Debris mitigation and mirror cleaning for Sn-fueled EUV source

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DPP Source Performance Roadmap

Metrics	1Q-2005	3Q-2006	1Q-2008 EUVA final	2009 for HVM
Fuel gas	Xe	Sn	TBD	TBD
EUV power at IF	19 W *1	55~62 W *2	>50 W	>115 W
Etendue limit	10 mm^2sr	3.3 mm^2sr	< 3.3 mm^2sr	< 3.3 mm^2sr
Pulse repetition rate	7 kHz	8 kHz	7-10 kHz	7-10 kHz
Energy dose stability (over 50 pulses, 1σ)	1.3% (free running)	2.4% (free running)	< 0.5 %	0.1%
Mirror lifetime (10% degradation)	> $1x10^7$ pulses	> $3x10^7$ pulses	> $0.5x10^6$ sec	CoO dependent

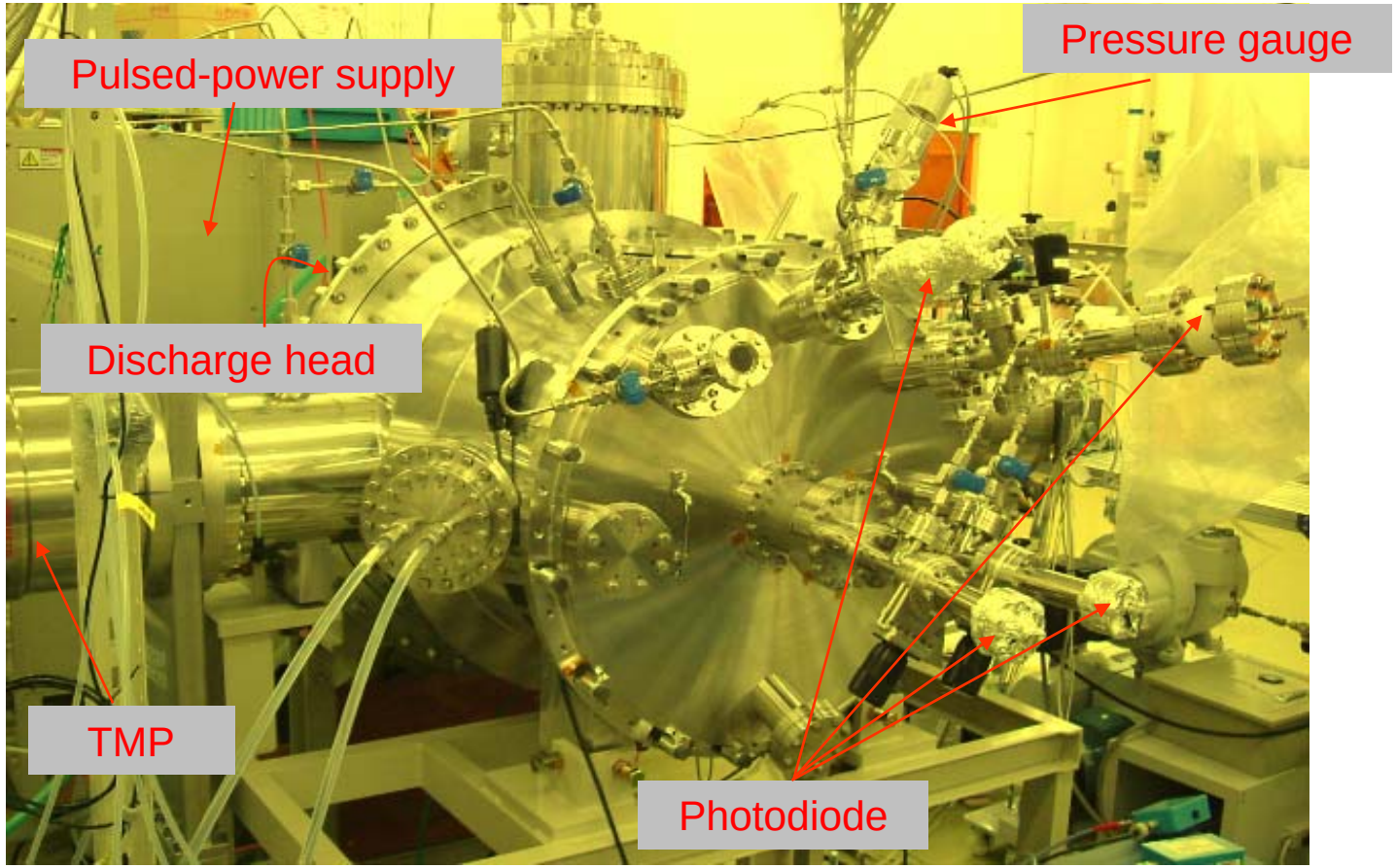
This study is explaining DMT, mirror lifetime, and cleaning system

notes)

*1 : Nested-shell type collector optics, assuming 80% of debris shield transmission and 90% of gas transmission.

