Mass fabrication of resistive random access crossbar array by UV-NIL

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Nanoimprint lithography is a low-cost method of fabricating nanoscale patterns as small as 6 nm. It has been emerged as a key technology for the fabrication of devices with nanoscale patterns, such as polarizer, optical devices, bio devices, and patterned media. The ultraviolet nanoimprint lithography (UV-NIL) process is also a promising alternative to the expensive conventional optical lithographic process for producing non-volatile memory. Resistive random access memory (RRAM), which utilizes the resistance change effect of oxide material, has attracted considerable attention and been widely investigated due to its potential application in memory devices.

In this study, we investigated the characteristic of nonvolatile memory fabricated by the UV-NIL process. Bottom and top electrodes were fabricated by UV-NIL process. Figure 1 shows the fabrication process for the RRAM. The UV-NIL experiments were performed using SFIL process of Imprio 100 by Molecular Imprint Inc. In the UV-NIL process, low-viscosity picoliter volume resin droplets were dispensed on the Si substrate, where 50 nm thick metal layer was deposited. Quartz stamp with memory pattern engraved was pressed the dispensed resin and UV light was exposed to cure it. The imprinted polymer was transferred to metal layer by the dry etch process. Resistive switching elements such as Al_2O_3 and NiO for unipolar switching and TiO_2 for bipolar switching were formed on patterned bottom electrodes. After top electrode metal deposition, above UV-imprint and etch process were performed again. This process was used to align the nanowires 1 μm long and 100 nm wide. Figure 2(a) shows the fabricated RRAM cells on a 6-inch diameter SiO_2/Si wafer, with 25 fields including four 16×16 arrays in each field. Figures 2(b) and (c) show SEM images of well-aligned memory cells of 16×16 arrays.

The fabricated circuits were tested as 256-bit random access memories at room temperature under ambient conditions. The direct current (DC) sweep voltage for the Agilent 4155B semiconductor parameter analyzer was applied to contact pads of a 16×16 crossbar circuit. The area of active switching elements in such a crossbar circuit was about 80×80 nm. Figure 3(a) shows the typical *I–V* characteristics of the Al/native Al_2O_3/Al structure for the first bit, which exhibited unipolar resistive switching. Figure 3(b) shows the *I-V* characteristics of the Pt/polycrystalline-TiO_2/Pt structure, which exhibit bipolar resistive switching. The resistance off/on ratio ($>10^6$ in fig.3 (a) and $>10^2$ in fig. 3(b)) was obtained with a reproducible change from a low resistance state to a high resistance state. The experimental data indicated that high-density cross-bar arrays could be well replicated and that the electrical performance of these arrays was reliable.

