Microtarget Mass Production for the RAL High Accuracy Microtargetry System.

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Outline

1. Introduction
2. Motivation
3. Background
4. Fabrication
    - Basic processes
    - Special precautions
5. Targets for RAL High Accuracy Microtargetry System
6. Conclusions

Scitech Precision

Based at the Rutherford Appleton Laboratory a spin out from the Central Laser Facility Target Fabrication group.

Target delivery of >30 contracts / year with over 50 years combined experience in experimental target integration, design consultancy and manufacture using integrated target fabrication techniques such as MEMS, micro-machining and precision assembly.

Collaborative research with the CLF, AWE, TUD, LULI, Imperial College, Oxford University, Queen’s University Belfast.

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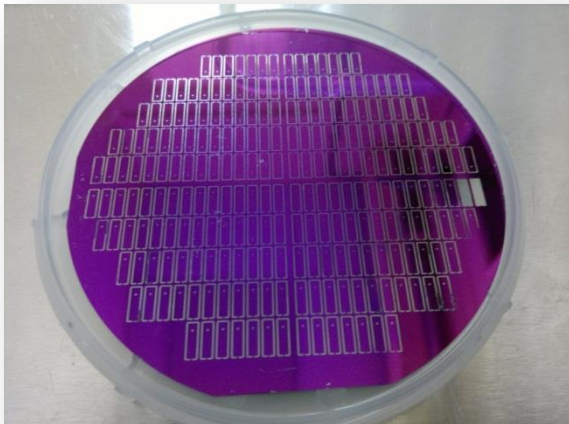
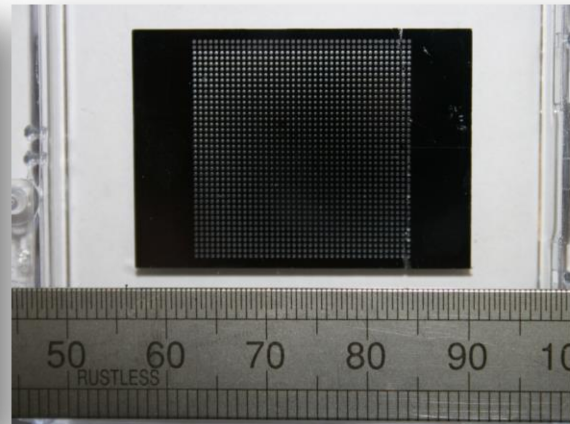
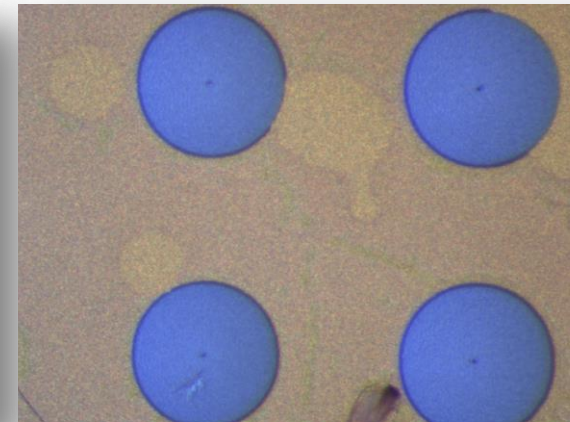
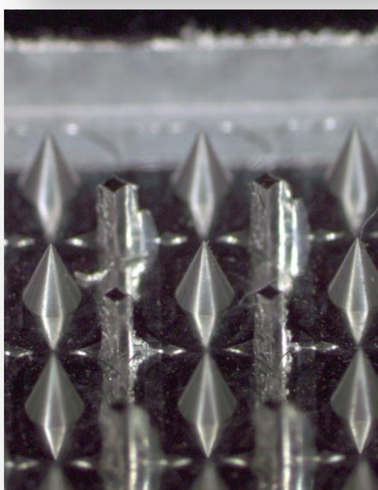
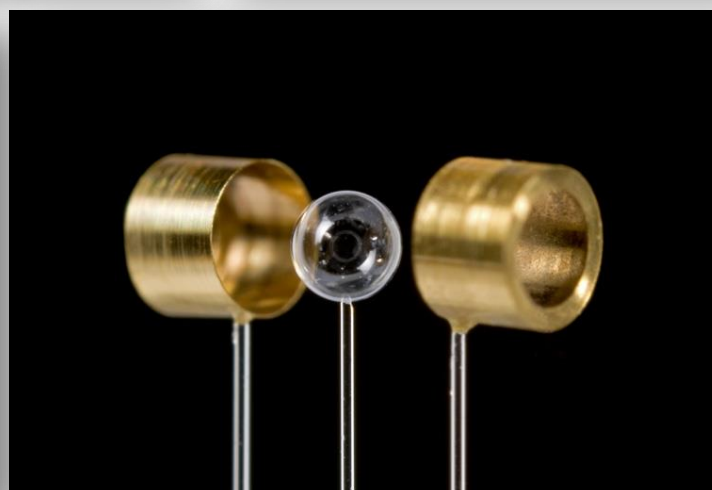
Example Targets

