Process Benefits of a 'Clean' Sputter Target by Dynamic Plasma Movement on Circular Planar Magnetrons

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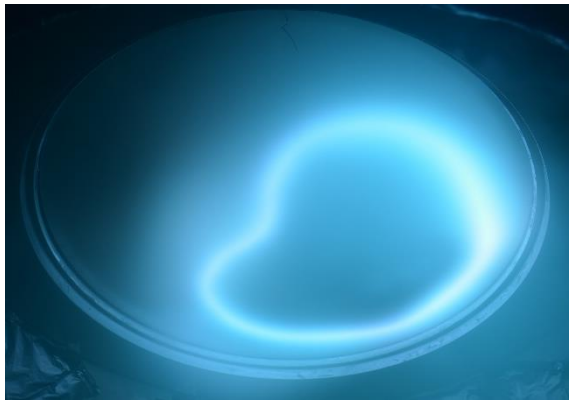
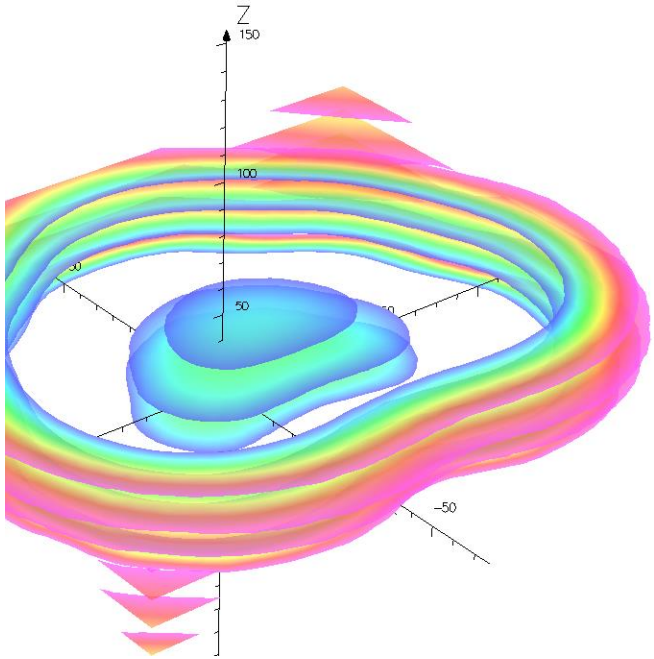
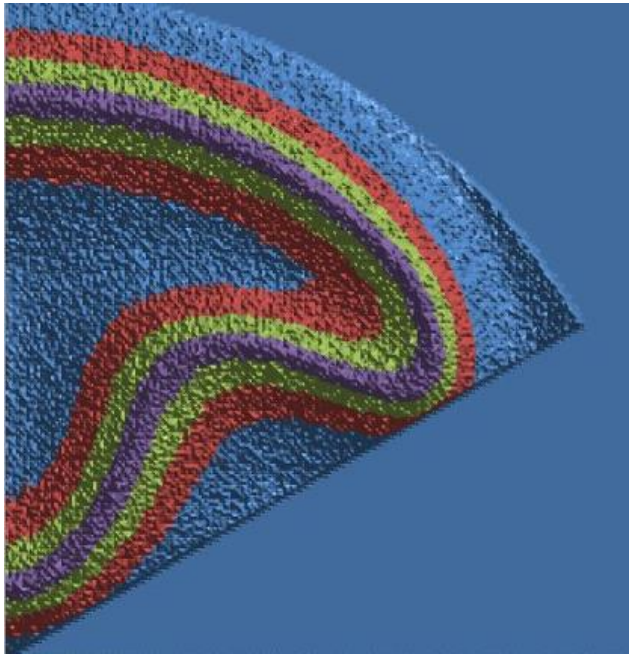
Gencoa Ltd UK







Gencoa Circular Magnetron Cathode Product Overview

	BP φ	Standard 2 pole (SW/PP)	Magnetic Materials	High Yield HY	HU High Uniformity	MRS - Multi-ring static	VT variable	FFE
2”	50							
3”	75							
4”	100							
5”	125							
6”	150							
8”	200							
10”	250							
12”	300							
14”	350							
16”	400							

3G

Gencoa Circular Magnetron Range

ffe *is the focus of this talk*

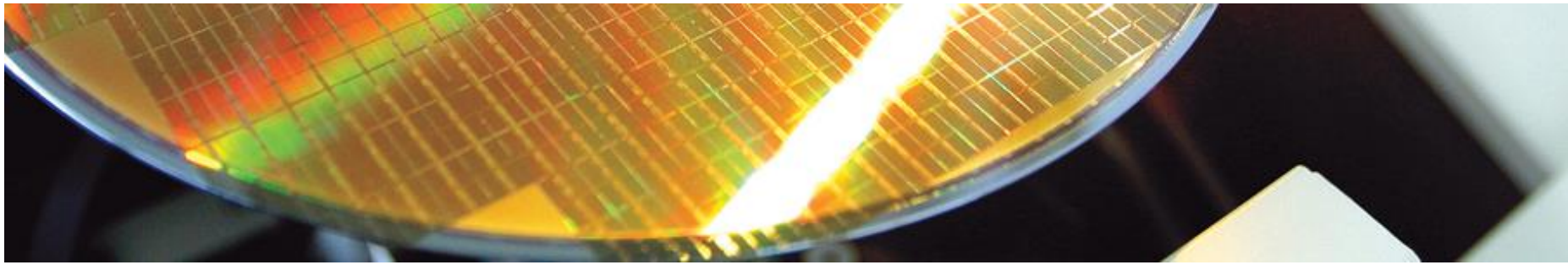
- **Standard Circular & 3G Magnetrons**
  - Available from 2” to 16” target size
  - Various magnetic and mechanical option available
  - R&D, Small scale production
- **Variable (V-tech Magnetron)**
  - Available in 2”, 3”, 4” and 6” target
  - Easy adjustment of the magnetic field including adjustment during the process
  - R&D, Small scale production
- **Full Face Erosion (ffe) Magnetron**
  - Broadly classified into small ffe (3”-8” target) and large FFE (10”-17” target)
  - **High target use** and **better coating uniformity**
  - Semiconductor, R&D, precious metal sputtering, Optics

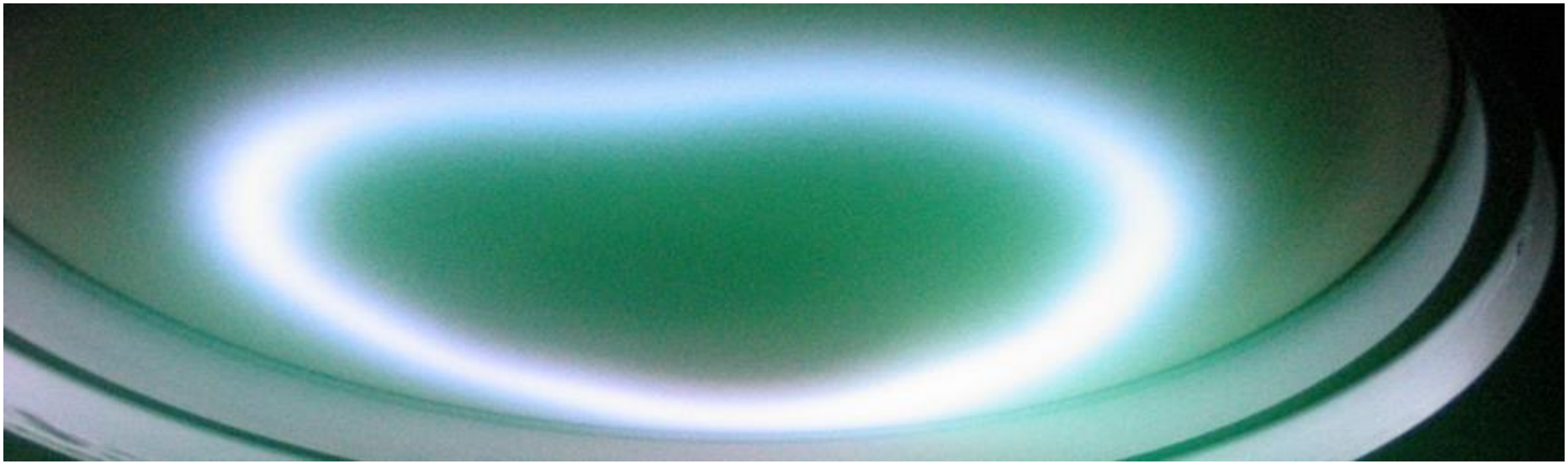
SW|PP

ffe

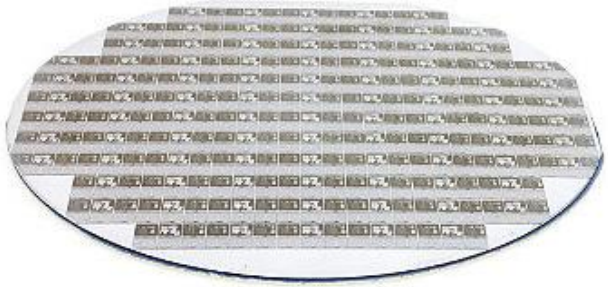
Vtech

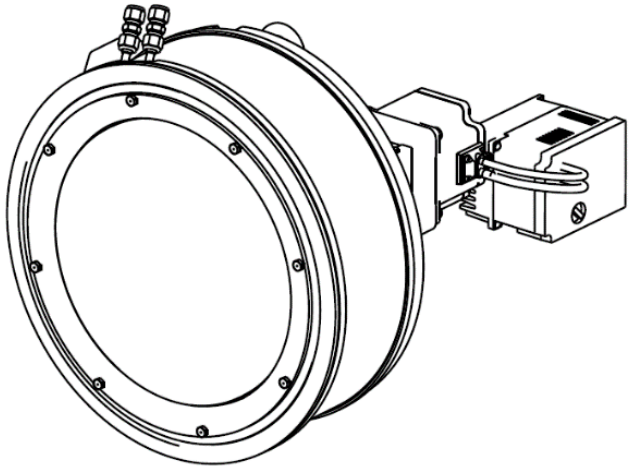
FFE – Full Face Erosion Sputtering - Applying good practice from Semiconductor Sputter Applications to the wider thin film market



