Semion pDC System

Measure the Ion Flux and Ion Energy incident on your substrate with sub-microsecond time resolution

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

The Semion pDC RFEA System

Suitable for DC, Pulsed DC biasing & RF or 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

Button Sensors Available

- ✓ Low density 0.001 to 1.5 A/m2
- ✓ Standard 0.01 to 25 A/m2
- ✓ High density 0.5 to 350 A/m2
- ✓ (6x reduction for time-resolved)

Specification

- ✓ 3 grid RFEA
- ✓ 2keV ion energy range
- ✓ Apply up to 400 V pulsed DC biases
- ✓ Pulsed DC frequencies 100 Hz to 600 kHz
- ✓ Available in anodized aluminum, bare aluminum and stainless steel
- ✓ Easily replaceable button probes
- ✓ 44 nanosecond time resolution available (per 350 mm of cable)
- ✓ 1 microsecond time resolution when RF shielding included in holder (on request)

Also available: High Voltage Semion

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

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

Impedans PLASMA MEASUREMENT

Key Features

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

Compatible with majority of Biasing Conditions
Suitable for Grounded, Floating, DC and Pulsed DC 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

Impedans PLASMA MEASUREMENT

Technical Specifications

Parameters Measured	Range
Ion Energy Range	0 to 2000 eV (Standard/Low/High Density Buttons)
Ion Flux	0.001 to 350 A/m^2 (Dependent upon button)
Pressure Range	300 mTorr (Standard/Low/High Density buttons) 2 Torr (High Pressure Buttons)
IEDF Resolution	1 eV nominal; 0.1V step size available
Max Pulsed DC Bias voltage (applied to probe)	400 V_{PK-PK}
Max DC Bias Voltage (not pulsed)	-1940 V
Bias Frequency Range	100 kHz to 600 kHz

