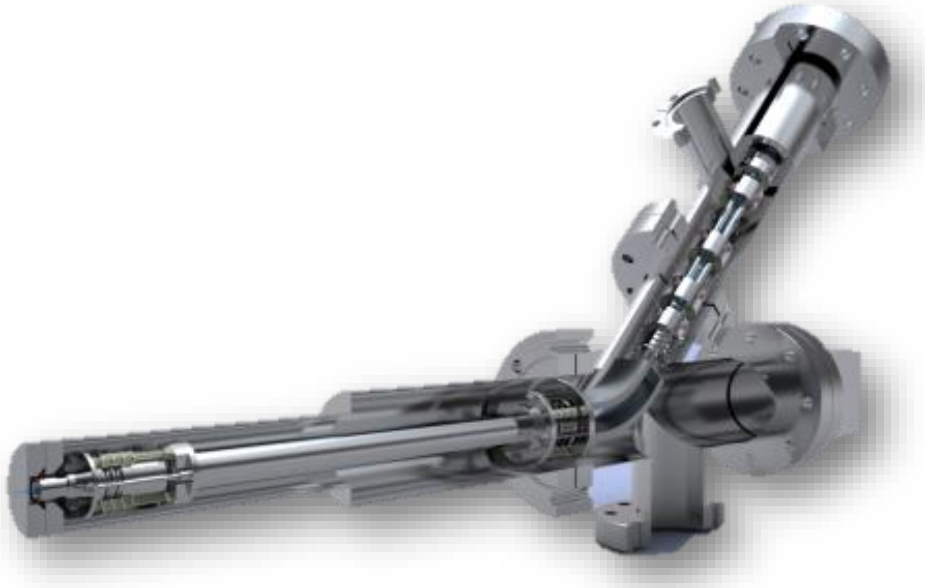
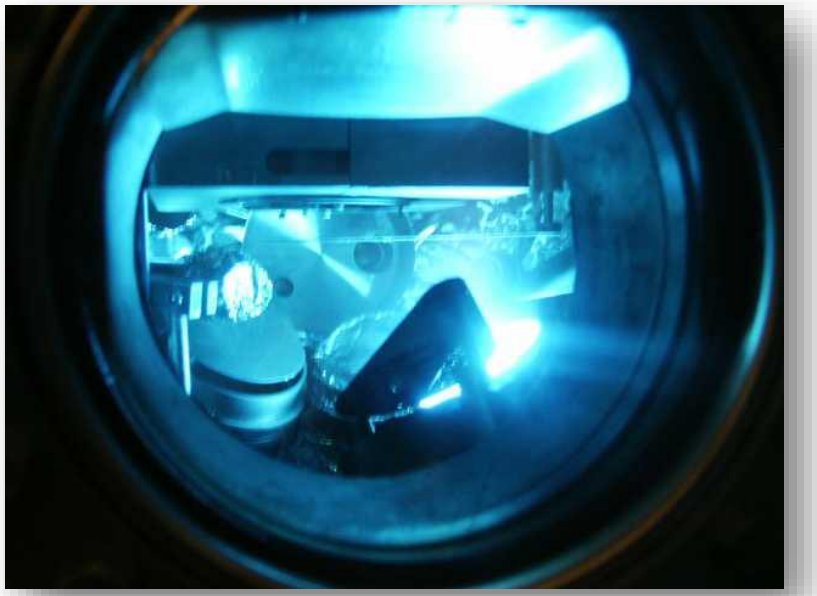
Hiden EQP Applications

