Semion 3 keV System

Measure the Ion Flux and Ion Energy incident on your substrate in high bias conditions

https://www.impedans.com/semion-3kev/

Impedans
PLASMA MEASUREMENT

The Semion 3kV RFEA System

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

Parameters Measured:

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

Specification

- ✓ 4 grid RFEA
- ✓ 3x RF bias range compared to standard Semion
- ✓ 3keV ion energy range
- ✓ Apply up to 1.5kV 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/m2
- ✓ Standard 0.01 to 50 A/m2
- ✓ High density 0.1 to 700 A/m2

Also available: Time-Resolved Semion

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

Also available: Semion Multi

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

Advantages of the Impedans Semion RFEA:

- ✓ 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, or 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 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 average energy and ion flux calculations

Technical Specifications

Parameters Measured	Range
Ion Energy Range	0 to 3000 eV (Standard/Low/High Density Buttons)
Ion Flux	0.001 to 700 A/m^2 (Dependent upon button)
Pressure Range	300 mTorr (Standard/Low/High Density buttons)
IEDF Resolution	$\pm$1 eV nominal; 0.1V step size available
Max RF Bias voltage (applied to probe)	1.5 kV (peak to peak) @ 13.56 MHz ; approx. -1100 VDC
Max DC Bias Voltage (independent of RF bias)	-2940 V
Bias Frequency Range	100 kHz to 80 MHz

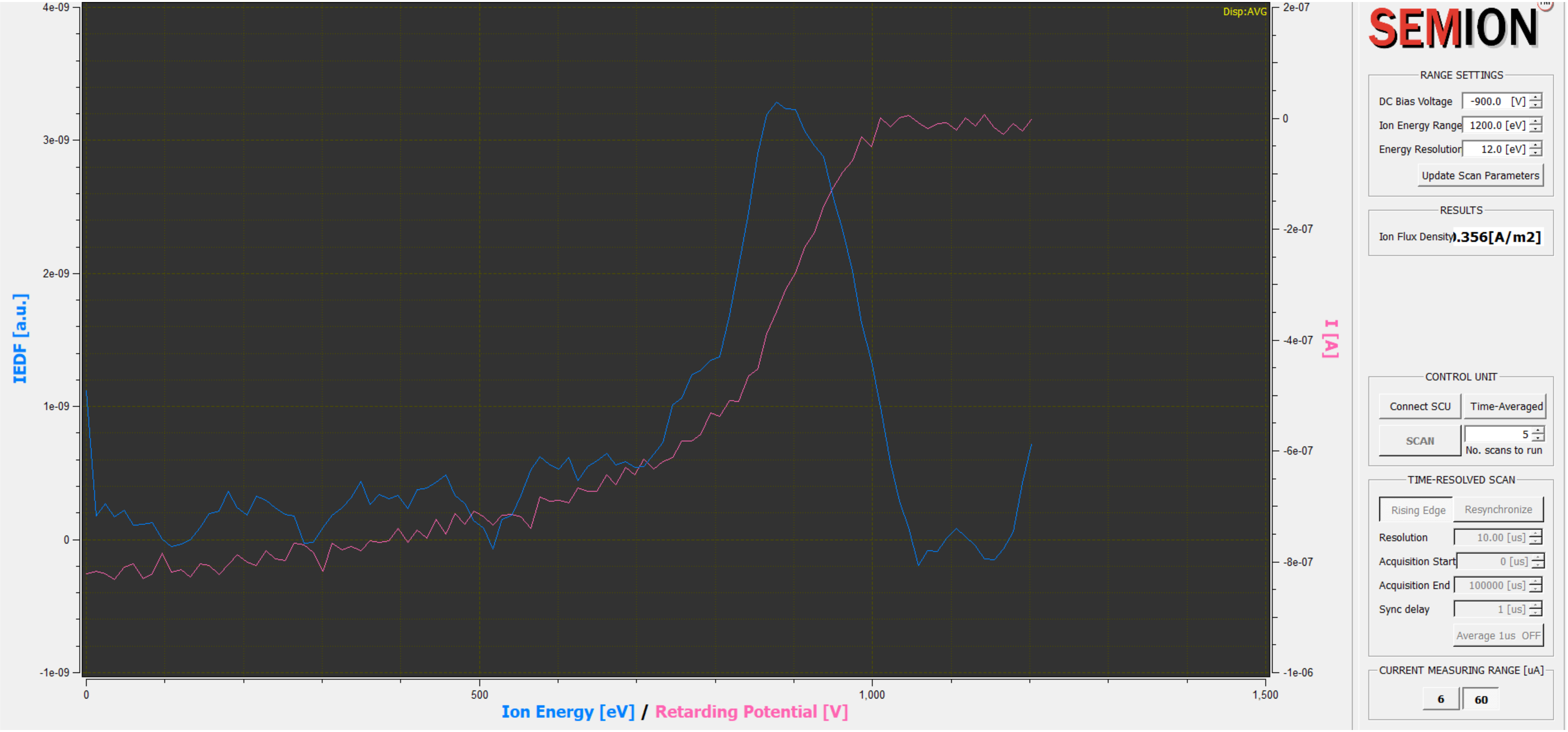
- ✓ For more detailed specifications and different models available, visit https://www.impedans.com/semion-3kev/
- ✓ To see if the RFEA is suitable for your plasma application, see the applications list at impedans.com/semion-applications
- ✓ To arrange a technical discussion, contact support@impedans.com

