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Benefits of Telemark's Low Pressure Ion Sources

Wayne Sainty, Telemark, Battle Ground, WA

Telemark ion beam sources have been designed to provide superior performance across large and small substrates. Telemark technology offers low pressure operation (10-5 mbar) for a longer mean free path and higher ion energies than traditional End Hall sources. The source design is extremely low maintenance with no consumable components except for filaments. The Telemark ion beam source line is capable of either mixed gas or pure oxygen operation, allowing for deposition of metal oxide films of the highest index and lowest stress. Pulsed Mode for ion assisted fluorides provides fully compacted, damage free results not achievable with any other ion source. Telemark sources achieve stable films with no substrate pre-heating and are an excellent choice for depositing durable films on low temperature substrates.

 DOI: https://doi.org/10.14332/svc25.proc.0034

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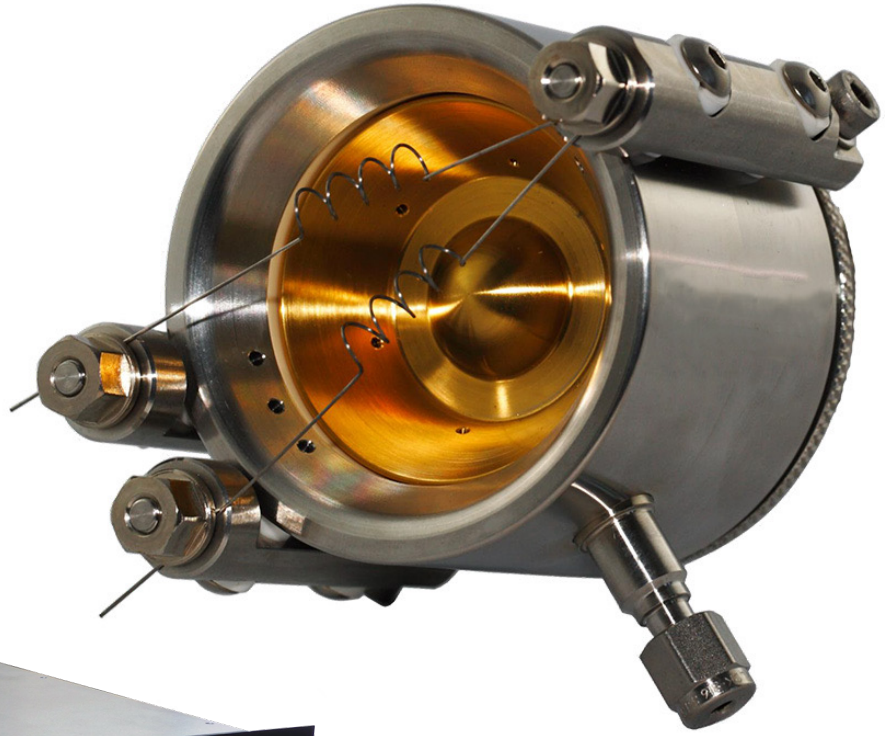
Low Pressure Ion Sources

Dr. Wayne Sainty



Telemark Vacuum Ion Beam Products

Low Pressure Ion Assisted Deposition (LP-IAD)

In this presentation:

- Low-Pressure Ion-Assisted Deposition explained - What does it mean?
- Not another Plasma Source!
- LP-IAD - An enabling technology - Multilayer coatings to plastics
- Case studies & examples

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LP-IAD

LP-IAD is an ion-assisting deposition process conducted at low enough pressures to ensure that the Mean Free Path (MFP) for ions is greater than the source to substrate distance.

For example:

At 1.0 x 10-4 mBar, MFP is approx. 120 mm (4.5”)

At 1.0 x 10-5 mBar, MFP is approx. 1.0 meter (40”)

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Limitations of Plasma Sources

- Plasma sources typically operate at pressures where the MFP is much less than the source to substrate distance.
- The plasma is accompanied by a bright visible glow discharge - see next slide
- Source operates at very high temperatures
- The high energy electrons in the plasma raise the temperature of the substrates - plastics cannot be coated!

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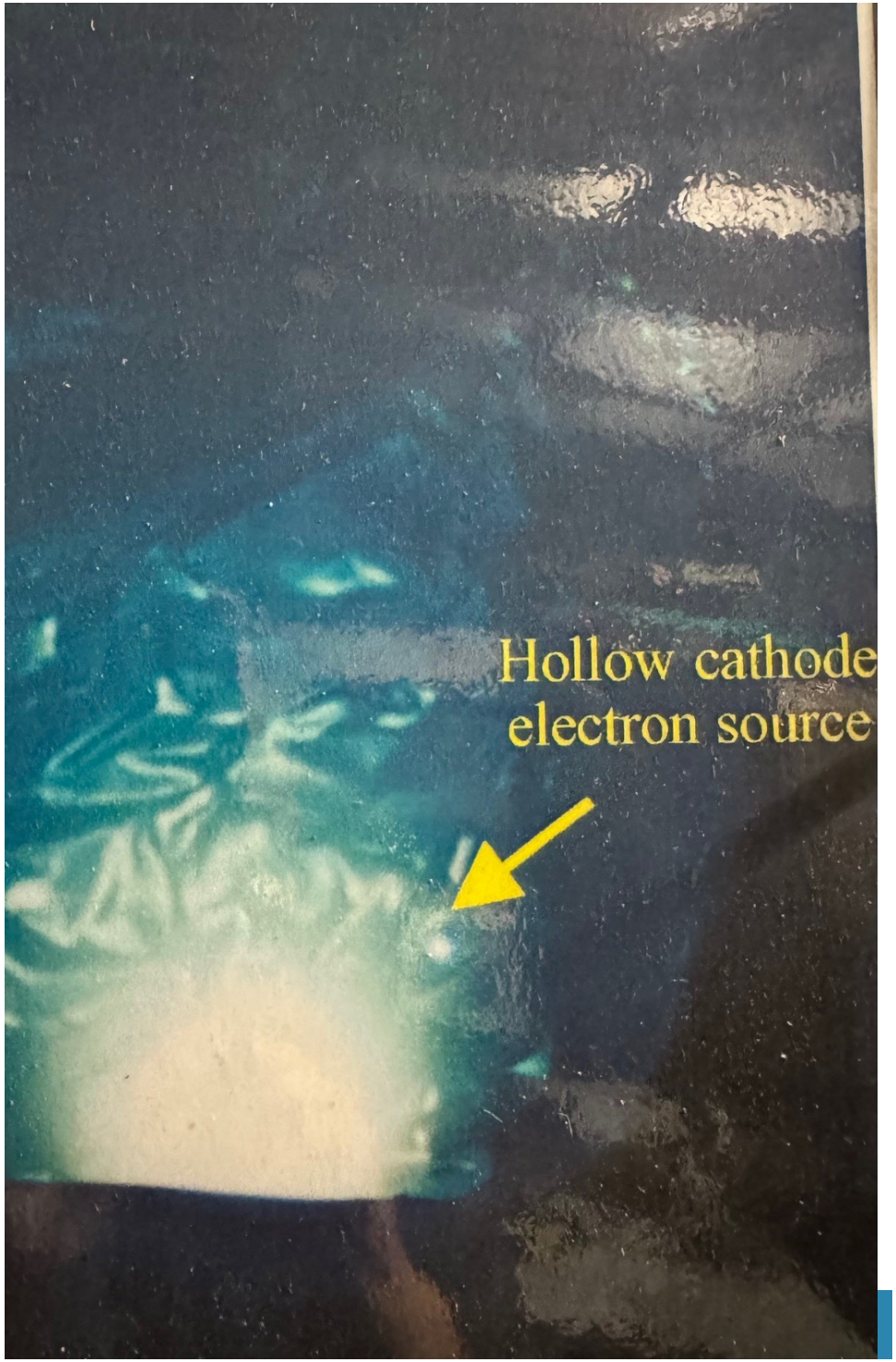
The plasma glow from a Veeco MkII Hi Output.

