

Characterization of Debris Mitigation Techniques for a Sn- and Xe-fueled EUV Light Source

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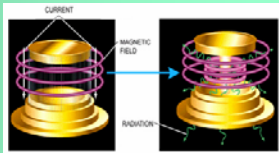
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Introduction

- A commercial XTS 13-35 z-pinch device with xenon and tin fuels is being used to characterize emitted source debris fields and investigate the effectiveness of various schemes aimed at increasing collector optics lifetimes.
- The XTS 13-35 EUV source is fitted with a spherical sector energy analyzer which yields ion energy, species, and charge state when coupled with time-of-flight information.
- Comparisons are made between the emitted debris of the source with Xe and Sn source fuels
- Pulsed foil trap and RF plasma mitigation techniques are investigated to determine their viability in decreasing the negative effects of pinch debris
- Methods of preventing flaking of electrode materials are investigated

XTS 13-35 Source Operation

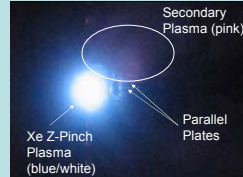
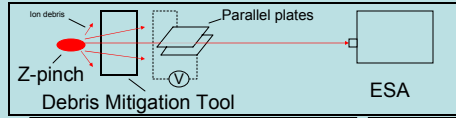
- Xenon or SnCl₄ feed gases
- Debris mitigation with foil trap and buffer gas
- Up to 1500Hz Continuous Pinch Frequency
- Rated EUV Power = 35W over 2π for xenon
- Chamber pressure during operation is 3mTorr to 14mTorr depending on the buffer gas flow rate
- Temperature at sample holder (56cm from pinch) remains <120°C after one hour of 256Hz operation
- ~1.5mm x 0.5mm ellipsoid pinch geometry



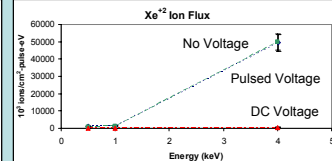
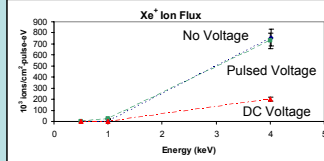
E-field Ion Mitigation

Concept:

A high voltage (>1kV) is applied to a set of parallel plates placed between the debris tool and optics area to create an electric field in the path of pinch ejecta, thus diverting ions and electrons which would otherwise contribute to the incident flux.



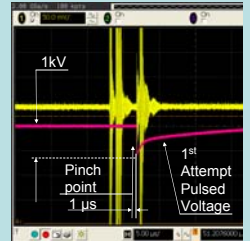
Parallel plates in front of the z-pinch with a dc voltage applied



Xenon ion flux measured with and with pulsed and dc voltages applied to the E-field mitigation plates, showing **3.75 x** reduction of 4keV Xe⁺ and **88. x** reduction of 4keV Xe²⁺. This is a dramatic effect!

Results:

- An applied dc voltage significantly reduces measured ion flux, showing that debris mitigation with electric fields is possible near the pinch site.
- A possible negative side effect of the dc voltage is that it creates a local plasma that could cause additional erosive flux
- With the 1st attempt at pulsing a voltage (trace below), no local plasma is created, but the ion flux is not reduced. Different voltage signals will be attempted.



Suppression of Metal Formation on Surfaces

Concept:

Erosion and re-deposition of various metals around the pinch area results in the formation of metal flakes that could potentially contaminate optics and other equipment placed downstream from the EUV source. Experiments are underway to discourage the counteract the formation of these flakes.



Si witness plates are placed on the forward facing surface of the XTS EUV source

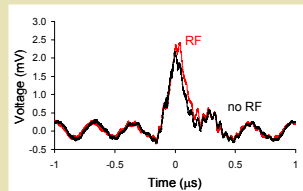
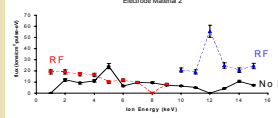
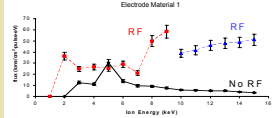
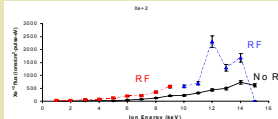
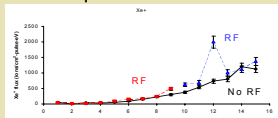
XTS forward facing surface with Si witness plates after exposure to 7M pulses of the Xe-fueled z-pinch



RF Debris Mitigation

Concept:

An RF plasma is created in the pinch area to increase the local ionization percentage in an effort to increase pinch efficiency and mitigate debris when combined with other techniques.



