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Supplementary Information for

Highly Reliable Switching via Phase Transition using Hydrogen Peroxide in Homogeneous and Multi-layered $GaZnO_x$-based Resistive Random Access Memory

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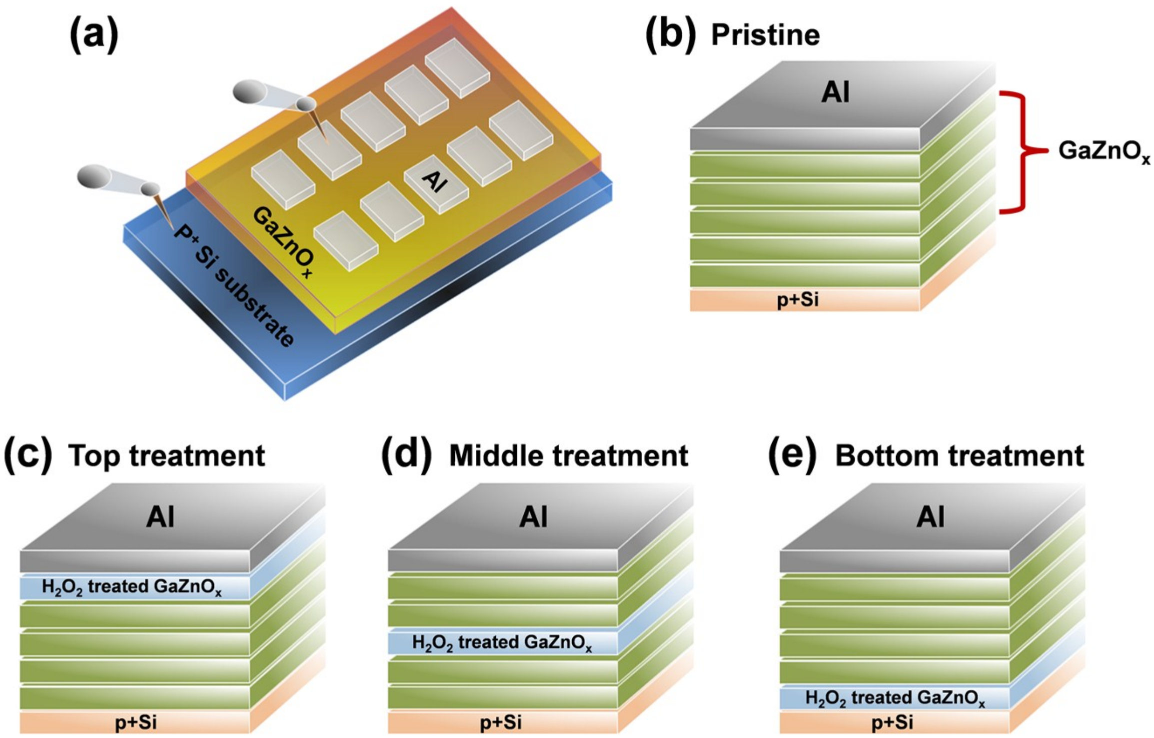

Figure S1. (a) The final schematic of the solution processed GaZnO$_x$ based RRAM device, and the illustration of treatment location for (b) pristine, (c) top treatment, (d) middle treatment, and (e) bottom treatment

A p$^+$Si substrate was used for the bottom electrode of the RRAM devices as shown in Figure S1(a), and ultraviolet-assisted annealing was carried out for 15 min to induce hydrophilic behavior. For the switching layer, 0.5 M GaZnO$_x$ solution was synthesized using Zn acetate dihydrate and Ga nitrate hydrate using 2-methoxyethanol as a solvent. Mono-ethanolamine stabilizers and acetic acid were added dropwise to improve the solubility of the precursors and homogenize the GaZnO$_x$ solution, respectively. The synthesized compound was stirred for 1 h at 60°C, filtered through a 0.2-µm microfilter, and then aged for over 24 h in ambient air. To deposit the H_2O_2 treatment layer, we mixed H_2O_2 in synthesized GaZnO$_x$ solution. The solution was then deposited on a p$^+$Si wafer using spin coating. To investigate the effect of H_2O_2 deposition location on bipolar resistive switching (BRS) behavior, we prepared four experimental samples: pristine (Figure S1.(b)), top treatment (Figure S1.(c)), middle treatment (Figure. S1(d)) and bottom treatment (Figure. S1(e)). Spin coating was performed in five steps including H_2O_2-embedded GaZnO$_x$ solution to achieve optimized thickness. After each spin coating step, the GaZnO$_x$ thin film was prebaked at 300°C in air for 15 min to remove the solvent. A post-annealing step was then carried out at 500°C for 2 hours. The thickness of all GaZnO$_x$ layers is ~ 240nm. Lastly, 200-nm-thick Al was deposited to define the device area, a rectangle feature of 1000-µm (vertical) and 1500µm (horizontal), using a thermal evaporator. The electrical properties of the devices were analyzed at room temperature in darkness and air, using an HP 4156C semiconductor parameter analyzer.