Controlling Sputter Processes by Optimizing Magnetic Filed Guidance and System Anode Interactions

D.Monaghan, V Bellido Gonzalez, Tommasso Sgrilli, Oihane Hernandez, Gencoa Ltd, UK
Ambiorn Wennberg, Ivan Fernandez, Nano4Energy, Spain

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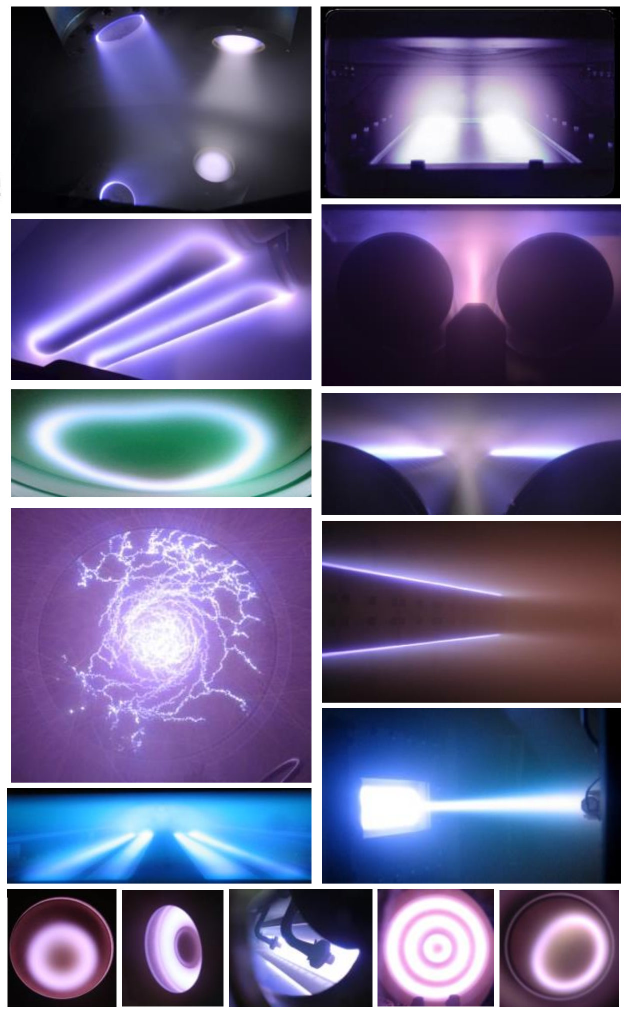

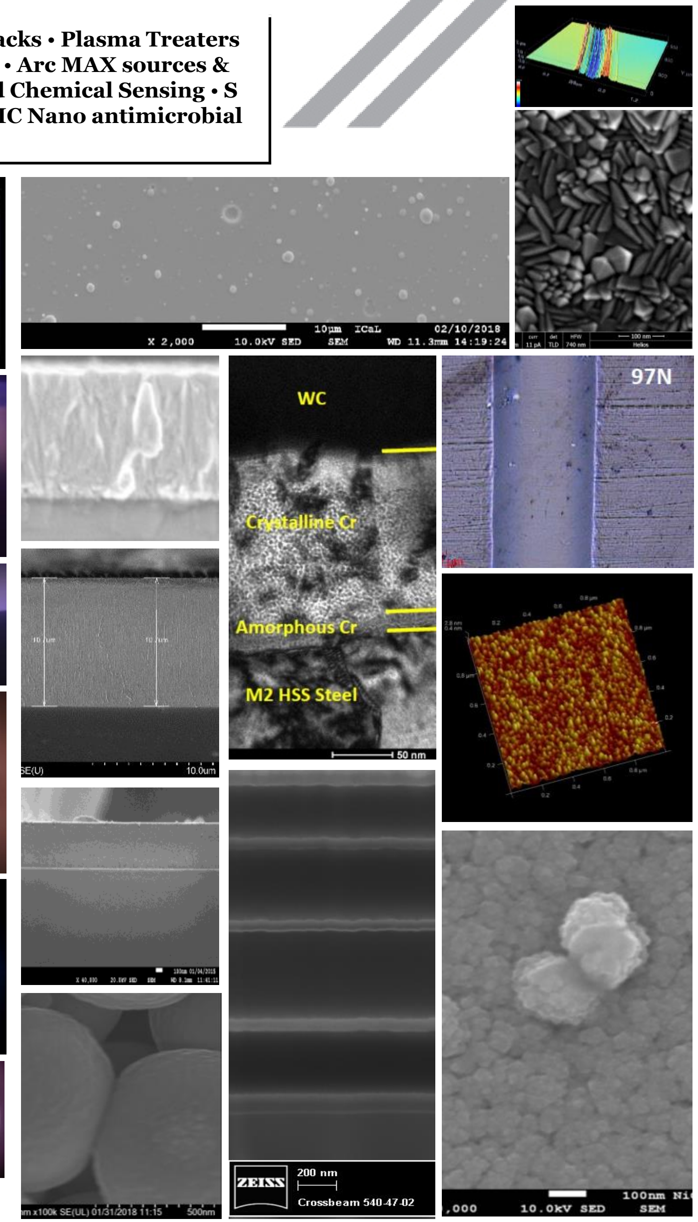

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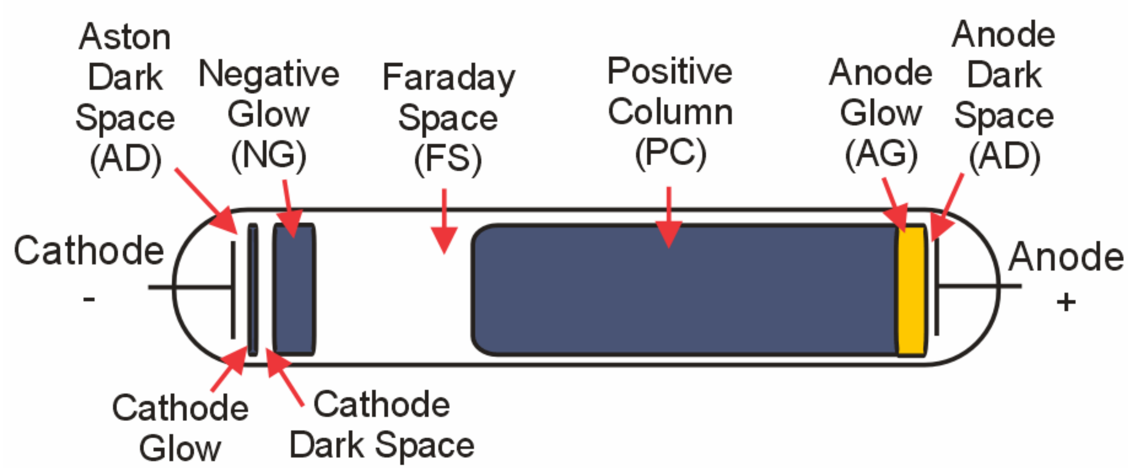
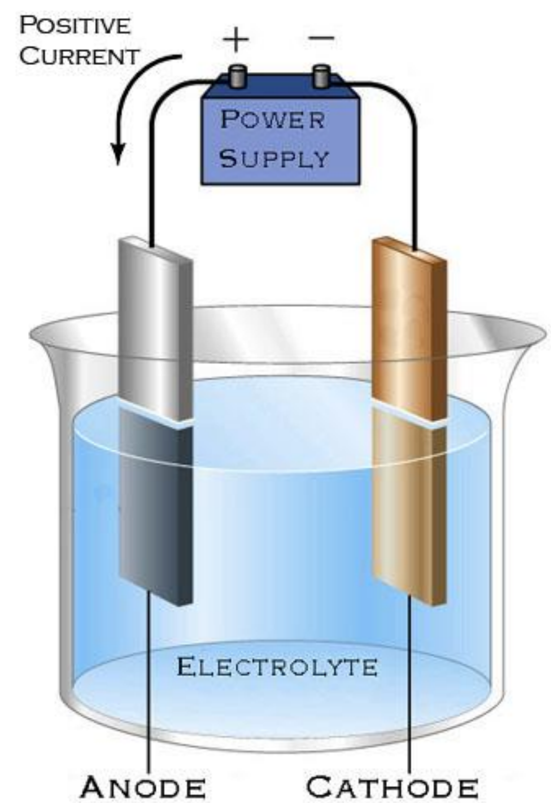
Active Anodes for magnetron plasmas

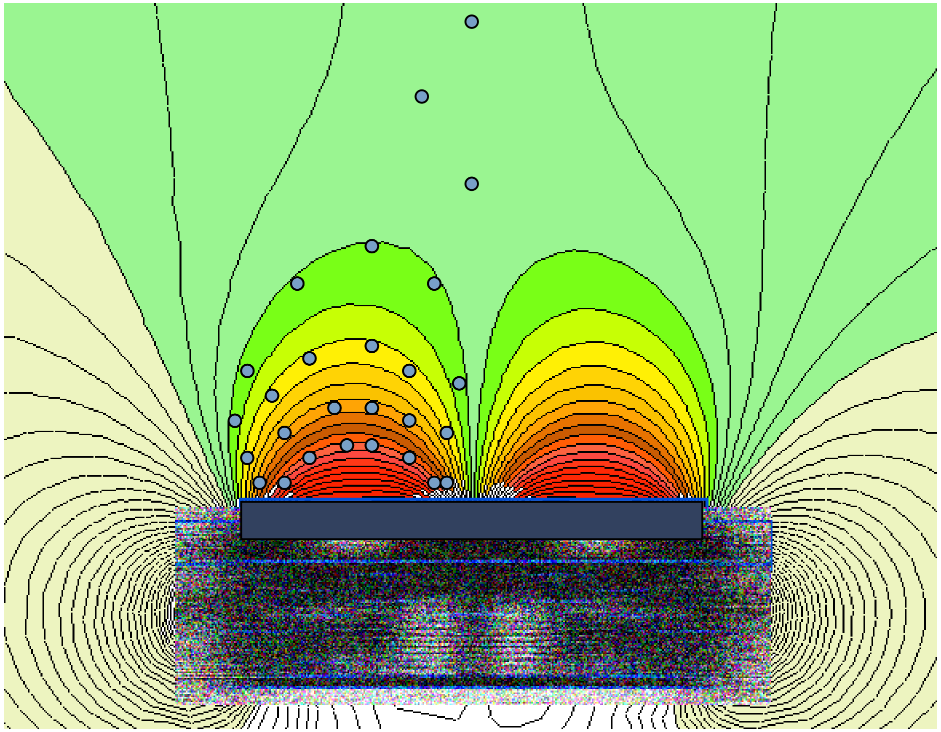
• A plasma is effectively an electric circuit with the target a negatively biased cathode and the chamber or separate mean providing the anode for the circuit return.

• Anodes are commonly earthed, although a positive charge is also possible.
• Whilst the plasma confinement in the near target area is governed by the magnetic field, the plasma spread away from the target is primarily an anode interaction effect.

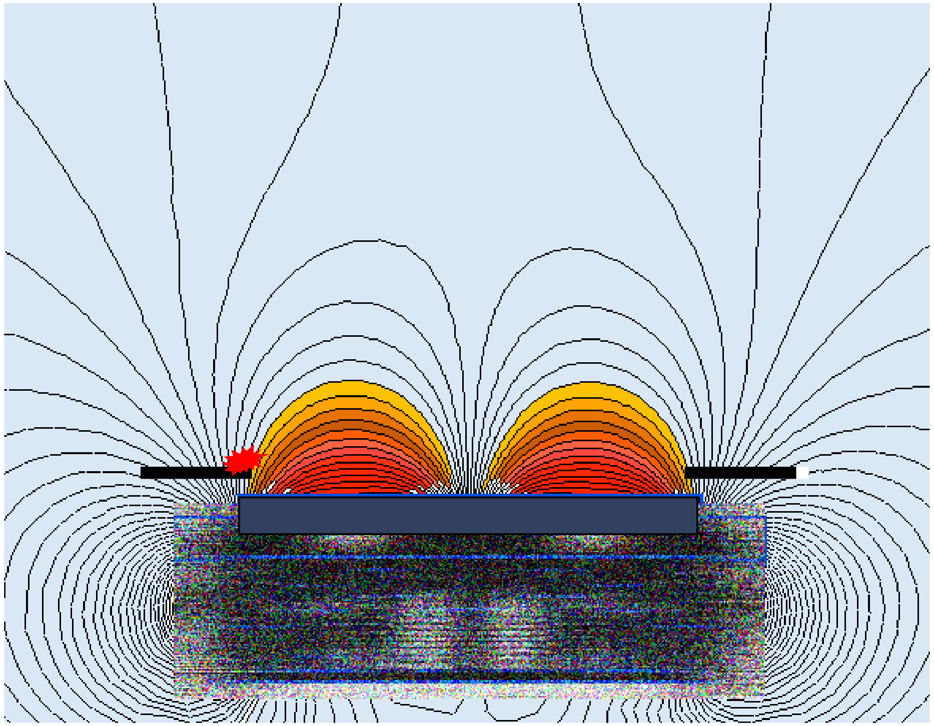




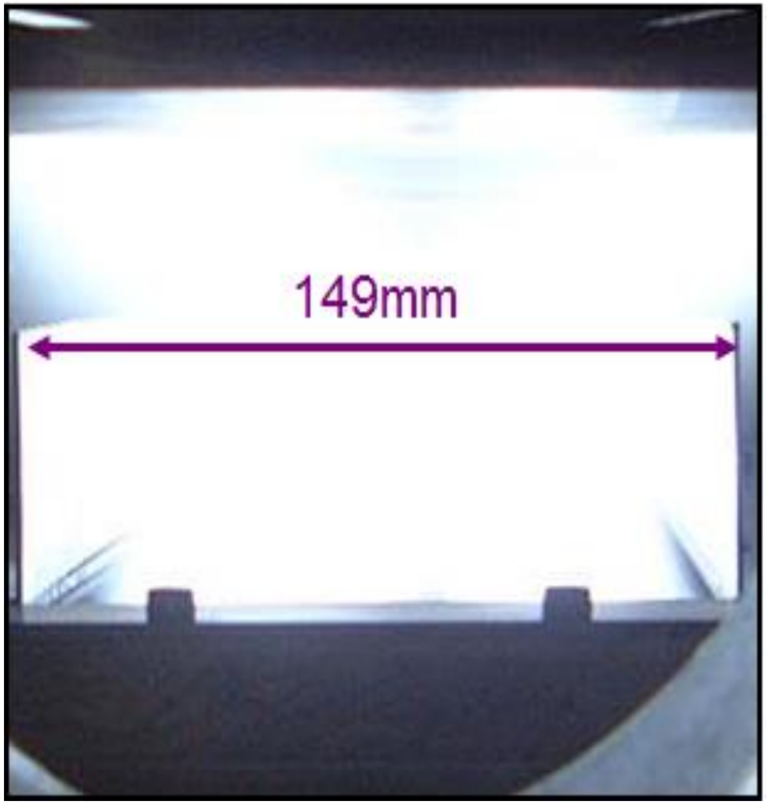
Electrons will spiral around field lines until enough energy is lost to escape the magnetic trap.

