Contamination Removal of EUVL masks and optics using 13.5-nm and 172-nm radiation

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IEUVI Resist & Contamination TWG Oct.19, 2006 in Barcelona

Method of contamination removal

(1) Cleaning of EUVL imaging optics

(The optics used for EUVL has been aligned in high accuracy. So the cleaning of imaging optics requires in-situ process.)

⇒ In-situ contamination removal by synchrotron radiation without heating

(2) Cleaning of EUVL masks

(Both large cleaning area and high speed are required.)

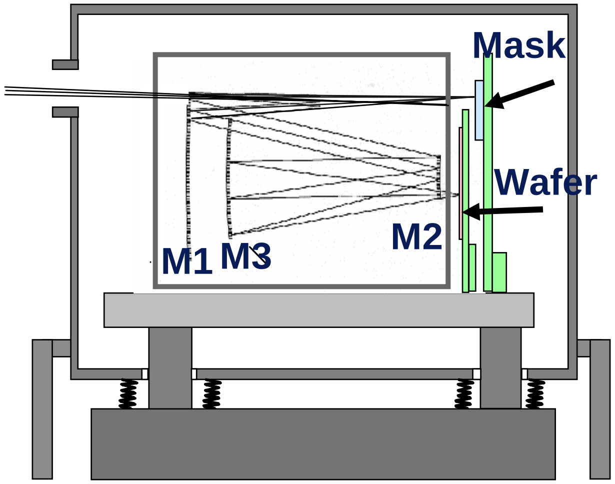
⇒ Contamination removal by 172-nm-wavelength.

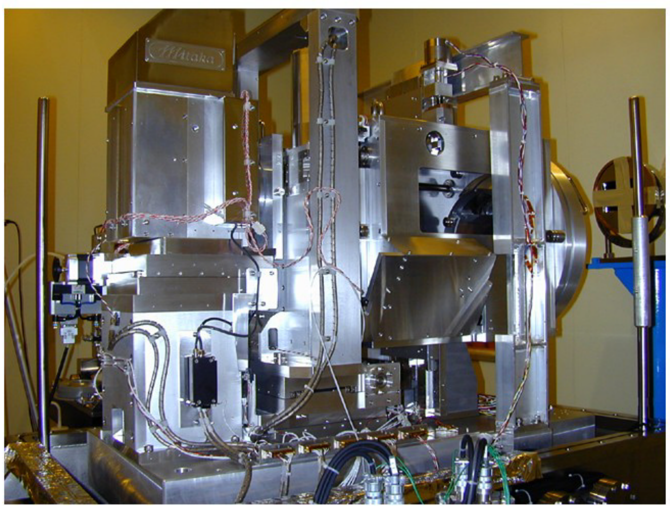
Evaluation between before and after removal

- Contamination thickness → Optical thickness measuring system
- Surface roughness → AFM
- Reflectivity → Reflectometer (NewSUBARU BL-10)

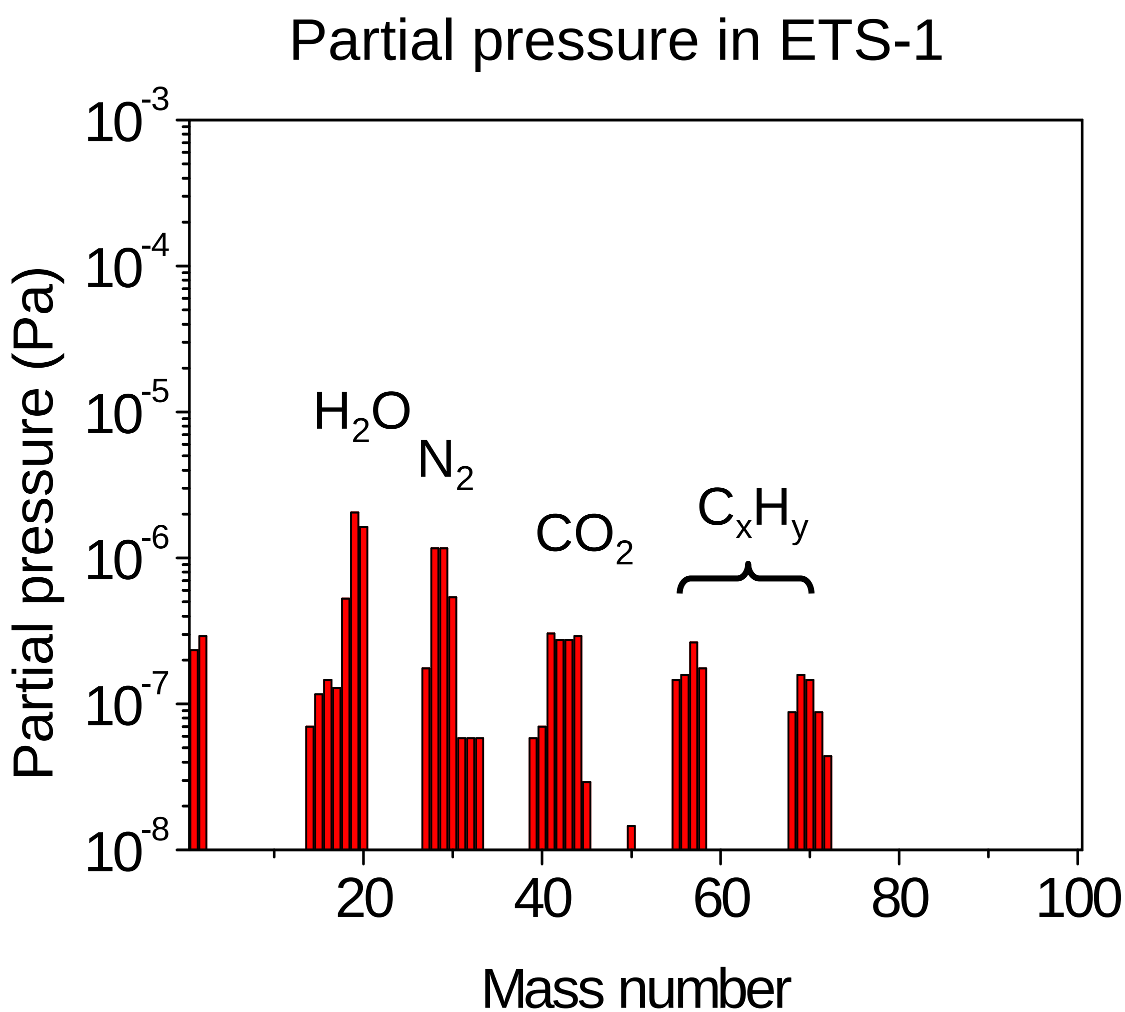
Online contamination removal by a wavelength of 13.5 nm

