KrF Laser Driven Xenon Plasma Light Source of a Small Field Exposure Tool

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ABSTRACT

A small field exposure tool (SFET) is currently being built in Japan by the Extreme Ultraviolet Lithography System Development Association (EUVA) and Canon Inc. The laser plasma light source of SFET has been developed at the EUVA Hiratsuka R&D center. The drive laser of the xenon plasma source is a short-pulse, high-power KrF laser, that has been developed in cooperation with Gigaphoton Inc. and Komatsu Ltd. The laser has a maximum output power of 580W at 4kHz repetition rate. The xenon target is a 50 micrometer diameter liquid jet with a speed of about 30 m/s. The source has been designed to generate 0.5W in-band power at the intermediate focus at a collecting solid angle of pi sr. The set-up of the source at the Hiratsuka R&D center has been completed and the source is now being evaluated.

Keywords: EUV lithography, exposure tool , laser produced plasma, KrF laser, Xenon

1. INTRODUCTION

The light source development for next generation EUV lithography currently follows two paths: 1) the development of front-end, high-power 13.5nm EUV sources with HVM specifications, i.e. beside others with an average power at the intermediate focus of larger than 115W[1], 2) the development of light source systems which are integrated in small field exposure tools[2] or alpha-tool full field exposure tools[3]. These tools allow the evaluation and the development of the full EUV lithographic process to which the light source is just one – but evidently essential – part. The Extreme Ultraviolet Lithography System Development Association (EUVA) in Japan started the HVM light source development in 2002 with research and development of discharge and laser produced plasma sources (DPP[4], LPP[5]). In 2005 EUVA and Canon Inc. decided the development of a small field exposure tool that will be installed this year at a Japanese research center. The main purpose of the exposure tool is the development of masks and resists for EUV lithography but the light source and the tool performance will also be evaluated. The light source has been set-up at the EUVA Hiratsuka R&D center and is currently being evaluated. After evaluation the light source will be installed into the exposure tool at the Canon Utsonomiya R&D center. After testing and evaluation SFET will finally be moved this year to a Japanese research center.

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2. SMALL FIELD EXPOSUE TOOL

2.1 Overview and Main Specifications

A schematic of the small field exposure tool is shown in **Fig. 1**. The dimensions of the vacuum chamber (main body) are about 1.5mx1.5mx2.3m (LxWxH). System specifications are listed in **Tab. 1**. The exposure tool is currently being set-up by Canon Inc. at the Utsonomiya R&D center. The light source of SFET is a laser produced xenon plasma that will be described in more detail in the following.

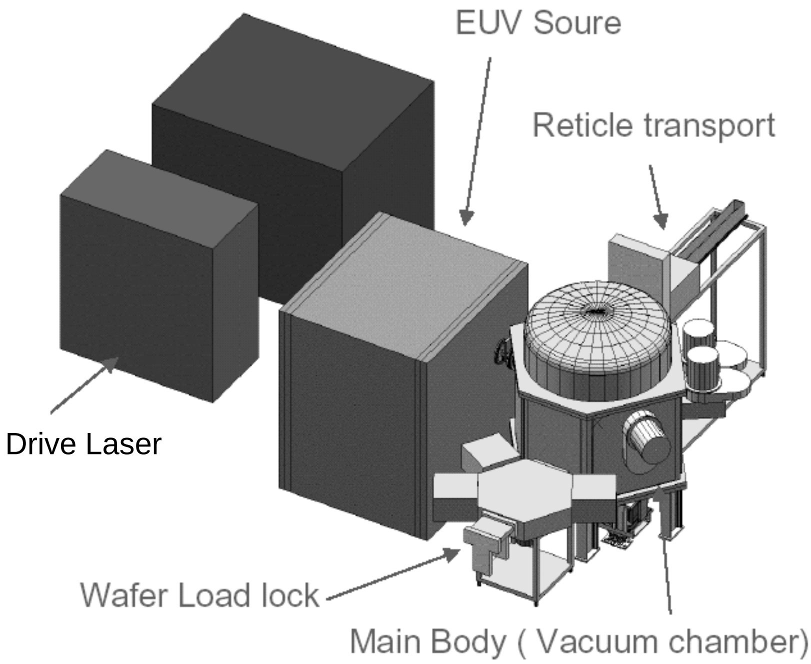

Fig. 1 Schematic of SFET.

