# Debris mitigation and 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, 1$\sigma$) | 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 |

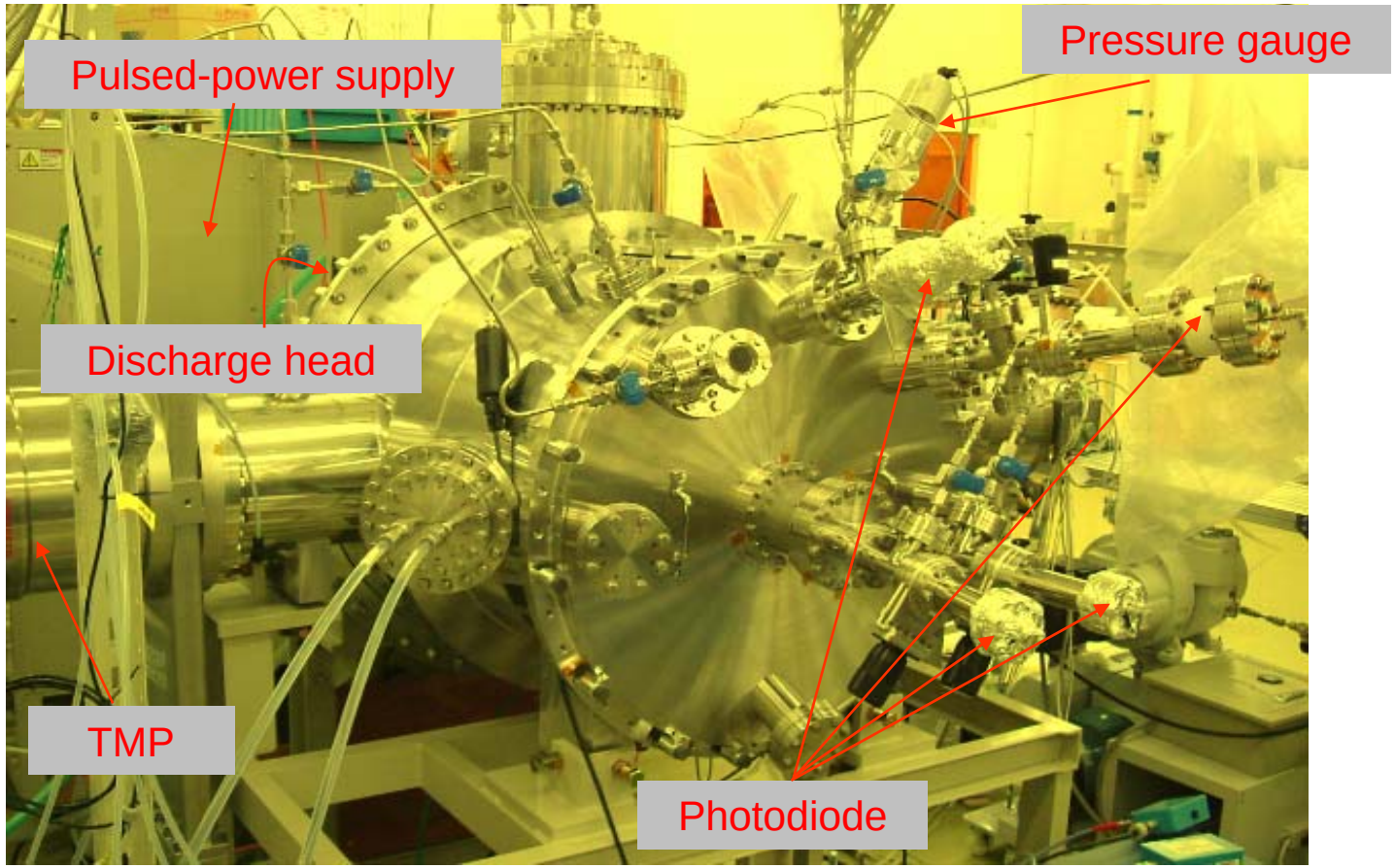
***This study is explaining DMT, mirror lifetime, and cleaning system***

notes)