Contamination adhesion in ETS-1 exposure system



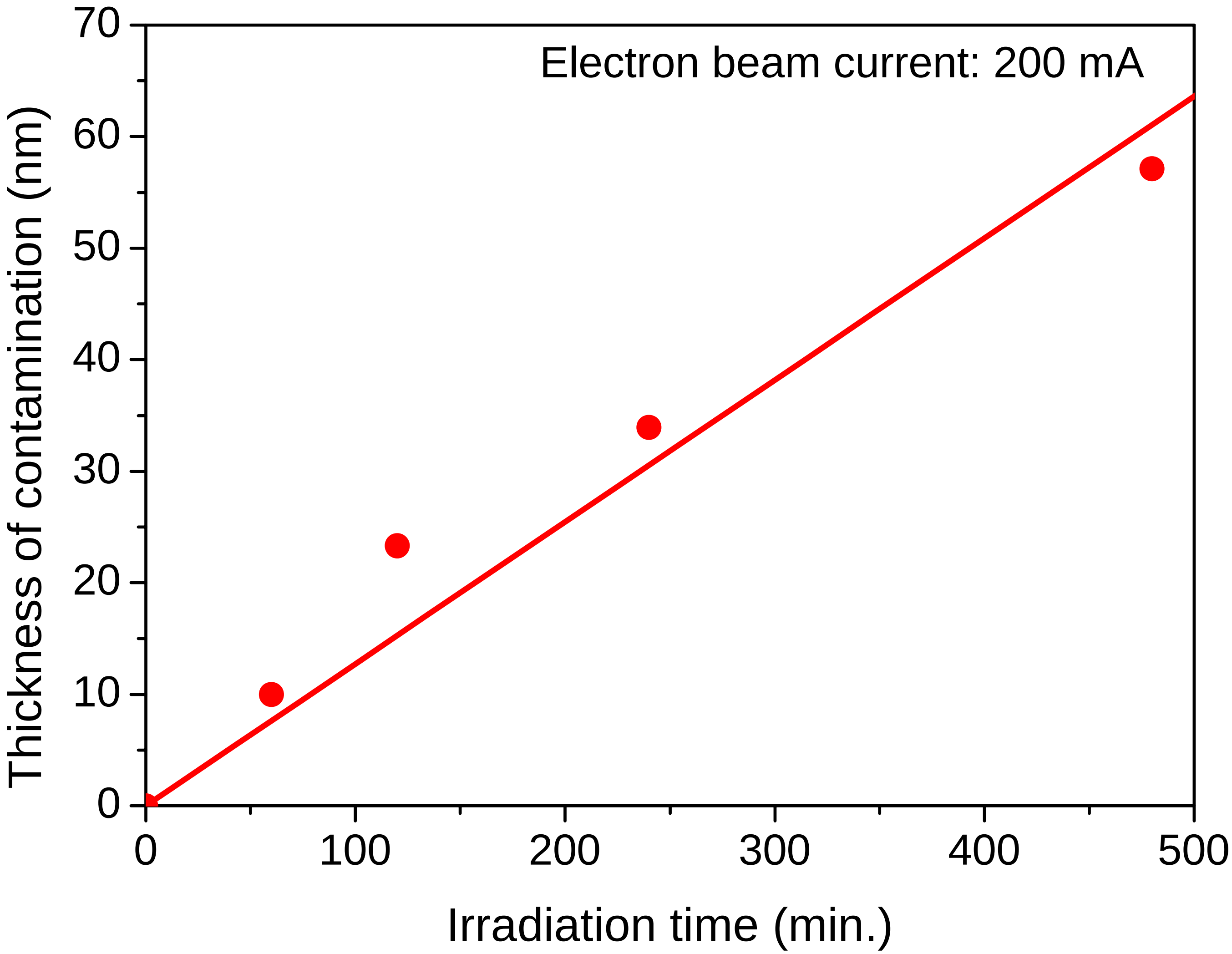


Sample of the multilayer is set on the mask stage, and EUV is irradiated.



