EUV ablation experiments with gas-puff and capillary discharge sources

L. Pina[2] C. Liberatore[1,2] , A. Bartnik[3], K. Mann[4], A. Endo[1] , T. Mocek[1] L. Juha[1]

[1]Institute of Physics ASCR, Prague, Czech Republic, [2]Czech Technical University, Prague, Czech Republic, [3]Institute of Opics and Electronics, Warszaw, Poland, [4]Laser Laboratorium Göttingen (LLG), Göttingen, Germany

Abstract

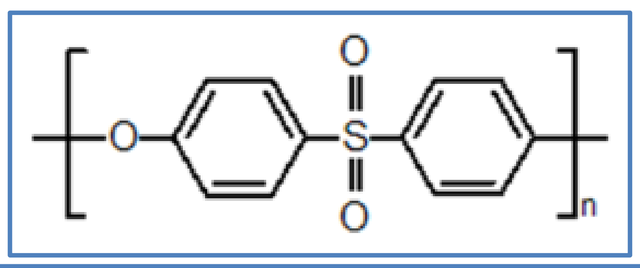
Three different EUV laboratory sources working at different wavelength were used for ablation experiments. PPEES polymer was studied as a potential material for EUV ablative micro/nano structuring.

Ablation mechanism

Ablation of polymer materials is initiated by photo-induced polymer chain scissions. The ablation occurs due to forming volatile products in the polymer EUV radiolysis released from the irradiated surface into the vacuum. In general, a cross-linking of polymer molecules can compete with the chain decomposition.

Target

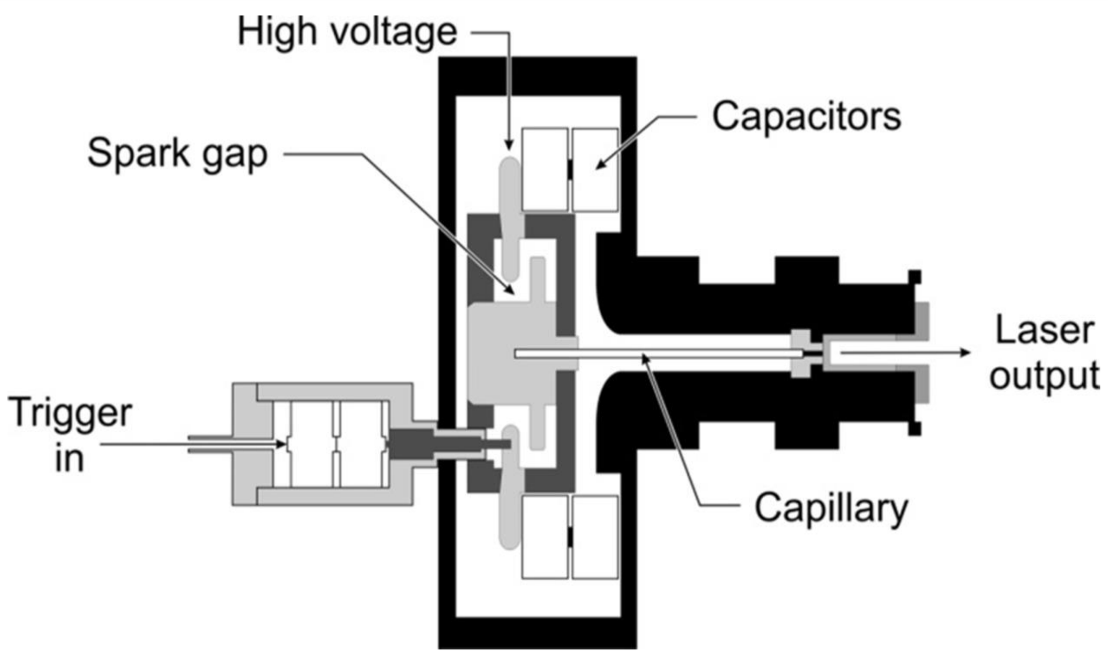
The target used during the experiment is Poly(1,4-phenylene ether ether-sulfone).



