Debris shield effect on mitigation of discharge debris

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Objective

- Observation of the EUV energy of the high repetition rate.
- Investigation about the decrease of reflectance of Mo/Si multilayer mirror by the discharge debris

EUV Sources

13.5-nm EUV source for next generation lithography

✓High power operation
- 2004, 2Q: 4 W
- 2006, 1Q: 10 W
- 2007 : 30 - 50 W

EUVA project (2004, 2Q and 2006, 1Q)

✓Long lifetime of the EUV source system
- electrodes
- optics

(7 kHz, 12 h, 20 days → 10^9 shots)

The *short* lifetime of an optical system by the discharge debris

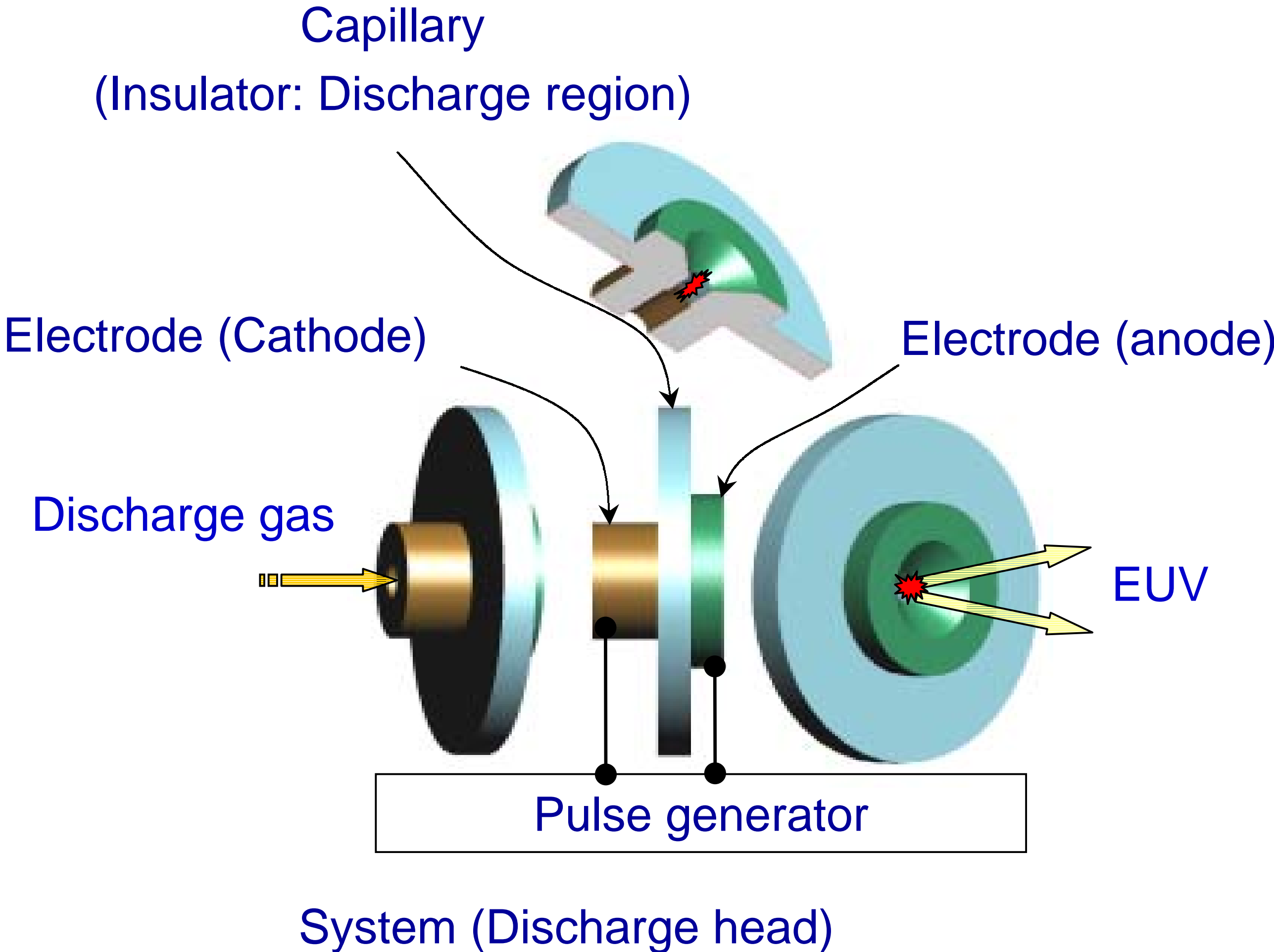
~Debris~

✓Electrodes, insulator

✓Discharge gas

→ Contamination
Erosion

System of DPP EUV Source



System (Discharge head)

