Materials 1 – Update on coating loss and structural measurements at Glasgow and Jena

M. Abernathy[1], I. Martin[1], R. Bassiri[1], K. Evans[1], G. Hofmann[2], J. Hough[1], J. Komma[2], I. MacLaren[1], P. Murray, R. Nawrodt[2], S. Reid[1], S. Rowan[1], J. Scott, C. Schwarz[2]

[1] SUPA, University of Glasgow

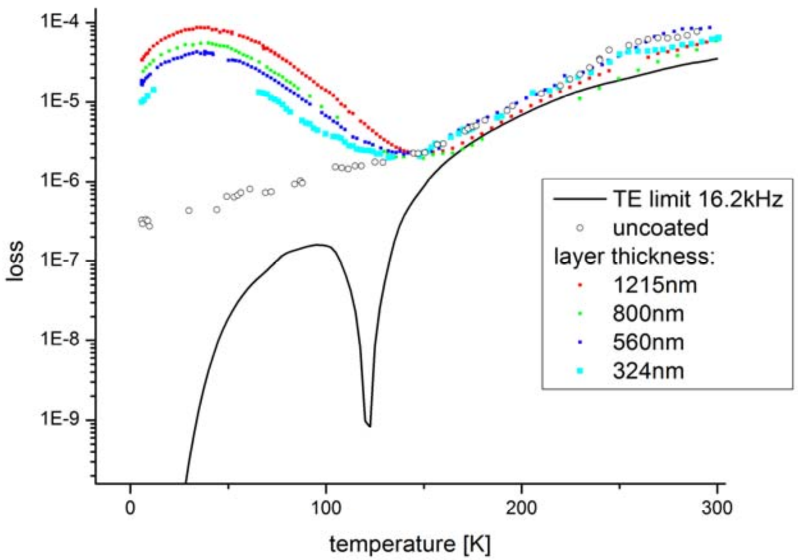
[2] University of Jena

26th May 2011, Gravitational Waves Advanced Detectors Workshop, Elba

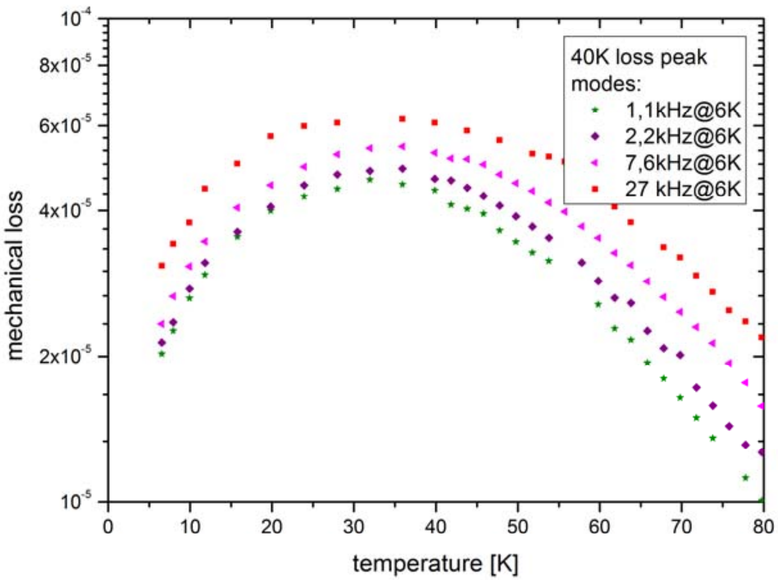
University of Glasgow

Investigation of the thickness dependence of loss parameters of thermal oxide [collab. Jena University, Glasgow University]

- systematic study of loss parameters in thermal oxide (as test material with higher losses)
- measurement of mechanical loss of oxidised Si-cantilevers
- oxide etched off and cantilever reoxidised → several oxide thicknesses investigated