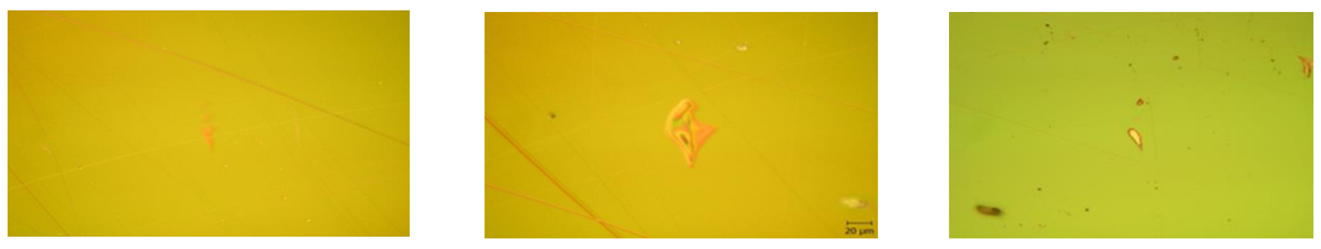
Capillary Discharche Laser at CTU Prague (from prof. J.J. Rocca, CU, USA)

characteristics:

Dimensions: 0.4 x 0.4 m2 (0.4 x 0.8 m2 with TM pump)
Weight: 400 kg
Wavelength: 46.9 nm
Pulse length: 1.5 ns (FWHM)
Pulse energy: > 10 mJ
Repetition rate: 5 Hz – typical, 12 Hz – maximum
Capillary lifetime: (2-3) x 104 pulses
Current: ~21 kA
Capillary: Al2O3 (inner diameter: 3.2 mm, length 210 mm), Ar filled (50 Pa)



CDD Laser at CAS: results for 1-10-100 shots

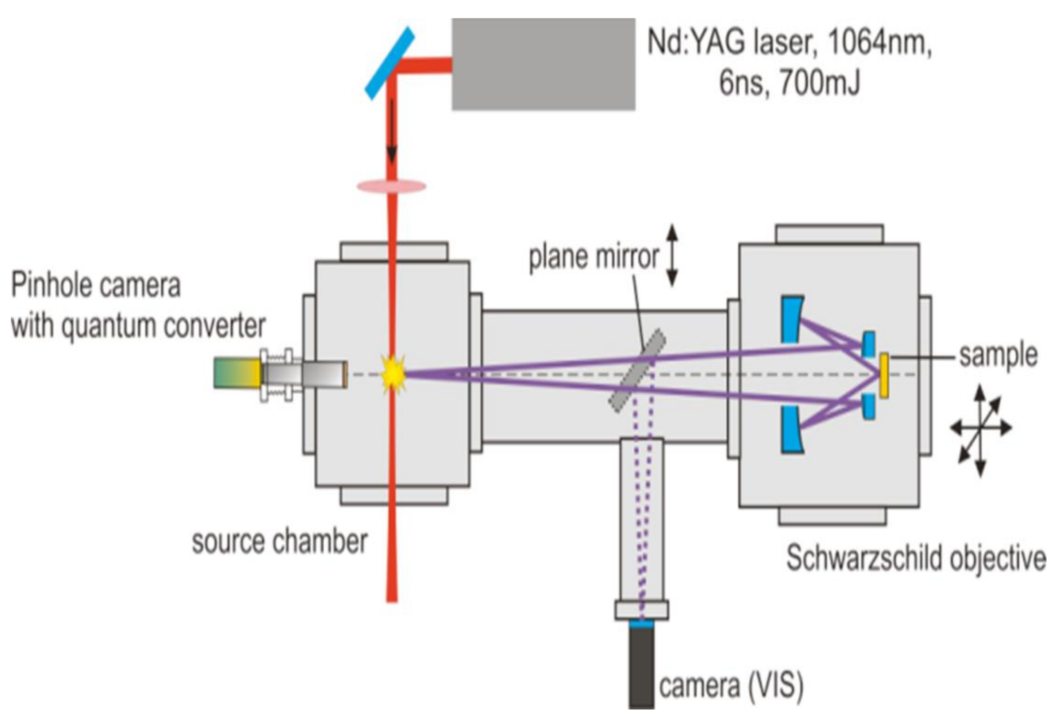


Gas-puff source at LLG

Fluence: 127 mJ/cm2
A new laser (1.2J) replaced the old one to increase the fluence
A new Schwarzschild optics was inserted in the system.
Characteristic:

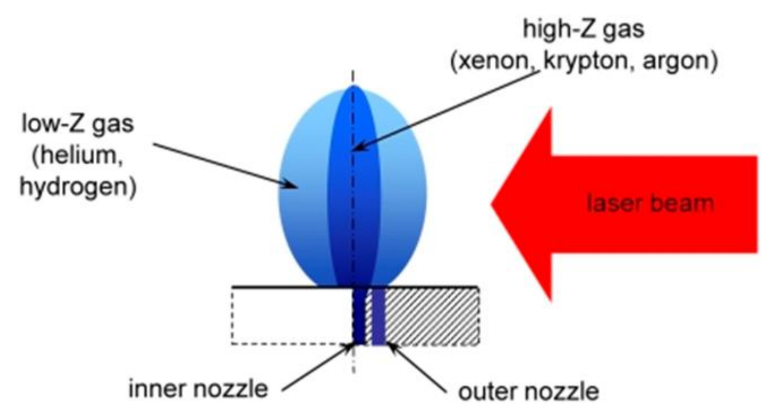
- Modified design
- Mo/Si multilayer coating
- Peak wavelength 13.5nm (± 2%BW)
- Imaging of plasma
- Micro-focus with high EUV fluence

Xenon target



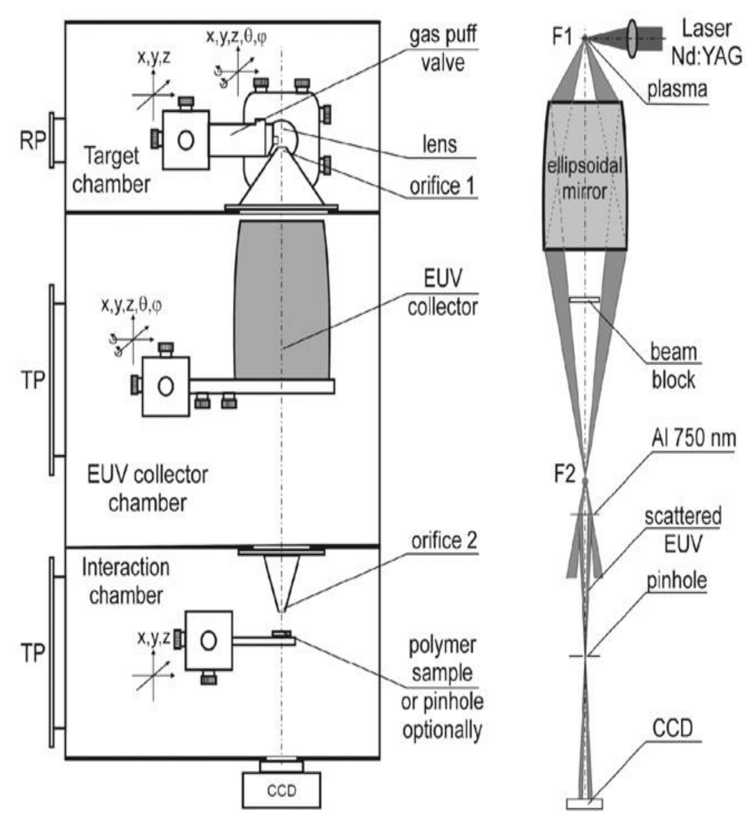
Double stream Gas-puff source at WAT

EUV wavelength max 11.8
Pressure KrXe 7bar He 5bar
Fluence 50 mJ/ cm²



Double stream gas puff target plasma source

Advantages:
✓ no debris from gaseous targets
✓ compact construction, high repeatability
✓ high conversion efficiency, very robus – thousands of shots/day

