Fabrication of Micro-Structured Surfaces for Diagnosing the Proton Source by Single Point Diamond Turning

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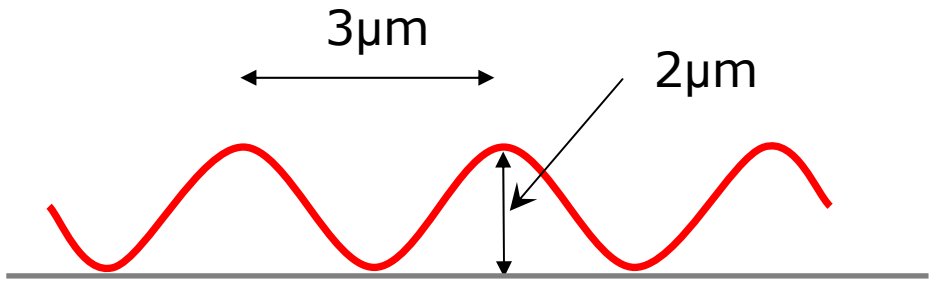
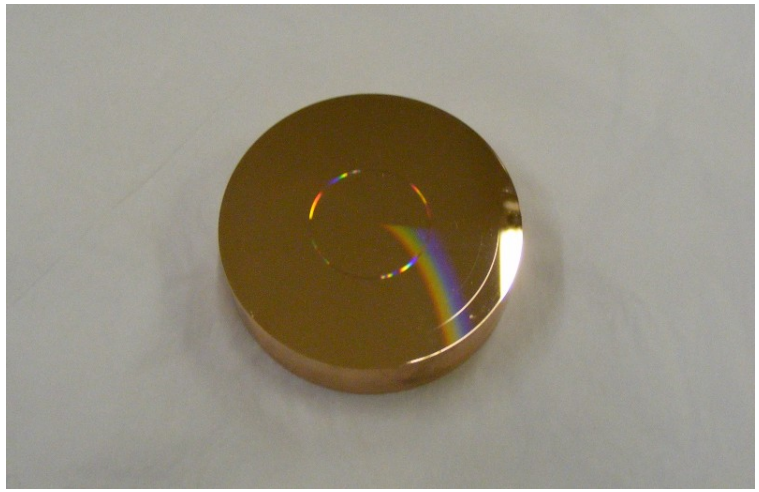
Fabrication of Micro-Structured Surfaces by SPDT: RAL target mandrel requirement



A sinusoidal pattern extending from the edge of an Oxygen-Free High Conductivity Copper disk 13mm inwards.
Roughness requirement: 25nm RMS

The OFHCC disks were then used by RAL as mandrels to replicate the sinusoidal pattern using coating techniques to produce thin foil targets for high power laser experimentation



The size of the sinusoidal pattern is very challenging!

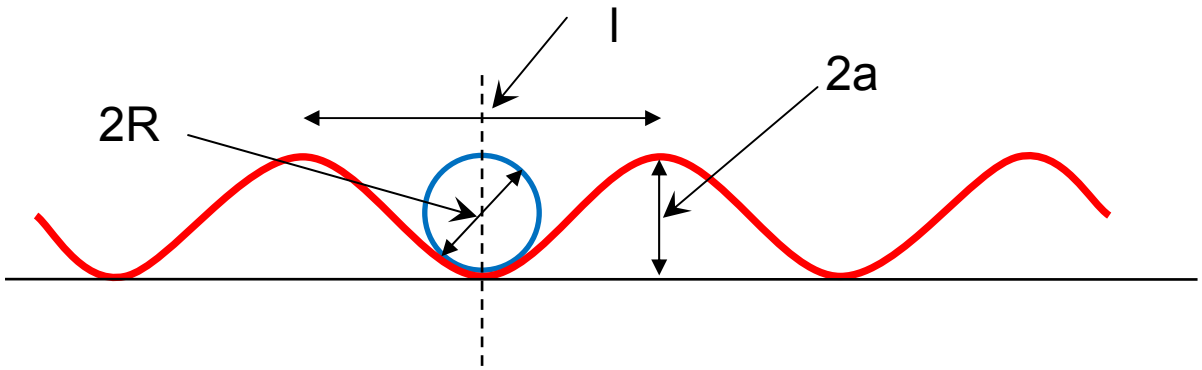
Approach

The cutting parameters, NC programs and tool selection were reviewed rigorously by Cranfield to ensure the small features required could be diamond turned.

1. NC programs require a very ‘dense’ number of tool positions and a very slow feed rate to achieve the sinusoidal pattern.

