

Multi Layer and Micro Graded Stress Analysis

Richard Langford, Xiaofeng Zhou, Christopher Gill, Joe
Keller, Toby Ayers, Philip Withers

Materials Science Centre, Manchester University, UK

Aims

- To develop a method to measure stress through coatings and layers
- Site specific analysis in sub micron areas, e.g. in grains with different orientations

Slit method - N. Sabate, D. Vogel, A.Gollhart, J. Keller, and B. Michel. Applied Physics Letters 88,071910 (2006)

Slit Milling Method

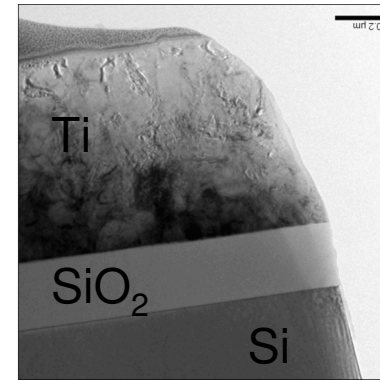
- Mill a slit and use image correlation to determine the relaxation of the material around the slit.

Cantilever Method

- Prepare a slice from the material using the lift-out method and then cut a cantilever from the slice and measure the deflection.

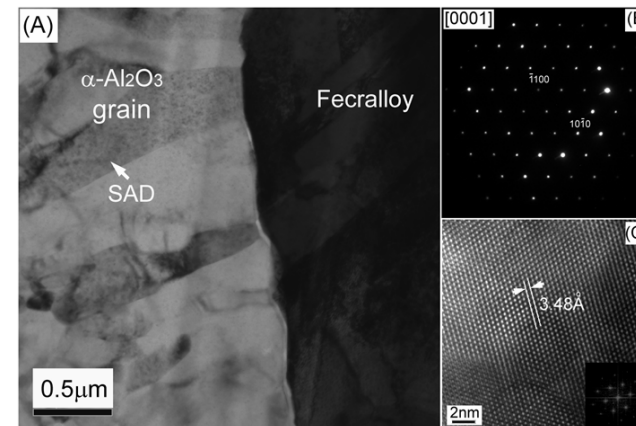
- Two samples

- 800 nm thick sputtered Ti layer on 300 nm SiO₂ (thermally grown) on 100 Si wafers



- FeCr alloy

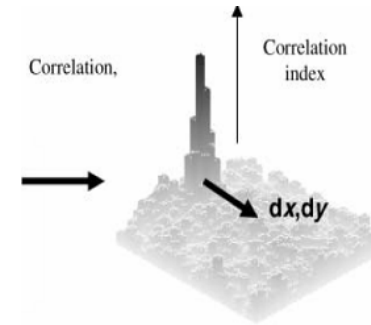
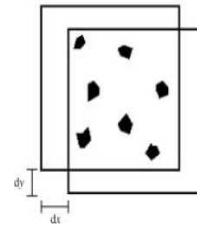
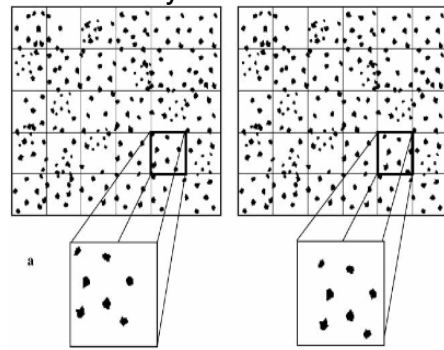
- (Fe72.8, Cr22, Al5, Yt0.1 and Zr 0.1 wt%).
 - Oxidised - 1200°C for 4 hrs, heating and cooling rate 3°C min⁻¹
 - Stress within the Fecralloy – 200 GPa
 - Stress within the oxide - 400 GPa



Al₂O₃ - Band of equiaxial grains on top of a band of columnar grains

Image Correlation and Imaging Artifacts

- Da Vis software – La Vision
 - Sub pixel accuracy



- Scanning artifacts
 - elongation, rotation
 - Series of tests so we can identify these effects
 - charging
 - sudden changes in shift vectors
 - stage drifts
 - image shifts on changing between beams
 - changes in the charging conditions
- What is the noise tolerance on image correlation when using real time imaging?