Mass/Energy Analyser for Plasma Diagnostics and Characterisation



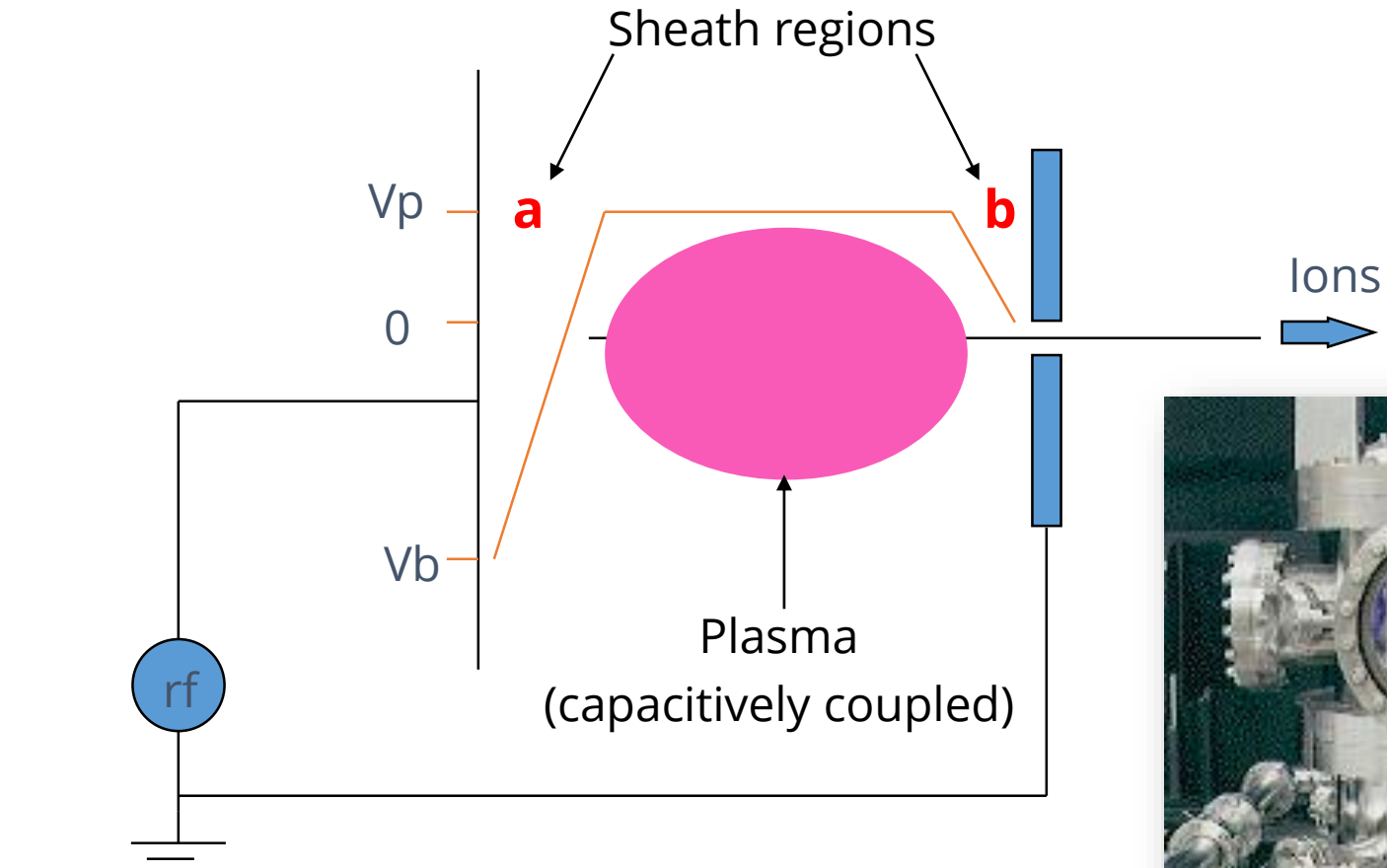


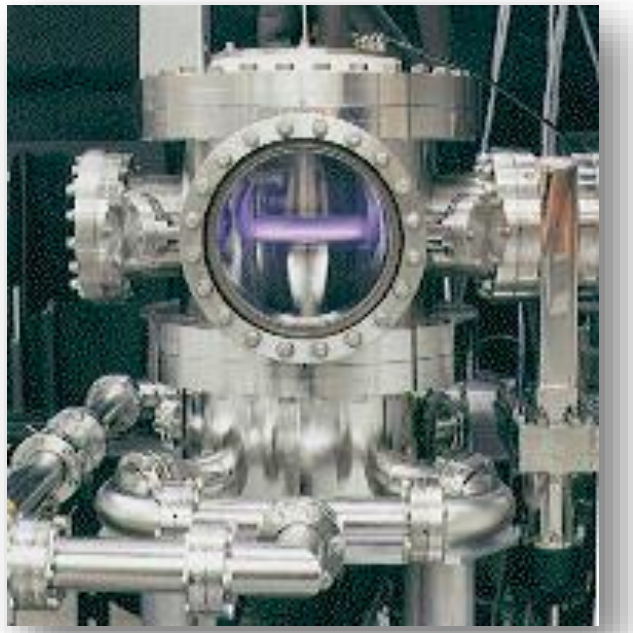
EQP Overview

The Hiden EQP System is an advanced plasma diagnostic tool with combined high transmission ion energy analyser and quadrupole mass spectrometer, acquiring both mass spectra at specified ion energies and ion energy distributions of selected plasma ions.

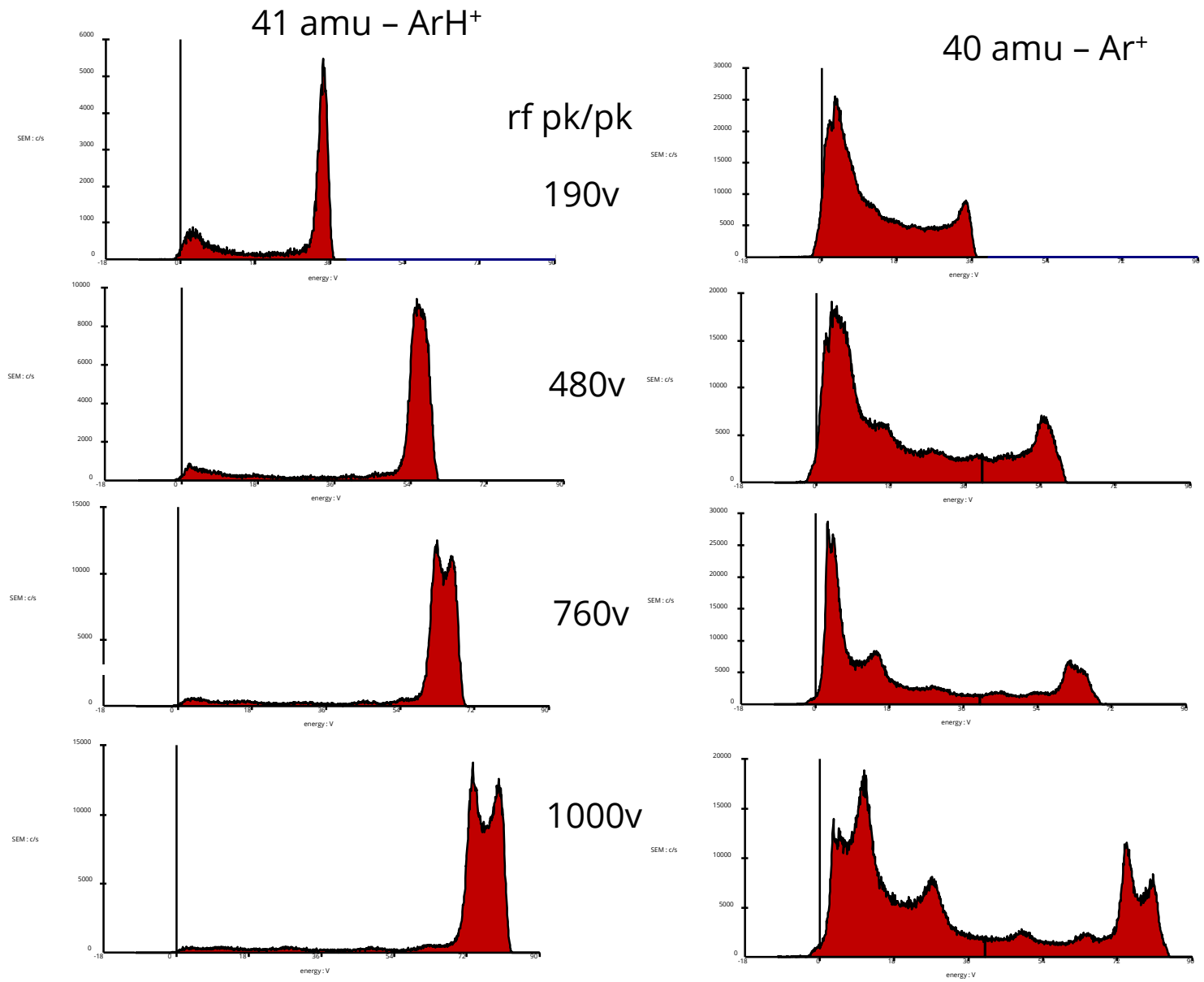
The advanced EQP ioniser allows neutral and radical detection, the electron attachment ionisation feature further enhancing the detection capability for radicals in electronegative plasma chemistries.

The NIST GEC Test Cell





NIST GEC Example Energy Spectra



NIST GEC Example Data - Conclusions

As the rf amplitude is increased both Ar^+ and ArH^+ show:

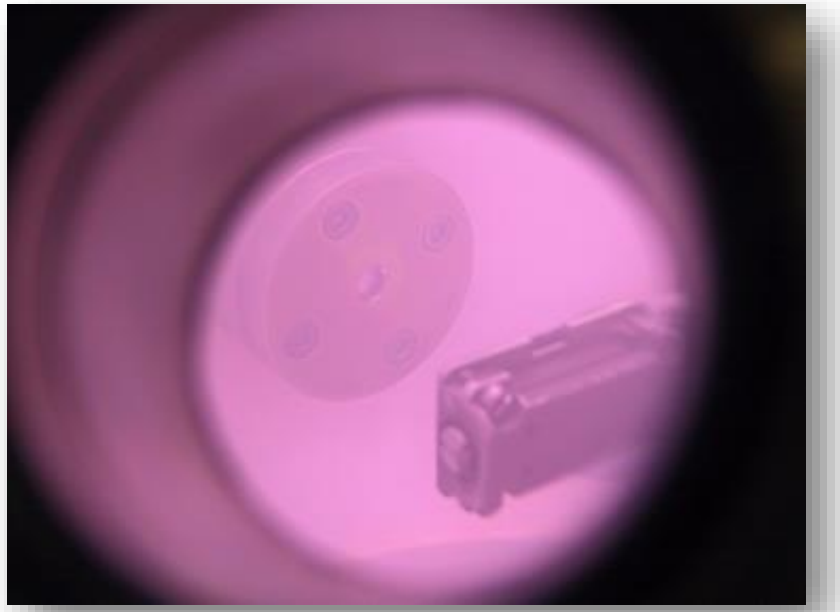
- Increases in Plasma Potential
- Increases in Ion Energy
- Splitting of the high energy peaks

