Semion RFEA System

Measure the Ion Flux and Ion Energy incident on your substrate

https://www.impedans.com/semion-rfea-system/

Impedans PLASMA MEASUREMENT

The Semion RFEA System

Suitable for DC, CW RF biasing & pulsed RF source (sensor deployed on the grounded pedestal)

Parameters Measured:

- ✓ Ion energy distribution function (IEDF)
- ✓ Number of sensors: 1 – 13
- ✓ Average energy & ion flux
- ✓ Vdc

Specification

- ✓ 4 grid RFEA
- ✓ 2keV ion energy range
- ✓ Apply up to 1kV pk-pk RF bias
- ✓ RF frequencies 100 kHz to 80 MHz
- ✓ Available in anodized aluminum, bare aluminum and stainless steel
- ✓ Easily replaceable button probes

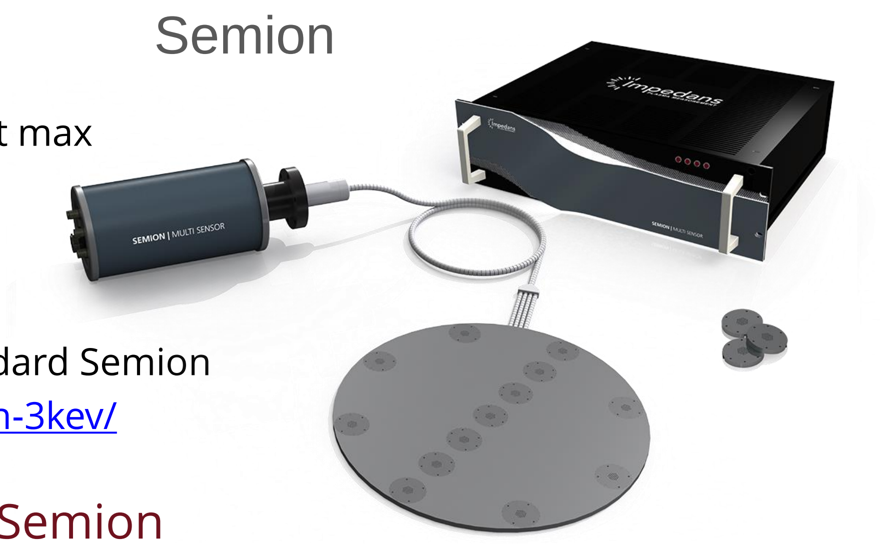
Button Sensors Available

- ✓ Low density 0.001 to 3 A/m^2
- ✓ Standard 0.01 to 50 A/m^2
- ✓ High density 0.1 to 700 A/m^2

NEW: High Pressure Buttons

- ✓ HP button extends range to 2 Torr
- ✓ Limited to 150 eV scanning range at max pressure in Argon

Semion



NEW: High Voltage Semion

- ✓ 3x RF bias range compared to standard Semion
- ✓ https://www.impedans.com/semion-3kev/

Also available: Time-Resolved Semion

- ✓ https://www.impedans.com/semion-pdc/

Advantages of the Impedans Semion RFEA:

- ✓ Integrate up to 13 sensors into a single wafer for uniformity measurements
- ✓ Various shaped and sized wafers to suit the tool
- ✓ Over 200 publications using this hardware, trusted by universities and industry alike: impedans.com/semion-applications

Key Features

Various Holder Designs
Holders of different shapes and sizes available upon request

Compatible with majority of Biasing Conditions
Suitable for Grounded, Floating and RF Biased conditions

Material Finishes
Sensor elements and holders available in anodized aluminium, bare aluminium, stainless steel

Replacable Sensor Elements
Can change the sensor elements to account for different plasma densities

Portable for use in many chambers
Standard vacuum flanges available, different holder form factors for any substrate shape

In-situ measurements of uniformity
Ion energy and ion flux contour maps produced in real time in the software

Data for industry and R&D
Provides data for plasma-substrate interaction for tool characterization and to quickly identify process issues

Advanced software
Fully automated software analysis of the IEDF and automatic DC bias potential measurement.

Technical Specifications

Parameters Measured	Range
Ion Energy Range	0 to 2000 eV (Standard/Low/High Density Buttons) 0 to 150 eV (High Pressure Button)
Ion Flux	0.001 to 700 A/m^2 (Dependent upon button)
Pressure Range	300 mTorr (Standard/Low/High Density buttons) 2 ≤ 2TorrTorr (High Pressure Button)
IEDF Resolution	± 1 eV nominal; 0.1V step size available
Max RF Bias voltage (applied to probe)	1 kV (peak to peak) @ 13.56 MHz ; approx. -500 VDC
Max DC Bias Voltage (independent of RF bias)	-1940 V
Bias Frequency Range	100 kHz to 80 MHz

- ✓ For more detailed specifications and different models available, visit https://www.impedans.com/semion_sensors
- ✓ To see if the RFEA is suitable for your plasma application, see the applications list at impedans.com/semion-applications
- ✓ To arrange a technical discussion, contact support@impedans.com

Semion Electronics

Semion Vacuum Feedthrough

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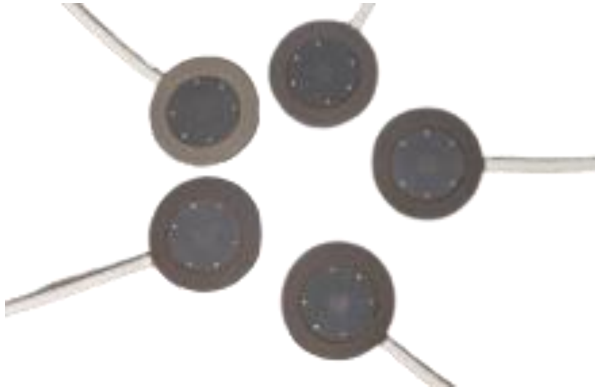
Sensor Holder Options