The substrate to substrate distance 500mm (20”)

Pressure 2.5 x 10-4 mBar

MFP approx. 100mm (4”)



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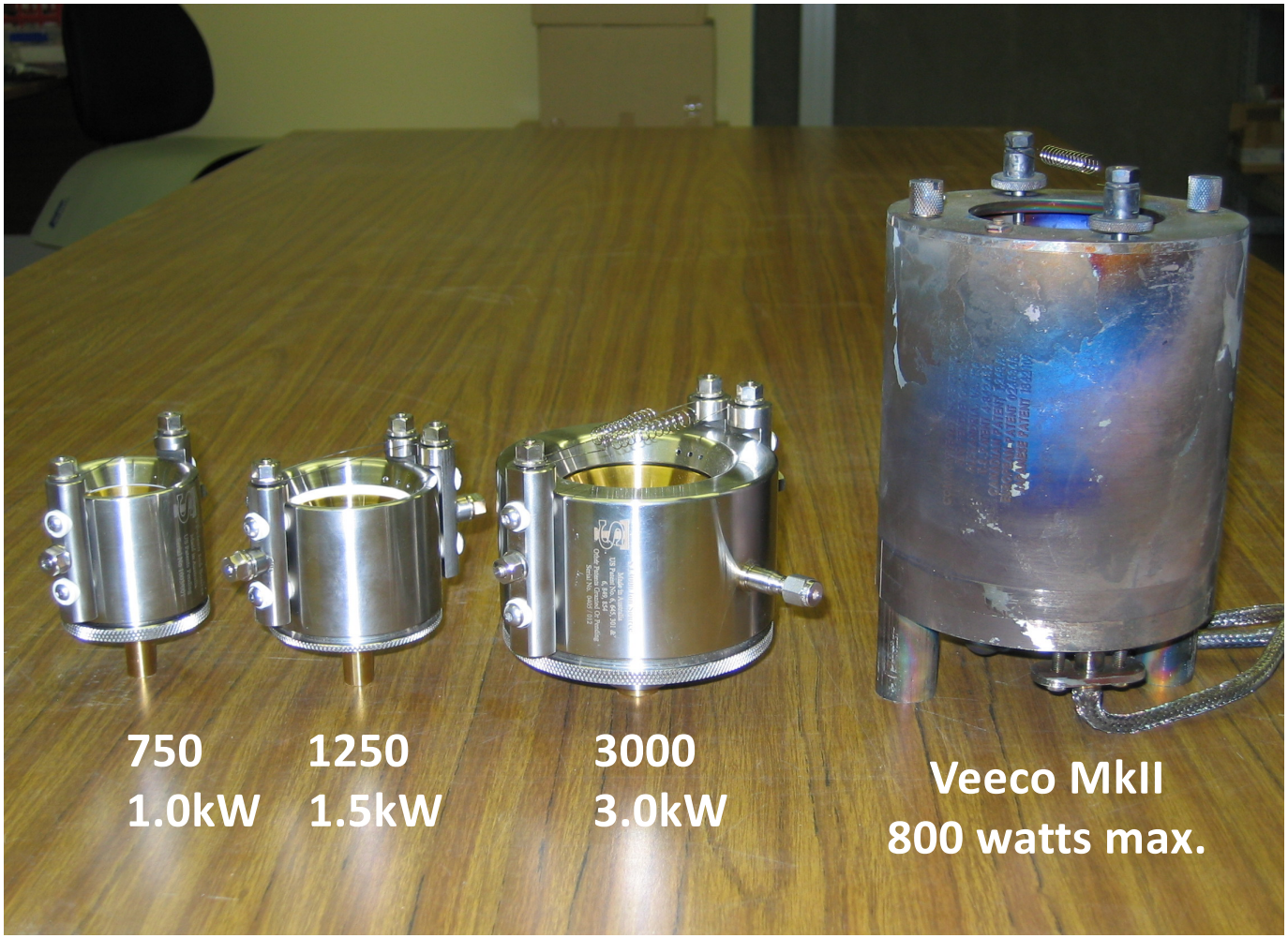
Telemark Systems compare with Veeco MkII



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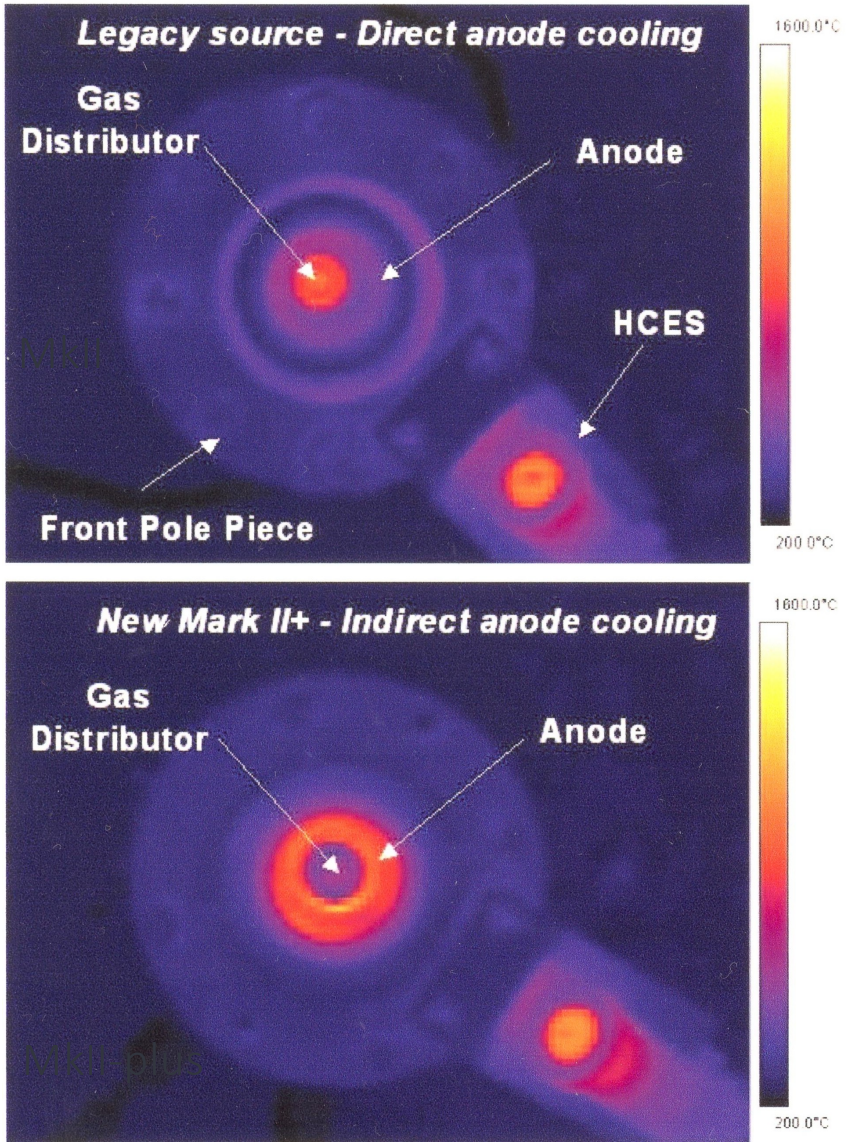
Highly Radiant Source

Thermal imaging* of Veeco MkII and New MkII-plus

Note the highly radiant HCES!

For both models, the Front Pole Piece operates at a temperature >. 500°C

*Vacuum Technology & Coating September 2006 pages 58-64
by D. Siegfried & L. Mahoney, Veeco



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The Highly Radiant Source (cont.)

Comment by Veeco*

"Practitioners working with ion beam processes involving heat sensitive materials (plastics, etc.) may be concerned that any increased radiant heat from the Mark II Plus may damage the substrates. However, the advantages of enhanced serviceability and increased ion beam output are likely to far outweigh problems associated with the increased thermal radiation"

*from Vacuum Technology & Coating, Sep 06, pages 58 - 64

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It’s not the Radiant Heat!

Contrary to common belief, it is not the RADIANT HEAT that creates the limitation for coating of plastics.

It is the PLASMA itself.