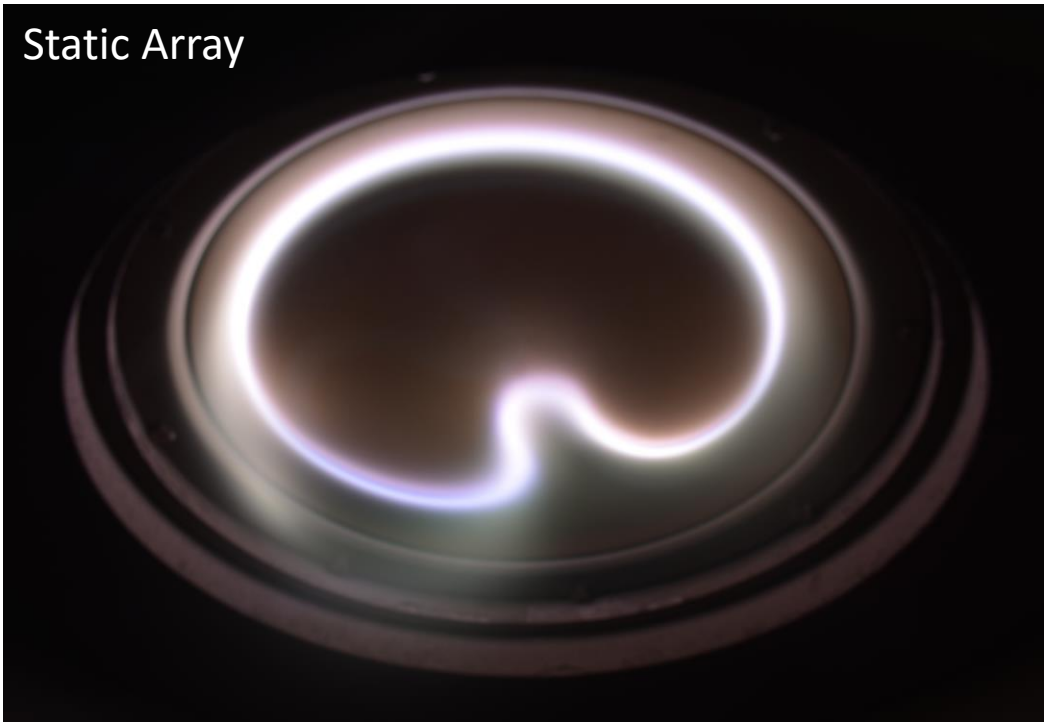


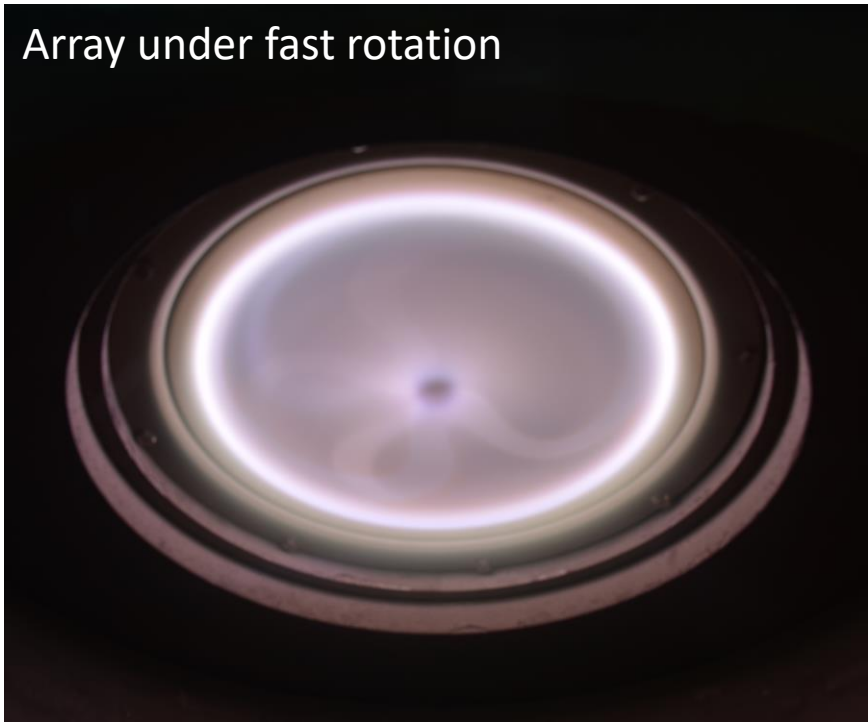
For static wafer coating whilst a multi-ring plasma can create a good uniformity, a dynamic moving plasma is preferred for film quality





A static plasma trap with a defined plasma erosion pattern can be converted to a whole target erosion effect by rotation of the magnetic array





Rotating magnetic arrays have been used since the 80's to prevent re-deposits on the target surface and reduce defects on devices

- Rotating magnetic arrays (Patent by Garrett ,1983)
- Fujitsu, Varian

EP 0 451 642 A2

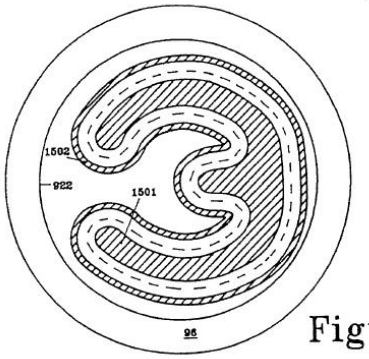
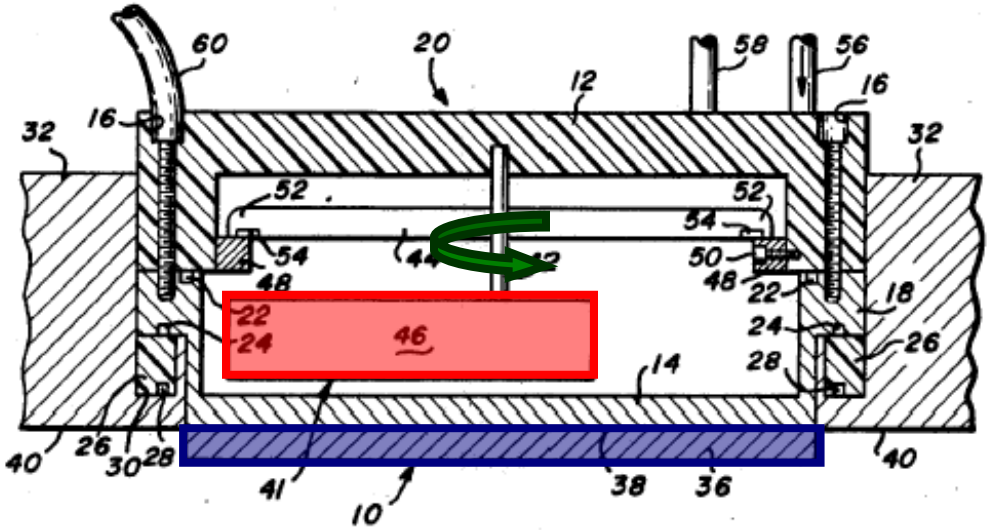


Figure 15A



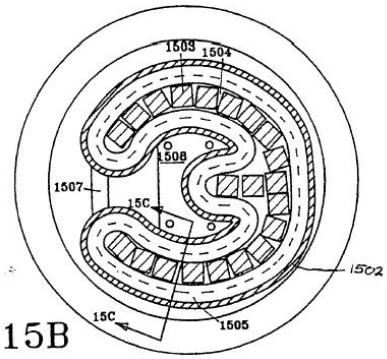
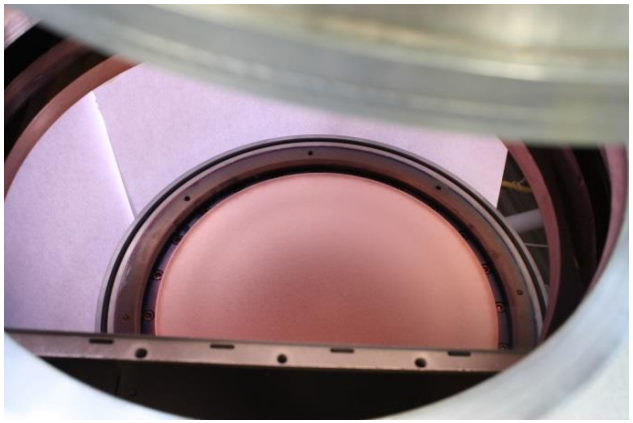
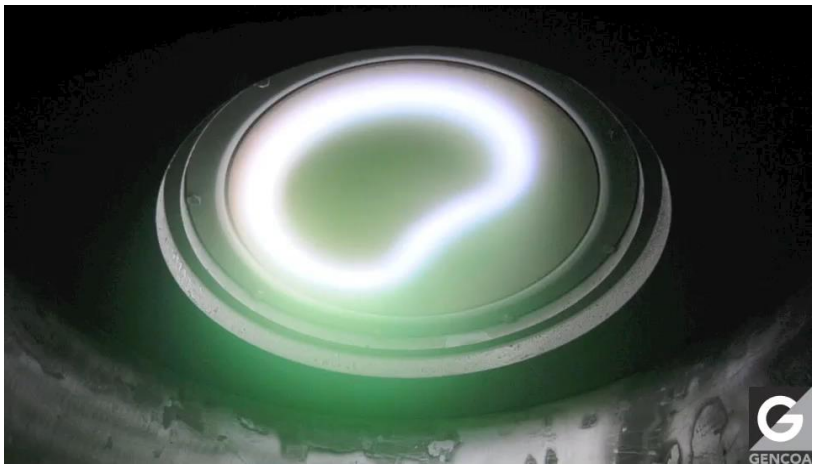