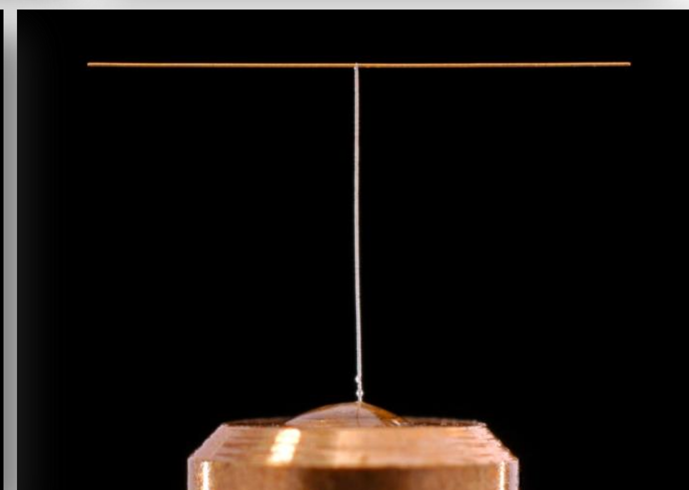












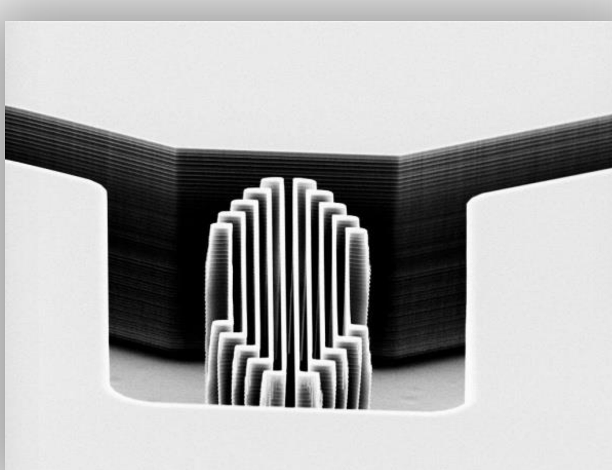
Motivation

- Target Numbers
  - Laser repetition rates are going to 1Hz and higher
  - Target numbers will be driven much higher
- Large Arrays of Targets
  - **Serial processing** – i.e. Fabrication and assembly of targets on an individual basis is too expensive & slow for the large numbers required
  - **Parallel processing** – i.e. MEMS-based fabrication allows 10s - 1000s of targets to be fabricated on a single wafer in very precisely defined arrays

Background

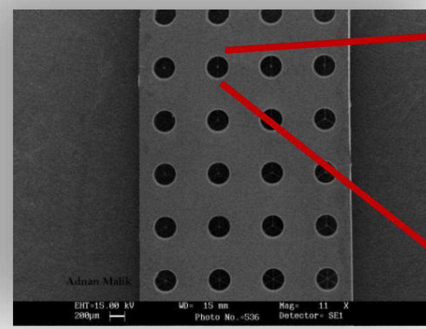
Central Laser Facility programme to deliver high specification targets using MEMS technology

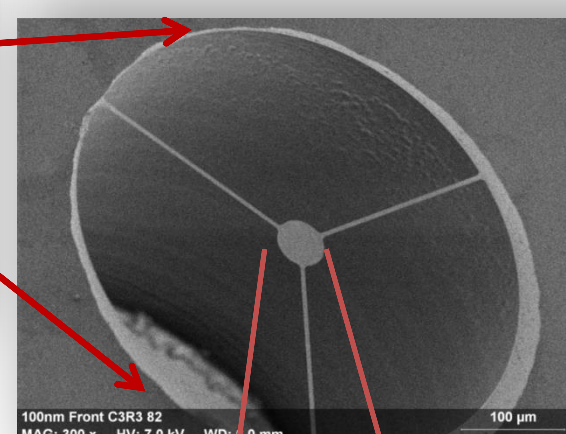
2004 – Vane Targets



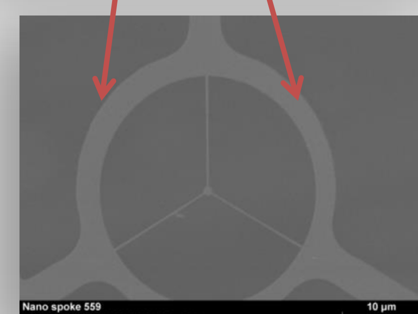
2um thick Si vanes with 2um spacing dimensions 80um long x 40um high

2006-2009 – Membrane Targets





Ultra-thin membrane targets - 32um diameter, 40nm thick SiN membranes supported on 1µm wide, 40nm thick arms over hole etched through 400µm thick Si.