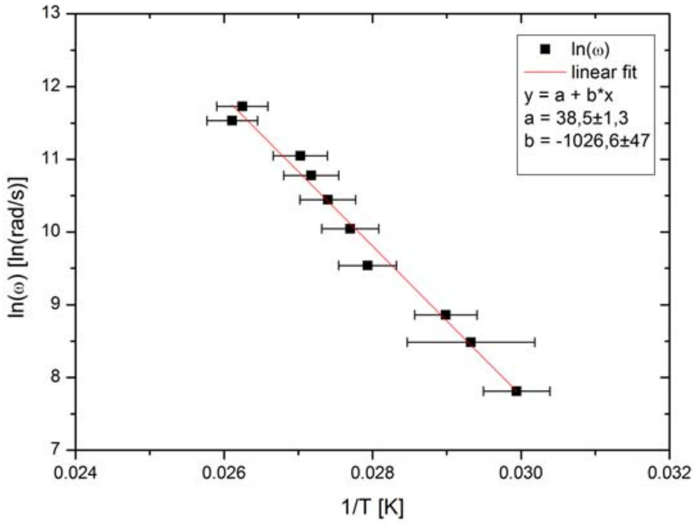
typical set of data



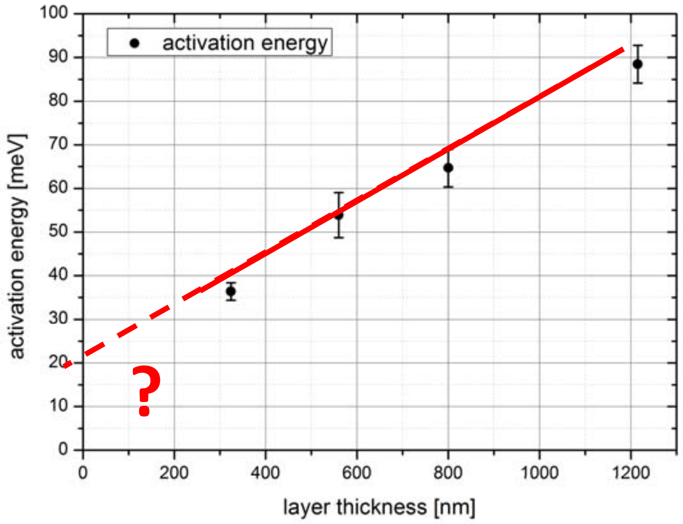
frequency dependence indicates thermally activated process

Investigation of the thickness dependence of loss parameters of thermal oxide [collab. Jena University, Glasgow University]

• loss process parameters from Arrhenius plot



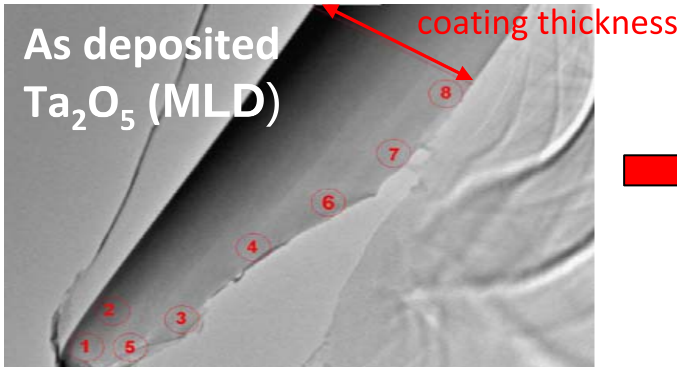
Extraction of loss parameters from an Arrhenius plot for one thickness



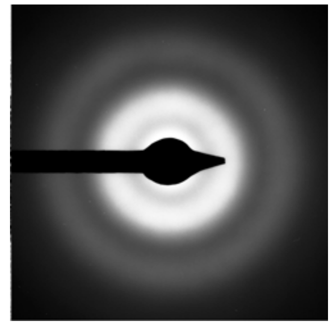
Thickness dependence of the activation energy of thermal oxide of different thicknesses

• further investigation needed (origin of dependence: chemistry of layer? interface?)

