Abstract #802, 223rd ECS Meeting, © 2013 The Electrochemical Society

Resistive switching in silicon oxide containing silicon nanoinclusions

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We review our recent results demonstrating resistive switching in silicon-rich silica. Simple MOS devices containing 30-40nm-thick layers of silicon-rich silica (SiO_x) exhibit resistance changes of up to five orders of magnitude under the application of appropriate electric fields. The switching is reproducible – we demonstrate several thousand cycles – and the two resistance states are indefinitely stable. Importantly, switching is filamentary and intrinsic to the oxide layer, allowing operation in ambient conditions. Such devices thus have great potential as non-volatile memory (NVM) elements.

Both unipolar and bipolar switching can be seen in our devices. In the former, field-driven formation of conductive filaments within the SiO_x is followed, at higher fields, by dissolution of the filaments by Joule heating. In the latter case, field alone drives the formation and dissolution of filaments by controlling the migration of oxygen vacancies within the oxide matrix.

Atomic Force Microscopy (AFM) and Scanning Tunneling Microscopy (STM) results indicate that the SiO_x layers, grown by sputtering, have a columnar structure in which excess silicon aggregates around the column boundaries. We hypothesise that switching occurs at these sites. Columns are typically of the order of 10s of nanometers or less in diameter, suggesting the possibility of aggressive scaling of NVM elements to the 10nm technology node and beyond.

The use of SiO_x as the switching layer in our devices has important consequences, from ease of integration with CMOS fabrication processes, to an intrinsically nonlinear ON state. The latter enables the use of SiOx resistive switches as both memory and selector elements, overcoming one of the major bottlenecks in the development of realistic arrays of NVM elements in Resistive RAM (RRAM) devices.

Recent results indicate the presence of quantized conductance steps in the current-voltage characteristics of our devices. This suggests ballistic electron transport in atomic point contacts at the point of filament formation and rupture.