Background

Targets demonstrated batch production of the various geometries and were used in ‘single shot’ mode on Vulcan Laser system.

- High energy of the Vulcan system allows only one shot chip.

With lower energy Astra Gemini type systems have the possibility to fully utilise the mass production capabilities of this type of target

- Recent tests show good survival rate of Silicon based targets on Astra Gemini

Fabrication

- MEMS (**M**icro-**E**lectro-**M**echanical **S**ystem) -based fabrication processes
- Substrate - (usually) silicon wafer
- Processes developed from semiconductor industry
  - Original s/c processes are shallow
    - few microns
  - For MEMS, techniques have been improved to allow much deeper processing
    - up to millimetre scale

Basic Processes

- Pattern Transfer
  - Microlithography (optical or e-beam)
- Deposition
  - sputter, thermal evaporation, CVD, PLD, electro-deposition, spin/dip-coating
- Etching
  - Dry (plasma) etching or wet etching

Pattern Transfer

- Optical lithography
  - Mask aligner (contact printing)
  - Projection printing (wafer stepper)
  - Both use photomasks of required pattern
- E-beam lithography
  - Higher resolution than optical
  - Direct writing on wafer

Deposition

- Physical vapour deposition (PVD)
  - sputter, thermal evap., pulsed laser deposition
  - most metals
- Chemical vapour deposition (CVD)
  - Diamond-like carbon
- Electro-deposition
  - Gold, chromium, nickel
- Spin/dip coating
  - Polymers, photo and e-beam resists

Etching

- Dry (plasma) Etching
  - Reactive Ion Etching (RIE)
    - Shallow etch only
  - Deep Reactive Ion Etching (DRIE)
    - Etching up to millimetre-scale depths possible
- Wet Etching
  - Uses etching chemicals (e.g. acids) in solution
  - Beakers (single or a few wafers)
  - Automated tools (wafers in batches)

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cility

Spin-coater

Mask aligner

E-beam

DRIE

Stepper

RIE

Target Fabrication

- Pattern transfer, Deposition and Etch carried out in predetermined order, and as many times as required
- Builds up target structure layer-by-layer until complete.
- Inspections can be carried out at any point
- Final inspection either on whole wafer or after wafer is diced

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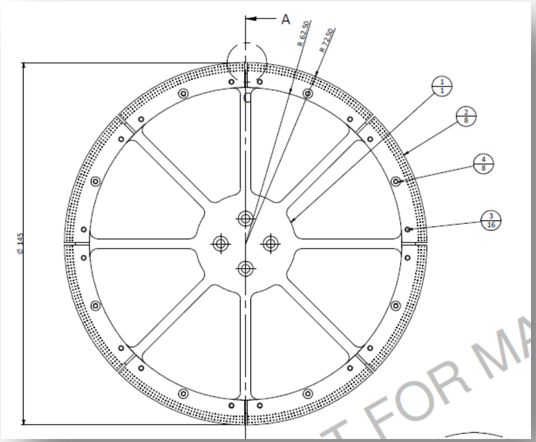
Special Precautions

- Semiconductor manufacturers use few materials
  - Silicon, aluminium, gold, chromium, copper, ...
- Laser Target Fabrication requires a much wider range of materials
  - Nd, Sm, Te, CsI, Sn, Au, Cu, Bi, Ag, Gd, Fe, etc, etc.
- To ensure compatibility during processing, it may be necessary to add extra masking layers, e.g.,
  - Standard Gold etch solution also etches iron
  - Adhesion of metallic coatings on polymers or Si

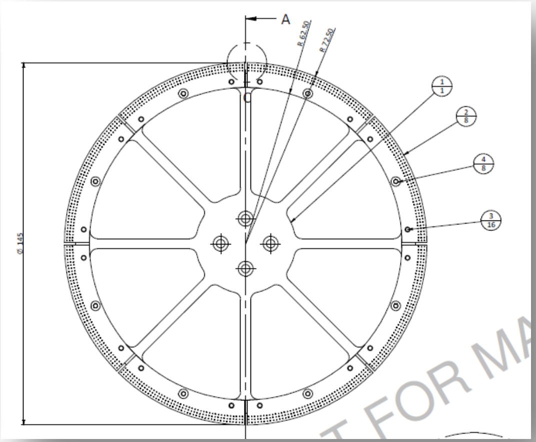
Targets for RAL High Accuracy Microtargetry System

- Targetry segments mounted on nano-positioning wheel of RAL High Accuracy Microtargetry System



Targets for RAL High Accuracy Microtargetry System

- Targetry segments mounted on nano-positioning wheel of RAL High Accuracy Microtargetry System
- Targets arranged in rows around circumference