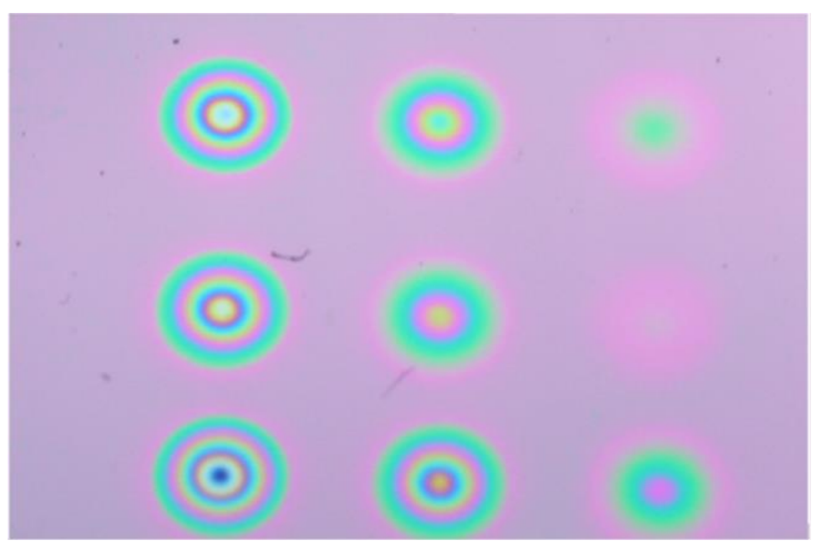


Ablation test on PPEES gave no positive results at LLG. This can be explained, with respect to the results obtained in Prague, considering that for PPEES, which has a density of about 1.24 g/cm³ and the following elemental composition C18SO4H12, the attenuation lengths at a wavelength of 13.5 nm (photon energy: 91.8 eV) is 215 nm. The attenuation length at a wavelength of 46.9 nm (photon energy: 26.4 eV) is approx. 20 nm.

So, there is at least one order of magnitude higher energy density in PPEES near-surface region when irradiated at 46.9 nm than in the case of irradiating the material at 13.5 nm at the same surface energy density. Positive results at WAT are due to polychromaticity of used optics resulting in higher fluence.

- *at 46.9 nm the ablation threshold should be much lower than at 13.5 nm;*
- *during the exposure at 13.5 nm, the near surface region is not so "overexposed/overheated" as in the previous case (at 46.9 nm), so that single-photon radiolytical processes would play an important role in material ablation, causing the difference in radiation stability of PPEES and PMMA.*

WAT Results

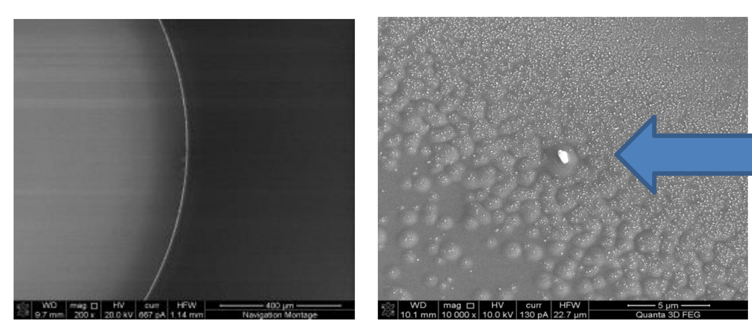


Number of shots:

30	15	5
40	20	1
50	25	10

The rings may be due to Fresnel effect

In the inner circle it is possible to see the damaged silicon substrate



Some conical structures are visible on the target. They can be caused by the coating or they can be EUV microstructures

Conclusion

Ablation was obtained in Prague and in Warsaw's laboratories.

Some conditions are convenient to obtain EUV ablation:

- Non monocromacity;
- Long wavelength;
- High fluence;
- High density target (to create the plasma).

Acknowledgment

The experiments were funded by financial support from EU COST MPO1203, from the Ministry of Education, Youth and Sports, COST CZ VES14 LD14032, HiLASE (CZ.1.05/2.1.00/ 01.0027) and DPSSLasers (CZ.1.07/2.3.00/ 20.0143), from the European Regional Development Fund, RVO 68407700 and from the "Deutsche Forschungsgemeinschaft" within the Sonderforschungsbereich 755 "Nanoscale Photonic Imaging".