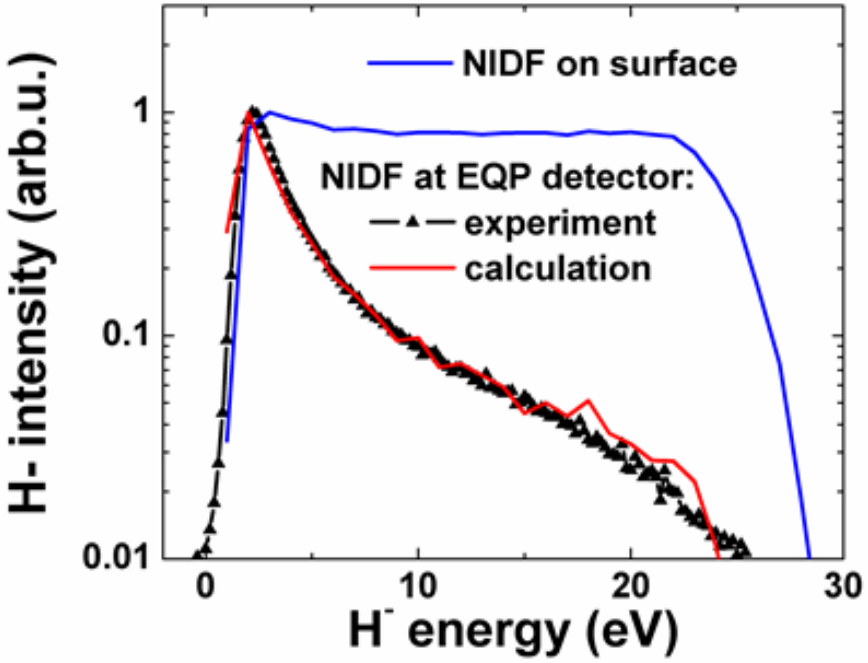
  - transition time across the sheath $\Rightarrow$ rf

- Ar^+ also exhibits high concentrations of lower energy ions

  - due to inelastic collisions between Ar / Ar^+

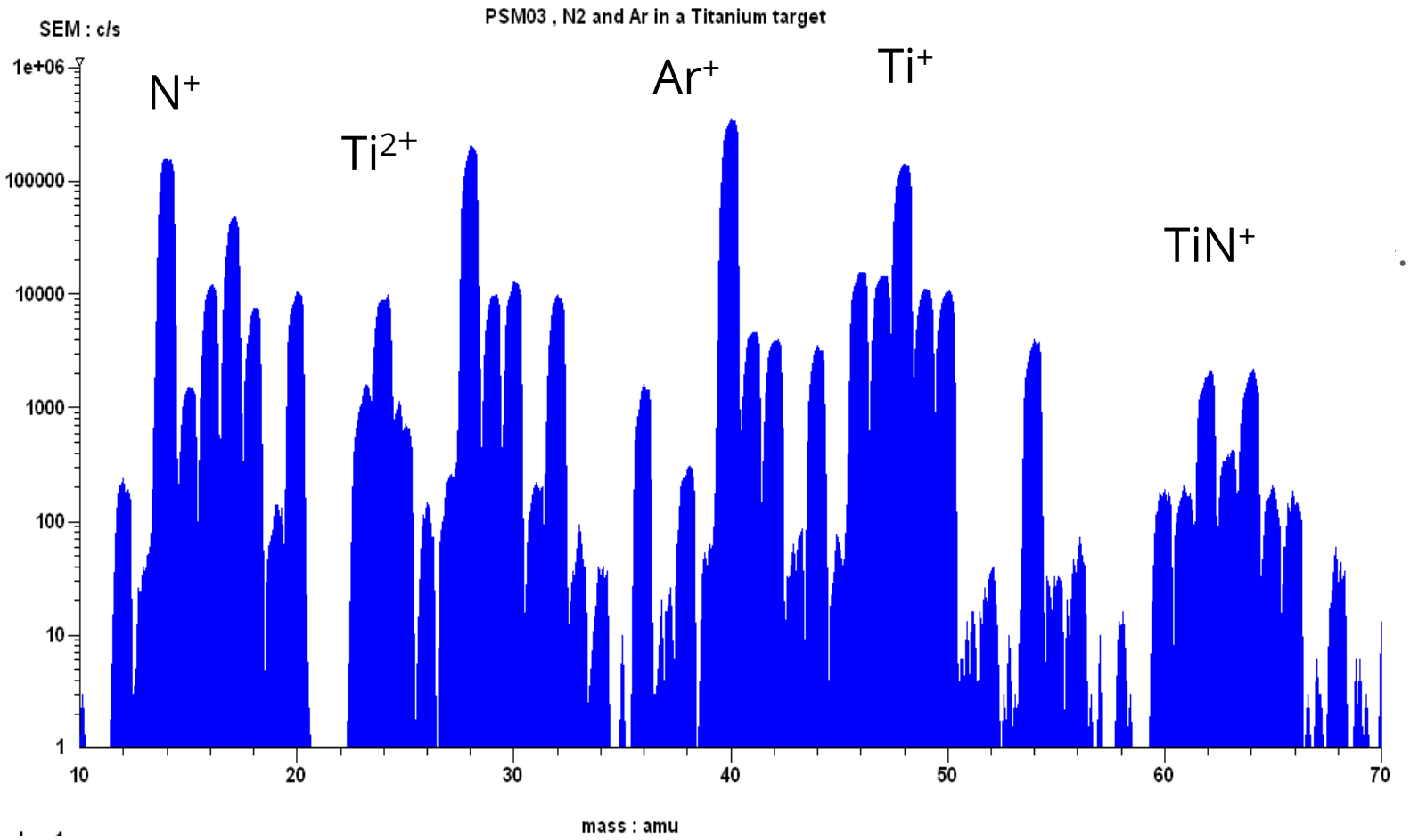
Detection of Negative Hydrogen Ions from bombardment of a Carbon Sample in a Capacitively Coupled Plasma