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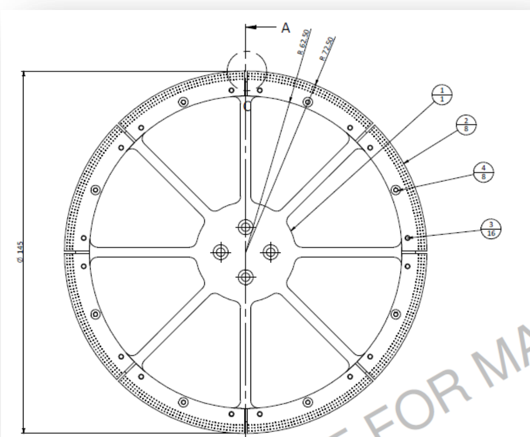
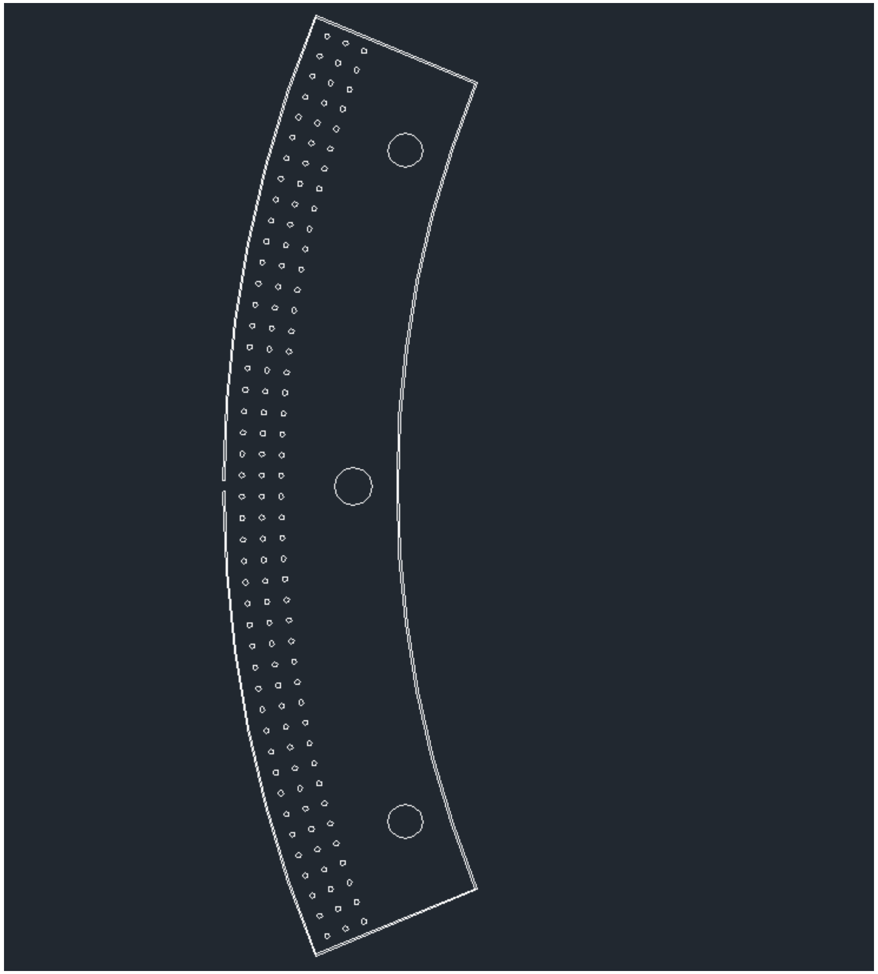
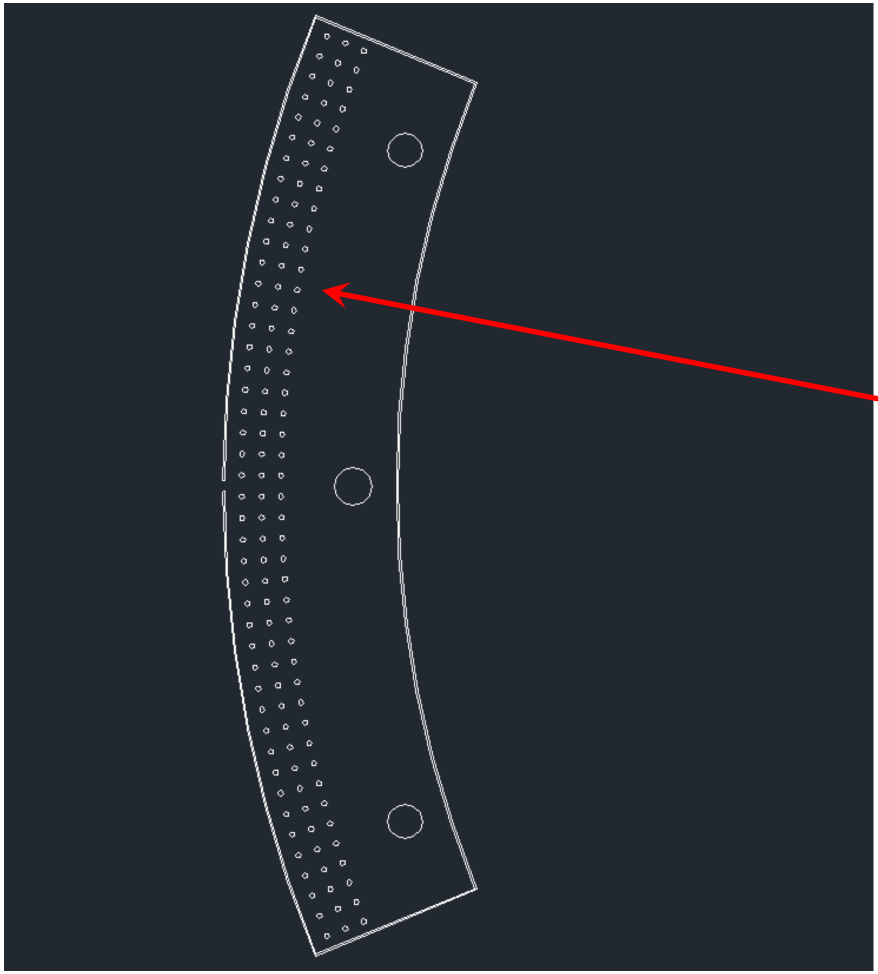
Targets for RAL High Accuracy Microtargetry System

