The Full Range of Magnetic Array Options for Planar Magnetrons – Too Much Choice?

Dr Dermot Monaghan, Gencoa Ltd, plus 25 years of help from Victor Bellido-Gonzalez & Robert Brown
26 Years of Products and Technology from Gencoa

- Rotatable & Planar Magnetron Sputter Cathodes
- Retrofit magnetic packs
- Plasma Treaters
- Speedflo Reactive Gas Controllers
- IM Ion Sources & power supplies
- Arc MAX sources & power supplies
- Active Anodes and Gas Delivery Bars
- OPTIX Gas and Chemical Sensing
- S and Se Sensor
- PEC Pulsed Effusion Cell
- V+ DLC - Transparent DLC
- IC Nano antimicrobial layer technology
- Process implementation & tuning
Rectangular planar magnetrons offer a wide range of magnetic array choices

*All offer different process advantages – the ‘devil’ really is in the detail*

- Not just a case of offering the highest target use. Other important elements to consider are:
  - Target cleanliness
  - Reduction in defects (within the coating)
  - Power mode of operation (DC, MF, RF, Hipims)
  - Pressure of operation (low or high)
  - Desired voltage of operation (low or high)
  - Layer uniformity
  - Energy required for the growing film – extra impact for decorative and hard coatings
  - Interaction of the magnetic field lines with the anodes, substrates and vacuum chamber components
  - Heat tolerance of substrates
  - Is the target ferromagnetic?
  - Budget
To create an optimum magnetic design and magnetron performance, 2D and 3D modelling is combined with plasma testing and analysis of the target erosion, layer uniformity and the thin film properties – it's an iterative process.
This is a summary of the magnetic options (arrays) developed by Gencoa for rectangular planar magnetrons over the last 26 years

All offer different process advantages – the ‘devil’ really is in the detail

<table>
<thead>
<tr>
<th>Array Code</th>
<th>Schematic</th>
<th>Key Advantage</th>
<th>Description</th>
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<tr>
<td>SW (LS – SS – HS)</td>
<td><img src="SW.png" alt="Schematic" /></td>
<td>Simple with strength options</td>
<td>Sputter Wall, 2 pole balanced</td>
</tr>
<tr>
<td>PP (SS - HS)</td>
<td><img src="PP.png" alt="Schematic" /></td>
<td>Extra process energy</td>
<td>Plasma Plume, 2 pole unbalanced</td>
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<tr>
<td>Hy</td>
<td><img src="Hy.png" alt="Schematic" /></td>
<td>Higher target use</td>
<td>High Yield, multi-pole magnetics</td>
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<td>XH</td>
<td><img src="XH.png" alt="Schematic" /></td>
<td>Highest target use, clean</td>
<td>Extra High, moving magnetics</td>
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<tr>
<td>LOOP</td>
<td><img src="LOOP.png" alt="Schematic" /></td>
<td>Thick ferro-magnetic targets</td>
<td>LOOP magnetics and target design</td>
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<tr>
<td>Mz (Hy)</td>
<td><img src="Mz.png" alt="Schematic" /></td>
<td>Long lifetimes for metal targets</td>
<td>Metallizer for machinable materials</td>
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<tr>
<td>VT</td>
<td><img src="VT.png" alt="Schematic" /></td>
<td>Variable balance and strength</td>
<td>Vtech independent pole movement</td>
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<tr>
<td>VT-R</td>
<td><img src="VT-R.png" alt="Schematic" /></td>
<td>Variable ion bombardment</td>
<td>Vtech rotation of auxillary poles</td>
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<td>VT-Flex</td>
<td><img src="VT-Flex.png" alt="Schematic" /></td>
<td>Adapt strength to tune uniformity</td>
<td>Vtech flexibility for uniformity</td>
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<tr>
<td>VT-S</td>
<td><img src="VT-S.png" alt="Schematic" /></td>
<td>Field strength and voltage tune</td>
<td>Vtech simple retraction of array</td>
</tr>
<tr>
<td>HU</td>
<td><img src="HU.png" alt="Schematic" /></td>
<td>Ability to improve layer uniformity</td>
<td>High Uniformity – array fine tune</td>
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</table>
SW Sputter Wall & PP Plasma Plume 2 pole magnetics
Offer excellent plasma control in different strength and balance

Lowest cost of magnetron, target use around 30%, clean target in non-reactive mode, strength and magnetic balance / unbalance can be tuned widely – flexible process setup

SW – Sputter Wall
Interacts with the anode to limited plasma release in order to reduce energy and heating of the substrate

PP – Plasma Plume
Avoids interaction with the anode to increase plasma release in order to enhance energy of bombardment of the substrate
High Yield HY type multipole magnetic arrays yield for 40-50% target use

High Yield magnetics use 7 or 8 lines of magnets in order to create a flatter magnetic field over the target surface. This produces a wider and flatter erosion track. The voltage change with lifetime is less and the target remains cleaner with reactive sputtering.
High Yield HY type multipole magnetic arrays yield for Hip³

High Yield magnetics produce much fewer defects when Hipims power is deployed.

Very long deposition runs with Hipims power results in defects from arcs as the target re-deposit builds up. The HY target is ‘cleaner’ and hence less arcing over time. XH is another potential solution.

For example, Hip 12µm TiAlN in 15hrs run with no difficulty, and the same for TiN & TiSiN.

