Effect of RF Substrate Bias on the Switching and Stability of TaOx-Based ReRAM for Analog In-Memory Computing

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Analog in-memory computing (IMC) offers an energy-efficient alternative to von Neumann architecture by performing computations directly within memory arrays [1]. The capability to hold a precise conductance state is critical with minimal noise and drift is critical for accurate analog inference. Because the switching behavior and stability of oxygen-vacancy-driven resistive random-access memory (ReRAM) depends strongly on oxide stoichiometry [2], we examine how RF substrate bias during reactive sputtering tailors the analog switching characteristics of TaOx-based ReRAM. Devices were fabricated by lift-off with the stack Pt (30 nm)/Ta (15 nm)/TaOx (7 nm)/Pt (40 nm). TaOx films were deposited with and without an RF bias, and their compositions were quantified by X-ray photoelectron spectroscopy (XPS). Devices without RF-bias required higher electroforming voltages, whereas RF-biased devices formed at 4–5 V, indicating effective defect engineering. Despite a slightly higher high-resistance state (HRS), RF-biased devices exhibited markedly lower HRS variability across samples (Fig. 1), consistent with the more oxygen-deficient Ta_2O_{5-x} matrix revealed by XPS. In addition to improved forming behavior and reduced device-to-device variability, RF-biased devices also showed superior temporal stability. Both device types supported stable analog conductance modulation in the range of 50 µS to 350 µS, which is critical for accurate analog IMC inference. Notably, both random telegraph noise (RTN) and mean device to device conductance drift and variability following programming was significantly lower in RF-biased devices compared to their non-biased counterparts (Fig. 2). This is consistent with the general observation that RTN is typically lower than device-to-device variability. RF substrate bias increases ion bombardment energy during reactive sputtering, yielding denser and more compositionally uniform TaOx films with higher oxygen vacancy concentrations and modified stoichiometry, thereby suppressing conductive-filament variability. These findings demonstrate that introducing an RF substrate bias is a practical lever for simultaneously reducing electroforming voltage, narrowing device-to-device variability, and mitigating time-dependent drift and RTN, thereby advancing material–device co-optimization for analog IMC applications.

References

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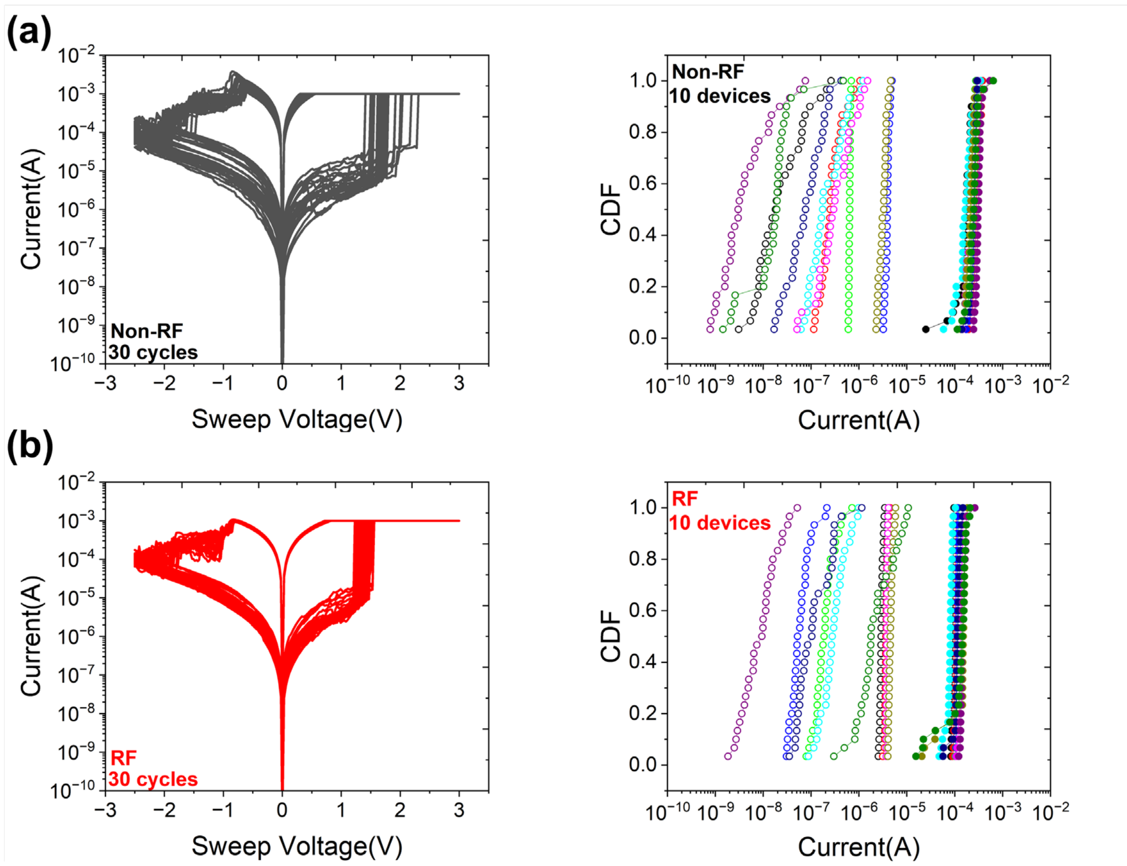

