

A Behavioral Model of Unipolar Resistive RAMs and its Application to HSPICE Integration

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Resistive RAMs (ReRAMs), where the resistance is changed by voltage and current biases, have extensively been studied to develop high-speed and large-capacity nonvolatile memories as well as functional nonvolatile memories. ReRAMs are so far intended for use as alternatives to contemporary flash memories, but the applications are not limited to Boolean alternatives. Although physical mechanisms of resistive switching in ReRAMs have not fully been understood, to explore novel computing architectures (e.g., brain-like computers), mathematical or circuit-level ReRAM models based on behavioral characteristics of ReRAMs have to be developed in advance. Behavioral mathematical models of “bipolar” ReRAMs (memristors) have already been proposed in the literature, and have widely been accepted by many researchers (e.g., [1]-[4]). For “unipolar” ReRAMs, a behavioral circuit model has been proposed for a popular circuit simulator (HSPICE) [5]. The model showed good agreement with experimental results of transient ON/OFF switching characteristics. Although practical unipolar ReRAMs exhibit innegligible dependence of the compliance currents on the resistance and the threshold values (e.g., [6]), the ON resistance and OFF threshold current in the model were fixed, and were independent of the compliance current. Furthermore, the model consisted of many nonlinear circuit elements; i.e., an RS flipflop for ON/OFF storage, six transfer gates for ON/OFF switching, two operational amplifiers (comparators), etc., which may prevent us from very-large-scale circuit-level simulations. It was also very hard to transfer the model in numerical simulators (MATLAB, etc.) due to the lack of explicit definition of the model dynamics.

We here propose a behavioral mathematical model of “unipolar” ReRAMs which has compliance-current dependence of the ON resistance and OFF threshold current. The model is described by three simple dynamics which can easily be integrated in any numerical or circuit simulator. As an example, we integrate the model on HSPICE, and show the simulated results using experimental parameters extracted from fabricated ReRAMs of TiO₂ thin films.

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