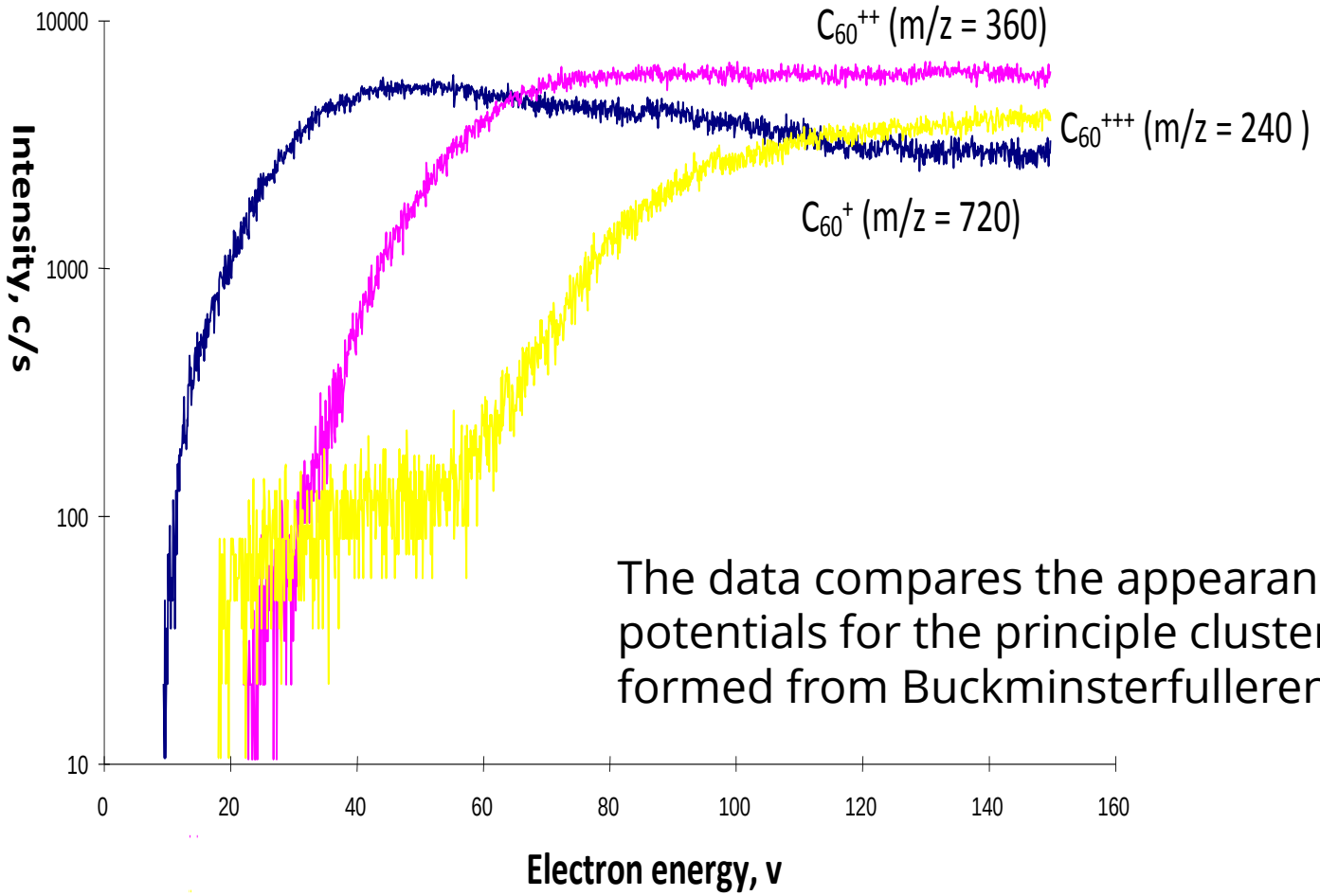


- Negative Ion Distribution Functions (NIDFs) obtained using the 45° Sector Field Energy Analyser.

Positive Ion Species from a HIPIMS Plasma

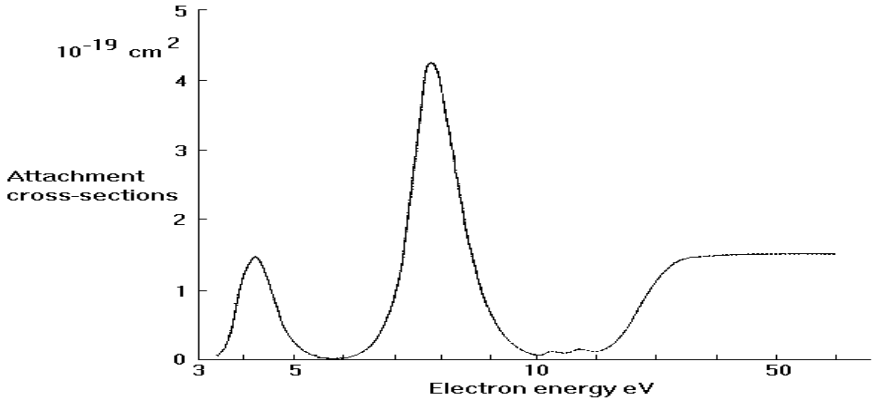


Electron Energy Spectra

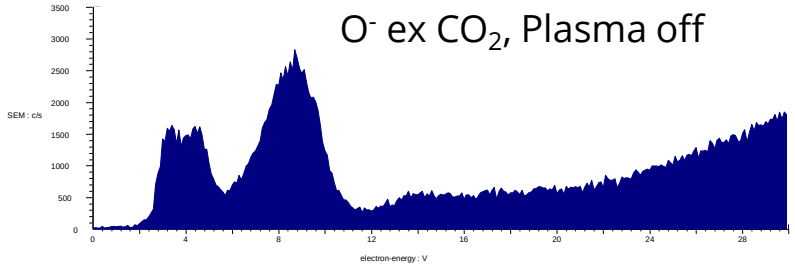


The data compares the appearance potentials for the principle cluster ions formed from Buckminsterfullerene

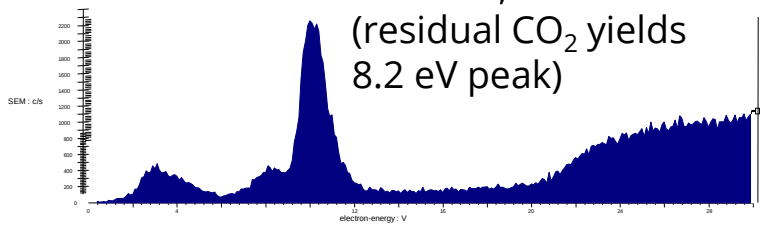
Electron Attachment Cross-Sections



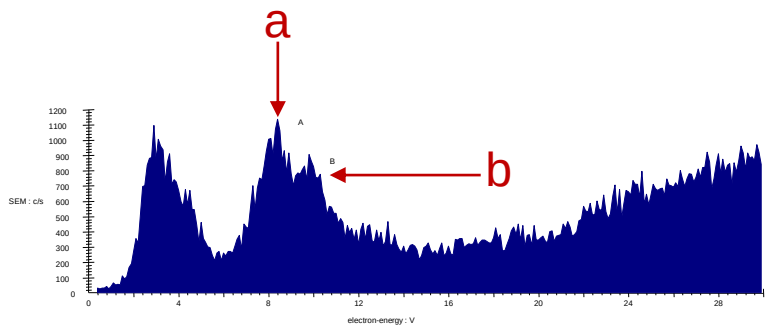
Attachment cross-sections for CO_2 (Rapp and Briglia)



O^- ex CO_2, Plasma off



O^- ex CO, Plasma off. (residual CO_2 yields 8.2 eV peak)