High energy electrons in the plasma bombard the substrates ……

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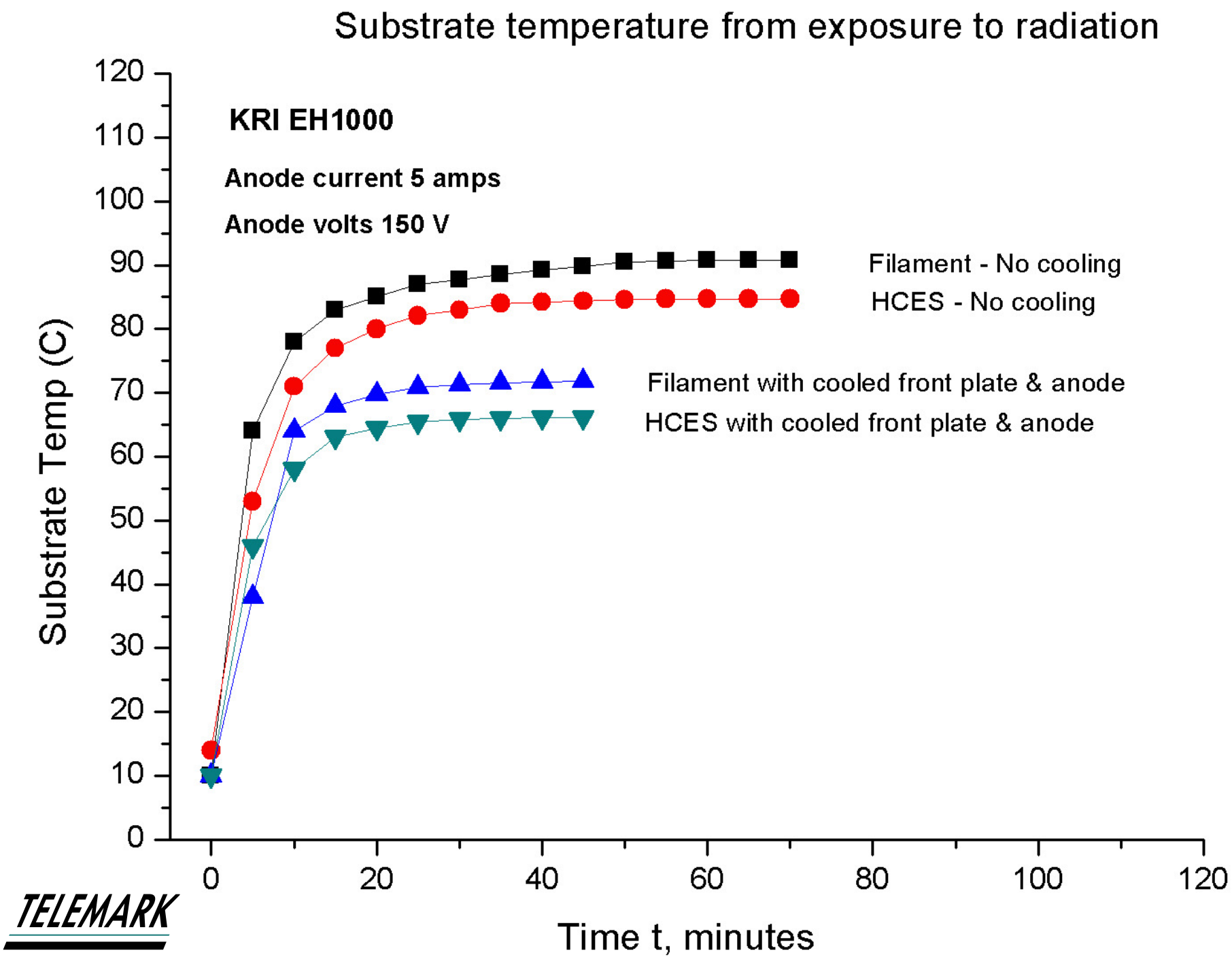
Substrate temperature from exposure to radiation
KRI EH1000
Anode current 5 amps
Anode volts 150 V
Filament - No cooling
HCES - No cooling
Filament with cooled front plate & anode
HCES with cooled front plate & anode
Substrate Temp (C)
Time t, minutes
0
10
20
30
40
50
60
70
80
90
100
110
120
0
20
40
60
80
100
120

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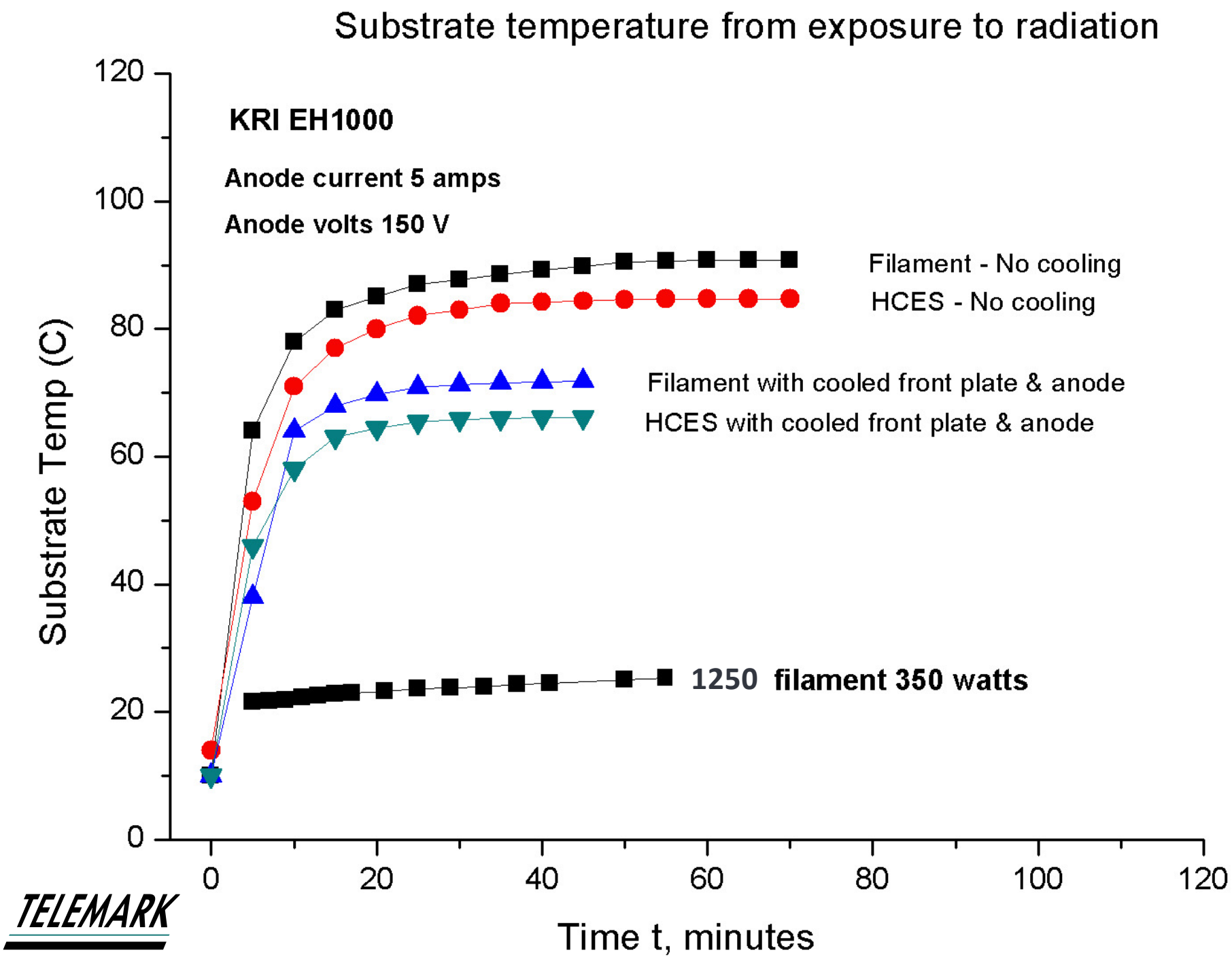
Substrate temperature from exposure to radiation
KRI EH1000
Anode current 5 amps
Anode volts 150 V
Filament - No cooling
HCES - No cooling
Filament with cooled front plate & anode
HCES with cooled front plate & anode
1250 filament 350 watts
Substrate Temp (C)
Time t, minutes
0
20
40
60
80
100
120

