Low-power Resistive Switching in Ultra-smooth Native AlO_x Thin Films Fabricated by Template Stripping

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Resistive switching devices are promising for many applications such as memory, logic and neuromorphic network [1]. Usually a resistive switch consists of two metal electrodes and a switching material layer (e.g., oxide) sandwiched in between. One way to eliminate the electroforming step and to lower down the power consumption is using a thinner oxide layer. Current challenges faced by this family of devices include the device reliability and repeatability, especially for devices with very thin switching layers.

To address these issues, we developed low-power resistive switches using ultra-smooth native AlO_x that are fabricated by template stripping. These devices exhibited reliable and repeatable switching behavior with high ON/OFF conductance ratio (~ 10^7) and low power consumption.

Fig. 1 schematically illustrates the device fabrication process. Al bottom electrodes were first fabricated on a prime grade Si substrate by evaporation through a shadow mask or nanoimprint lithography defined resist stacks. The substrate was selectively treated with a self-assembled monolayer of anti-sticking agent so that the Al wires were not in direct contact with the substrate. A UV-curable polyurethane (PU) liquid layer was spin-coated onto a glass slide and then brought into contact with the Al patterns on the Si substrate. After UV crosslinking, the PU became solid and the glass slide was separated from the Si substrate, during which process the Al patterns were transferred from the Si substrate into the PU on the glass slide. The template stripped Al were exposed to air in a clean room environment overnight, developing several nanometers thick native AlO_x as confirmed by x-ray Photoelectron Spectroscopy (XPS). The top Al electrodes were fabricated by Al evaporation through a shadow mask or patterned imprinted resist stacks.

Template stripping has been proved to be a highly efficient method to make both micro- and nanoscale features with high yield. Fig. 2 shows images of template stripped bottom Al wires of 5 μm, 10 μm, 15 μm and 50 nm and contact pads of 50 and 100 μm. The device yield was nearly 100%. More importantly, the surface of AlOx developed from the template stripped Al was much smoother. As shown in Fig. 3, the root mean square (rms) roughness was 2.0 nm for the AlOx film from the as-evaporated Al while that for films from template stripped Al was 0.26 nm, an order of magnitude improvement.

Devices based on AlOx from template stripped Al exhibited much better electrical performance. Fig. 4 shows the typical IV curves for devices with 10 μm by 10 μm junction area (40nm Al/~4 nm AlOx/40 nm Al geometry). Native oxide based on as-deposited Al did not show resistive switching phenomena (it cannot be RESET any more after the first SET sweep) (Fig. 4a); however, repeatable switching with up to 10^7 ON/OFF ratio can be obtained in oxide that based on template stripped Al (Fig. 4b). The electrical characterization of nanosclae devices will also be reported.

[1]. Yang, J. J et al. Nature Nanotech. **8**, 13 (2013).

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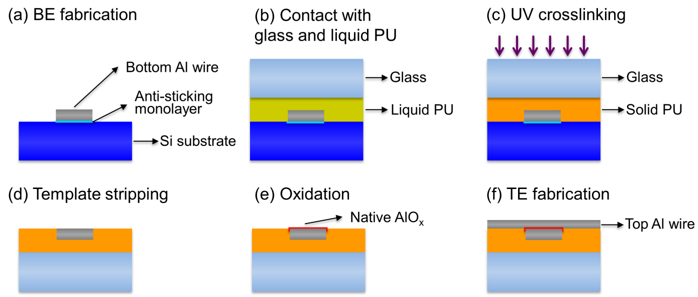

Figure 1. Schematic illustration of the device fabrication process based on template stripping.

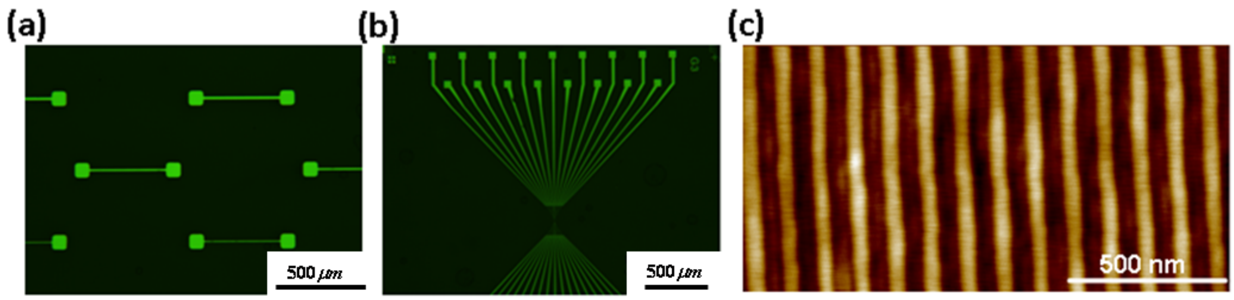

Figure 2. Optical images of template-stripped Al patterns that were patterned by (a) shadow mask and (b) NIL; (c) AFM image of nanowires with 50 nm half-pitch after stripping.

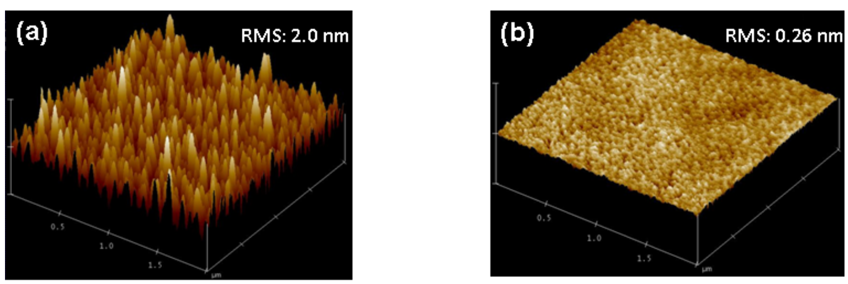

Figure 3. Tapping-mode AFM micrographs of the surface morphology for native oxide based on (a) as-deposited Al and (b) template-stripped Al.

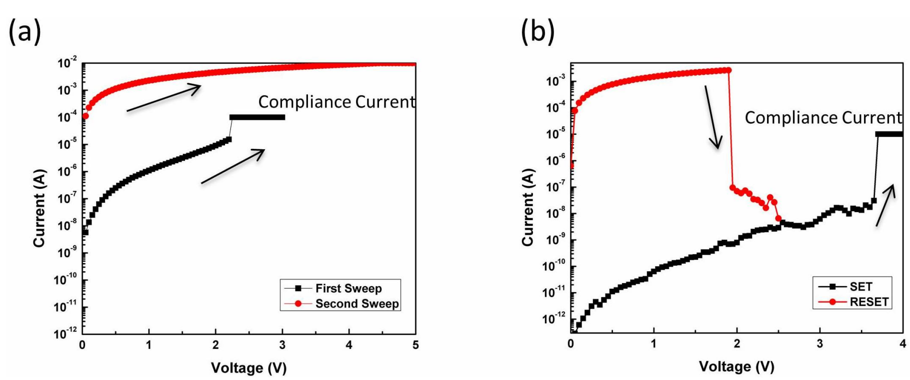

Figure 4. Typical electrical characterization results of native oxides based on (a) as-deposited Al and (b) template-stripped Al. The cross point area was 10×10 μm^2. The bias voltage was applied to the top electrode with the bottom electrode grounded during measurements.