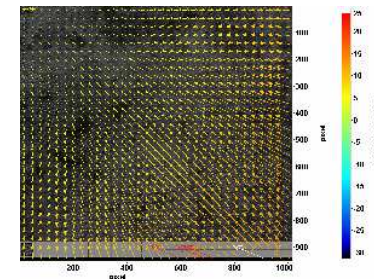


Image stretching

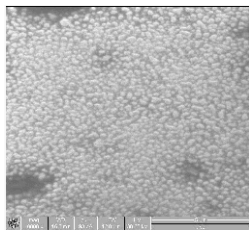
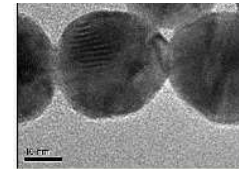


Image charging

Software can correct for shift, rotation, pin cushion effects

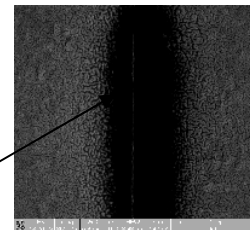
Image correlation

- Require surface features/textures for the image correlation
 - Pt deposits - too low a density smallest sizes 30 to 50 nm
 - Ok for few point measurements
 - Nanoparticles
 - Decoration over a large area
 - Evaporated Au - easily sputtered by the beams tails