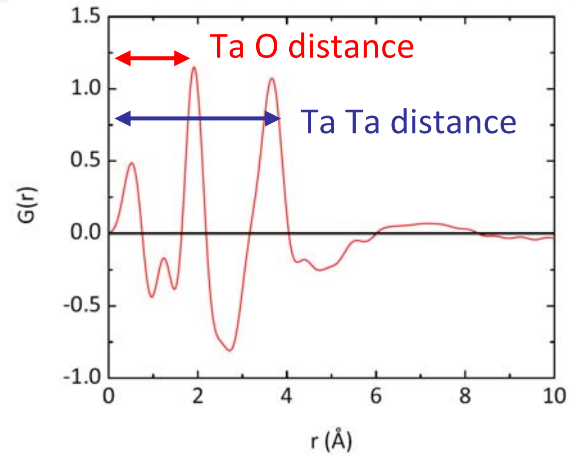
Investigation of variations of coating atomic structure throughout the thickness of a tantala film



Measurement locations

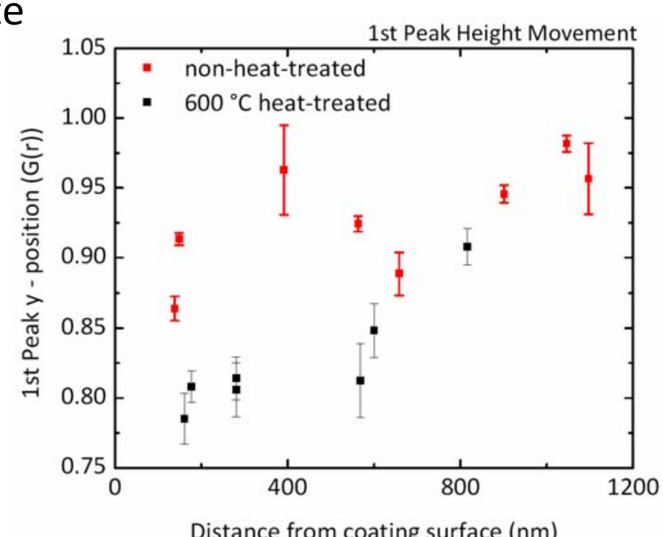


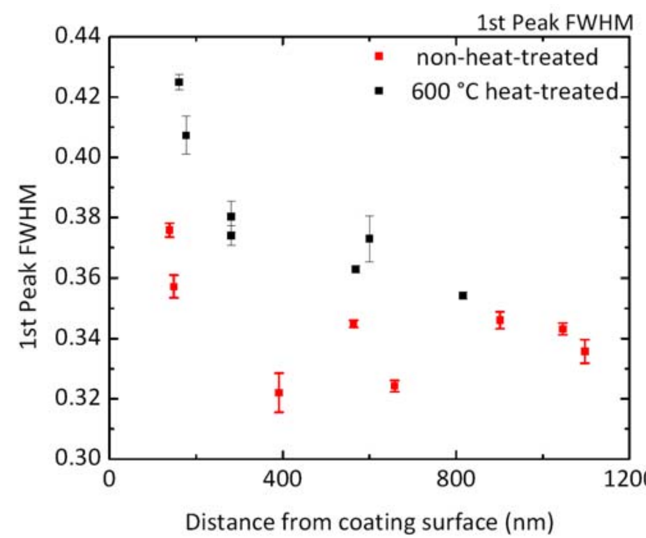
Azimuthal averaging of electron diffraction pattern