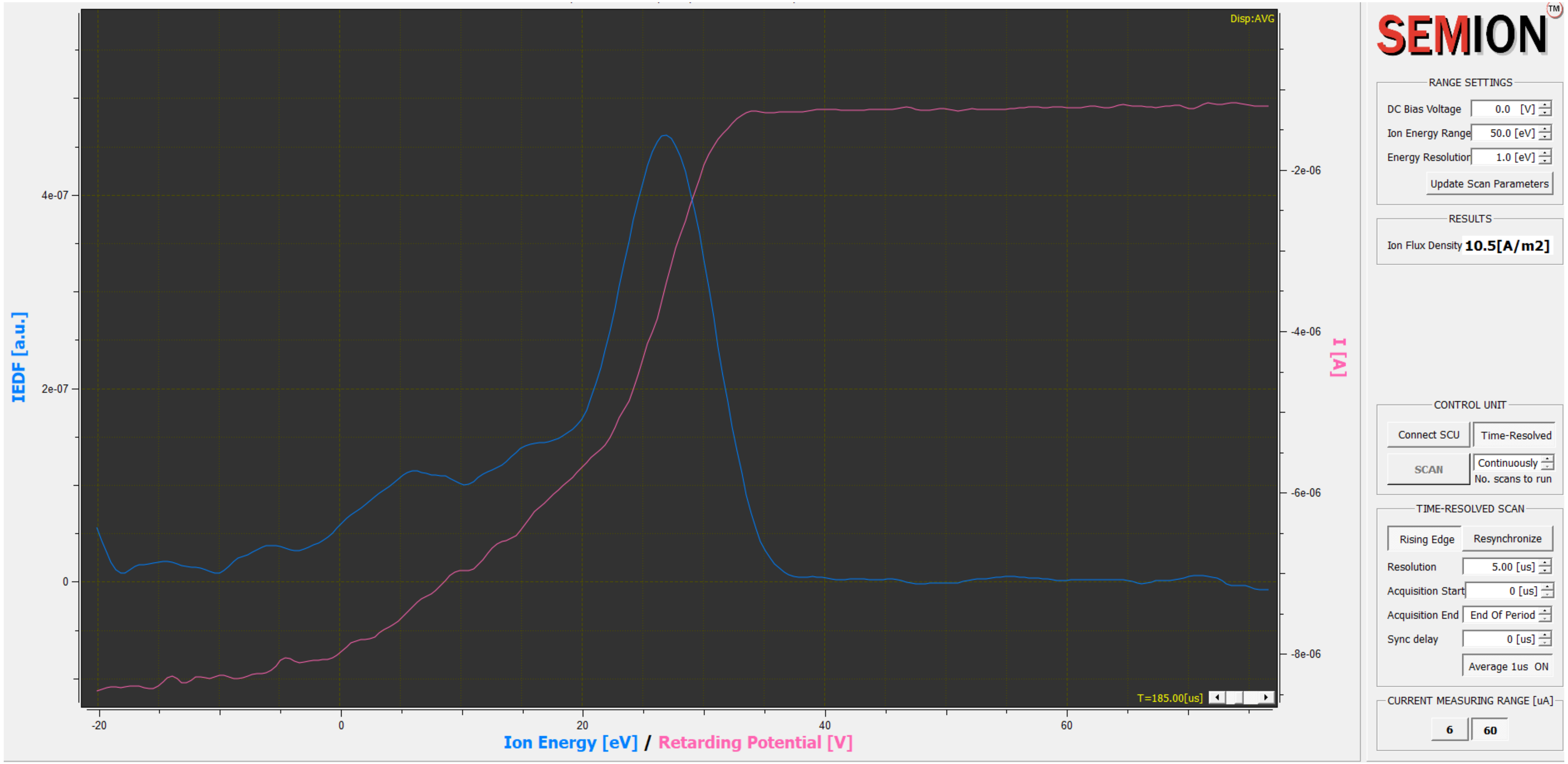
Holders

Button Probes

- ✓ For more detailed specifications and different models available, visit
- ✓ Semion pDC | Impedans
- ✓ 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