- Targetry segments mounted on nano-positioning wheel of RAL High Accuracy Microtargetry System
- Targets arranged in rows around circumference
- Up to ~1000 targets in all eight segments – allowing multiple target types on one wheel

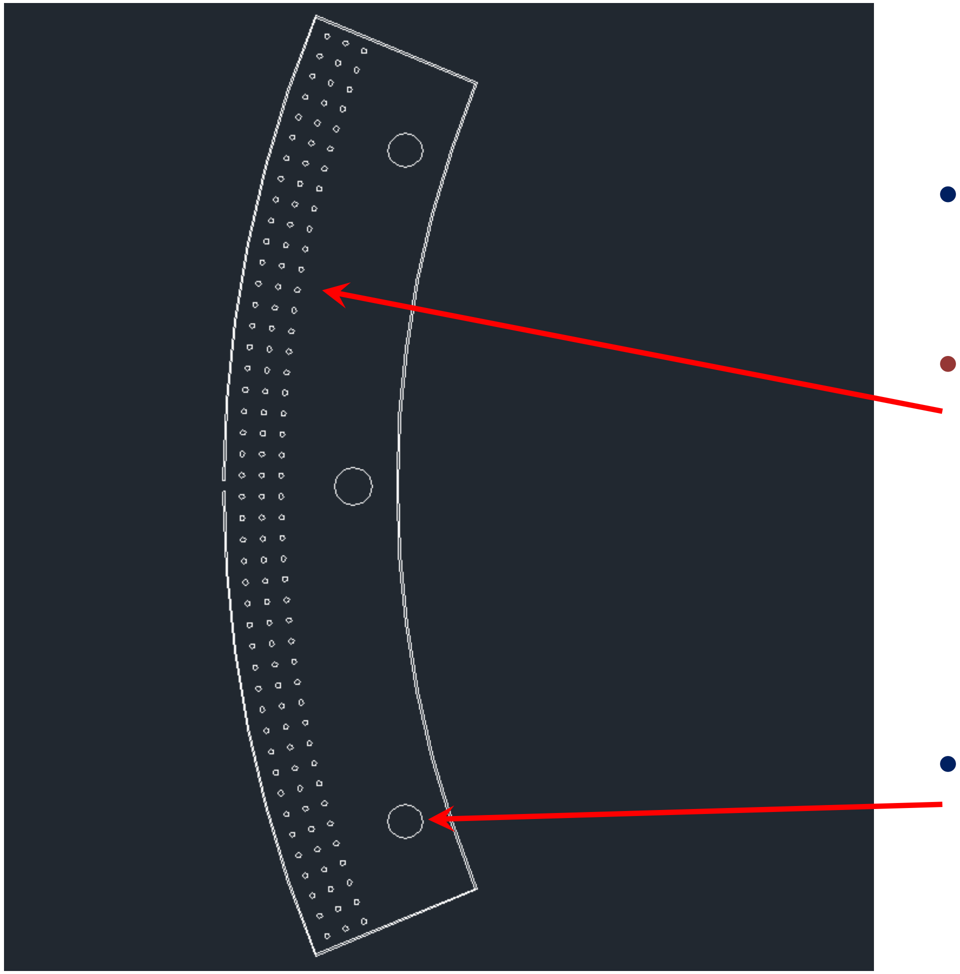




- Eight segments make up full circle of wheel



- Eight segments make up full circle of wheel
- Three rows of target apertures shown at close spacing – this configuration gives 1000's targets per full wheel