 - provides good decoration
 - Natural surface texture

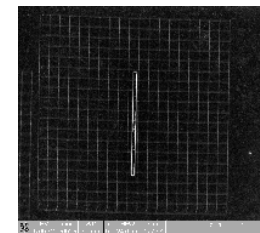


Particles

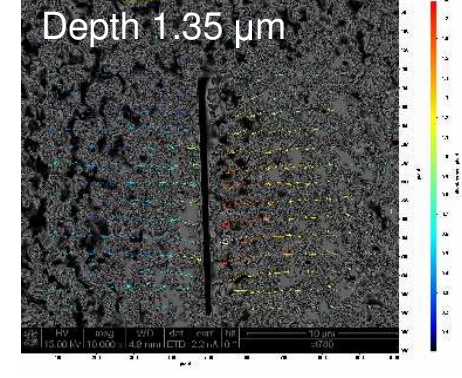
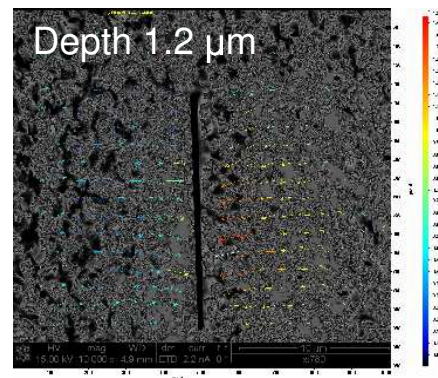
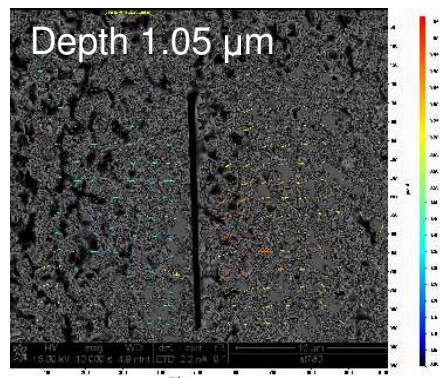
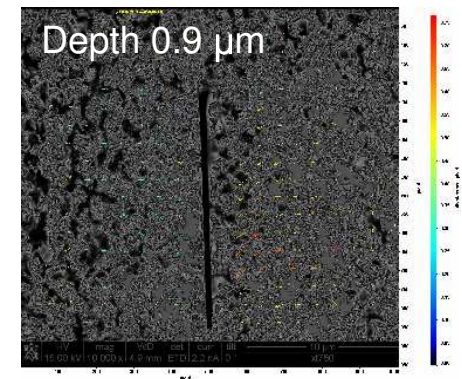
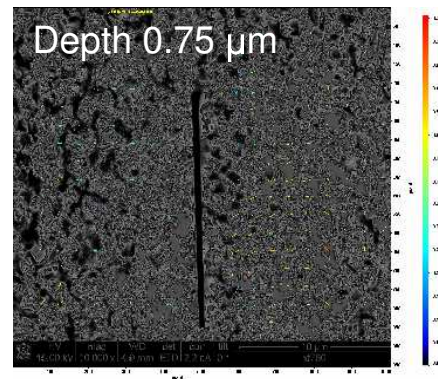
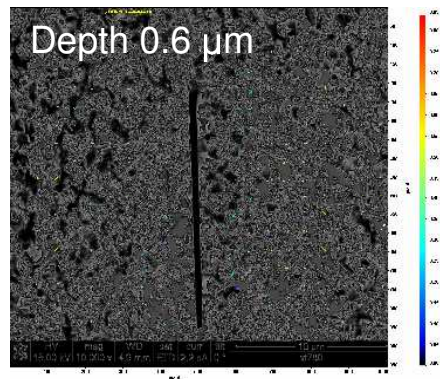
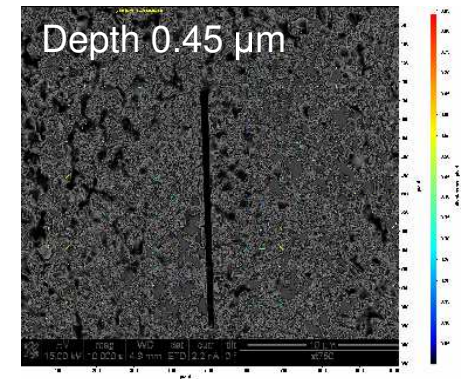
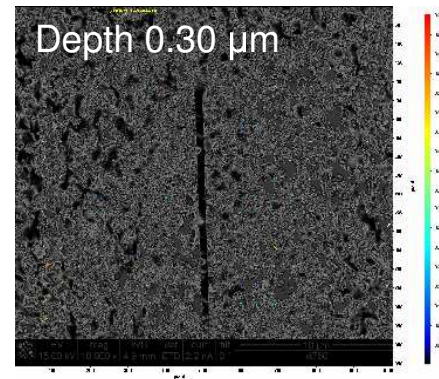
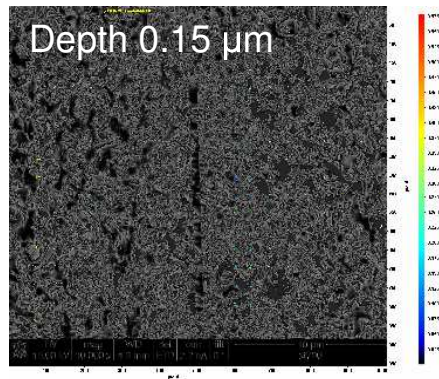
Lost info hundreds of nm from cut edge