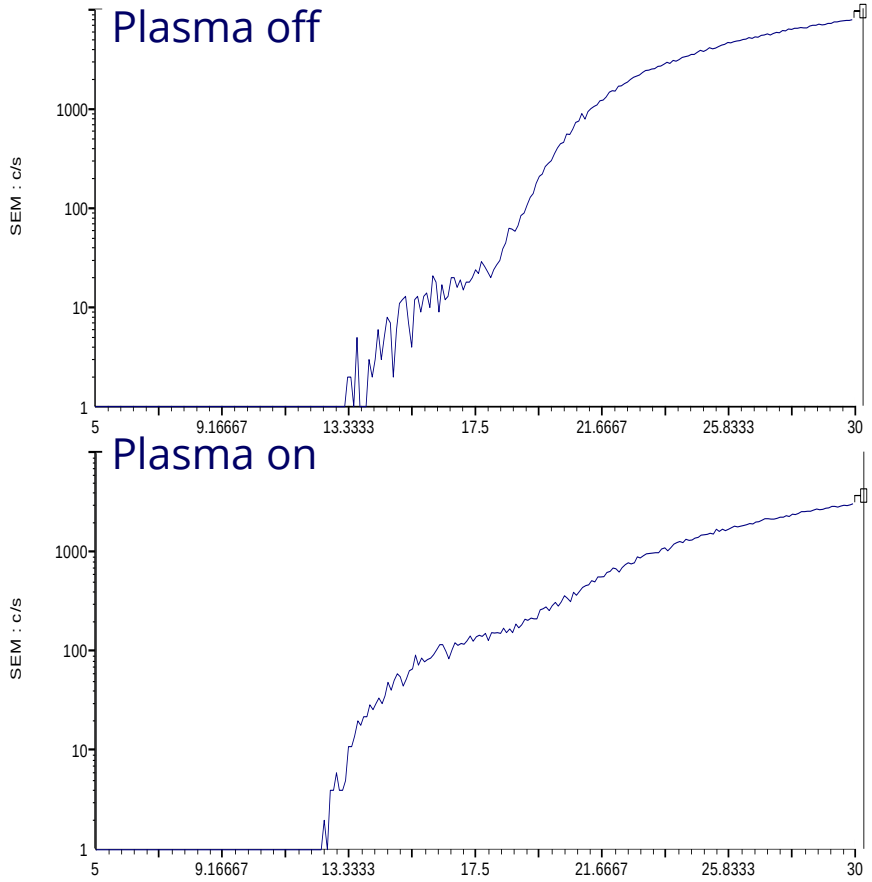
O^- ex neutrals ex CO_2, Plasma on

a is O^- ex CO_2

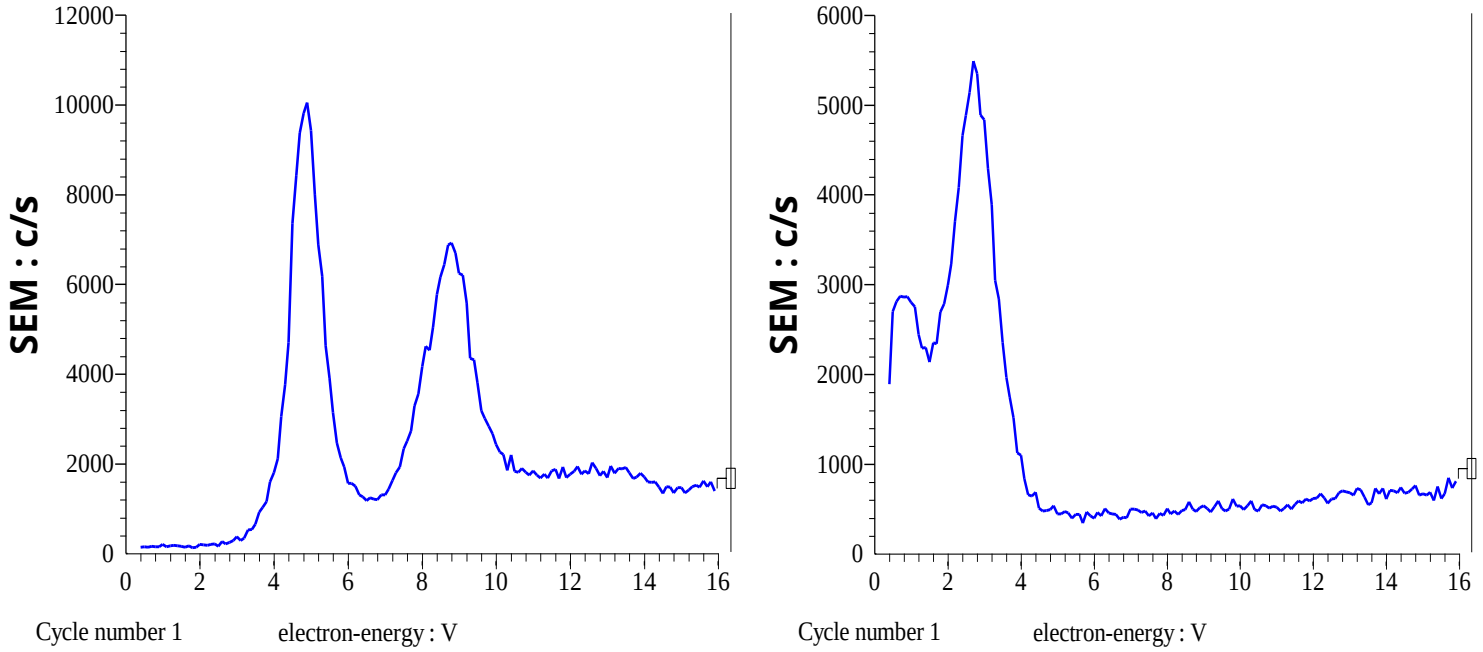
b is O^- ex CO_2 + e^- → CO_2^- → CO+ O^-

Electron Energy Spectra for CF_4 Plasma

- Two parent species for CF_2^+ can be seen when the plasma is active.
- The plasma derived species produce a characteristic feature at lower energies.

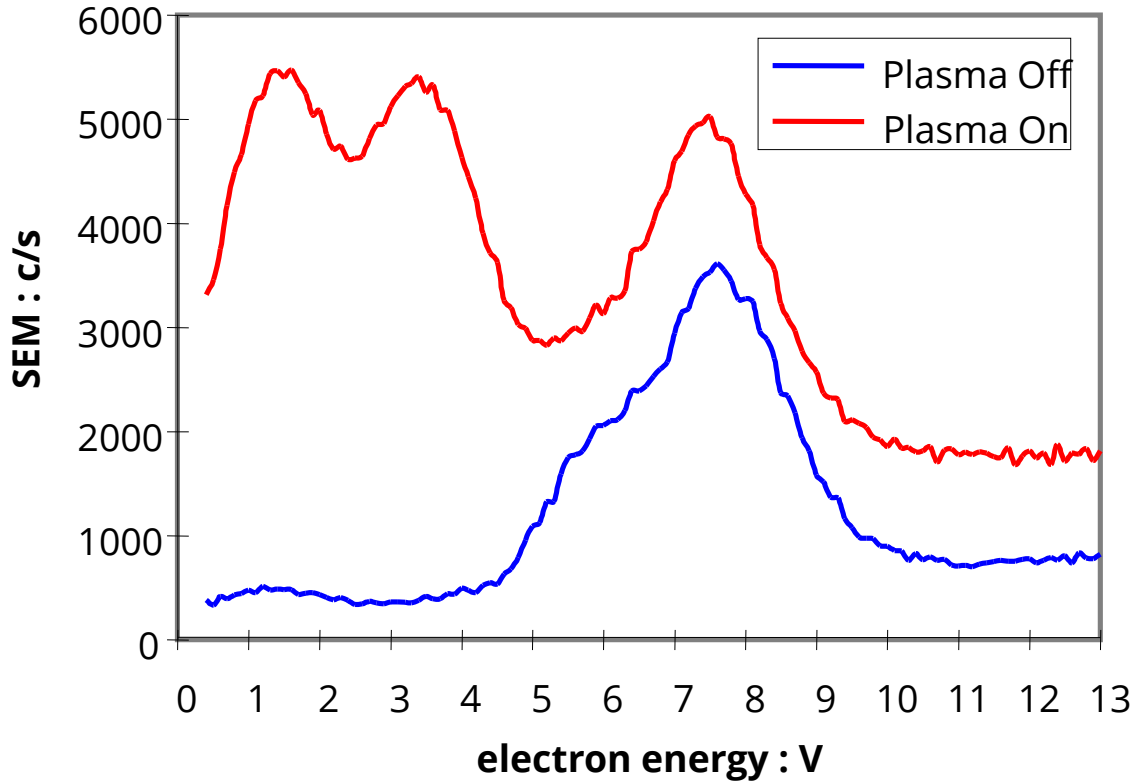


Electron Attachment Spectra



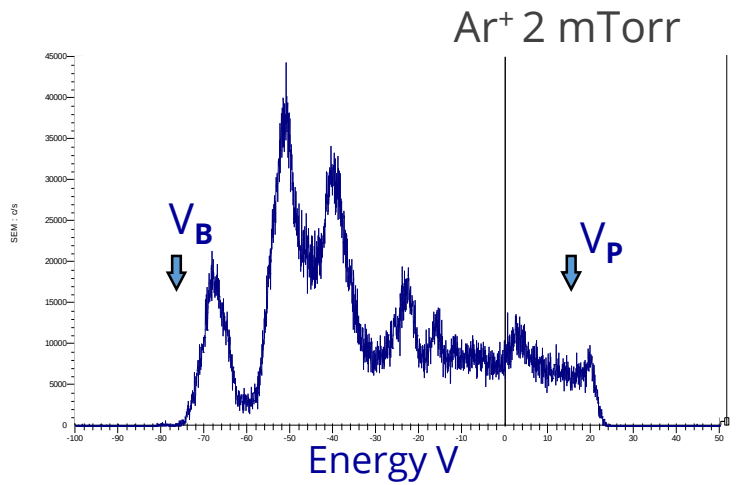
- O^- species may be formed from various precursors e.g. CO, CO_2, N_2O via electron attachment and subsequent dissociation.
- The low energy resonant electrons required for this process are characteristic of the precursor involved.