- Eight segments make up full circle of wheel
- Three rows of target apertures shown at close spacing – this configuration gives 1000's targets per full wheel
- Mounting/alignment achieved using three larger apertures

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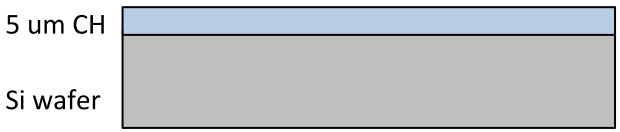
Six Basic Process Steps

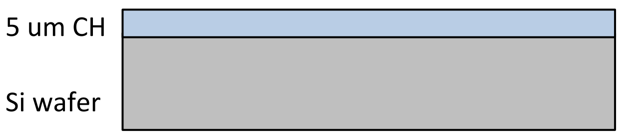
(simple membrane targets)



Coat wafer with 5um CH

Six Basic Process Steps

(simple membrane targets)

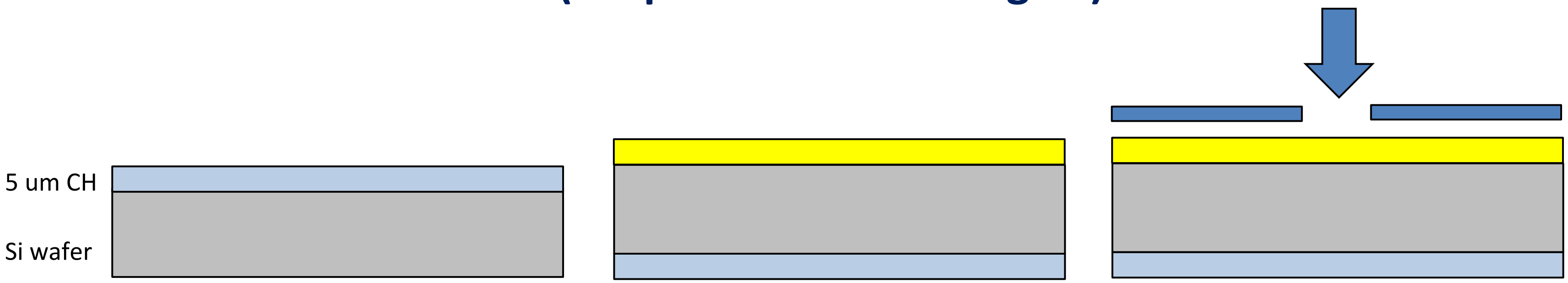


Coat wafer with 5um CH

Spin resist on rear surface

Six Basic Process Steps

(simple membrane targets)



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Optical exposure of resist through photomask

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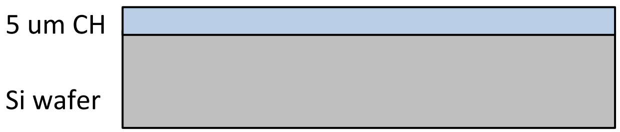

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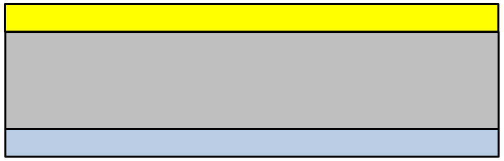
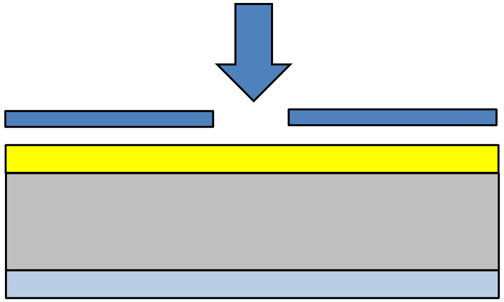


Spin resist on rear surface



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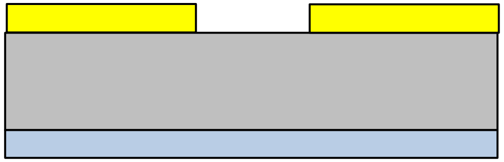
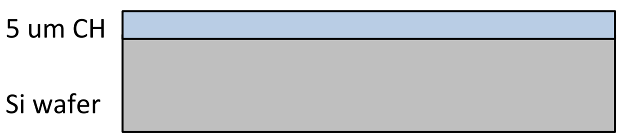


Develop exposed resist to leave Si uncovered

Six Basic Process Steps

(simple membrane targets)



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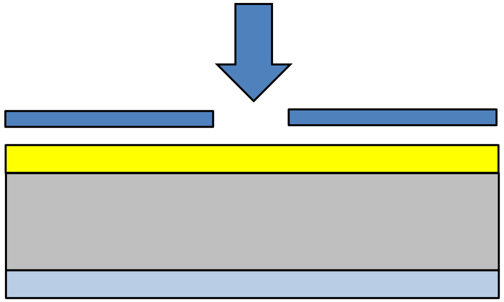