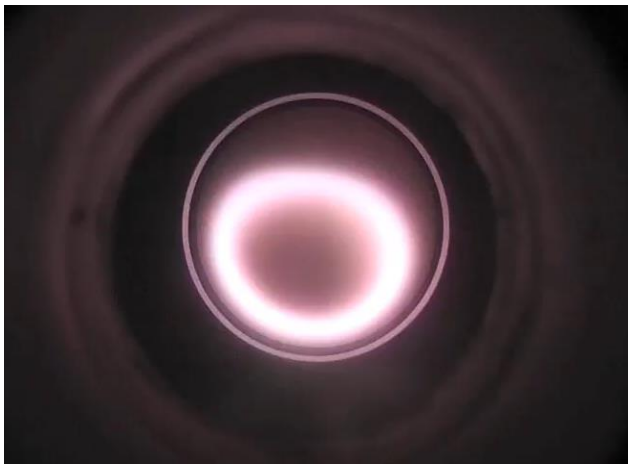
Figure 15B



For 40 years the benefits of a rotating plasma has been applied in the semiconductor market to good effect

Now the rest of the thin film sector can benefit

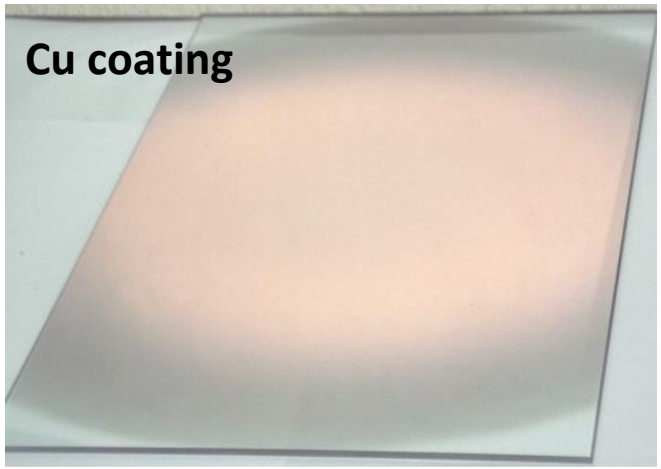


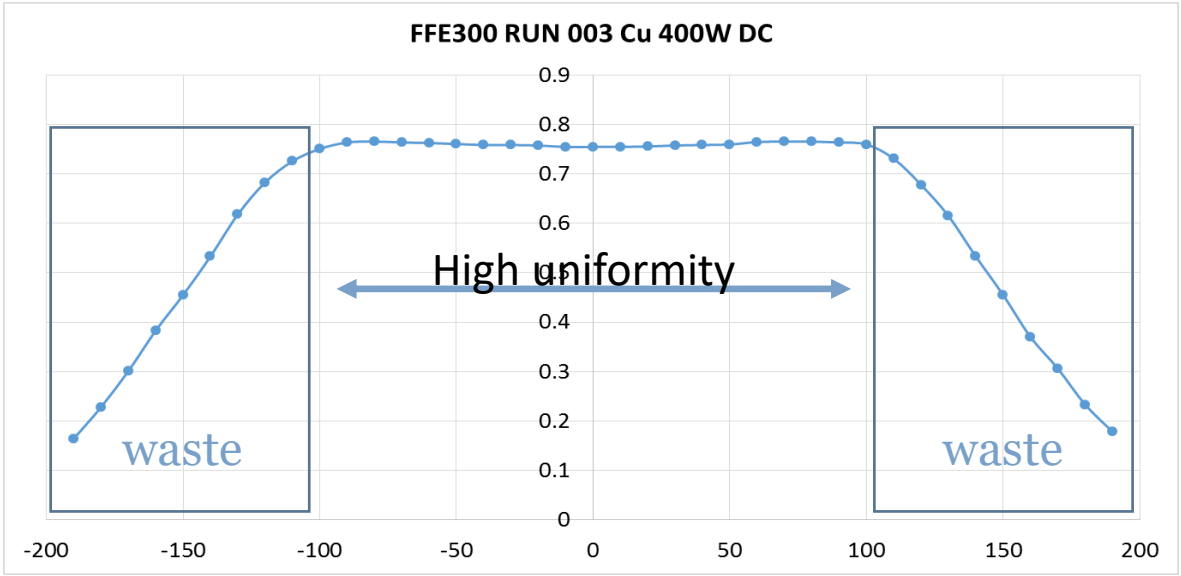


Benefit No 1

High rates & efficient material transfer from target to the substrate

For large diameter ffe targets, the separation to the substrate is very low – 60 to 75mm, hence **most material deposits on the substrate** and less wasted to the chamber walls.



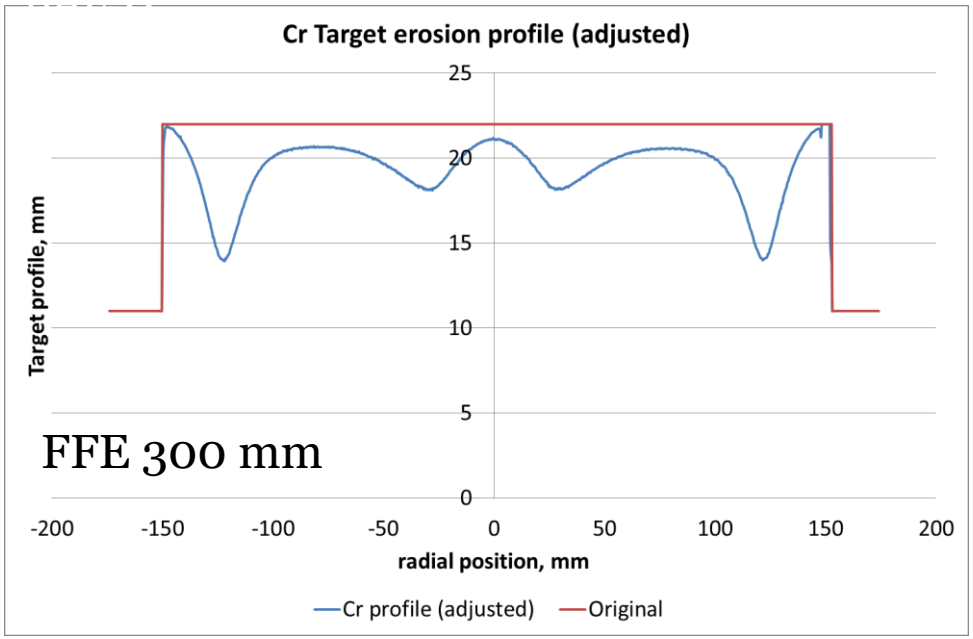


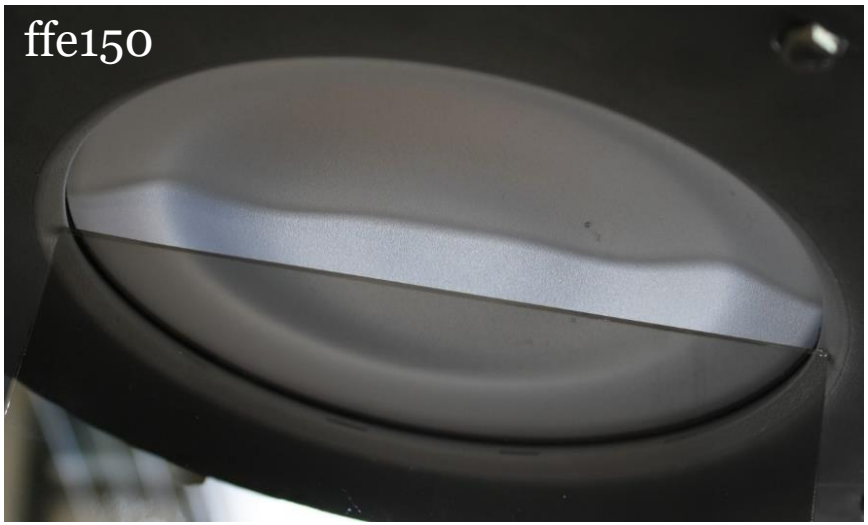
Benefit No 2

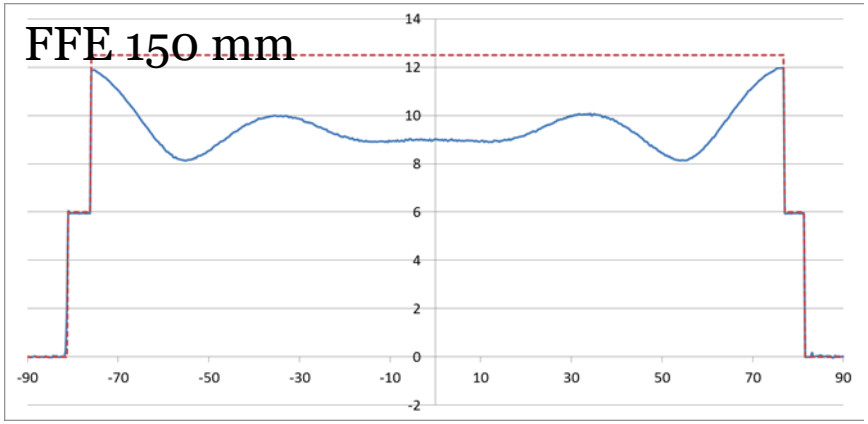
Efficient material use – high target erosion efficiency