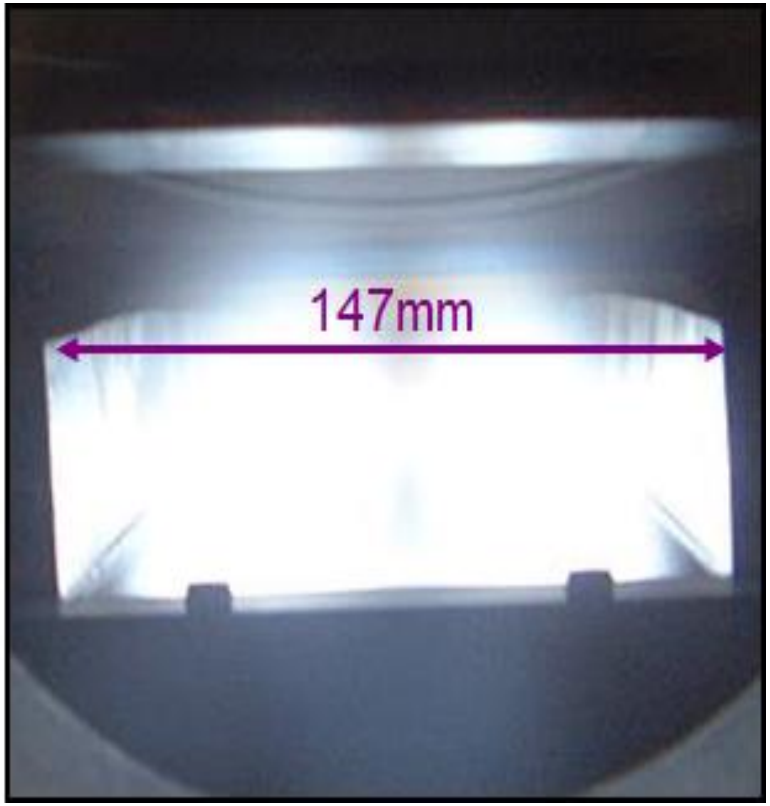


If an anode intersects a magnetic field line it will collect the electrons, so they are lost to the plasma and do not add to substrate heating

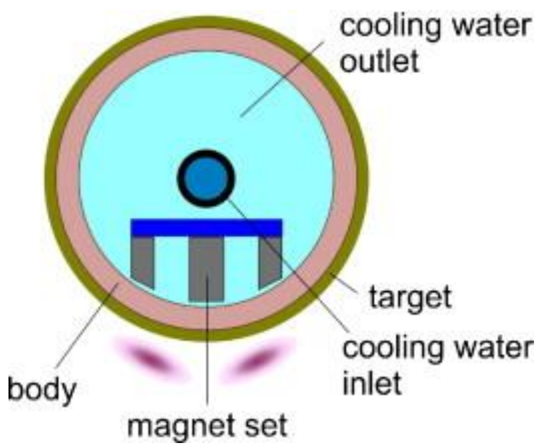


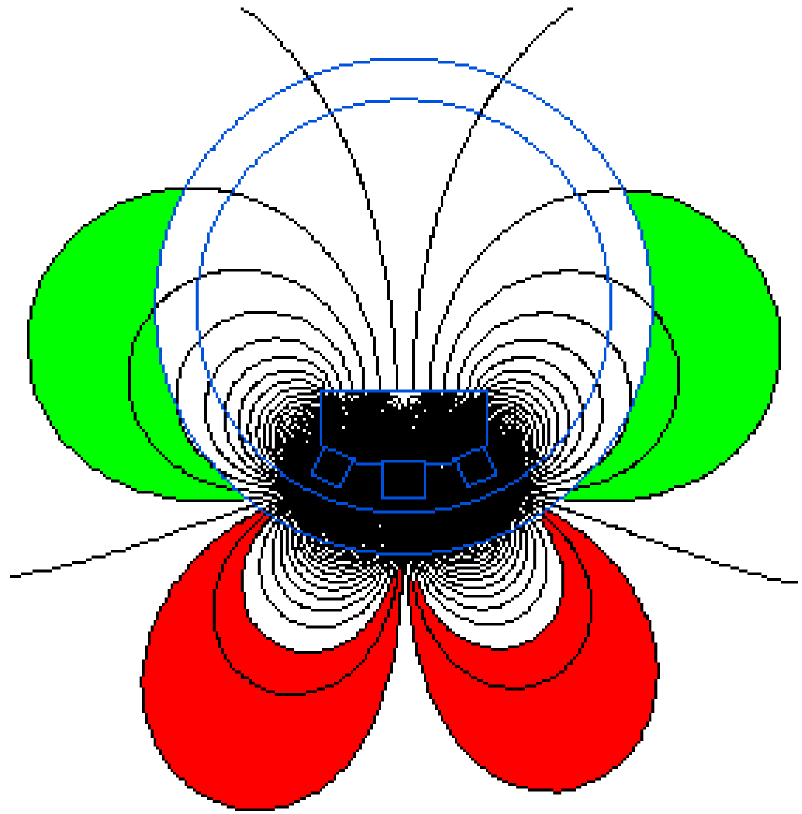
Comparison of the plasma expansion with an anode that intersects with the magnetic field and one moved just 1mm to avoid a magnetic interaction



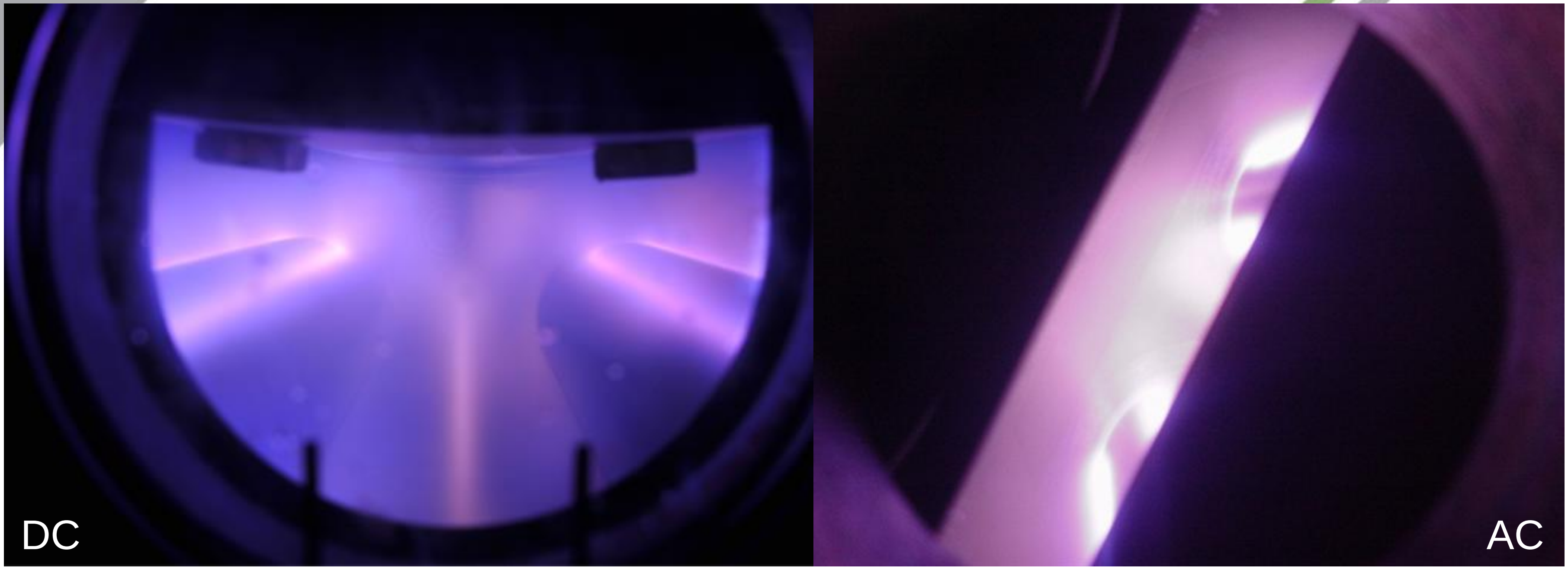


Whilst for a planar magnetron discharge and anode can be used to confine the plasma, typically for rotatable magnetron no anode is close-by



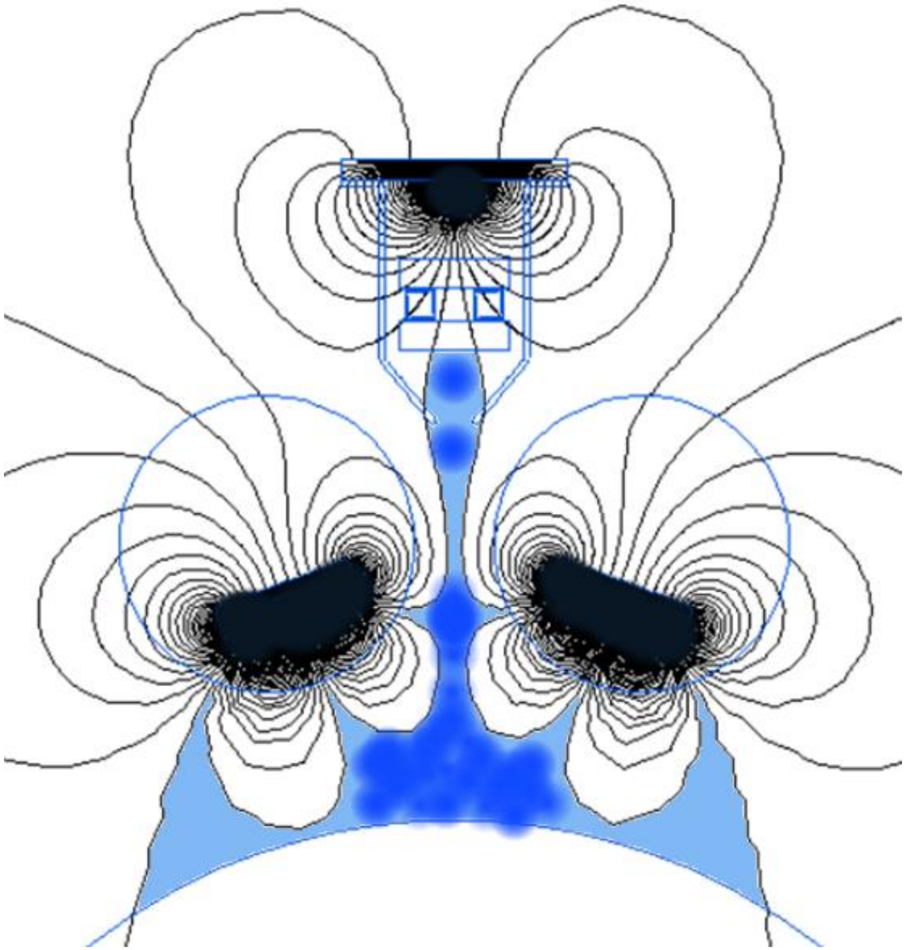


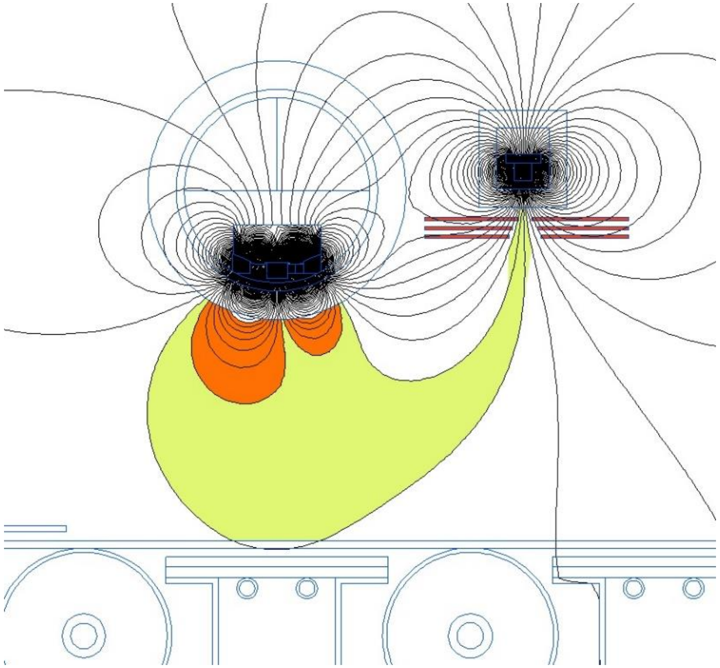
Absence of anode can be seen in a plasma spread away from the target area

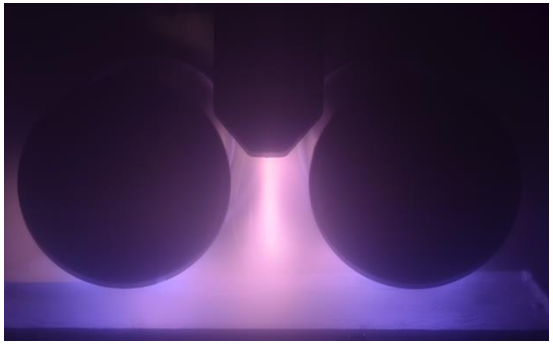


- A stable anode will prevent parasitic plasma's, process drifts / fluctuations, poor uniformity and instability.
- Anodes are most effective close to the target and intersecting with the magnetic field lines of the plasma trap (like a planar magnetron).
- Rotatables work better if no extra components are close to the target as they will become coated and products flakes and defects – this present a problem of where best to locate an anode.

Gencoa Active Anodes guide electrons for process stability and activates gas passing through the anode





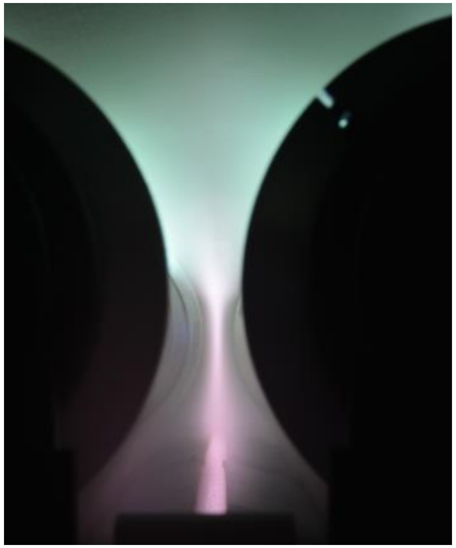
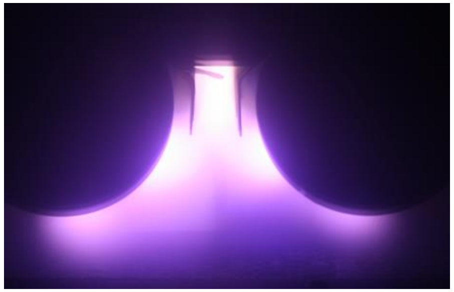
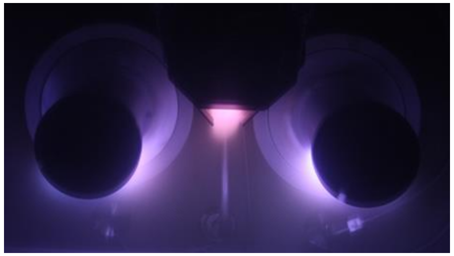
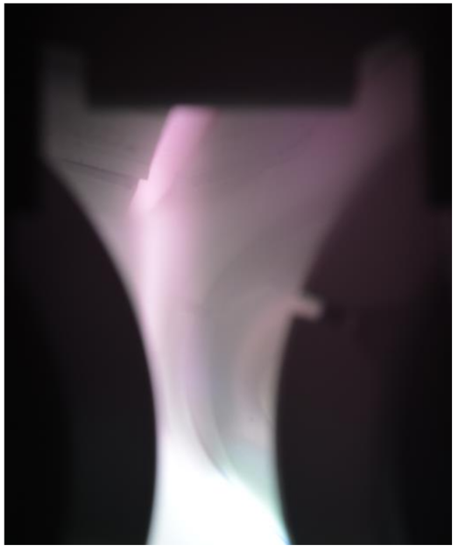


– covered by Gencoa's DLIM patent.