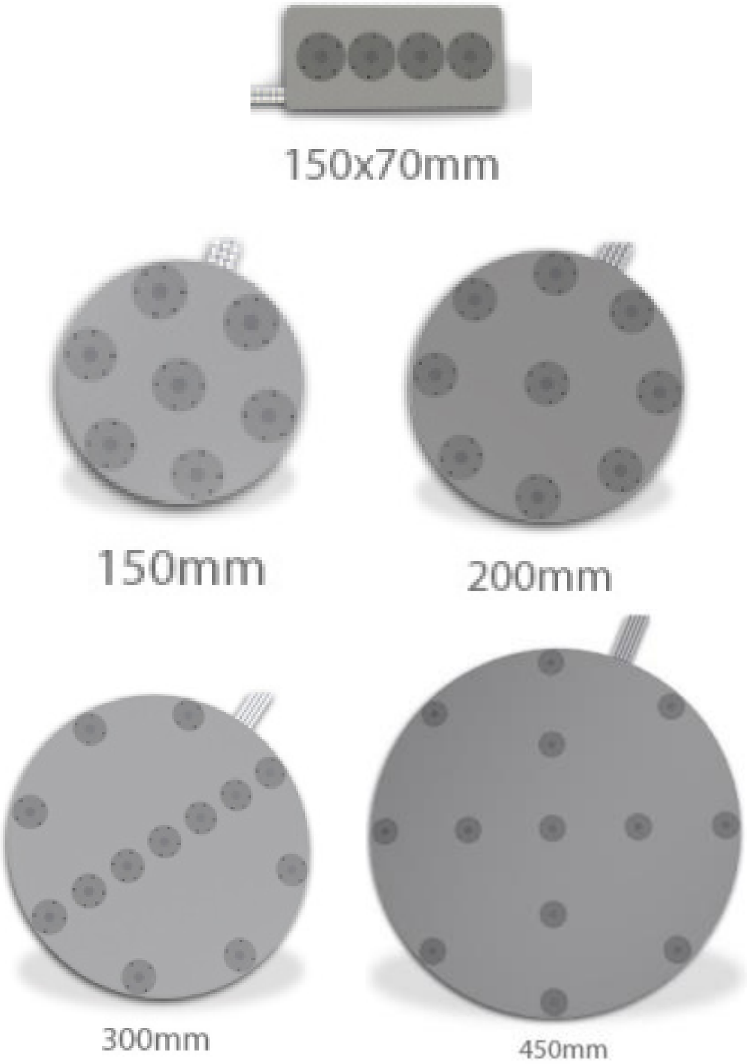
Sensor Type	Available Options
Single Holder	70 mm, 100 mm, 200 mm, 300 mm. Mounting holes available on request
Multi Holders	150 x 70 mm with 4 sensors 150 mm with 7 sensors 200 mm with 9 sensors 300 mm with 13 sensors Mounting holes available on request
Multi-Branched Holders	Up to 13 positions available Each position a single holder with a single sensor
Holder Material Options	Anodized Aluminium (standard), Bare Aluminium and Stainless Steel
Cable Options	Ceramic Beads (standard), Stainless Steel Any length available; 650 mm default length
Plug Options	17 pin 23 mm diameter (standard) 8 mm adaptor for small ports available on request Individual wiring pins (no socket) available

Single sensor holder



Multi-Branch with 5x single holders

For arbitrary measurement positions in large substrate tools



Button Probe Options

Sensor Type	Available Options
Standard Pressures (< 300 mTorr) Max ion energy range 2 keV	Standard Density (0.01 to 50 A/m^2) [Recommended] Low Density (0.001 to 3 A/m^2) High Density (0.1 to 700 A/m^2) [ICP tools]
High Pressures (< 2 Torr) Max ion energy range 150 eV	Standard Density (0.01 to 50 A/m^2) Low Density (0.001 to 3 A/m^2) [Recommended] High Density (0.1 to 700 A/m^2)
Measurement position options	Centered (standard); Offset (5mm from edge)
Material Options	Anodized Aluminium (standard), Bare Aluminium and Stainless Steel
Capillary Plate Options *Placed on top of sensor for ion angle filtering*	10:1; 20:1; 50:1; 80:1; 100:1; 200:1 Typically 1 mm thick, 10 mm diameter
Button Lifetime before replacement	Etch conditions: Time to etch 30 microns of Nickel Deposition: 10 microns of deposition
Chemical Compatibility	All typical research and semiconductor gases Not compatible with Carbon Monoxide plasmas