Moving the plasma enables a **high target erosion efficiency**, smaller FFE's have up to 70% material usage – saving cost

Coating uniformity can also be prioritised in larger ffe's, array refined to reduce central sputter



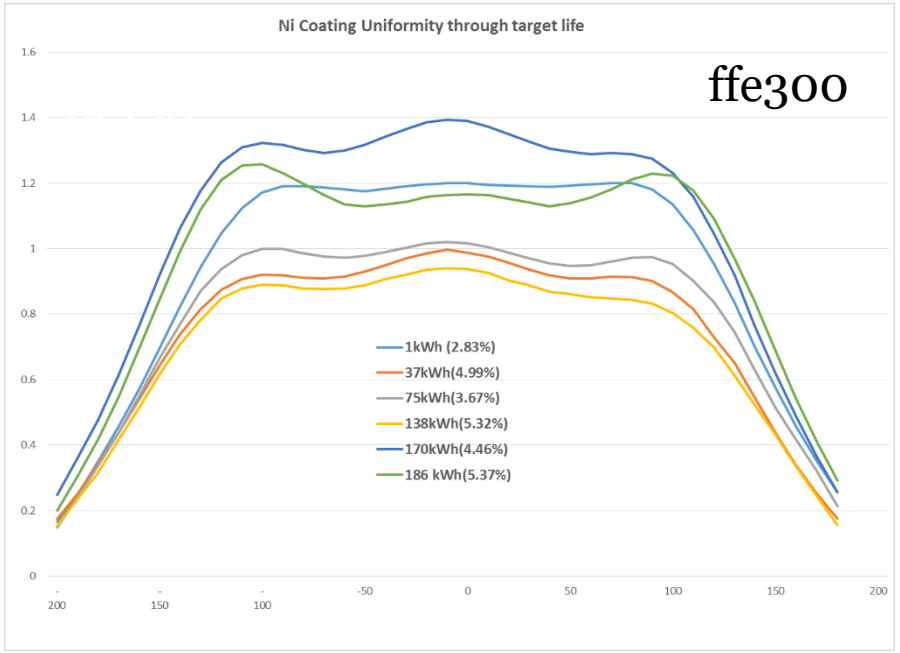




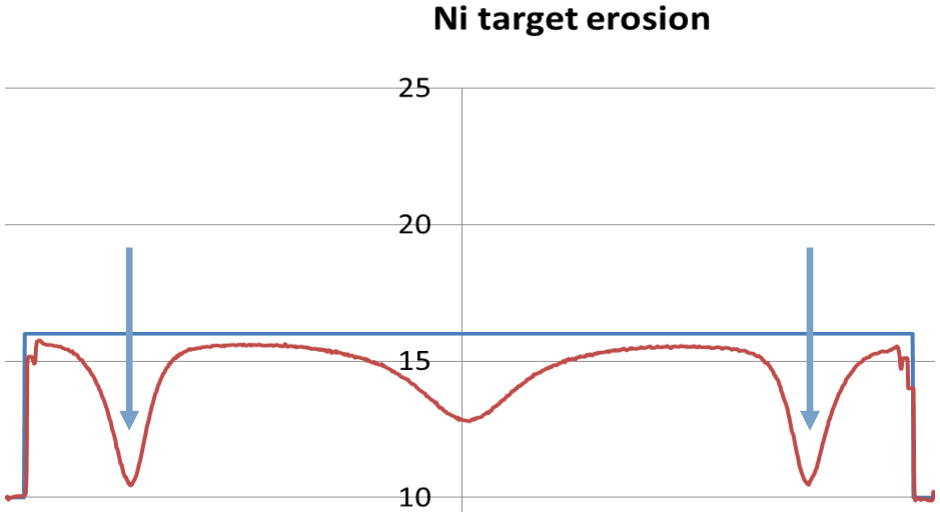
Benefit No 3

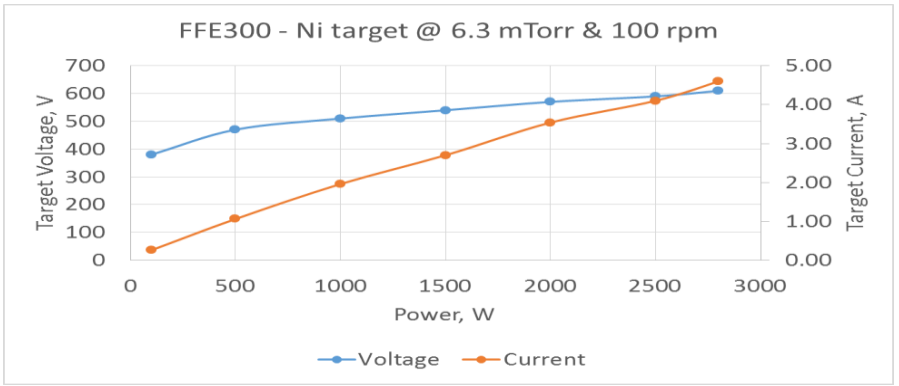
Handling problematic ferromagnetic target materials

Moving a high strength magnet pack reduces the '**magnetic pinching**' which results when sputtering ferromagnetic target materials improving target use and uniformity through life. Defects are also reduced as no magnetic re-deposit flakes are present on a cleanly eroded target surface.



