Ion energies in EUV induced plasma: Measuring methods

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Ion energies in EUV induced plasma: Measuring methods

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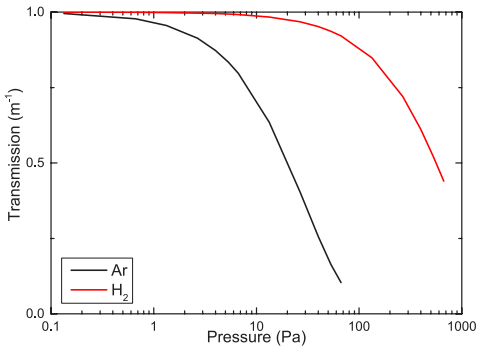
Ionization by Extreme Ultra-Violet photons

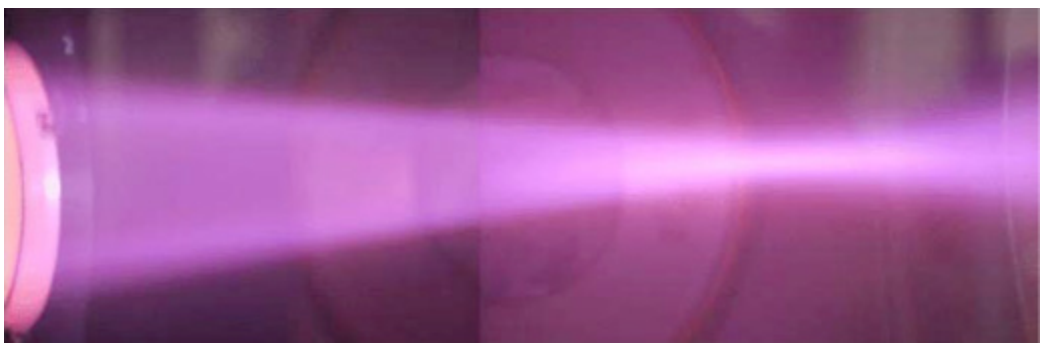
By exposure to high energy photons gasses can be ionized to form a plasma. In this research Extreme Ultra-Violet (EUV) light is used to induce a plasma in low pressure gas mixtures. Understanding these plasmas is important for industrial applications such as EUV lithography.

Plasma produced in free space

Photon energy: *92 eV*
Wavelength: *13.5 nm*
Pulse duration: *~ 150 ns*
Ionization degree: *< 0.1 %*
Low pressure monoatomic and molecular gasses and mixtures



EUV transmission as function of pressure [1]



Research questions

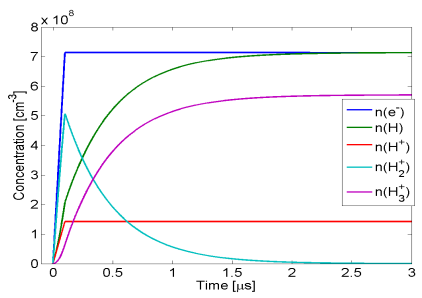
The plasma creation is not yet fully understood. Questions we have so far include:

- What happens with the remaining photon energy after ionization?
- Which processes create excited species?
- Why is the emission confined to the EUV beam path?
- What is the influence of plasma-wall and EUV-wall interactions?

Plasma composition and energy distributions

Simulations have been made in the past to predict plasma composition and ion energy distribution functions (IEDF)[5]. High energy ions (> 20 eV) are expected but have not been measured yet.

The electron density has been measured by Van der Horst[4] which can be used for a global model. In pure hydrogen the photoionization creates mostly H_2^+ ions which is readily converted to H_3^+.

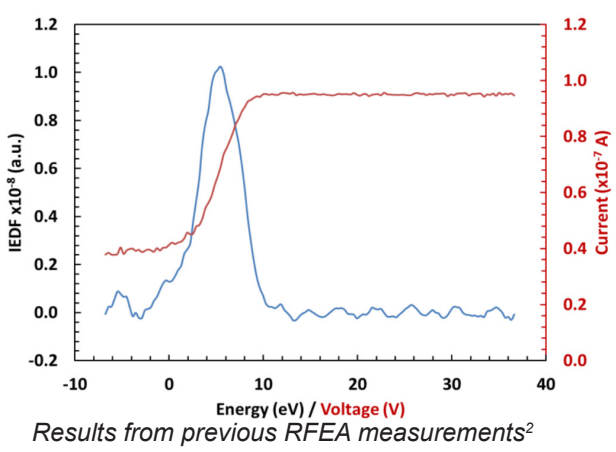


The development of concentrations in a hydrogen plasma according to a basic global model.