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

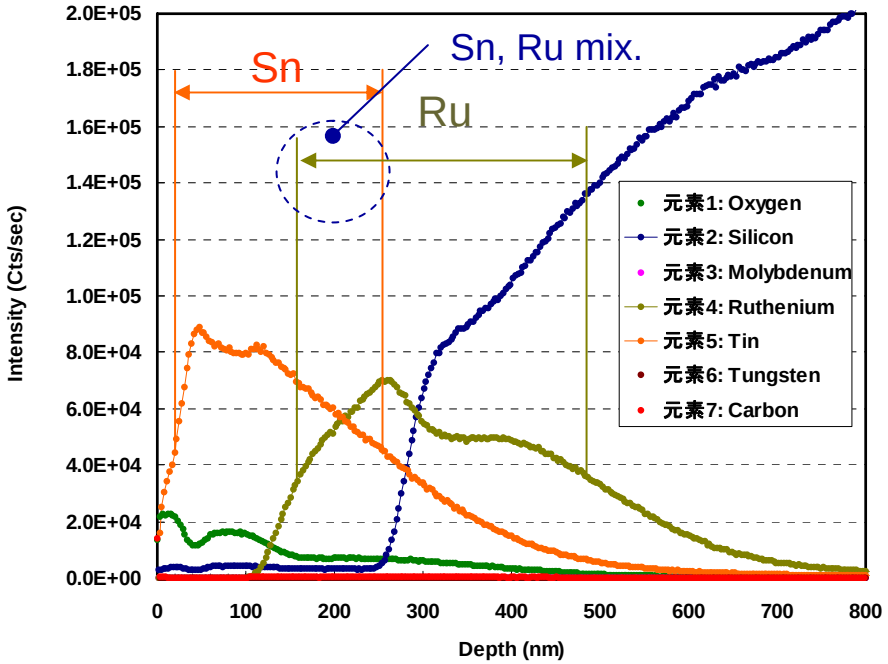
*2 : Nested-shell type collector optics with foil-trap assembly, assuming 90% of gas transmission.