100 mm and 200 mm

70 mm x 45 mm

Button Probes

Example Data: IV curve and IEDF Curve

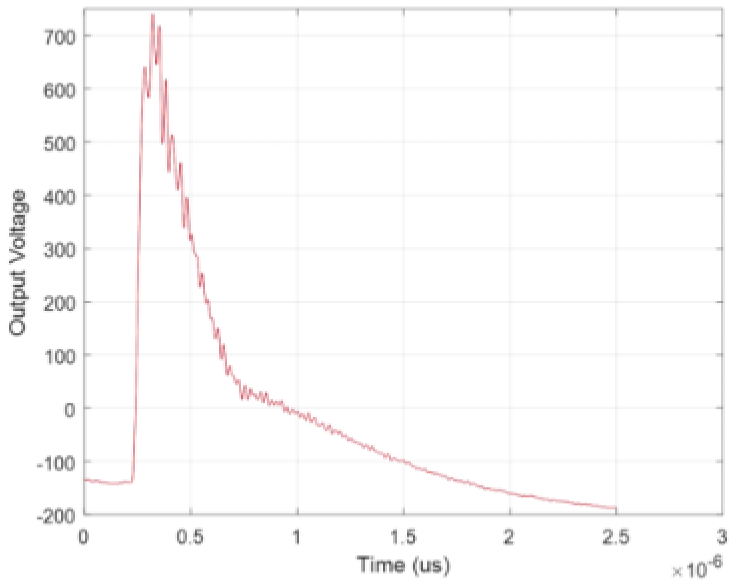


RF Biased IEDF

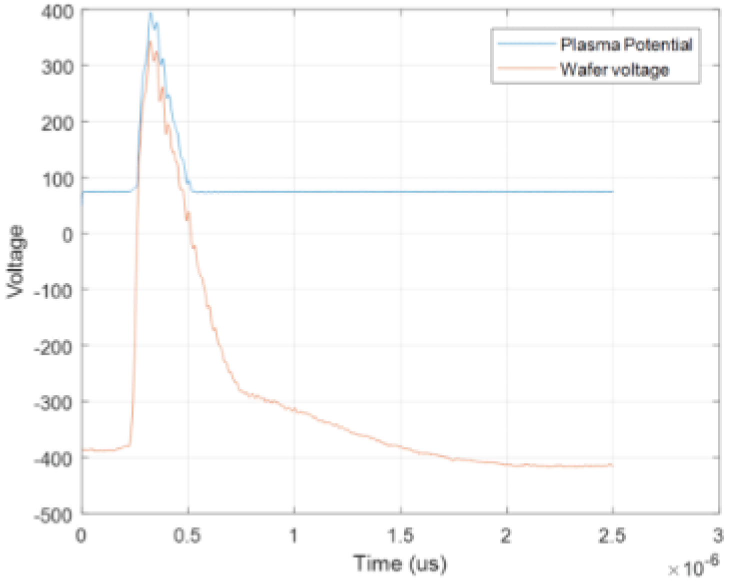
Semion Applications

Tailored Waveform Biasing