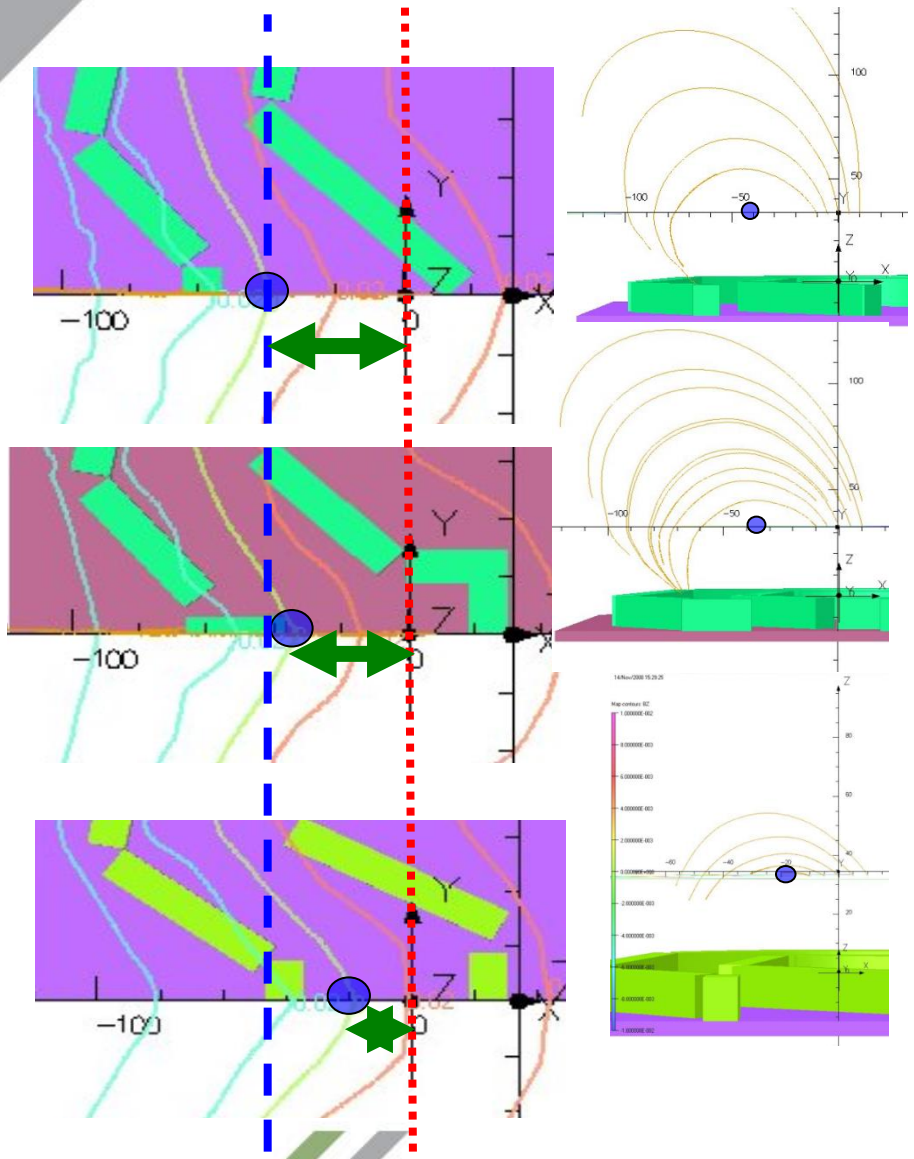
Non FFE target erosion

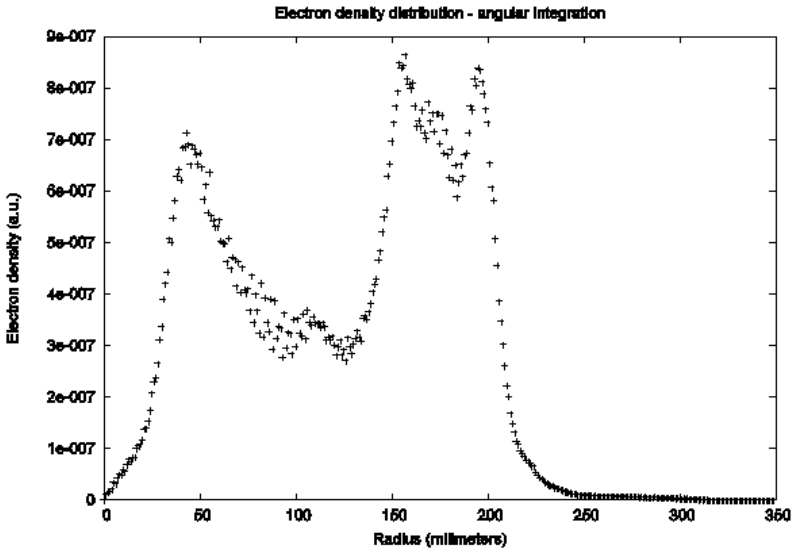


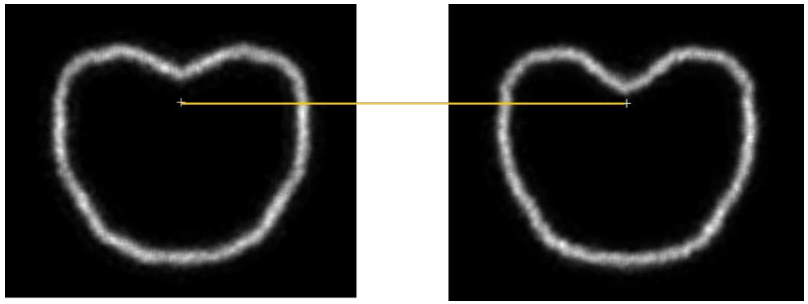


Benefit No 4 high uniformity

The design of magnetic geometry in relation to the rotation centre creates a high uniformity

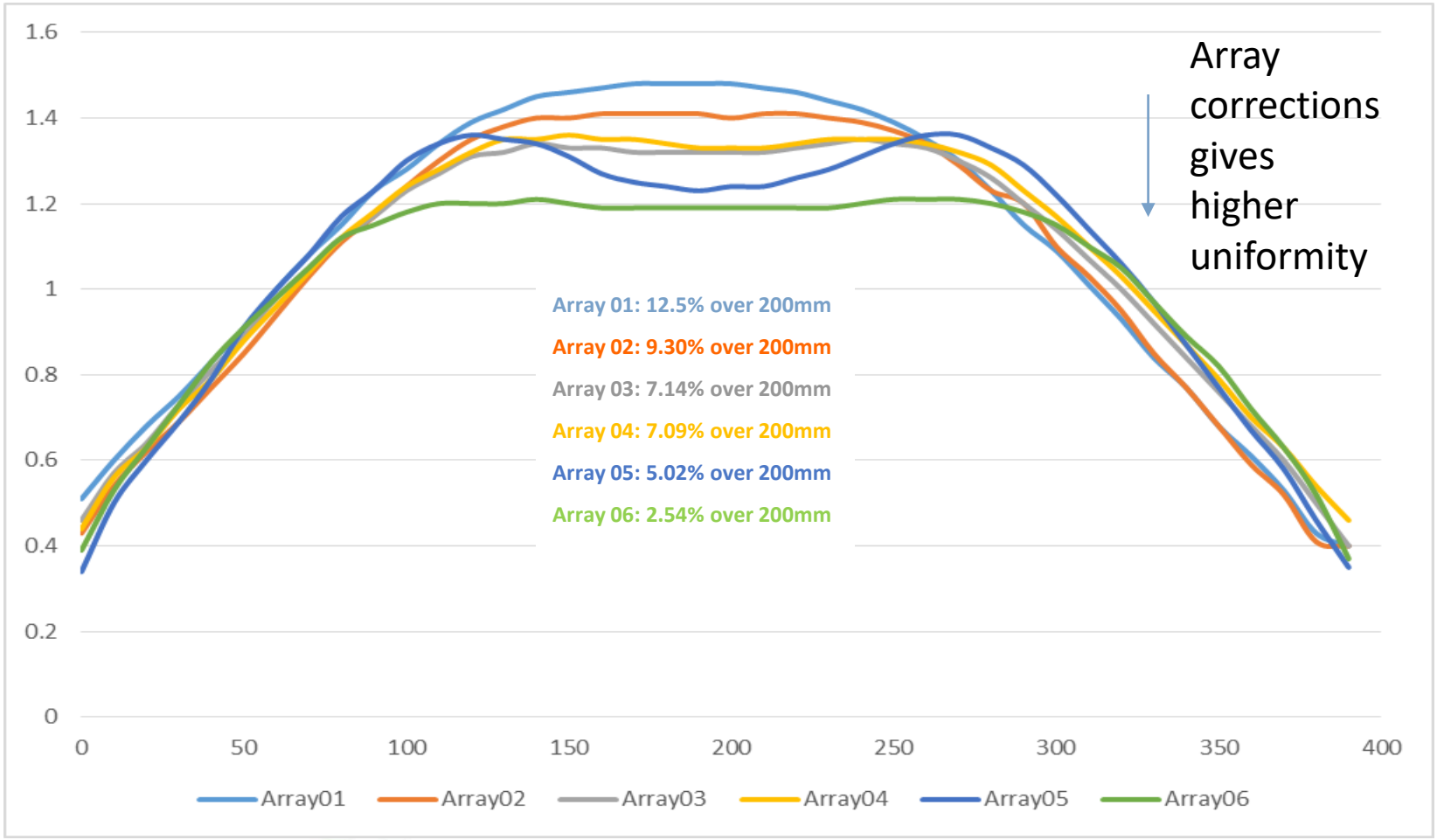






Benefit No 4 high uniformity

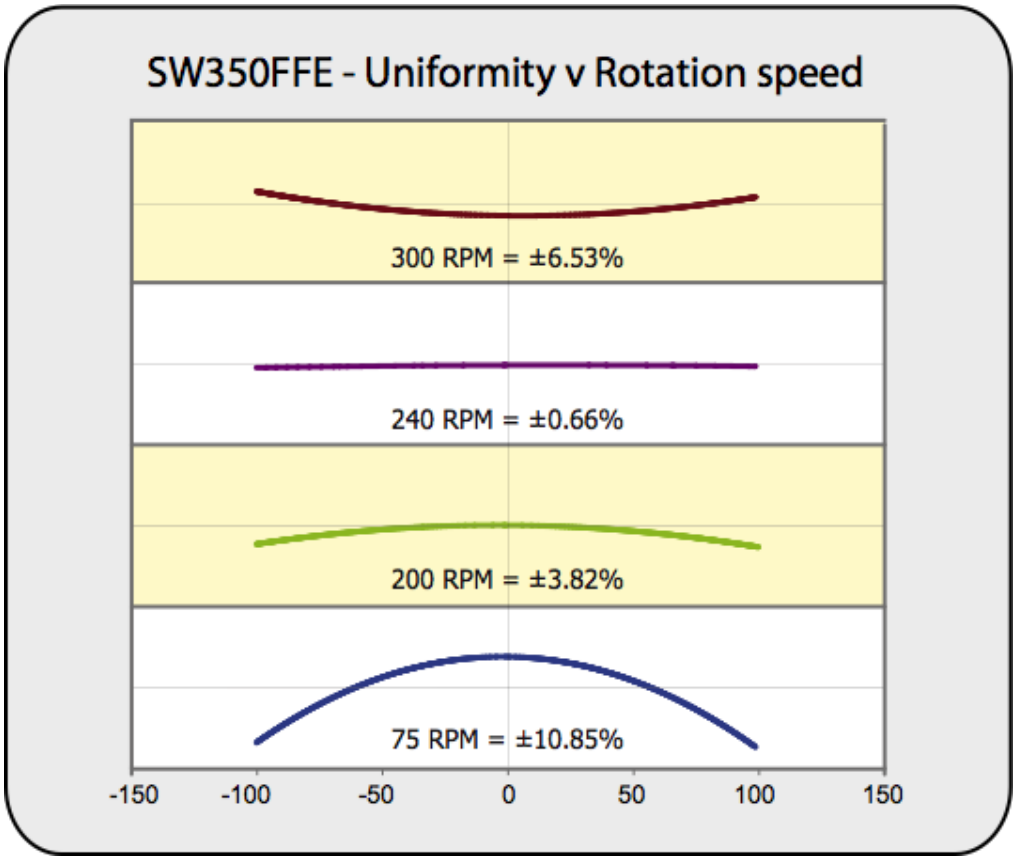
The design of magnetic pack & rotation creates a high uniformity – as seen below by changing the design of the magnetic array, the uniformity is adjusted and optimised