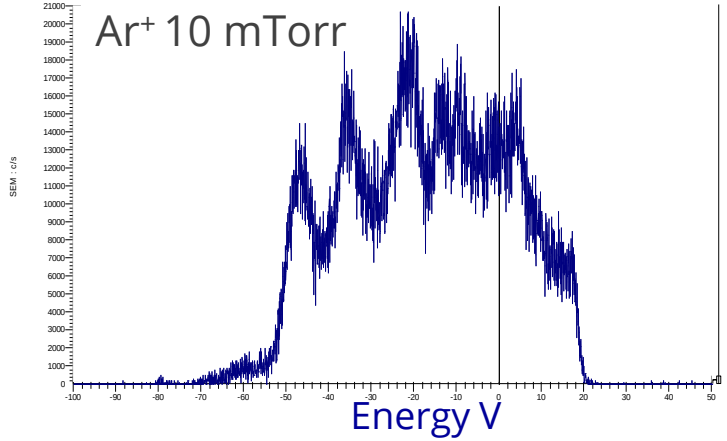
Electron Attachment in a CF_4 Plasma

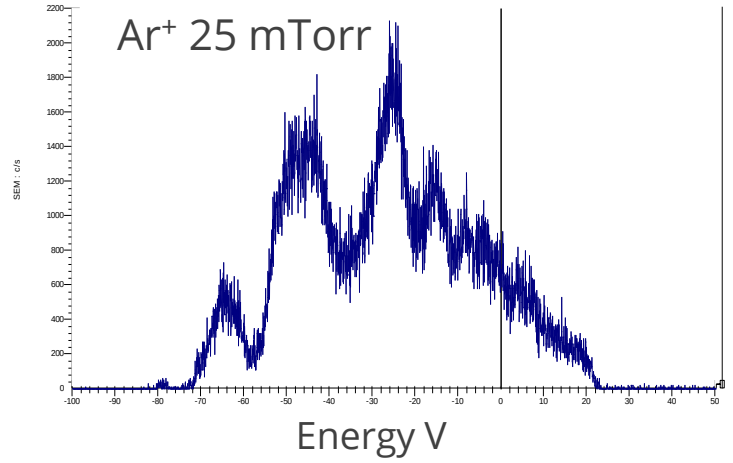


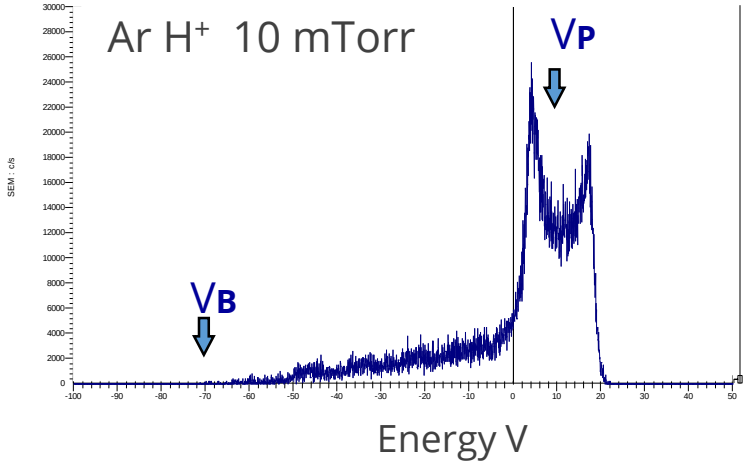
Formation of F^- species can occur in the absence of plasma but the under working conditions there is a dramatic increase in F^- concentration and type from plasma derived precursors.

Plasma Analysis using the Driven Electrode

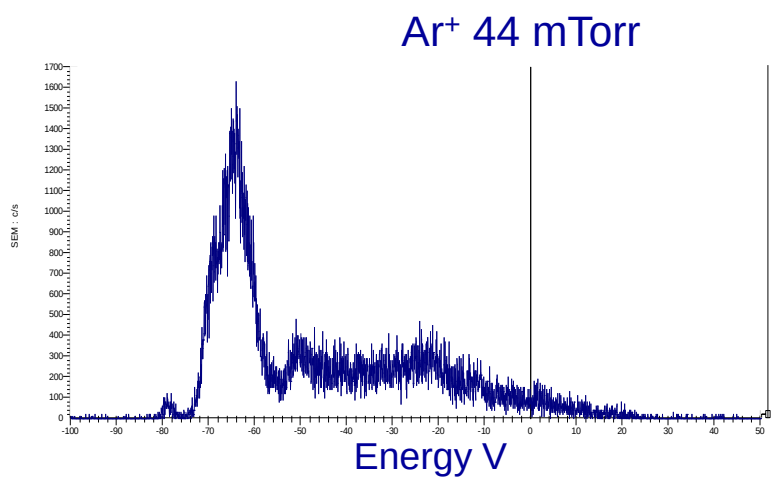


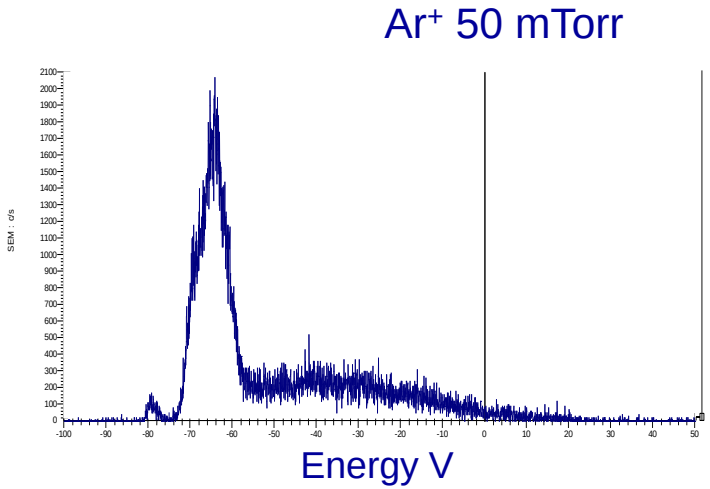






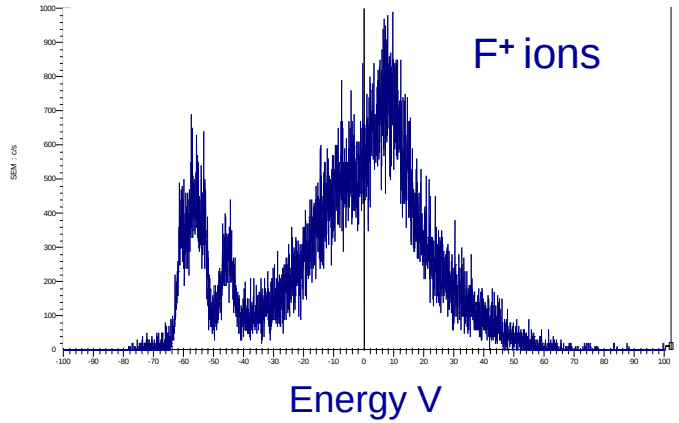
Plasma Analysis using the Driven Electrode