Example Data: IV curve and IEDF Curve

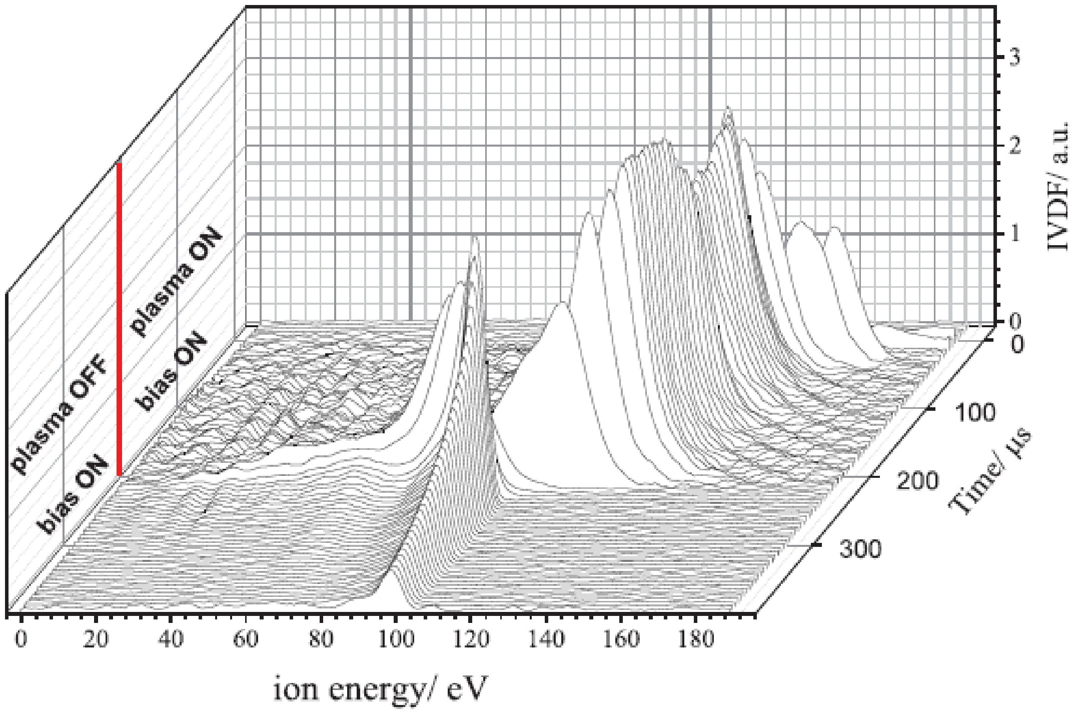


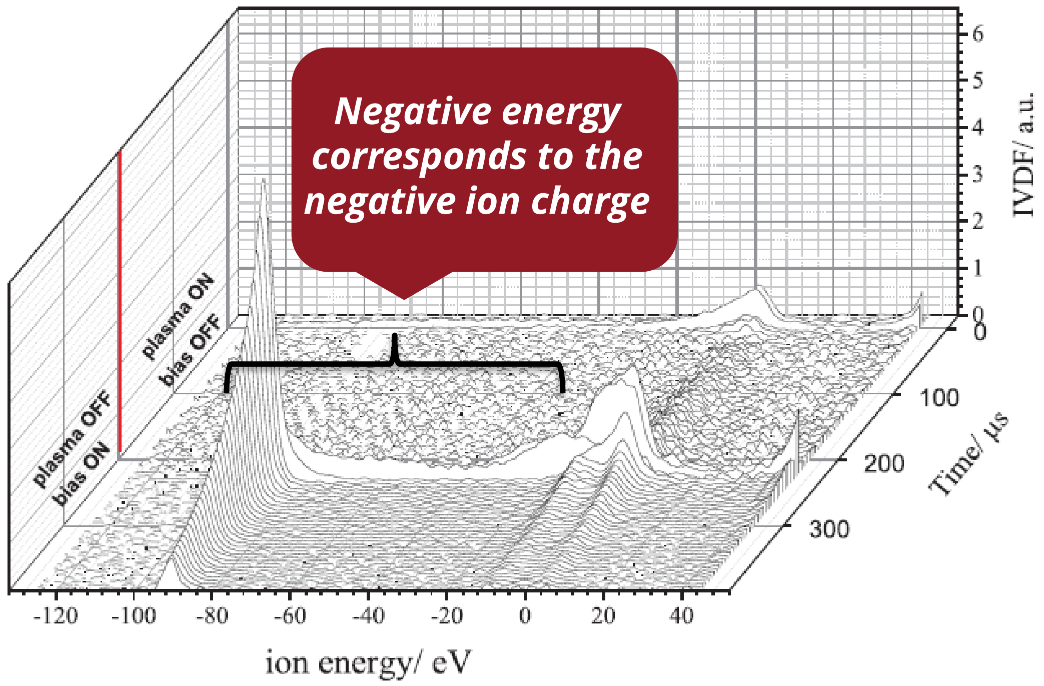
Grounded IEDF with 2 kHz pulsed DC source

Semion Applications

Extraction and acceleration of positive and negative ion beams from a pulsed inductively coupled plasma in SF_6

SF_6 at 3.3 Pa, modulation frequency 2 kHz, pulse duration τ_{pulse} = 200 µs, peak RF power P_{RF} = 400 W





Time-resolved IVDF of the positive ion beam extracted from a pulsed discharge.
(a) A continuous bias voltage U_{bias} = 100 V.
(b) A pulsed bias voltage U_{bias} = −95 V.