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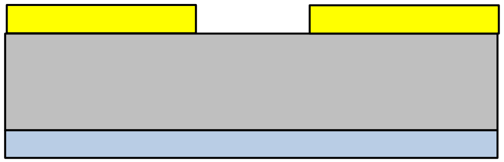

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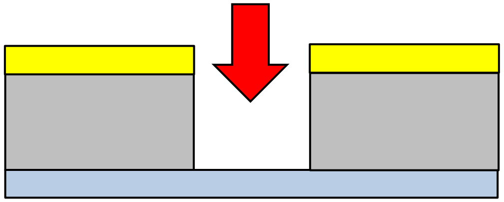
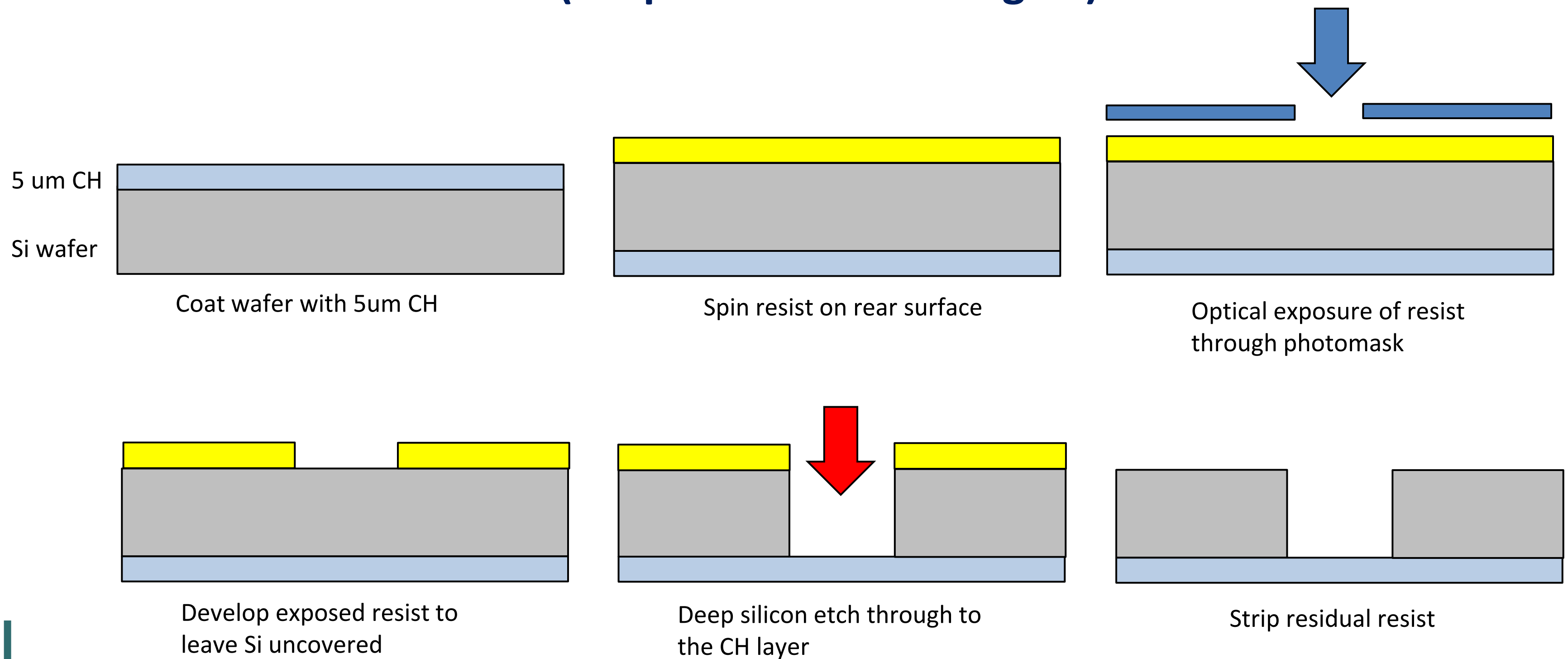


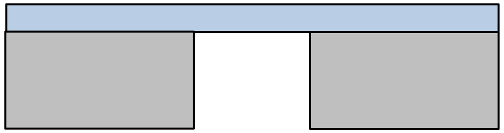
Deep silicon etch through to the CH layer

Six Basic Process Steps

(simple membrane targets)



Additional steps may be added to produce more complicated targets – e.g. microdot targets