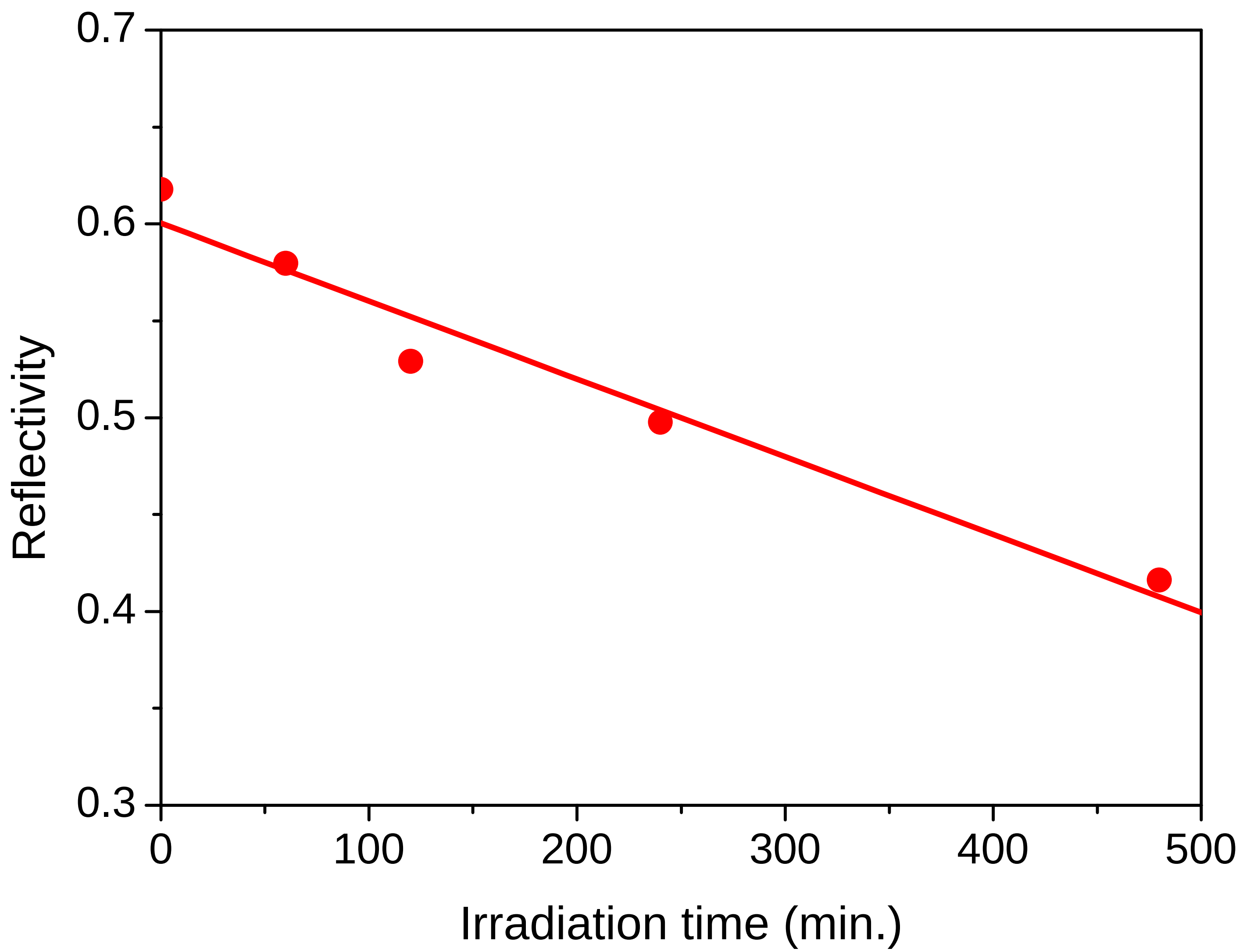
Total pressure: 1×10^{-5} Pa

Thickness of contamination



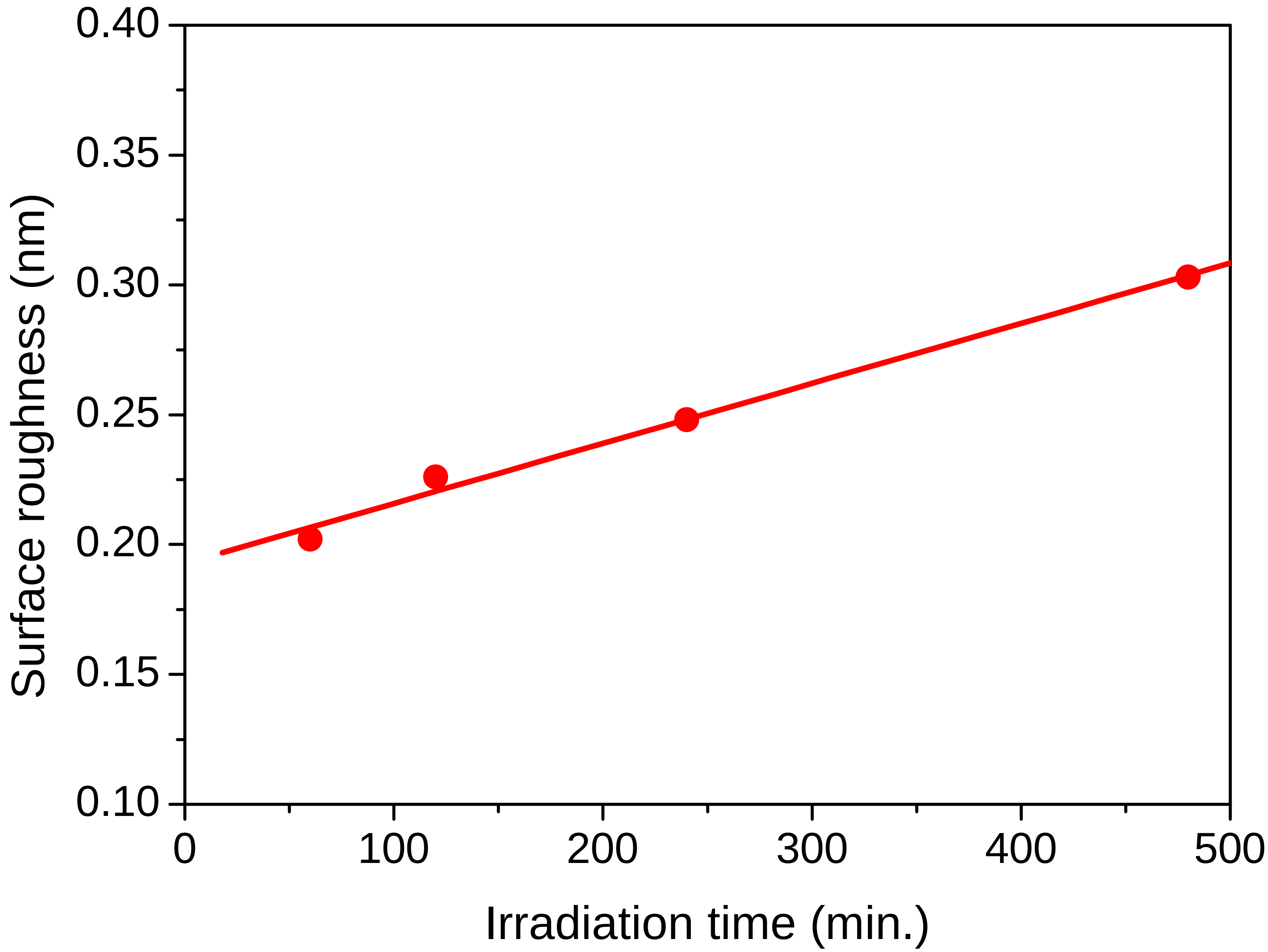
Deposition rate: 7.5 nm/hr (0.125 nm/min)