Waveform of EUV Emission and Spectrum

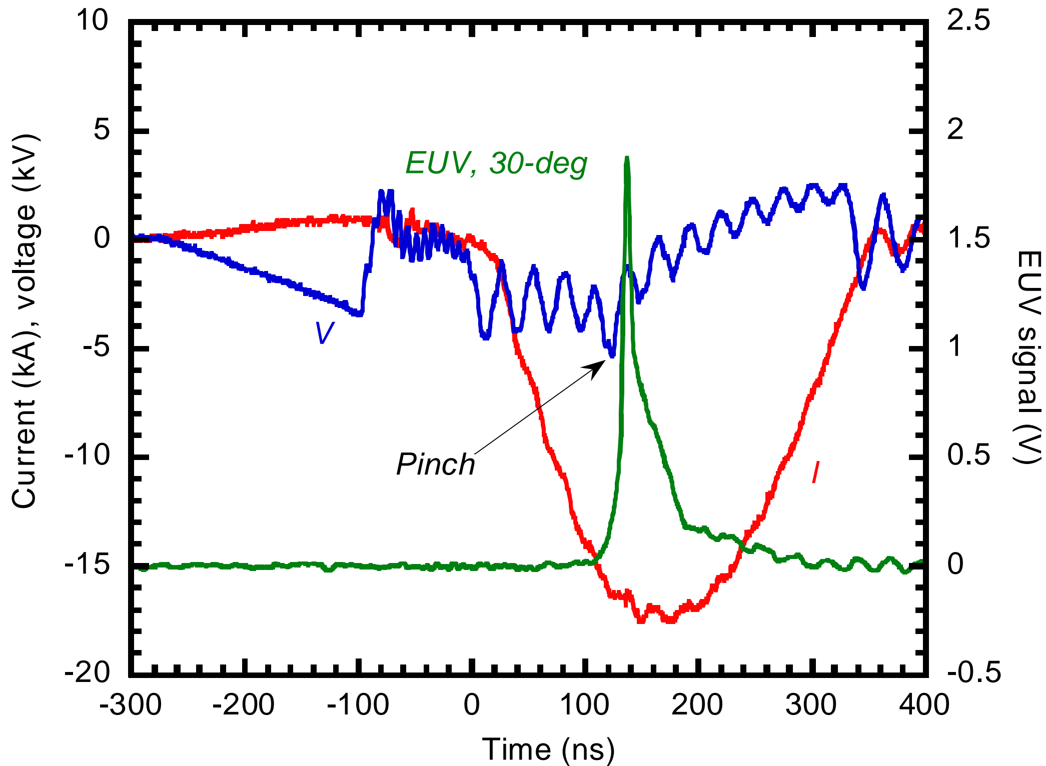


Fig. Time history of EUV emission, discharge current and voltage

2% BW: for EUV litho.