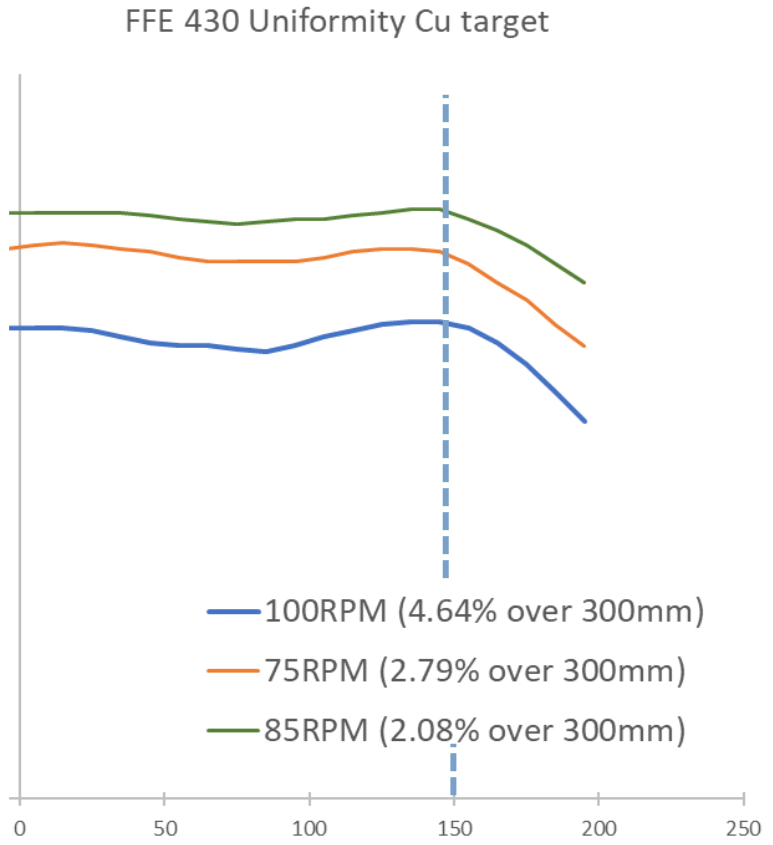


Benefit No 4 high uniformity

The adjustment of the speed of rotation

The speed of magnetic array rotation can adjust the uniformity in order to tune for different target material types or uniformity changes as the target erodes

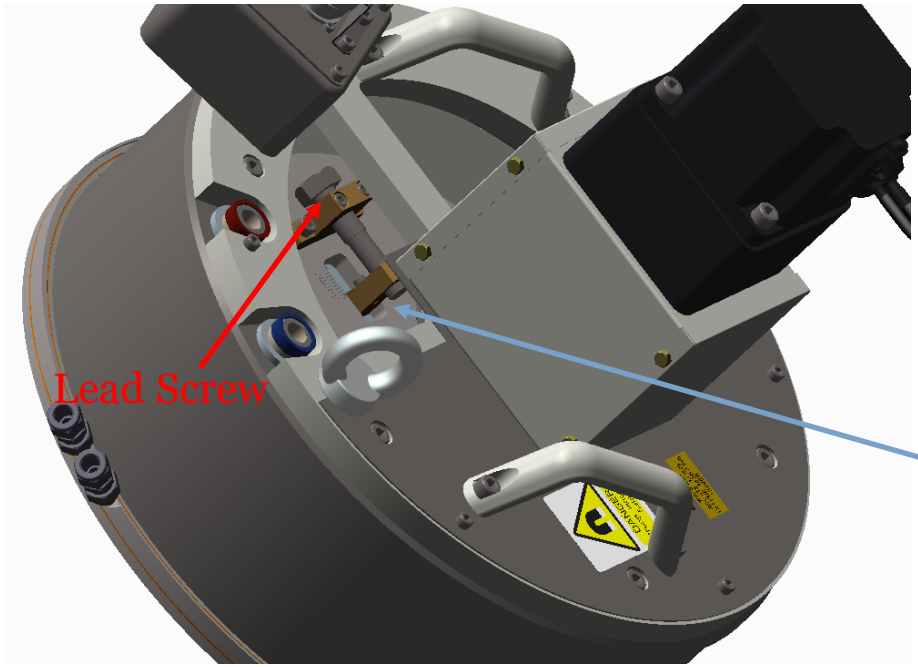


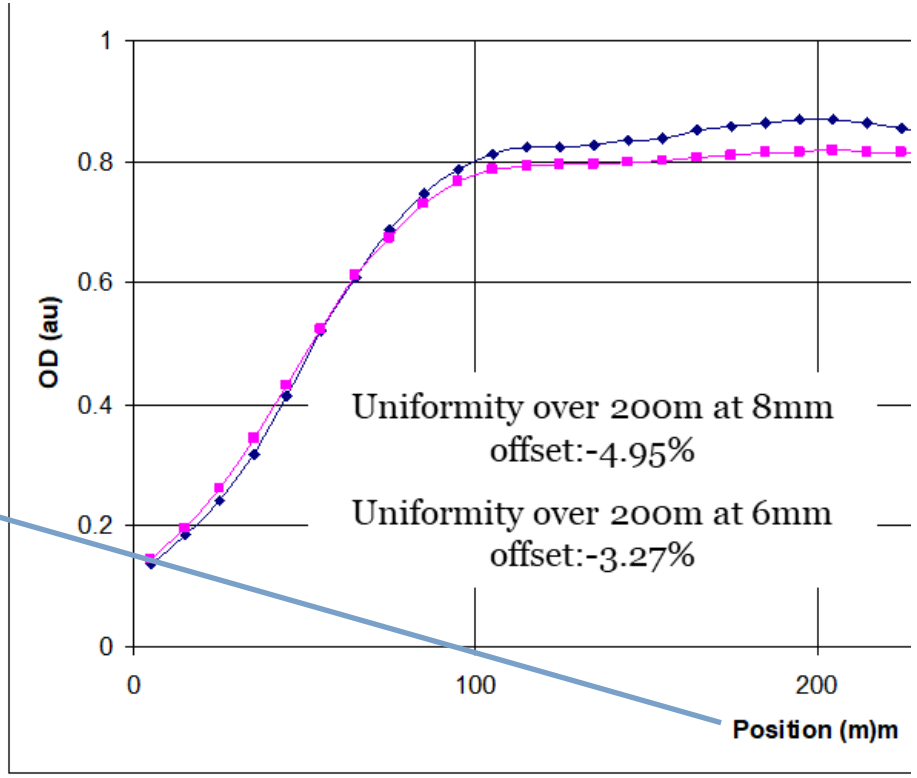


Benefit No 4 high uniformity

The adjustment of the position of the magnetic array offset location

The radial offset of the array can produce a tuning of the uniformity



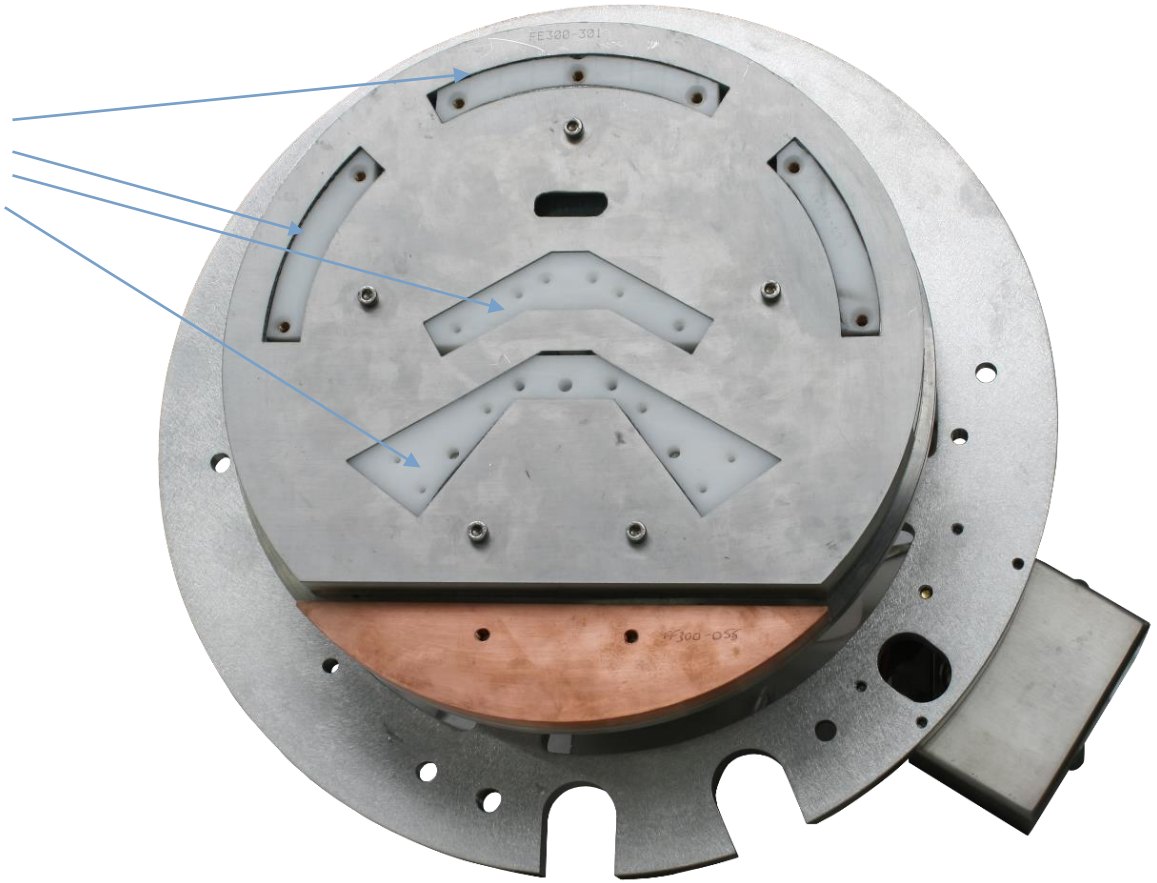


Benefit No 4 high uniformity

The adjustment of the magnetic array by shunt location to adjust uniformity trend