Reflectivity of multilayer

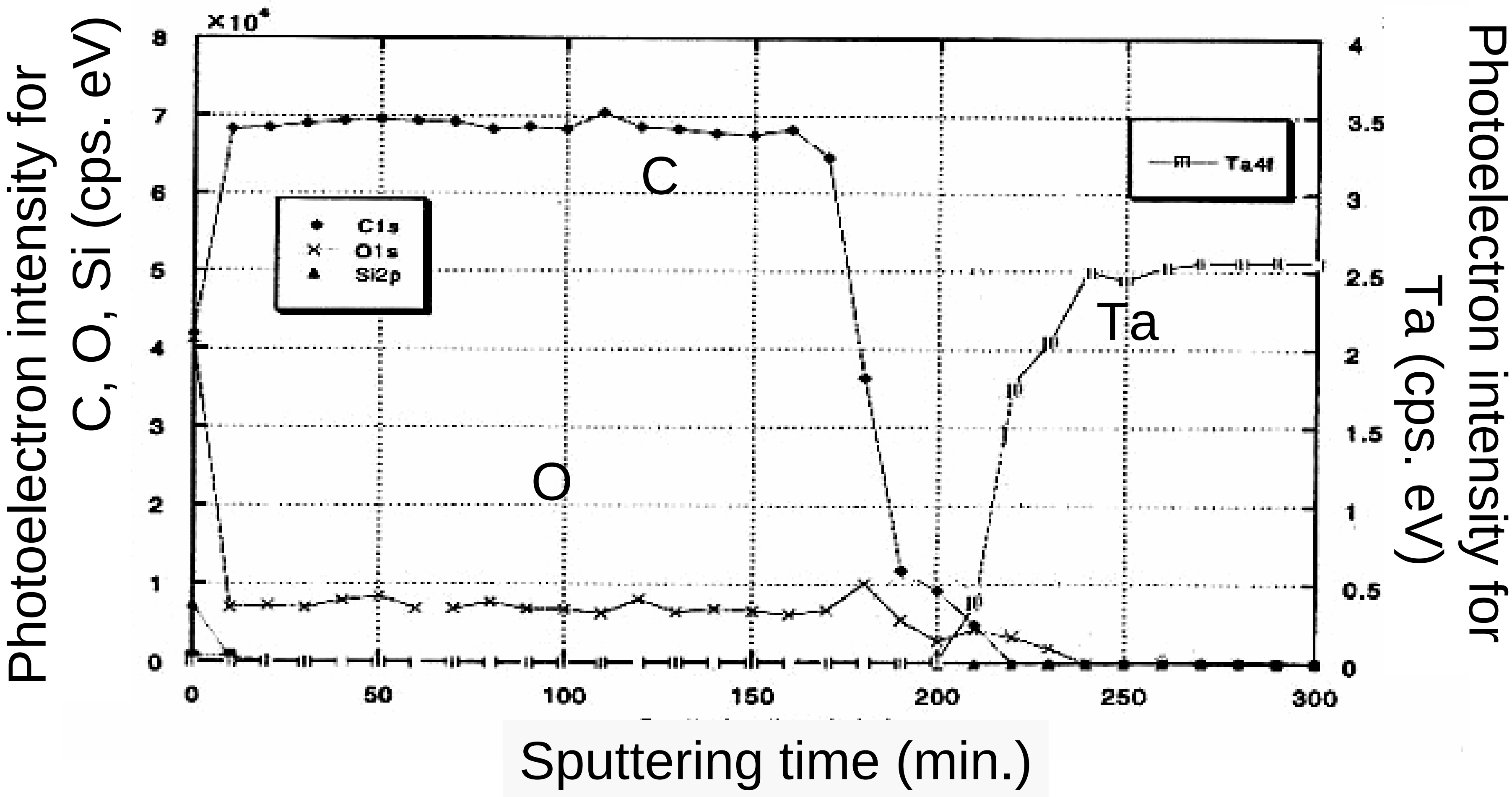


Multilayer reflectivity of 10% decreased
by 4 hours irradiation

Surface roughness of multilayer

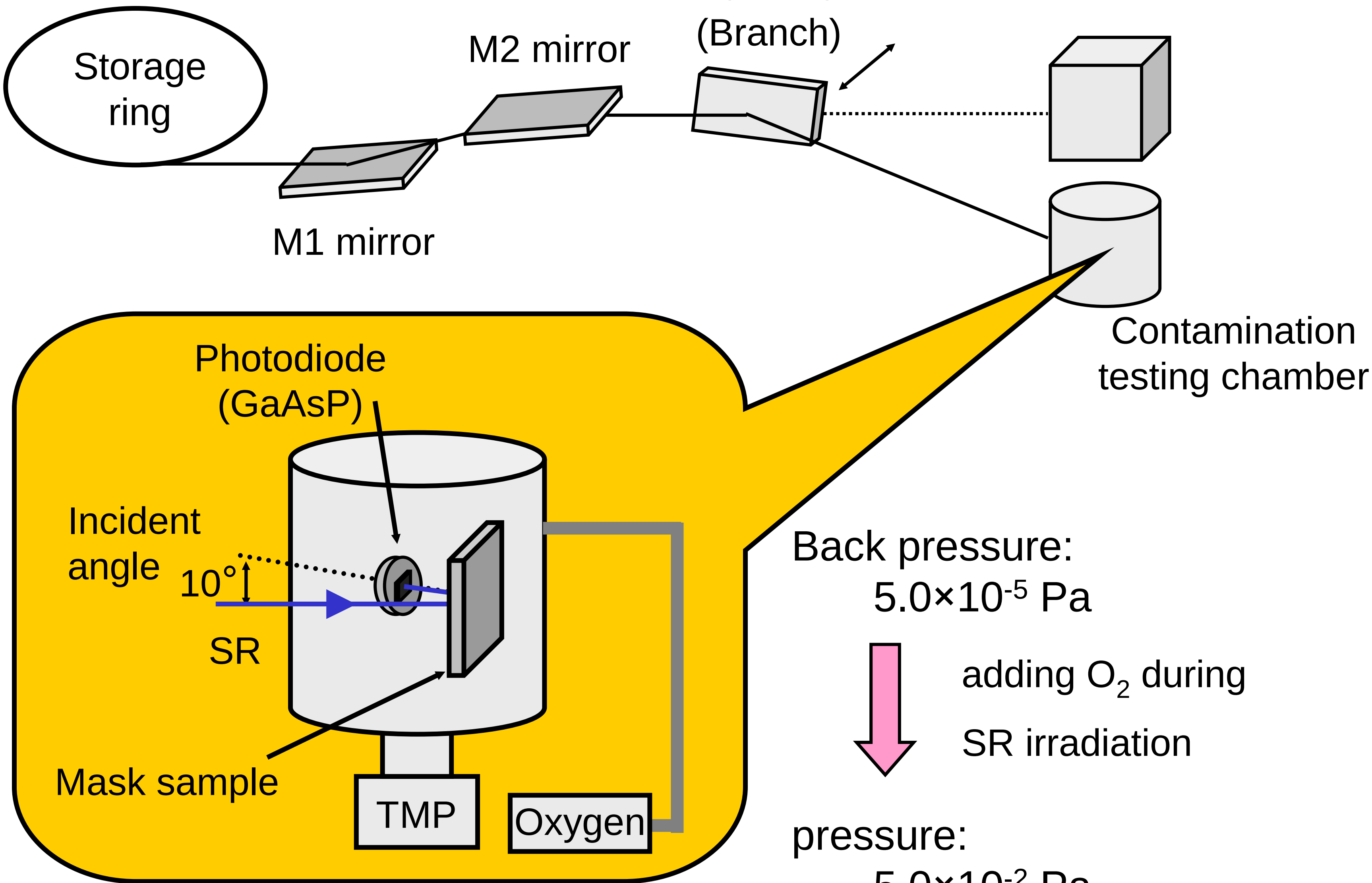


AES spectrum of contamination of mask



The ratio of C to O is 96:4

Experimental setup of SR cleaning

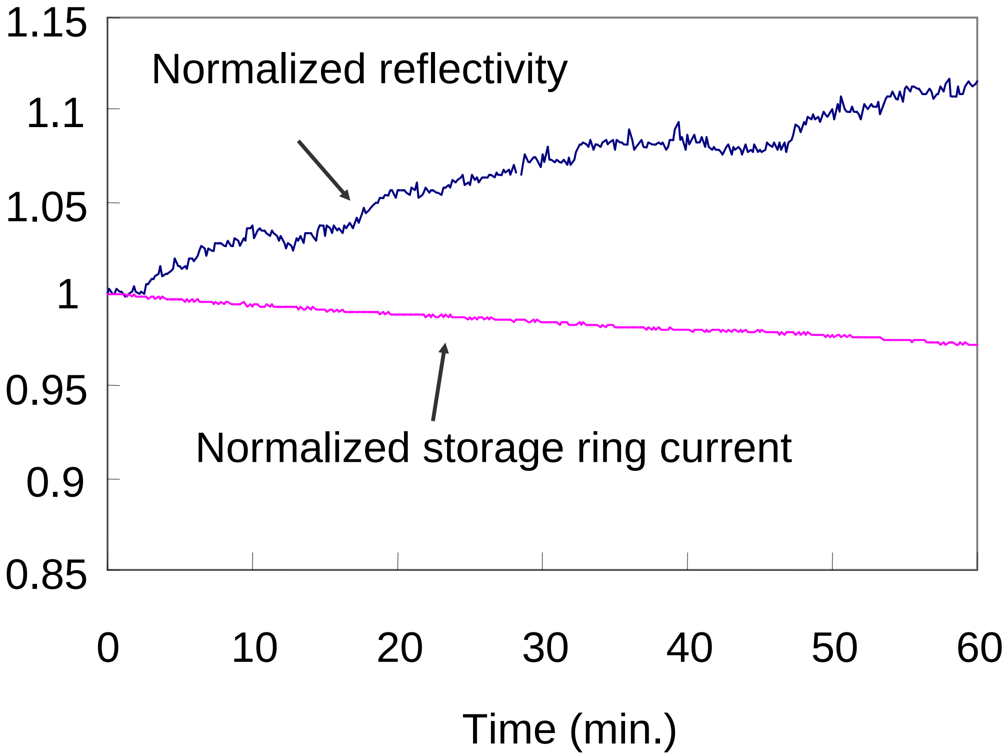


Back pressure:
5.0×10^{-5} Pa

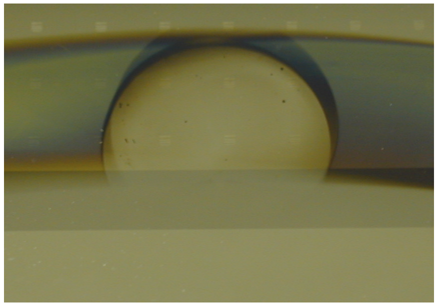
adding O_2 during SR irradiation

pressure:
5.0×10^{-2} Pa

Experimental results



Before cleaning



After cleaning

Pressure: 5.0×10^{-2} Pa

Electron beam current: 130 mA

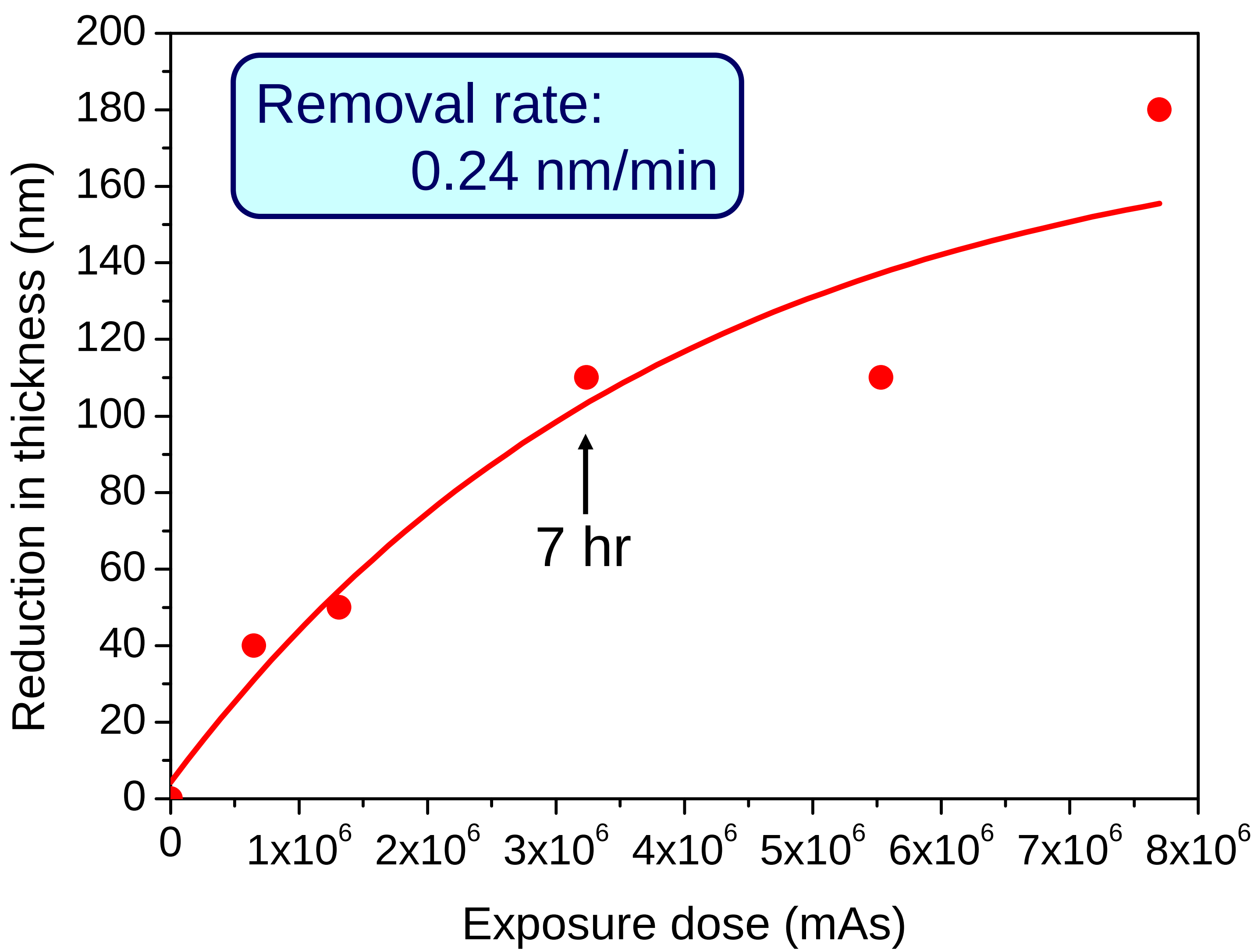
Irradiation: 7 hr

⇩

Contamination of 0.1-μm-thick was removed.

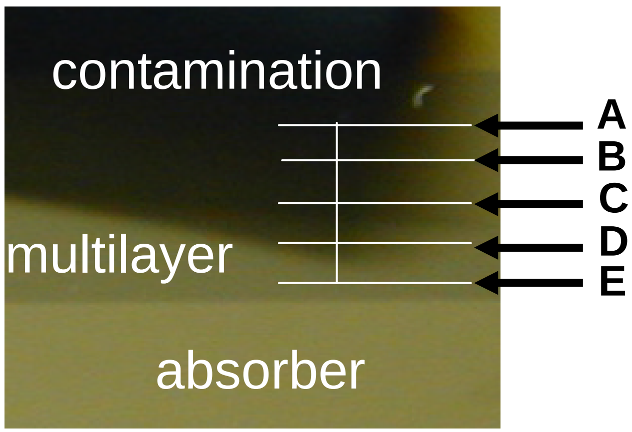
Reduction of contamination thickness

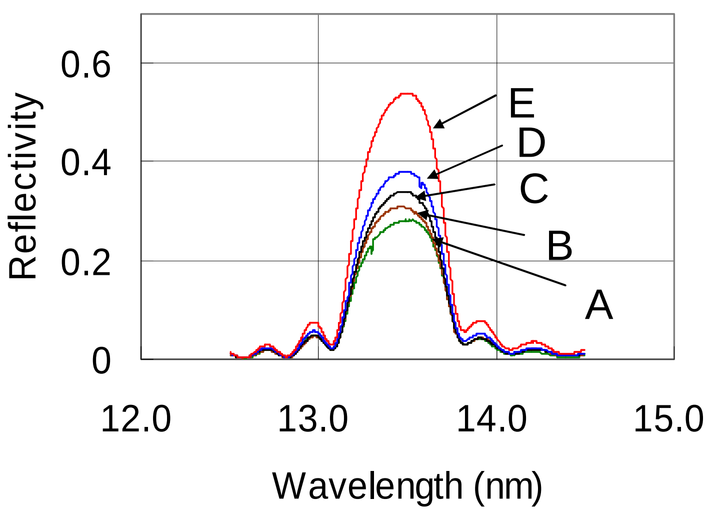
Electron beam current: 130 mA



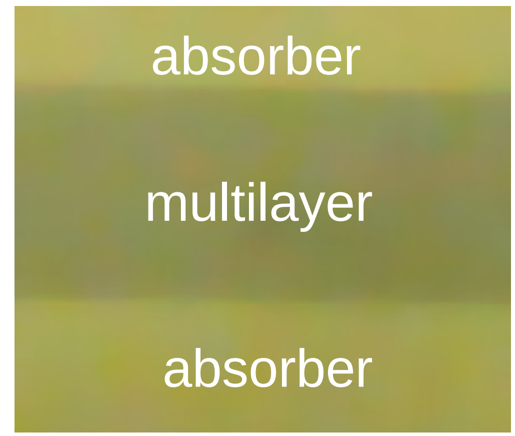
Reflectivity of multilayer (measurement: NS-BL10)