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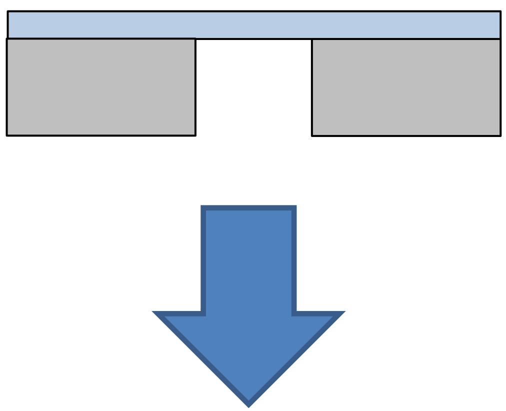

- Approx seven more process steps, including:
  - Advanced resist processing
  - Wafer back-side alignment
  - Metal deposition
  - Resist lift-off

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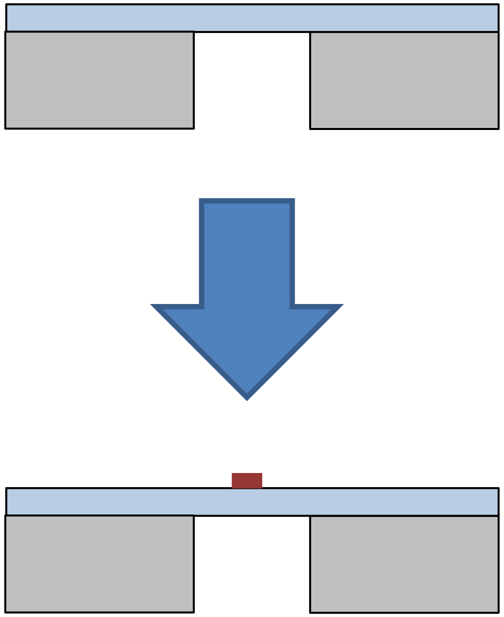

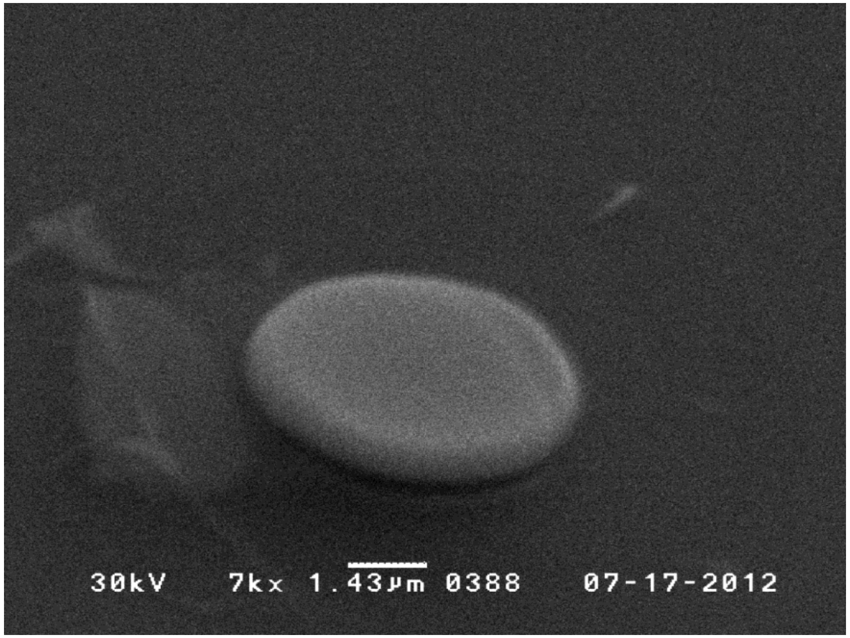

Delivered to XFEL (LCLS) experiment in 2012 – 1600 target array

In Conclusion

- CLF and Scitech Precision have developed a robust delivery stream for laser targets using MEMS-based fabrication
  - Excellent definition on each individual target
  - Excellent repeatability/uniformity across silicon wafer
  - Ideal technique for high rep-rate target arrays
  - Can also be used to fabricate other micron-scale structures such as backlighters, diagnostic filters and other secondary structures

THANK YOU!

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University of St Andrews

5th Target Fabrication Workshop
6 - 11 July 2014, University of St Andrews, Scotland.
First Announcement

On behalf of Target Fabrication Workshop organising committee, it is a pleasure to announce the 5th Target Fabrication Workshop which will take place at the University of St Andrews, Scotland, in July 2014.

St Andrews is a coastal medieval town situated in the county of Fife in Scotland and the University celebrating its 600th anniversary in 2013. It has a wonderful atmosphere for meeting and exchanging ideas in a rich historic and cultural surroundings.

The meeting will comprise of oral and poster presentations and we would like to see all the previous attendees and hopefully many new ones in 2014. Group leaders are encouraged to inspire the younger researcher and scientist to attend this meeting.

For informal enquiries and more information please contact **Wigen Nazarov: wn9@st-andrews.ac.uk**

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