Focusing EUV Radiation from the Capillary Discharge Source

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Abstract

Capillary discharge source has been constructed at the Czech Technical University in order to study the discharge as an extreme ultraviolet (EUV) source for scientific and industrial applications. Rotationally symmetric ellipsoidal mirror was used in order to focus EUV beam from the capillary. Obtained focal spot size is 220 μm. We used focused radiation in order to obtain ablated imprints in the PMMA layer. New larger vacuum chamber has been installed to allow more complex and precise experiments.

Keywords: capillary discharge, EUV radiation, EUV lithography, EUV microscopy

Introduction

EUV radiation (λ = 2.88 nm – in water window) generated by capillary nitrogen discharge was focused using the EUV optics and detected by CCD camera with scintillator. The scintillator was then replaced for a PMMA photoresist.

Compact low-inductance capillary discharge system is able to produce plasma Z-pinch in gas by switching of 30 nF capacitor bank into gas load in 210 mm long alumina capillary at voltage up to 80 kV. The capillary current pulse is measured by Rogowski coil and at 80 kV charging voltage its maximum is 10 kA, half period is 170 ns and rise time is 60 ns.

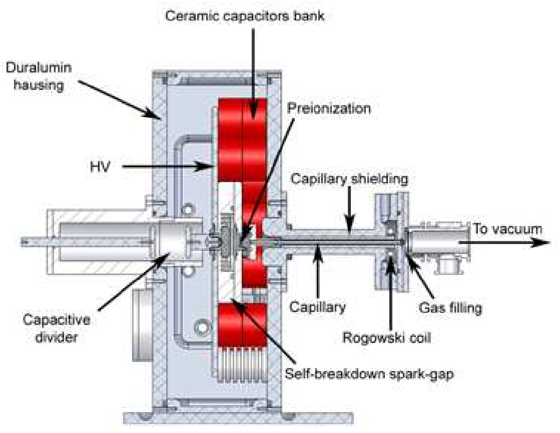

Fig 1. Capillary discharge source

Experimental arrangement

Although the larger vacuum chamber (see Fig. 2, 3) offers space for vacuum optical test bench with more electronically controlled positioners and detectors, we chose arrangement with a CCD camera outside and the scintillator or PMMA photoresist inside the vacuum chamber. The experimental arrangement with the new vacuum chamber is shown in Fig 4.

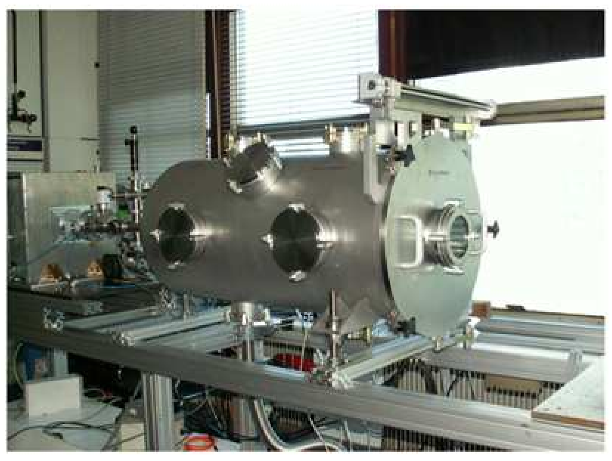

Fig 2. The new vacuum chamber

Fig 3. View into the new vacuum chamber

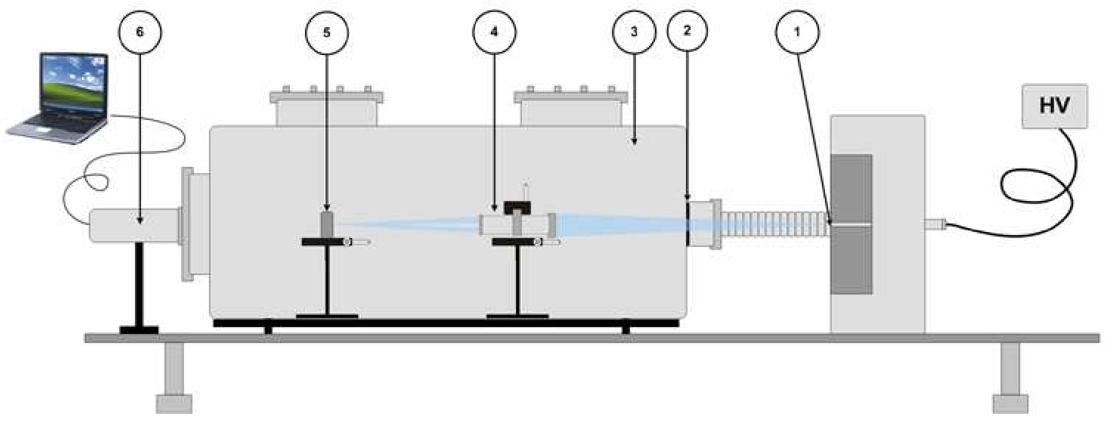

Fig 4. Experimental arrangement (1. Alumina capillary, length 210 mm, diameter 3.2 mm, + aperture with diameter 1 mm, Nitrogen, voltage up to 80 kV; 2. 400 μm Aluminum filter; 3. vacuum chamber; 4. ellipsoidal EUV optics, gold reflection layer, diameter 22/20 mm, length 124 mm; 5. scintillator or PMMA photoresist; 6. camera)

The experiment set-up is shown in Fig 5. Transmition of the filter used in experiment is shown in Fig 6. Pre-alignment of the optics was done in visible part of spectrum with no VIS blocking filter in optical path.

