Multiscale Modeling of Memristor Devices for Novel Memory and Logic Architectures

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RRAM devices have been subjected to an intense research effort, and they were proposed for non-volatile memory and neuromorphic applications. In this paper we describe a multiscale modeling platform connecting the microscopic material properties to the RRAM devices. This modeling platform allows self-consistently modeling charge and ion transport and the material structural modifications occurring during RRAM operations and reliability, i.e. conductive filament creation and partial disruption. It allows describing the electrical behavior (current, forming, switching, cycling, reliability tests) of RRAM device in static and transient conditions, and their dependence on external conditions (e.g. temperature). Thanks to the kinetic Monte-Carlo approach, the inherent variability of physical processes is properly accounted for. Simulation results can be used to either investigate material properties (including atomic defect distributions), and optimize stack and bias pulses for optimum device performances and reliability.
Among the wide number of applications that can be potentially targeted, in this presentation we will show how to use this modeling platform to design ReRAM devices and selectors based on binary/ternary oxides (HfO_2, Al_2O_3, TiO_2, ..) and 2D materials (hBN).