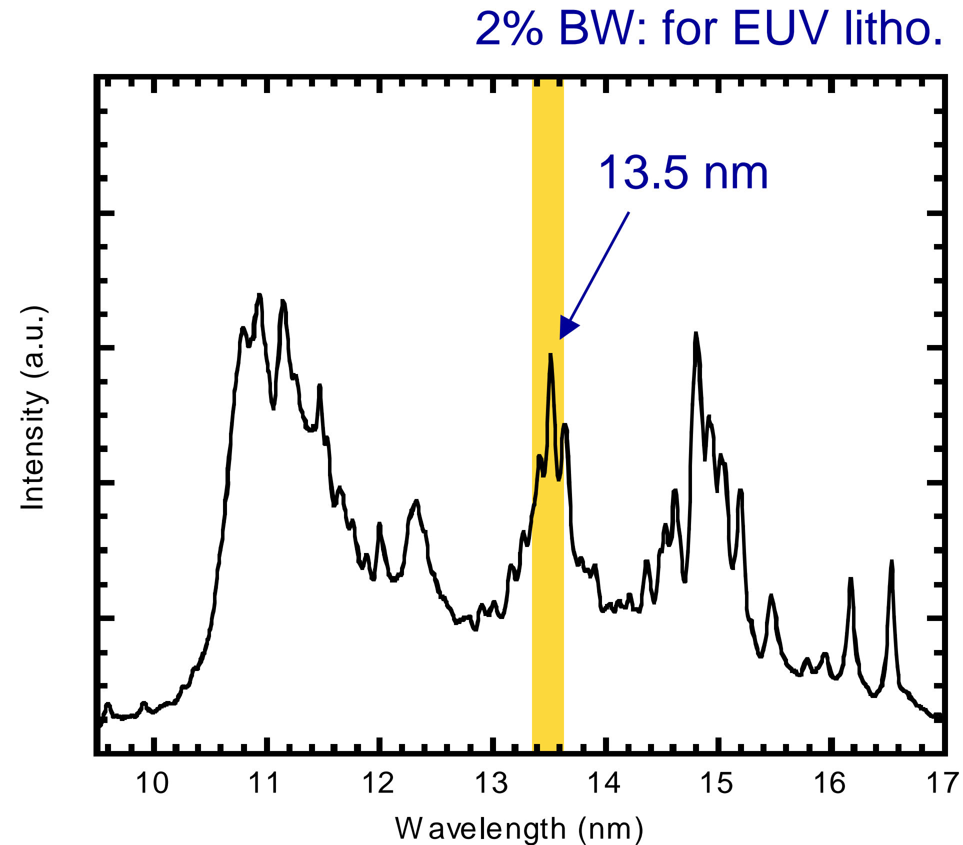
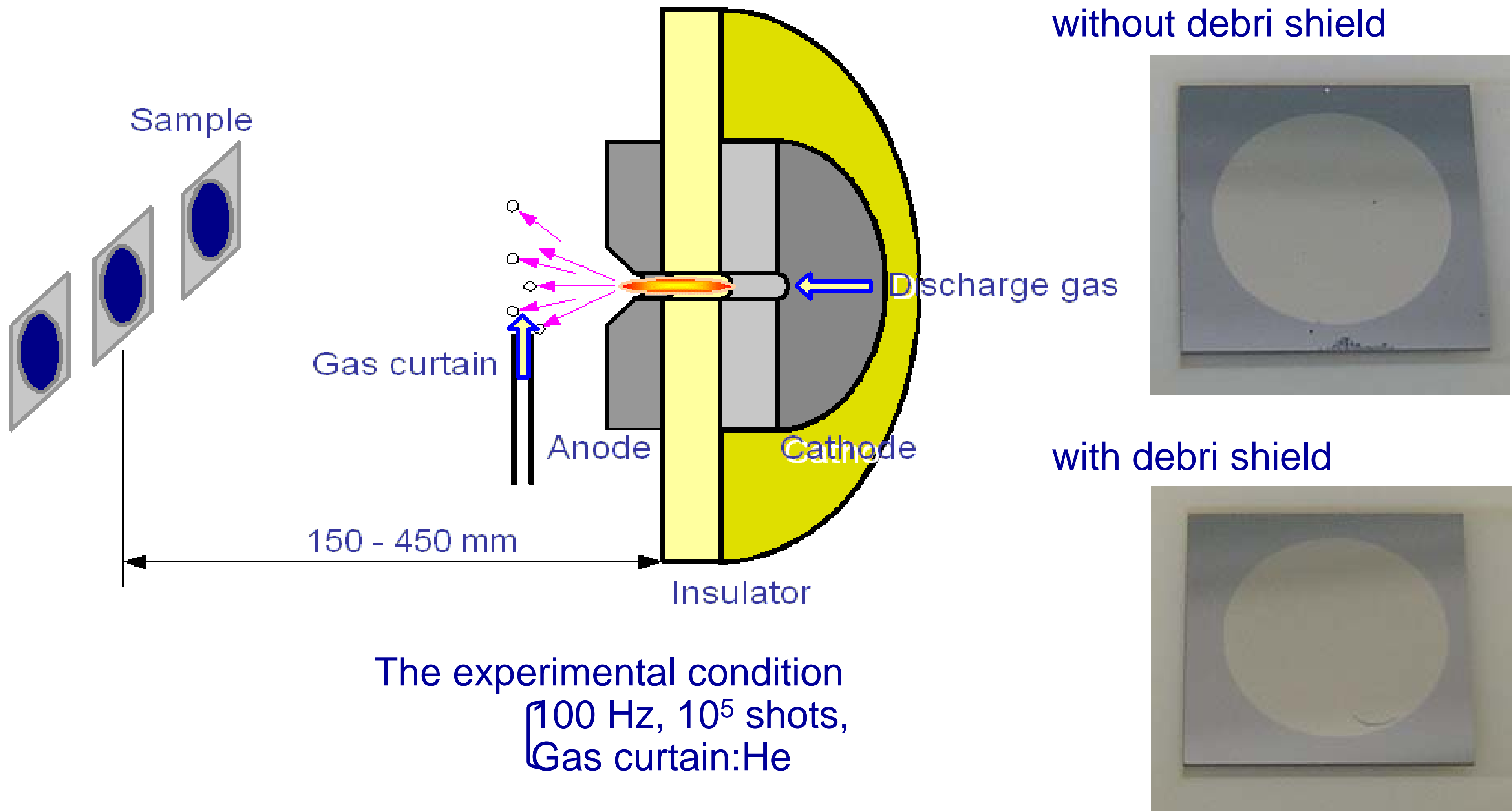


