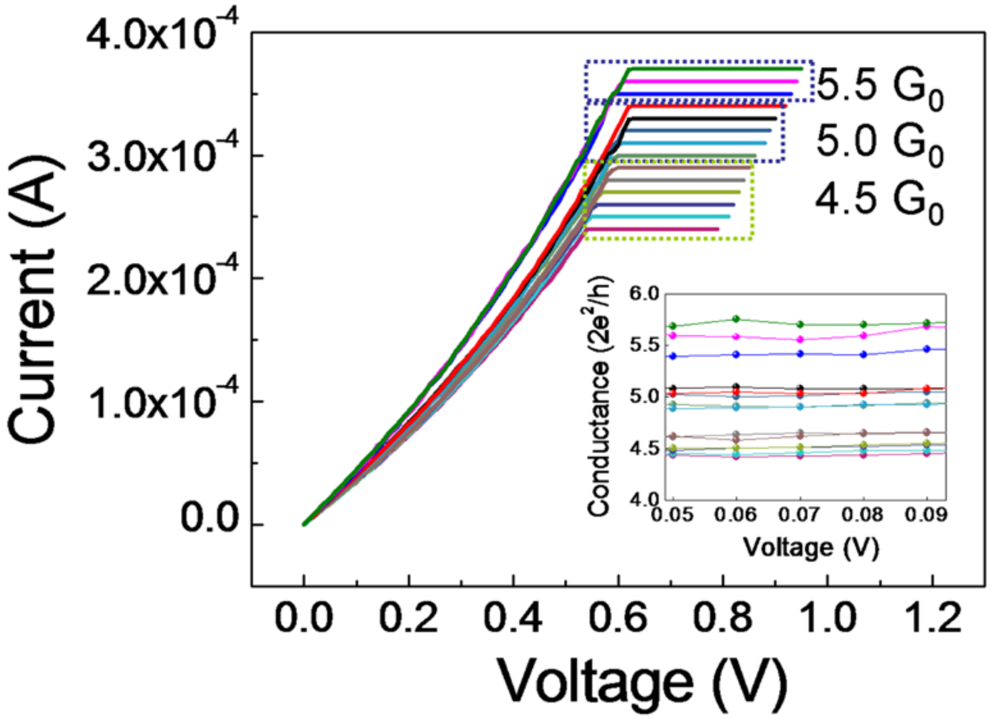

Figure S3. *I-V* curves with small current compliances changes in steps of 1.0×10^{-5} A for a Nb/ZnO/Pt device in the Set process. Inset: Corresponding conductance values read at 0.05, 0.06, 0.07, 0.08 and 0.09 V in different voltage sweeping cycles. Clear margins can be observed between 4.5, 5.0 and 5.5 G_0.

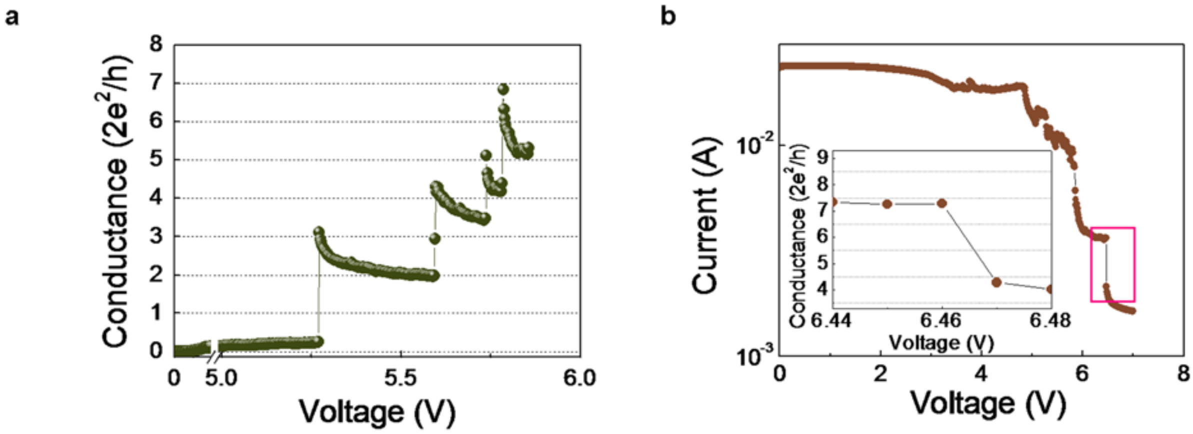

Figure S4. Quantized conductance in ITO/ZnO/ITO devices. a, *G-V* curve for a device showing discrete conductance jumps in the Set process. b, *I-V* curve for a device in the Reset process. Inset: corresponding *G-V* curve in a voltage range from 6.44 to 6.48 V.