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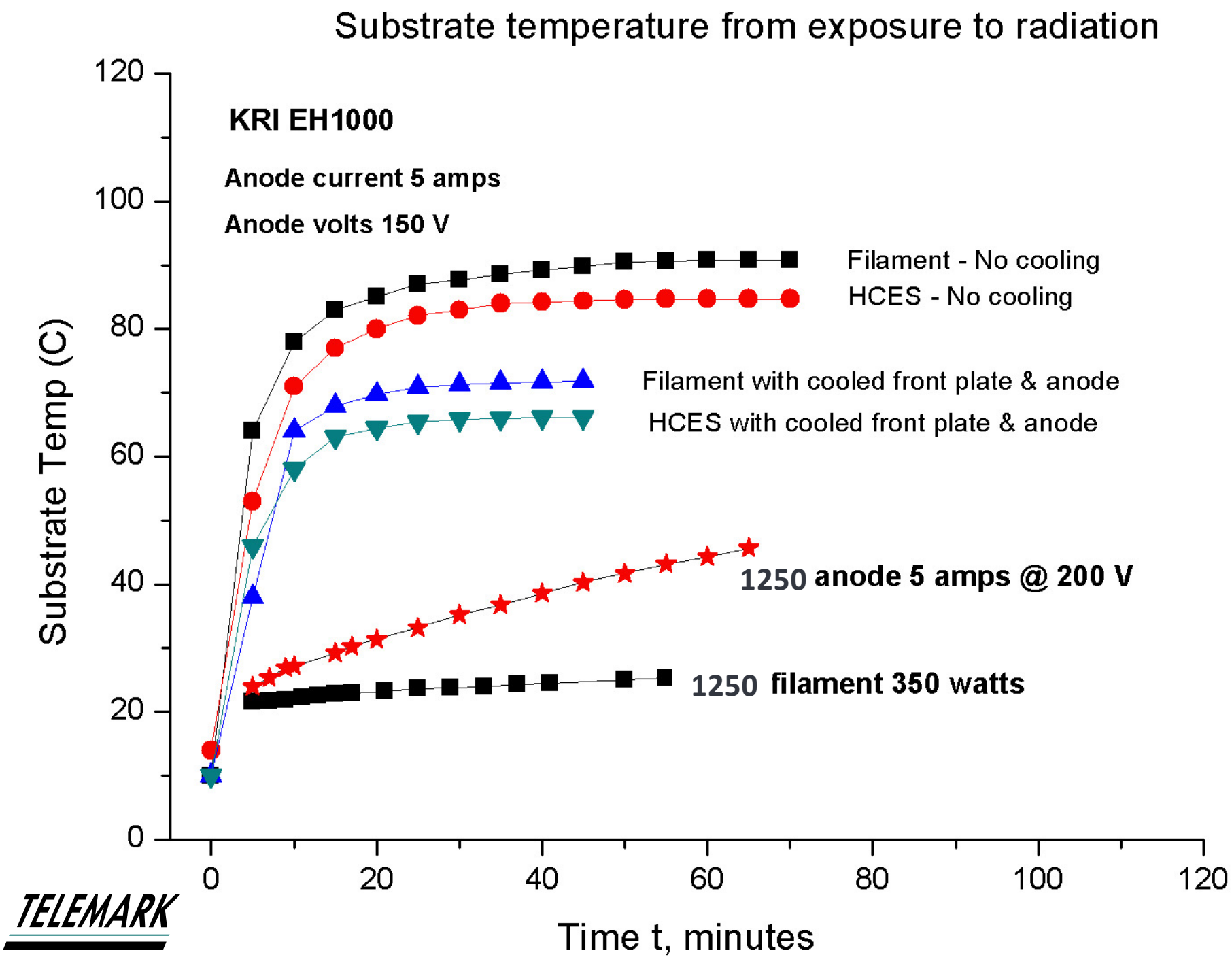
Substrate temperature from exposure to radiation
KRI EH1000
Anode current 5 amps
Anode volts 150 V
Filament - No cooling
HCES - No cooling
Filament with cooled front plate & anode
HCES with cooled front plate & anode
1250 anode 5 amps @ 200 V
1250 filament 350 watts
Substrate Temp (C)
Time t, minutes
0
20
40
60
80
100
120

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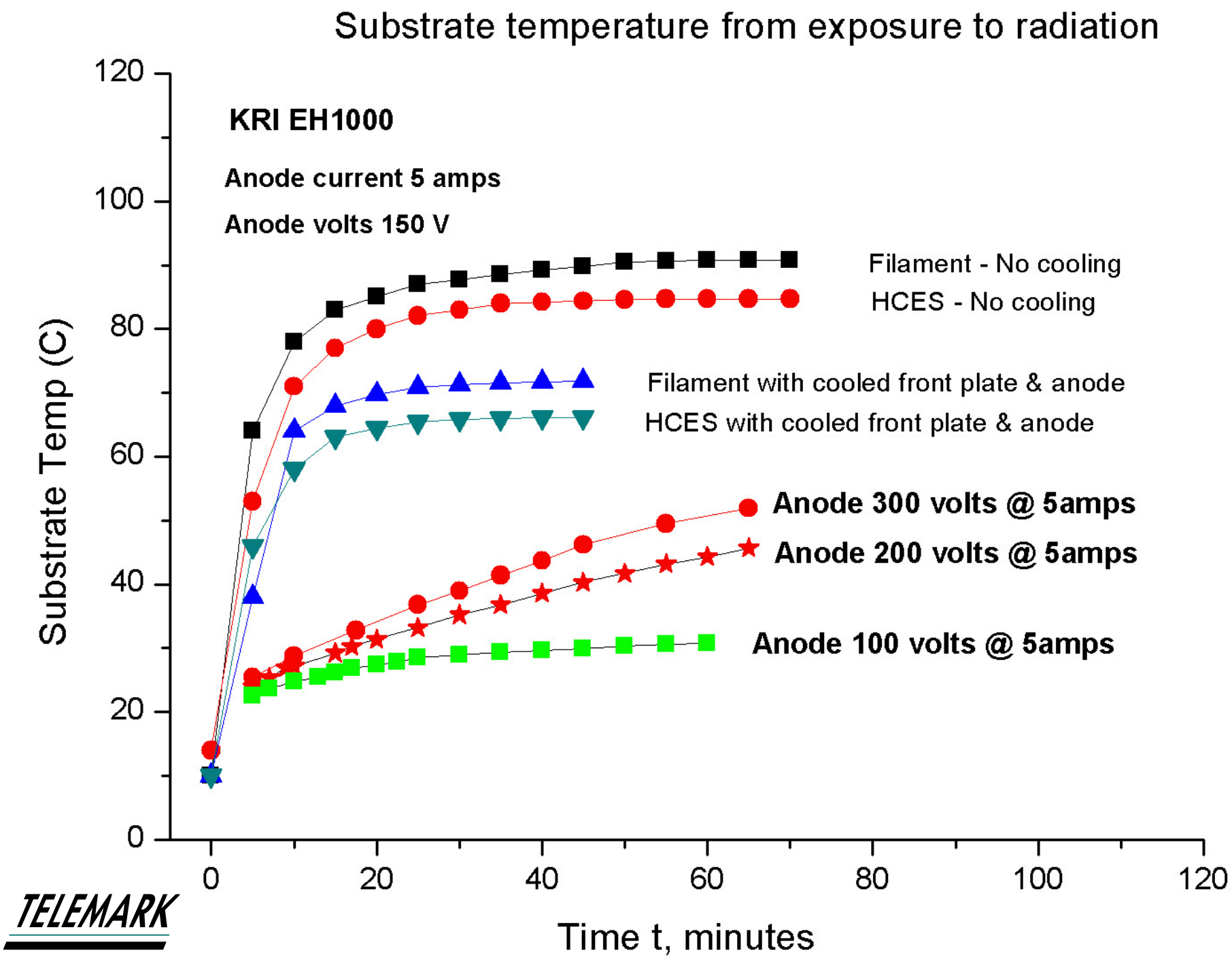
Substrate temperature from exposure to radiation
KRI EH1000
Anode current 5 amps
Anode volts 150 V
Filament - No cooling
HCES - No cooling
Filament with cooled front plate & anode
HCES with cooled front plate & anode
Anode 300 volts @ 5amps
Anode 200 volts @ 5amps
Anode 100 volts @ 5amps
Substrate Temp (C)
Time t, minutes
0
20
40
60
80
100
120

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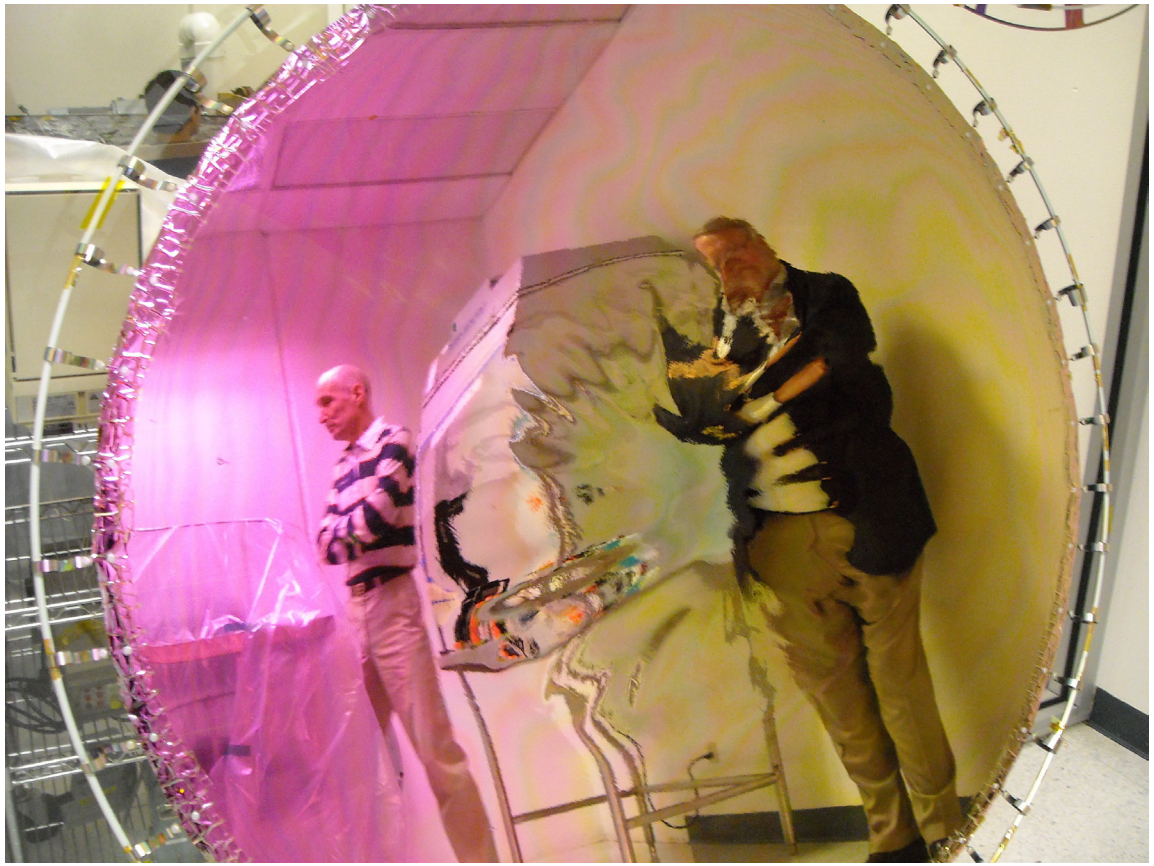
Complex multilayers can be deposited to plastic film

Thin plastic film can be successfully coated with multilayer dielectric film stacks.