Gencoa have developed and patented a method to provide an effective anode away from the coating flux that can collect all electrons escaping the plasma

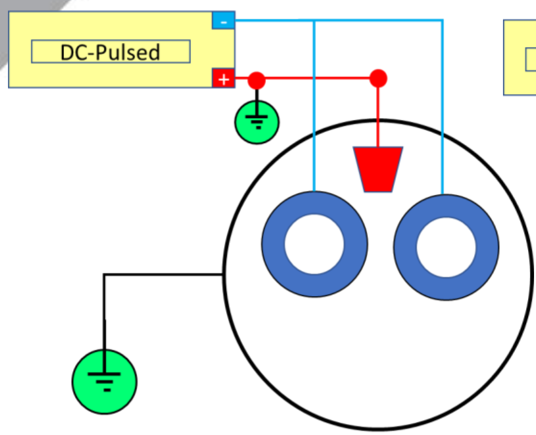
The method effectively combines magnetic trapping with electrostatic attraction of electrons

- The magnetic field from a single or double magnetron (shown) combined with the magnetic field of the anode to form a closed trap for the electrons to guide them to the anode – electrons do not possess sufficient energy pass the field lines and escape the trap.
- The anode can be at varying potentials but the most convenient and cost effective method is to have the anode at earth potential.
- For example, when used with AC power between two targets, the active anode improves process stability.

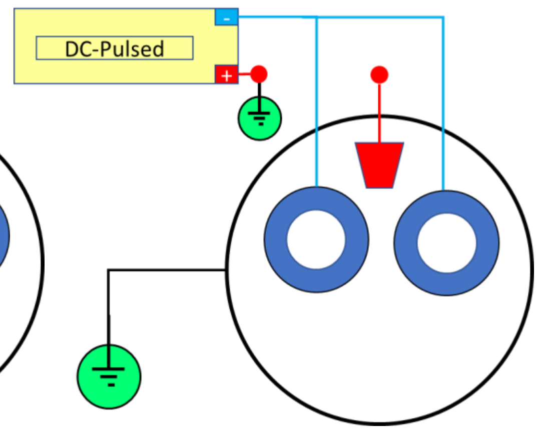






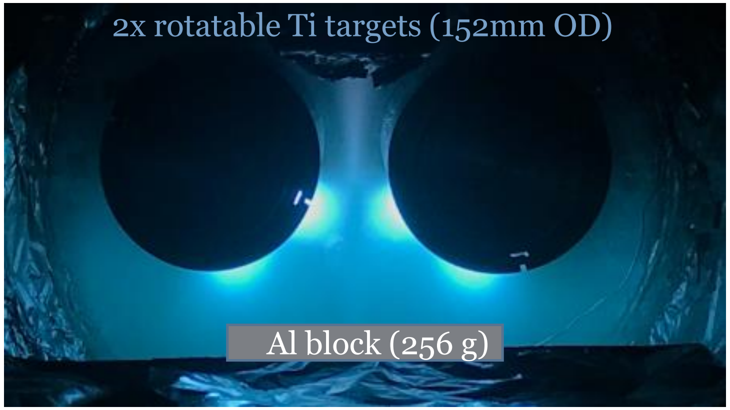
Substrate temperature reduction for DC-Pulsed configurations

Grounded anode

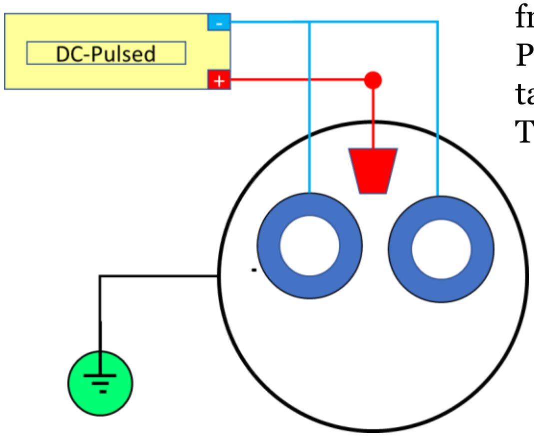


Floating anode

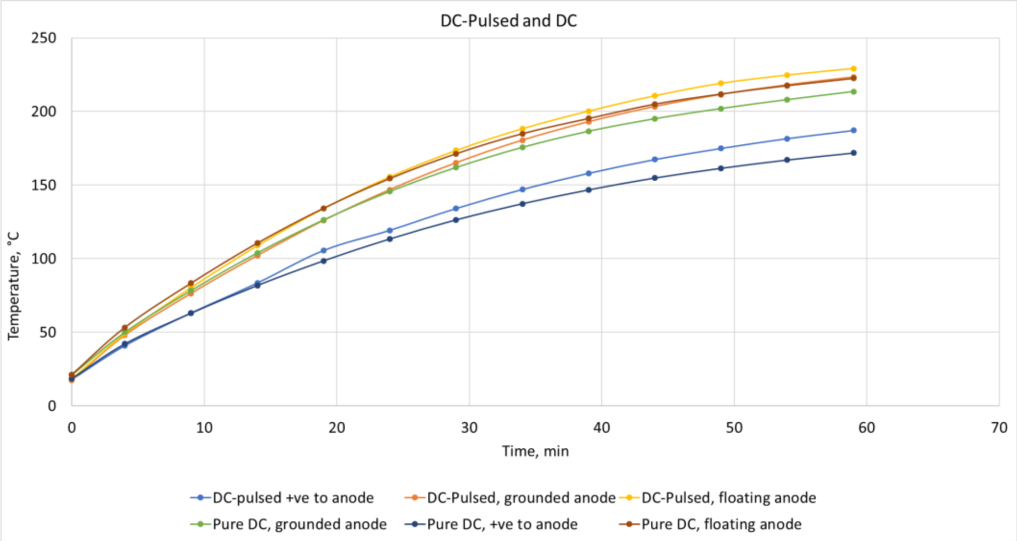




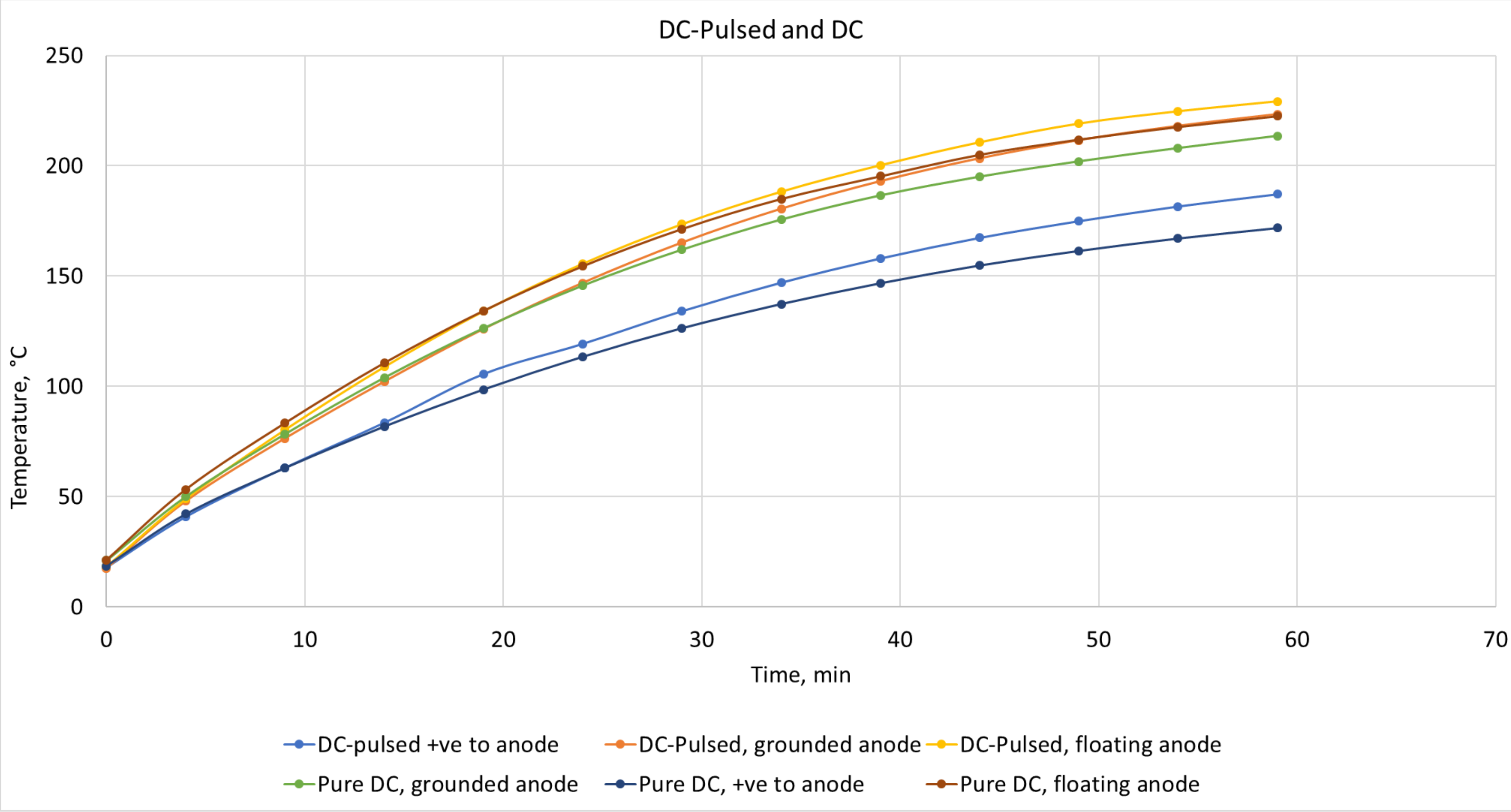
Positive output to anode



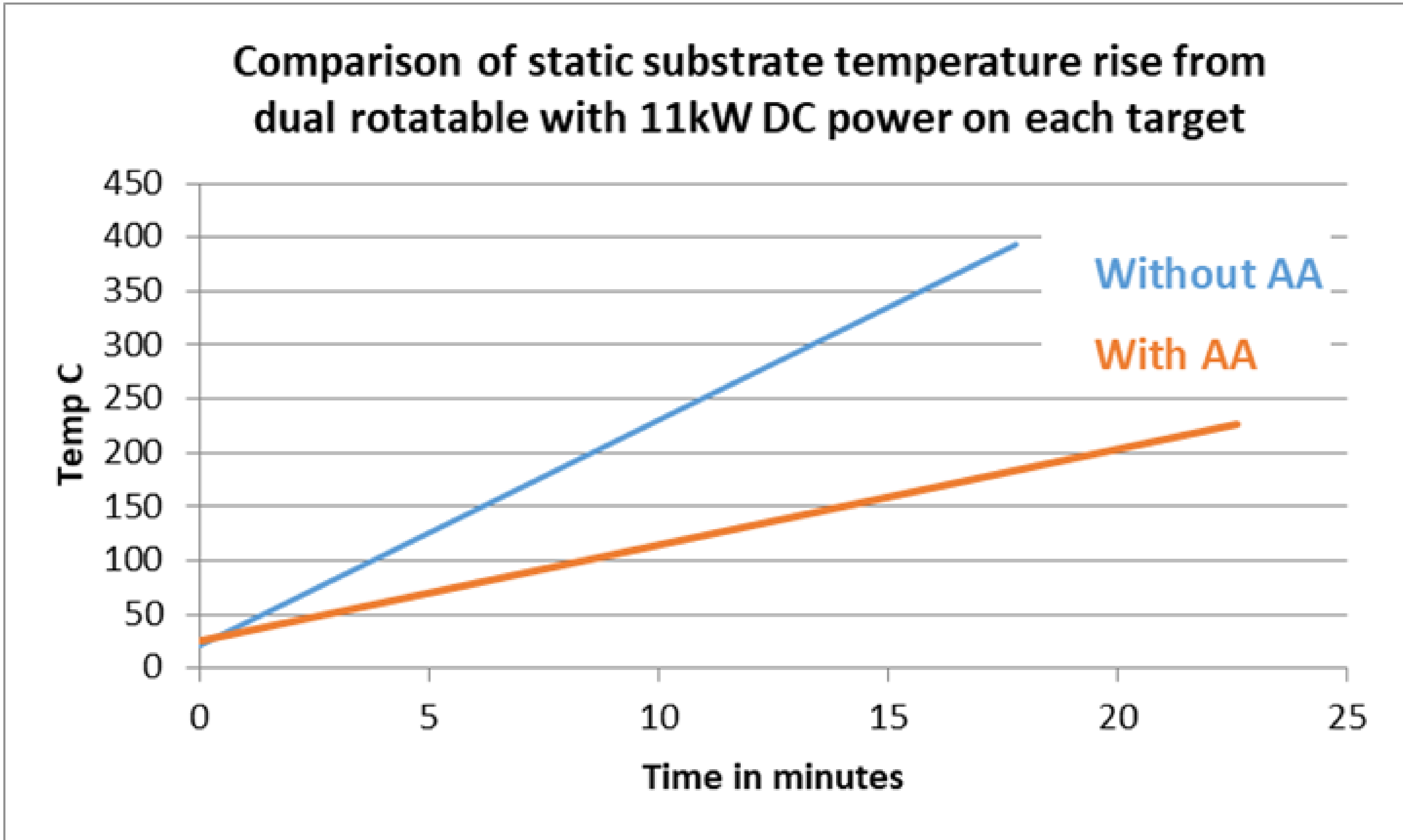
Power on (6kW)
100 kHz pulse frequency
Power split to 2 targets
Total time: 60 mins