Fig. EUV spectrum

Output of EUV Emission

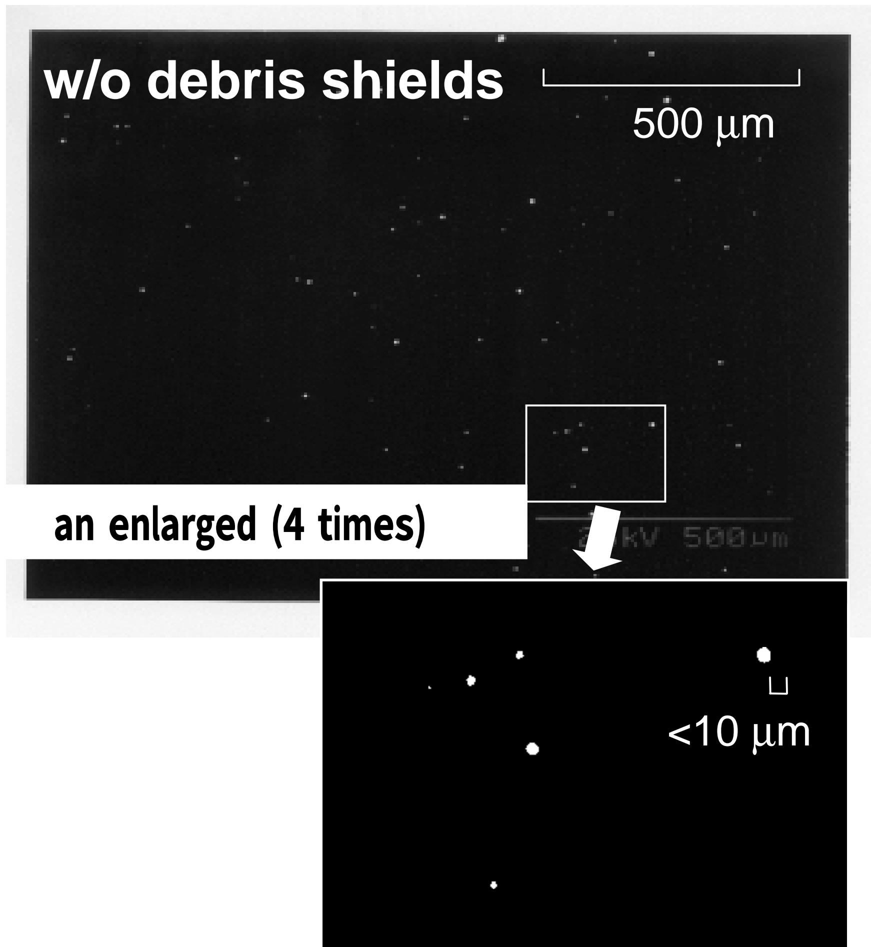
	Apr. 2003	Sep. 2003	May. 2004
In-band (2%BW) power from primary source	6.3 W/2.1 sr (19 W/2π sr)	9.7 W/1.55 sr (39 W/2π sr)	*12.6 W/1.45 sr* *(55 W/2π sr)*
EUV conversion efficiency (for dissipated power)	---	1.97 %/2π sr	*0.83%/2π sr*
Dissipated power in discharge head	---	2 kW	*6.5 kW*
EUV dose stability (1σ, 50-pulse ave.)	1.3%	2.1%	*1.1%*
Angular distribution stability (1σ)	---	---	*8.2%*
Demonstrated maximum repetition rate	2 kHz	2 kHz	7 kHz