DOI: https://doi.org/10.1088/0963-0252/24/6/065008

Impedans PLASMA MEASUREMENT

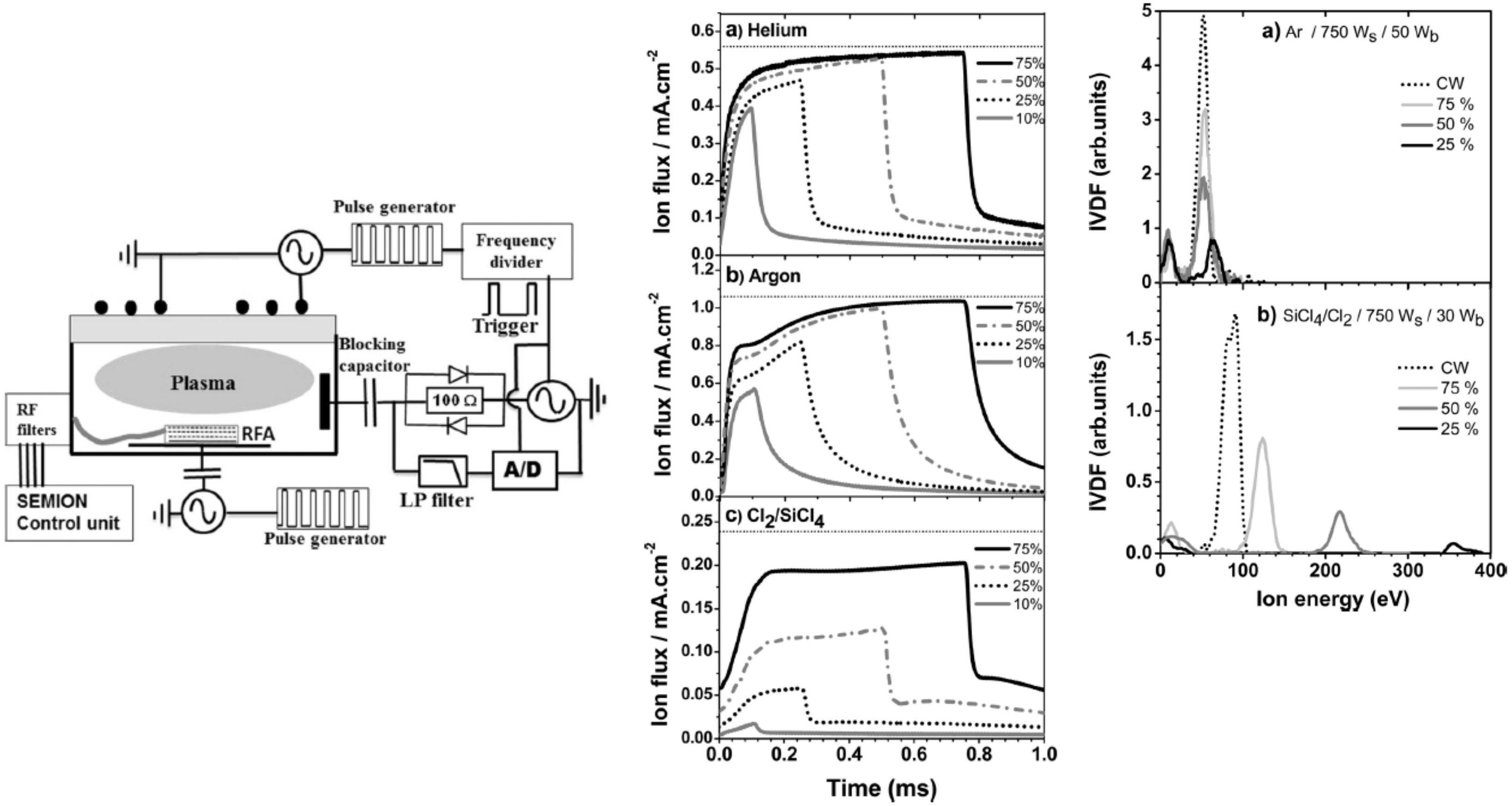
Impact of pulsed ICP operated over a range of duty cycles

Ion flux and ion distribution function measurements in synchronously pulsed inductively coupled plasmas

Brihoum M et al, Laboratoire des Technologies de la Microélectronique CNRS, France
Impedans Ltd., Ireland
The Open University, Walton Hall, United Kingdom

DOI: https://doi.org/10.1116/1.4790364

In this paper, authors reported experimental measurements of the impact of the duty cycle on the time variations of the ion flux and on the time averaged ion distribution function measured at the wafer surface in an ICP (13.56 MHz) processing chamber subject to pulse modulation of source excitation and bias at 1 kHz, in several plasma chemistries.



Experimental setup and example of the ion flux and IVDF measured in synchronously pulsed ICP plasma operating in rare gas (Ar or He) and reactive $SiCl_4/Cl_2$ plasmas.

