Switching noise modelling in RRAM devices

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As all physical systems, resistive random access memory devices (RRAM) are not immune to the random effects of noise. Noise has been researched in the context of resistive memories before[1,2], either in the form of random telegraph noise[3] or as part of bottoms-up physicochemical RRAM models[4,5]. Even when the overall resistive of a device is arguably changing there is a clear uncertainty in between consecutive measurements (fig. 1). However this uncertainty is an *aggregate* of many different sources and there cannot be a distinction between purely random effects and the process of switching itself, what we define as *switching noise*, that manifests during the programming of the device.

In this paper we are quantifying and modelling said switching noise effects in devices. Using alternating programming pulses, similar to our previous work[6], we gather a large dataset above and below the switching threshold so as to construct the *increment plots*. These depict the change in resistance, ΔR under the influence of a voltage pulse of fixed duration and amplitude as a function of the initial resistive state, R. We then present a statistical analysis to estimate the localised uncertainty among consecutive data points using a sliding window of up to N points accounting for any statistical artifacts that arise. By separating the data accumulated during reading and programming and analysing them individually we can substract a baseline noise floor, $B(R,V)$, from the overall uncertainty, $F(R,V)$.

$$N(R,V) = \sqrt{F^2(R,V) - B^2(R,V)}$$

Surface, $N(R,V)$, models the uncertainty of the device during programming and is decoupled from other underlying forms of uncertainty. It can be incorporated readily as an additional component to existing behavioural switching models by drawing from a Gaussian distribution centred at the predicted noiseless ΔR with standard deviation derived from the $N(R,V)$ surface (fig. 2).

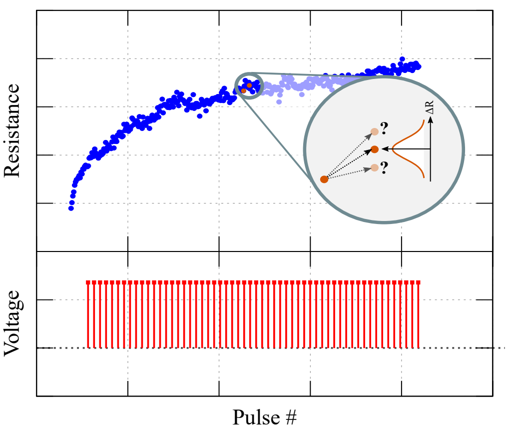

Figure 1 Illustration of the response of an RRAM device under constant bias. Despite the overall increase in the resistive state of the device there is a degree of uncertainty between consecutive points. This is expressed as *switching noise* which is distinct from other underlying forms of uncertainty.

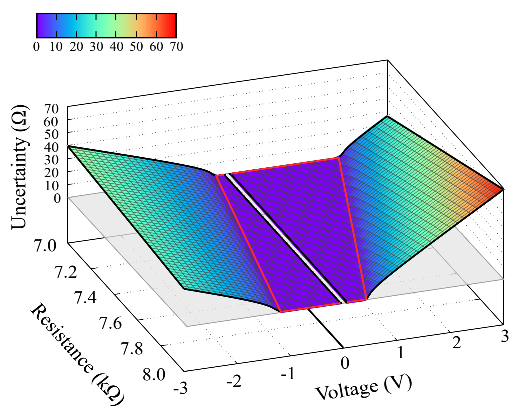

Figure 2 Resistance uncertainty, N, of a $Pt/TiO_2/Al_xO_y/Pt$ device in a first-order approximation as a function of its underlying resistive state and applied stimulus. In the area enclosed by the red line calculated switching noise is below the read-out noise threshold so it is not related directly to switching.

References

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