# Mirror lifetime measurement chamber

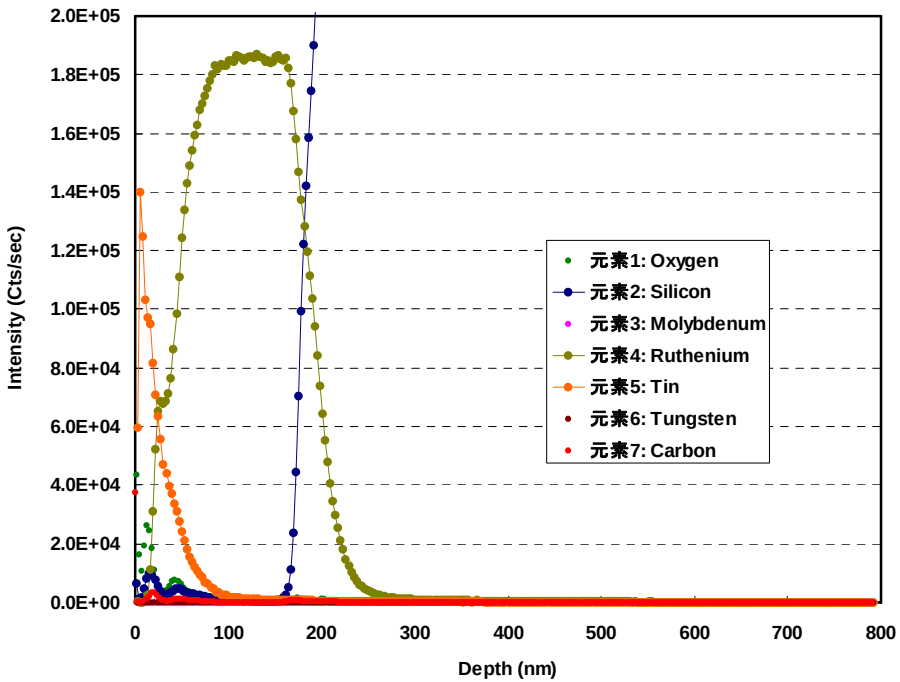



Mirror lifetime measurement chamber and pulse-power supply

# Depth profile of Sn contamination (SIMS)



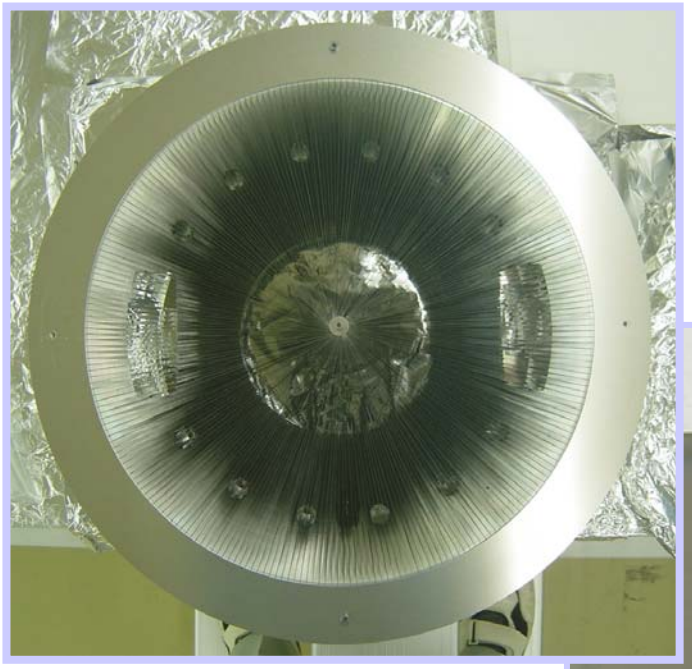

**Sample mirror -1**
**(Angle: 90 deg. L=210 mm)**



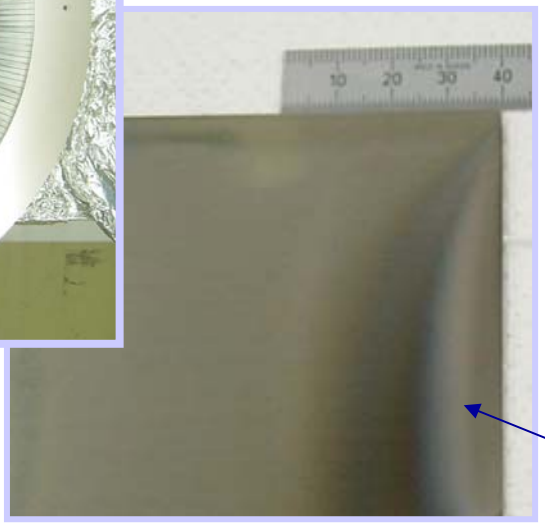

**Sample mirror -2**
**(Angle: about 15 deg. L=360 mm)**

Depth profile of Sn contamination was measured by Second Ion Measurement system (SIMS). The experimental setup used $SnH_4$-based EUV source, operated at 1 kHz of repetition rate without DMT (foil tap and gas curtain). The number of pulses were 0.25 Mshots. Sn thickness was 254nm@QCM (close to mirror). The mixing layer of Sn and Ru was occurred.