The ffe magnetic arrays have location for magnetic shunt insertion as a convenient way to adjust the magnetic design without having to change magnets

Strategically placed shunts will produce changes to the magnetic field profile over the target surface and hence the resulting plasma control and uniformity

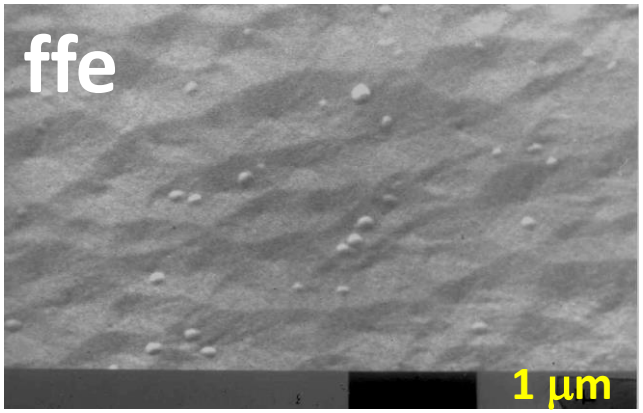


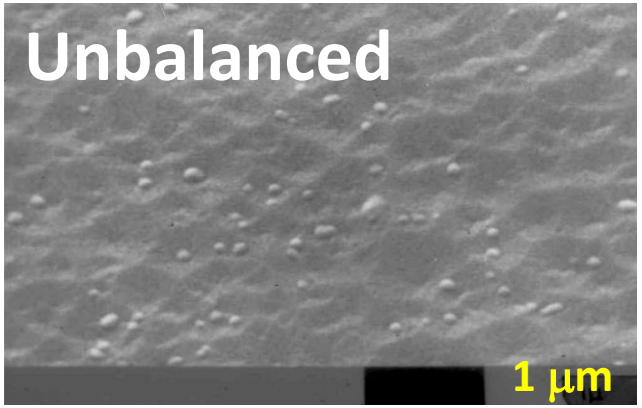
FFE Benefit No 5
High quality films – low defects

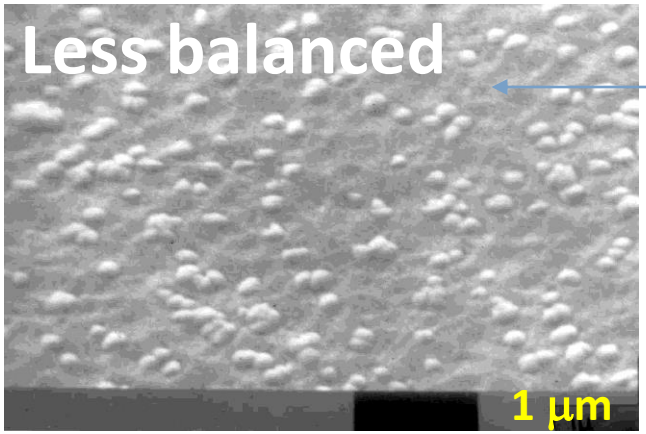
The biggest benefit for microelectronics of using the ffe method is the zero defects in the films as a result of the clean target and the coating redeposit away from the target avoiding process 'dust'

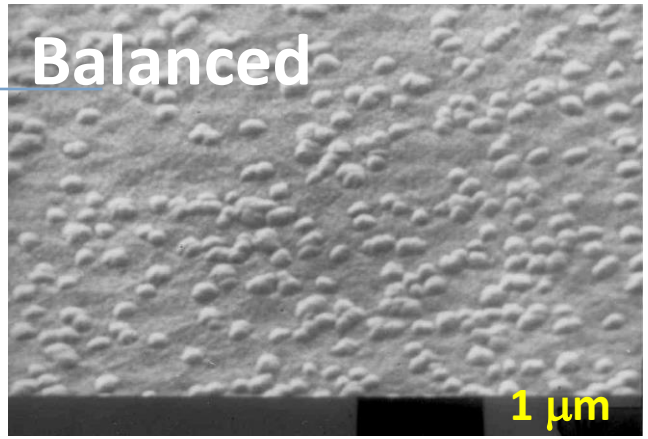
The SEM images to the right are of reactively deposited TiO2 films by pulsed DC power with a convectional (non-ffe) magnetron with differing amounts of re-deposit on the target surface, the cleaner the target the fewer the defect count.

FFE (top left) deposited layers are defect free making them ideal for all applications and precision optical layers



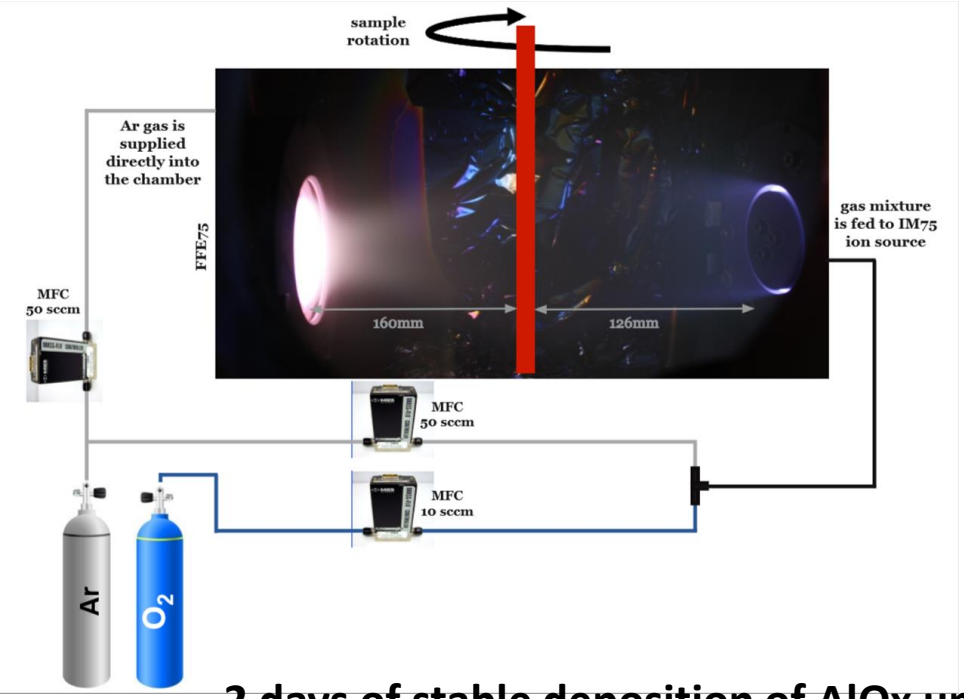


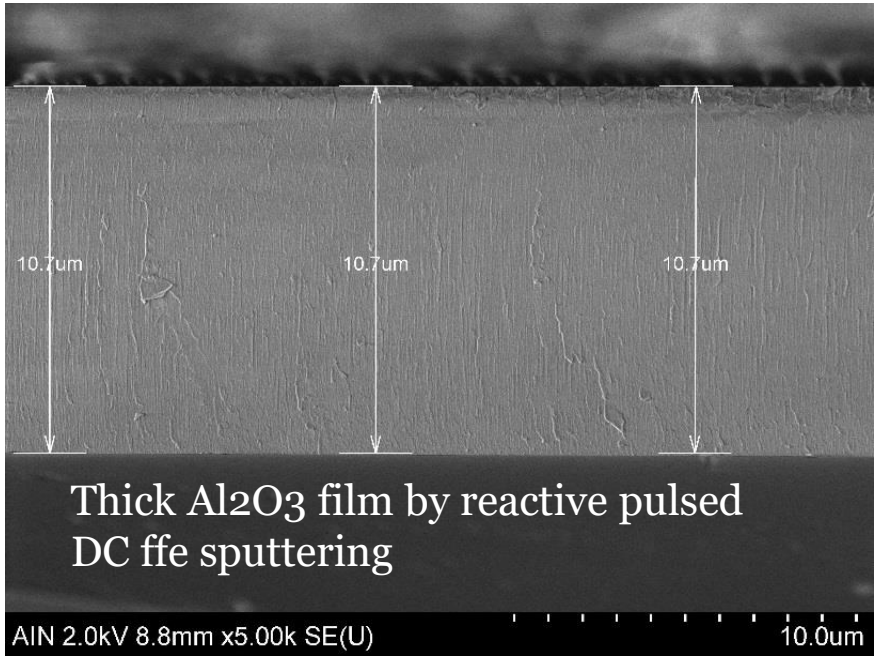




FFE Benefit No 6
Reactive dielectrics from a single target

The clean target erosion even in reactive mode means that the target is in a metallic state, and arcing is avoided during the deposition. Non-ffe magnetrons will develop plasma arcs rapidly on the target as the redeposited dielectric layer on the target charges up. **FFE magnetrons can run for days without instability.**