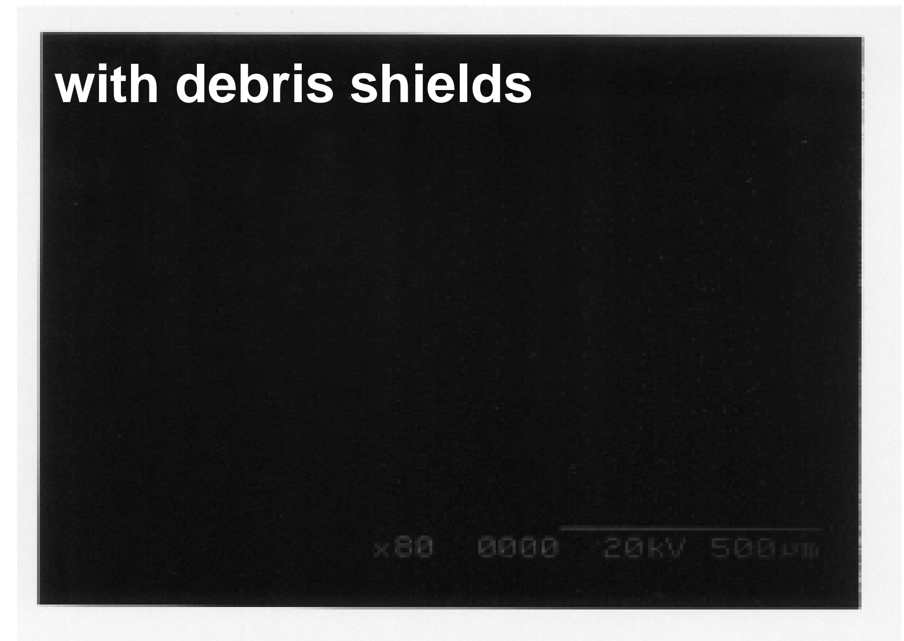
Analysis of the Discharge Debris



Debris Removal with Shields

Experimental conditions:distance from discharge to sample:450 mm, 100 Hz, 10^5 shots





The number of debris

debris shields	w/o	with
+10 μm	0	0
-10 μm	**71**	0

Reflectance of Mo/Si Multilayer Mirror

EUV energy (mJ/sr@13.5 nm,2%BW)

5
4.5
4
3.5
3
2.5
2
1.5

Before
After

decrease by 16%

Exposed mirror

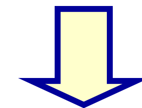
0
10
20
30
40
50

Angle (deg)

Fig. Angle distribution of EUV energy

Exposed conditions:

Distance from EUV source to the sample mirror: 160 mm
2 kHz, 0.5 sec, 10^4 shots

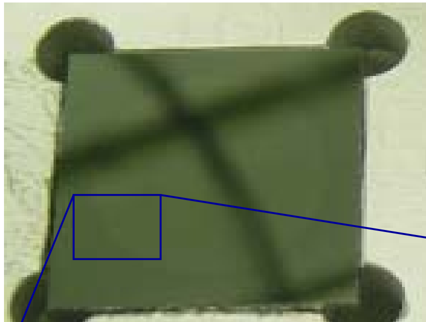


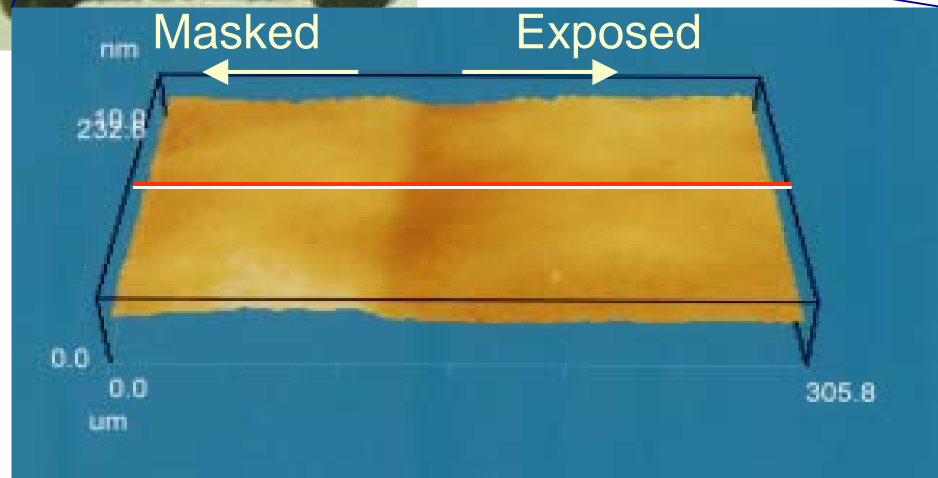
(R = 68.7%→57.9%@13.5 nm)

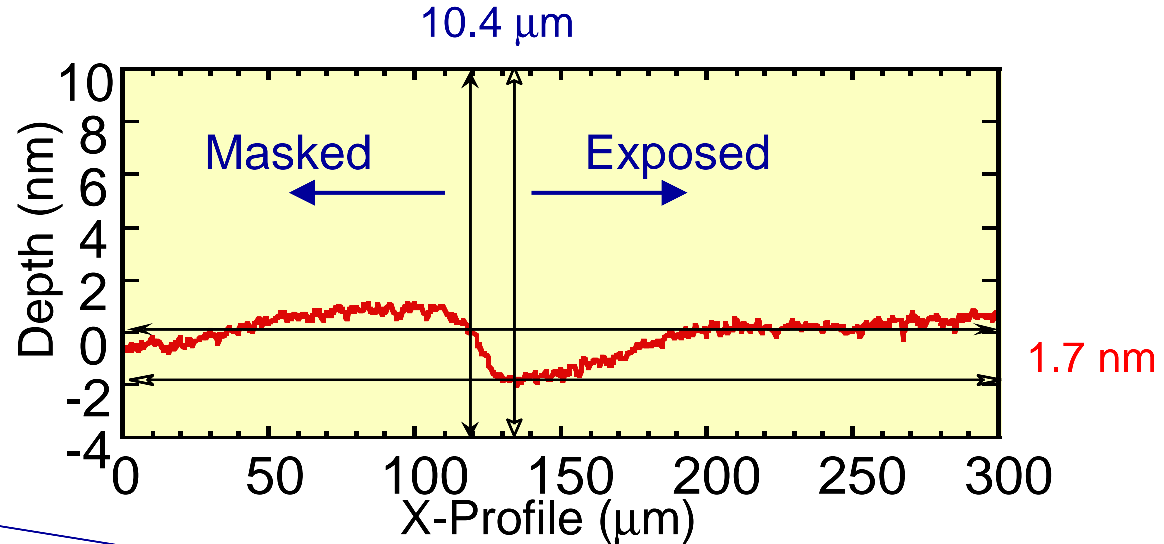
Mo/Si Multilayer Mirror Surface Roughness

Surface measurement system (WYKO NT-2000)