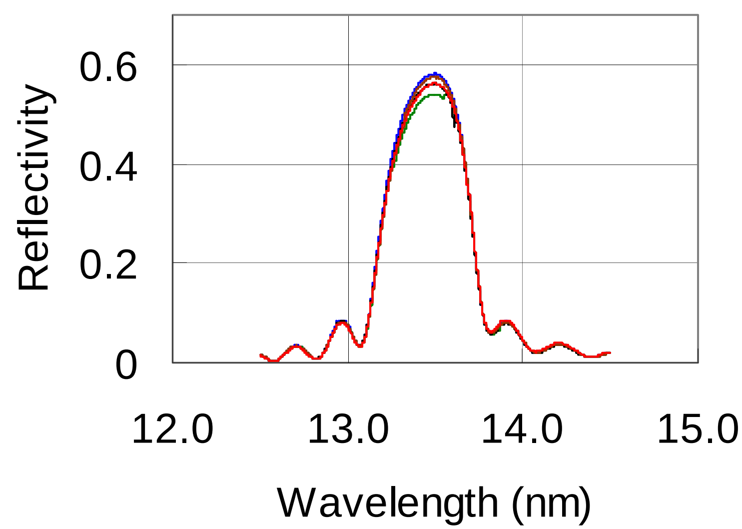
Before cleaning





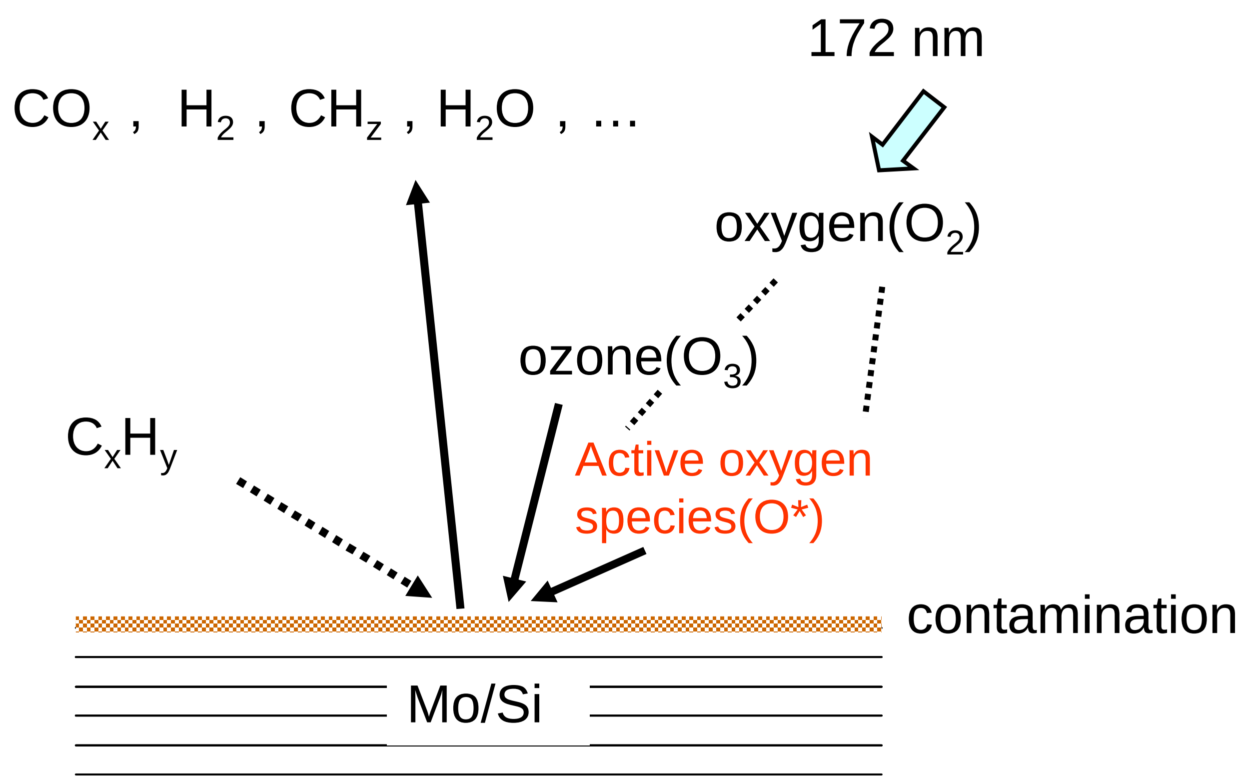
After cleaning





Offline contamination removal by a wavelength of 172 nm

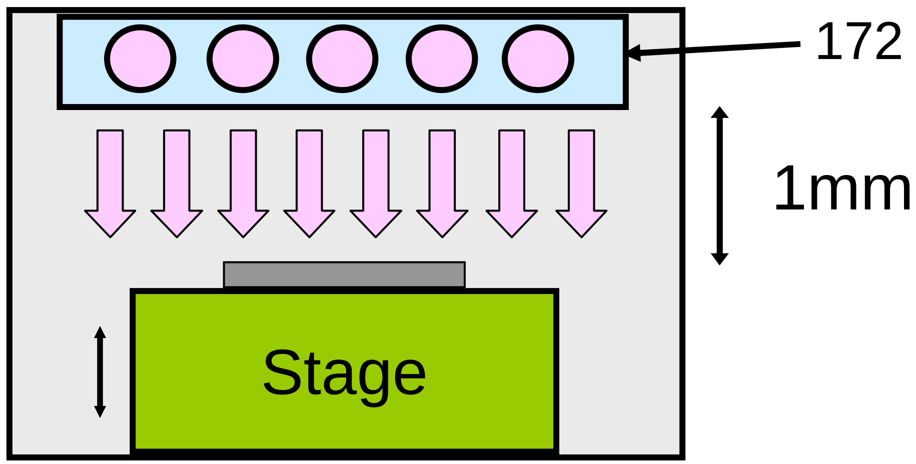
Mask cleaning using 172 nm-excimer VUV/O_3



The absorption coefficient to the oxygen molecule at the wavelength of 172 nm is 20 times larger than that at the wavelength of 185 nm of the low-pressure mercury lamp.

⇒ A high density active oxygen species can be generated.