2. The diamond tools requirements were analysed. It was found the tool maximum radius was 228 nm.

Diamond tools: geometry & size



a= 1µm

l= 3 µm

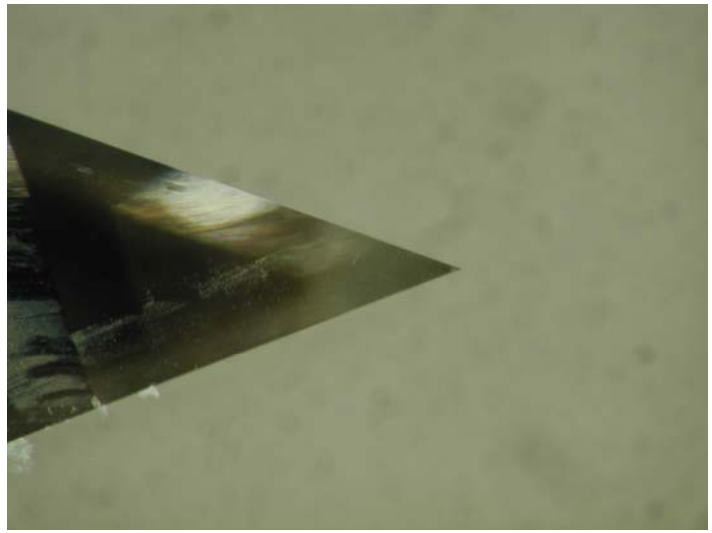
Tool geometry and size are critical!

Max. tool radius size:

$$z = a(1 - cos\frac{2\pi x}{l})$$

$$\frac{d^2z}{dx^2} = kN \qquad k = \frac{1}{R}$$

For a= 1 and l= 3 then R ≈ 228nm Max



Tools were supplied with a sharp edge point (no nominal radius)!

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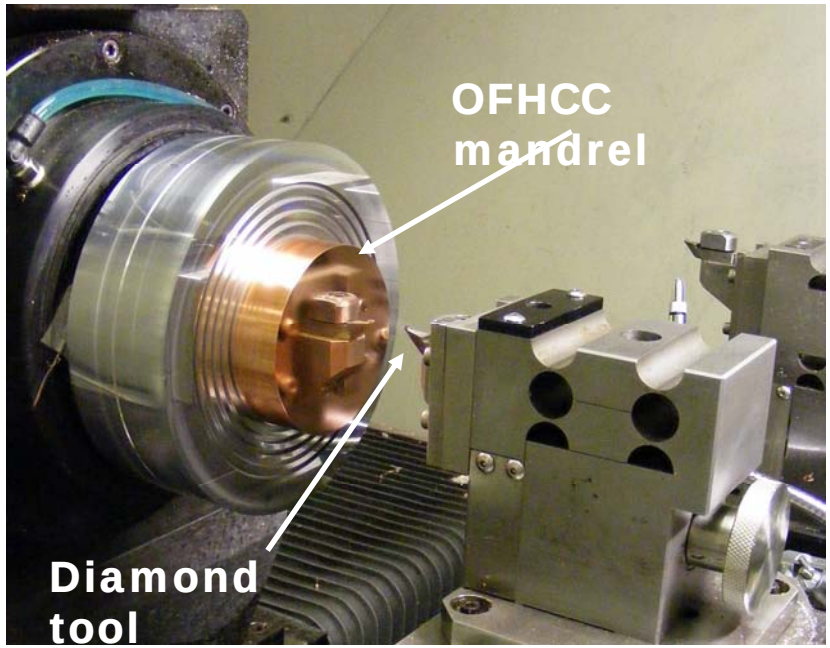
Single point diamond turning process

Diamond turning set up



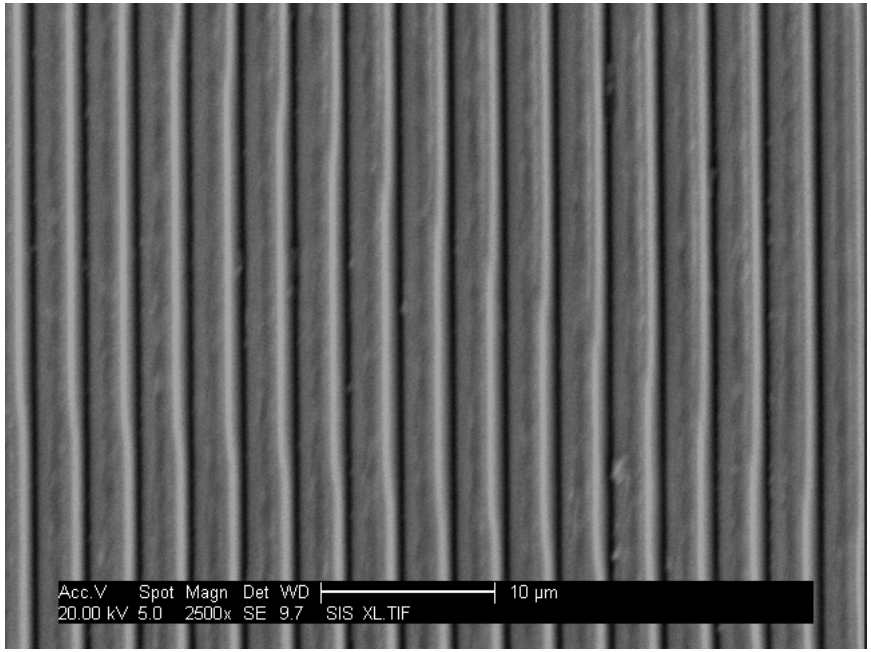
Moore 350 Ultra-precision lathe:

- aerostatic spindle (up to 6000 rpm)
- hydrostatic guide-ways (X & Z axis)
- Temperature controlled environment (±0.1°C)

Cutting parameters and conditions

- Work-piece: oxygen-free high conductivity copper, 75 mm in diameter x 20 mm thickness
- Tools: Sharp point edge natural gem tools (tool radius ≈ 200nm)
- Cutting speeds: 2000 and 3000 rpm
- Cutting fluid: White spirit spray mist

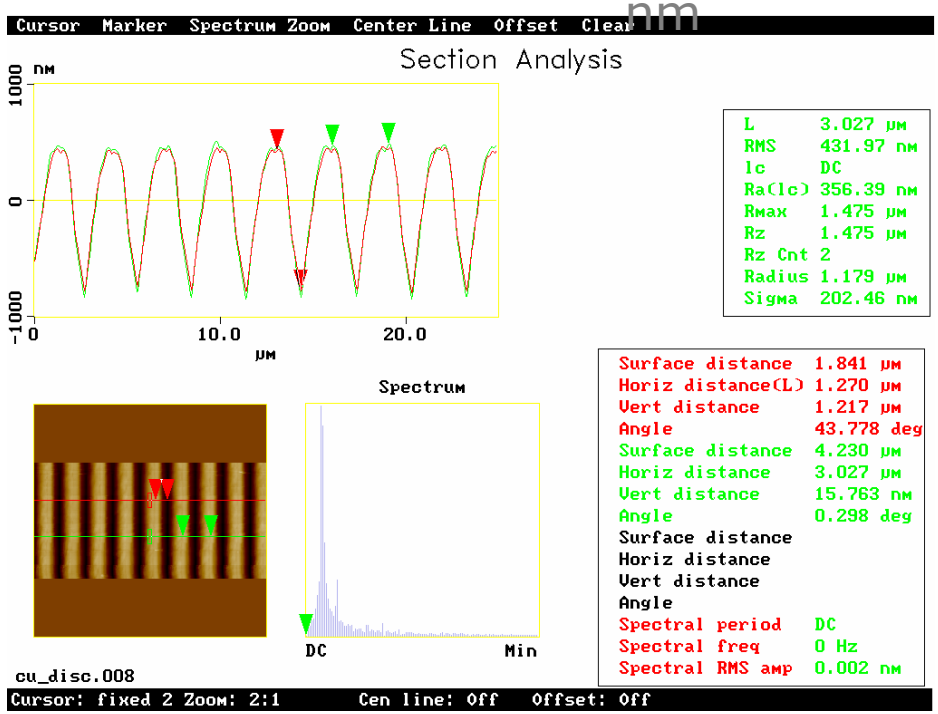
Results specimen 1