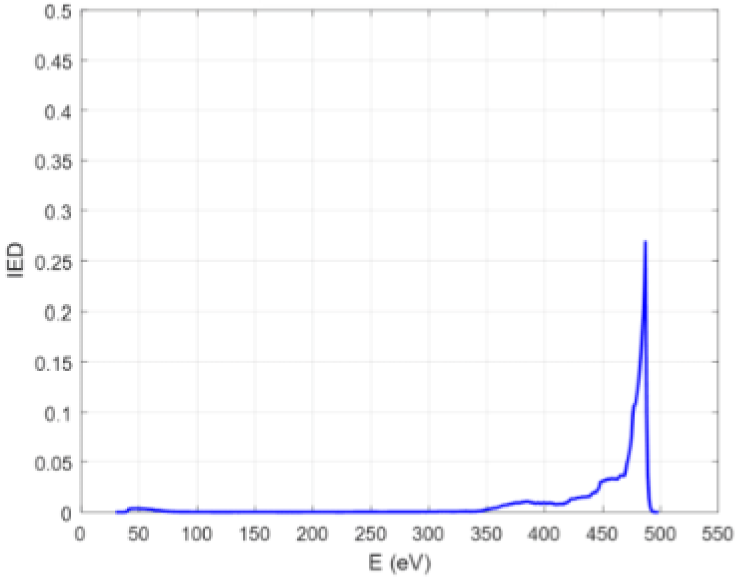
Measured output voltage



Measured wafer voltage



Ion Energy Distribution



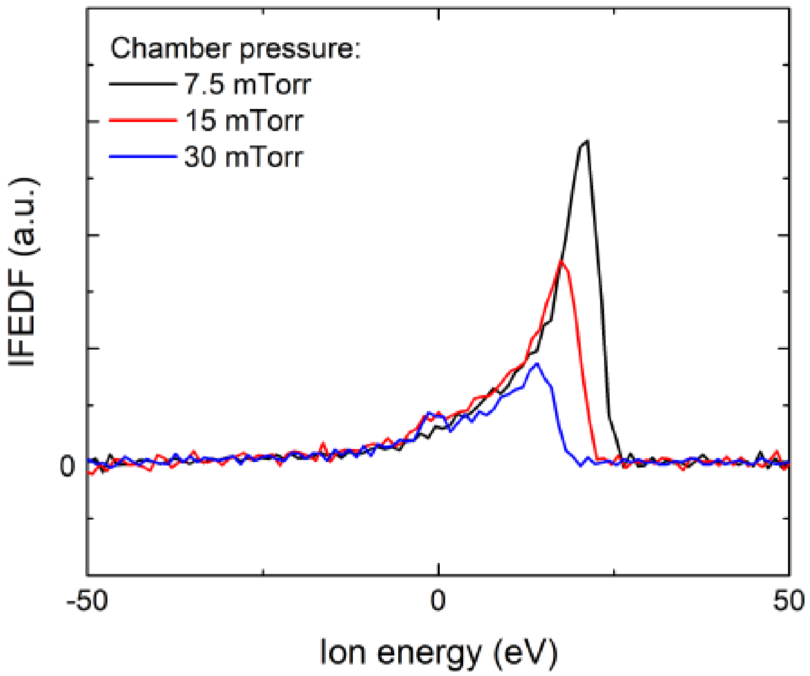
https://ehtsemi.com/resources/real-time-voltage-and-ion-energies/