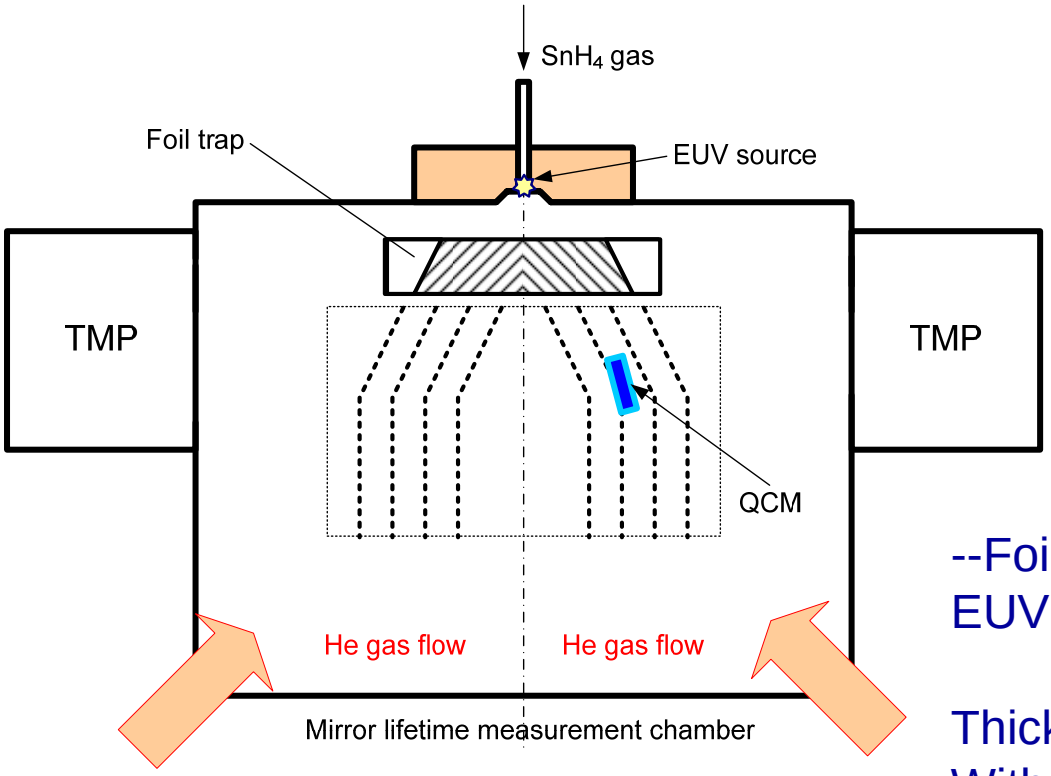
*2 : Nested-shell type collector optics with foil-trap assembly, assuming 90% of gas transmission.

Mirror Lifetime Measurement Chamber



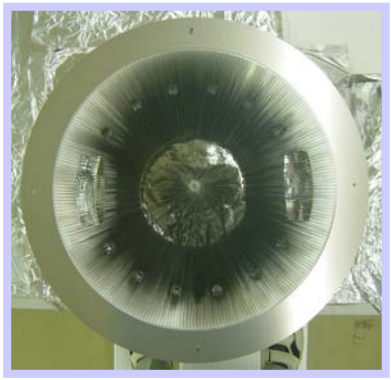
Mirror lifetime measurement chamber and pulse-power supply

