A Kinetic Monte Carlo Study of the Scalability and Variability of the Forming Voltage of Transition Metal Oxide ReRAMs

Balasingam, Namrata

I developed a fast kinetic Monte Carlo (kMC) simulator and applied it to a study of the geometrical scaling and statistical properties of resistive random access memories (ReRAMs). These devices are under intense investigation because they are promising alternatives to flash-based nonvolatile memories, which are not expected to scale to dimensions below ~20nm. "Forming" is performed just after manufacturing to functionalize the ReRAM by creating a conductive filament whose resistance is then modulated to encode "0" or "1" memory states. Since forming is a one-time process and since the underlying physics is stochastic in nature, statistically meaningful experimental characterizations of filament formation are difficult to perform and are not available. I addressed this problem by developing a simulator that captures the unique physics of ReRAMs: strongly coupled ionic and electronic transport. I treat the electronic effects using equivalent resistor networks, and oxygen vacancy/ion effects using kMC. The distribution of vacancies determines the linear/nonlinear elements of the resistor network, and the heat generated by electron flow in this network determines the vacancy/ion generation rates in kMC. Using this simulator, I found that the critical voltage V_f at which the filament forms depends roughly linearly on device thickness and logarithmically on device width. I motivate the thickness dependence using an effective field argument, and then offer a plausible statistical argument to explain the width dependence. I also investigated the effects of (a) external temperature, (b) voltage ramp rate and (c) maximum current at forming on V_f and its variability.

Awards Won:

Second Award of $2,000