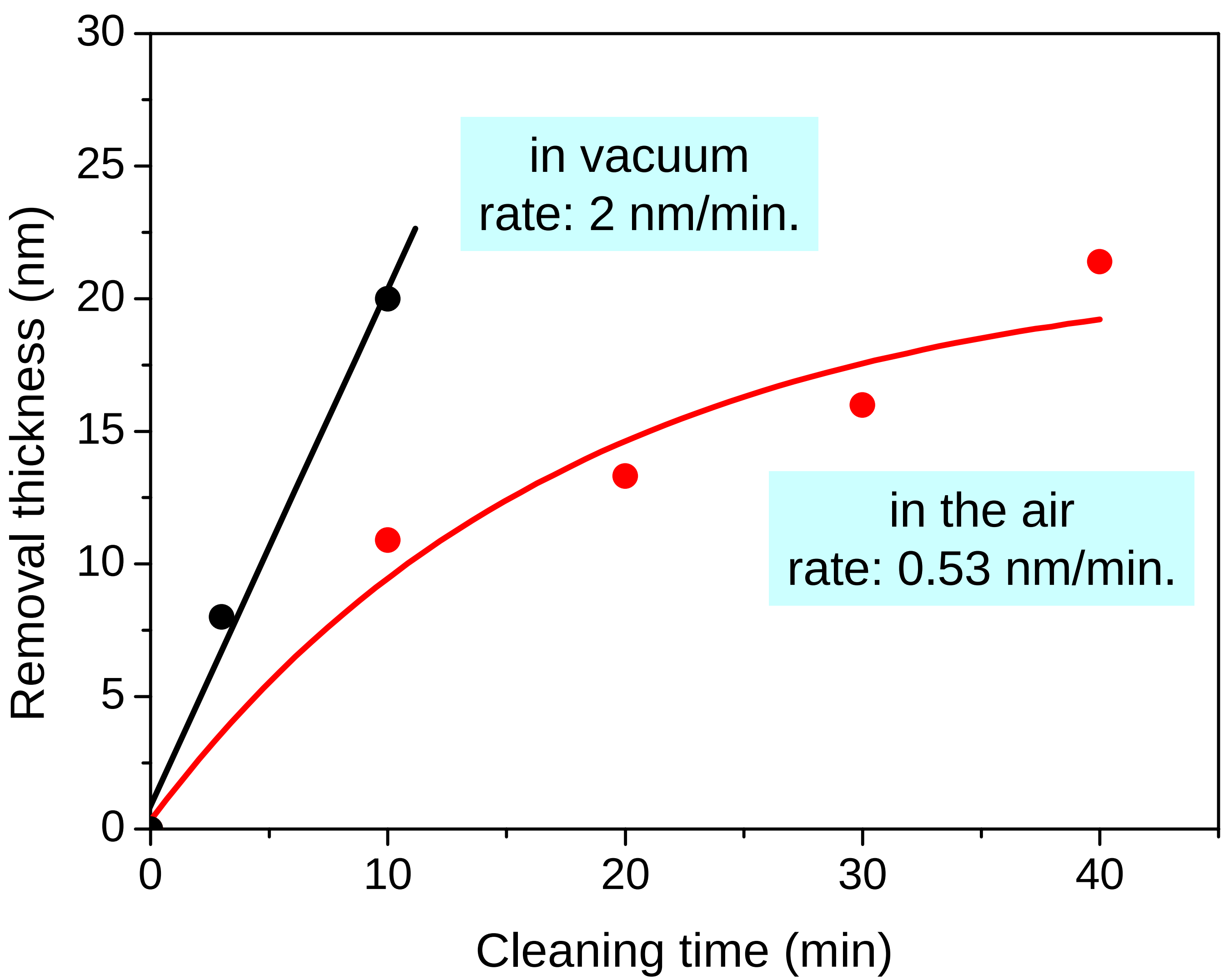
Experimental setup of 172 nm cleaning



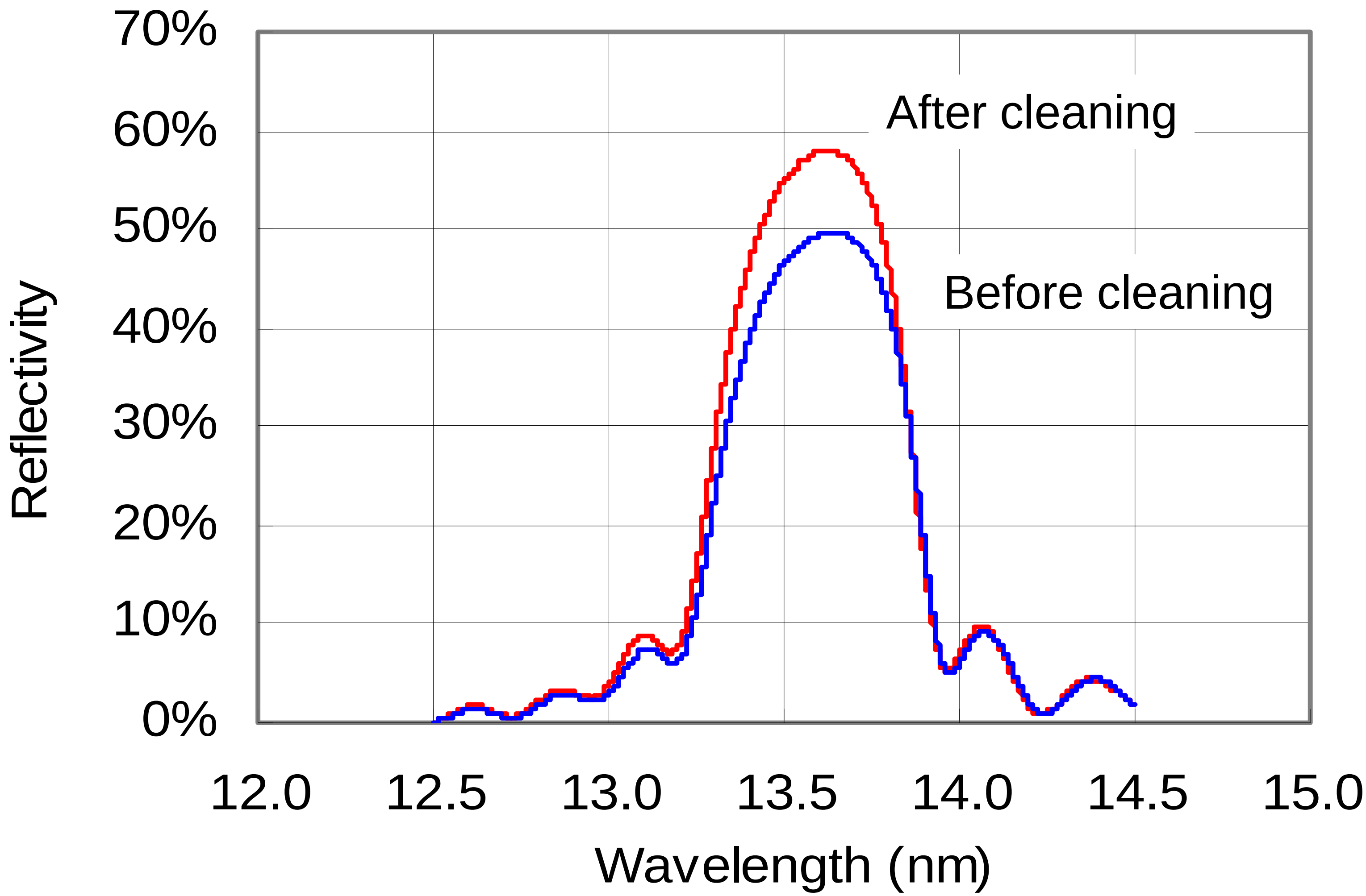
Intensity	20 mW/cm^2
Distance	1 mm
Sample size	8-inch
Temperature	25℃
Environment	in the air / in O_2-rich vacuum

O_2-rich vacuum environment:
The initial back pressure of the chamber was 500 Pa by scroll pump, and an O_2 flow kept the pressure at $2×10^3$ Pa.

Results of mask cleaning using 172 nm-excimer lamp
(1) Reduction of contamination thickness



Results of mask cleaning using 172 nm-excimer lamp
(2) Reflectivity of multilayer



Summary

(1) From the result of AES, it has been understood that the element of contamination is almost carbon.

(2) The effectiveness of the contamination removal for EUVL imaging optics using both in-situ and non-heating method by EUV irradiation in the oxygen atmosphere is confirmed.

(3) The effectiveness of the contamination removal for the finished EUVL mask in off-line process using the 172 nm-excimer lamp in the O_2-rich vacuum atmosphere at the room temperature is confirmed.

Thank you for your attention!!