Debris Mitigation System



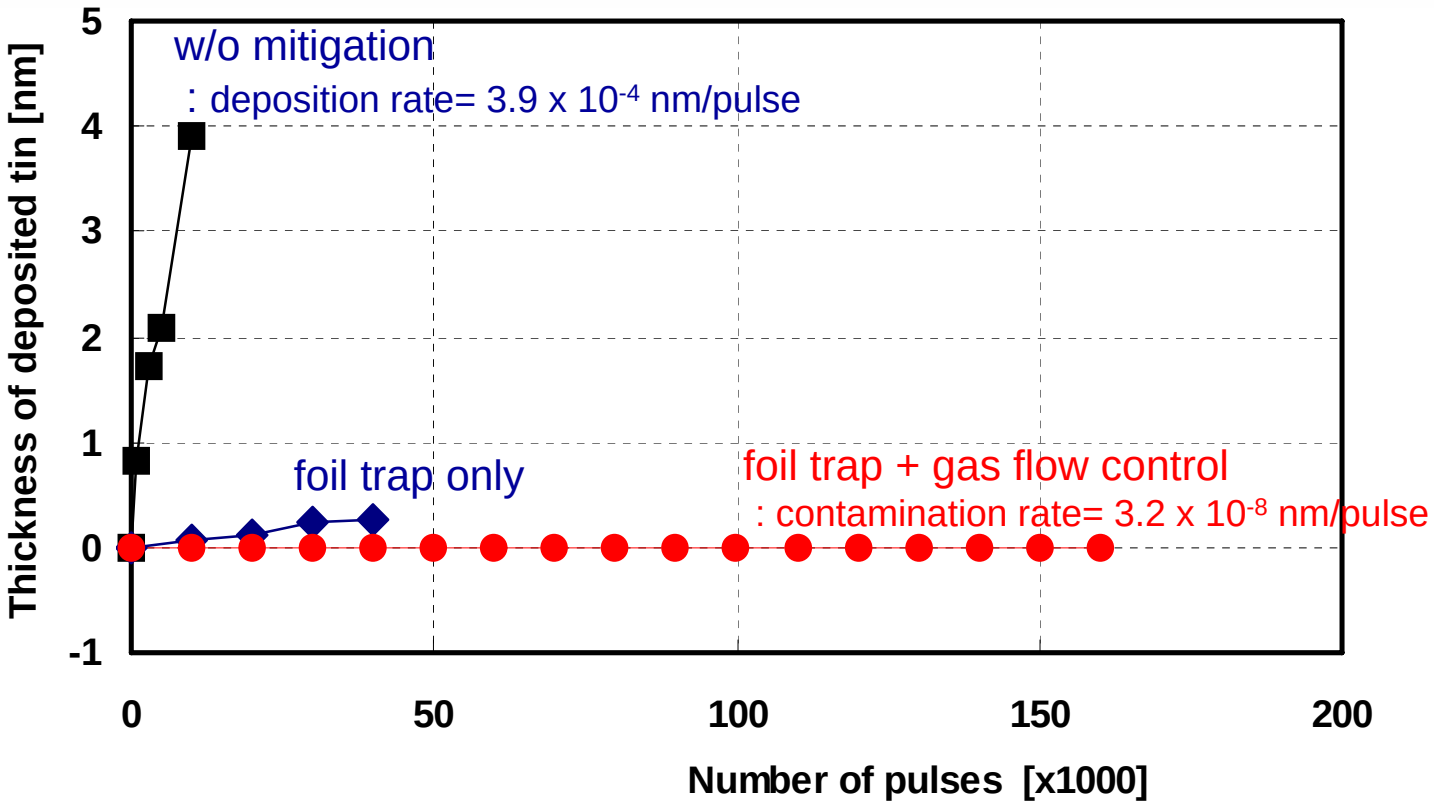
--EUV Source--
～60 mJ/pulse

--QCM crystal--
- Surface: polished
- Au-electrode + Ru layer
- Roughness: ～1.5 nm



