A TiO_2 – based Radio Frequency Resistive Switch

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The non-volatile state, good reliability and easy fabrication on stiff and flexible substrates[1] of oxide RRAM devices are attractive properties also for developing radio frequency switches. By comparison with the high resistance RRAM required for neuromorphic crossbar integration, the RF RRAM switches need to be optimized to have very low capacitances and ON resistances (few Ω) for high isolation and low insertion loss. RF switching using phase-change materials[2] is emerging with encouraging performance, but it is limited by the high switching power and the requirement for rather exotic materials (e.g. GeTe). The air gap CBRAM switches have great performance, but reported low endurance[3].

This paper reports the first experimental and simulation results of a radio frequency RRAM switch for the X band using heavily reduced TiO_x as active material. The device was fabricated using a coplanar waveguide design with 100µm signal line width and 60µm gaps to ground (Fig. 1) on HRSi wafer of resistivity ~10^4 Ω·cm. Three photolithography steps were performed using a MA6 Suss MicroTec aligner and lift-off. To reduce the device dimensions below the resolution limit and thus lower the capacitance, the top electrode was mis-aligned from the bottom electrode, with a sacrifice to the yield. The smallest obtained working device had a ~0.5 μm^2 area (Fig 1c). After the lithography for the top litography, a ~30nm TiO_x film was deposited by e-beam deposition in vacuum from TiO_2 pellets, followed by electrode metal deposition. This method ensured a clean interface between the TiO_x layer and top electrode.

The as-fabricated devices showed a highly conductive, almost linear behavior, with resistances ~38 Ω @ 0.05 V. The devices had low switching voltages (±1V) (Fig. 2a). The maximum OFF resistance was ~35 kΩ, while the minimum ON resistance was measured as ~28Ω. The switches were switched at least 20 times at room temperature in air. Attempts to use higher set currents to further reduce the ON resistance led to irreversible device damage. The switch shows good insertion loss (-2.1 dB) and isolation (-32 dB) at 10GHz (Fig 2b). Simulations in ADS were performed using the model[4] in Fig. 2c, with good results.

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[2] El-Hinnawy N. et al. Compound Semiconductor Integrated Circuit Symposium, Oct. 2014.

[3] Pi S. et al. Nature communications, vol. 6, p. 7519, 2015.

[4] Wainstein N., Kvatinsky S., IEEE Symposium on Circuits and Systems, May 2017

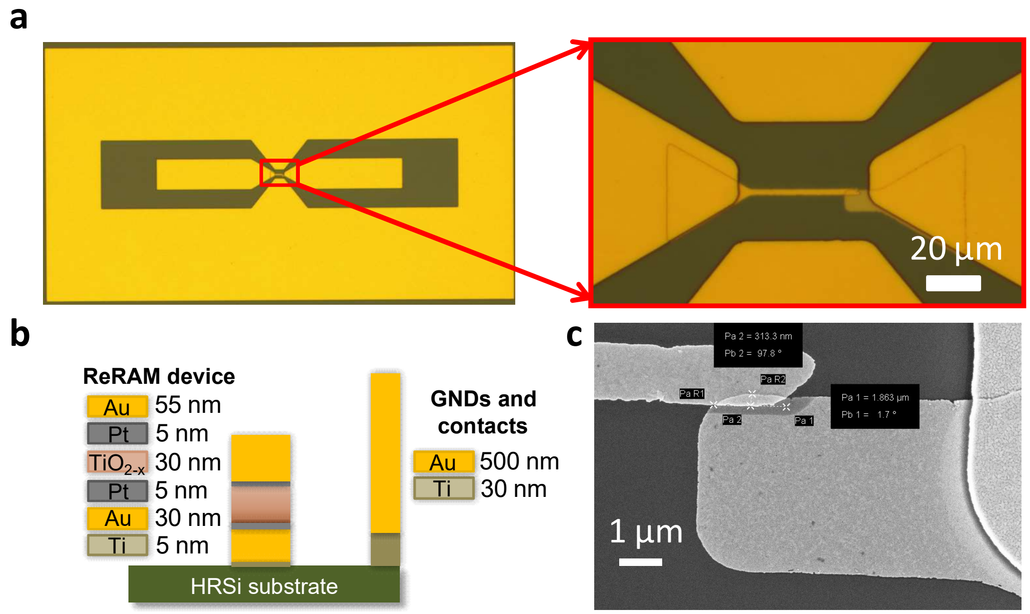

Figure 1: Fabrication results: (a) RF switch coplanar waveguide design and RRAM device detail (b) Layer thicknesses for RRAM device and signal/ground lines (c) SEM photo of RRAM device showing an area of ~300nm x 1.8µm.

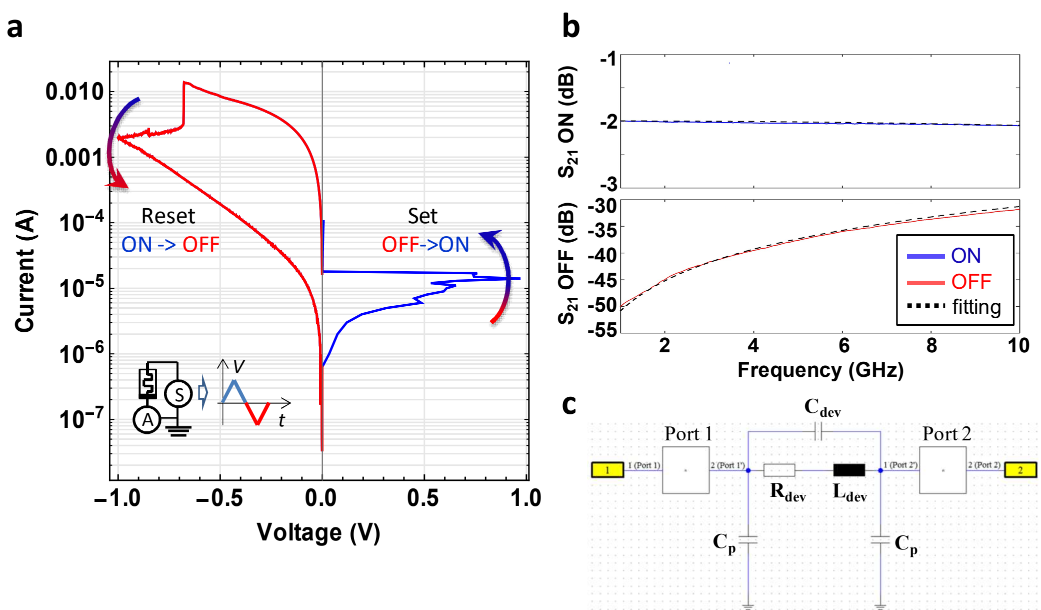

Figure 2: Measurements: (a) quasi-DC characteristics; (b) experimental vs. fitted S_{21}-parameters; (c) RRAM RF switch equivalent model used for simulations.