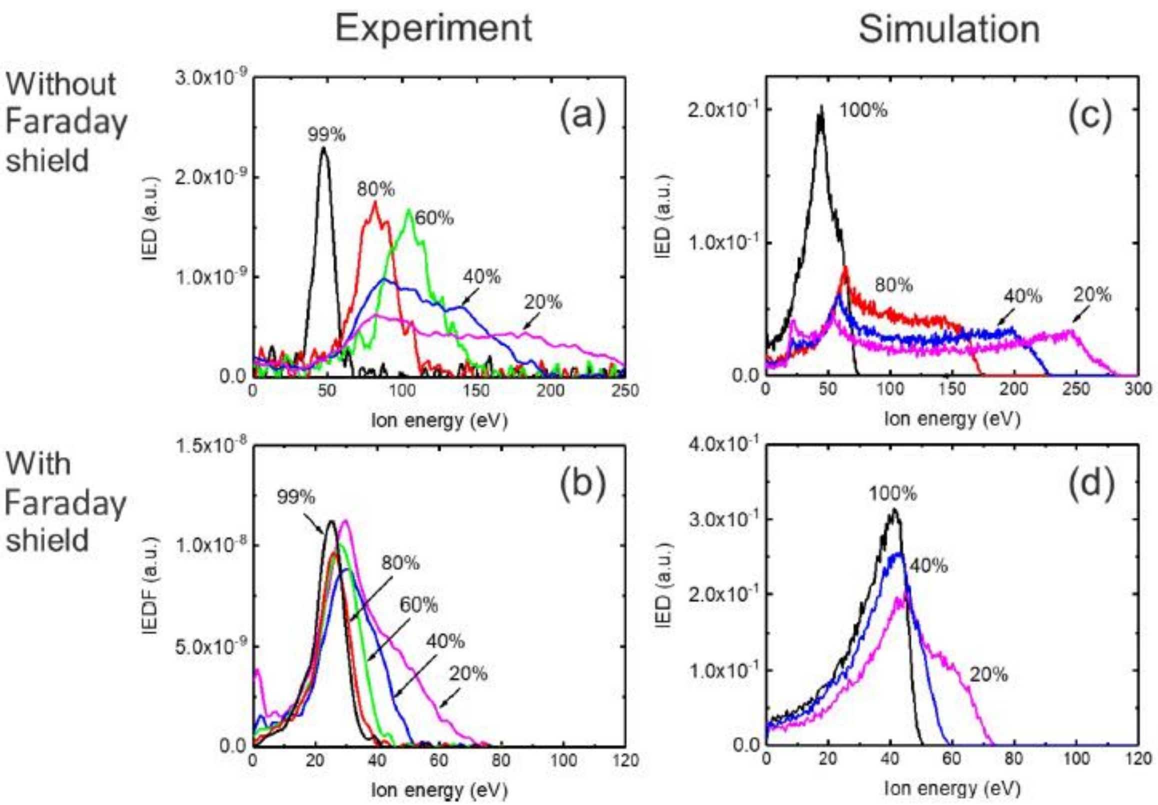
IED in compact ICP Argon plasma with and without a Faraday shield

Factors influencing ion energy distributions in pulsed inductively coupled argon plasmas

Zhiying Chen et al, Tokyo Electron America, USA
Tokyo Electron Miyagi Ltd., Japan

DOI: https://doi.org/10.1088/1361-6463/ab8b08

In this work, authors investigate the origin of important features of ion energy distributions during pulsing.
Ion energy distributions (IEDs) were measured for a range different duty cycles using source pulsing with a coaxial coil inductively coupled plasma source with and without a Faraday cage to isolate capacitive coupling. The effect of duty cycle on the IEDF is discussed using simulation results for context.