ESEM image of sinusoidal pattern

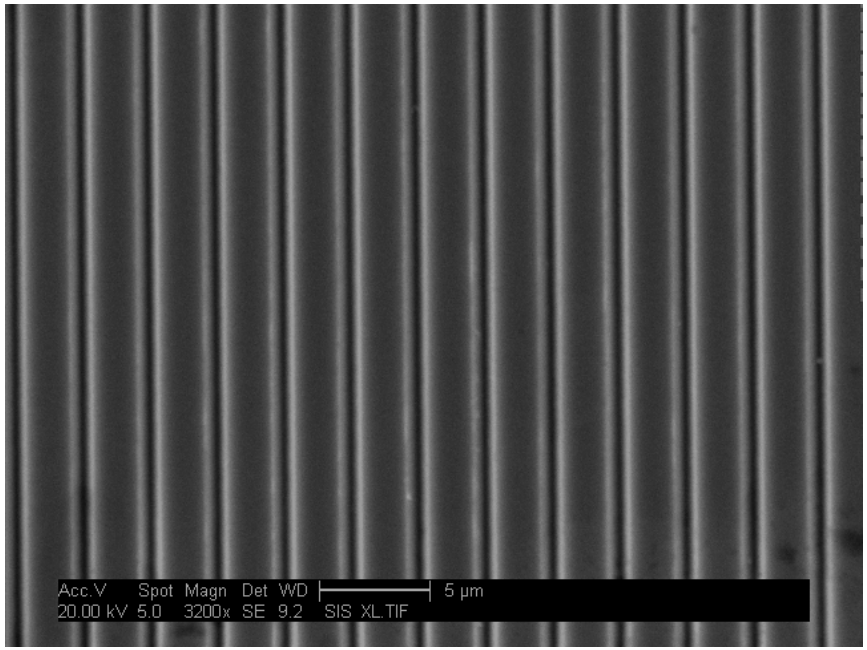
Spindle speed 3000 rpm

RMS 432 nm



AFM analysis of sinusoidal pattern

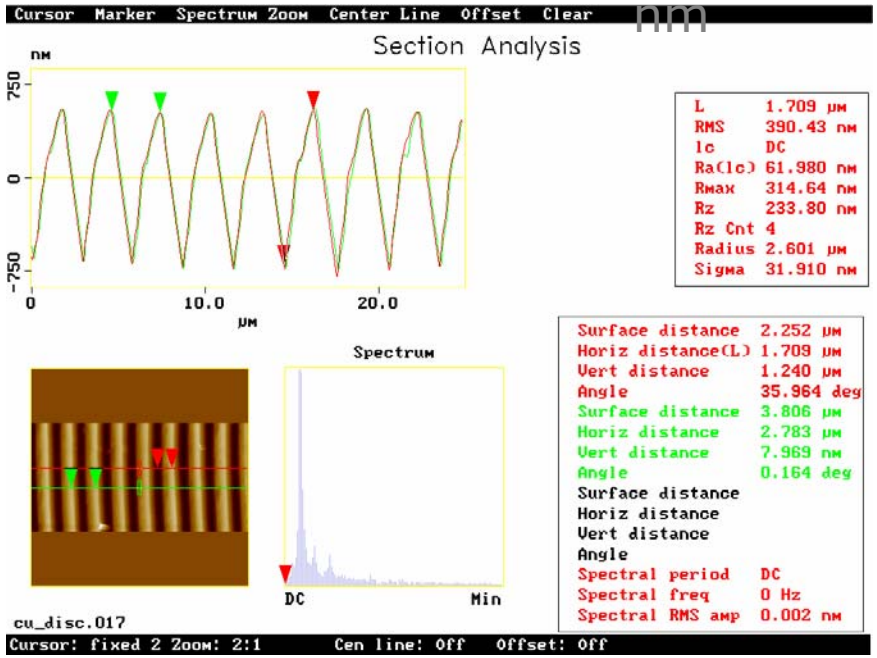
Results specimen 2



ESEM image of sinusoidal pattern

Spindle speed 2000 rpm

RMS 390 nm



AFM analysis of sinusoidal pattern

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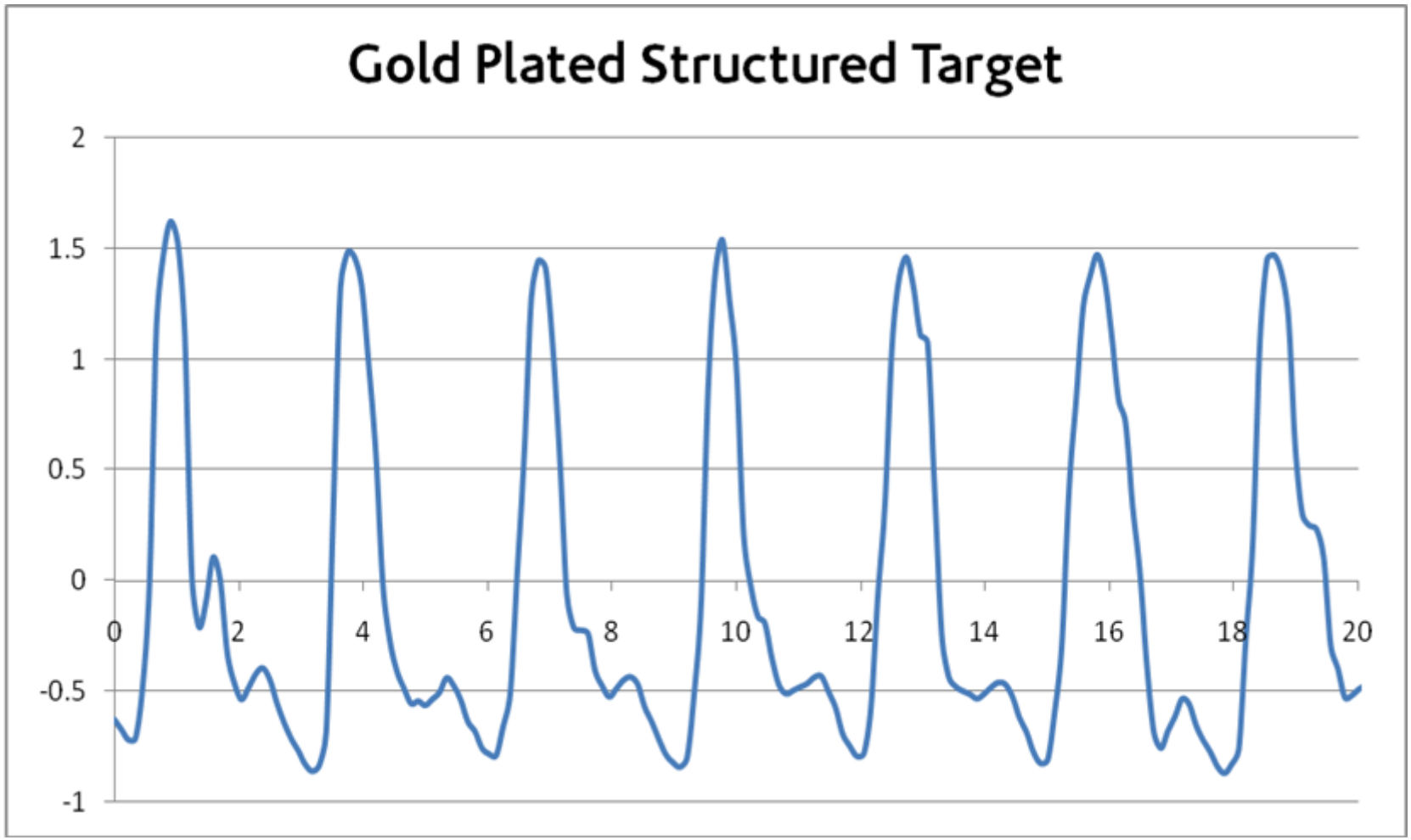
Replication process results