https://ehtsemi.com/wp-content/uploads/2023/11/AVS-2023-Ion-Control.pdf

Pressure and Gas Impact on IEDFs

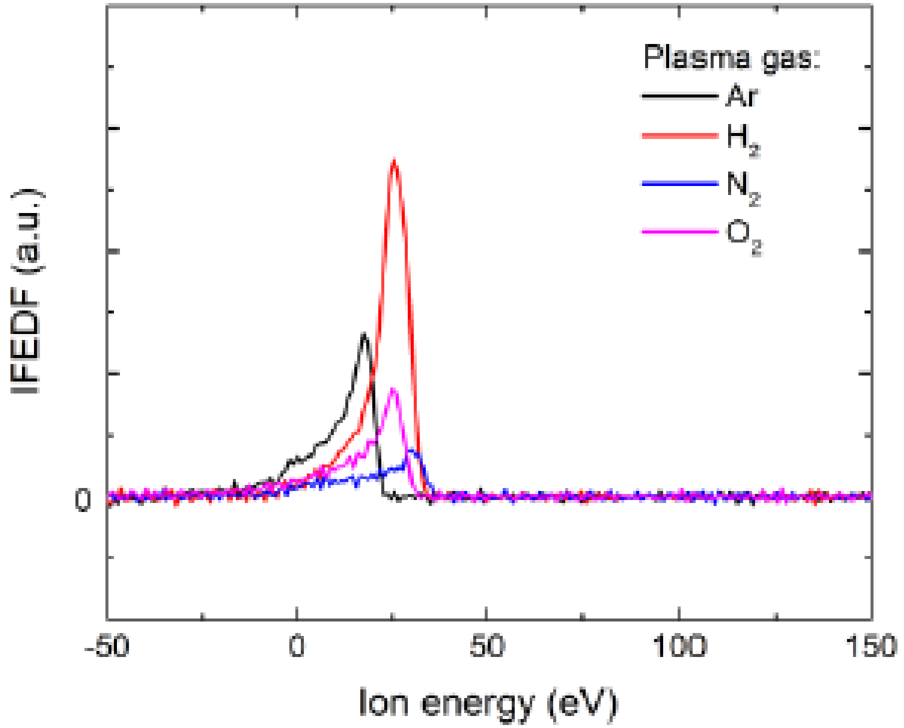
IEDF at different pressures for Argon

100 W ICP



IEDF for different gases

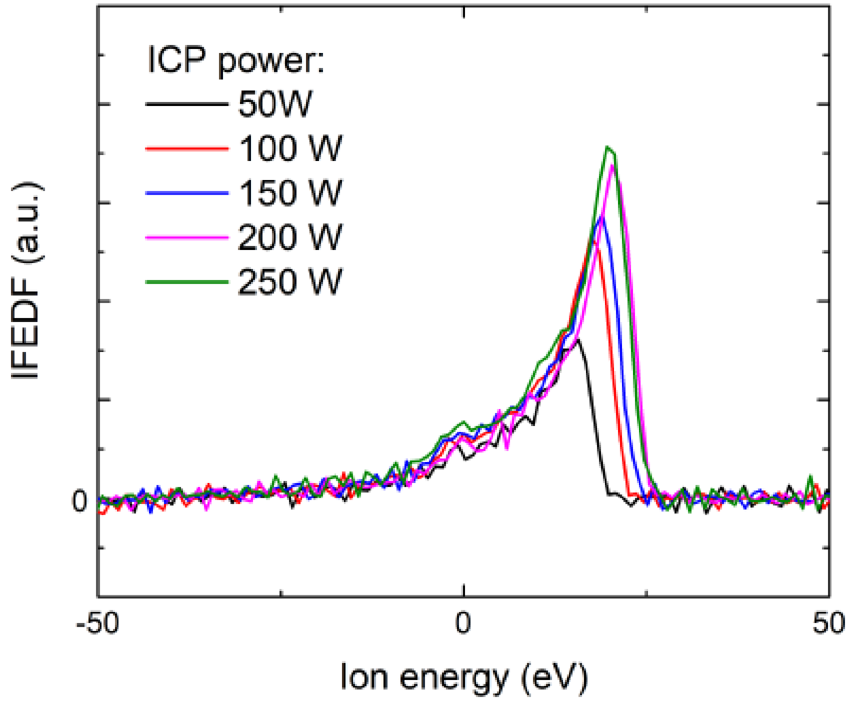
15 mTorr & 100 W ICP



Source Power Impact on IEDFs

IEDF at different power
(Top ICP)

