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On the reliability of Metal Oxide RRAM

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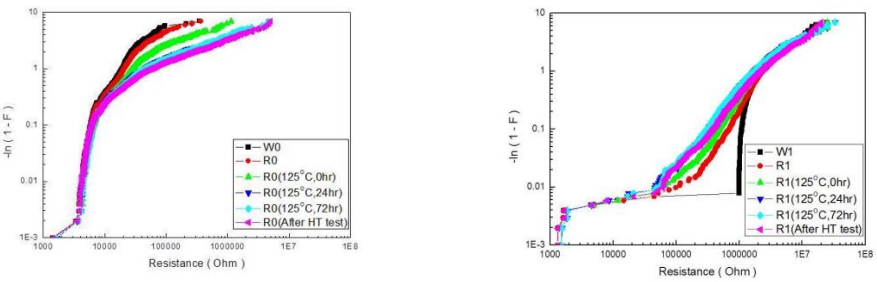
Metal oxide RRAM (Resistive Random Access Memory) has been shown to possess excellent performance and scalability that are suitable for high density and embedded applications [1]. The reliability of the device, especially in the chip array level, has to be satisfactorily demonstrated before it can be put into mass production with 100% yield of the device. However, deriving from oxide breakdown, the stochastic nature of formation and rupture of the conducting oxygen vacancy filament in the RRAM device, which dominates its electrical properties, has inevitably random distribution of resistance of either high or low states over time and cycling. Other than that, the data retention at high temperature has to be verified for extrapolation to 10 years at room temperature as a non-volatile memory should be.

It is found that the low resistance state with low compliance SET current and high resistance state with low RESET voltage are unstable with time. Both can fluctuate in both directions. In another word, in between the stable high and low states, there's a mix of high and low states. This trend of instability is independent of its original state. (Fig. 1) Local diffusion of an individual oxygen ion, either due to structure relaxation, concentration gradient or random vibration, in the vicinity of the filament can contribute to the formation of percolation path, i.e. the oxygen vacancy filament. Compound with the localization and delocalization of electron to the oxygen vacancy (or trapping and de-trapping of charge of the defect), which is the source of RTN (Random Telegraph Noise), the state in this resistance range becomes very unstable. This can also account for RRAM's high speed switching (<1 nsec). Device, process and operational parameters, including stack structure, layer thickness, composition, annealing condition, pulse width, amplitude etc. have been changed to check the effect and all lead to a universal result. The result shows that an upper bound of stable low resistance state which corresponds to resistance of a single complete ballistic conduction path, i.e. ~ 12.9 Kohm. This is also consistent with the result of analytical model in literature [2].

[1] H.Y. Lee et al., "Low Power and High Speed Bipolar Switching with A Thin Reactive Ti Buffer Layer in Robust HfO2 Based RRAM", pp. 297-300, IEDM 2008
[2] S. Ambrogio et al., "Understanding switching variability and random telegraph noise in resistive RAM", pp. 782-785, IEDM 2013



(a) (b)

Fig. 1, Evolution with temperature and time of resistance distribution of LRS (a) and HRS (b) of 1 kb HfOx RRAM