Results: Replication process in gold (RAL)



Images courtesy of C. Spindloe (RAL)

Results: Replication process in gold (RAL)

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Veeco

3-Dimensional Interactive Display

Date: 08/29/2008
Time: 13:47:43

Surface Stats:

Ra: 668.16 nm

Rq: 773.65 nm

Rt: 5.11 um

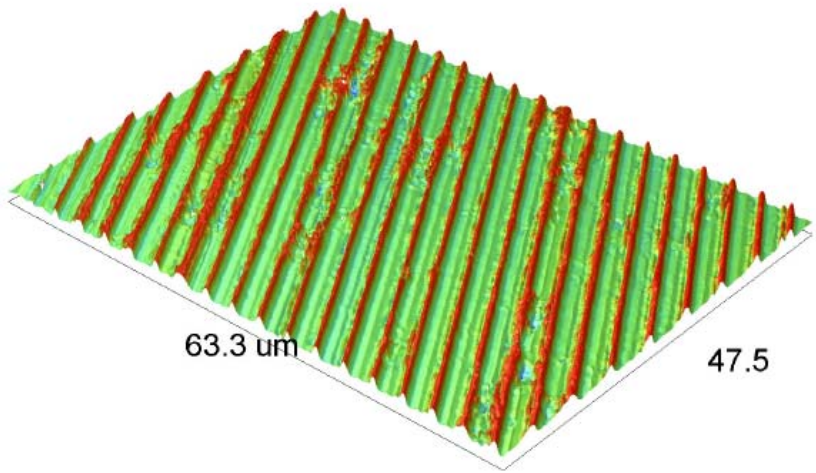
Measurement Info:

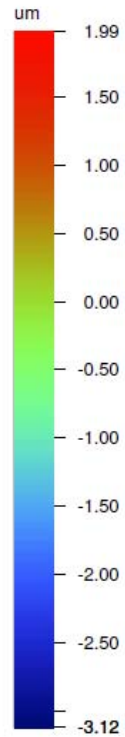
Magnification: 100.04

Measurement Mode: VSI

Sampling: 98.96 nm

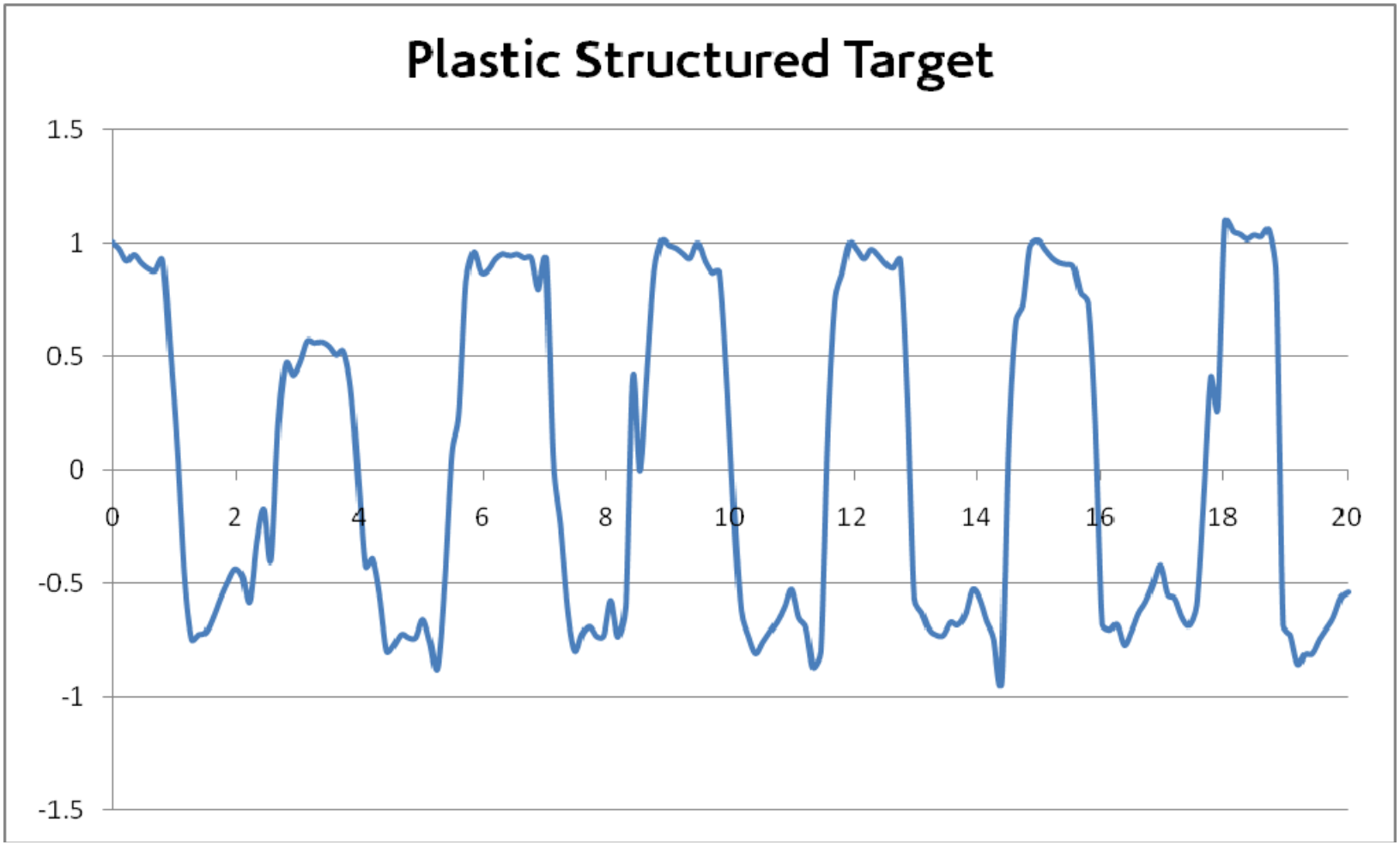
Array Size: 640 X 480





Title: Gold Plated Part
Note: Edge of Sample

Results: replication process in plastic (RAL)



Results: replication process in plastic (RAL)

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Veeco

3-Dimensional Interactive Display

Date: 08/15/2008
Time: 14:37:34

Surface Stats:

Ra: 691.85 nm

Rq: 732.88 nm

Rt: 4.96 um

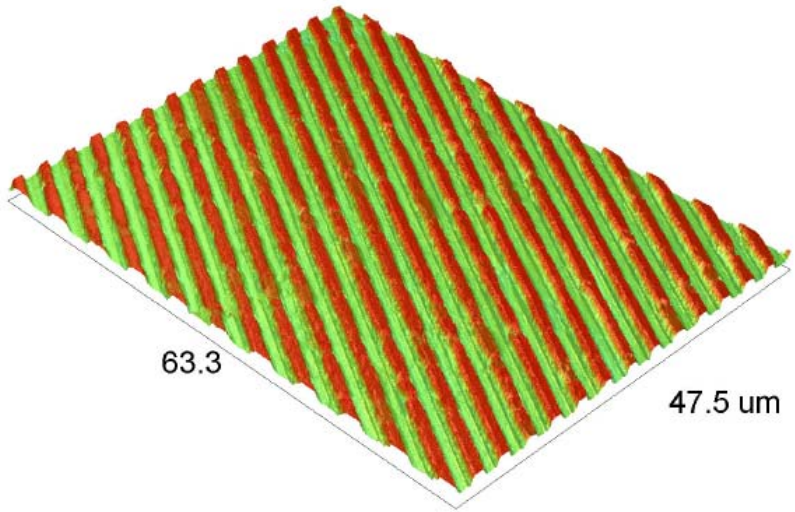
Measurement Info:

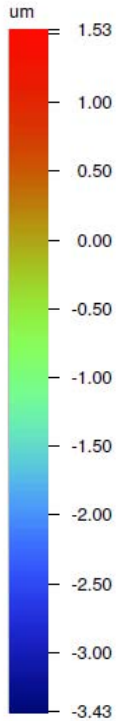
Magnification: 100.04

Measurement Mode: VSI

Sampling: 98.96 nm

Array Size: 640 X 480





Title: Plastic Coated Part
Note: Edge of Sample

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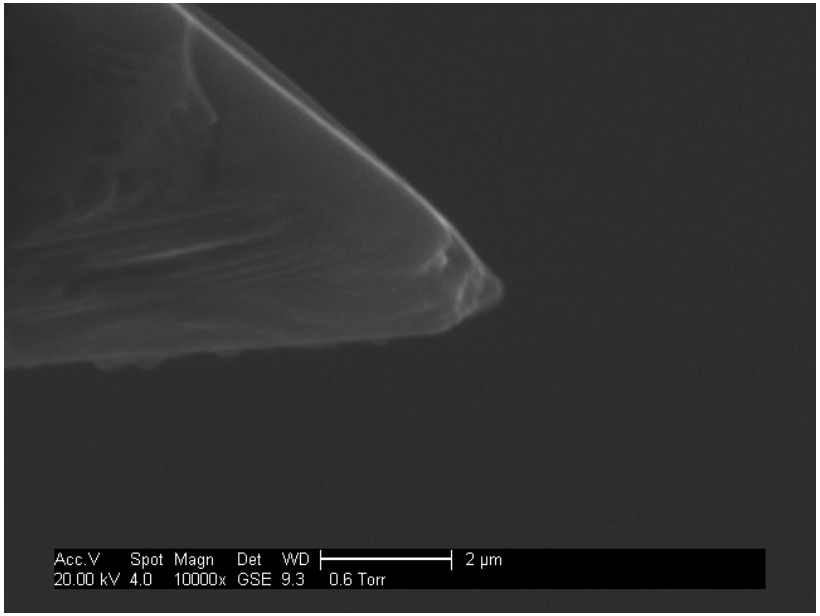
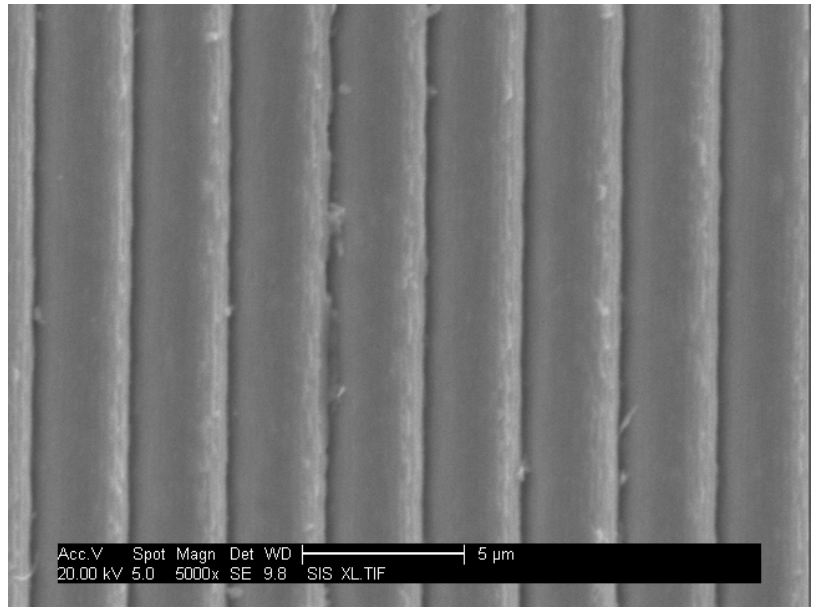
Fabrication issues

Fabrication issues: Rapid tool wear





ESEM micrograph of diamond tool showing ‘chipping’ and wear of the tool tip after cutting 78Km (approximately 3h) . A tool under these conditions cannot generate the required profile.

To minimise tool wear effects, each mandrel was fabricated with a ‘fresh’ tool

Fabrication issues: profile/roughness characterisation

A number of instruments were considered to characterise the mandrels surface texture

- Form Talysurf (stylus tip radius is too large =2μm)
- Talysurf CCI 600 (high % of the data missing as maximum measuring slope of this instrument is 27.7 deg)
- AFM used for profile characterisation
- 3D Topo-Wyko provided RMS results of 4-14 nm (!)

Fabrication of Micro-Structured Surfaces by SPDT: further work & some observations

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- Results indicate that a sinusoidal pattern having 3μm wavelength and 2 μm amplitude can be achieved by SPDT. The sinusoidal pattern has been successfully replicated by RAL in thin gold foil and Parylene-C plastic targets. However, this work has shown that further work is required to fully develop and establish a diamond turning capability at the required RMS level (25 nm)
- Diamond tool design and fabrication are critical to further development
- Surface characterisation, profile & roughness parameters, procedures need to be reconsidered

