Monte Carlo Simulation of Bipolar Resistive Switching Memories

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We have developed a stochastic model of the resistive switching mechanism in resistive random access memory (RRAM) based on electron hopping. A hysteresis cycle of RRAM switching simulated with our stochastic model is in good agreement with experimental results.

We associate the resistive switching behavior in the oxide-based memory with the formation and rupture of a conductive filament (CF). The CF is formed by localized oxygen vacancies (V_o) or domains of V_o. Formation and rupture of a CF is caused by a redox reaction in the oxide layer under a voltage bias. The conduction is due to electron hopping between the V_o vacancies. (Fig.1)
The simulated RRAM switching hysteresis cycle is shown in Fig.1. The cycle is in good agreement with experimental results.
The interpretation of the RRAM hysteresis cycle obtained from the stochastic model is as follows. If a positive voltage is applied, the formation of a CF begins, when the voltage reaches a critical value sufficient to create V_o by moving O^{2-} to an interstitial position. This leads to a sharp increase in the current (Fig.1 Segment 1) signifying a transition to a state with low resistance. When a reverse negative voltage is applied, the current increases linearly (Fig.1 Segment 3), until the applied voltage reaches the value at which annihilation of V_o is triggered by means of moving O^{2-} to V_o. The CF is ruptured and so the current decreases (Fig.1 Segment 4). This is the transition to a state with high resistance.
The proposed stochastic model can be used for performance optimization of RRAM devices by better understanding the resistive switching mechanism.

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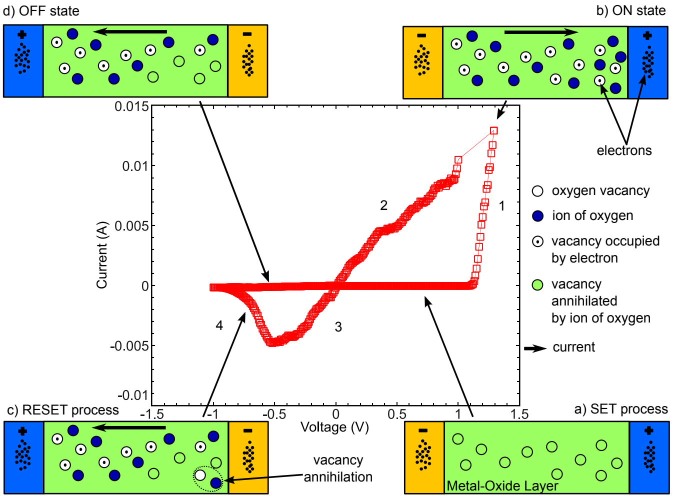

FIG. 1: Hysteresis cycle in RRAM obtained from our stochastic model and illustration of the resistive switching mechanism in bipolar oxide-based memory cell: (a) Schematic illustration of the SET process. (b) Schematic view of the conducting filament in the low resistance state (ON state). (c) Schematic illustration of the RESET process. (d) Schematic view of the conducting filament in the high resistance state (OFF state). Only the oxygen vacancies and ions which impact the resistive switching are shown.