Substrate temperature reduction for DC-Pulsed configurations

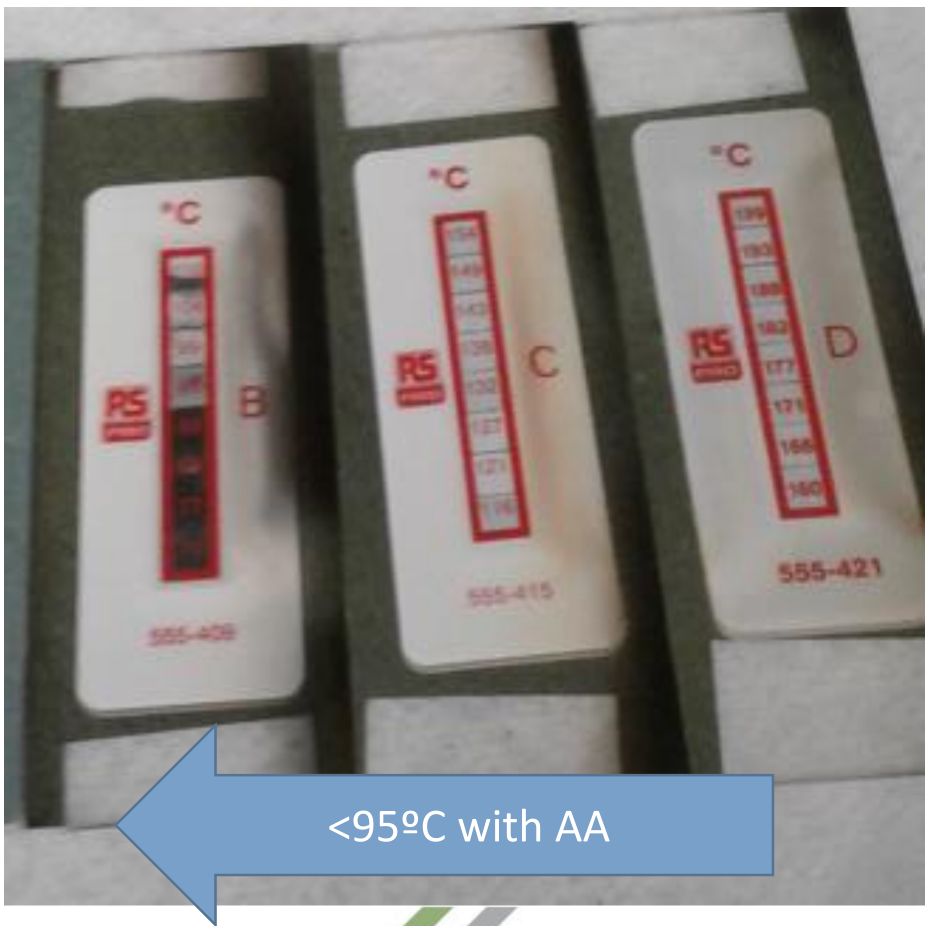


Reduced substrate temperatures with the Active Anode and DC power modes

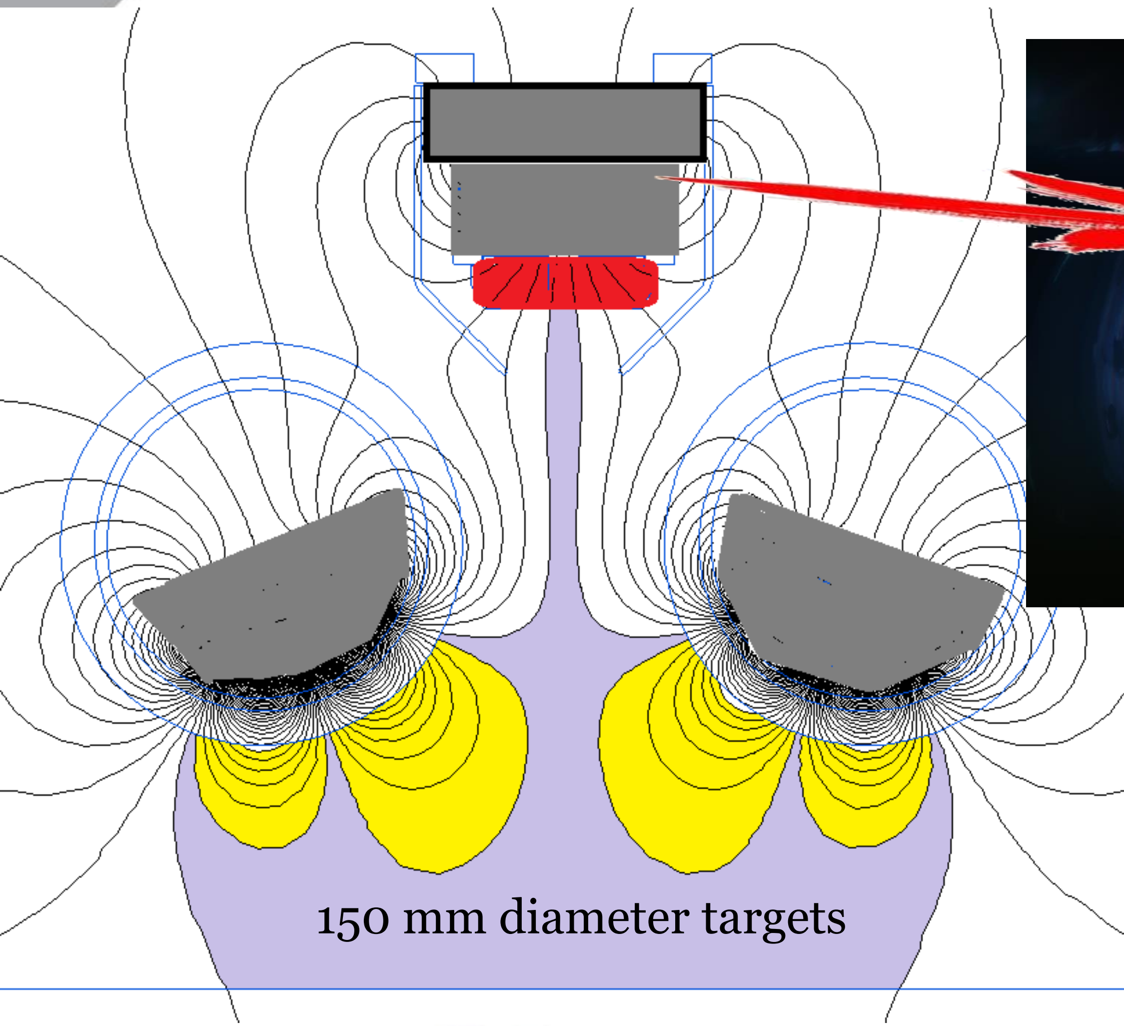


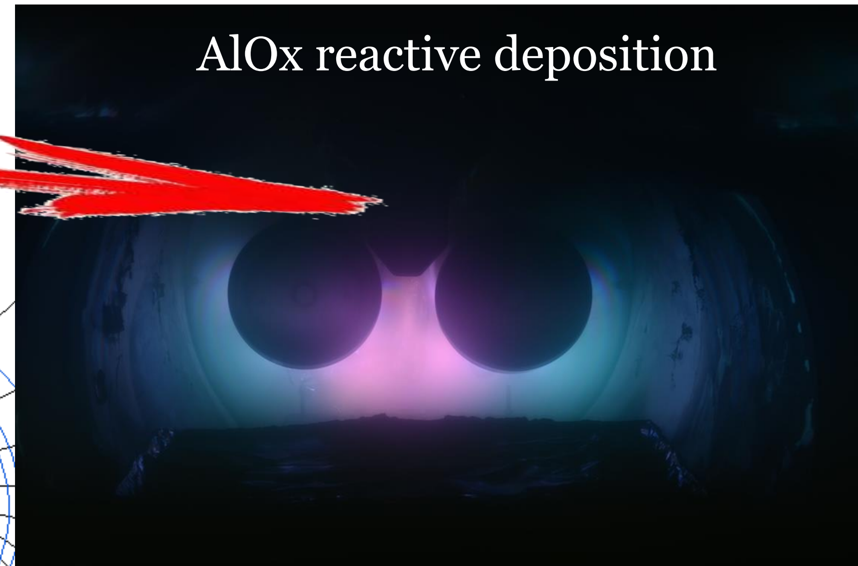
Reduced substrate temperatures with the Active Anode and DC power modes

Temperature indicator strips on the rear of substrates coated with 1 micron Aluminum with and without the active anode



Gencoa dual AC rotatable with grounded "anode"

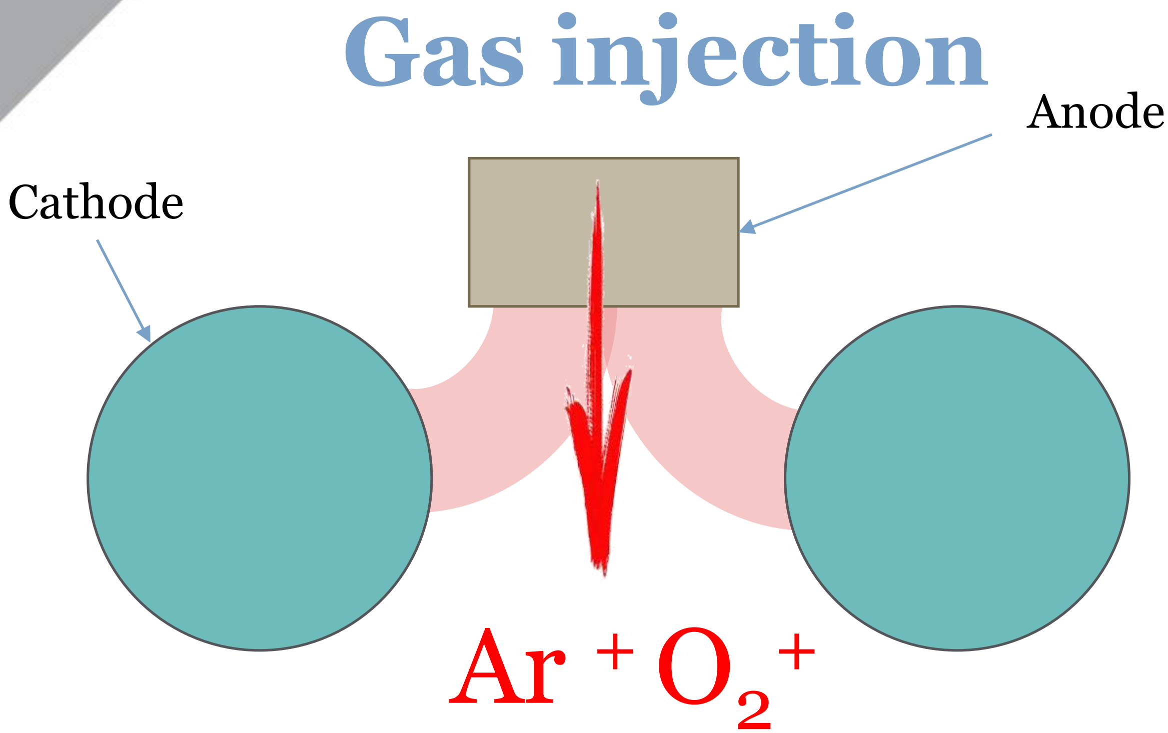


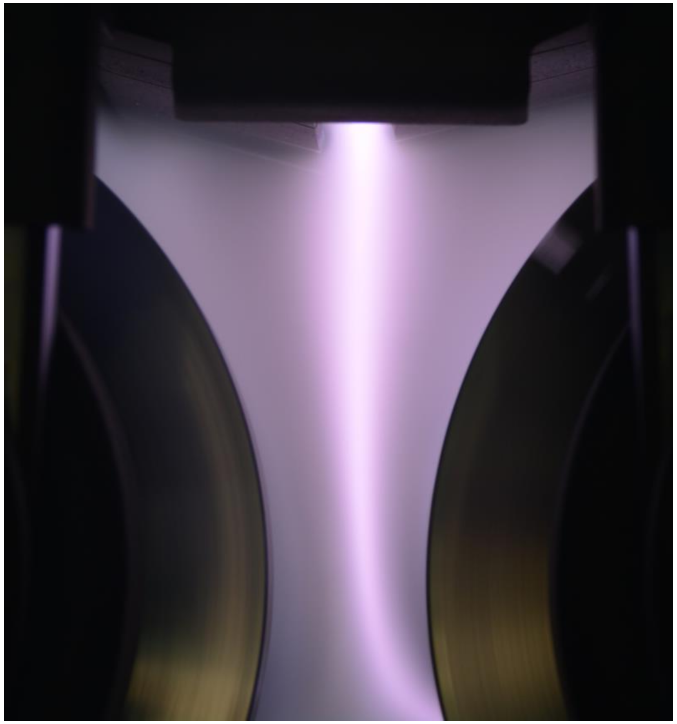


Magnetically guided "anode" assists the electron confinement in the plasma discharge

Magnetic confinement

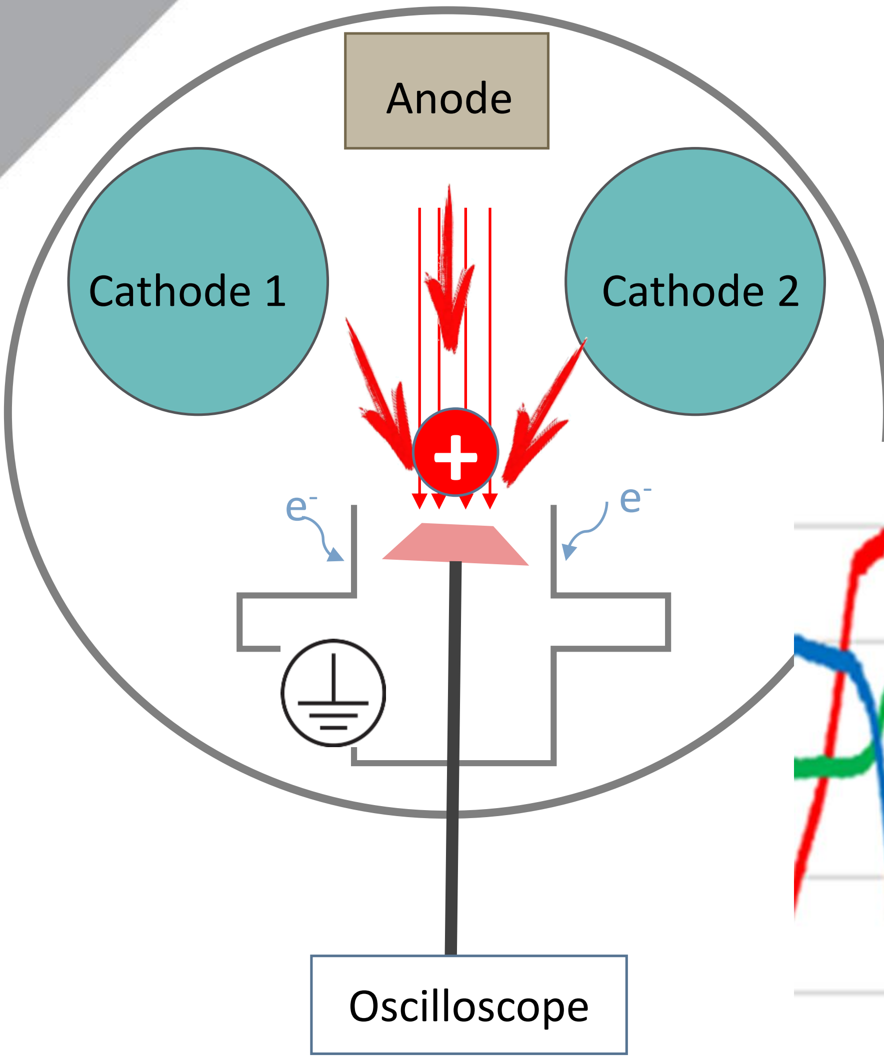
Effect of plasma activation

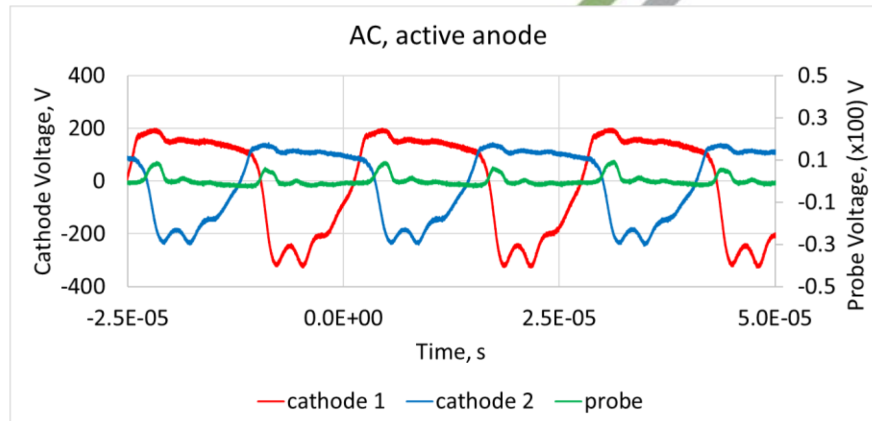


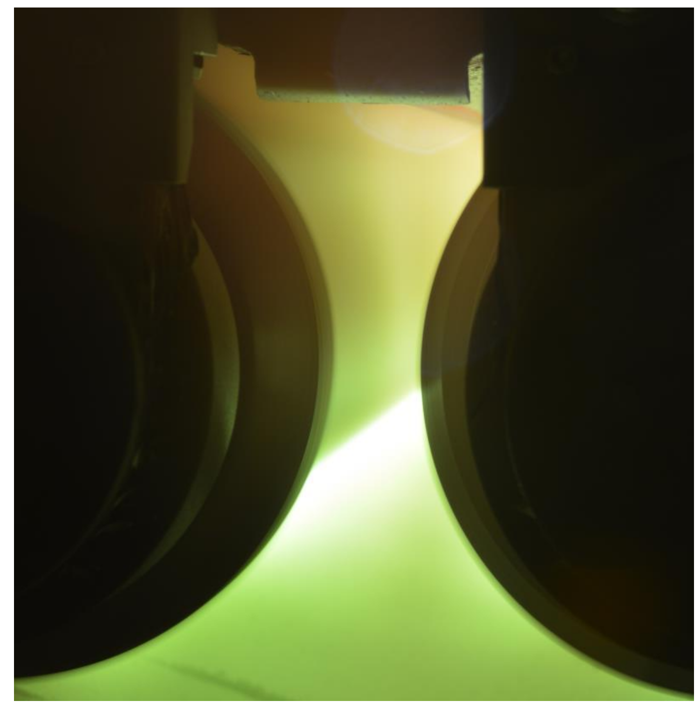


Gas injection / activation

Active anode and AC power mode produces both positive Ar and O2 bombardment and negative

