TiO_2 Sol-Gel Based Memristor Crossbar Arrays with Triangular Top and Bottom Metal Electrodes

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Memristive devices are promising candidates for next-generation memory and computing applications.[1] One challenge for these devices is how to achieve uniform cycle-to-cycle and device-to-device switching behavior. Previous approaches to better switching uniformity include embedding Ru nanodots[2] into the switching layer and adopting a bilayer device structure[3]. In this work, we address the uniformity challenge from the perspective of electrode geometry. We use nanostructured metal wires with triangular cross-sections as top and bottom electrodes for a crossbar array, and a layer of TiO_2 sol-gel sandwiched in between as the switching material, as illustrated in Fig. 1. Conductive filaments are likely formed at the triangular tips due to the enhanced electric field. The localized filament formation and small filament size will lead to better switching uniformity and lower power consumption. As shown in Fig. 2, the electric field at the triangular electrodes is much localized at the tips compared with the conventional device structure.

Fig. 3 shows the schematic of the fabrication process. First, triangular Si nanowires arrays were obtained through a combined dry/wet etching process on a SOI wafer using metal masks defined by nanoimprint lithography. Pt with Ti adhesion layer was deposited on top of the Si ridges as the bottom electrodes. A thin layer of TiO_2 sol-gel was applied on the bottom electrode as the switching material. Pt top electrode was deposited in the triangular trenches on a donor silicon wafer and subsequently transfer-printed onto the sol-gel layer by a water soluble PVA template, concluding the crossbar fabrication. The printing process was guided by a homemade alignment system to ensure good registration to the bottom electrode. The devices were then annealed at 250°C for 24 hrs before testing.

Figs. 4a, 4b show the SEM images of bottom electrodes on SOI substrate. 13 nm Pt with 3 nm Ti cover top of the triangular Si ridges, and width of the top ridge is 10 nm. Figs. 4c, 4d are the SEM images of 15 nm thick Pt top electrodes transferred from the donor wafer to the PVA template. A typical final 11 by 11 crossbar arrays with fanout structure and contact pad are shown in Fig. 4e, with the active device area highlighted in SEM image in Fig. 4f.

In summary, we have fabricated TiO_2 sol-gel based memristor crossbar arrays with triangular top and bottom electrodes. The nanostructured electrodes localize the electric field and confine the confine the filament formation and size, and thus more uniform switching is expected. The fabrication technique developed in this work can also be used to for multiple layer crossbars and for devices on flexible substrates.

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[1] J. J. Yang, D. B. Strukov, and D. R. Stewart, Nat Nanotechnol **8** (1), 13 (2013).
[2] J. H. Yoon, J. H. Han, J. S. Jung, W. Jeon, G. H. Kim, S. J. Song, J. Y. Seok, K. J. Yoon, M. H. Lee, and C. S. Hwang, Advanced materials **25** (14), 1987 (2013).
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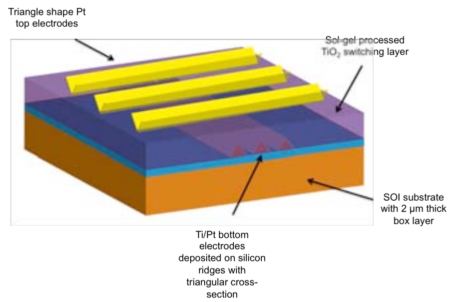

Figure 1: Illustration of memristor crossbar arrays with triangular top and bottom electrodes. Filaments are likely to be formed at the triangular tips due to the enhanced electric field.

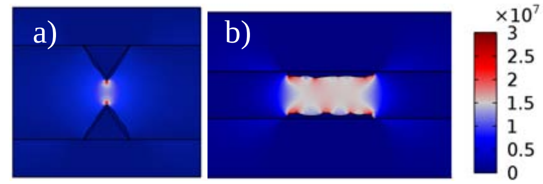

Figure 2: Simulation of electric field distribution of device with (a) triangular and (b) flat electrodes. High intensity of electric field in between two triangular electrodes will likely confine the filament locations during operation.