# Debris mitigation tool (Foil trap)



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

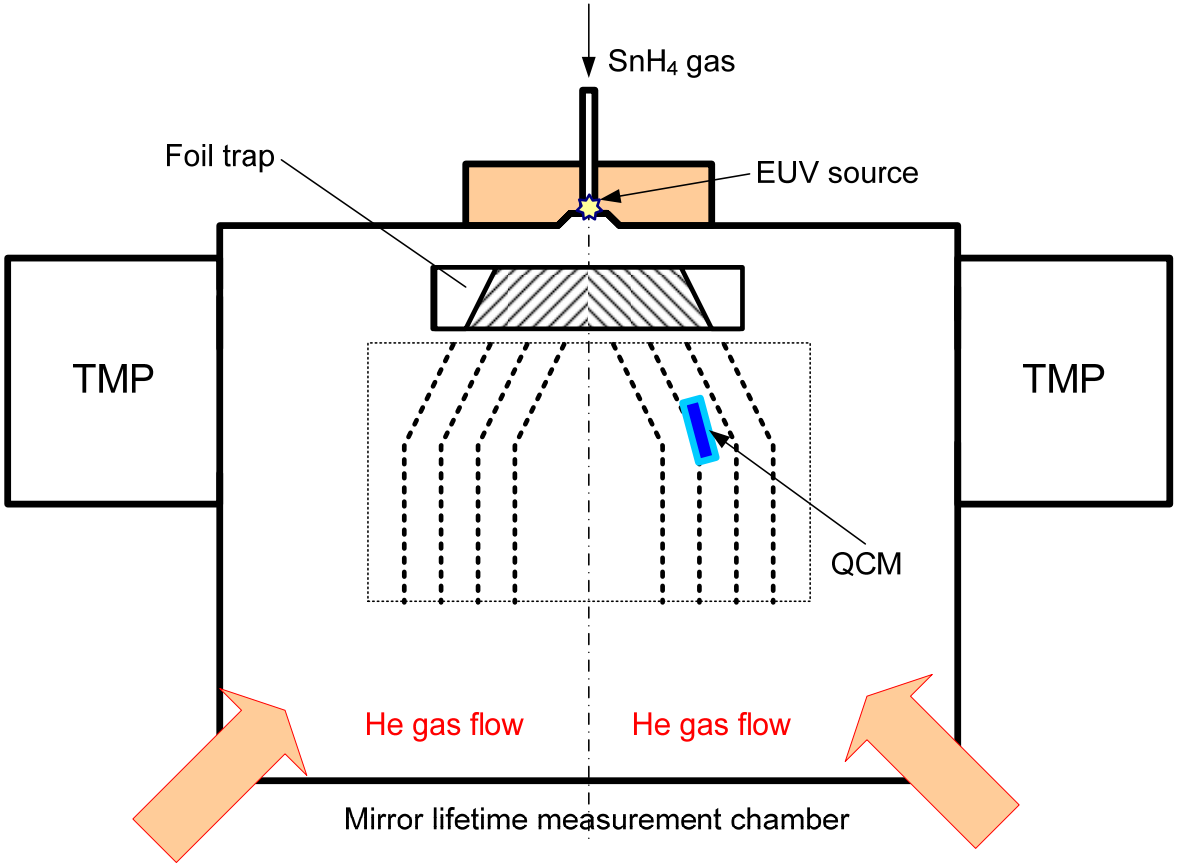


This foil was exposed to about 5 Mshots of pulse. Sn contamination was 30 mm from the side of EUV source.

