MAR13-2012-020592

Abstract for an Invited Paper
for the MAR13 Meeting of
the American Physical Society

Nanoionic switching in metal oxide nanostructures

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Ion migration in oxide nanostructures is a key process in information storage technologies, where the logic data are stored as nanoscale conductive filaments [1]. Due to the inherently nanoscale size of the ionic switching location (few cubic nanometers), the local electric field and current density induce extremely high temperatures as a result of Joule heating [2,3]. To develop and design advanced nanoionic materials and devices with improved performance and reliability, the ion migration phenomena in metal oxides must be carefully understood and modeled. This talk will address the modeling of ionic migration and the consequent switching in HfO_x layers of RRAM devices [4]. The model solves drift/diffusion equations for thermally-activated hopping of positive ion, such as oxygen vacancies (V_O^+) and metal cations (Hf^+), in presence of intense Joule heating and electric field. The impact of the ion distribution on the local conductivity is described physics-based models of defect-assisted electronic conduction in semiconductors [5,6]. Microscopic parameters, such as the energy barrier for ion hopping, are directly inferred from the experimental switching kinetics at variable voltages. The simulation results picture the filament growth/depletion with time and account for the observed switching characteristics, such as the progressive opening of a depleted gap and the possibility of electrode-to-electrode migration of ions. Finally, new phenomena, such as switching variability at atomic-size filaments and stress-induced symmetric switching, will be discussed.

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