2 meter diameter



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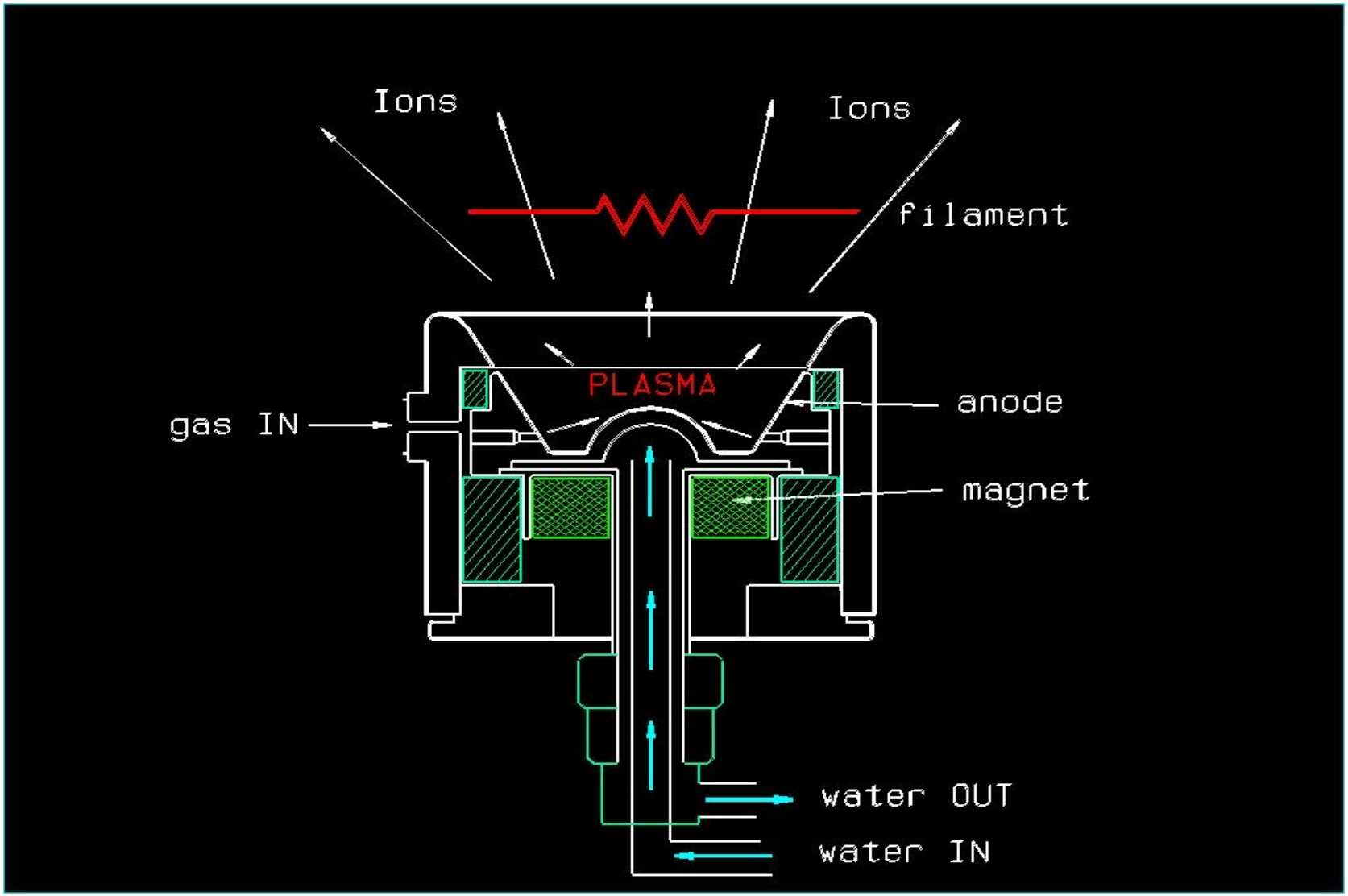
Highly Efficient Ion Generation



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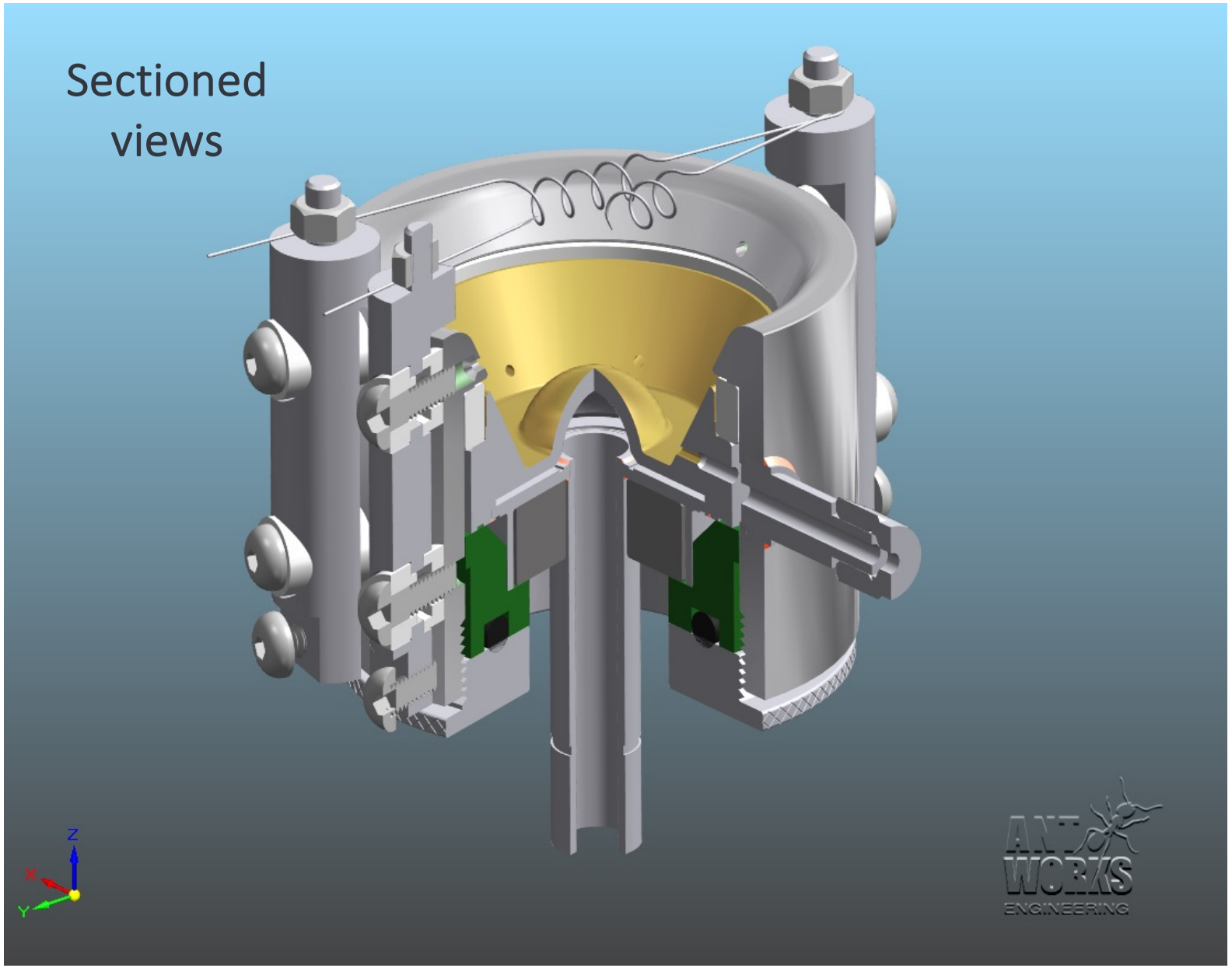
Sectioned views