NA	0.3
Field Size	0.6 mm x 0.2 mm
Aberration	0.5 nm rms (target)
Flare	7 % (calculated, MSFR)
Source Power	0.5 W at IF
Focus Accuracy	< 7 nm

Tab. 1 Main Specifications of SFET.

3. LIGHT SOURCE

3.1 System Layout

A schematic of the light source is shown in **Fig. 2**. A liquid xenon jet is injected into the vacuum chamber at a maximum speed of 30m/s. The jet has a diameter of about 50 micrometer and it is recovered by a partial pressure unit that is not shown in the schematic. In combination with three turbomolecular pumps (TMP) having a total xenon pumping speed of about 6000 l/s the pressure inside the vacuum chamber remains below 0.2 Pa during light source operation. The drive laser is a 248nm KrF excimer laser having a maximum output power of 580W at a repetition rate of 4kHz. The laser has been developed by Gigaphoton Inc. and Komatsu Ltd. It is based on a Gigaphoton lithography laser and has been mainly chosen for two reasons: 1) Gigaphoton lasers are well established in the current lithography light source market and their reliability is outstanding, 2) the interface for laser control and system integration is already available and also well proven.
A Mo/Si coated collector mirror with a clear aperture of 290mm is used to collect the plasma emission and a spectral purity filter having a 50mm clear aperture is used to suppress out-of-band radiation as well as residual laser light.
The set-up of the light source system has been completed at the EUVA Hiratsuka R&D center and the evaluation of the source is currently being done by Canon (see **Fig. 3**).

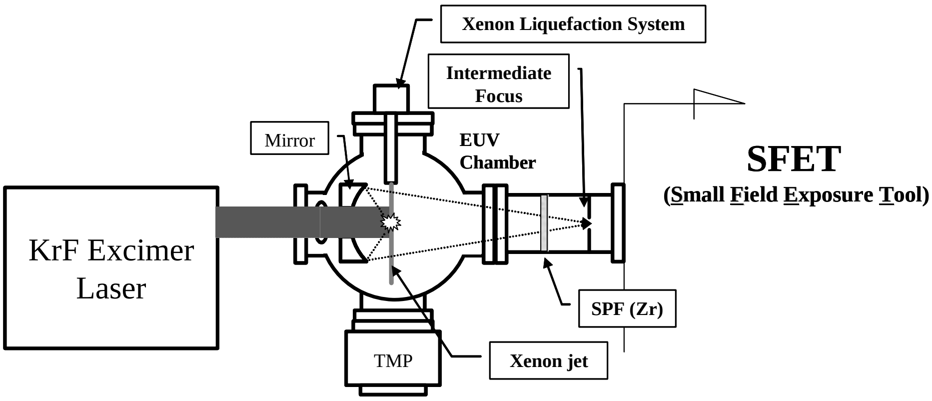

Fig. 2 Schematic of the light source.