Au

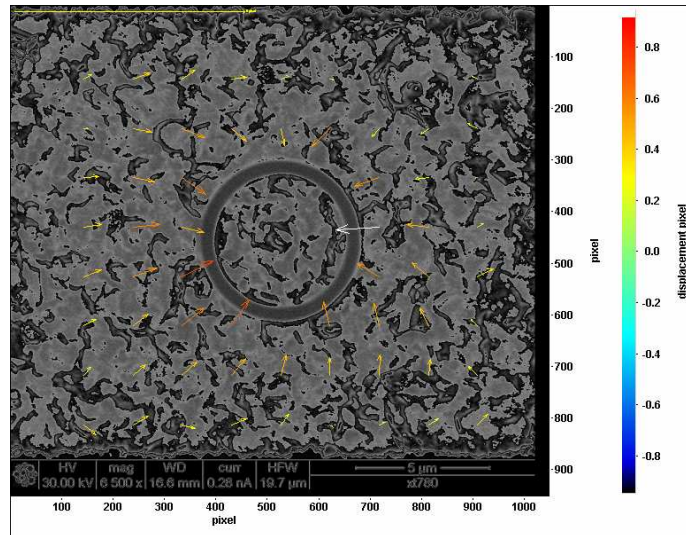


Pt grid

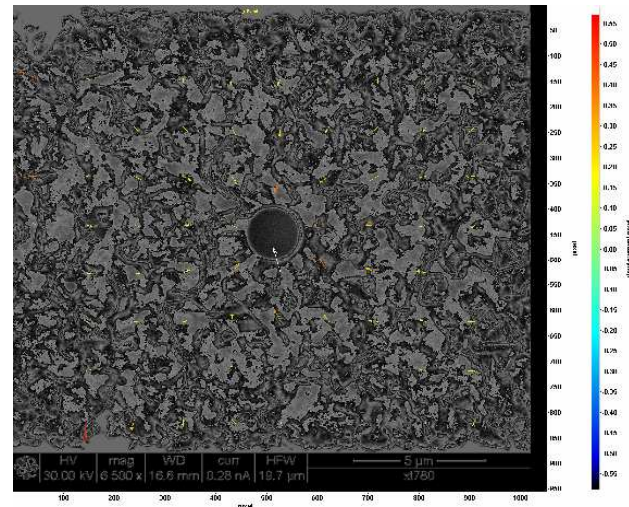


FeCr alloy, slot 10 μm \times 0.5 μm , depth 1.4 μm

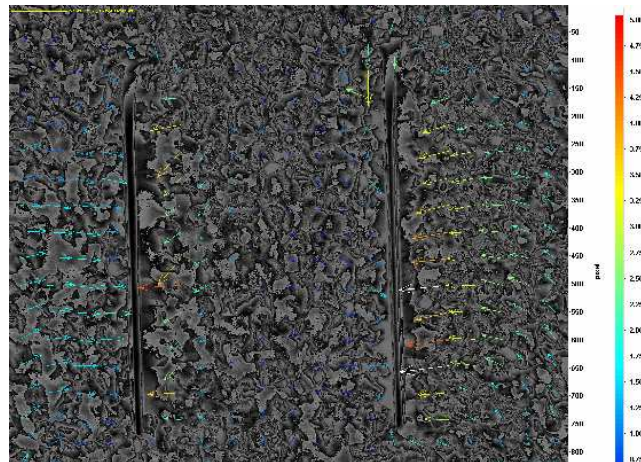
Core



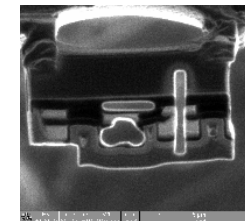
Hole



- Currently addressing
 - Minimum sizes
 - TEM specimens?

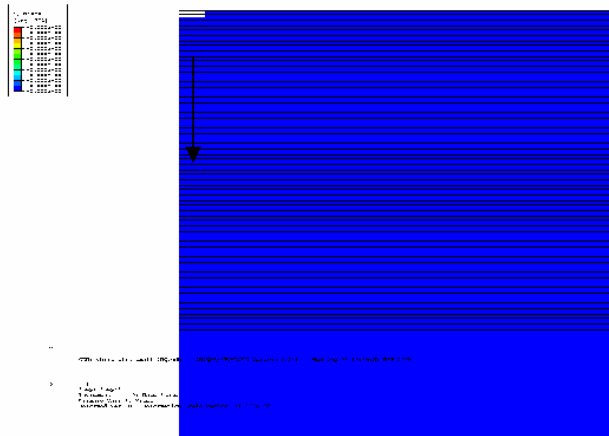


Double slot



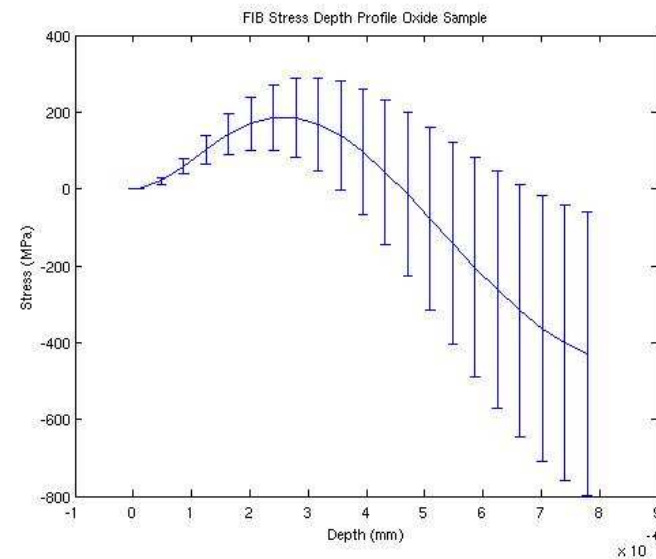
Calculating stress through the layers

Preliminary results



Assumed a slot of uniform width with depth. Need to change the model to account for tapering

