First-ever measurements of ion energy distribution functions in EUV induced plasma

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FIRST-EVER MEASUREMENTS OF ION ENERGY DISTRIBUTION FUNCTIONS IN EUV INDUCED PLASMA

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Introduction
The EUV sources for ASML’s next-gen lithography tools allow us to investigate EUV induced plasmas, which up to recently, have been exclusively investigated by astronomers.

EUV-induced plasmas are of significant importance with respect to the lifetime of components in EUV lithography tools. An important parameter is the ion energy distribution function (IEDF).

For the first time ion energy distribution functions (IEDFs) have been measured in an EUV induced plasma.

Surface interactions
IEDFs have been measured with the EQP in parallel and perpendicular configurations. In the perpendicular configuration EUV light hits the EQP sample plate. In the parallel configuration there are no surfaces exposed to EUV.

Parallel

EUV induced plasma

Perpendicular

- Broad distribution
- Energy cut-off at 18 eV
- $H_3^+$ is converted to $H_2^+$ by collisions with background: $H_3^+ + H \rightarrow H^+ + H_2^+$
- Secondary electrons reduce the $T_e$ and $V_{th}$, thereby reducing the ion energy

Spectral effects
The spectrum produced by the EUV source also contains substantial amounts of lower energy Vacuum UV. A spectral filter, with a pass band of 10-20nm can be used to reduce this out of band radiation.

- IEDFs of different species react similar to change in spectrum
- VUV increases the ions density due to larger ionization cross section
- Addition of VUV doesn’t change IEDF shape
- High spectral power creates a high energy shoulder

References

Experimental setup
The setup consist of an EUV source, collector vessel and measurement vessel. The EQP can be positioned in multiple configurations.

- Source
- Collector
- Measurement vessel
- EQP
- Filter
- Detector
- Optical setup
- Sampling orifice
- Mass filter
- Plate
- Ion optics
- Vacuum UV. A spectral filter, with a pass band of 10-20nm can be used to reduce this out of band radiation.

- IEDFs of H$^+$ measured with and without Spectral Purity Filter. The filter reduces the total power with 70%, therefore a measurement is done with a reduction plate of 30%.

- IEDFs of different species react similar to change in spectrum
- VUV increases the ions density due to larger ionization cross section
- Addition of VUV doesn’t change IEDF shape
- High spectral power creates a high energy shoulder

Outlook
- Verify numerical (PIC) models made by D. Astakhov (ISAN, Russia)
- Quantification of ion fluxes to assess EUVL tool lifetime
- Investigate scaling laws to deduce ion dynamics

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Science
- EUV-induced plasma
- Ion energy distribution function (IEDF)
- Ion dynamics
- EUV lithography
- EUV induced plasma
- EUV source
- Collector vessel
- Measurement vessel
- Electrostatic Quadrupole Plasma analyser (EQP)
- Mass filter
- Ion optics
- Vacuum UV
- Spectral filter
- Filter Transmission Calibration Certificate
- Physikalisch-Technische Bundesanstalt (PTB)
- Braunschweig and Berlin, 2015

Spectroscopy
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- Vacuum UV
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Software
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