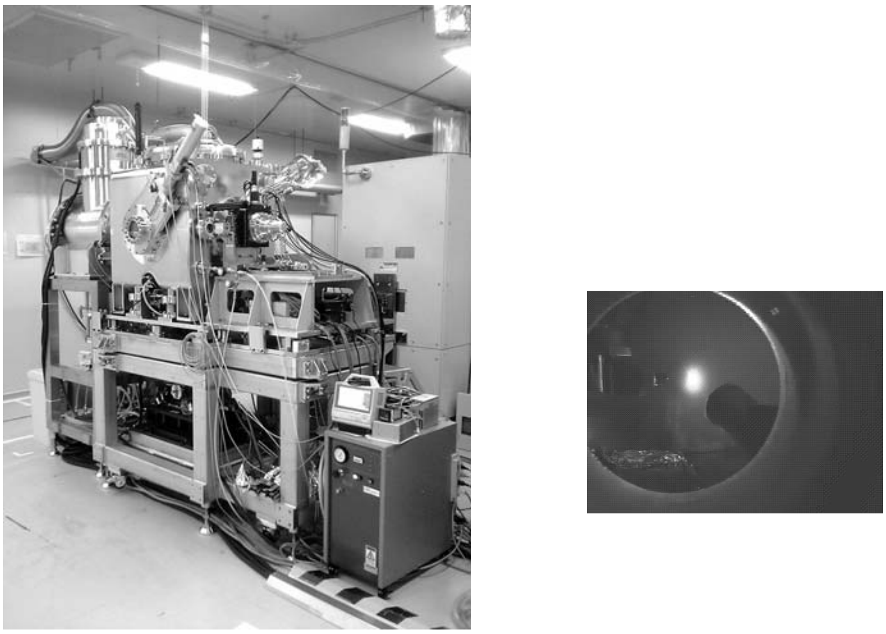

Fig. 3 KrF laser driven xenon light source (left) and visible plasma emission (right).

3.2 Drive Laser

The KrF drive laser is based on a Gigaphoton lithography laser (**Fig. 4**). The wavelength is 248nm and the maximum output power of the laser is 580 W at a repetition rate of 4 kHz, i.e. the maximum pulse energy is 145 mJ. **Fig. 5** shows the focused laser spot at the jet position having horizontal and vertical fwhm values of 57 and 67 micometer respectively. Horizontally, the laser spot compares with the jet diameter in order to obtain an efficient laser heating of the plasma. The temporal dependence of the laser pulse is shown in **Fig. 6**, having a fwhm pulse length below 10 ns.

Fig. 4 Light source KrF drive laser.

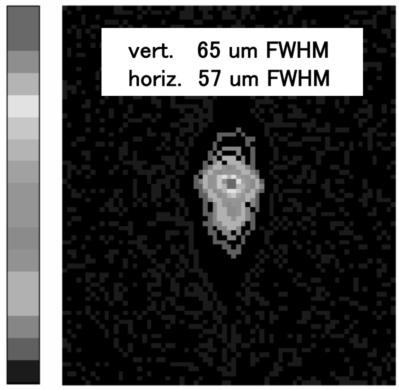

Fig. 5 Laser spot size at Xe jet position.

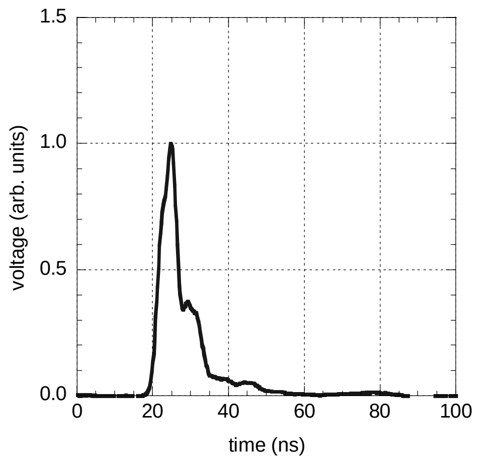

Fig. 6 Temporal profile of the drive laser pulse.

3.3 System Components

Additional system components are the collector mirror and the spectral purity filter. The mirror (Fig. 6) has a 300mm diameter silicone substrate. The collecting angle is pi sr. The mirror has the standard Mo/Si multilayer which has a gradient due to the large clear aperture of 290mm. The mirror reflectivity and the center wavelength have been measured and are > 60% and 13.5 nm, respectively. **Fig. 7** shows the in-band plasma emission at the intermediate focus. The fwhm plasma size is 48 and 66 micrometer, horizontally and vertically respectively.

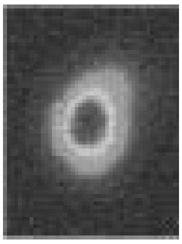

Fig. 7: In-band plasma emission; measured by Canon Inc.

A spectral purity filter is used to suppress out-of-band radiation including scattered laser light. The filter has a clear aperture of 50mm. It is supported by a mesh and has a Silicone/Zirconium/Silicone structure. The thickness is 50nm each resulting in a transmission of about 50%.

4. CONCLUSION

A small field exposure tool will be set-up this year at a Japanese research laboratory. The tool has a KrF laser driven xenon light source that has been developed by EUVA (Hiratsuka R&D center), Komatsu and Gigaphoton. The light source has been installed at the EUVA Hiratsuka R&D center and is currently being tested. After testing the source will be installed into the exposure tool, being developed by Canon, at the Canon Utsonomiya research center.

5. ACKNOWLEDGEMENTS

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