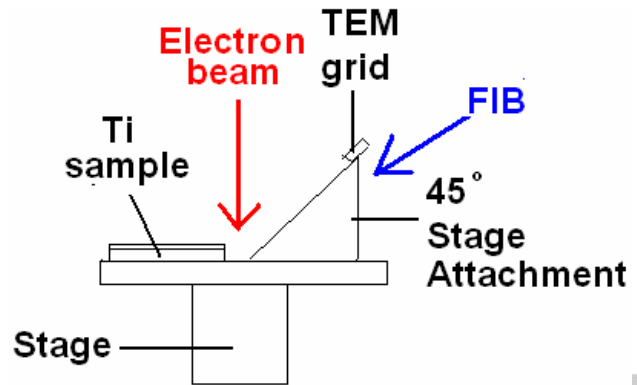
FE modelling of the sequential milling



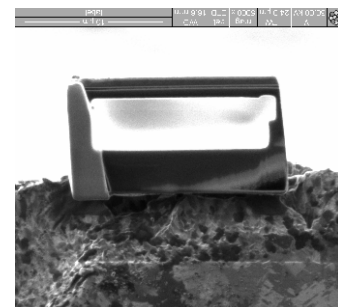
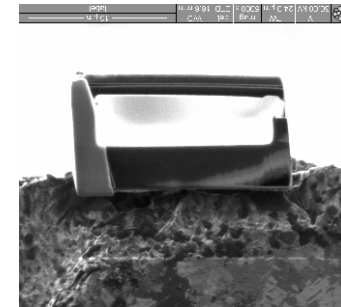
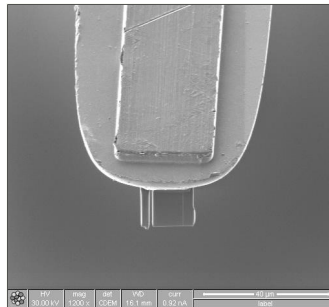
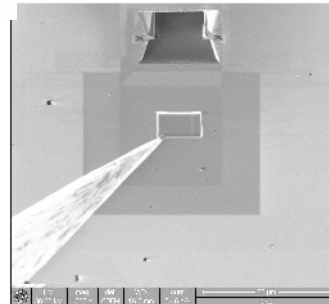
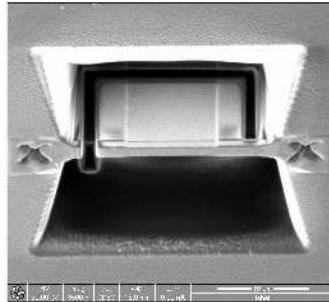
Analysis of an early data set

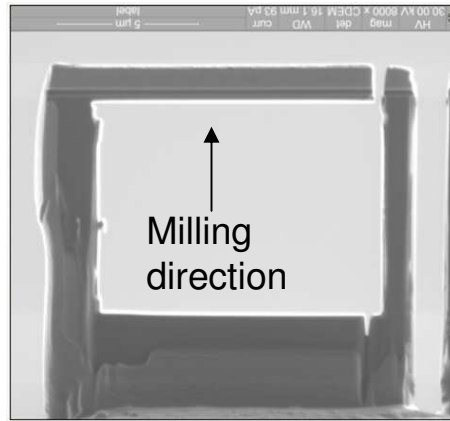
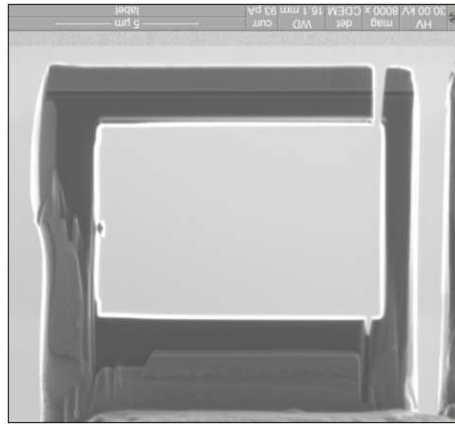
Now we can repeatedly collect the data we are in the process of analysis it

Cantilever Method



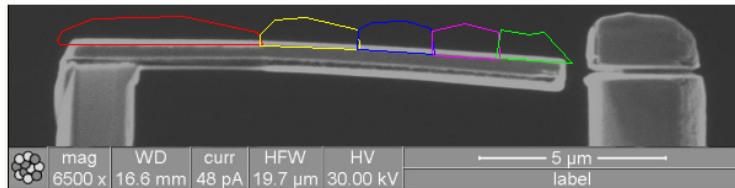
Modified Stoney's equation for the analysis
Milling away different layers





ImageJ for edge analysis

Pixel movements

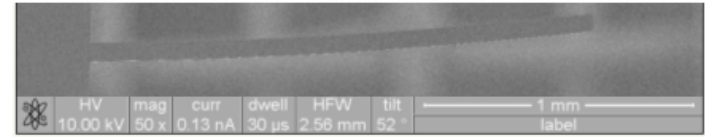


Cannot use line milling as cantilever relaxes.