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Semion Buttons

Offset Semion Buttons

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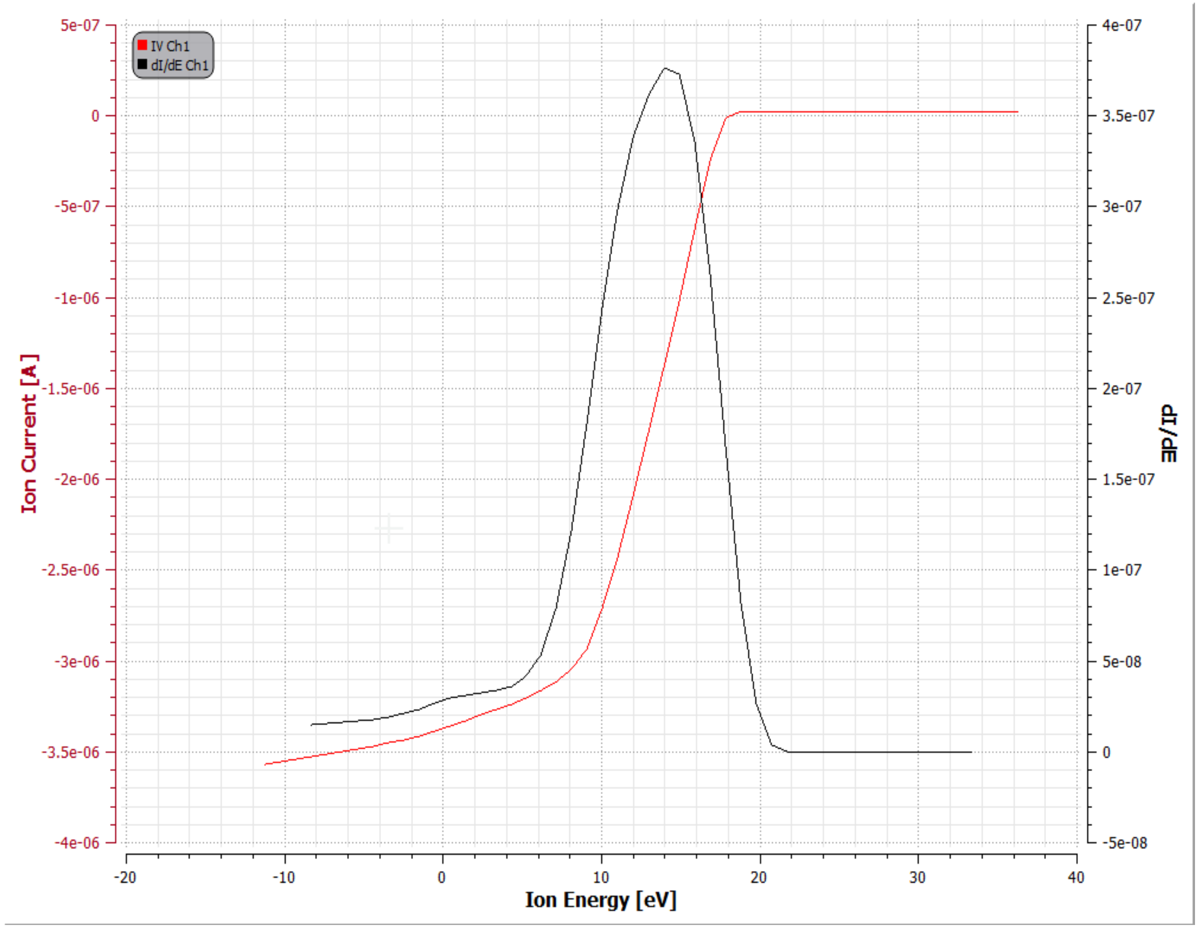
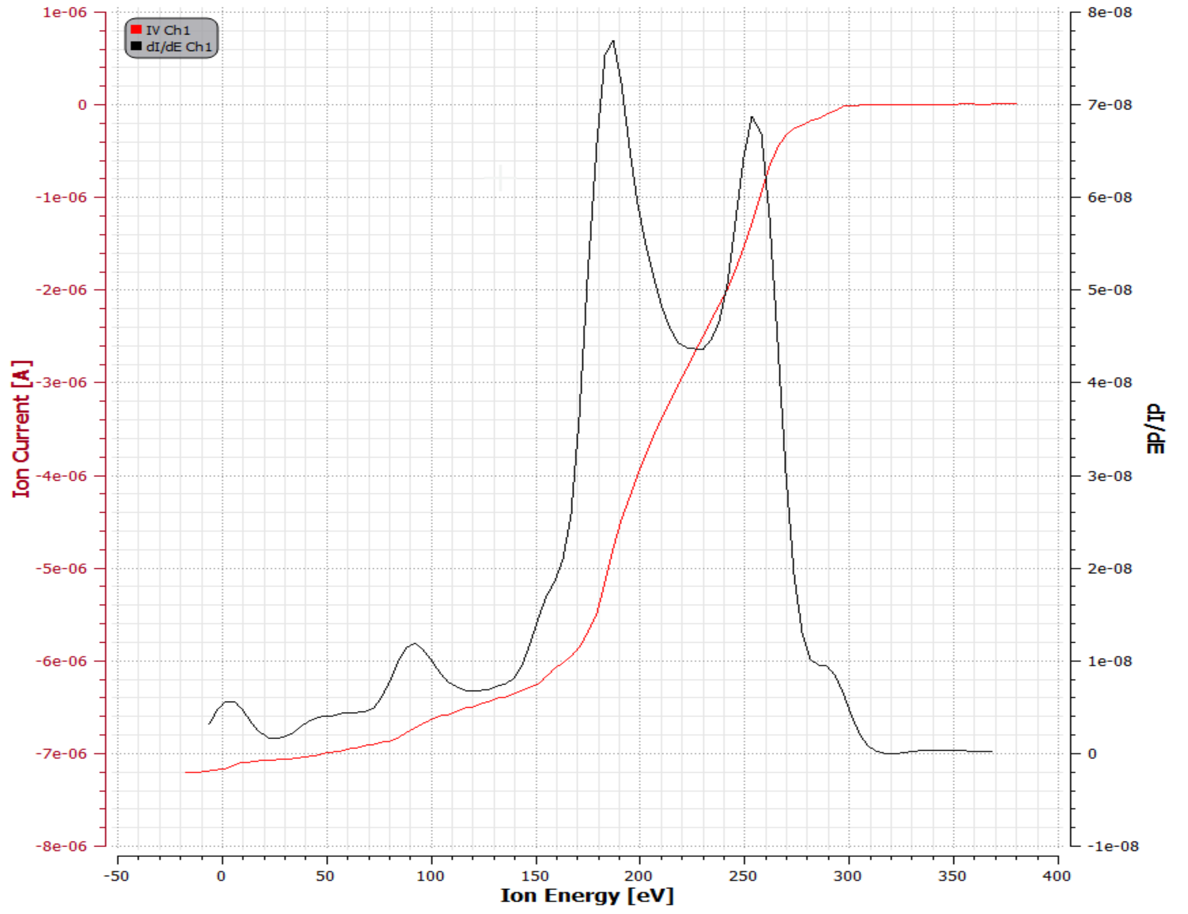
Example Data: IV curve and IEDF Curve