15 mTorr

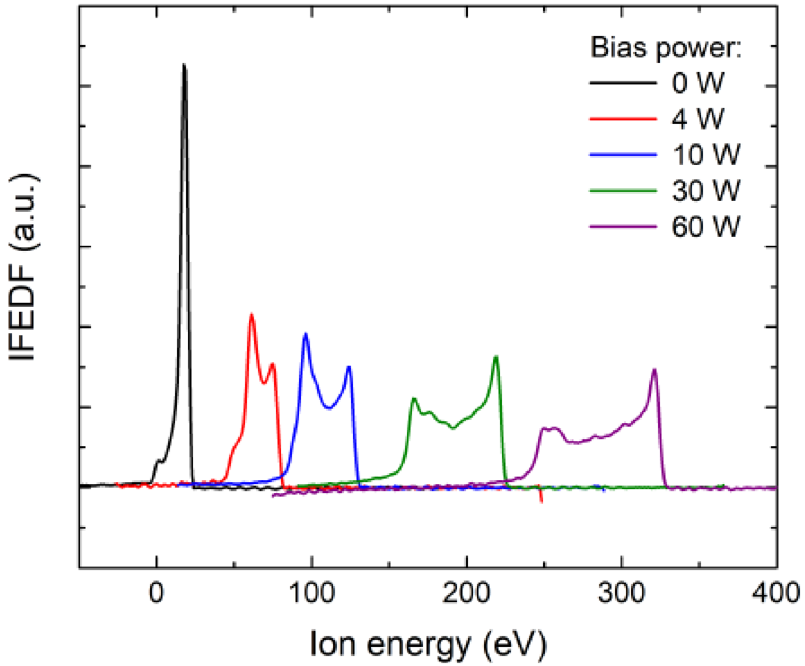


- ✓ As power is increased on an electrode or coil above the substrate, the ion flux increases
- ✓ The ion energy also increases, but not by much
- ✓ The energy increase is from increases in the plasma potential

Bias Power Impact on IEDFs

IEDF at different power
(Bias Electrode)

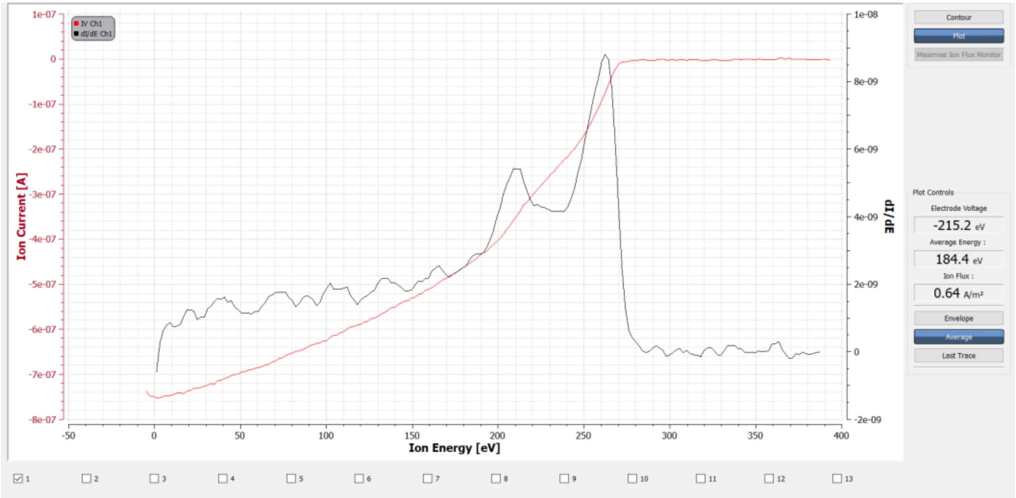
9 mTorr & 600 W Top



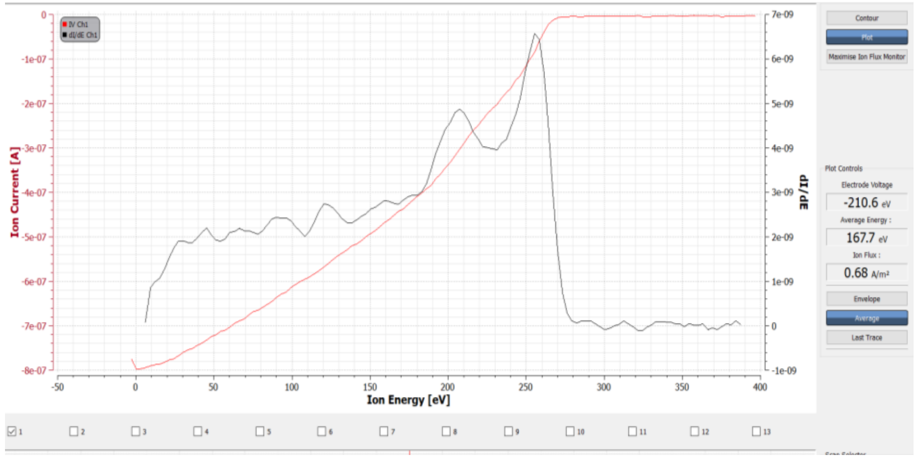
- ✓ On the RF biased electrode, even a small power increase causes a large change in the ion energies
- ✓ IEDF splitting also increases with power, so there's a wider ion energy spread
- ✓ Note: Power on the generator is not the same as power delivered to the electrode. Match boxes and transmission lines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