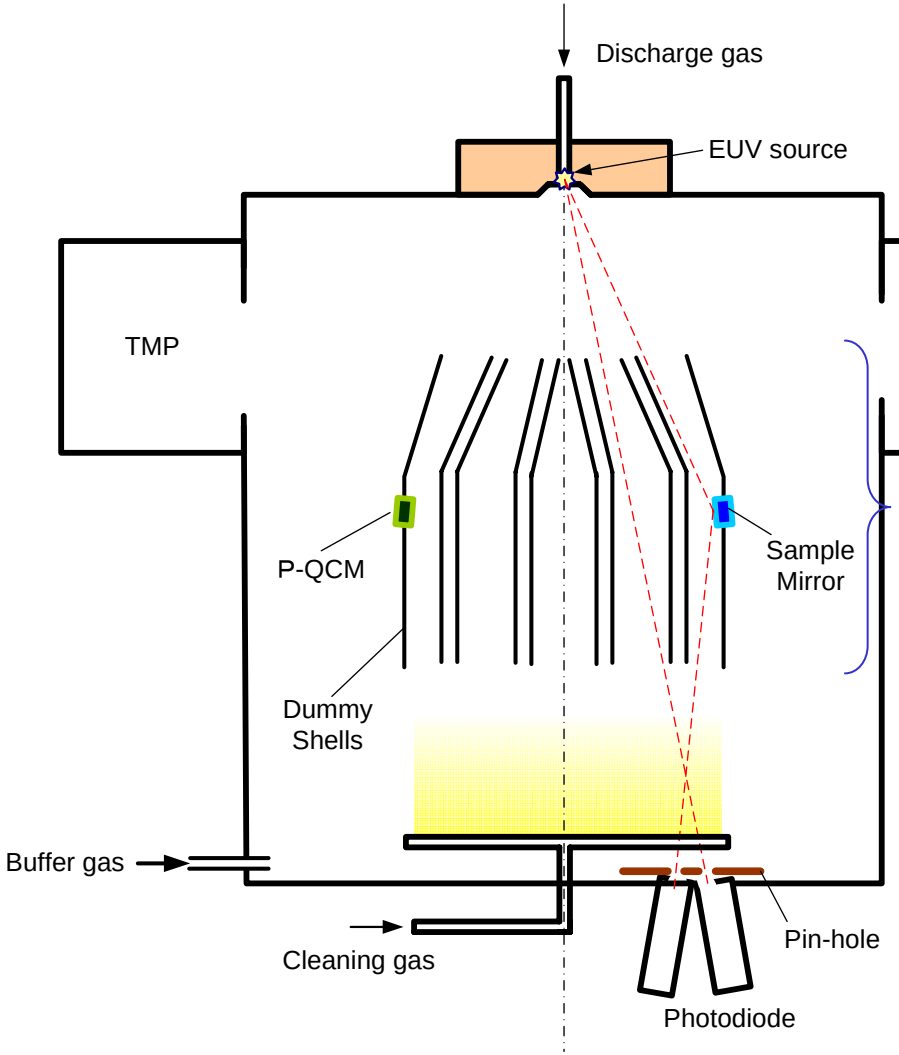
--Foil trap--
EUV incident angle:
±45 deg.
Thickness of foil: 0.1 mm
Without cooling
(Next DMT with cooling system)

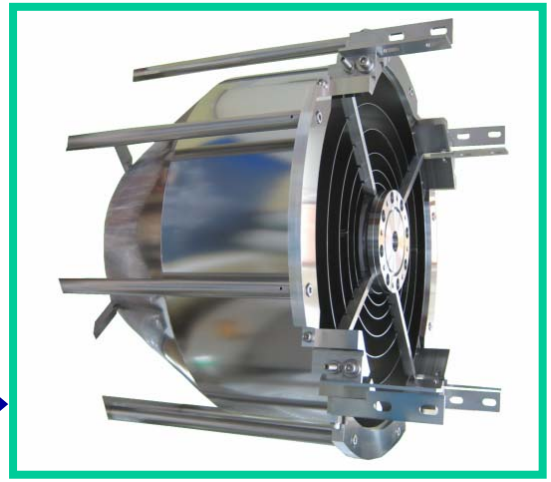
Sn Contamination Rate



Sn contamination rate was **1.0 x 10^{-6} nm/pulse** with the foil trap. Sn contamination rate was **3.2 x 10^{-8} nm/pulse** with the foil trap and gas flow control. The experimental condition was 1 kHz of pulse repetition rate, 10 sec/set, polished QCM-crystal with Ru layer.