Grounded IEDF



RF Biased IEDF

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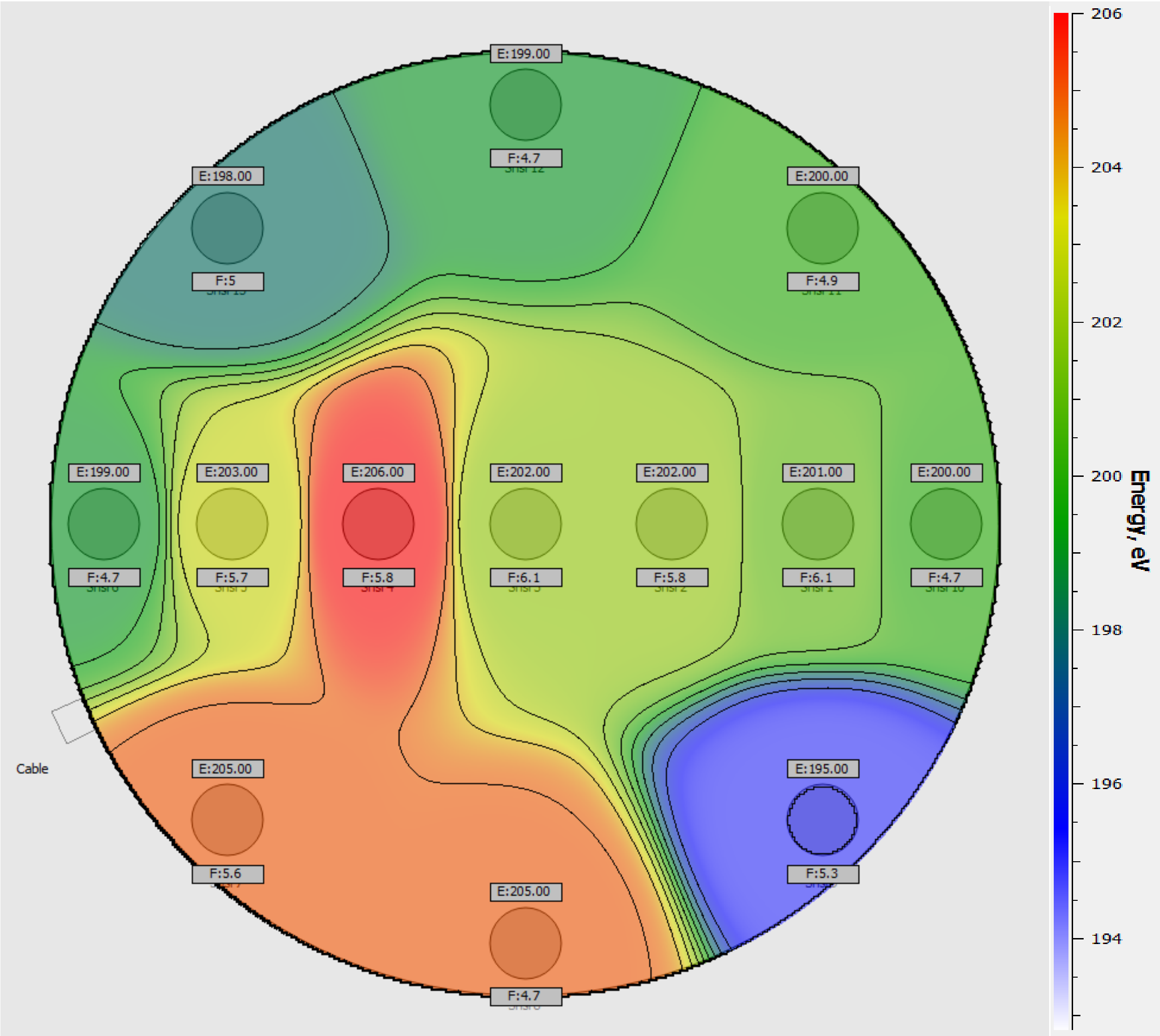
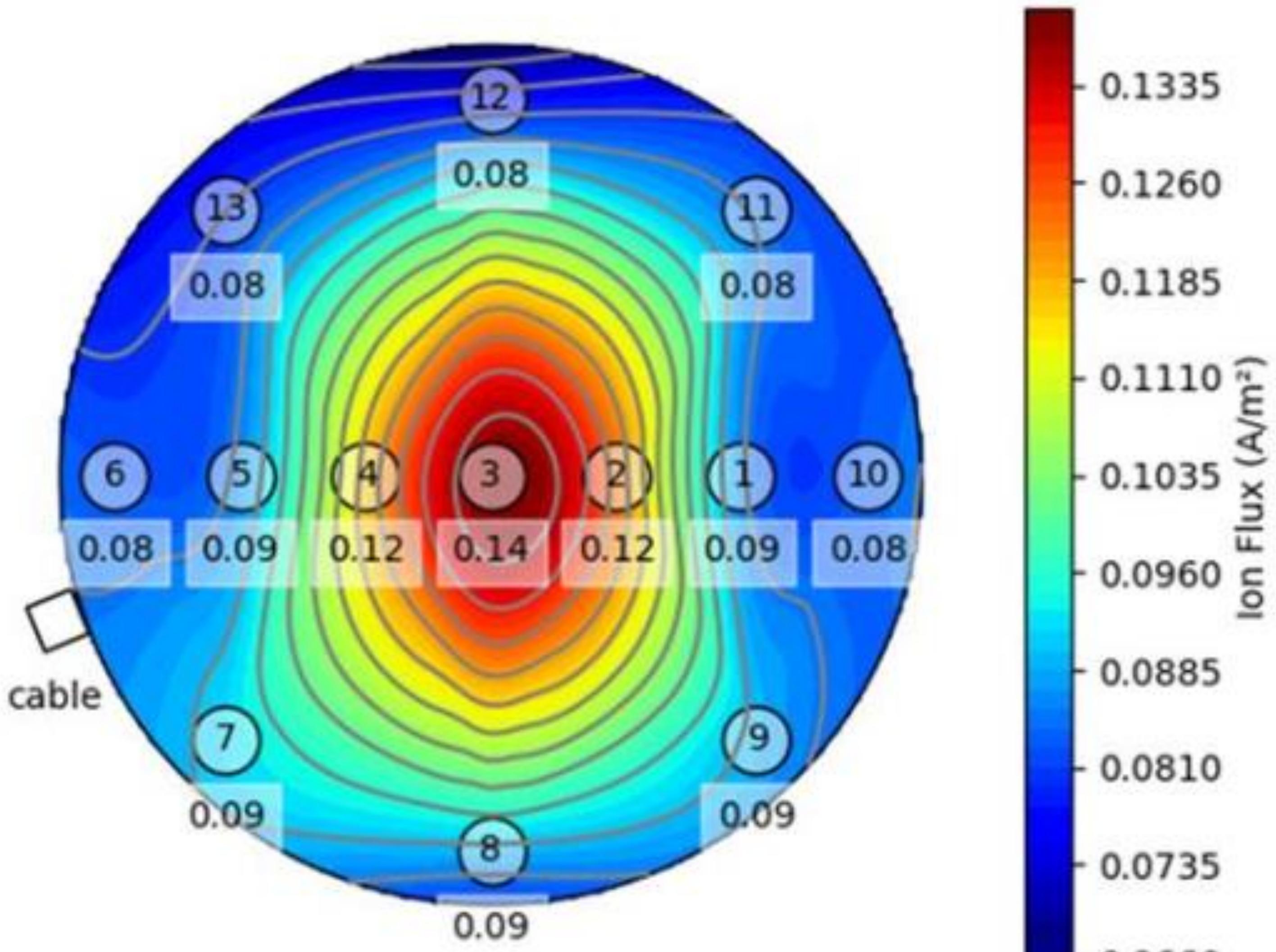
Example Data: Ion Energy Contour Map



