Ion-beam synthesis of transition-metal oxide/suboxide heterostructures for non-volatile memory applications

R.G. Elliman[1], D.K. Venkatachalam[1], X. Liu[1], S. Li[1], S.K. Nandi[1,3,4], K. Belay[1], P. Grande[1,2], M. Vos[2], S. Ruffell[5] and J. England[5]

[1] *Department of Electronic Materials Engineering, Research School of Physics and Engineering, The Australian National University, Canberra, ACT 0200, Australia.*
[2] *Atomic and Molecular Physics Laboratory, Research School of Physics and Engineering, The Australian National University, ACT-0200, Australia*
[3] *Research School of Astronomy and Astrophysics, The Australian National University, ACT 0200, Australia*
[4] *Department of Physics, The University of Chittagong, Chittagong-4331, Bangladesh*
[5] *Varian Semiconductor Equipment, Silicon Systems Group, Applied Materials Inc., USA*

As thin films, transition-metal oxides (TMOs) can be subjected to high electric fields and exhibit characteristic resistance changes that are of interest for future non-volatile memory applications, such as resistance random access memory (ReRAM). The resistance changes in a ReRAM are sensitive to film stoichiometry and can often be better controlled by using stoichiometric (oxide)/sub-stoichiometric (suboxide) heterostructures. In this study, we show that ion-implantation provides an effective means of fabricating such heterostructures at room temperature, and that these exhibit resistance changes that are suitable for ReRAM applications.

Specifically, oxide/suboxide heterostructures are fabricated by oxygen implantation of Ta, Hf and Nb films using either directed beam implantation or plasma-immersion implantation. Detailed compositional, structural and electrical characterisation is reported, including analysis using a newly developed electron backscattering technique that is analogous to Rutherford backscattering spectrometry (e-RBS). The e-RBS technique provides important insight into the electronic structure of the films and shows that ion-beam synthesised films are indistinguishable from their bulk counterparts, despite being formed at room temperature. Standard electrical characterisation of ion-beam synthesised ReRAM devices show sub-100ns switching speeds with switching currents <100μA, and endurance $>10^6$ cycles for particular structures.

Oxide/suboxide composition profiles are compared with predictions from the dynamic Monte Carlo simulator, TriDyn, and electrical characteristics are compared with finite elements models based on defect drift and diffusion.