Cleaning Test & Reflectivity Measurement Apparatus





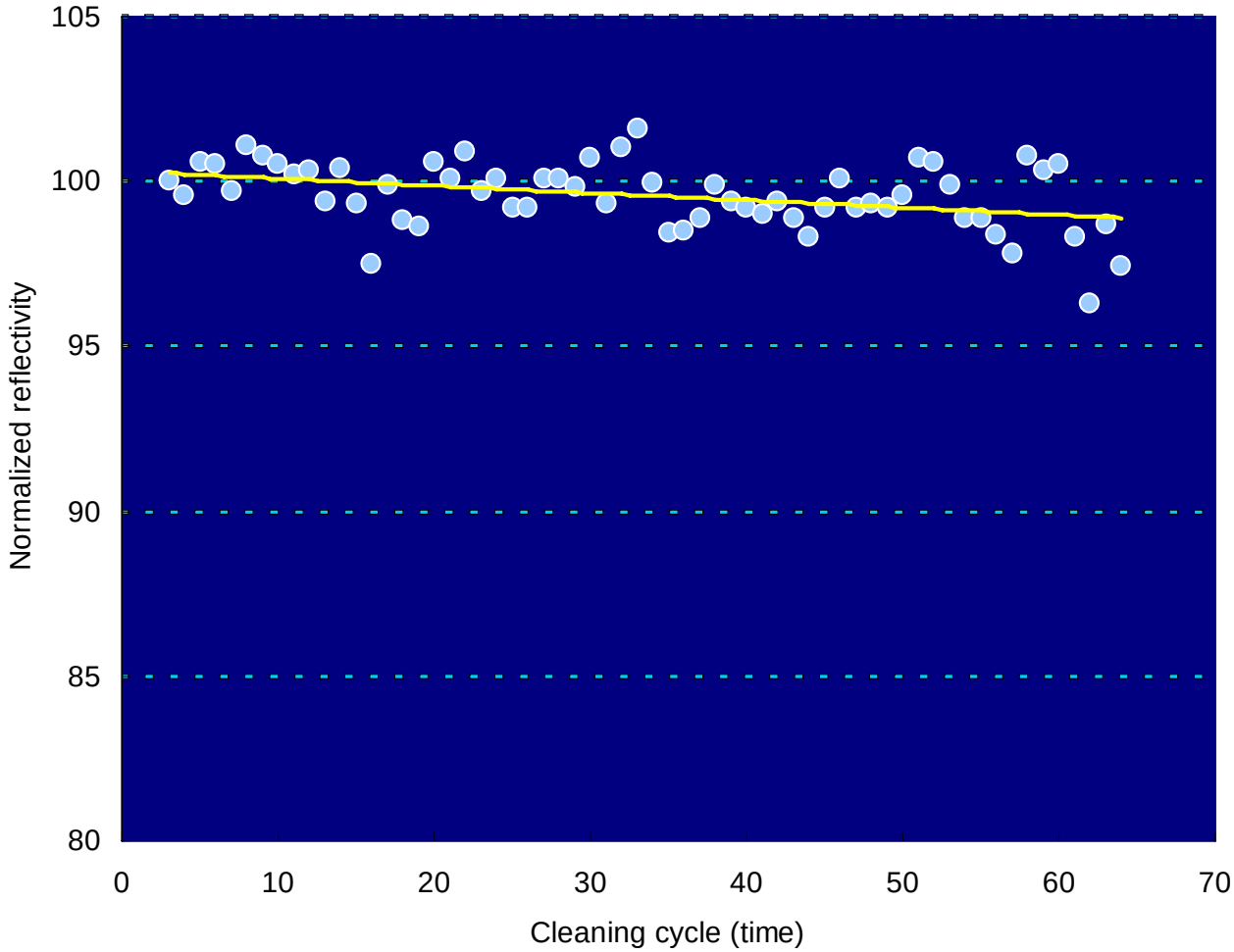
Dummy Shells

Cleaning test cycle

Sn DPP operating
- Sn contamination on the mirror
- Reflectivity measurement

Halogen cleaning
- Sn cleaning
- Reflectivity measurement

Mirror Lifetime Test of Halogen Cleaning



-Calculation Mirror Lifetime-

$R_{normalized}$ = 90%

@ 454 time of cleaning

Sn deposition rate =

3.2×10^{-8} nm/pulse

Sn thickness (R = 90%) = 0.4 nm

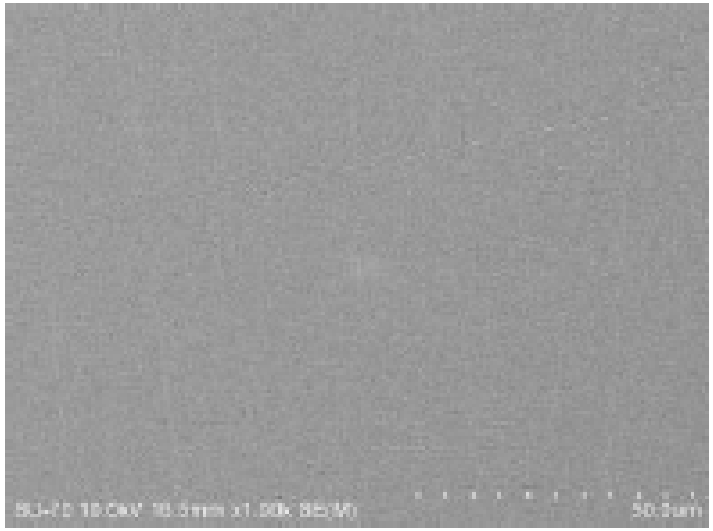
$0.4/3.2 \times 10^{-8}$

12.5 Mpulses