Typical RDF

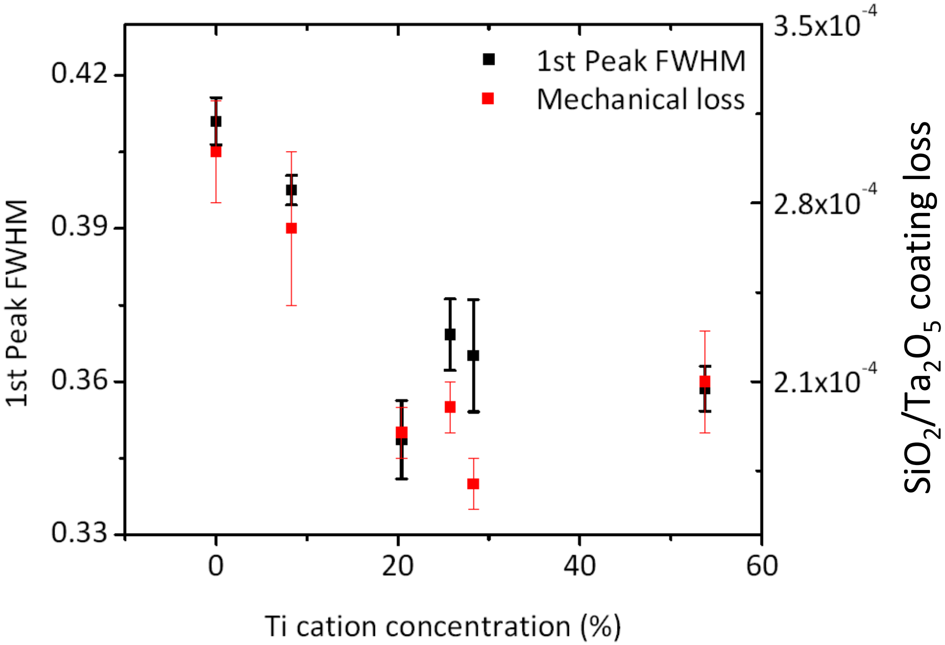
Preliminary Reduced Density Function analysis of electron diffraction measurements from different depths in the coating layer indicate that the atomic structure may vary throughout the thickness of the coating, with the structure tending to become more ordered close to the substrate





Effect of Ti doping on loss and structure of Ta_2O_5

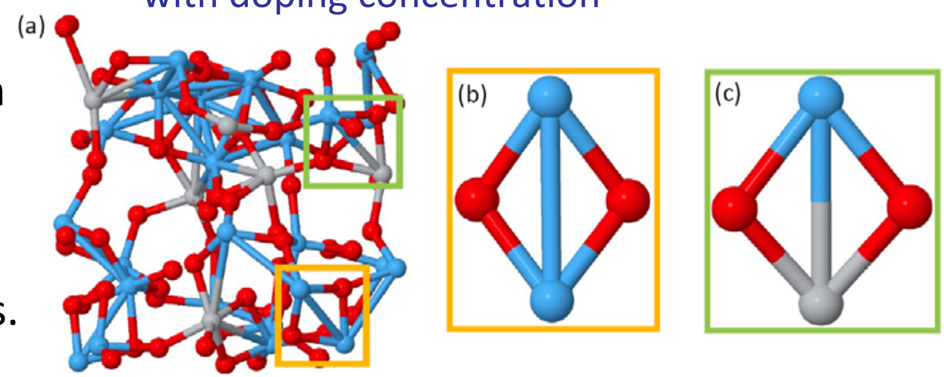
- TiO_2 doping of Ta_2O_5 has been shown to reduce loss of SiO_2/Ta_2O_5 coatings
- RDF analysis suggests correlations between TiO_2 doping concentration, atomic structure and mechanical loss
- Ongoing work to use RDF data, along with molecular dynamics and Reverse Monte Carlo modelling, to model the coating structures
- Ring structures (building blocks of crystalline Ta_2O_5), have been identified in the modelled amorphous structure