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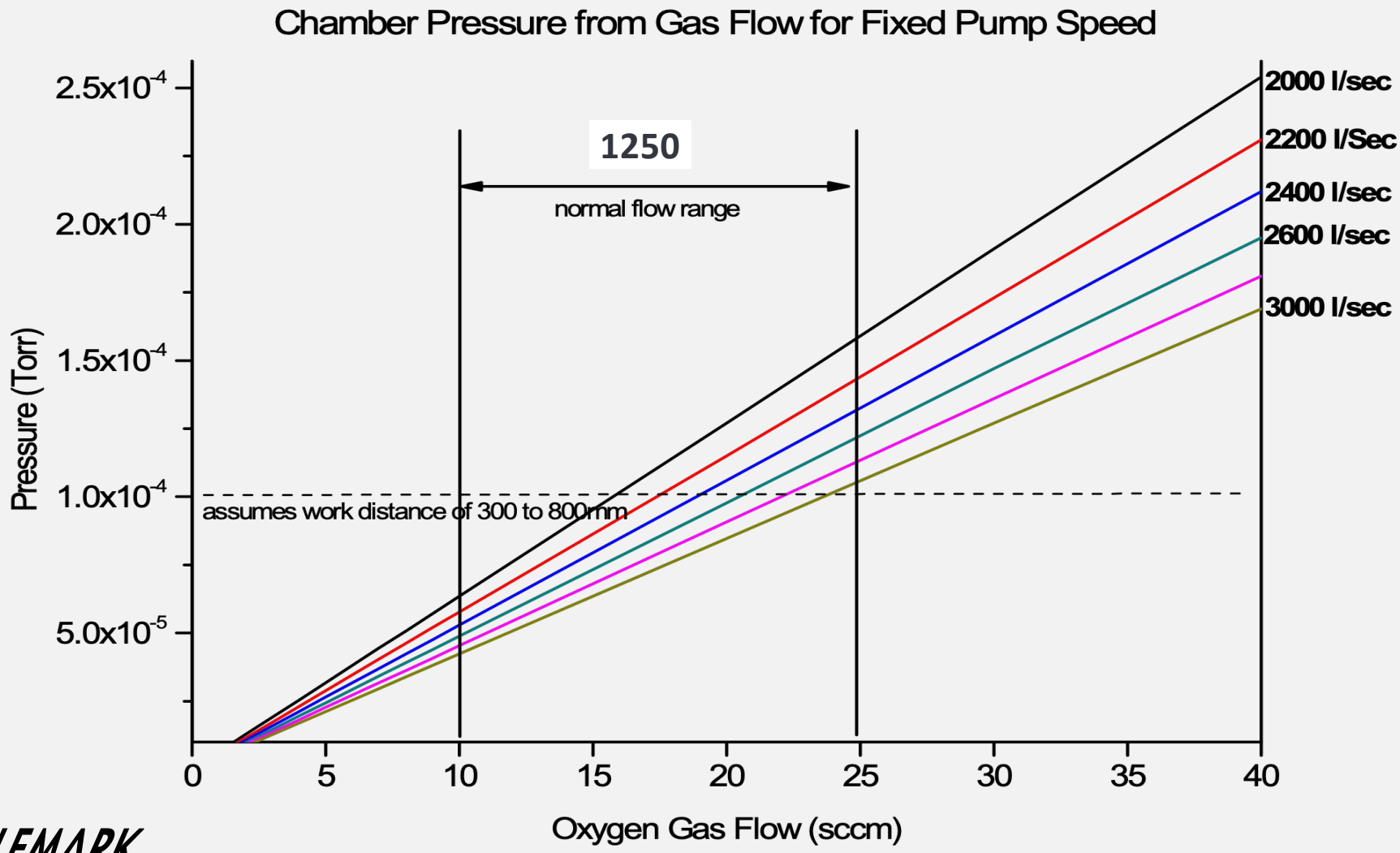
Vacuum Considerations for Optimal IAD Performance



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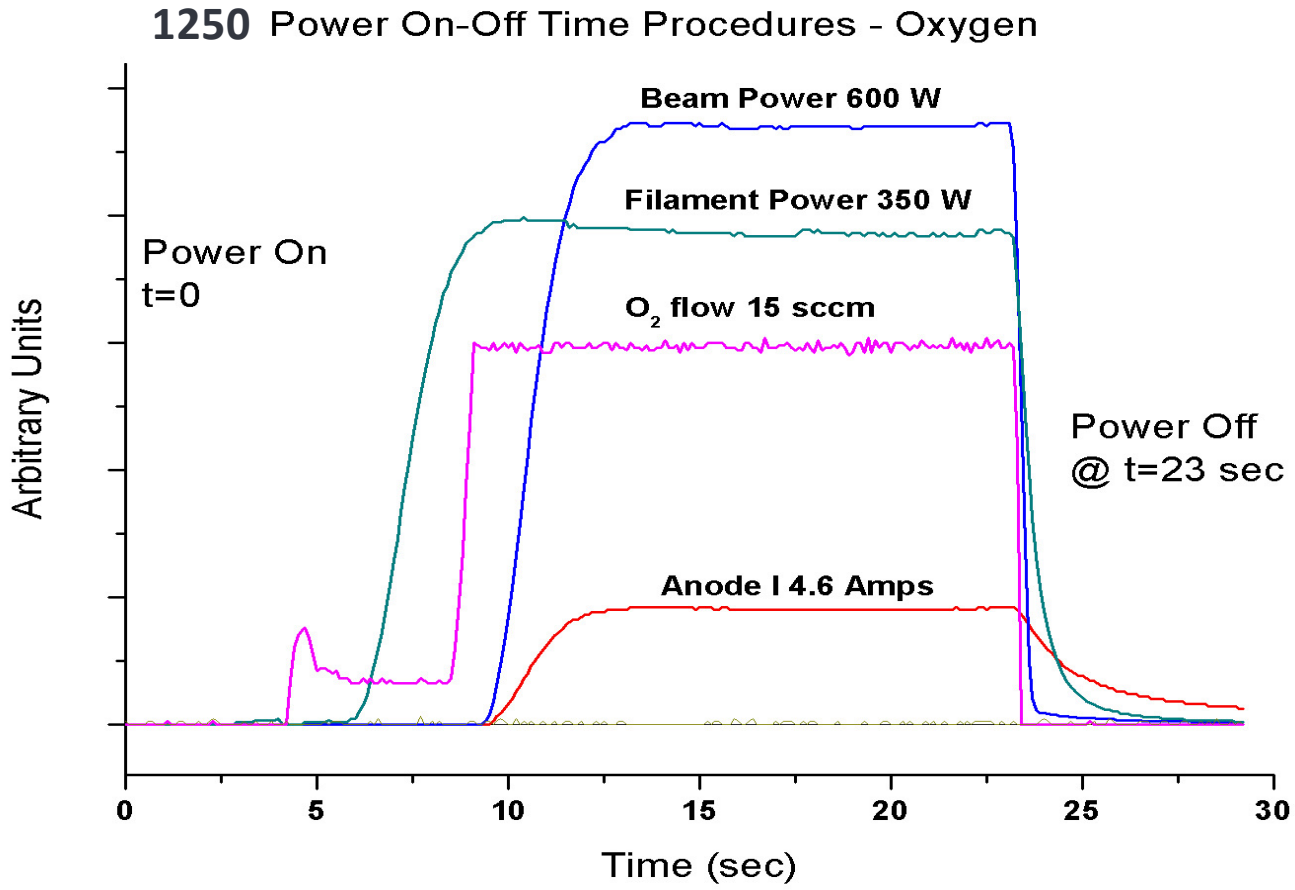
Rapid & Reliable Start-up

From start-up, beam is fully stabilized within

12 seconds



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The Effect of Water Vapor on the Optical Properties of Titanium Dioxide

- 3 films prepared by O+ IAD
- All films prepared with same deposition conditions
- Each film deposited with different water vapor partial pressures