Outgassing Measurement in University of Hyogo

-Short summary-

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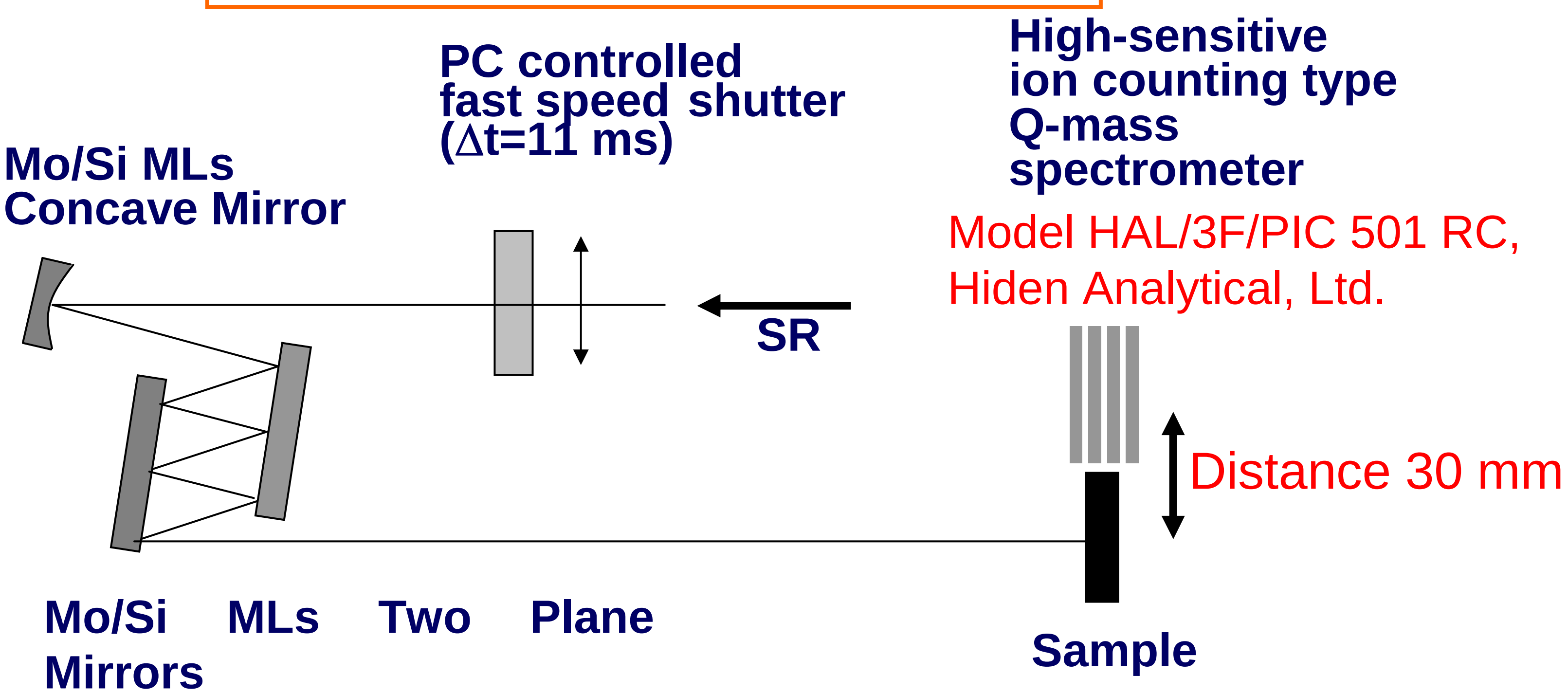
Setup of novel resist evaluation system

1) Measurements of sensitivity
2) Outgas characteristics
3) Chemical reaction analysis

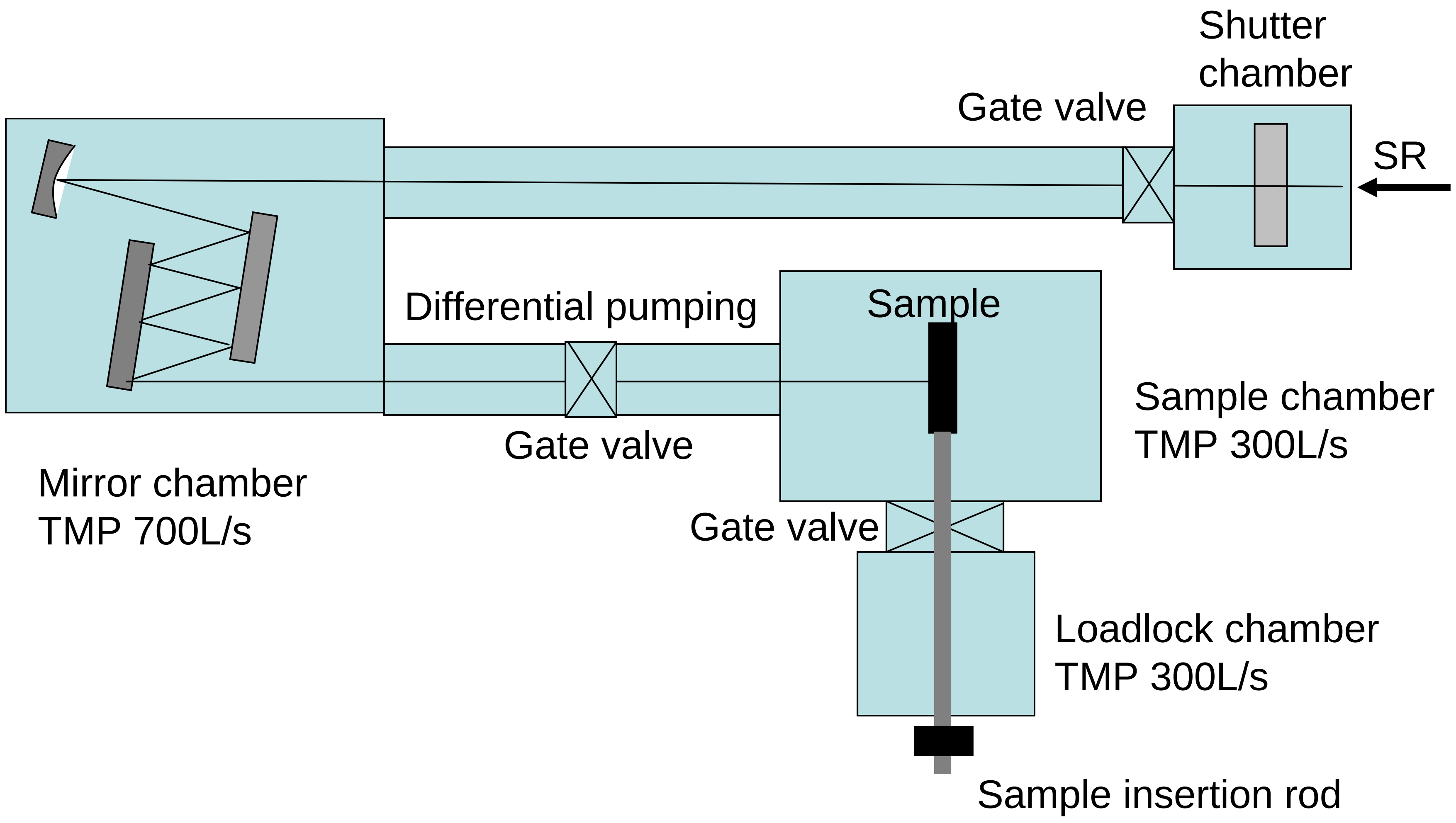
Simulating six-mirror optics

↓

Practical exposure spectrum



Setup of novel resist evaluation system



By Takeo Watanabe, Univ. of Hyogo   2006 Oct 19

Institute	Method	Results		Estimate Rate Molecules/cm^2/s @Prod. Tool (0.4 W/cm^2)
		Molecules/cm^2 @5.6 mJ/cm^2 dose	Molecules/cm^2/s @each intensity condition	
Intel	Synchrotron GC/MS	4.37×10^{11}	7.3×10^{9} 0.09 mW/cm^2	1.3×10^{13}
SEMATECH	Synchrotron GC/MS	3.9×10^{13}	2.6×10^{12} 0.37 mW/cm^2 35-435 amu	1.1×10^{15}
ASET	Synchrotron Online QMS	1.9×10^{14}	4.5×10^{12} 0.13 mW/cm^2 1-200 amu	5.7×10^{15}
BOC Edwards	Stand-alone source Online QMS	2.8×10^{14}	5×10^{13} 1 mW/cm^2 ??-??? amu	8.3×10^{15}
Univ. of Hyogo	Synchrotron Online QMS	7.1×10^{15}	3.4×10^{14} 0.27 mW/cm^2 1-200 amu	2.9×10^{17}
		9.4×10^{14} 35-200 amu	4.5×10^{13} 35-200 amu	6.7×10^{16} 35-200 amu
		4.3×10^{14} 35-200 amu Excluding 44 amu	2.1×10^{13} 35-200 amu Excluding 44 amu	3.1×10^{16} 35-200 amu Excluding 44 amu