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Development of a Gas Jet Type Z-pinch EUV Light Source

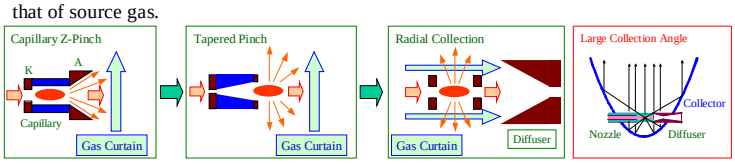
Tokyo Institute of Technology

Eiki HOTTA*, Kazuhiko HORIOKA, Akitoshi OKINO, Toru KAWAMURA, Masato WATANABE, Majid MASNAVI, Smruti R. MOHANTY, Inho SONG, Toshiro SAKAMOTO, Yasunori KOBAYASHI
Tokyo Institute of Technology, Yokohama 226-8502, JAPAN
*ehotta@es.titech.ac.jp

Motivation

High power and clean EUV light source is necessary for EUVL. However, DPP EUV source has disadvantages of low collection angle, which is due to discharge head structure, and debris in spite of its advantages of low cost and small size. To solve these problem, other discharge concepts such as tapered pinch and star pinch have been proposed and developed. But even these methods cannot satisfy requirements (high collection angle and debris-free) at the same time.

Low collection angle of DPP source comes from using axial radiation of EUV and difficulty of debris mitigation comes from that the flow of curtain gas is perpendicular to that of source gas.

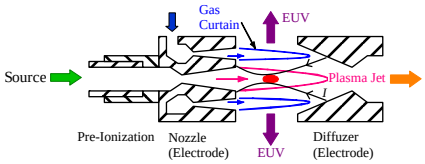


Objectives of this work :

To demonstrate the radial collection of EUV emission from the pinch plasma to provide large collection angle and to realize a coaxial gas curtain for debris mitigation.

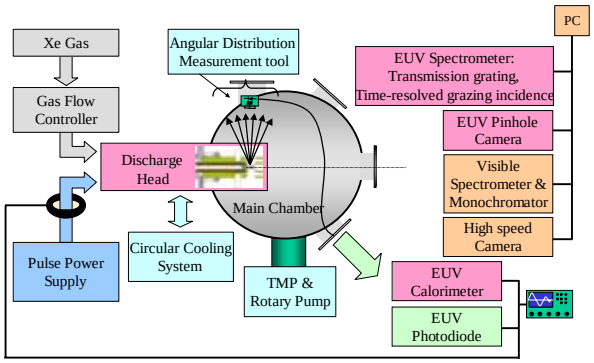
Introduction

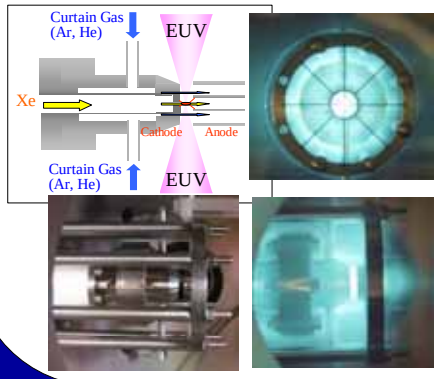
New gas jet Z-pinch EUV light source having double gas jet electrodes has been developed. It has two nozzles and two diffusers. The EUV emission is collected from the side of pinch plasma, generated in the gap between the inner nozzle and the corresponding diffuser. A cylindrical shell of He gas curtain produced by the outer nozzle is specially designed for shielding the debris and suppressing the inner gas expansion.



Here, we report the preliminary results on gas jet type Z-pinch EUVL source. We have succeeded in generating EUV energy of 1.22 mJ/sr/2%BW/pulse at 13.5 nm with gas curtain. The estimated dimension of EUV source is FWHM diameter of 0.07 mm and length of 0.34 mm, and FW $1/e^2$ diameter of 0.15 mm and length of 1.2 mm.