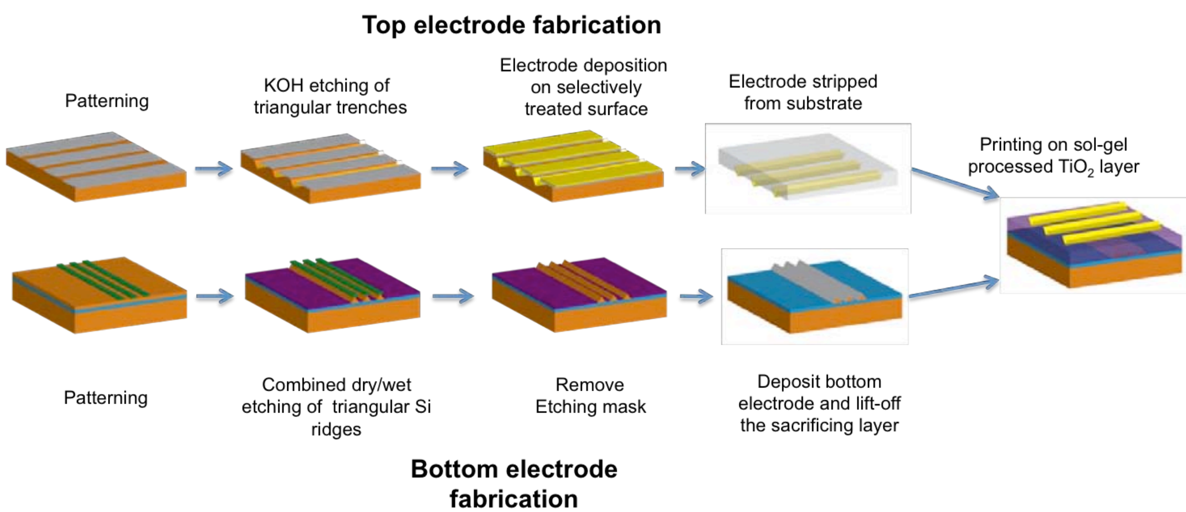

Figure 3: Schematic of the fabrication process

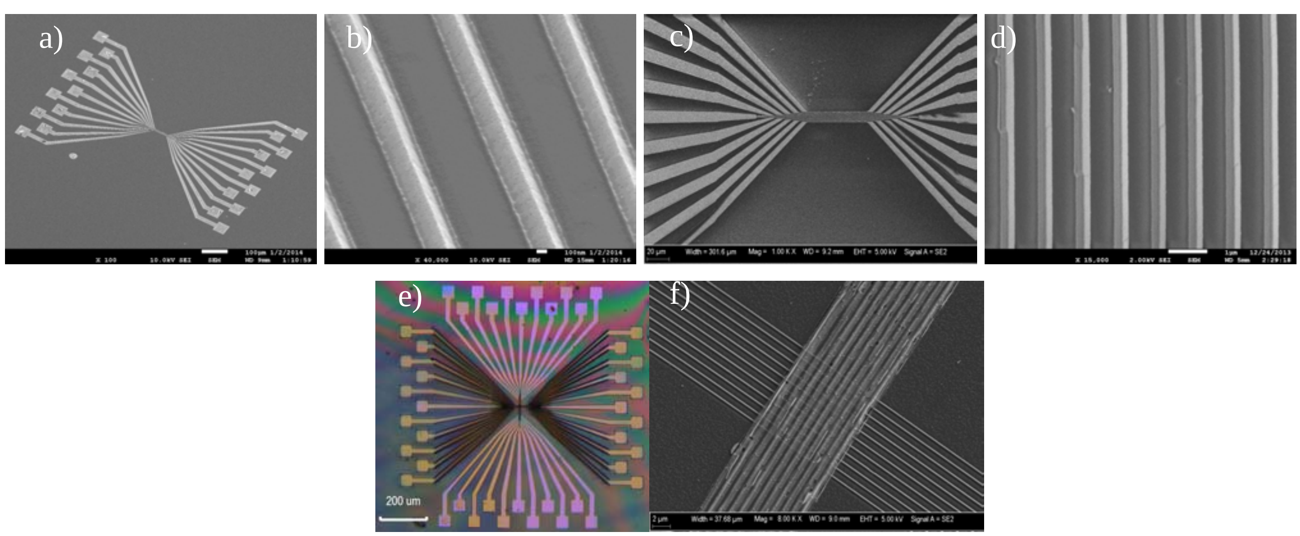

Figure 4: (a-b) SEM images of bottom electrodes on SOI substrate. (c-d) SEM images of top electrodes on PVA template. (e) Optical image and (f) SEM image of the final device.