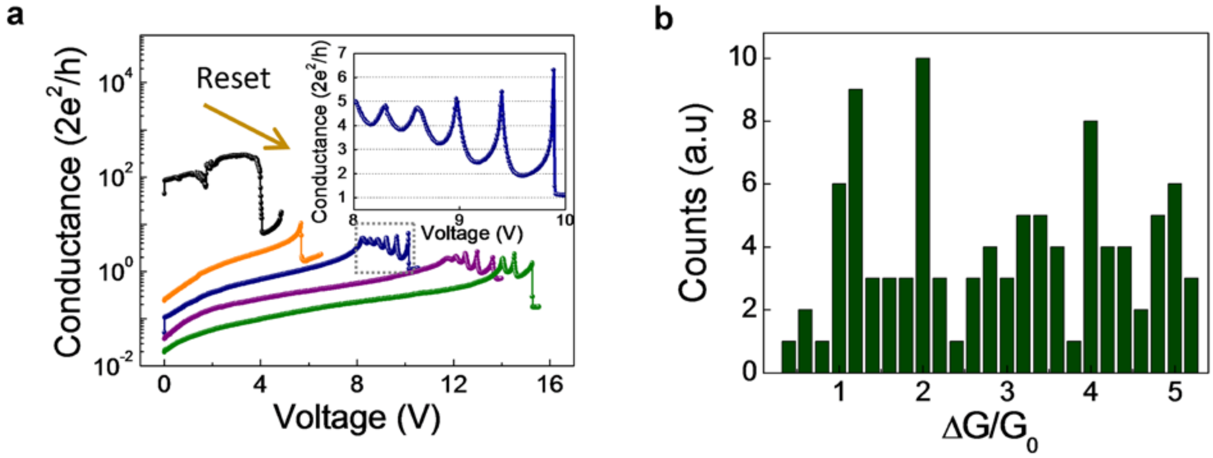

Figure S5. Quantized conductance oscillations for a ITO/ZnO/ITO device in Reset process. a, Oscillation behaviors observed with different sweeping voltage ranges. Inset: *G-V* curve (blue) in a voltage range from 8.0 to 10.0 V. The amplitudes of the oscillations are concentrated on integer values of G_0. b, Histogram of the conductance changes $\triangle G$ obtained from ~ 20 curves. Peaks can be observed around integer values of G_0.

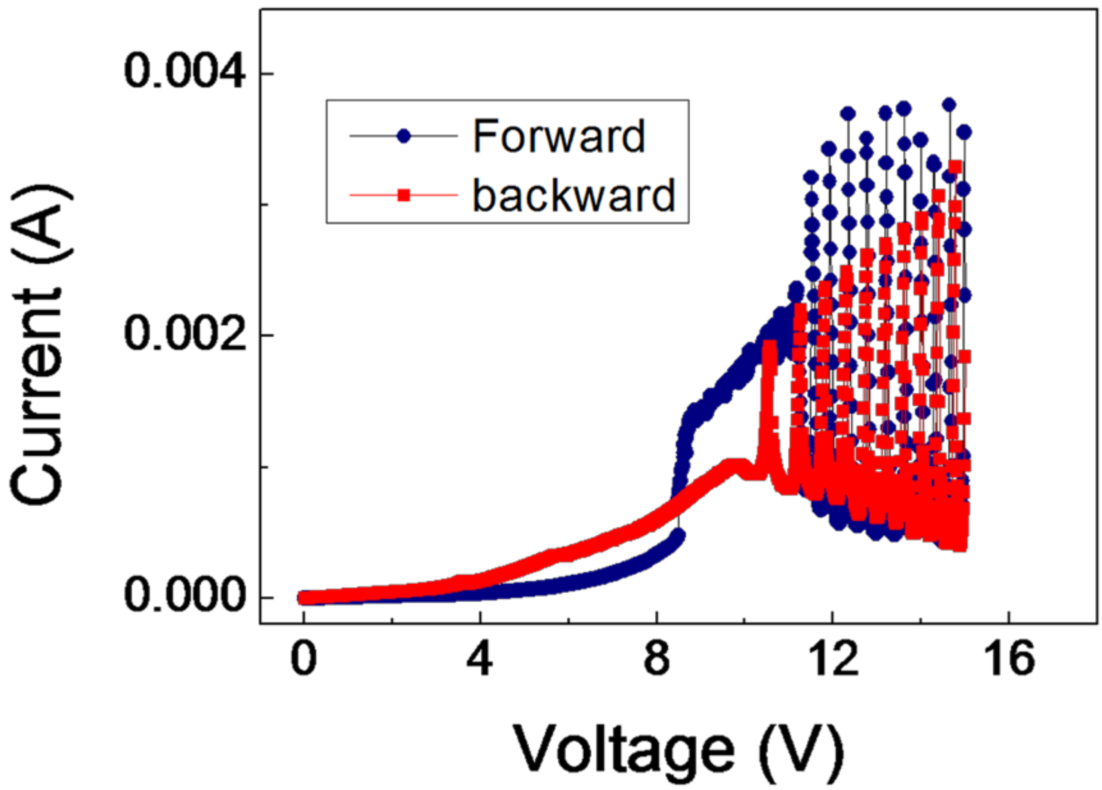

Figure S6. Current oscillation behaviors in a whole voltage sweeping process in an ITO/ZnO/ITO junction.