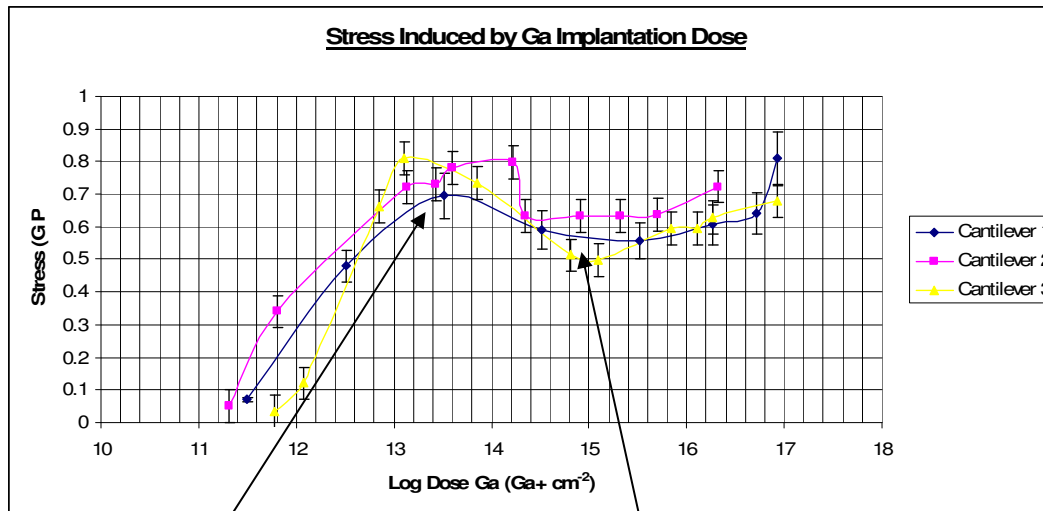
Short mills – repositioning lines along length of cantilever

Currently analysing data

Stress in Si due to Ga implantation

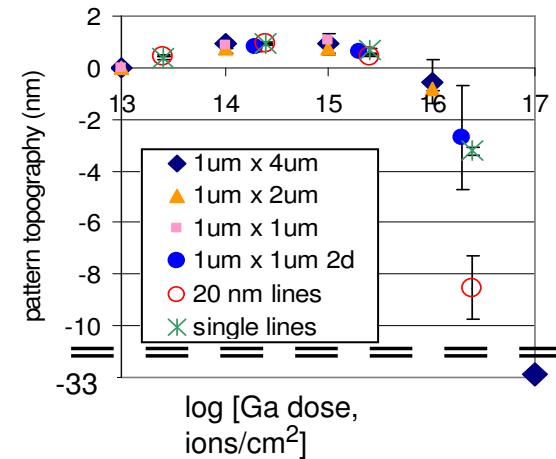


Micro-machined a series of cantilevers
 Implanted Ga and measured the deflection



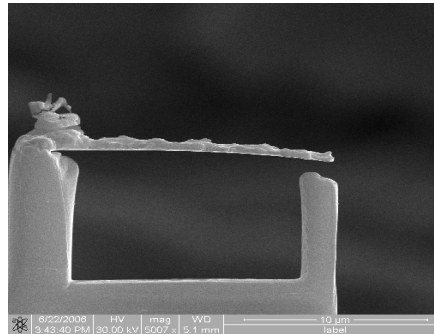
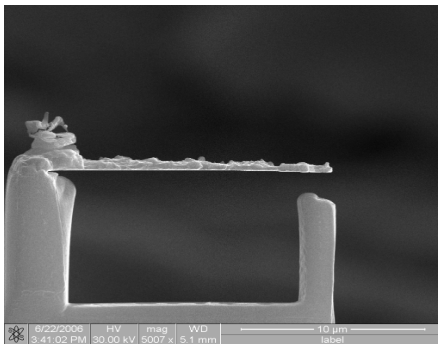
Lattice visible
HREM

Amorphous 20 nm
band



Stress deposited Pt

- Deposited 500 nm of Pt onto a Cu cantilever
 - Ion beam deposition, 100 pA, 50% overlap
 - Calculated stress in Pt 170 MPa



Need to redo with cantilever of uniform thickness.