Example Data: Ion Flux Contour Map

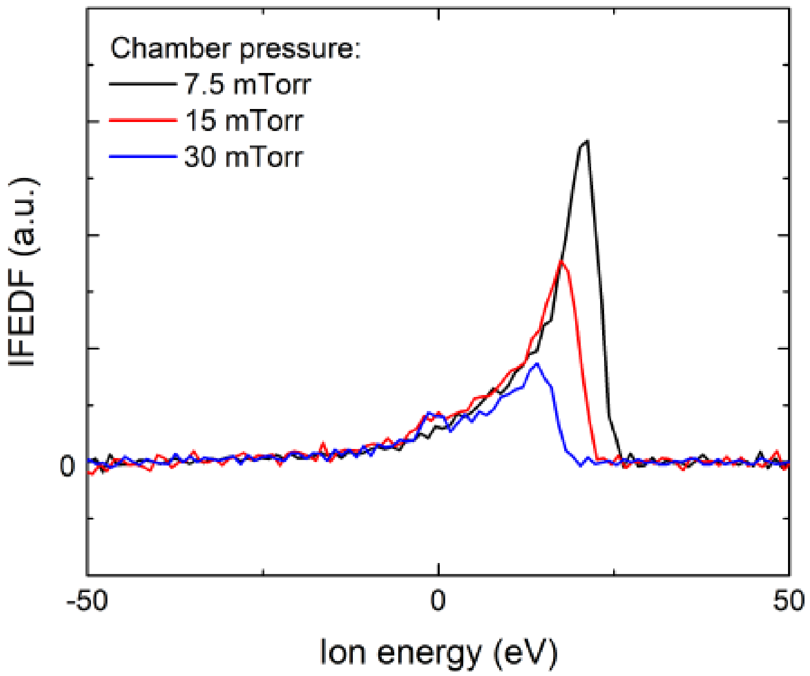


Semion Applications

Pressure and Gas Impact on IEDFs

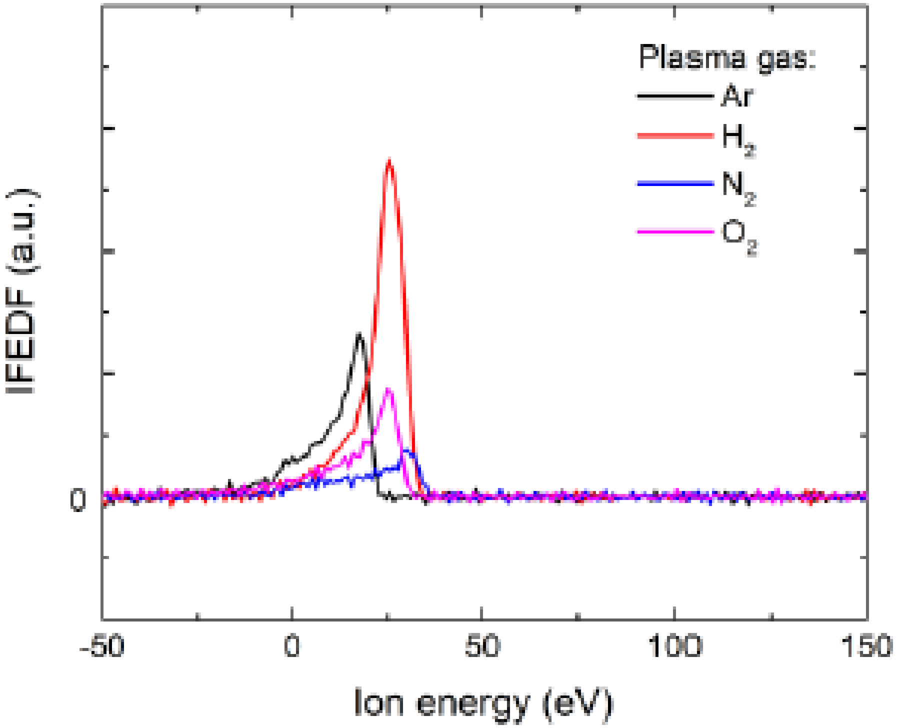
IEDF at different pressures for Argon

100 W ICP



IEDF for different gases

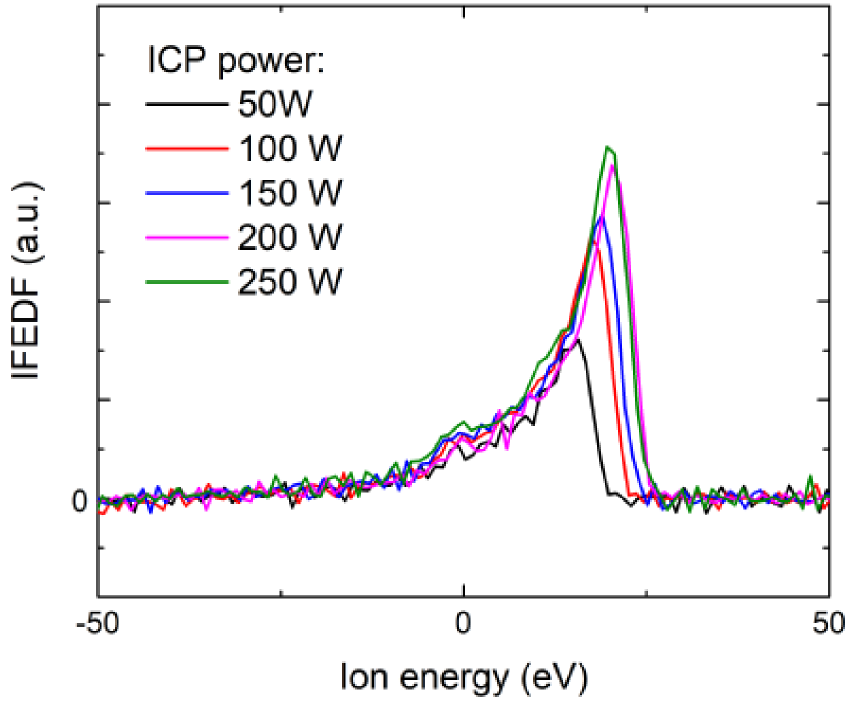
15 mTorr & 100 W ICP



Source Power Impact on IEDFs

IEDF at different power (Top ICP)