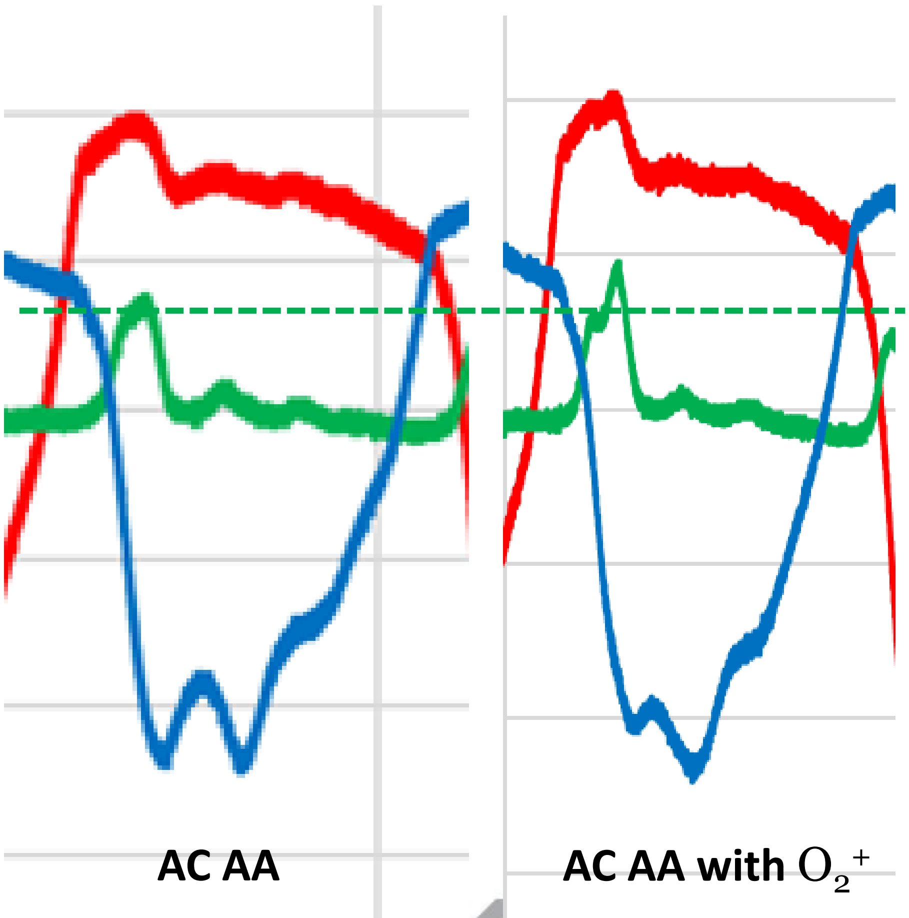


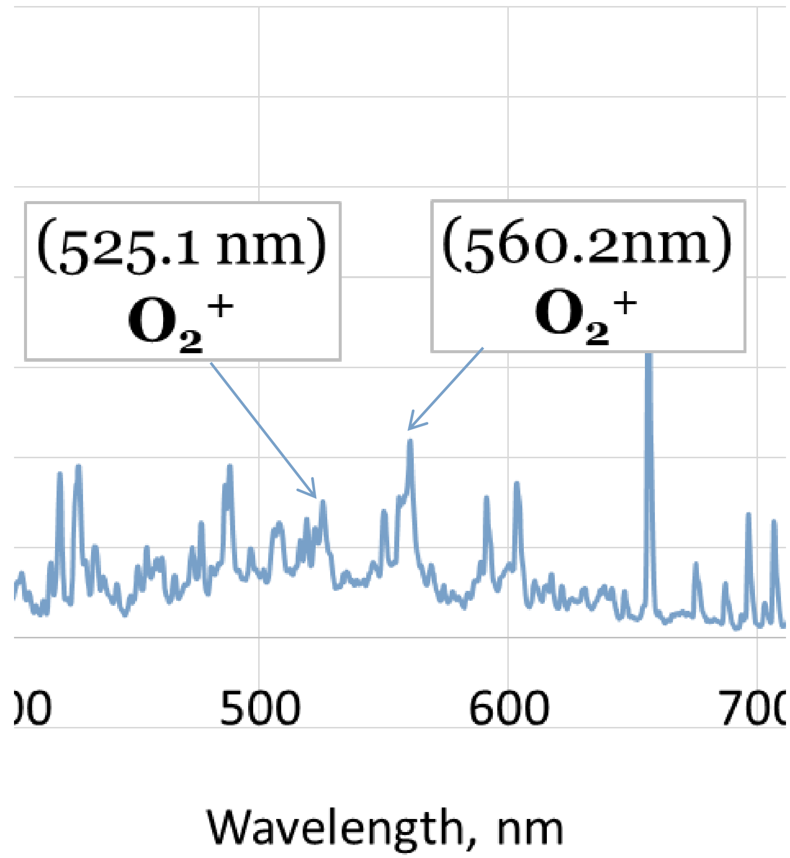




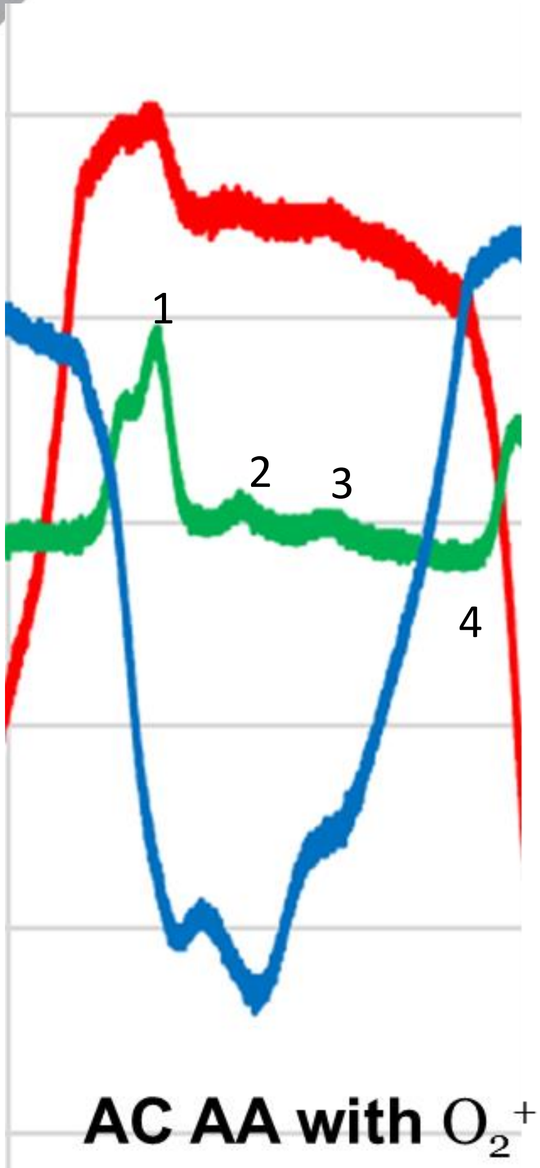
Oxygen ions positive pulse are generated in the plasma and bombard the growing film to enhance film structure and quality

Introducing O_2 through the plasma in the anode zone increases the V(+) pulse intensity and produces higher O_2^+ ion bombardment





3 positive waves of bombardment followed by a negative wave produces both high density and low stress layers



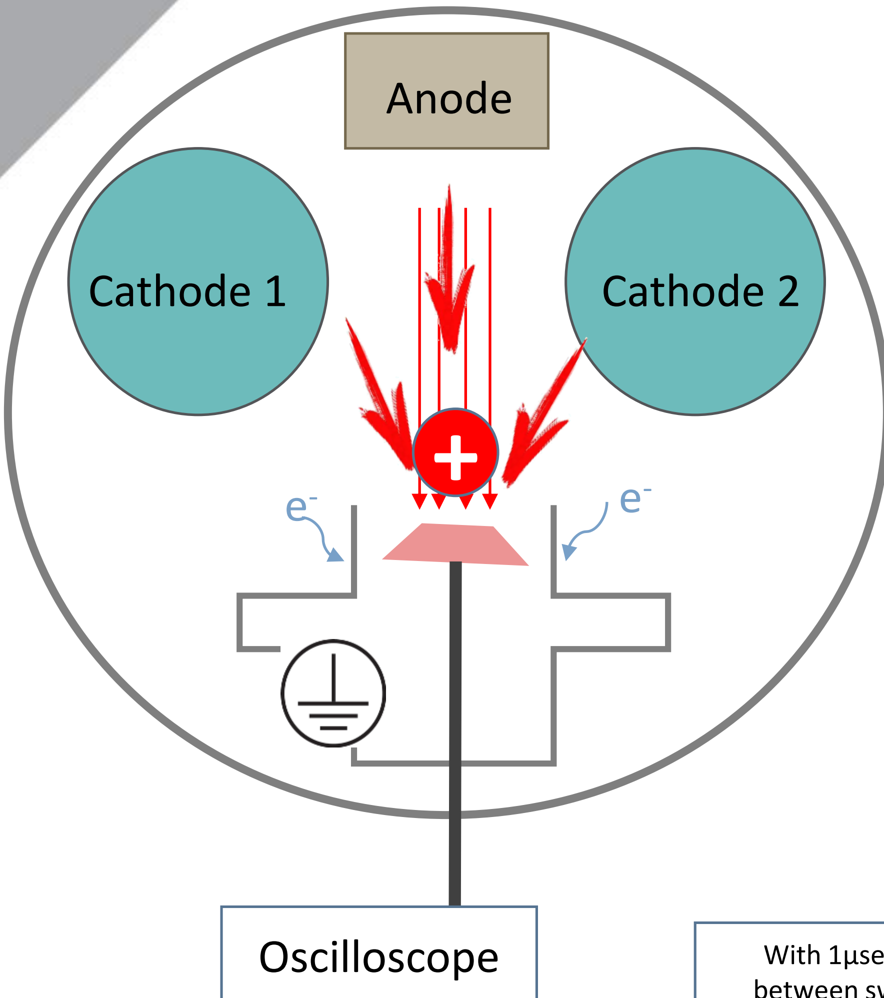
1. 10 ev positive bombardment
2. 1 ev positive
3. Neutral flux
4. Negative 2 eV bombardment (discharges the glass or plastic – avoids arcs on substrate

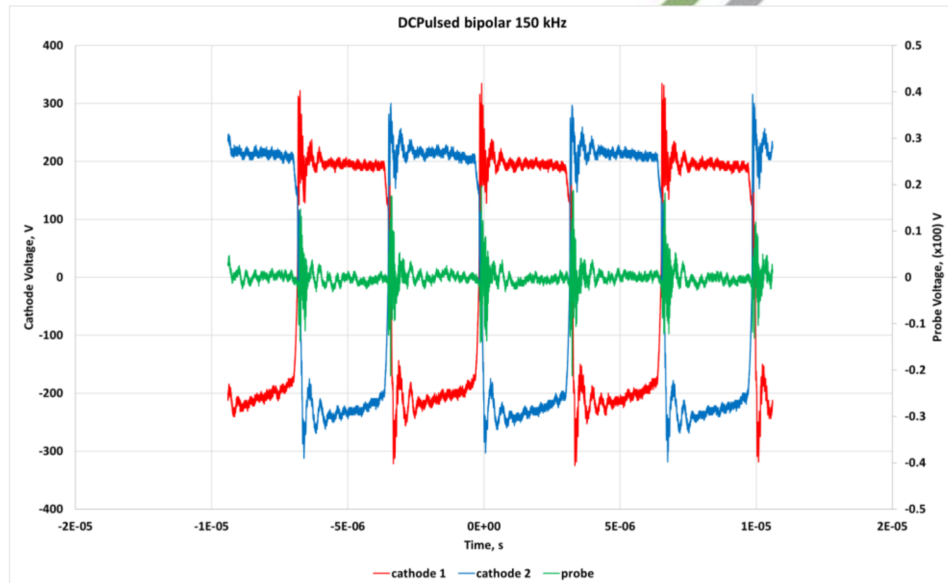
The films produced by this method exhibit no stress but very dense and smooth structures.
The oxide films can be 20 microns thick and have not internal stress.
This is a result of the modulated bombardment and the combined positive and negative bombardment.