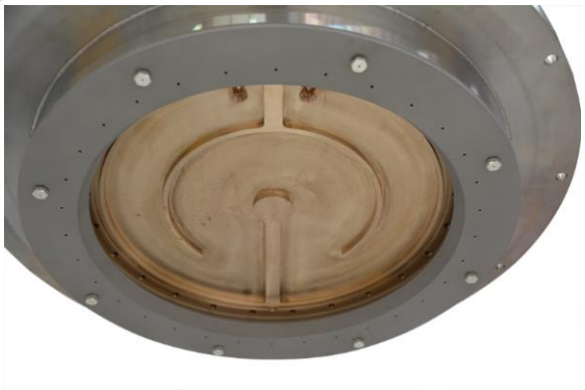


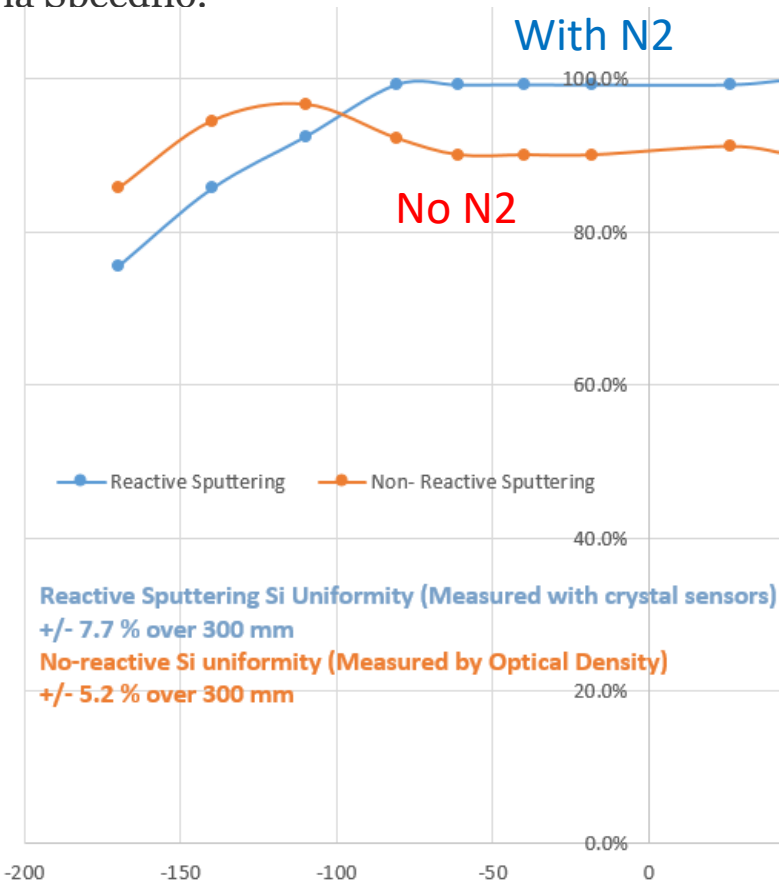
2 days of stable deposition of AlOx under feedback control

FFE Benefit No 6
Reactive dielectrics from a large single target

The clean target erosion can be combined with reactive gas injection close to the target and a hidden anode to provide stable deposition of compound layers from metallic targets. Typically the use of a reactive gas will **require adjustments to magnetic array to correct for the effect of the gas on the uniformity profile**. Equally important is sensing and fast reactive gas feedback control via Speedflo.

Example of change in distribution of coating with addition of N2 gas and Si sputtering. The edge drop-off needs to be 'counteracted' by magnetic changes / tuning



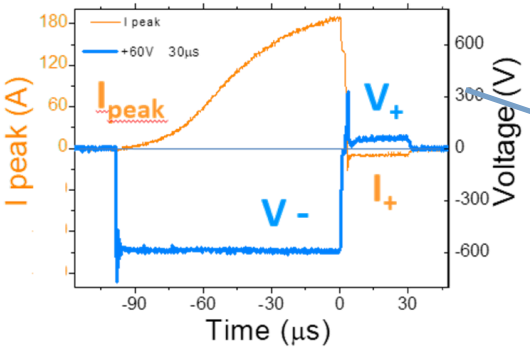


Reactive Sputtering Si Uniformity (Measured with crystal sensors)
+/- 7.7 % over 300 mm
No-reactive Si uniformity (Measured by Optical Density)
+/- 5.2 % over 300 mm

FFE Benefit No 7
HiPims & HipV3+

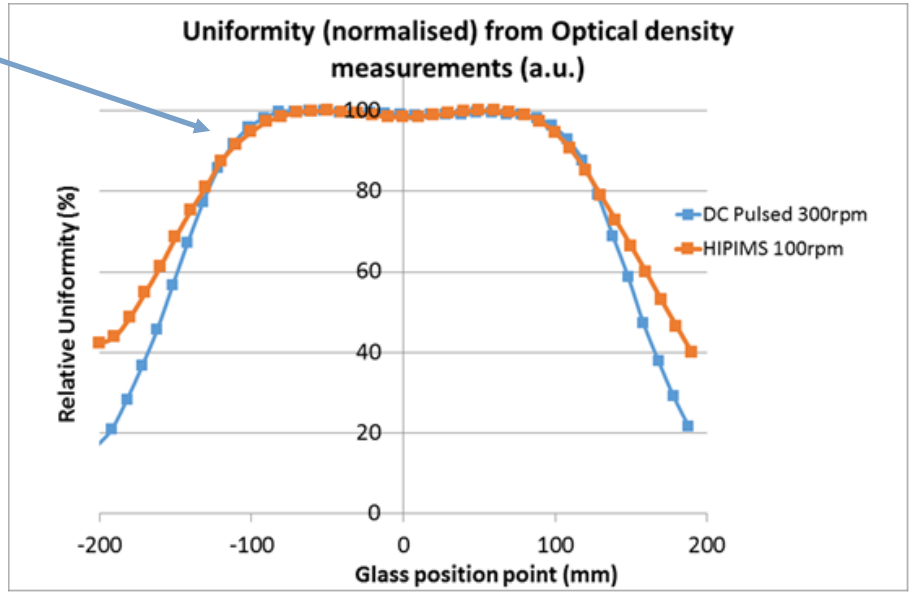
The clean target erosion and moving plasma is an ideal environment for the Hipims Power method as the clean target allows higher currents without the risk of arcs and plasma instability

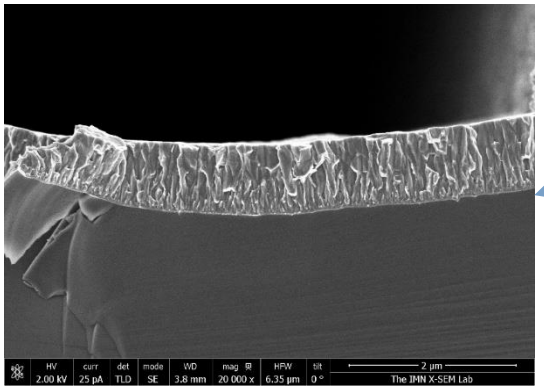
HIPIMS

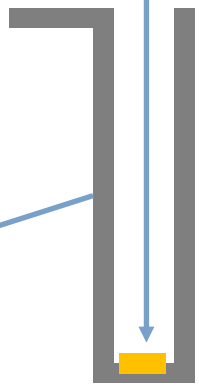


1. Ionised metallic coating – highly directional

2. Varying rotation speed to give DC pulsed uniformity with HiPIMS pulse







Ti layer, 5kW HipV+
12µm wide trench,
aspect ratio 12.5

Gencoa FFE for clean target sputtering benefits on a small or large scale


ffe430


ffe300


ffe100


ffe150


ffe75


ffe200


ffe150

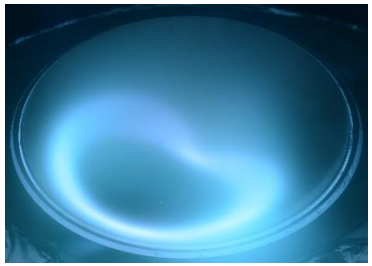
Uniformity control and tuning

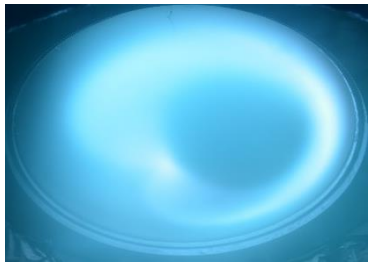
• Large FFE sources have excellent uniformity results & the ability to tune via various methods to adapt for different target materials and processes:

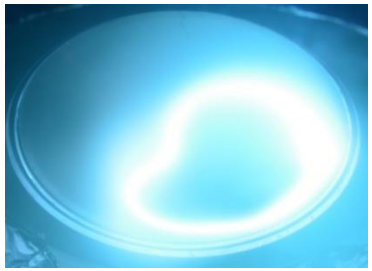
1. The design of magnetic pack & rotation creates a high uniformity
2. Adjustment by varying rotational speed of the array (50-450 rpm)
3. Adjusting position of the magnetic pack relative to the central axis of rotation – mechanical change
4. Use shunts to tune magnetics – mechanical change

Summary of the advantages of a clean sputter target for high quality sputtered layers

- Inherently better films due to smooth layers/few defects and good density
- Ability to tune film uniformity by magnetic and geometric adjustments
- Slow to fast rotation of the magnets provides:
  - **Uniformity tuning ability** via speed control
  - **Better arcs suppression** – less time for charge-build-up at higher rotation speeds
  - **Few layer defects** from arc events
- Same magnetic pack suitable for different target materials by using offset and speed control (non-magnetic targets)
- Suitable for long term reactive deposition and HiPIMS processes







Thank you for your attention
Please come to booth 413