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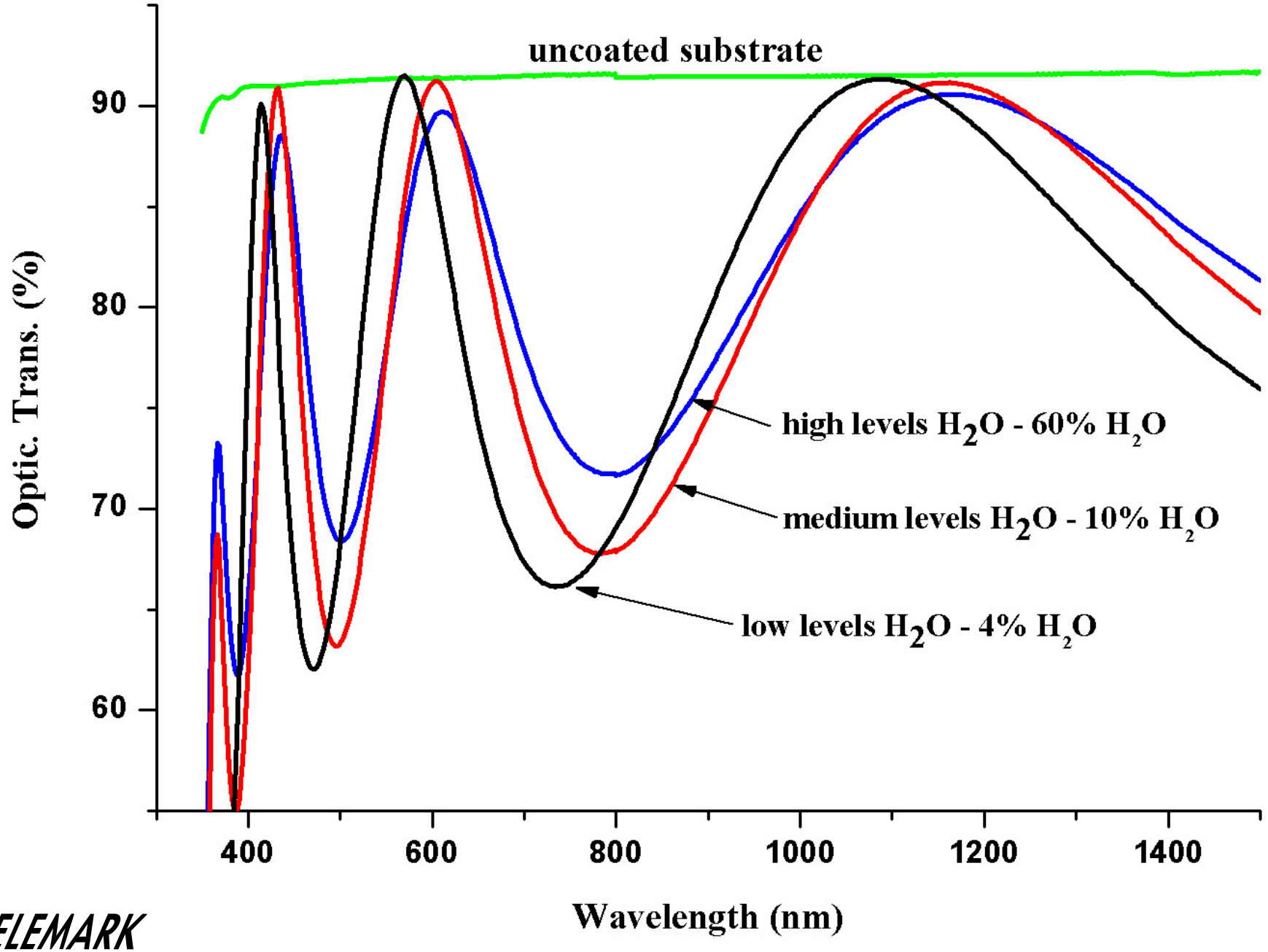
uncoated substrate
high levels H_2O - 60% H_2O
medium levels H_2O - 10% H_2O
low levels H_2O - 4% H_2O
Optic. Trans. (%)
90
80
70
60
400
600
800
1000
1200
1400
Wavelength (nm)

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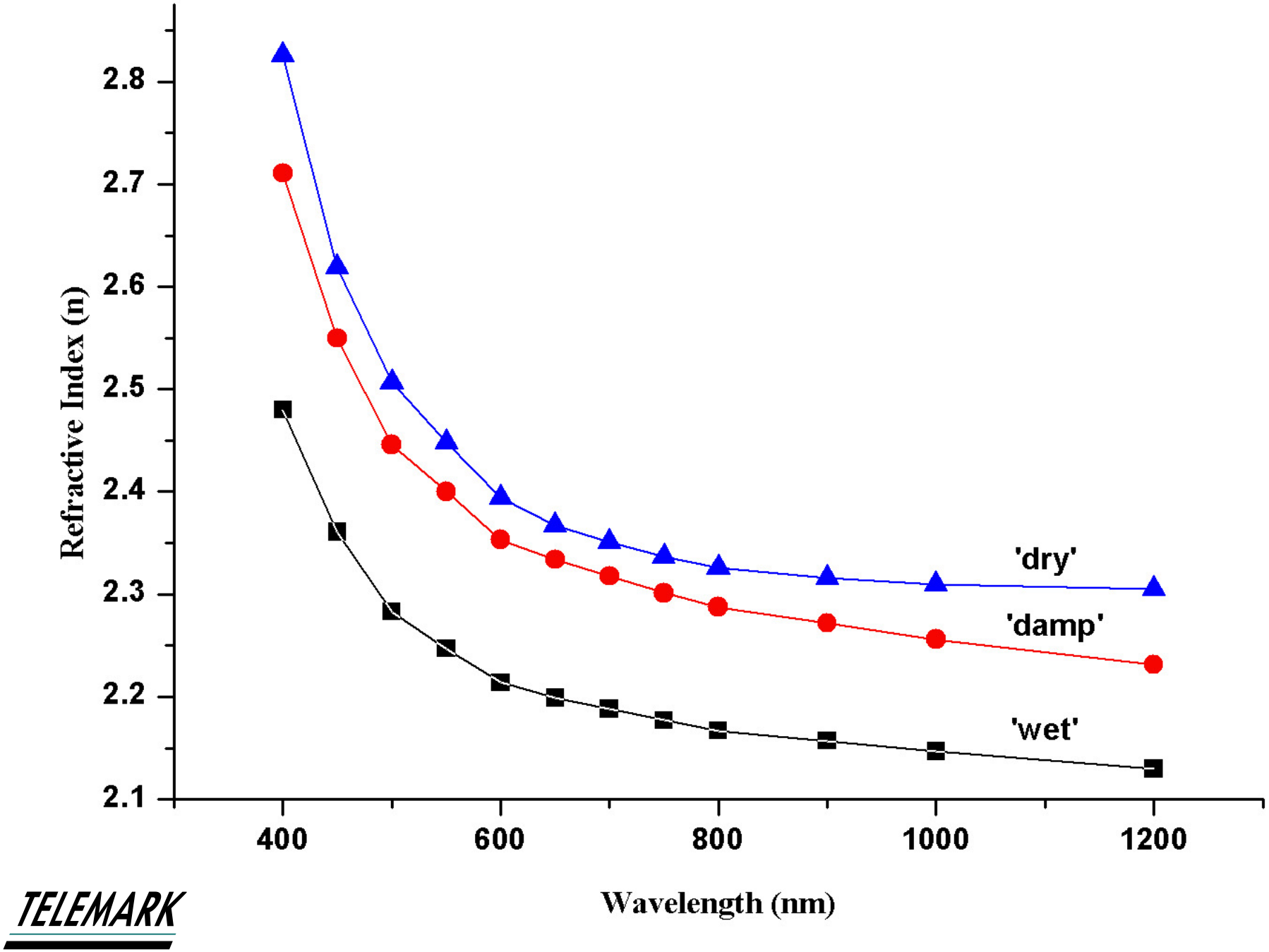
Refractive Index (n)
2.8
2.7
2.6
2.5
2.4
2.3
2.2
2.1
400
600
800
1000
1200
Wavelength (nm)
'dry'
'damp'
'wet'

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Process Economics

What benefits can we expect from using an Ion Gun in PVD Processes?

- Improvements to quality of process and products.
- Produce products more efficiently by reducing process time, lowering process temperatures, operating at lower process pressures, etc.
- Improve the reliability of products in end use
- Reduce plant operating costs by reducing routine maintenance, labour costs and consumption of consumables

So, how well can these objectives be achieved?

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Case Study – Coatings Inc.

- Coatings Inc. large quantities of optical filters;
- Operated 3x 100” cryo-pumped box coaters – 3x shifts /day
- Coat multilayer stacks of TiO/SiO dielectrics > 40 layers.
- Coating process: e-beam evaporation with IAD. Substrates heated to 550ºF (approx. 300ºC). Only one MkII was used at any one time due to instability when operated together.
- Averaging about one complete production run per shift.
- Success rate 35% mostly related to adhesion problems.
- Maintenance issues: Veeco sources require weekly removal for refurbishment. Approximate cost of $400 each per week. There were four sources to be serviced each week by one service technician who was employed for just this function.

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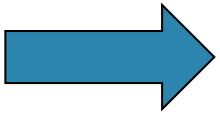
Coatings Inc



Coatings Inc installed two Model 2000 ion systems in one 100 inch chamber.