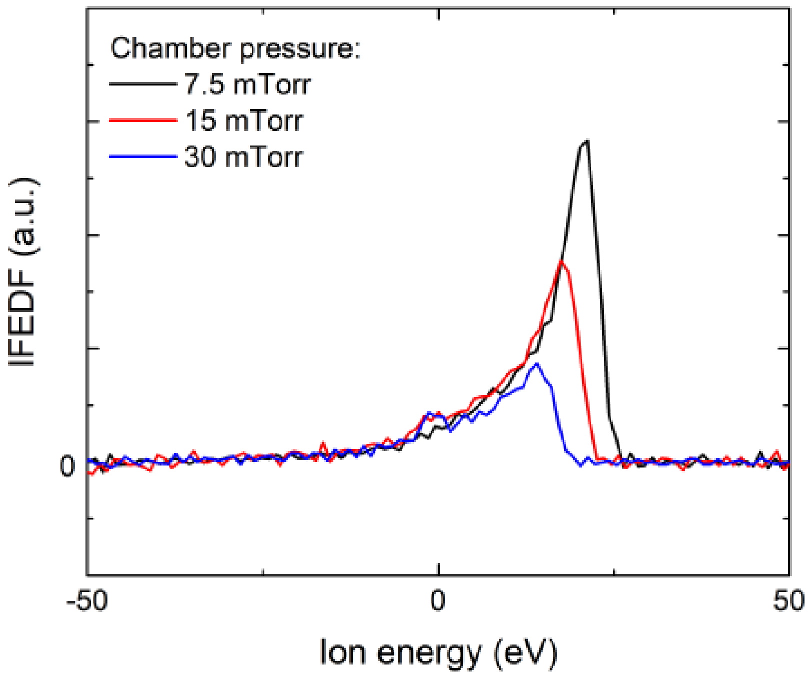


Example of measured and simulated IEDs for different RF duty cycles under pulsed plasma conditions with time average power of 150 W and pressure of 20 mT (2.67 Pa) without a Faraday shield (a) and with a Faraday shield (b).

