Effects of Al_2O_3 layer addition on retention timescales in $Ag/SiO_x/Pt$ volatile memristors

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Neuromorphic computing, exploiting time as a computational variable, needs the development of devices able to show rich dynamic over multiple timescales to simulate short-term plasticity, long-term plasticity and neuronal functions. Volatile electrochemical metallization (ECM) memristive devices are among the more promising candidates for this role thanks to their complex relaxation dynamics: after the application of a voltage stimulus that causes the transition from a high resistance to a low resistance state, due to the formation of a conductive filament, these devices spontaneously reset in a tunable time interval, called retention time. [1]

Our work investigates complex retention dynamics of $Ag/SiO_x/Pt$ volatile ECM devices emerging from the addition of an Al_2O_3 layer between the Ag active electrode and the SiO_x. We analyzed, thanks to quasi-static electrical characterization, retention properties of devices with two different alumina layer thicknesses (1 nm and 2.5 nm), comparing them to the reference $Ag/SiO_x/Pt$ device. The main effects of the Al_2O_3 layer insertion are shown in figure 1: it increases the retention time of at least one order of magnitude and, furthermore, it induces cumulative effects, producing an additional increase in retention time related to the repetition of set - spontaneous reset cycles. Such accumulation effect is reversible if enough time is left for the device to recover between one cycle and the following. In this work we give a quantitative time-resolved assessment of retention and cumulative – recovery effects, and we correlate these timescales with alumina layer thicknesses and programming conditions. Such complex relaxation dynamics give access to unexplored physics of the devices and can be exploited in neuromorphic applications, to implement time-dependent brain-inspired computation.

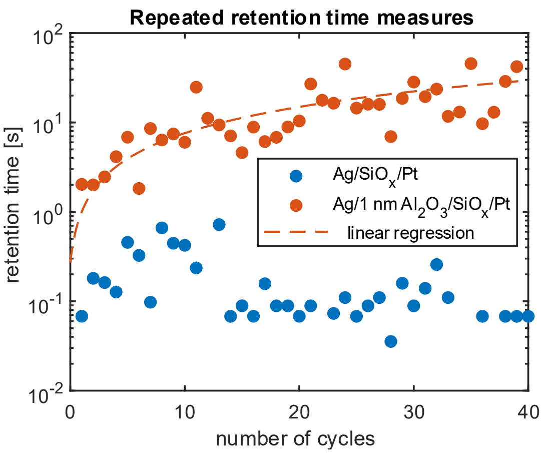

Figure 1: Evolution of retention time as a function of programming cycles composed by a triangular pulse separated by 30 seconds hold time on two different devices (without alumina layer, in blue, and with 1 nm Al_2O_3 layer, in orange). The device with the alumina layer shows longer retention time and cumulative retention.

[1] R. Wang and al., *Adv. Intell. Syst.* Vol. 2, 2000055, 2020