- Temperature reduced to ~ 100ºC - reduces pump-down time.
- Pressure with both ion guns running down to 5x10-5 mbar. Considerable savings on maintenance. Cryopumps re-generated once per month instead of weekly.
- TiO2 index increased from 2.25 up to 2.45 reducing layers from typically 45 down to 31 to 33 – saves coating time (~40 minutes) – saves consumable materials.
- Coating quality improved – poor adhesion solved – coating consistency results
- As a result - the success rate up to ~ 85%
- The same two Telemark ion beam systems were still operating after more than 10 years in use. No major component parts were purchased in that time.

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and…when you get it right,
IAD can be an enabling technology

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The 1.4 meter Kepler Primary Mirror following coating at Surface Optics Corp San Diego, California. Coated with enhanced and protected silver.

Achieving the optical and environmental specification would not have been possible without Telemark ion technology

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Modular Radial System

- Flange mounted 1250 ion gun module. Shown is one of four radially mounted ion gun modules
- Each module is hinge mounted within a 1.8 meter diameter production coating system for the high rate deposition of multilayer dielectric coatings

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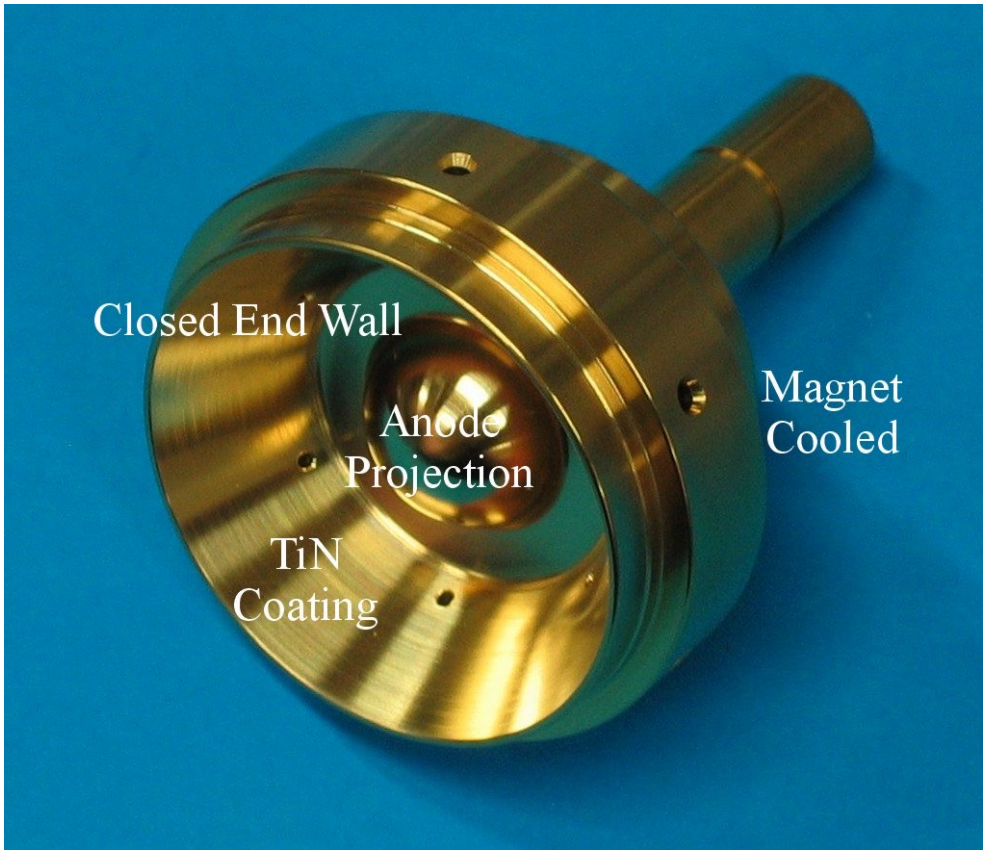
Patented technology

Ion source design

- Closed end wall of anode and anode projection
- Titanium nitride coating of anode
- Direct water cooling of anode
- Water cooled magnet



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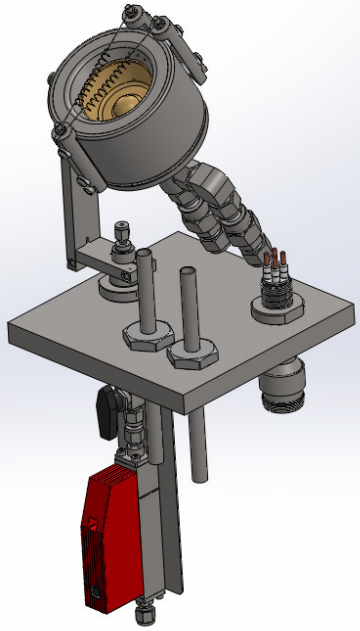
CF Mounting Available



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Arrays and Multiple Sources

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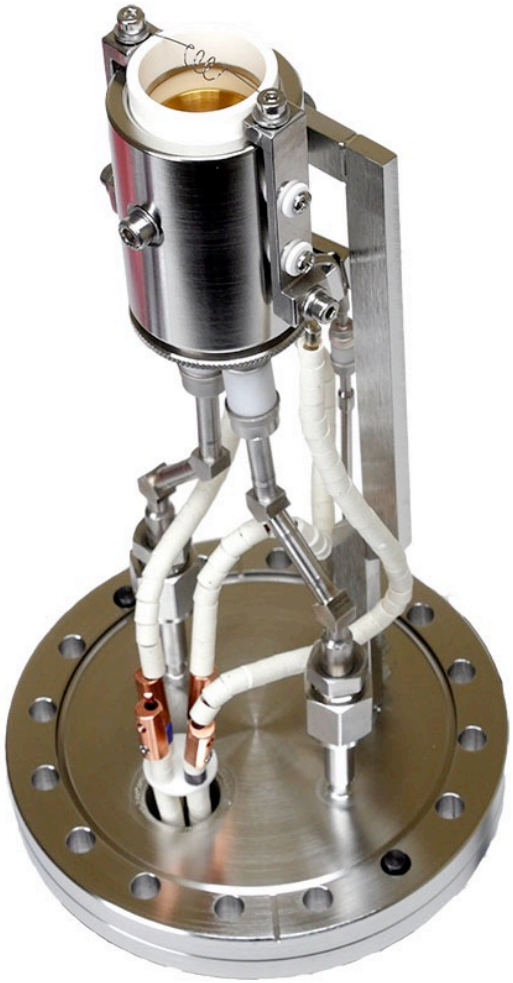
UHV Version Available

R&D applications
500W, 1.5 amps



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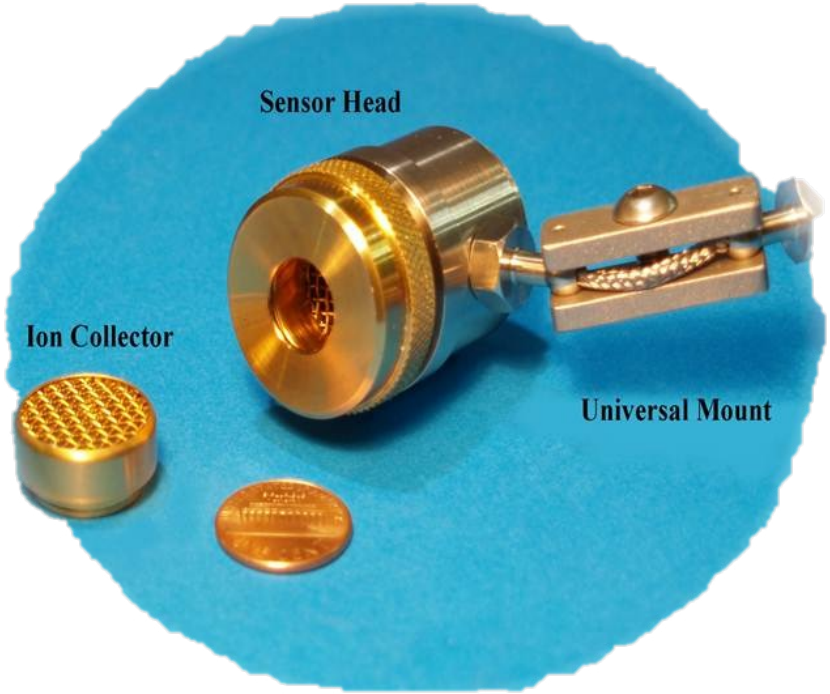
Ion Current Monitor

- Gridded Ion Collector allows continuous ion energy display even during film deposition
- Bias ability to minimize electron count
- Installed in the Ion Beam Power Supply or in a ½ Rack mounting configuration
- Maximum input is 2mA/cm2



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Arrays and Multiple Sources

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