Pressure and Gas Impact on IEDFs

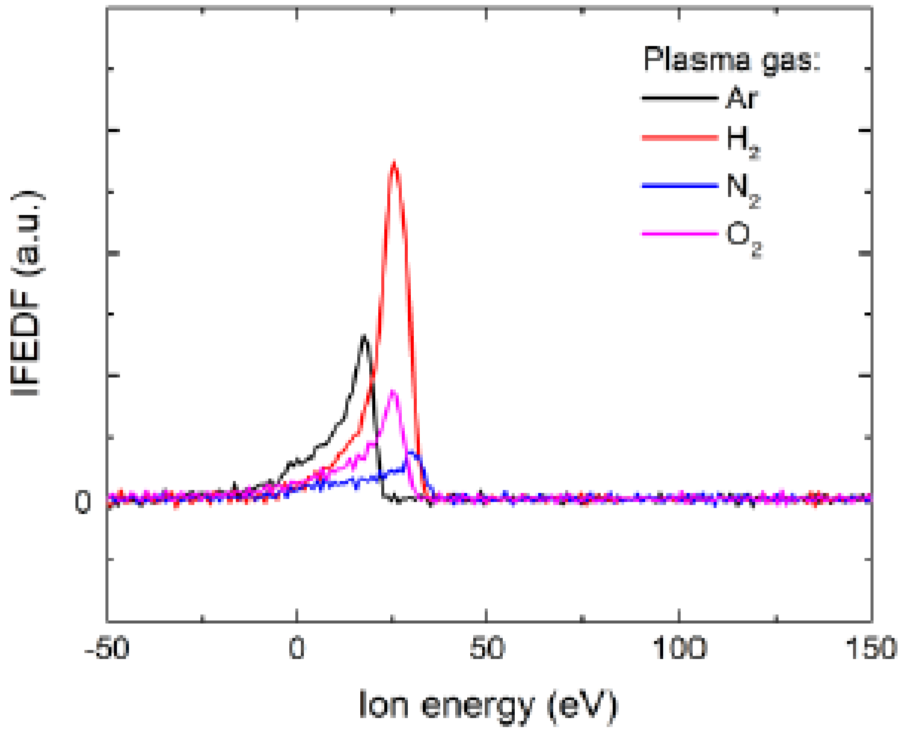
IEDF at different pressures for Argon

100 W ICP



IEDF for different gases

15 mTorr & 100 W ICP

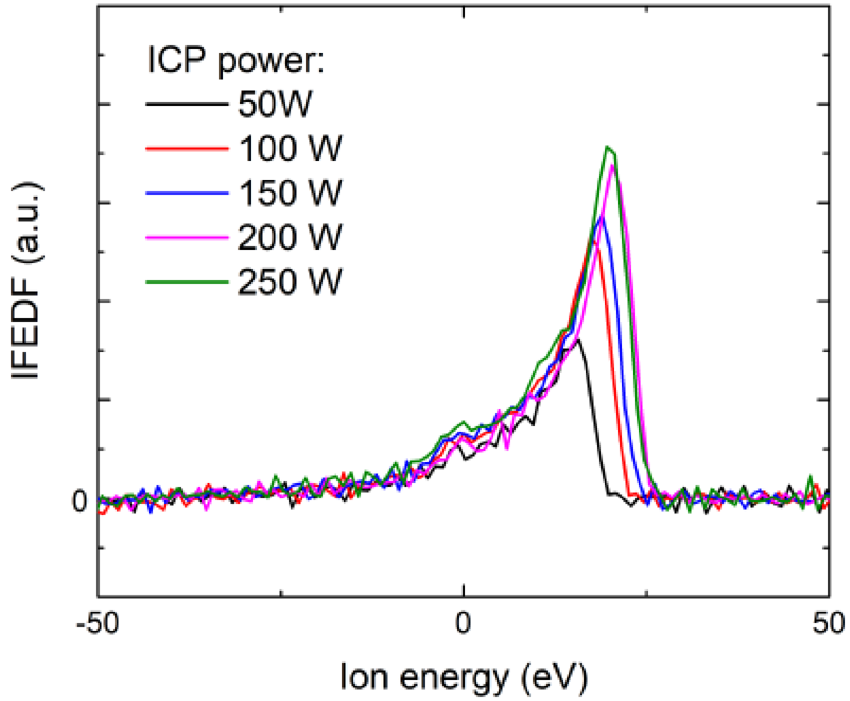


Impedans PLASMA MEASUREMENT

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

Semion Theory

Semion RFEA Structure

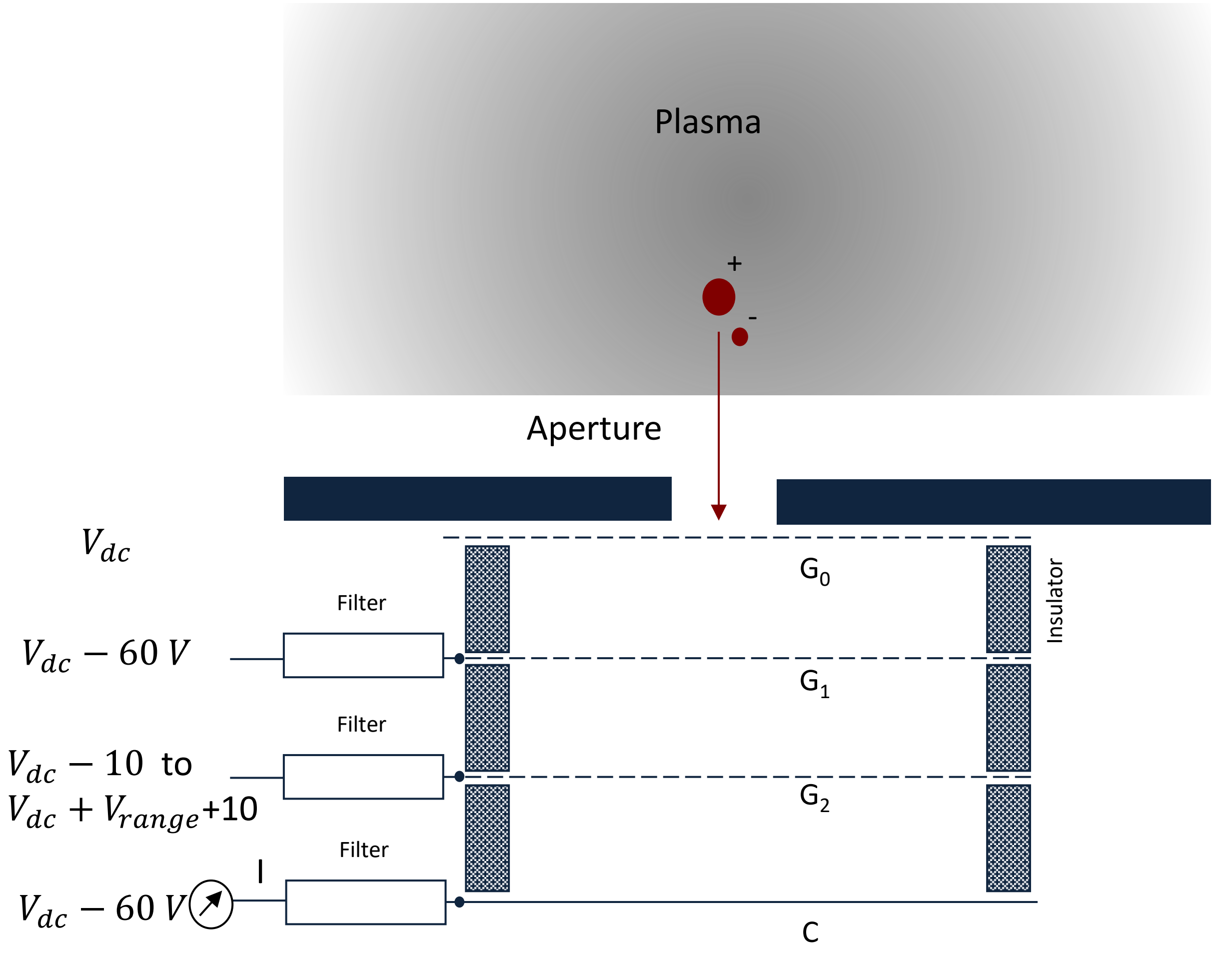
All grids are made of nickel with a 20 x 20 square apertures