Variation of loss and 1st RDF peak FWHM with doping concentration

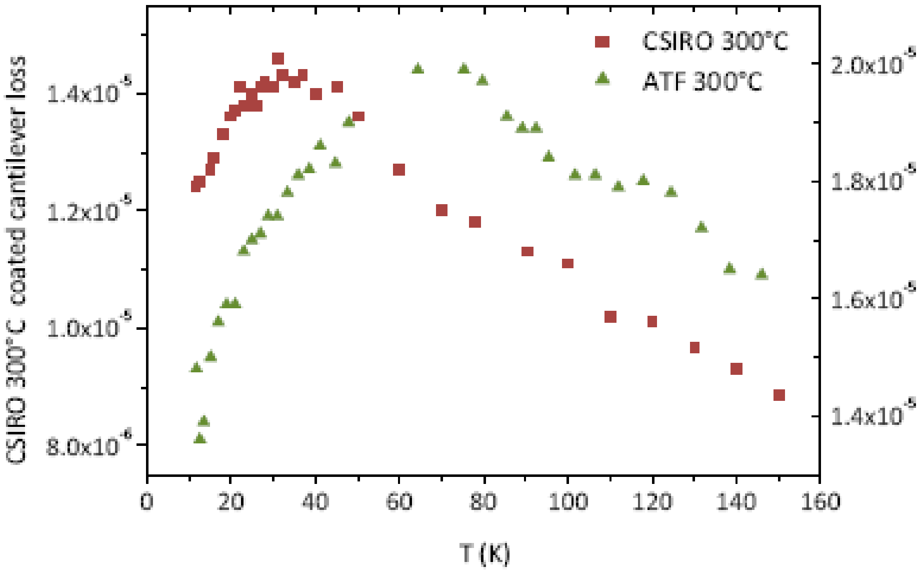
Strong evidence that **loss is correlated with local atomic structure** and that **structure varies throughout the coating thickness**.

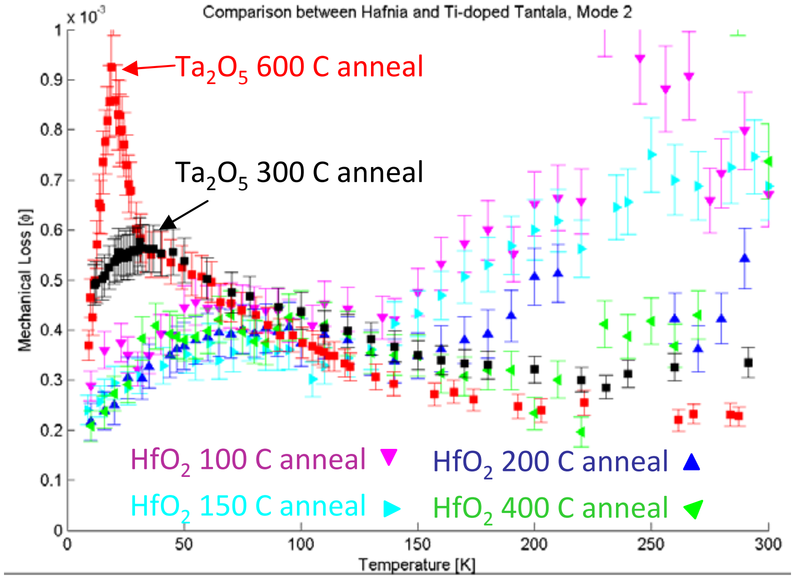
This possibly explains the observed change in activation energy and loss in thicker films. **Layer thickness is thus an important parameter in understanding coating loss**



Example model of 20% Ti-doped Ta_2O_5 (a), highlighting ring structures of Ta_2O_2 (b) and $TaTiO_2$ (c).