12µm TiSiN with 40GPa hardness on micro-tool for Ti machining
Metallizer for 100% increase in up-time – thicker profiled targets, hidden anode

Mz metallizer cathodes use the target top profile combined with the magnetic field shape to double the target life and produce a clean target for low defect films at high power densities.
The problem of sputtering a ferromagnetic target material is a result of the magnetic field being absorbed within the target and hence limiting strength over the target. This means a thin target and low target use due to ‘pinching’ as the target erodes. Looping the field over the target means much thicker targets can be used upto 4mm for pure iron and 10mm for nickel as examples.

**Loop** combines a very high field strength with a specific target design to project the magnetic field over the target surface to avoid saturation within the target material.
**eXtraHigh Magnetron** Maximises the target erosion from planar magnetron targets

**XH** uses a motor to drive the magnet pack side to side to make a flat erosion profile on the target.

The Genco XH150 type magnetron uses a 150mm wide target with a thickness of up to 20mm. The XH magnetics increases the target use up to 75% for bonded targets and 65% for thick mono-block style targets. Also produces a clean target surface, hence fewer coating defects.

7 mm erosion depth
12 mm erosion depth
Vtech varies field strength, shape and balance/unbalance to optimize plasma properties during the coating process.

The original VTech moves the inner and outer pole independently in order to vary the ion assistance of the process or the field strength over the target (or both combined).

Varying of the ion current is beneficial for ‘batch’ processes where a varying level of bombardment improves over layer performance and adhesion. It’s the ultimate research and development tool as all the magnetic field parameters can be adjusted and the effect on the layer properties studied.
Gencoa Planar Magnetrons - Vtech varies field strength, shape and balance/unbalance to optimize plasma properties during the coating process.

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Vtech R varies field shape and balance/unbalance to optimize plasma properties during the coating process.

The VT-R changes the degree of balance and unbalance via rotation of two auxiliary magnetic poles on the rear of the cathode – lower cost and faster action than the original VTech.
VT-R varies field shape and balance/unbalance to optimize plasma properties during the coating process.

Ability to change the ion bombardment is beneficial for batch processes where high bombardment is needed for substrate pre-cleaning and hard coating, and lower bombardment for low friction layer optimisation.

- No VT-R fitted
- VT-R most balanced
- VT-R most unbalanced

Adjusted via external magnetic poles either manually or motor adjusted.
**VT-R** adjustment of ion current at the substrate via VT-R position

Single cathode substrate currents from 10 to 32 Amps

**Tailoring coating ion assistance**

**Strong UBM**

- \( I_{\text{Bias}} = 32\text{A} \)
- \( I_{\text{Mag}} = 350\text{A} \)

**Balanced**

- \( I_{\text{Bias}} = 10\text{A} \)
- \( I_{\text{Mag}} = 350\text{A} \)
VT-Flex varies field strength locally on a magnetron target to adjust film uniformity.

The VTF has the ability to tune the magnetic field strength independently on small segments down both sides of the plasma racetrack. The different segments are adjusted by a manual digital locator that increases or reduces the field strength in the local region. The segments can be retracted or tilted in either direction, which allows smooth or ‘sharp’ changes in field strength over the racetrack.

The total flexibility allows uniformities of less than 1% to be achieved with relative ease. Adjustments can also be made during the process to correct shifts in uniformity with time.

The VTF magnetrons are particularly useful where high uniformity from large area RF sputtering processes are required. The more common DC and MF type power modes can likewise be adjusted to higher uniformity demanded from certain products.
VT-S varies field strength on a magnetron target to maintain the same target voltage from start to finish, or allow a switch from PVD to CVD type processes.

The VTS has the ability to adjust the magnetic field strength as the target erodes by retracting the whole magnetic array. This enables the target voltage to be set to a specific value which helps to reduce process drift and increase target use. For hybrid type PVD/CVD systems the magnets can be retracted to reduce stray fields in the chamber.
High Uniformity magnetic arrays are tuned to reduce the variation of the magnetic field to less than 2% over the linear part of the magnetron

100% of Gencoa magnetic arrays are scanned after assembly into the magnetron source as a quality control check. Standard field variations are in the ±2-3% range. HU magnetic arrays reduce the field variation by scanning and selecting each magnet before array assembly to reduce the field variations from individual magnets – rejecting magnets outside a certain range.

Coating Uniformity Plot: GRS75600PP magnetron for a 600mm long Cr target with 100mm target to substrate separation with DC power <±2% over 420mm

Lower magnetic field variations produce more uniform films
A wide range of optimized magnetic options available for all applications
Take your pick!

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<tr>
<th>magnetics</th>
<th>features</th>
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<td>SW</td>
<td>Standard optimised balanced 2 pole magnetics</td>
</tr>
<tr>
<td>PP</td>
<td>Standard optimised unbalanced 2 pole magnetics for ion assist</td>
</tr>
<tr>
<td>HY (SW or PP)</td>
<td>High yield multipole magnetics for &gt;45% target use</td>
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<tr>
<td>VT</td>
<td>VTech constantly variable system between SW and PP</td>
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<tr>
<td>FFE</td>
<td>Full face erosion for clean targets and low defects</td>
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<tr>
<td>LP</td>
<td>LOOP design for ferro-magnetic target sputtering</td>
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<tr>
<td>HS</td>
<td>High strength magnetics for low pressure &amp; low voltage sputtering</td>
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<tr>
<td>RF</td>
<td>Low strength magnetics for 13.52MHz sputtering</td>
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Gencoa planar magnetrons 26 years experience of enhanced plasma control & planar magnetron design and processes

A selection of ‘historic’ images from the archive from our first 15 years of operation
Rectangular magnetrons in ‘all shapes and sizes’
- Thank you for your ‘virtual’ attention