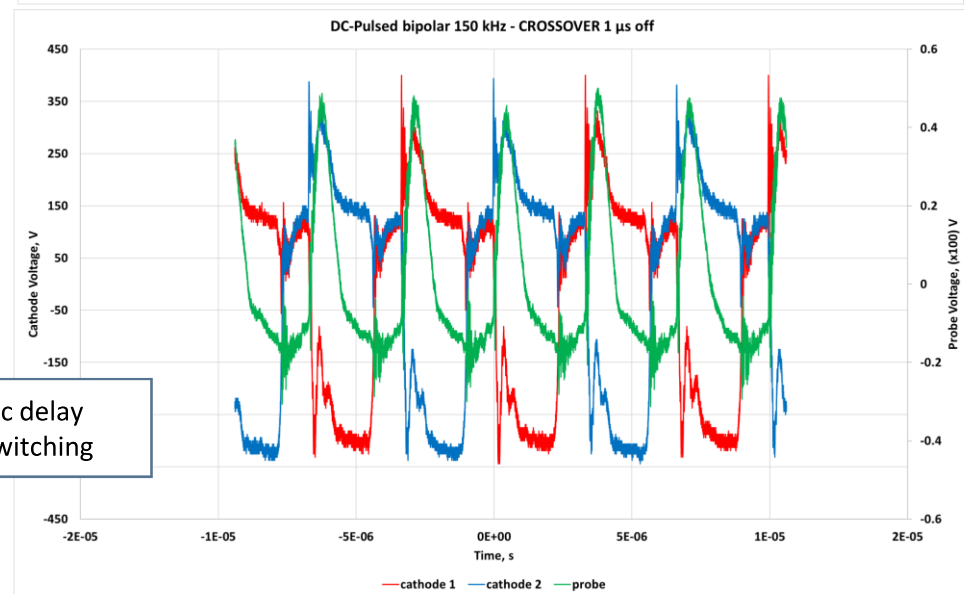
This 4 waves of energy assistance is happening at the frequency of the AC power – 20 to 100kHz.

This power and magnetic arrangement is ideal for ultra high quality optical layers at high rates.

Active anode and AC type power delivered by AE Ascent square wave type power supply with & without 'delay'

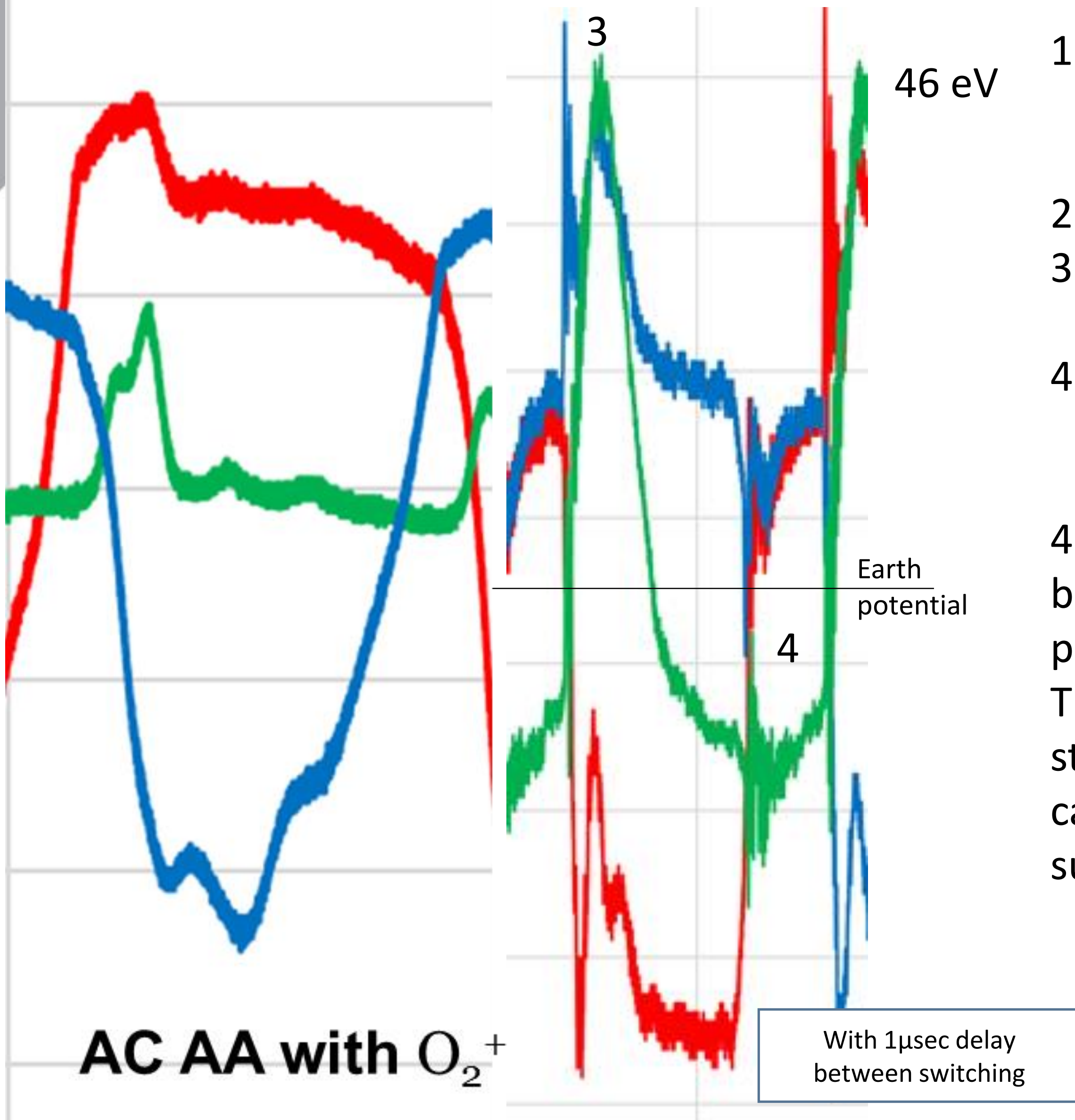






With 1µsec delay between switching

The use of an **Advanced** Energy Ascent type power supply

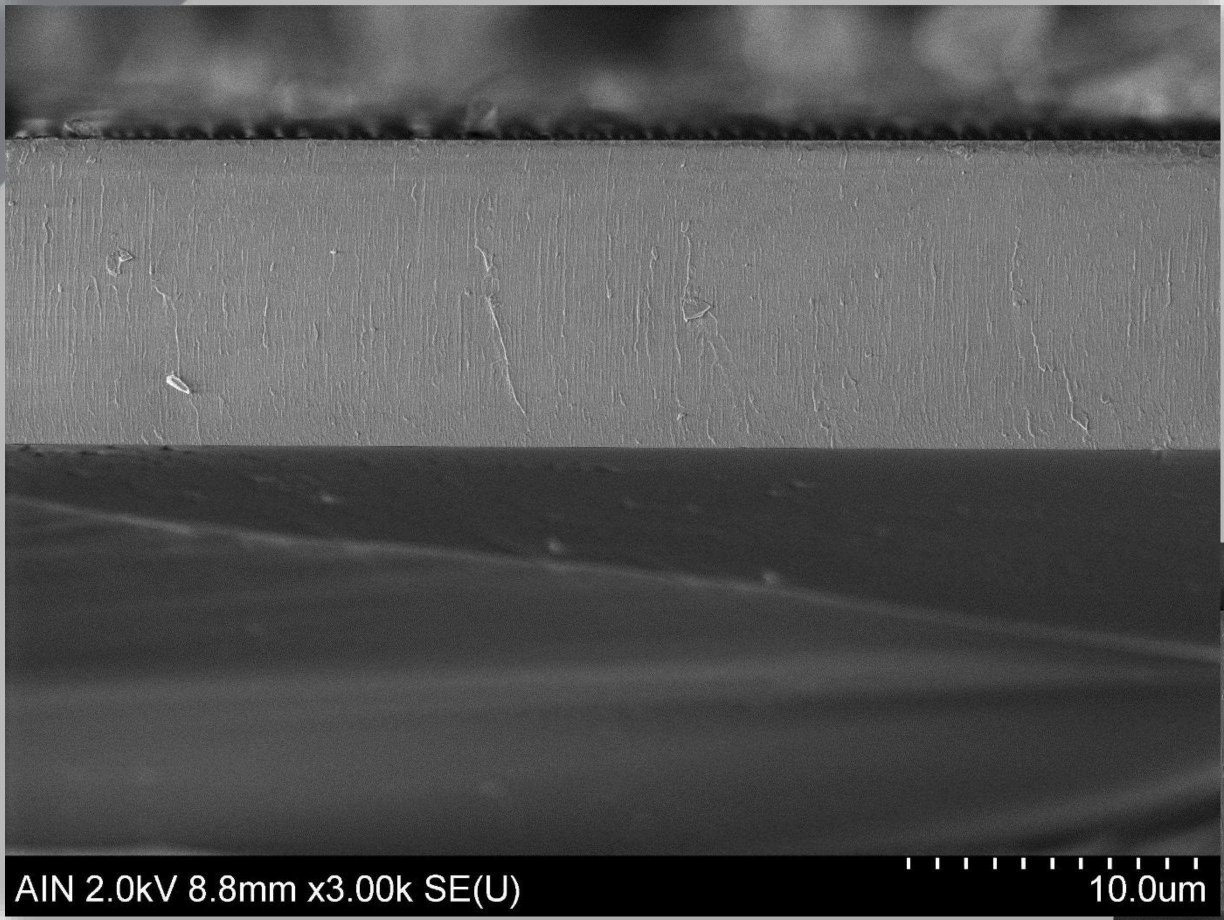


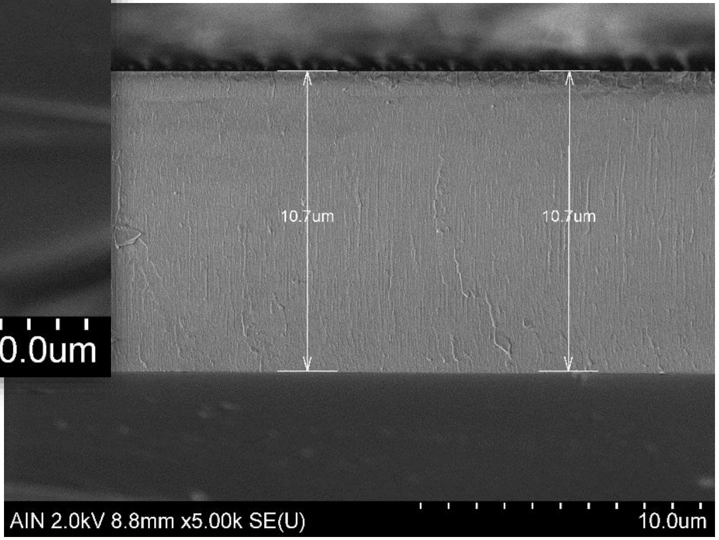
1. 10 eV positive bombardment for standard bipolar pulses like AC but more sub frequencies
2. 3 to -3 eV pulses
3. 46 eV positive bombardment when 1µsec
4. Negative 25 eV bombardment (discharges the glass or plastic – avoids arcs on substrate

4. Combining positive and negative bombardment equalizes film stress – prevents deformation.

The Acsent is more flexible than standard AC type power as the film can also be adjusted by the power supply parameters.

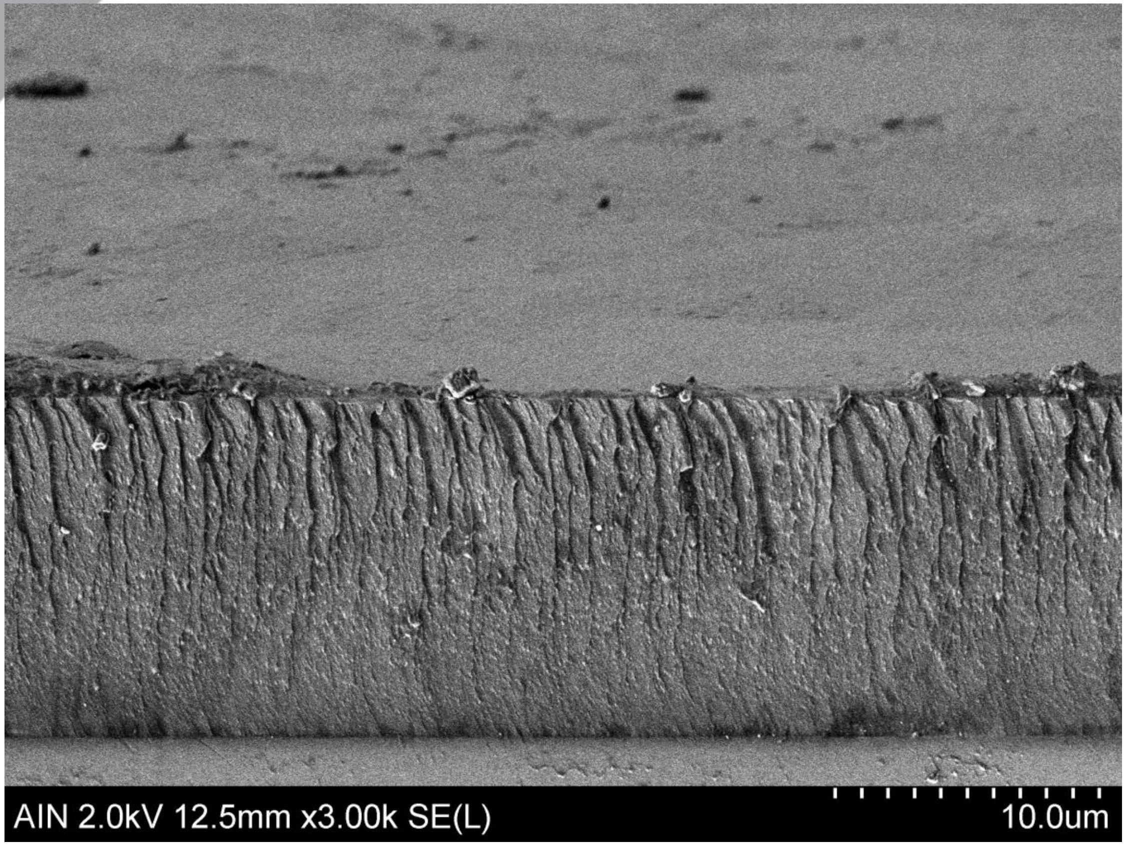
AC power on the targets with a grounded magnetic anode produces superior coatings to any other arrangement