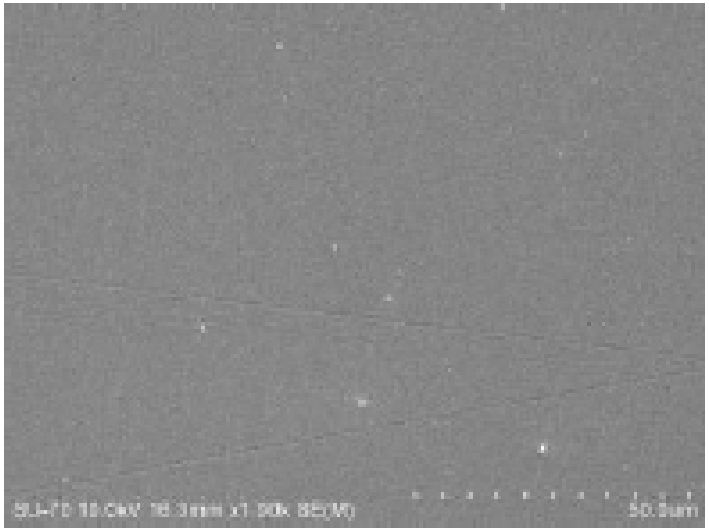
Mirror Lifetime = $454 \times 12.5 \times 10^{6}$ =

5.7 Bpulses

Mirror Surface Analysis after Lifetime Test



Unused



After test (Cleaning cycle: 93 times)

XPS result after cleaning sample:

Sn3d3: 1.8 at.%

Ru3d5: 44.2 at.%

→Sn/Ru = 0.04

- The value of Sn/Ru fit less than 0.1 nm of Sn thickness.

In this measurement condition, the EUV source didn't have DMT for fast Sn contamination rate, so that the mirror was contaminated by a electrode particles. Ru condition of the mirror surface was not changed by the Halogen exposed