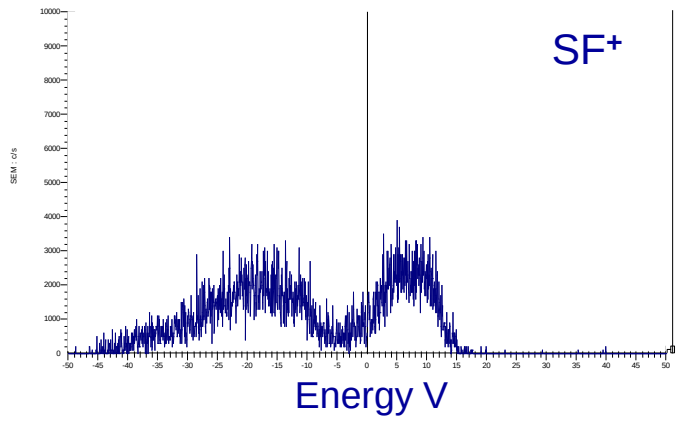


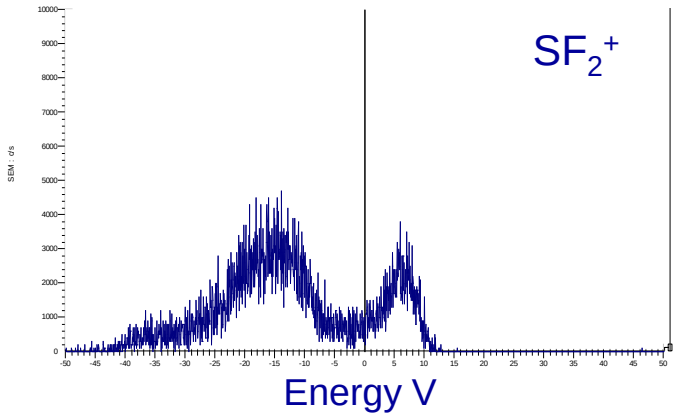


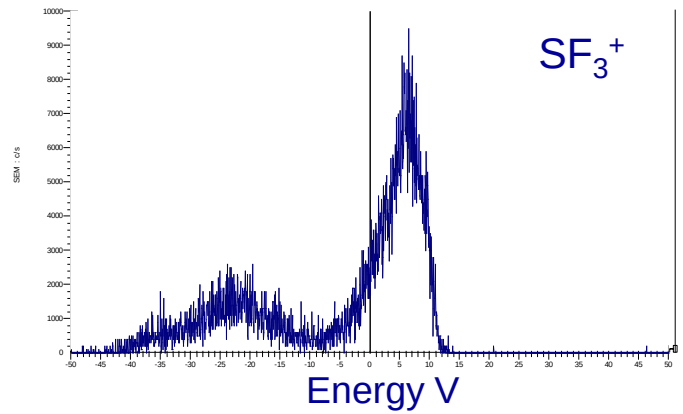
- Negative energy ions due to influence of the biased electrode (V_b)
- V_{peak} corresponds to centre of characteristic rf split peak feature
- As the pressure in the plasma increases inelastic collisional broadening / energy loss of Ar^+ (not ArH^+) is seen to dominate

Energy Analysis of Plasma Components



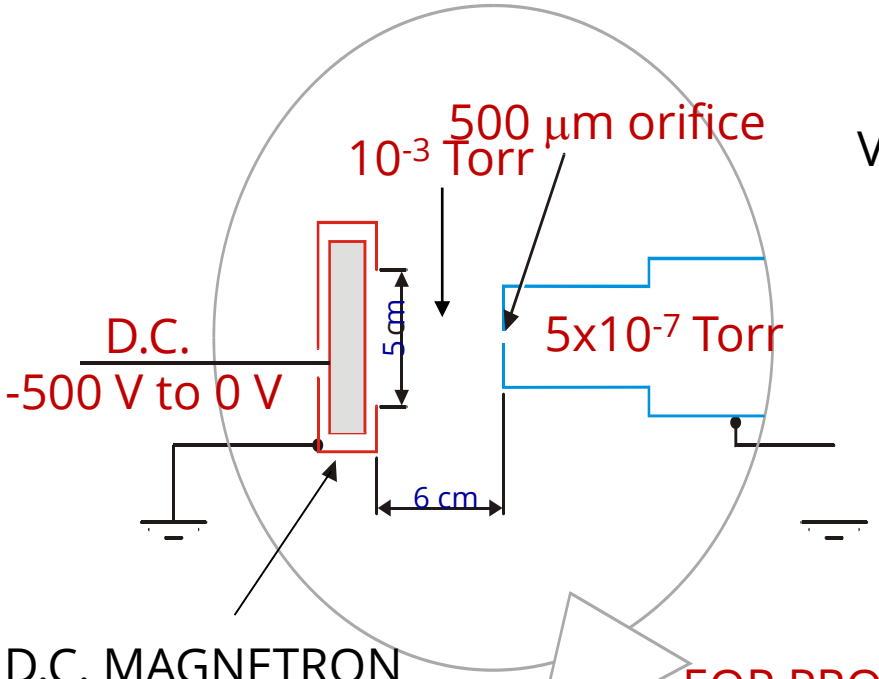






Even in an apparently homogeneous plasma the individual component species can exhibit a wide variation in energies.