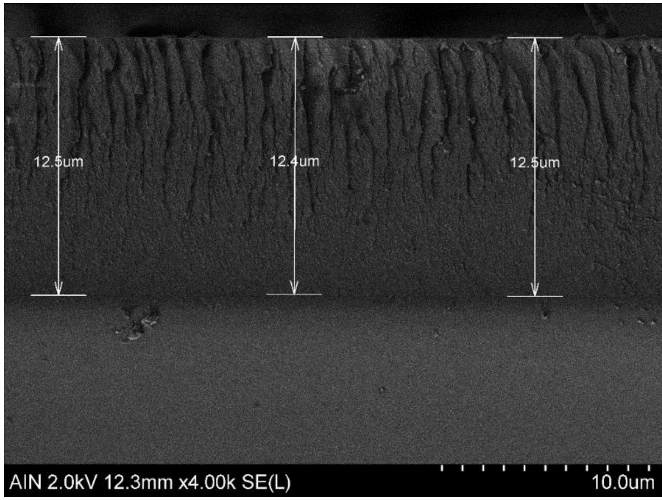


AlOx dense coatings

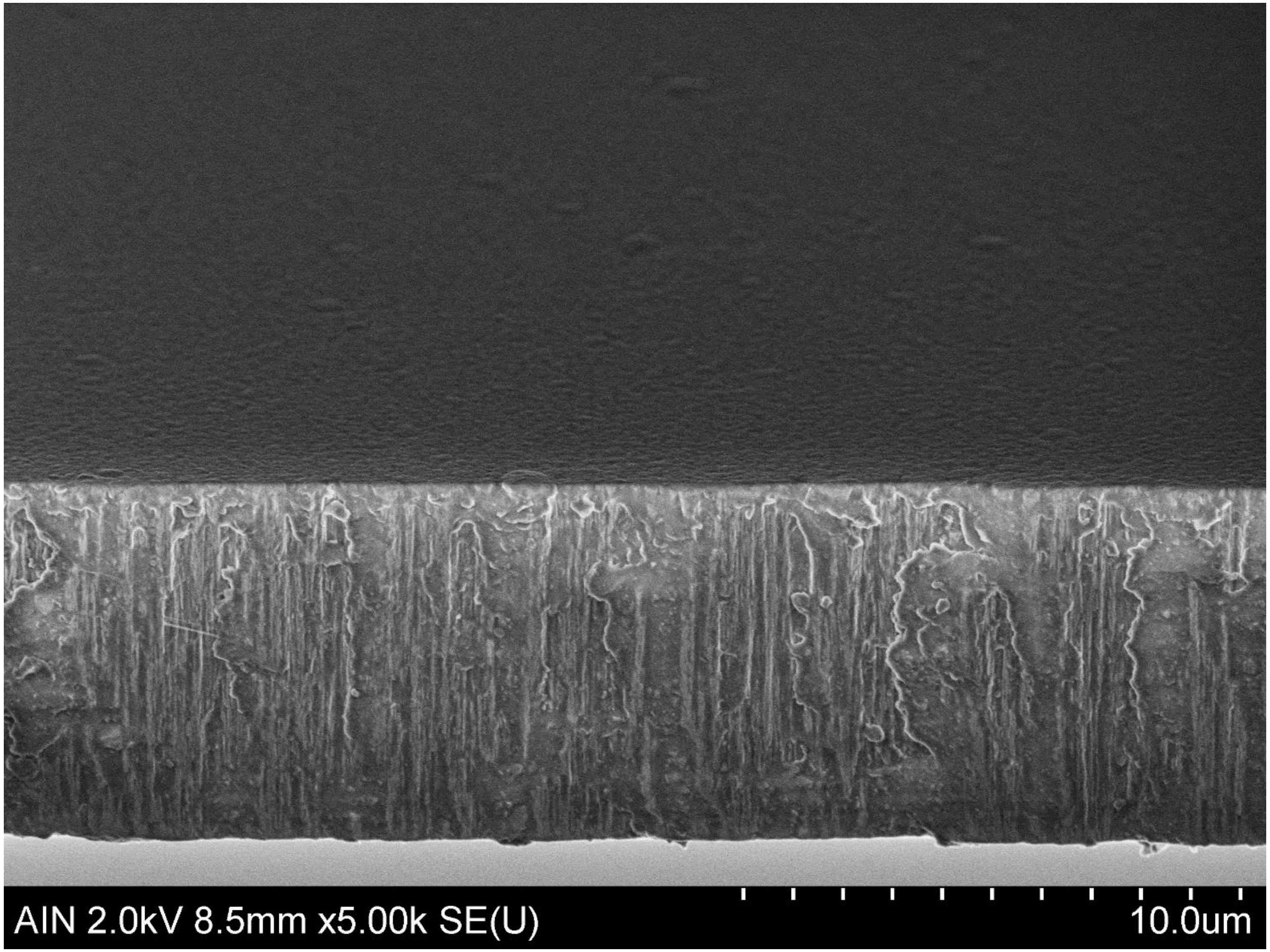
AC power on the targets without any anode does not produce as good a structure, although superior to pulsed DC



Flat top surface.
Also dense coating

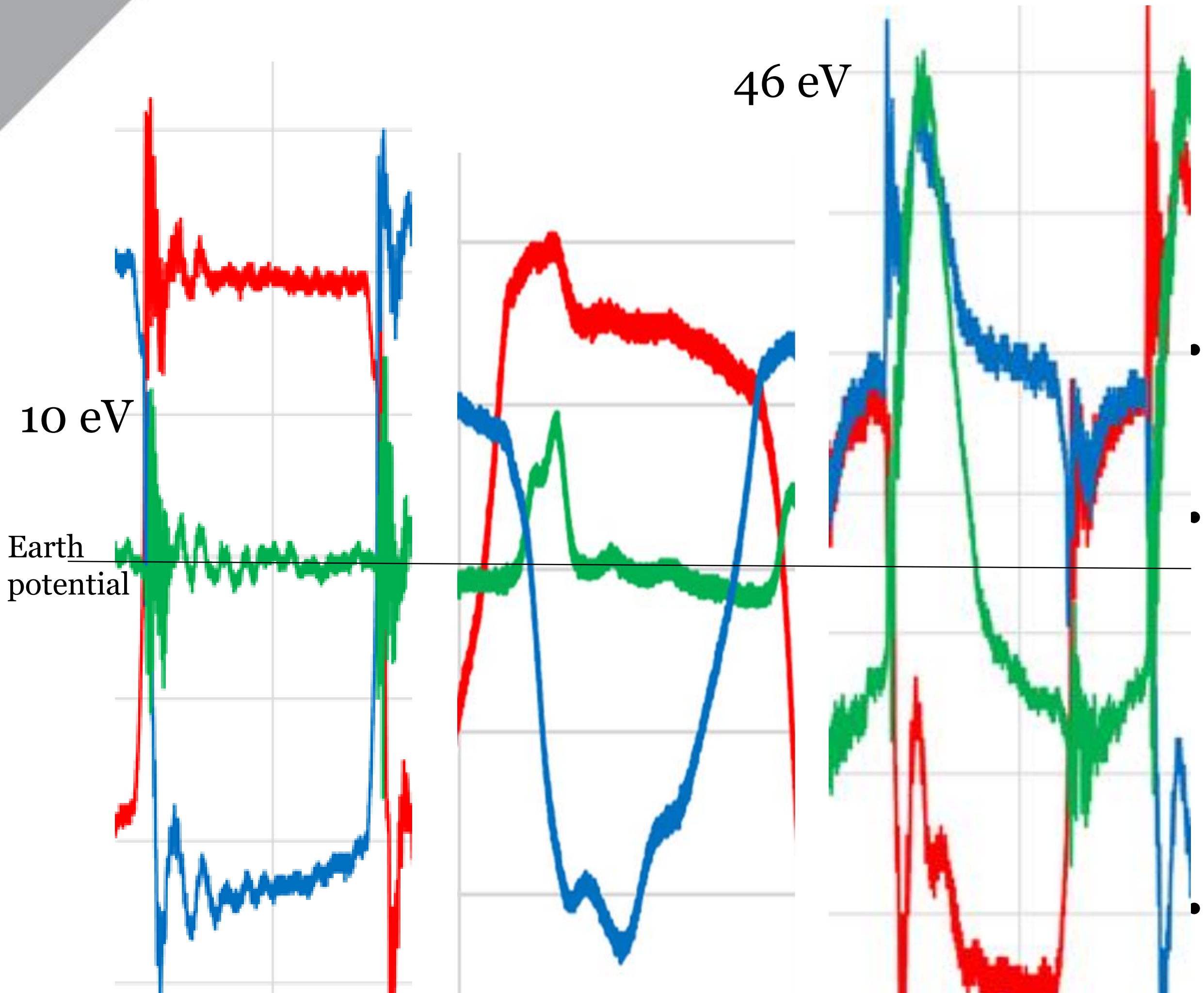


DC-Pulsed, coating structure, active anode improves the structure compared to without an anode



Dense columnar structures with DC-Pulsed and AA

Creation of extra energy via the use of switching power modes between 2 targets and the use of a magnetically guided earthed active anode



Standard square wave switching with Active Anode

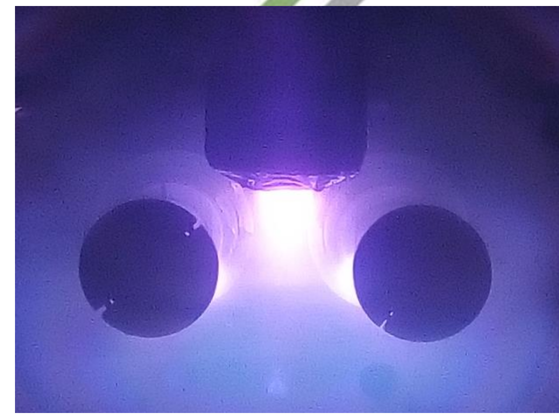
Standard AC power with Active Anode

Square wave switching with 1μsec delay and Active Anode

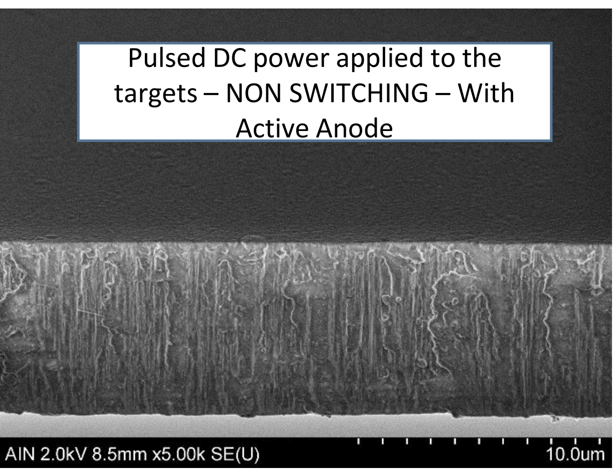
- By switching electrons between targets extra ionisation is created
- Active Anodes AA creates positive and negative energy bursts on the substrate (ideal for glass or plastic substrates without external bias)
- Introduction of a delay in the power switching

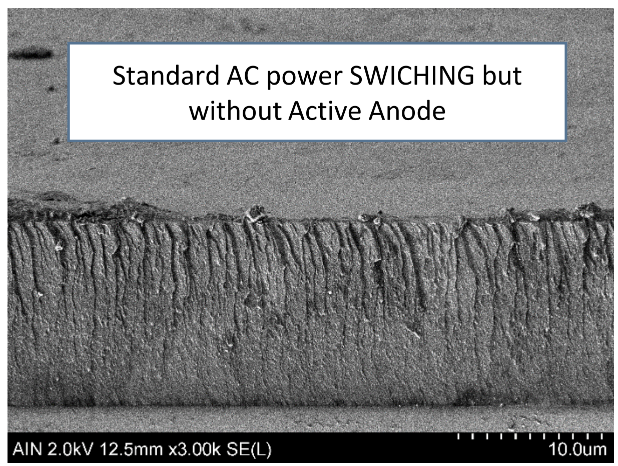
Creation of extra energy via power mode and Active Anode – comparison of coating structures

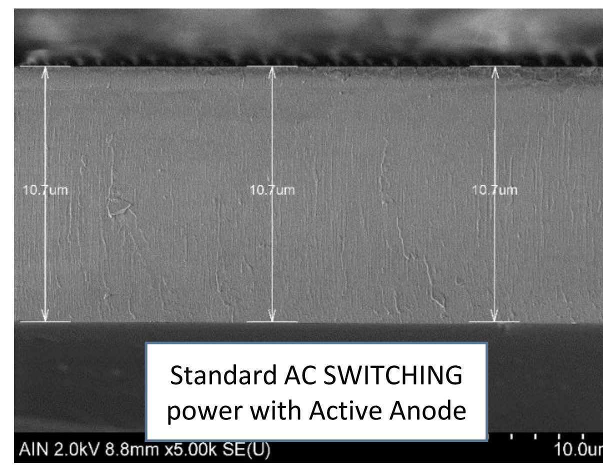
10 micron thick AlOx deposited onto glass (floating potential – no external bias) from a dual rotatable magnetron and with active anode



Increasing Energy Levels





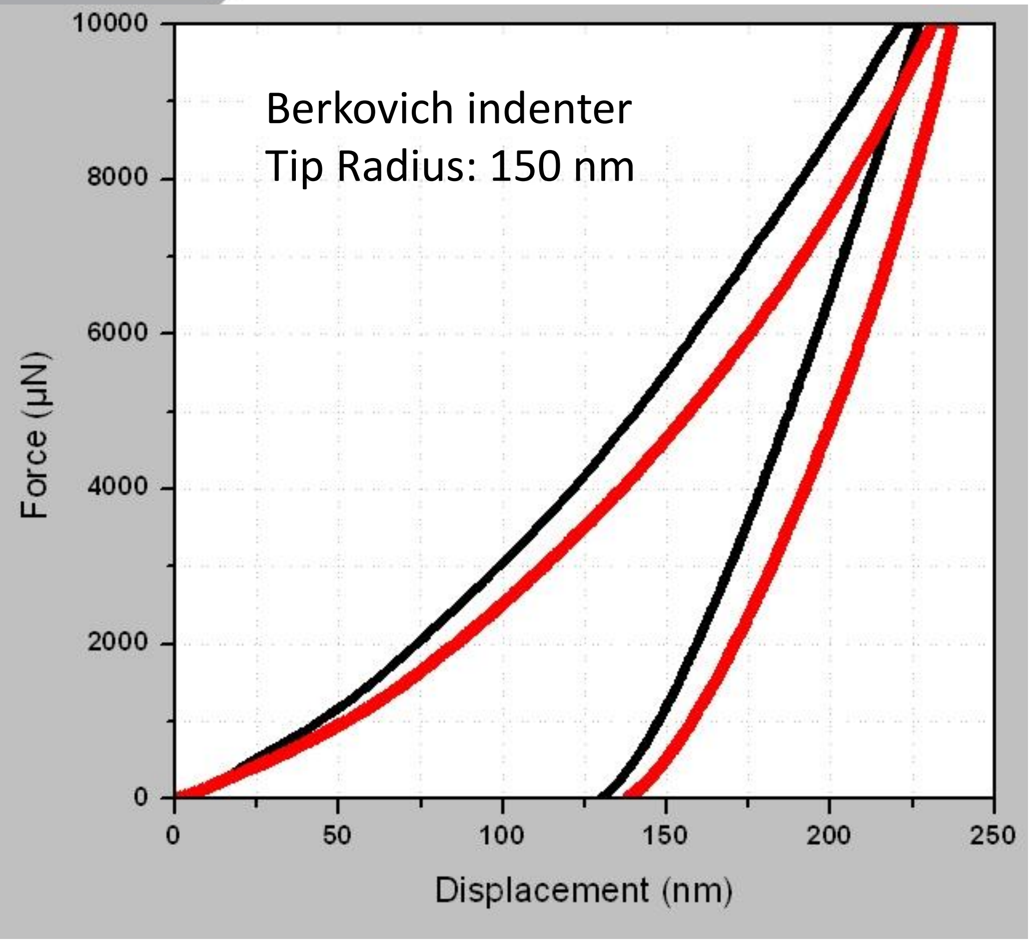


Columnar structures are recurrent when DC-Pulsed is used

AC switching power mode has improved structure compared to pulsed DC

AC with active anode Produces highly dense structure

AC power with a grounded magnetic anode produces the hardest coatings compared to any other arrangement



SAMPLE	*HARDNESS (GPa)*
DC-Pulsed no-anode	10.7
DC-Pulsed Biased anode	12.1
AC standard	11.6
AC active anode	13.1