15 mTorr

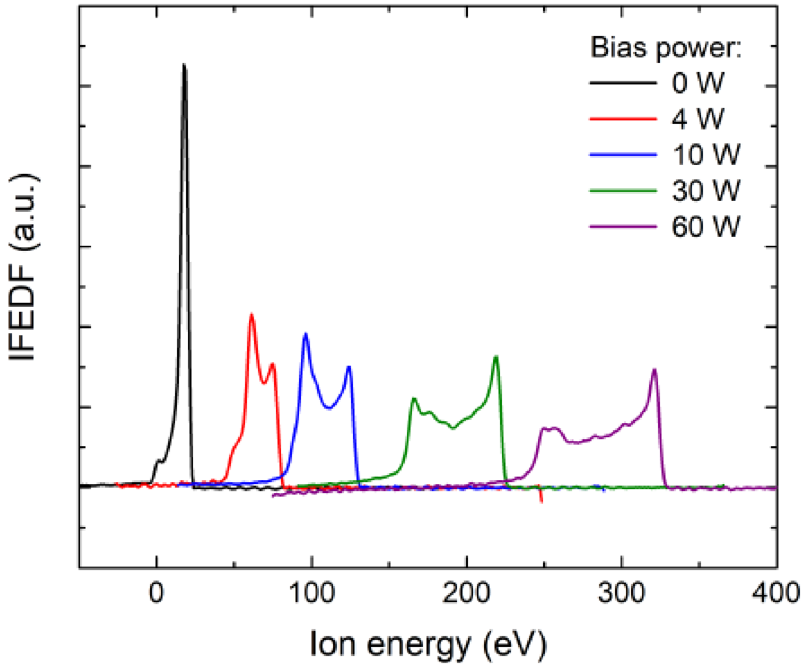


- ✓ As power is increased on an electrode or coil above the substrate, the ion flux increases
- ✓ The ion energy also increases, but not by much
- ✓ The energy increase is from increases in the plasma potential

Bias Power Impact on IEDFs

IEDF at different power
(Bias Electrode)

9 mTorr & 600 W Top



- ✓ On the RF biased electrode, even a small power increase causes a large change in the ion energies
- ✓ IEDF splitting also increases with power, so there's a wider ion energy spread
- ✓ Note: Power on the generator is not the same as power delivered to the electrode. Match boxes and transmission lines heat up, so power delivered changes over time

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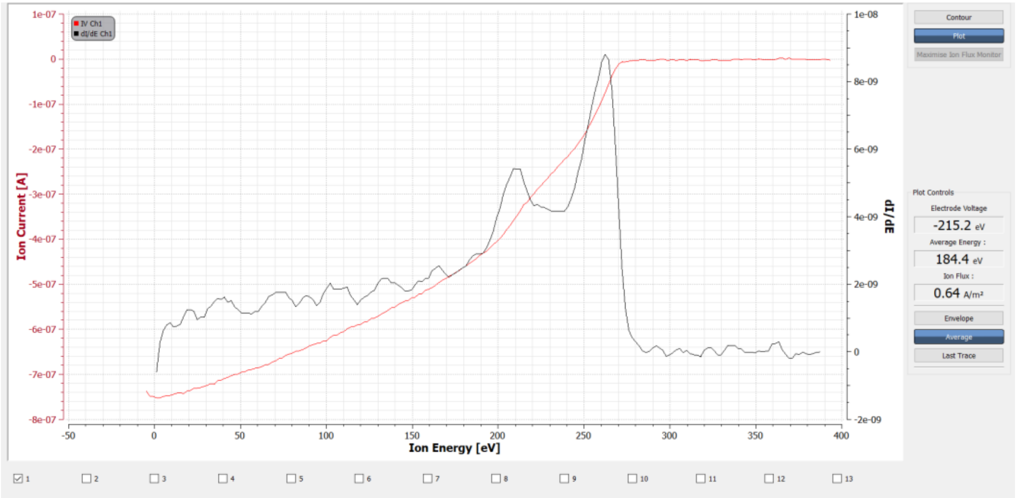
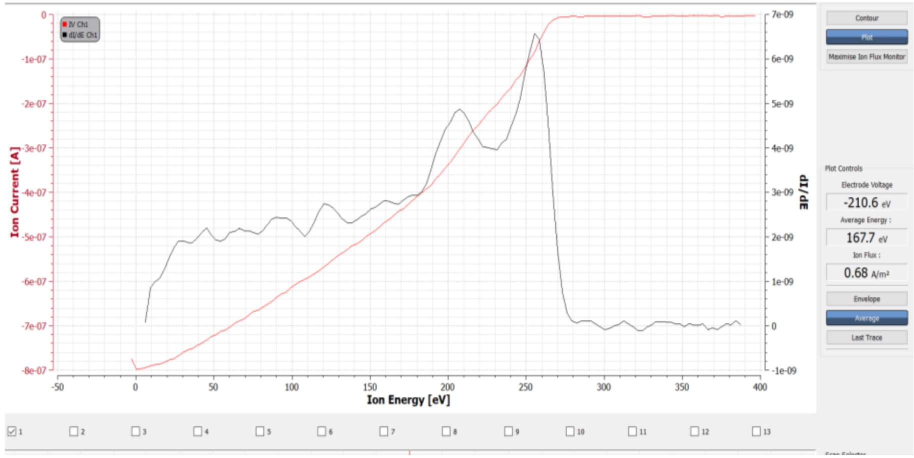
Collision-less to Collisional Plasma Impact on IEDF