Collision-less to Collisional Plasma Impact on IEDF

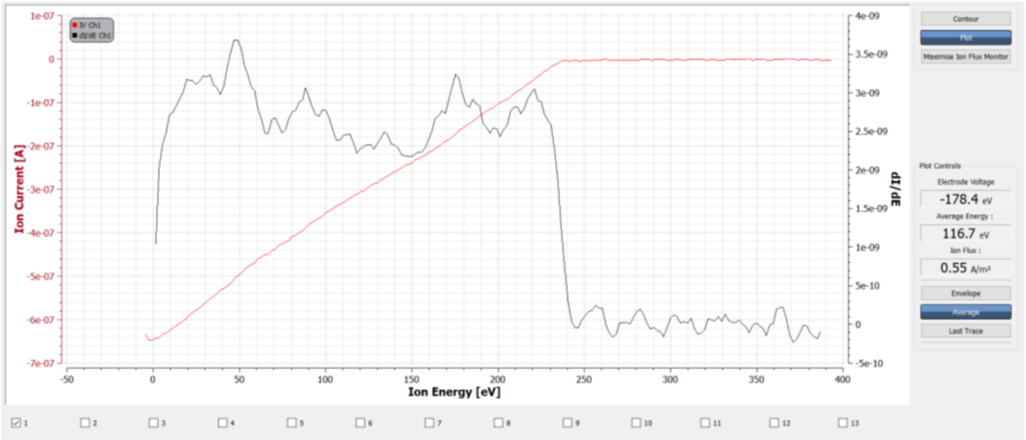
Ar 50W 1.2pa 45sccm.sdf



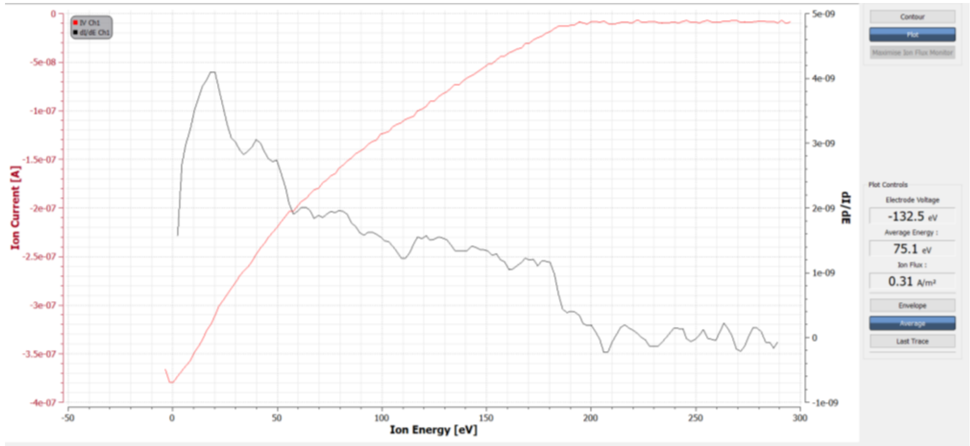
Ar 50W 2pa 85sccm.sdf



Ar 50W 2.5pa 100sccm.sdf



Ar 50W 3pa 132sccm.sdf



Semion Theory

Semion RFEA Structure

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

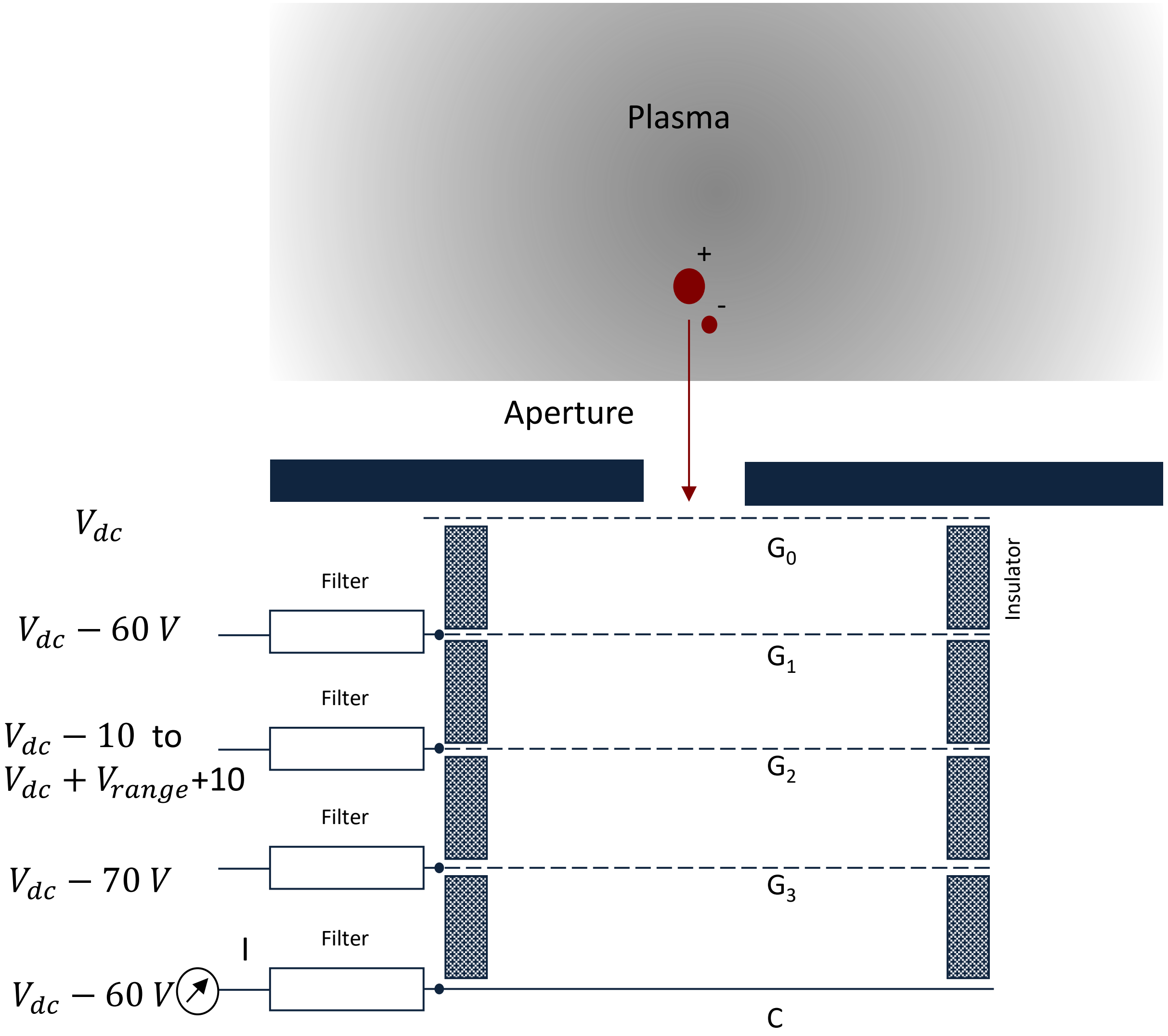
G_0 is designed to reduce the diameter of the sampling orifice to less than the Debye length in order to prevent plasma formation within the RFEA. The grid, which is connected to the body of the sensor (and therefore the electrode), will