2 kHz, 0.5s 10^4 shots







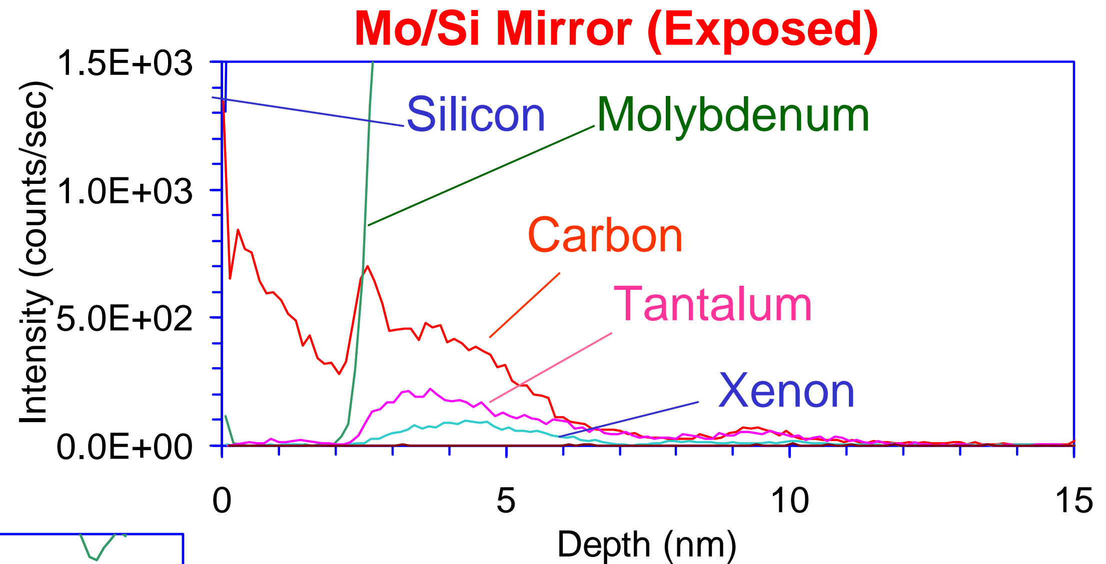
(nm)	Masked	Boundary	Exposed
Rs	0.5	0.4	0.4

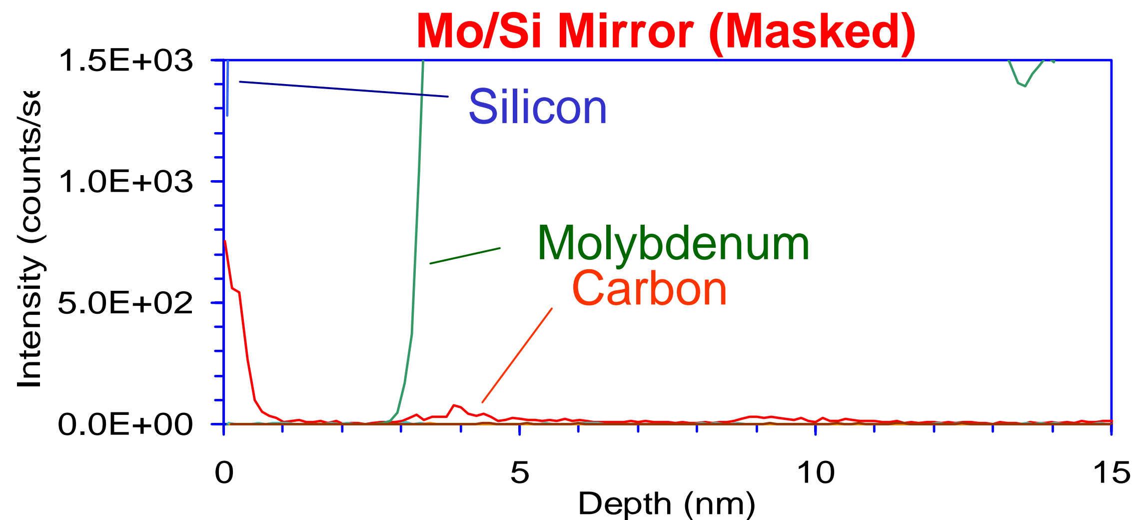
analysis using the AFM

(nm)	Masked	Exposed
Rs	0.21	0.10

Depth Profiling of Mo/Si Multilayer Mirror

- **Discharge gas：Xe**
- **Electrodes：Ta**
- **Insulator：SiC**
- **Sample：Mo/Si multilayer mirror**





Damage of mirror: Ta, Xe, C
(Faster ion or atom)

Summary

- The EUV energy was stabled at the high repetition rates.

- The debris was removed by the debris shields (foil trap and gas curtain).
  - ✓ Blowing debris off with the gas curtain
    (the debris are bent in the angle of 3 degrees or more by using gas curtain, and can be caught by the foil trap)
  - ✓ Decrease of mean free path by increased pressure in the chamber ($l \propto 1/P$)

- The reflectance of Mo/Si multilayer mirror was decreased.
  (68.7%→57.9%@13.5 nm)
  - ✓ Erosion of Mo/Si multilayer mirror (by Ta, W, Xe)
    → Mo/Si layer was damaged by debris