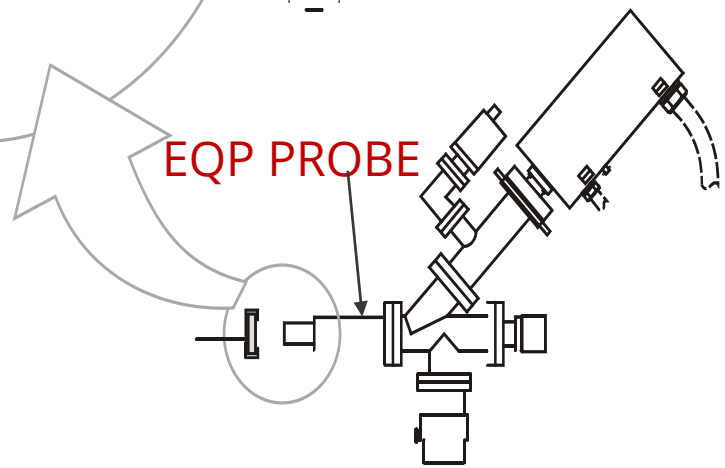
EQP Studies of a D.C. Magnetron Plasma



V_c= -300 V to -380 V

Magnetron Cathode:
Cu, Al, Mo or Graphite

Working Gas:
Argon or Sulfur Hexafluoride



D.C. Magnetron Plasma Data

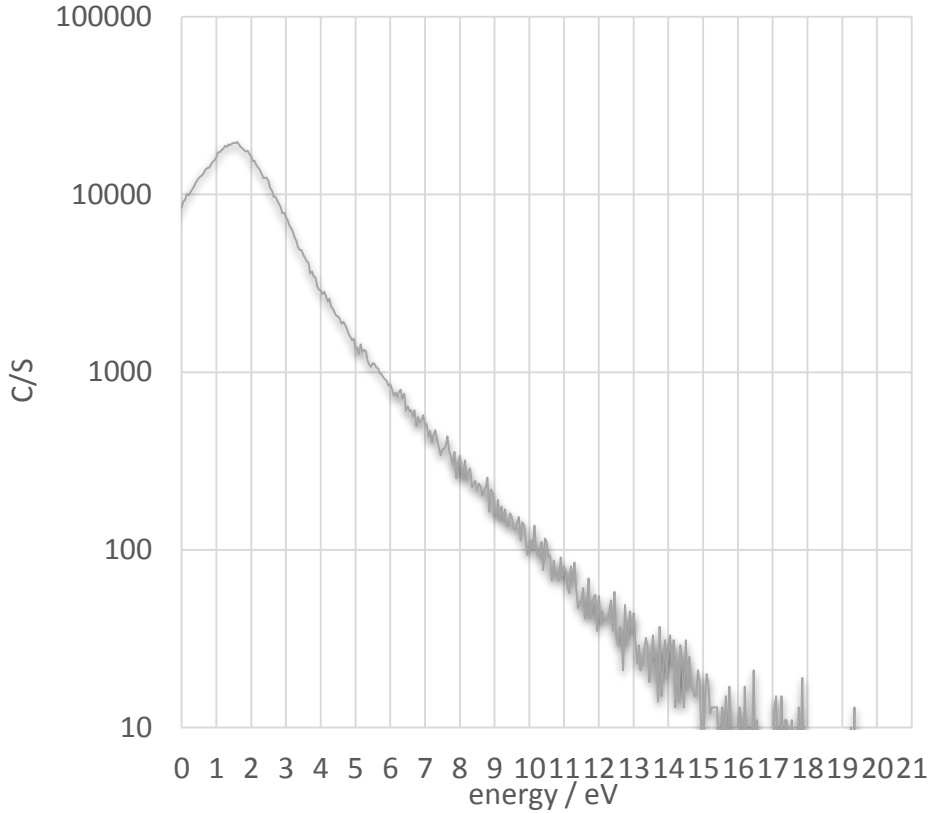
Fast Neutral Species

Power : 40 Watts

Ar pressure : 5 mTorr

Magnetron / EQP

Distance : 3.0 cm



High Energy tail (>5 eV) - energetic copper atoms ejected from magnetron cathode and ionised in the Ar plasma close to the EQP orifice and reflect the kinetic energies with which the atoms leave the cathode.

D.C. Magnetron Plasma Data

Fast Neutral Species

Power : 40 Watts

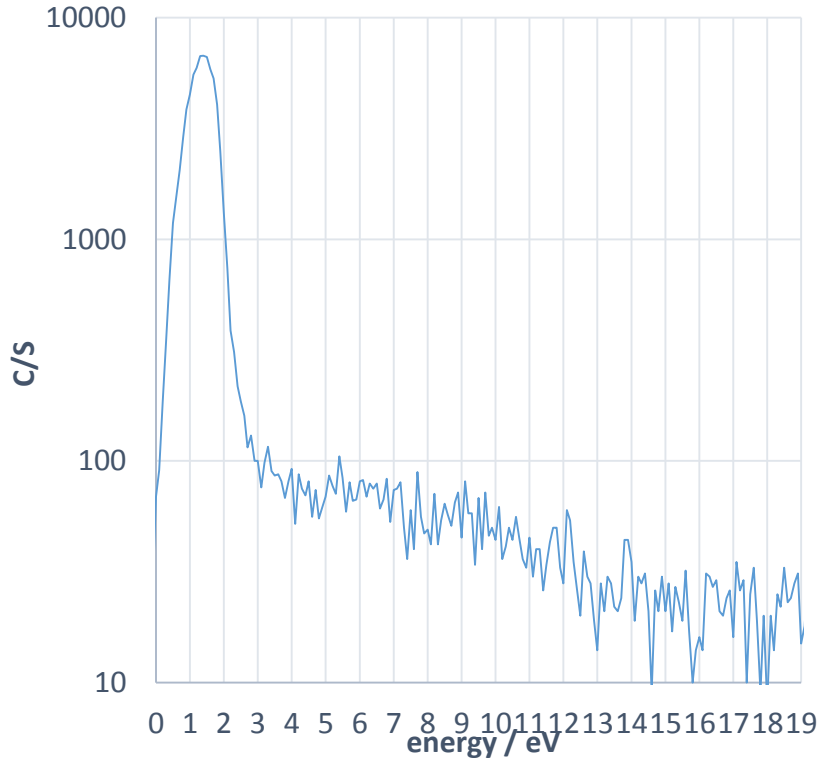
Current : 300 mA

Ar pressure : 5 mTorr

Magnetron / EQP

Distance : 3.0 cm

nb. The EQP was set to reject ions from plasma hence small background of ca. 20 c/s above 15 eV.



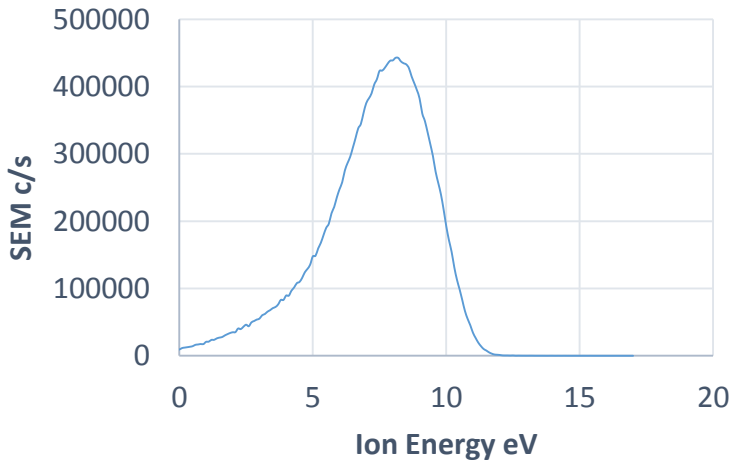
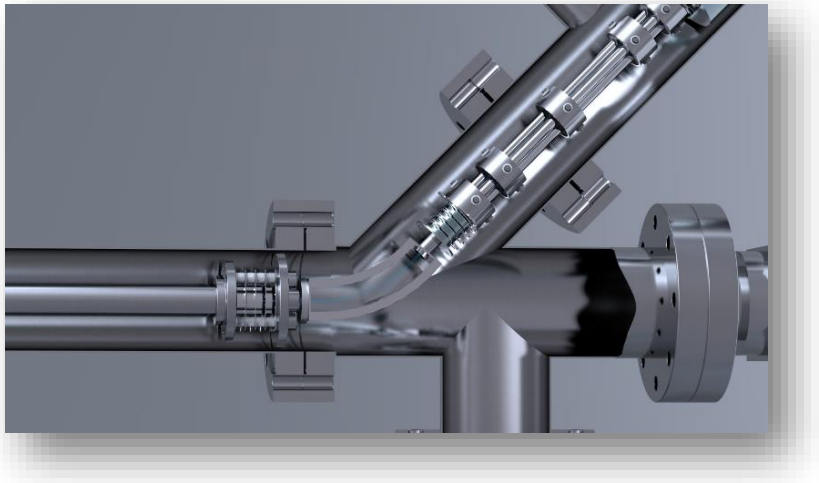
2 components, one due to strong, thermal energy + weaker feature extending up to 15 eV. Plasma off – no copper detected above 3 eV, indicating all kinetic ions produced in the ioniser / cage.

Selected Publications

- Latest publications
- Negative-ion surface production in hydrogen plasmas: modelling of negative-ion energy distribution functions and comparison with experiments. 2013. A Ahmad et al. *Plasma Sources Sci. Technol.* **22** 025006
- Spacially enhanced Langmuir probe measurements of a magnetically enhanced hollow cathode arc plasma. 2011. B Zimmermann et al. *Surface and coatings technology* **205** 5393-5396
- Quantification of the deuterium ion fluxes from a plasma source. 2011. A Manhard et al. *Plasma Sources Sci. Technol.* **20** 015010
- Advantages of highly ionized pulse plasma magnetron sputtering of silver for improved E. coli inactivation. 2012. O Baghriche et al. *Thin Solid Films* **520** 3567-3573
- Influence of high power impulse magnetron sputtering plasma ionization on the microstructure of TiN thin films. 2011. AP Ehiasarian. *J. Appl. Phys*. **109** 104314

Selected Hiden EQP Users

- INP Greifswald
- Xi'an Modern Chemistry Institute
- Universite d'Orleans
- Southwest Research Institute
- KRICT
- Applied Materials
- Fraunhofer IWS
- Ruhr-Universität Bochum

Summary

- High performance probe for mass and energy analysis of ions, radicals and neutrals from a plasma.
- A large number of options are available in order to sample from a variety of plasma types.
- The EQP sees use worldwide in a variety of plasma applications.