be biased (V_{dc}) according to the condition of the electrode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



Confidential

Semion RFEA Equations

Ion Energy Distribution Function (IEDF) Calculation:

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

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

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:

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

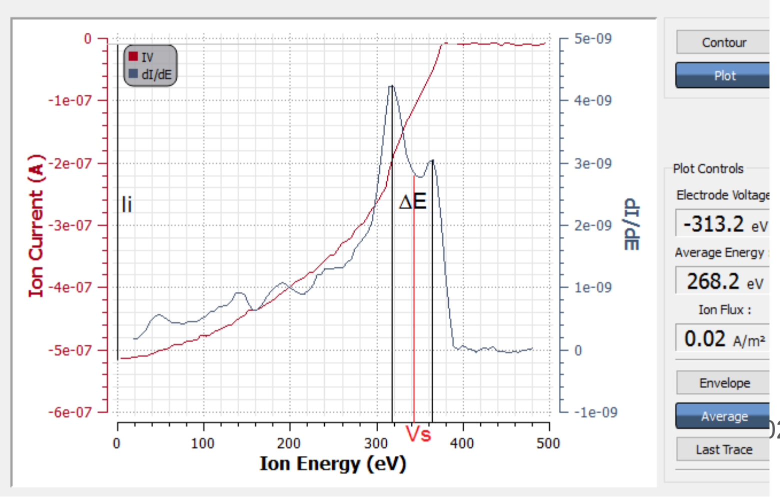
$\bar{V_s}$ is the DC sheath voltage

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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