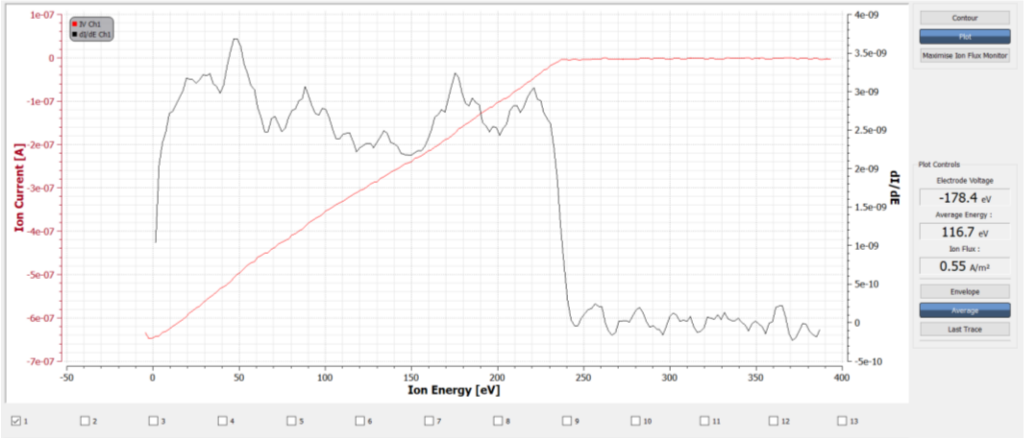
Ar 50W 1.2pa 45sccm.sdf



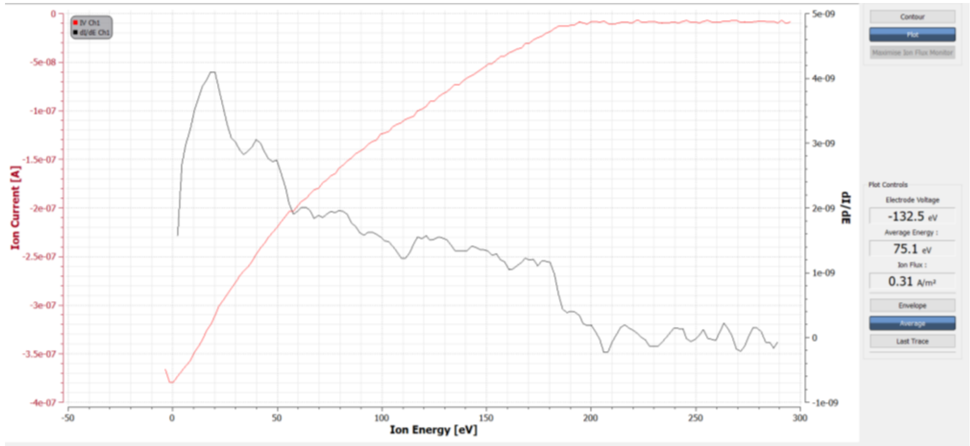
Ar 50W 2pa 85sccm.sdf



Ar 50W 2.5pa 100sccm.sdf



Ar 50W 3pa 132sccm.sdf



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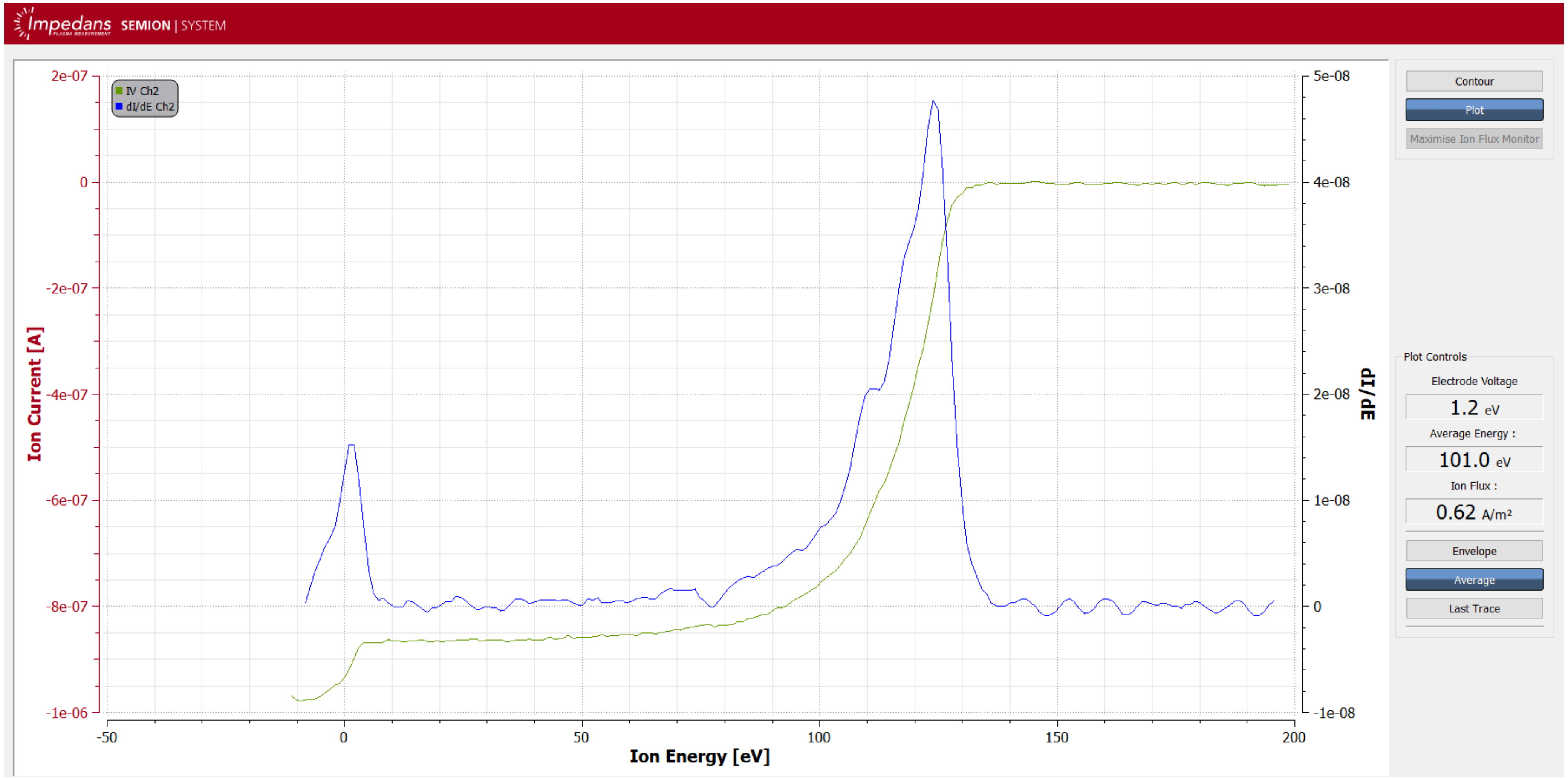
Ion Beam Tool IEDF



Ions are typically at the extractor potential PLUS the plasma potential!