Further work alternatives: Tool design and fabrication

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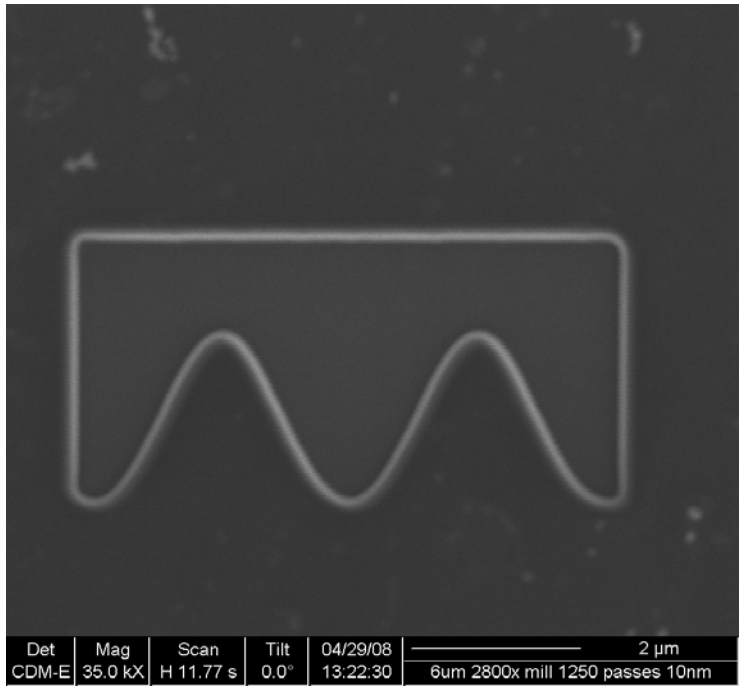
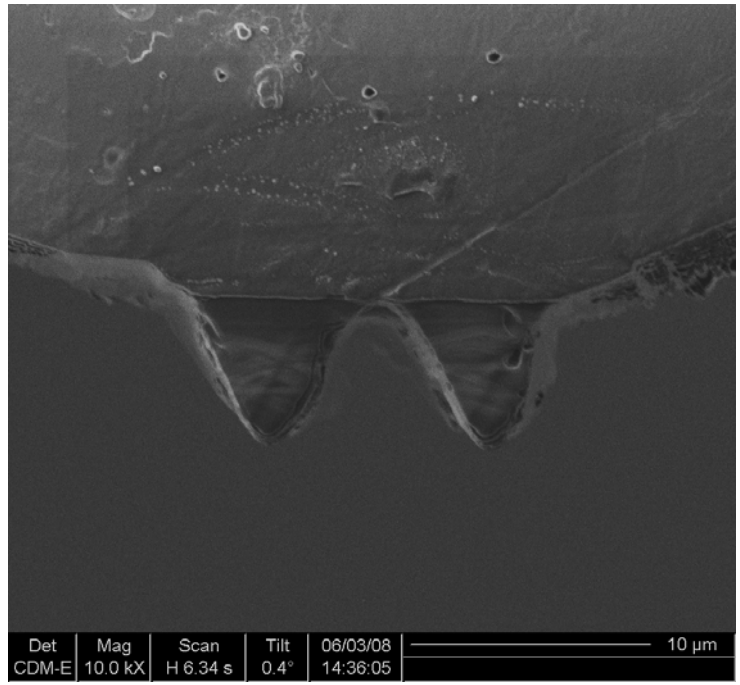
Cranfield sinusoidal FIB prototype diamond tool

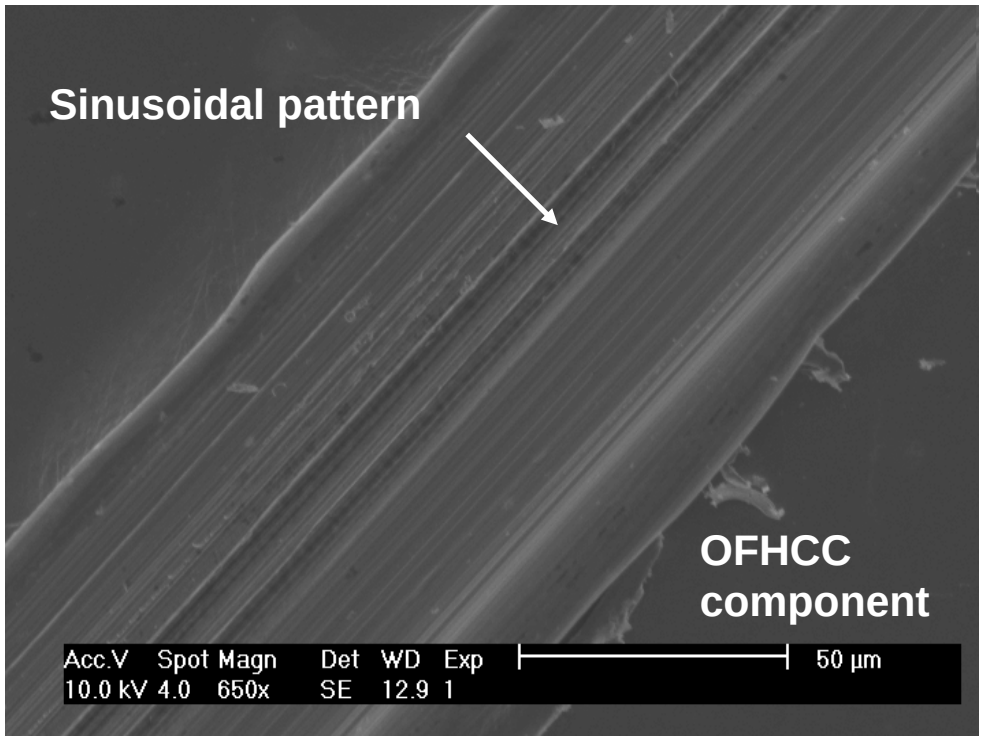
a= 2μm, l= 3μm





Allen D, Evans R, 2008.

Further work: FIB tooling



Allen D, Evans R, I Durazo-C, 2008 (to be published)

Acknowledgments

- A. Cox, Contour fine tooling, tool re-conditioning support
- X. Luo, Heriot-Watt University, initial NC programming support
- R. Evans, Cranfield University, FIB tool development
- C. Spindloe, RAL, surface characterisation and general support