G0 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 according to the condition of the electrode (Grounded, Floating, RF Biased).

G1 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.

G2 acts as the discriminator of the ions based on their energy. As the voltage is swept from to fewer ions are able to pass through the electric potential causing the current to change.

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:

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

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

x and y representing the voltage and current values respectively

Ion Flux:

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

Average Energy:

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

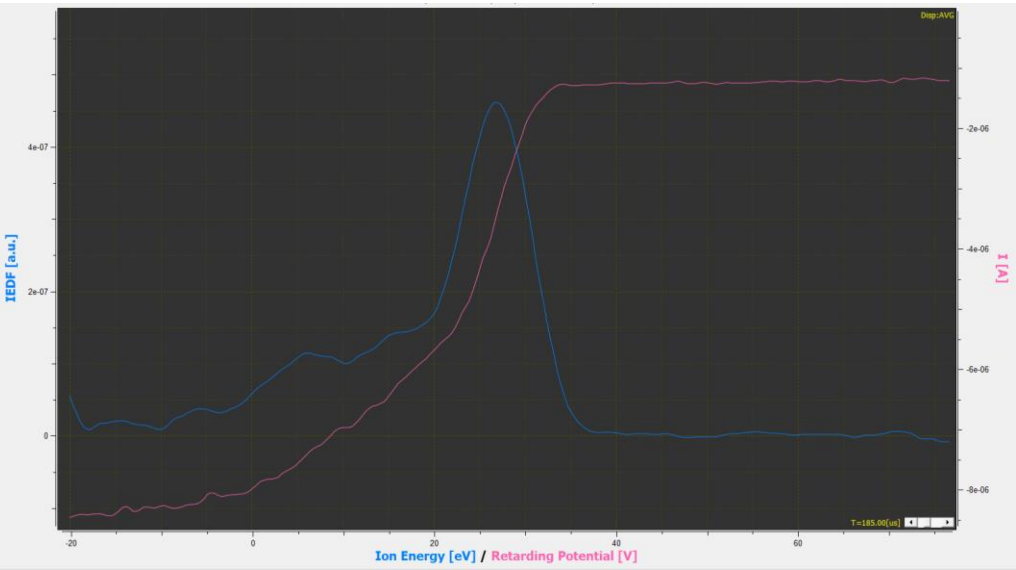
Sheath Width:

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

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

Ion Transit Time:

$$\tau_i = 3\ \bar{s} \sqrt{\frac{M}{2\ e\ \widehat{V_s}}} \tag{5}$$



Impedans Ltd

Chase House, City Junction Business Park, Northern Cross,

Dublin 17, D17 AK63, Ireland

Ph: +353 1 842 8826
Fax: +353 1 871 2282

Web: www.impedans.com
Email: support@impedans.com