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Nanoionic Memristive Switches – From Fundamentals to Applications

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A potential leap beyond the limits of Flash (with respect to write speed, write energies) and DRAM (with respect to scalability, retention times) emerges from nanoionic redox-based switching effects encountered in metal oxides (ReRAM). A range of systems exist in which highly complex ionic transport and redox reactions on the nanoscale provide the essential mechanisms for memristive switching. One class relies on mobile cations which are easily created by electrochemical oxidation of the corresponding electrode metal, transported in the insulating layer, and reduced at the inert counterelectrode (so-called electrochemical metallization memories, ECM, also called CBRAM). Another important class operates through the migration of anions, typically oxygen ions, towards the anode, and the reduction of the cation valences in the cation sublattice locally providing metallic or semiconducting phases (so-called valence change memories, VCM). The electrochemical nature of these memristive effects triggers a bipolar memory operation. In yet another class, the thermochemical effects dominate over the electrochemical effects in metal oxides (so-called thermochemical memories, TCM) which leads to a unipolar switching as known from the phase-change memories. In all systems, the defect structure turned out to be crucial for the switching process. The presentation will cover fundamental principles in terms of microscopic processes, switching kinetics and retention times, and device reliability of bipolar ReRAM variants. Passive memory arrays of ReRAM cells open up the paths towards ultradense and 3-D stackable memory and logic gate arrays.