Coating mechanical loss measurements

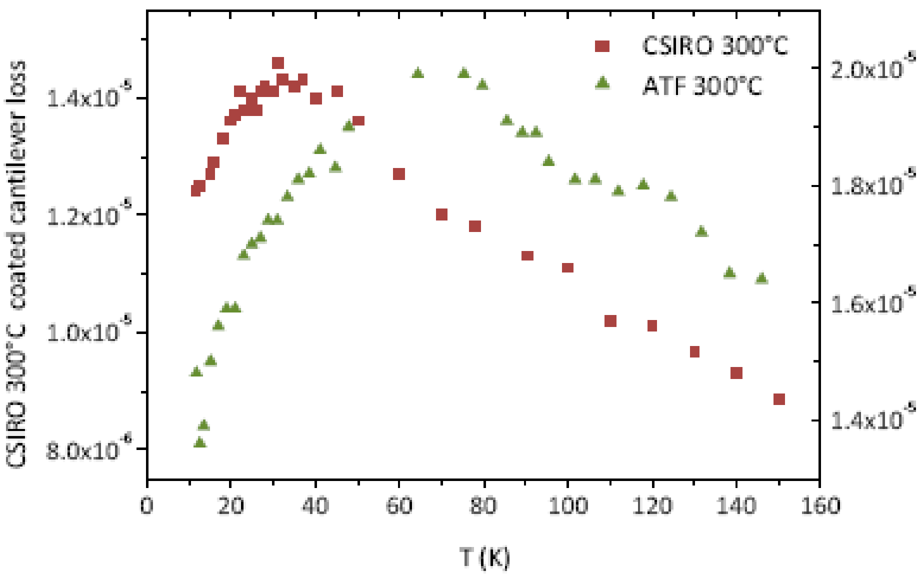


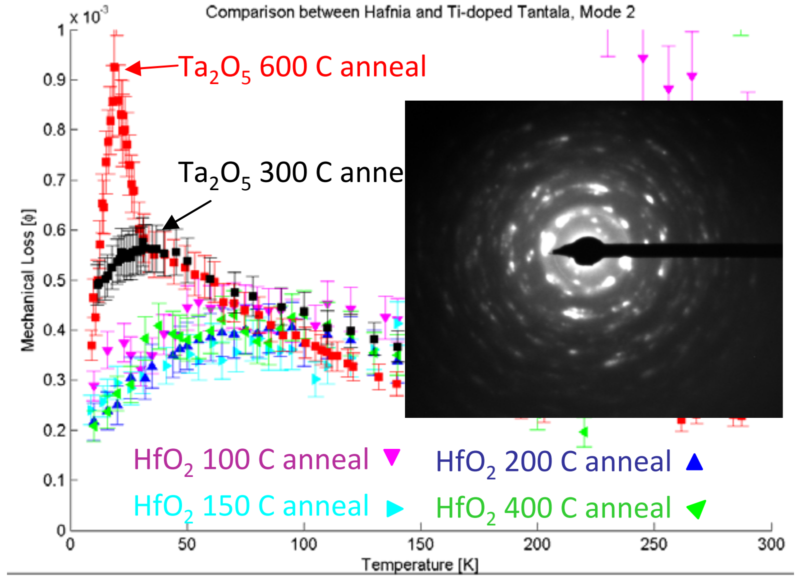


- Effect of deposition processes on Ta_2O_5 loss (left)
  - "low water content" tantala from ATF shows substantially different low temperature loss peaks to those observed in tantala from other vendors

- Hafnia coatings (right)
  - show lower loss than tantala below ~100 K, even though they are in a partially crystalline state
  - amorphous hafnia (achieved e.g. through doping with silica) may be of significant interest as a low-temperature coating

Coating mechanical loss measurements





- Effect of deposition processes on Ta_2O_5 loss (left)
  - "low water content" tantala from ATF shows substantially different low temperature loss peaks to those observed in tantala from other vendors
- Hafnia coatings (right)
  - show lower loss than tantala below ~100 K, even though they are in a partially crystalline state
  - amorphous hafnia (achieved e.g. through doping with silica) may be of significant interest as a low-temperature coating