Surface analysis with AFM -after cleaning test-

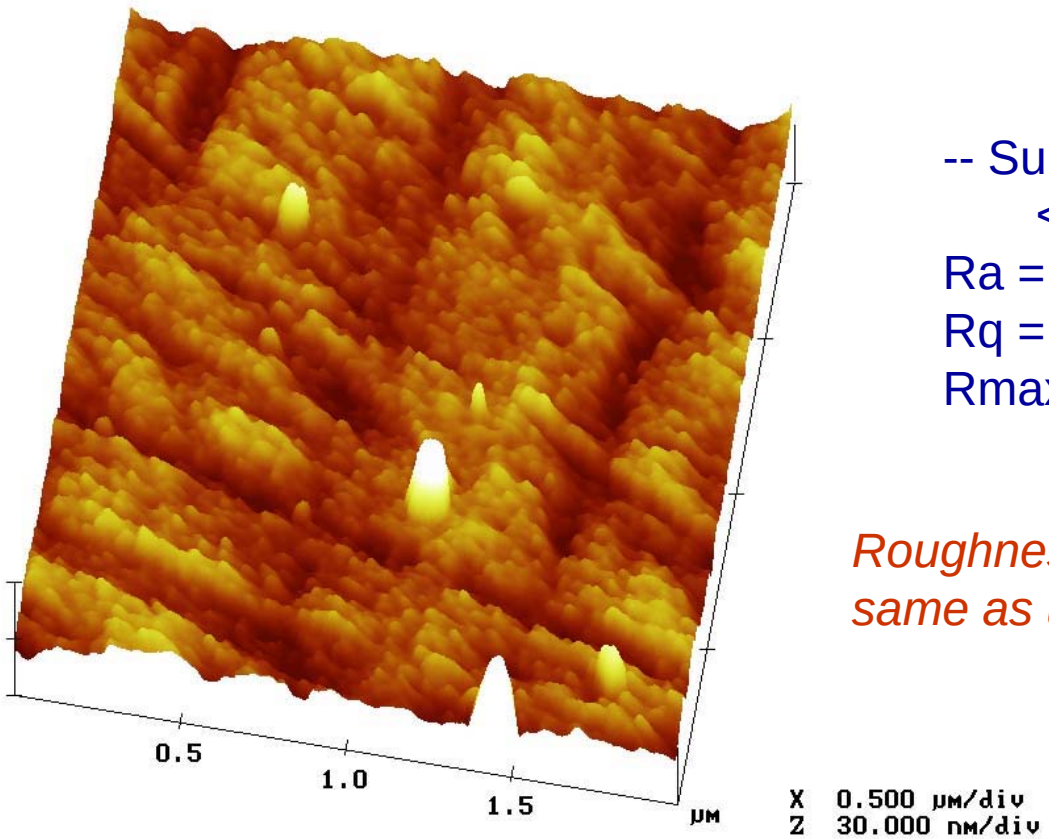


Fig.6 Perspective Image, M2#5

-- Surface Roughness --

<unused> → <after 93 cleaning>

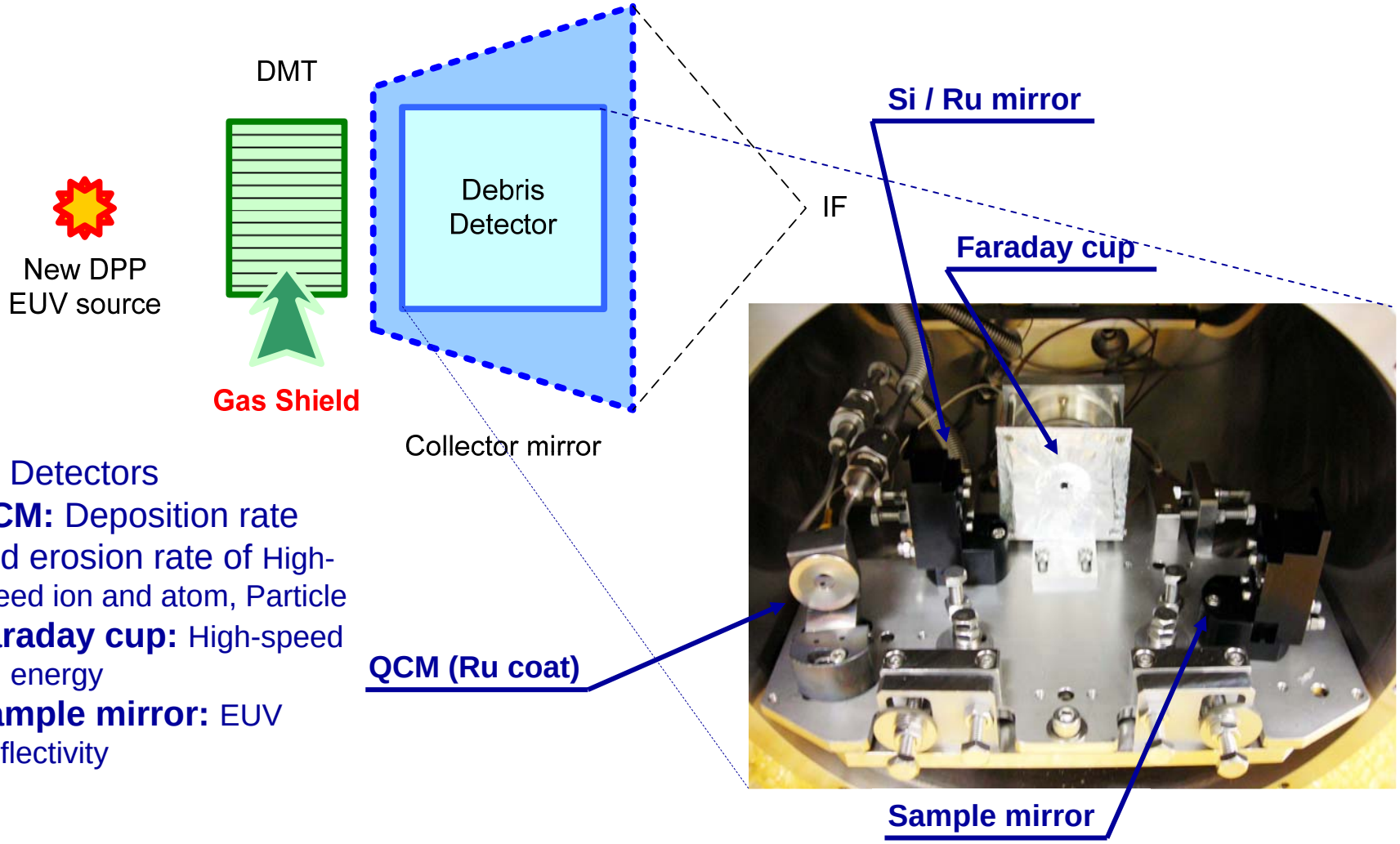
Ra = 2.8 → 2.5 nm

Rq = 3.6 → 3.3 nm

Rmax = 27.3 → 23.1 nm

Roughness after cleaning test was the same as unused sample mirror.