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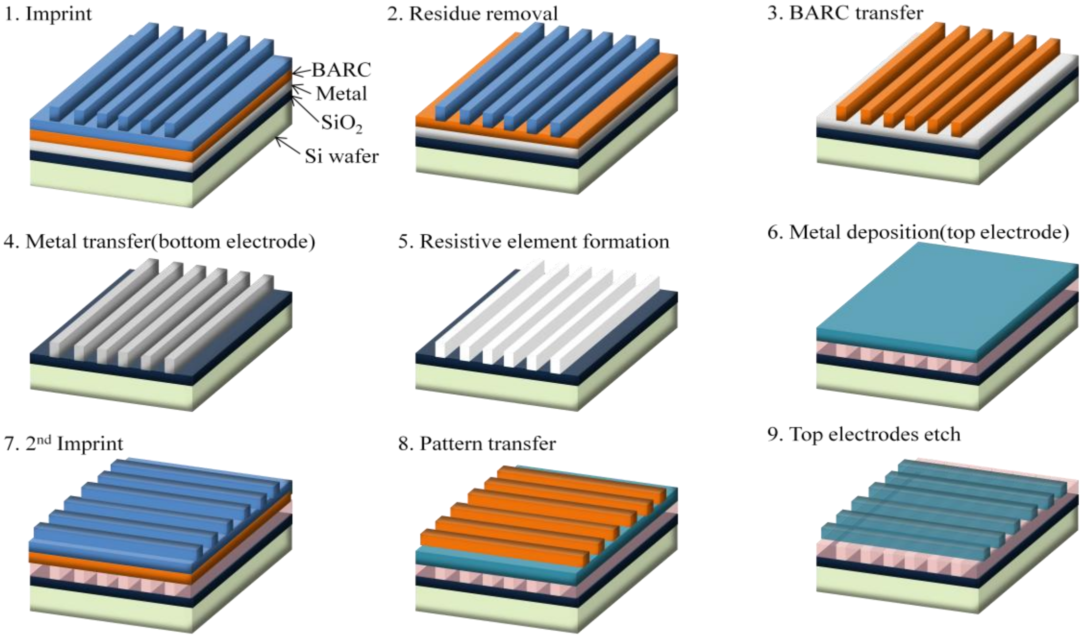
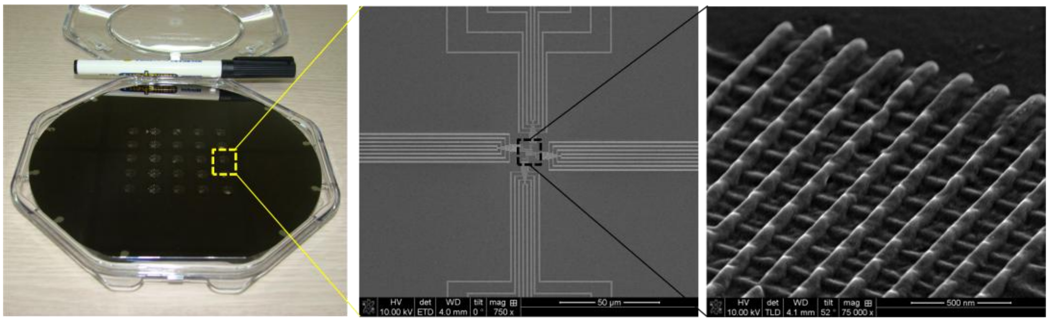
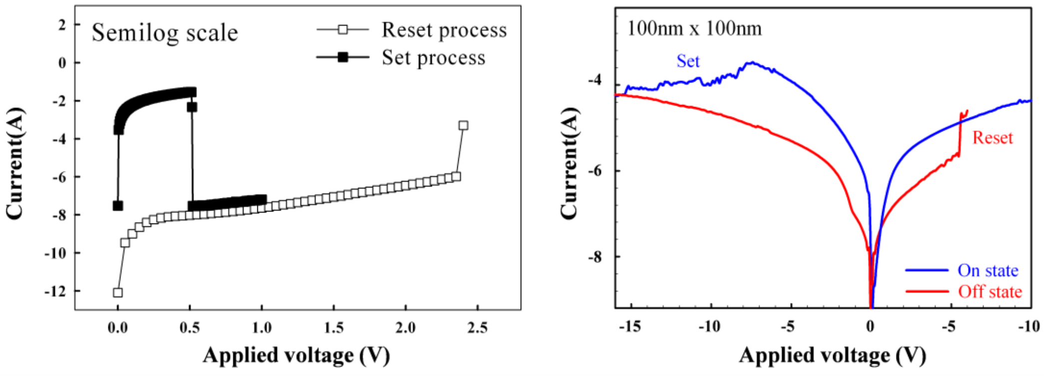


Fig. 1. RRAM fabrication procedure using the SFIL process with the direct metal etching process.



(a) (b) (c)

Fig. 2. (a) RRAM cells on 6-inch diameter SiO2/Si wafer with 25 fields including four 16×16 arrays in each field, (b) SEM image of well-aligned memory cell of 16×16 arrays, and (c) magnified cell array with 100-nm half pitch.



(a) (b)

Fig. 3. (a) I-V characteristics of Al/Al$_2$O$_3$/Al structure, and (b) bipolar resistive switching of Pt/TiO$_2$/Pt structure.