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Modeling the Operation of Resistive Switching Memory Devices

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Resistance change based nonvolatile memory devices are currently considered as leading candidates for future memory modules. To assess the scalability, retention and endurance properties of these devices, however, a detailed understanding of the underlying resistive switching mechanism is imperative. Filamentary arrangements of oxygen vacancies in transition metal oxides under applied electric field were investigated theoretically and recently detected experimentally. Generally, the process of forming in these systems may include a mechanism by which oxygen vacancies can cluster into filaments and/or the diffusion of oxygen atoms away from the oxide region to form a thin interfacial reduced oxide. During electroforming, oxygen vacancies and/or ions drift due to the applied bias, trap electrons or holes and facilitate the formation of vacancy ordered domains. We review the implications on the electronic structure and energetics of conductive filament channels formation corresponding to the "ON" state and discuss the interplay between the ionic and electronic transport mechanisms. We show that charge trapping effects play a significant role in the switching process under applied electrical field affecting the atomistic pathways of the filament rupturing/dissolution process from the "ON" into the "OFF" state. Furthermore, in order to improve on the device characteristics, favorable effects and "ON"-"OFF" transition process control can be achieved with preferential impurity doping.