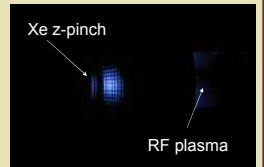
EUV output signals with and without RF

Results:

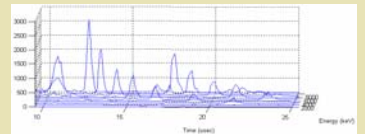
- The RF plasma caused a marked increase in electrode material ion flux
- The RF plasma did not appreciably change the EUV photodiode signal
- Singly-charged ion specie fluxes were higher with RF plasma than without



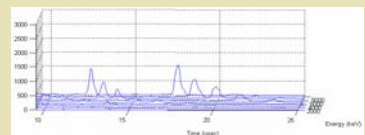
RF coil surrounding the pinch electrodes



RF Plasma striking in the XCEED chamber, visible as glow from behind the foil trap



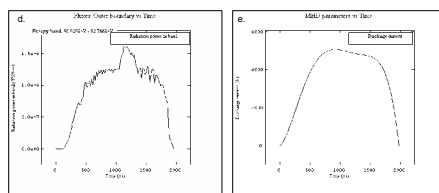
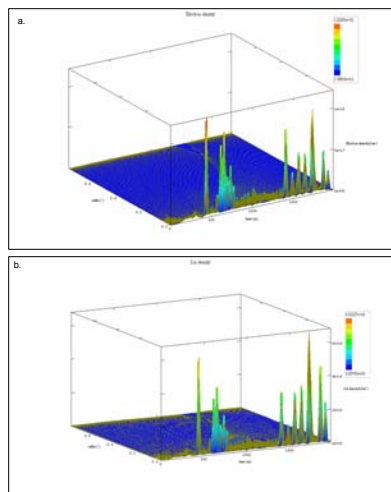
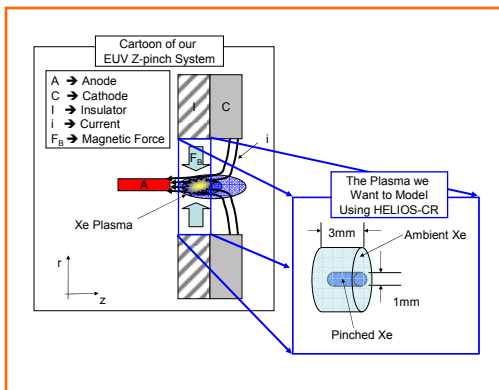
Xe fueled pinch raw spectra (1keV-9keV) for pinch with RF mitigation



Xe fueled pinch raw spectra (1keV-9keV) for pinch without RF mitigation

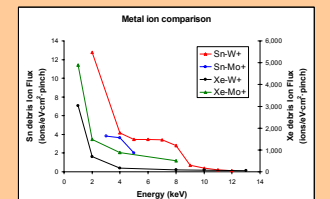
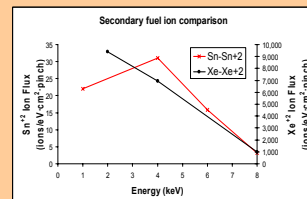
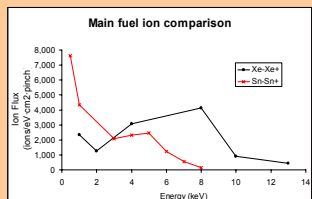
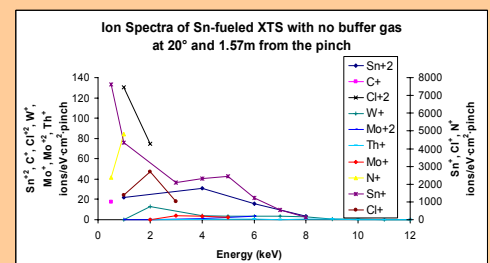
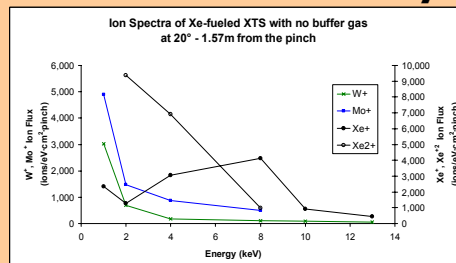
Below the ion spectra for the species present in XCEED are presented

Pinch Modeling with HELIOS-CR



a. 3D contour plot of the electron density vs. radius and time. b. 3D contour plot of the ion density vs. radius and time. c. Streak diagram of electron temperature in eV vs. radius and time. d. Predicted EUV emission into Ze. c. Discharge current.

Ion Debris Spectra Comparison Sn/Xe Fuels



Future Work

Modeling:

This work will be used as initial conditions for a secondary simulation that will be used to predict the ion energies at both the expected position of a collector mirror, as well as at XCEED's ESA.

Experimental:

- Extension of E-field ion diversion
- Prevention of metal flake formation
- Neutral particle flux measurement

Accomplishments

- Characterized debris spectra of Sn-fueled source up to 12keV
- Installed RF coil in XCEED chamber and conducted preliminary RF coil experiments
- Demonstrated the viability of an E-field diverter for mitigating ion debris near the pinch

Acknowledgements

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