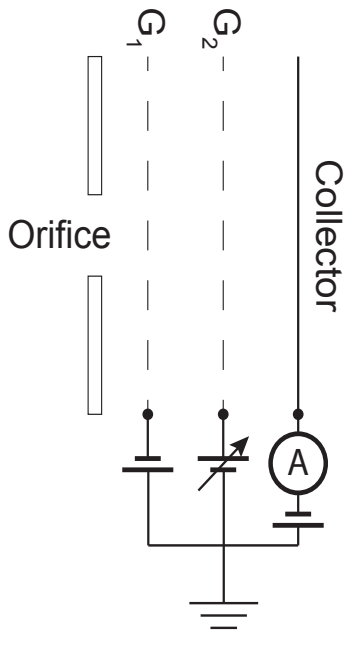
RFEA and EQP will be used to measure time resolved plasma properties.

Retarding Field Energy Analyzer (RFEA)

The RFEA probe measures ion fluxes discriminated by energy. Measurements made in the past showed the IEDF for low energy ions (< 10 eV) but lacked the resolution to detect the small fluxes of high energy ions.



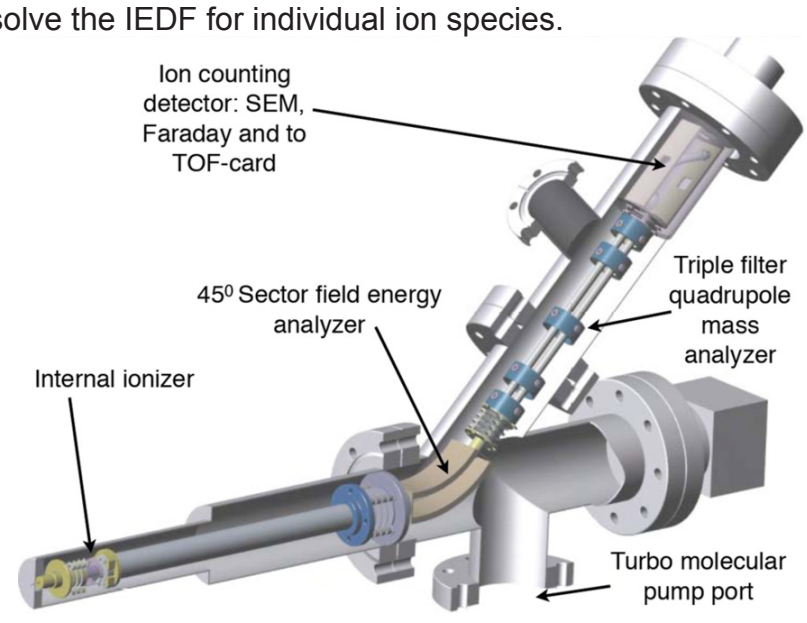
Results from previous RFEA measurements[2]



G_1: large negative bias to repel electrons
G_2: potential sweep to discriminate ion energies

Electrostatic Quadrupole Plasma (EQP) Mass Spectrometer

Simultaneous measurement of ion energy and mass makes it possible to resolve the IEDF for individual ion species.



Schematic of the EQP [5]

There are also optical techniques under consideration.

[1] B.L. Henke, E.M. Gullikson and J.C. Davis, *At. Data Nucl. Data Tables*, 54(2) (1993)
[2] Í. Doğan and E. Osorio (2014)
[3] D.I. Astakhov and V.V. Ivanov (2014)
[4] R.M. van der Horst et. al., *J. Phys. D: Appl. Phys.*, 47(30) (2014)
[5] Hiden Analytic LTD., Warrington, England, http://www.hidenanalytical.com/