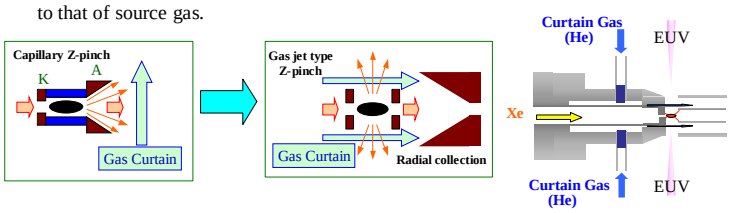
Development of a Gas Jet-Type Z pinch EUV Light Source for Lithography

Naoya Iizuka, Nozomu Kishi, Inho Song, Toshiro Sakamoto, Yasunori Kobayashi, Smruti R. Mohanty, Masato Watanabe, Toru Kawamura, Akitoshi Okino, Kazuhiko Horioka and Eiki Hotta*
Department of Energy Sciences, Tokyo Institute of Technology
*e-mail: ehotta@es.titech.ac.jp

Introduction

High power and clean EUV light source is necessary for EUVL. However, DPP EUV source has disadvantages of debris generation and low collection angle, which is due to discharge head structure, in spite of its advantages of low cost and small size.

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.



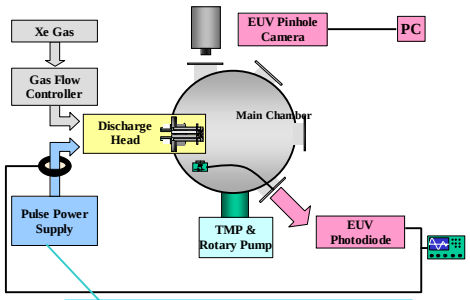
New gas jet Z-pinch EUV light source having double gas jet electrodes has been developed. It has two nozzles and two diffusers. The EUV emission is collected from the side of pinch plasma, generated in the gap between the inner nozzle and the corresponding diffuser. A cylindrical shell of He gas curtain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

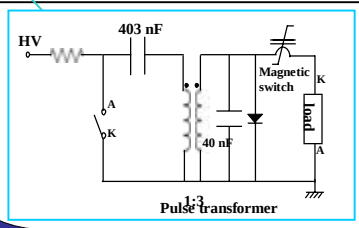
Here, we report the preliminary results on gas jet type Z-pinch EUVL source. We have succeeded in generating EUV emitting plasma of 0.14 mm FWHM diameter and 0.80 mm FWHM length..

Experimental details

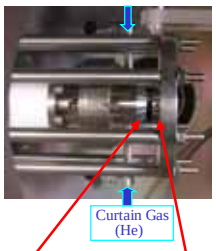
♦ Experimental conditions

- *V* charge = 12 kV (26 J)
- Gap distance: *d* = 4 ~ 12 mm
- Xe gas supplying = 10 ~ 30 Torr
- He gas curtain





Discharge head



Cathode (nozzle)

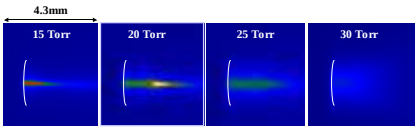
- Xe nozzle diameter: 2 mm
- He nozzle diameter
  - Inner diameter: 11.6 mm
  - Outer diameter: 12 mm

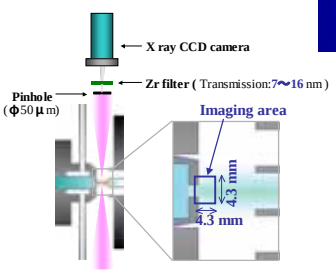
Anode (diffuser)

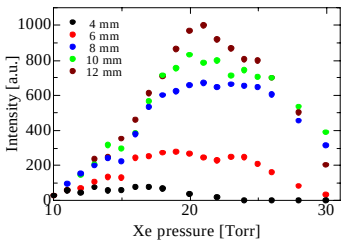
- Inner diameter: 6 mm
- Outer diameter: 20 mm

Experimental results

EUV pinhole images



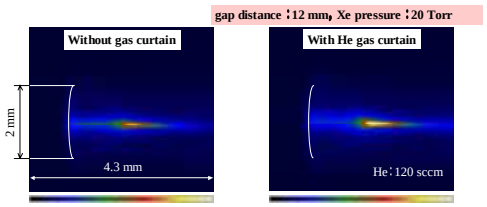




EUV pinhole images were recorded at 90 ° with respect to electrode axis for various electrode gap distances (4~12 mm) and Xe gas supplying pressures (10~30 torr).

The strongest intensity was obtained at electrode gap distance of **12mm** and Xe gas supplying pressure of around **20 torr** .

Effect of He gas curtain

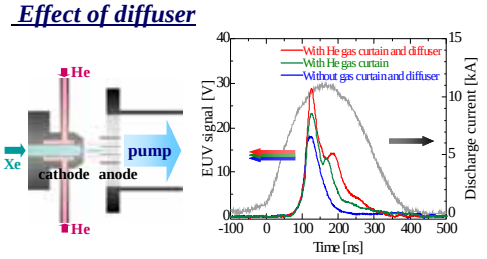


		Without gas curtain	With He gas curtain
Length [mm] (FWHM)	axial	0.92	0.80
	radial	0.16	0.14
Intensity [a.u.]		967	1213

The effects of He gas curtain in optimal conditions were examined.

The He gas curtain has an additional function of limiting the expansion of Xe gas.

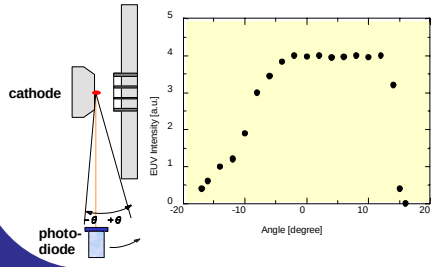
Effect of diffuser



To keep the pressure sufficiently low inside the chamber, the He curtain gas must be exhausted directly from the end of the anode.

The photodiode signals taken with diffuser is larger than that taken without diffuser (improvement of approximately 20% in peak value).

Angular distribution of EUV radiation



The effective solid angle estimated from this measurement is **2.35** sr while that of general capillary DPP source is about **1.8** sr.

The gas jet type Z-pinch source has been confirmed to have a large effective solid angle.

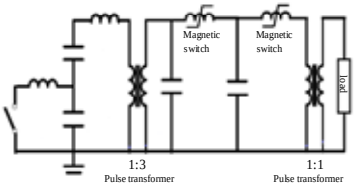
Conclusions

- The validity of radial collection of clean EUV light was successfully demonstrated by the new gas jet type Z-pinch discharge.
- At Xe gas supplying pressure of 20 torr and electrode gap distance of 12mm, the EUV emitting plasma is extremely small with 0.14 mm in FWHM diameter and 0.8 mm in FWHM length.
- The He gas curtain has an additional function of limiting the expansion of Xe gas and increasing the emission intensity.

Future works

- To confirm the flow of He curtain gas we will use Laser-Induced Fluorescence Technique (LIF) for visualization.

- A new pulse power supply system has been developed. It has two magnetic pulse compression stages to achieve higher discharge current.



ACKNOWLEGMENT : This work was partially supported by the New Energy Development Organization (NEDO) and by Grant-in-Aid for Scientific Research, the Ministry of Education, Culture, Sports, Science and Technology (MEXT), Japan.