Experiment





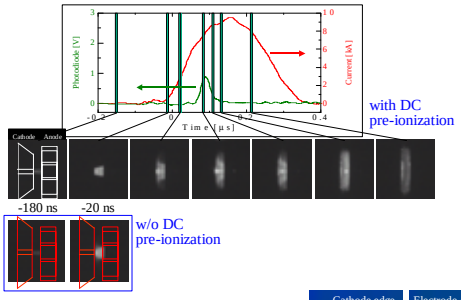
Cathode (nozzle)
- Xe nozzle diameter: 2 mm
- He nozzle diameter
  Inner diameter: 11.6 mm
  Outer diameter: 12 mm

Anode (diffuser)
- Inner diameter: 6 mm
- Outer diameter: 20 mm

♦ Experimental conditions
- V_{charge} = 9 ~ 12 kV (15 ~ 26 J)
- Xe gas supplying = 10 ~ 30 Torr
- Gap distance: d = 4 ~ 12 mm
- He gas curtain

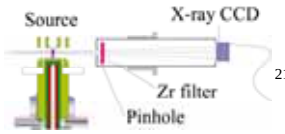
Experimental results

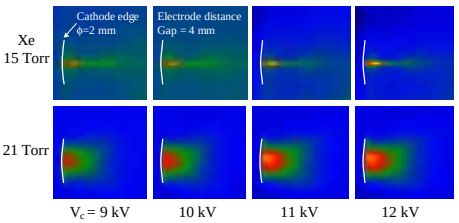
Framing photographs (10 ns resolution) and EUV photodiode



The dynamics of the plasma in the gas jet type Z-pinch was observed from the radial direction. The evidence of pinch plasma formation is prominent in the framing photo taken at a time around 80 ns. DC preionization provides stable and dense plasma

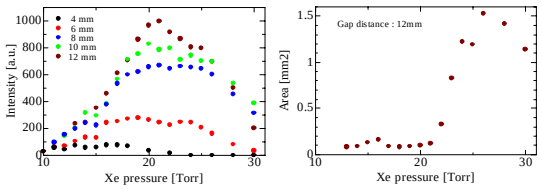
Pinhole camera





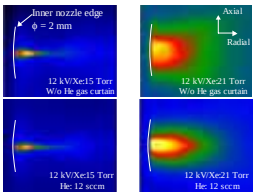
EUV pinhole images were recorded for various input energies and Xe gas supplying pressures. In the case of Xe 15 Torr, the EUV plasma images are found to have extremely narrow ellipsoidal shape, which are fairly symmetrical with respect to the axis. However, at 21 Torr, the shape of the EUV plasma is blunted and the EVU radiating plasma is seem to be located at the upstream inside the cathode nozzle. The effect of input energy on EUV intensity is easily seen in those images

Effect of gap distance



EUV output becomes high with increasing the gap distance and has optimum pressure value. Also, the Xe pressure controls the EUV plasma size.

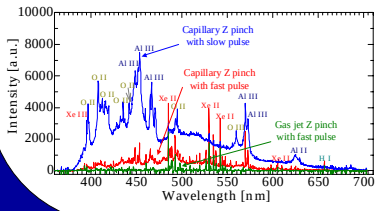
Effect of gas curtain



* 20 pulses averaged

He : 12 sccm gas curtain		W/o gas curtain	With gas curtain	Remark
15 Torr	Axial	0.81 mm	0.88 mm	- FWHM length - The EUV plasma becomes narrower, longer and brighter
	Radial	0.13 mm	0.10 mm	
21 Torr	Axial	1.33 mm	1.60 mm	
	Radial	1.10 mm	0.48 mm	

Spectra in visible region



The measurement of visible spectrum establishes that our gas jet type Z-pinch source radiates very clean EUV light with minor contamination in low ionization state of Xe and the prospects of radial extraction of EUV light seems to be fruitful.

Summary and Future Work

► The concept of radial extraction of EUV light was successfully demonstrated. No significant impurity spectra in visible range are marked in gas jet type Z-pinch discharge.

► The characteristics attained with our gas jet type Z-pinch source such as a small pinch plasma, large collection angle and a combination of debris shielding make it as a potential cost-of-ownership model for a commercial EUV light source.

► With the diffuser with recovery function and simple debris shield structure, Sn can be easily used as source material in gas jet type Z-pinch discharge head. Now, gas jet electrode discharge head, diffuser structure and pulse power supply are being improved.

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