Semion Theory

Semion RFEA Structure

All grids are made of nickel with a 20 x 20 μm square apertures

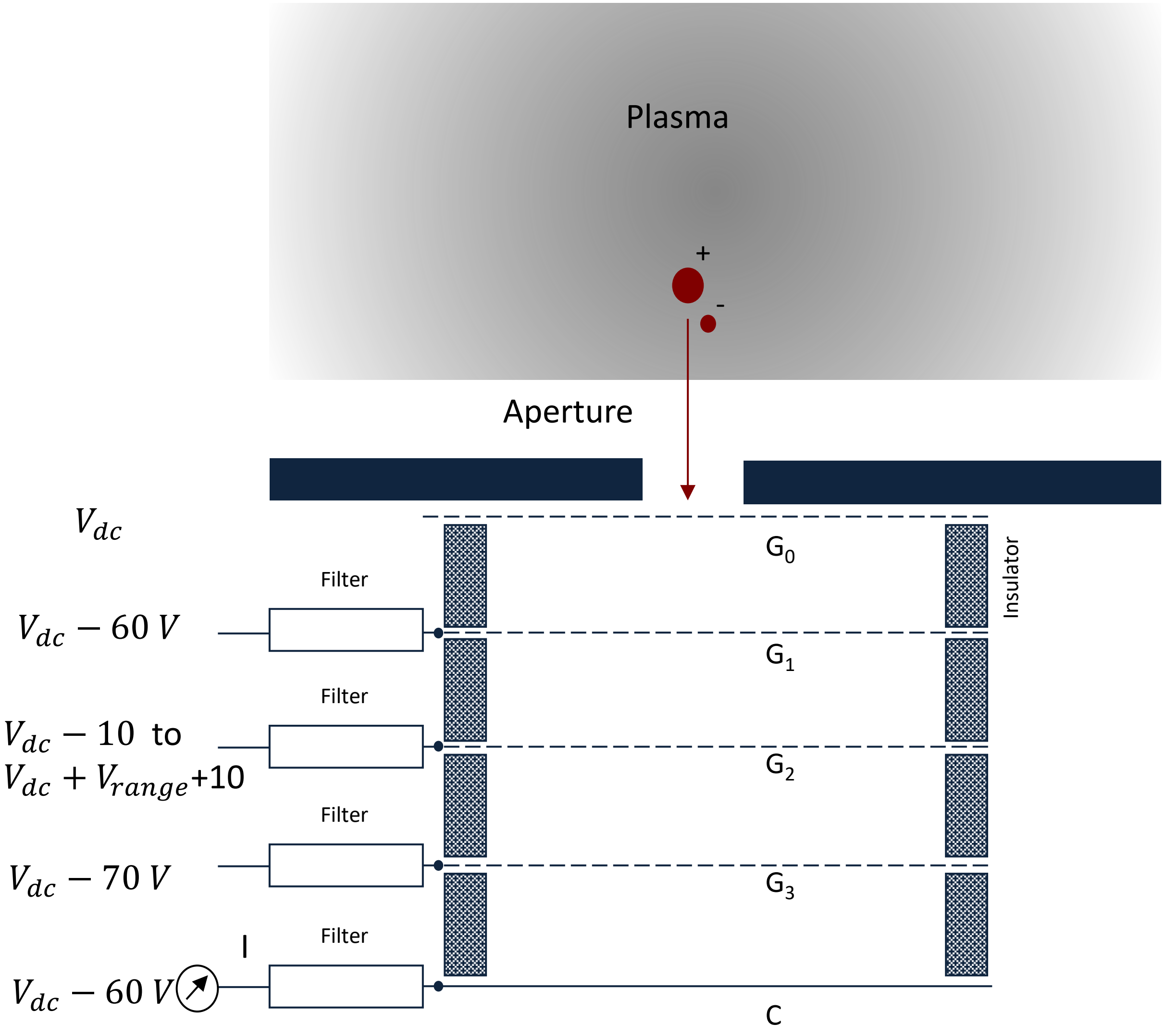
G_0 is designed to reduce the diameter of the sampling orifice to less than the Debye length in order to prevent plasma formation within the RFEA. The grid, which is connected to the body of the sensor (and therefore the electrode), will be biased (V_{dc}) according to the condition of the electrode (Grounded, Floating, RF Biased).

G_1 acts a an electron repulsion grid. This is designed to repel electrons from the plasma that enter into the sensor as they can distort the IED being measured.

G_2 acts as the discriminator of the ions based on their energy. As the voltage is swept from V_{dc} to $V_{dc} + V_{range}$ fewer ions are able to pass through the electric potential causing the current to change.

G_3 acts as a secondary electron suppression grid. It is negatively biased with respect to the collector ($C - 10\ V$ typically) to create a retarding potential for secondary electrons that can be emitted from the surface of the collector due to energetic ion impact.

C is the collector electrode to which a negative bias is applied to attract the ions for detection.



Semion RFEA Equations

Ion Energy Distribution Function (IEDF) Calculation:

$$f(x_i) = \frac{y_i - y_{i-1}}{x_i - x_{i-1}} \qquad \mathrm{n} = 1 \qquad (1)$$

$$f(x_i) = \frac{\sum_{j=1}^{n} y_{i+j} - \sum_{j=1}^{n} y_{i-j}}{\sum_{j=1}^{n} x_{i+j} - \sum_{j=1}^{n} x_{i-j}} \qquad n \geq 2$$

x and y representing the voltage and current values respectively

Ion Flux:

$$J_i = \frac{0.5\, f(x_i)}{Area\, *\, Transmission} \qquad (2)$$

Average Energy:

$$E_i = \frac{\int_{E_{min}}^{E_{max}} E\, f(E) dE}{\int_{E_{min}}^{E_{max}} f(E) dE} \qquad (3)$$

Sheath Width:

$$\bar{s} = \frac{2}{3} \left(\frac{2e}{M_i}\right)^{\frac{1}{4}} \left(\frac{\varepsilon_0}{\bar{J_i}}\right)^{\frac{1}{2}} \bar{V_s}^{\frac{3}{4}} \qquad (4)$$

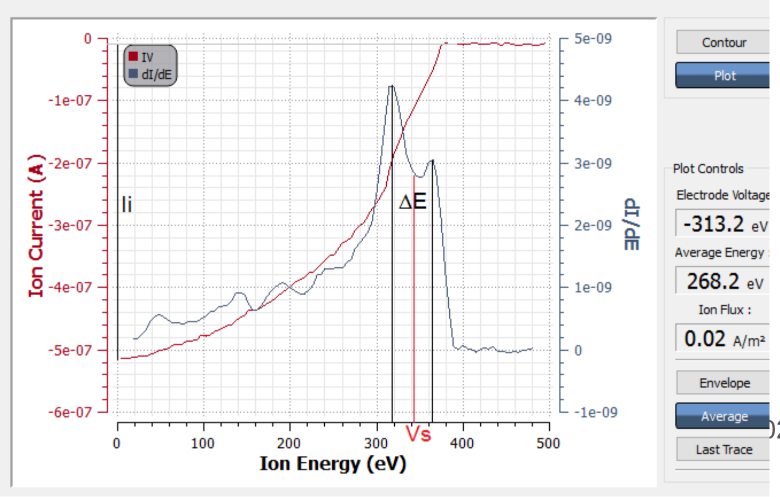
$\bar{V_s}$ is the DC sheath voltage

Ion Transit Time:

$$\tau_i = 3\, \bar{s} \sqrt{\frac{M}{2\, e\, \hat{V_s}}} \qquad (5)$$

Peak Separation:

$$\Delta E = \frac{2eV_{pp}}{\pi} \left(\frac{\tau_{RF}}{\tau_i}\right) \qquad (6)$$



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