# The Room-Temperature Synthesis of $HfO_2/HfO_x$ Heterostructures by Ion-Implantation

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Implantation of Hf films at room temperature with 3 keV oxygen ions is shown to produce $HfO_2/HfO_x$ heterostructures suitable for resistive switching applications [1]. The resulting films are characterised by transmission electron microscopy (TEM), glancing incidence x-ray diffraction (GIXRD), electron Rutherford backscattering spectrometry (e-RBS), reflection electron energy loss spectroscopy (REELS) and x-ray photoelectron spectroscopy (XPS).

Resistive switching characteristics of the films are compared with those of films grown by ALD at 200ºC. Analysis shows that irradiation to a fluence of $1x10^{17}$ $O.cm^{-2}$ is sufficient to produce a polycrystalline (monoclinic $HfO_2$) $HfO_2$ layer extending from the surface to a depth of ~12 nm, and an underlying graded $HfO_x$ layer extending an additional ~7 nm. The bandgap, dielectric strength and resistive switching characteristics of the films are shown to be indistinguishable from those of amorphous films deposited by atomic layer deposition (ALD) at 200 ºC. These results demonstrate the efficacy of ion-implantation for low-temperature synthesis of functional oxide layers.

[1]. Nandi, S.K., et al., *Room Temperature Synthesised $HfO_2/HfO_x$ Heterostructures by Ion-implantation.* Nanotechnology, **29**(42): p. 425601 (2018).