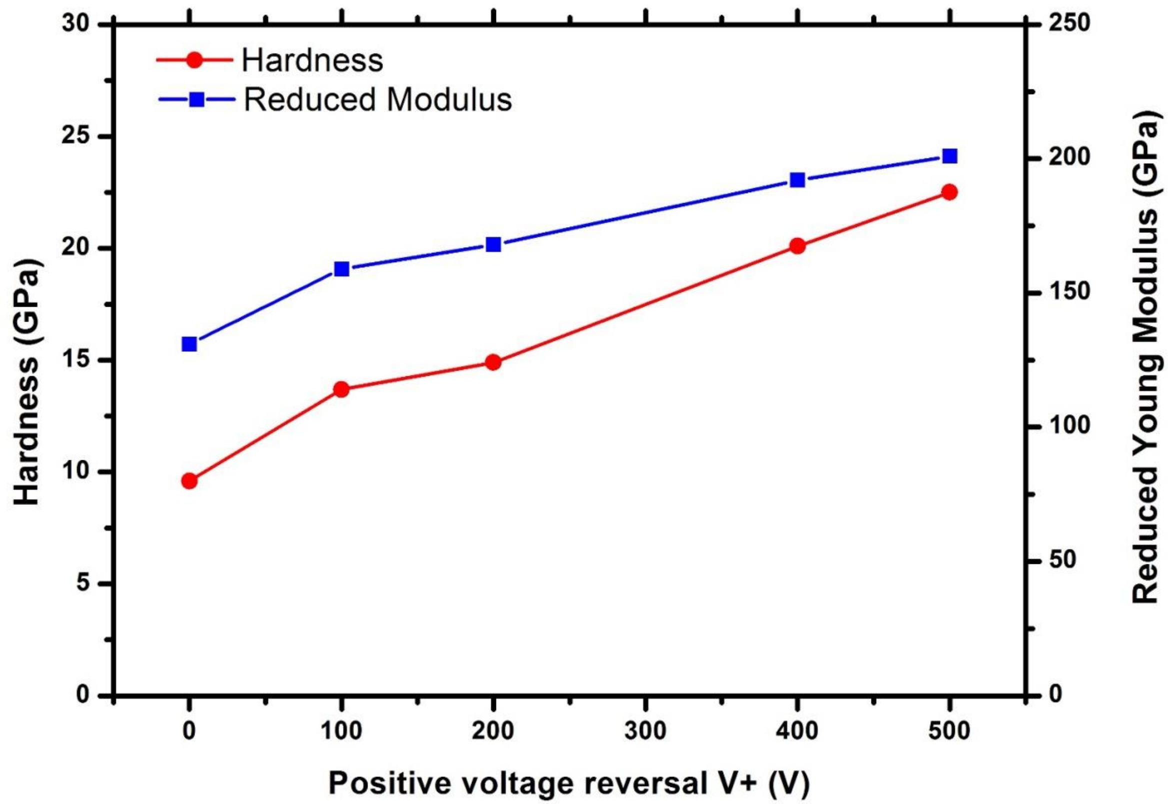
Thanks to: Dr Adrián Miguel Lorente*, Dr José Fernández Palacio, Dr Gonzalo García Fuentes,AIN, Cordovilla, Spain
*AMiguel@ain.es

Effect of positive pulse reversal and active anode on the hardness of sputtered carbon

The hard carbon deposition method uses a positive pulse reversal via the power supply combined with electron guiding into an active anode - patent pending

The higher the positive pulse, the more the bombardment and the harder the carbon layer

This 'smart' ion assistance does not require additional sources



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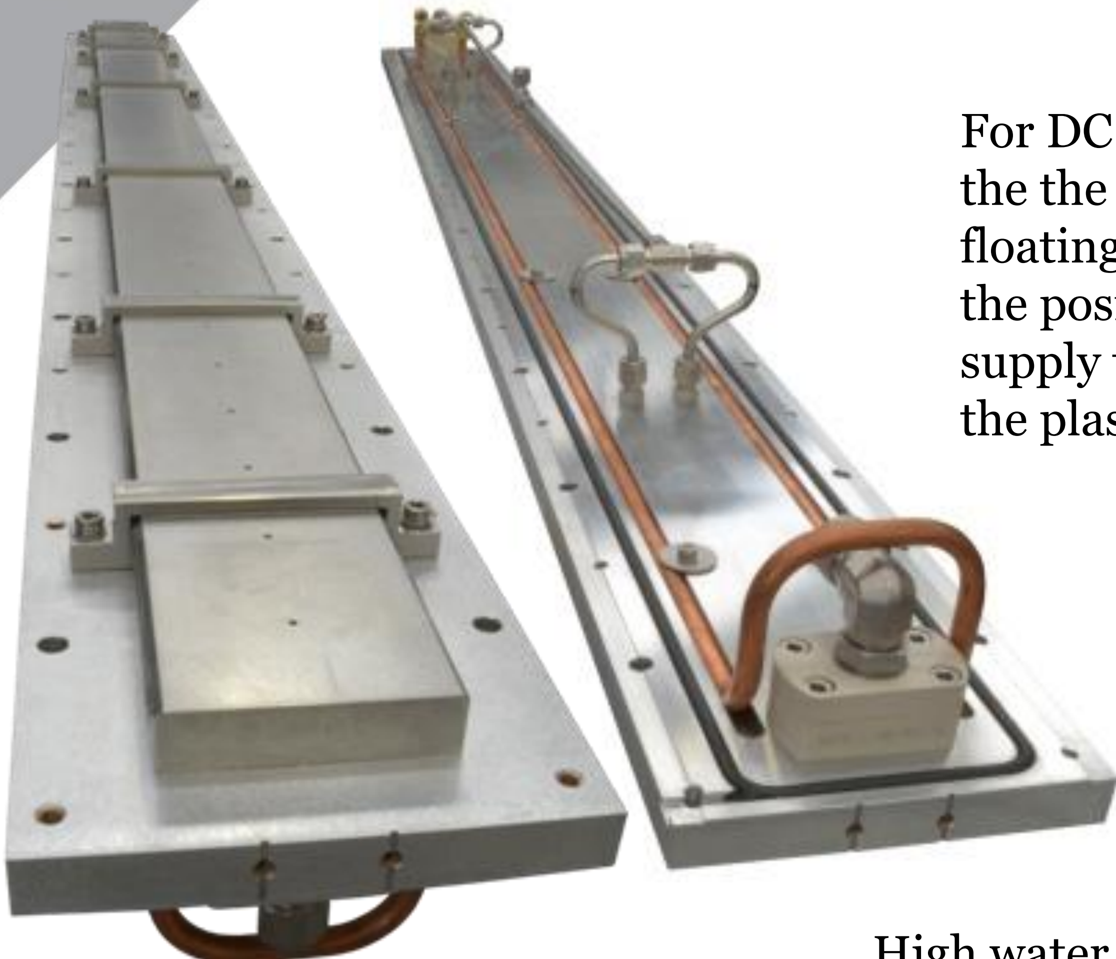
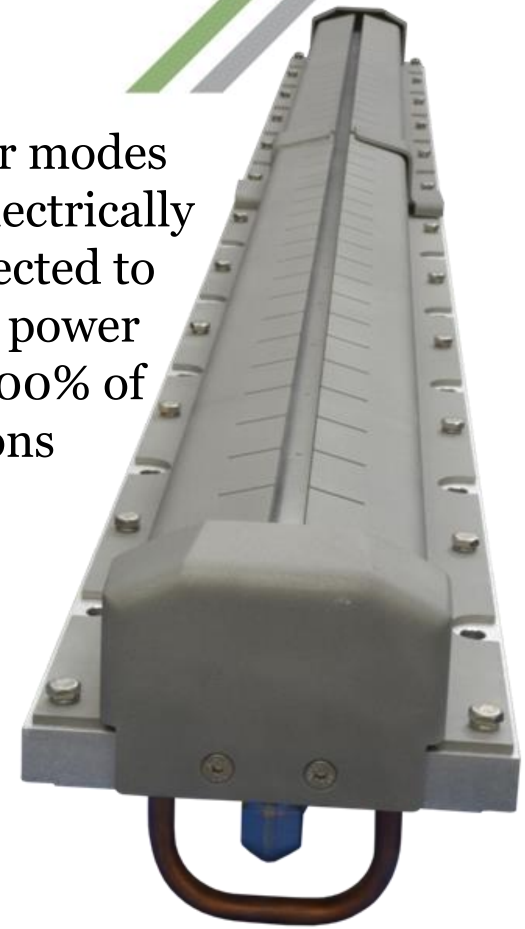
Gencoa Active Anodes available in two forms for switching AC type power or DC type power modes



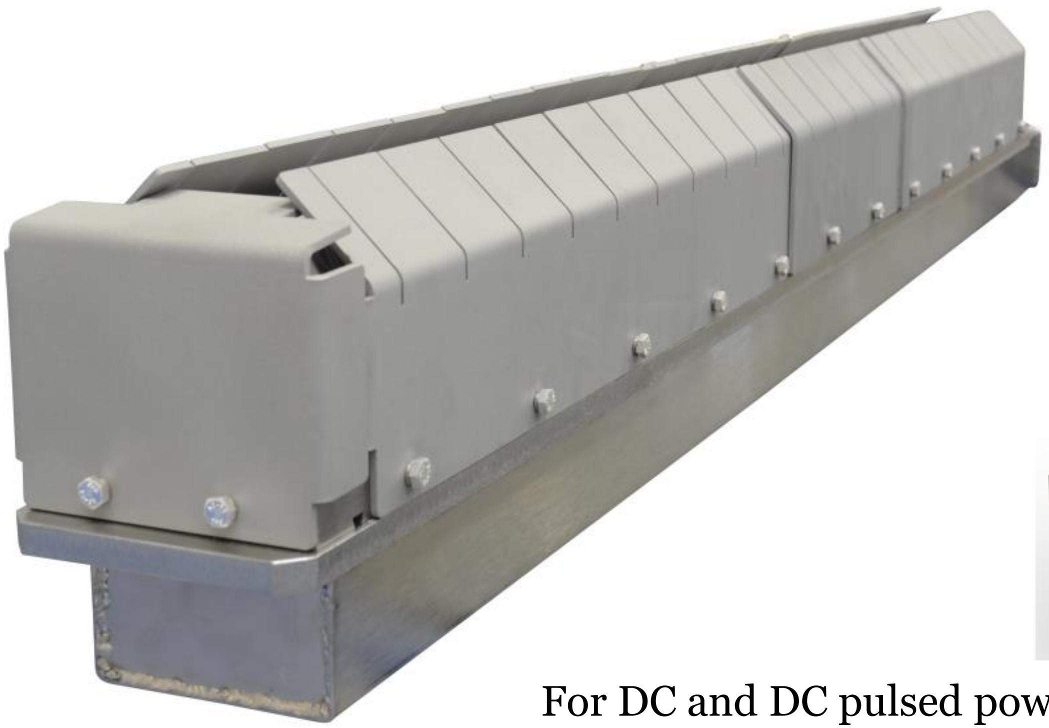
For DC type power modes the the anode is electrically floating and connected to the positive of the power supply to collect 100% of the plasma electrons

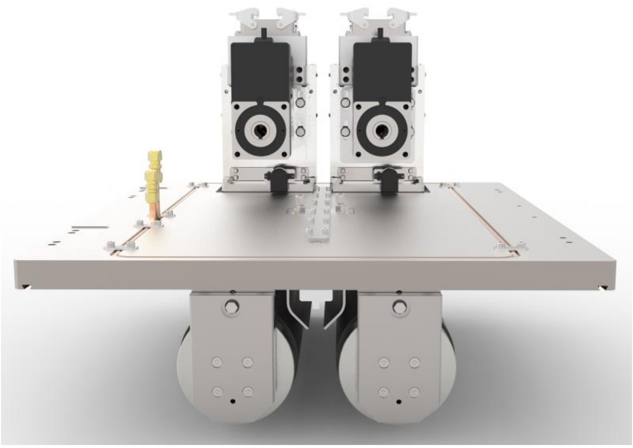


For switching double cathode AC power the anode is electrically earthed

High water flow to the anode structure ensures efficient heat removal and high power capability

Gencoa Active Anodes can be mounted internally or on the chamber wall





For DC and DC pulsed power the active anode is electrically floating an connected to the positive of the power supply. For AC type switching power the anode is at earth potential and can hence we a simpler construction.

Complete sub-assembly of triple GRS-C cathodes with 2 active anodes and gas bar

Gencoa Active Anodes reactive oxides with pulsed DC, a unique option compatible with AC and DC power modes

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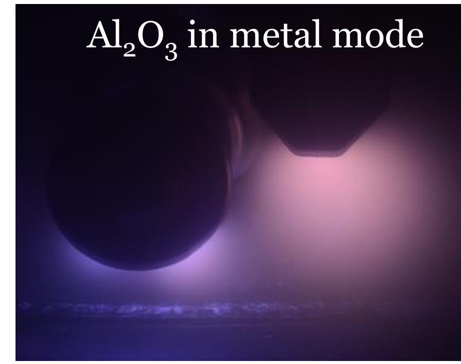
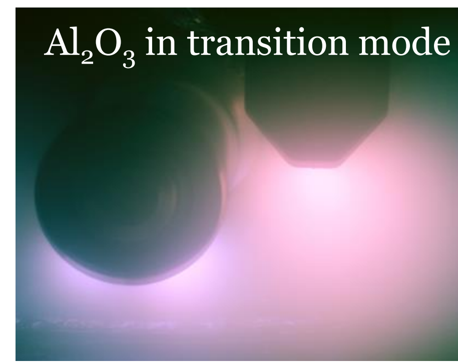
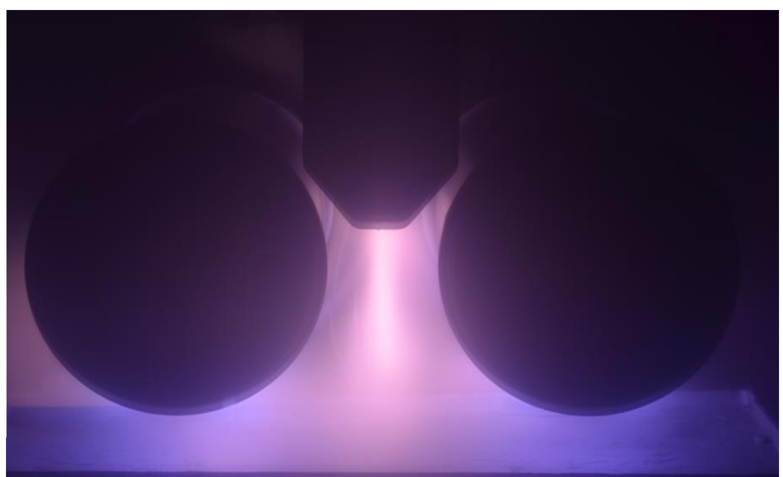
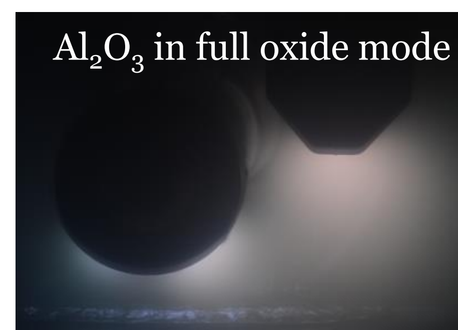
Gencoa's active anodes provides a long-term stable anode for rotatable magnetron operation which improves DC and pulsed DC processes from single or dual cathodes.





Highly insulating dielectric films can be deposited such as Al2O3 and SiO2 with a single pulsed DC cathode and an active anode. This gives an alternative for dual cathodes with AC type power.





Active Anodes dramatically improves ITO layer properties from rotatable magnetrons, 2.3 x 10-4 resistivity at 120 C.

iTO™