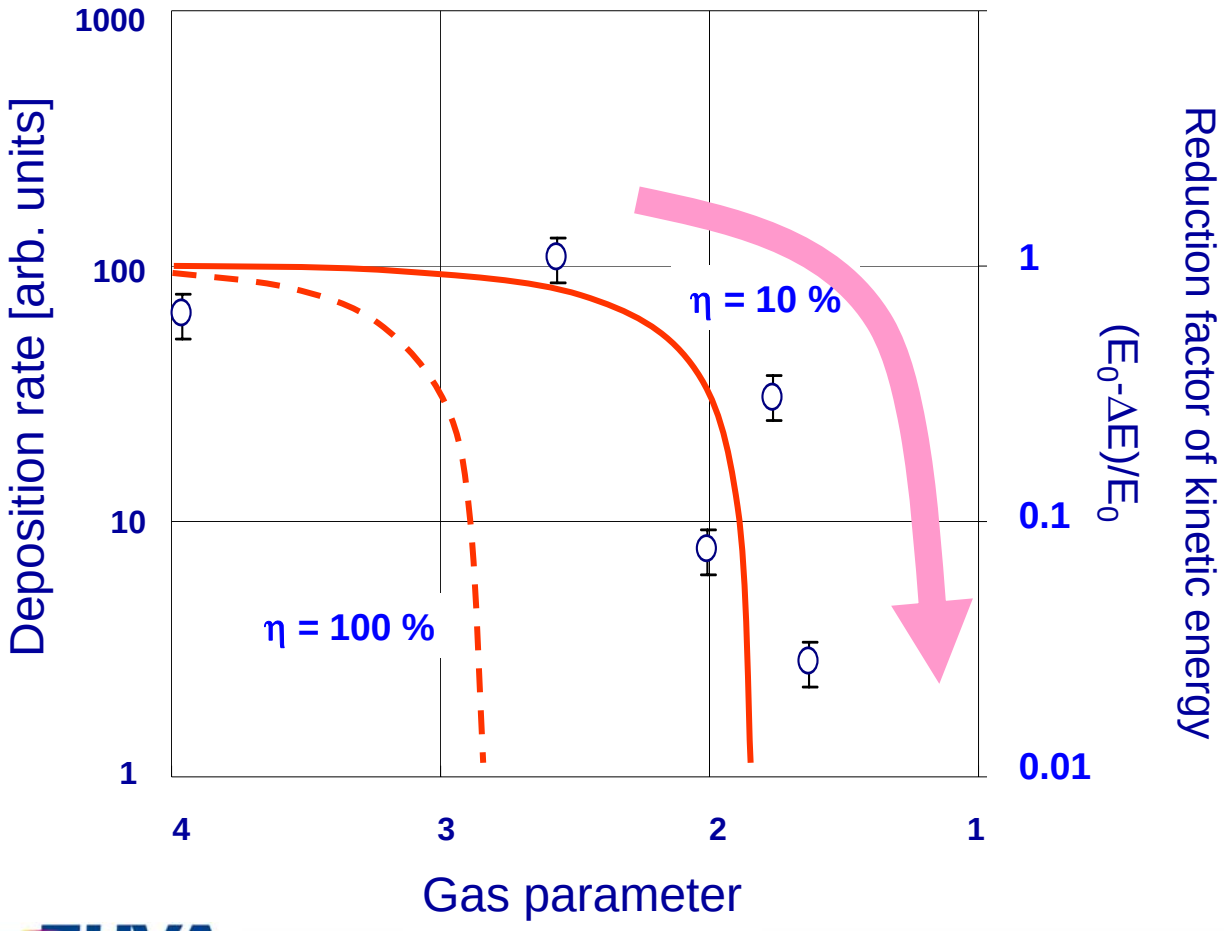
Debris Measurement Apparatus



Debris Detectors

- **QCM:** Deposition rate and erosion rate of High-speed ion and atom, Particle
- **Faraday cup:** High-speed ion energy
- **Sample mirror:** EUV Reflectivity

Sn Deposition Rate with Gas shield of New DPP Source



The debris was removed by gas shield. The deposition rate was decreased by ***97%***.

Summary

Latest achievement of mirror lifetime with DMT and mirror Halogen cleaning

Mirror lifetime was measured at normalized reflectivity. The pulse number of the mirror lifetime was calculated at **5.7 Bpulses**. The Ru surface of the after cleaning was not damaged, and had no change of the roughness.

The performance experiment of The DMT (Foil trap, gas shield, etc.) of New DPP source was performed. The debris was removed by gas shield. The deposition rate with QCM was decreased by **97%.**

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