Figure 1. Comparison of electrical switching characteristics and LRS/HRS distribution of ReRAM devices fabricated without(a) and with(b) RF bias.

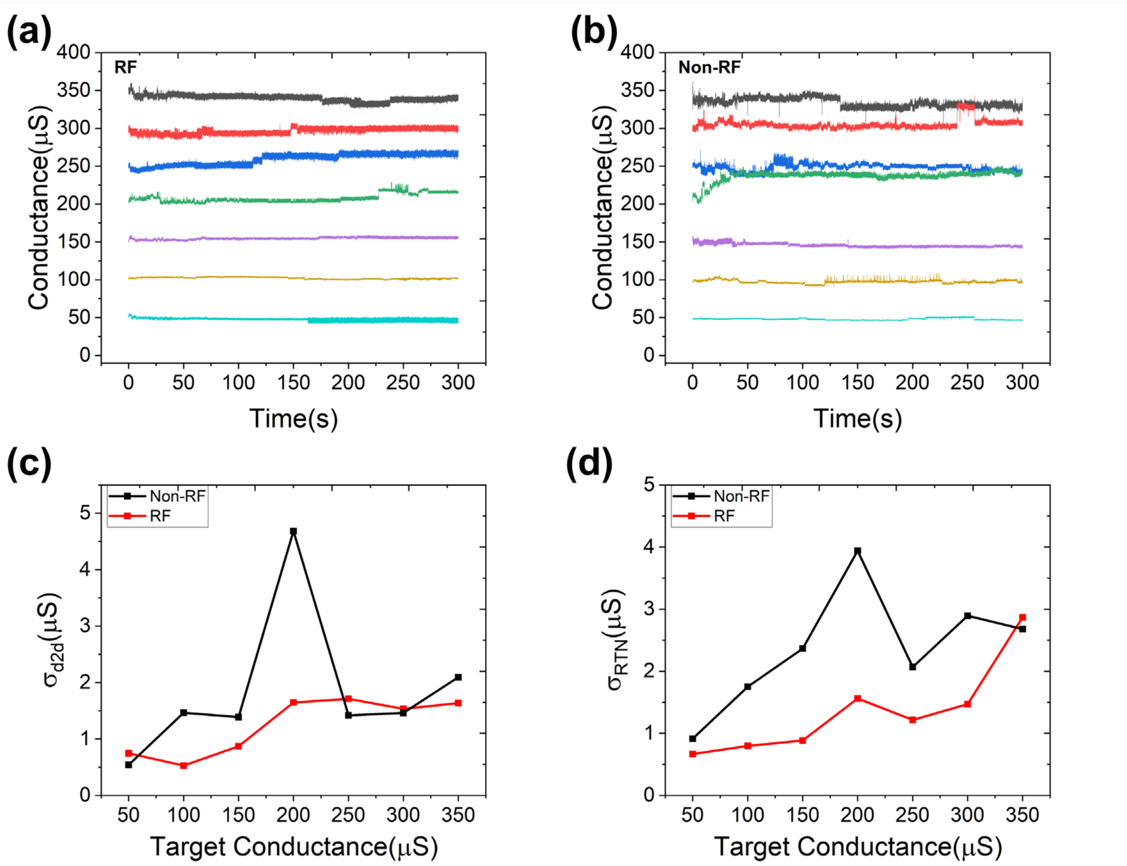

Figure 2. Random telegraph noise (RTN) behavior in ReRAM devices at multiple conductance levels. (a) Non-RF devices (b) RF-bias devices. Device-to device variability of 300s(c) and 1s(d) following programming