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In-vacuo growth studies and thermal oxidation of ZrO_2 thin films

ZrO_2 thin films might be used as capping layers for protecting extreme ultraviolet (EUV) optics against oxidation and other chemical degradation processes. These coatings should be homogeneous and form a closed layer, not degrade the underneath barrier/mirror, and have a thickness in the nanometre range to keep good reflection properties of the mirror. The initial growth of ZrO_2 films by reactive magnetron sputtering on top of amorphous Si was monitored by *in vacuo* low-energy ion scattering (LEIS). With this technique, the atomic composition of the outermost atomic layer of a surface can be probed. By monitoring for which deposited amount of ZrO_2 the signal from the underlying Si vanishes, the ZrO_2 thickness required for forming a closed layer was determined. In this way, LEIS was employed to study how deposition parameters influence the sharpness of the interface between the cap layer and Si. *In-vacuo* X-ray photoelectron spectroscopy (XPS) was used to find the optimal deposition conditions and the stoichiometry of the produced layers. Depending on deposition conditions, a fully closed layer can be formed with a deposited ZrO_2 thickness of 1.7 nm. Passivation of the Si underlayer by nitrogen or oxygen was found to have no influence on the sharpness of the interface with the ZrO_2 cap. Based on the smoothness of the as deposited layers, as probed by AFM analysis, it was concluded that intermixing, rather than island formation, is limiting the sharpness of the ZrO_2/Si interface. Finally, XPS was used *ex-situ* for probing oxygen diffusion through the capping layer after thermal oxidation in ambient. A 2 nm ZrO_2 cap on top of Si showed further intermixing up to 400 °C, without increase of the oxidation of the underlying Si. For higher temperatures, the cap does not block oxygen diffusion, resulting in further oxidation of the Si layer.

(Abstract PXNMRS 2016, University of Twente)