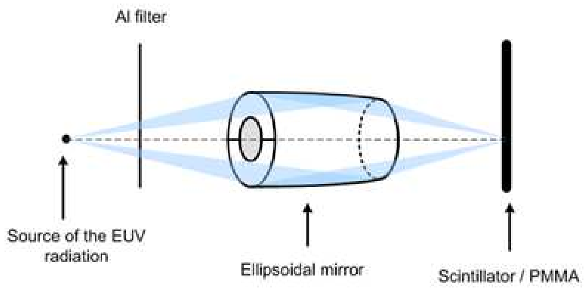

Fig 5. Experimental set-up with on-axis configuration

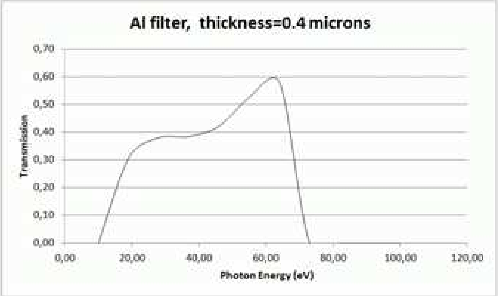

Fig 6. Transmission of the Al filter (0.4 μm) [2]

Experimental results

Obtained focal spot is shown in Fig. 8 (EUV camera). Focal spot size is 220 μm FWHM.
These values are in agreement with rough estimation based on approximate source size and optic demagnification factor.

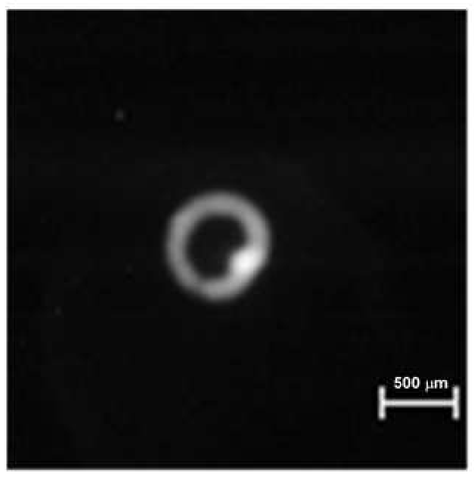

Fig 7. Slightly out of focus

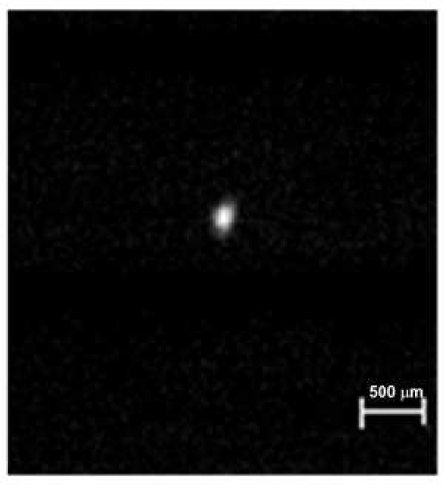

Fig 8. In focus

Focused beam created imprints in the PMMA photoresist. Optical microscope image of edge between iradiated and non iradiated parts of photoresist is in Fig. 9.

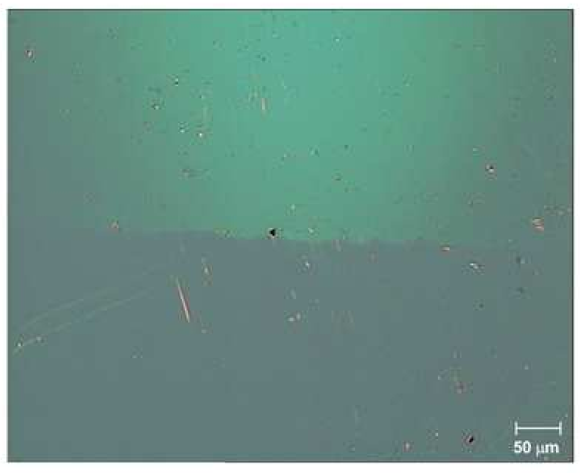

Fig 9. Edge between iradiated and non iradiated parts of photoresist

The number of photons incident on the scintillator / PMMA in one shot is obtained by knowing the number of photons going from the source [1]. Taking into account filter transmisivity, the number of photons hitting the optics and the mirror reflectivity we obtained the number of 10^8 photons in focal spot. This equals 37 $\mu J.cm^{-2}$ in one shot.

Conclusion

Compact capillary discharge source combined with rotationally symmetric ellipsoidal mirror in on-axis geometry gives high intensity in submilimeter focal spot. Useful results with focusing on the PMMA layer were obtained. These results shown that used setup is promising for laboratory EUV lithography and microscopy experiments.

References

[1] KOLÁŘ, P. *Spektrální vlastnosti plazmatických zdrojů EUV a XUV záření: Diploma thesis*. Kladno, 2010.
[2] *CXRO The Center for X-Ray Optics* [online]. 2010. Available from WWW: <http://www.cxro.lbl.gov>.

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