Sn contamination

Mirror ← →EUV source

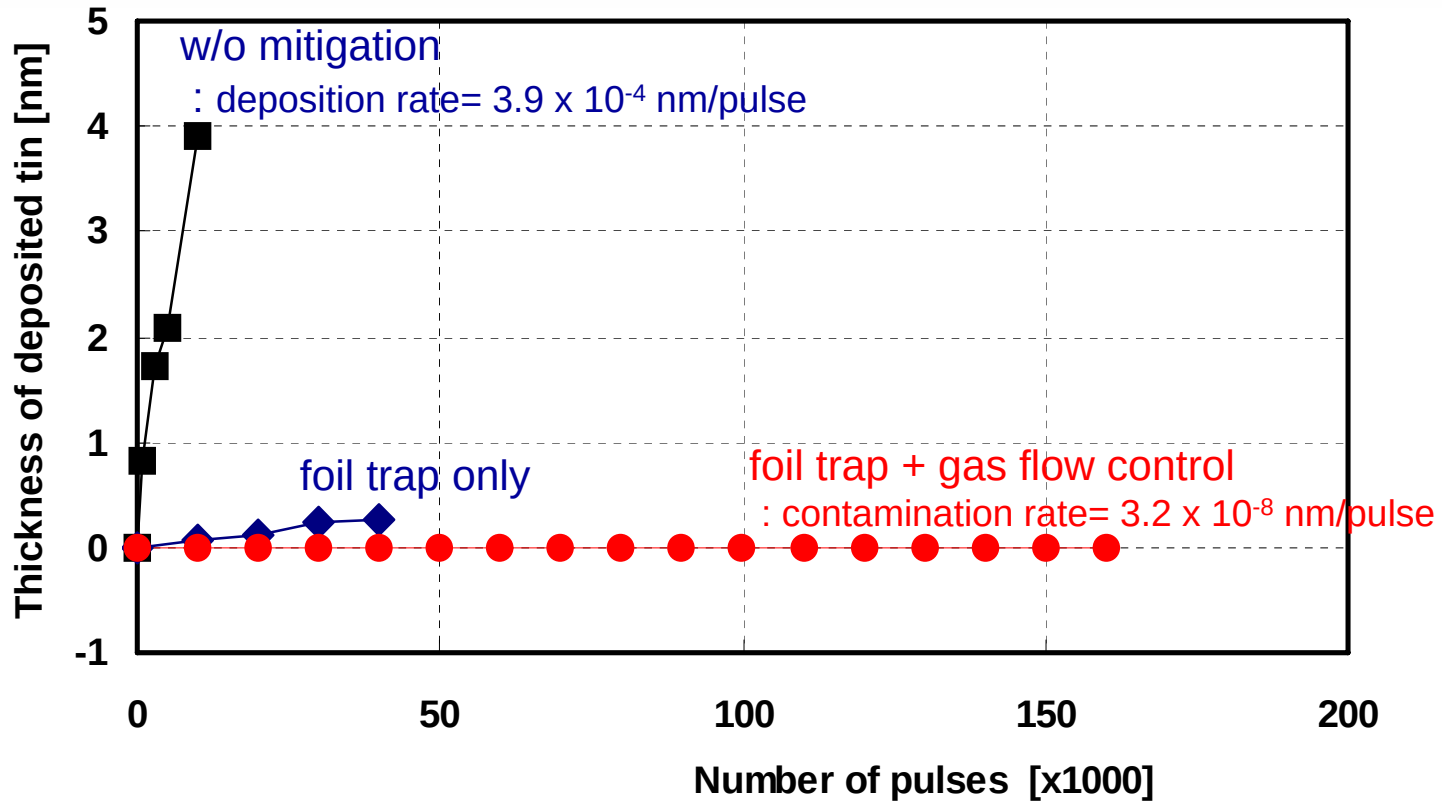
# Debris mitigation system




EUV Source
～60 mJ/pulse

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

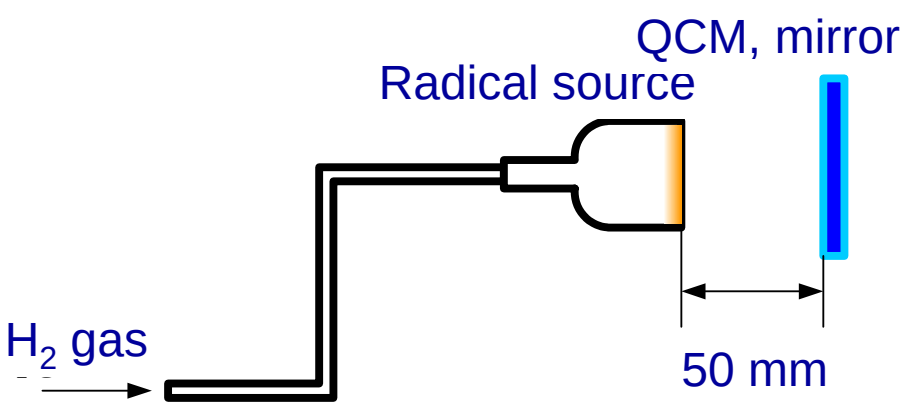
# Sn contamination rate

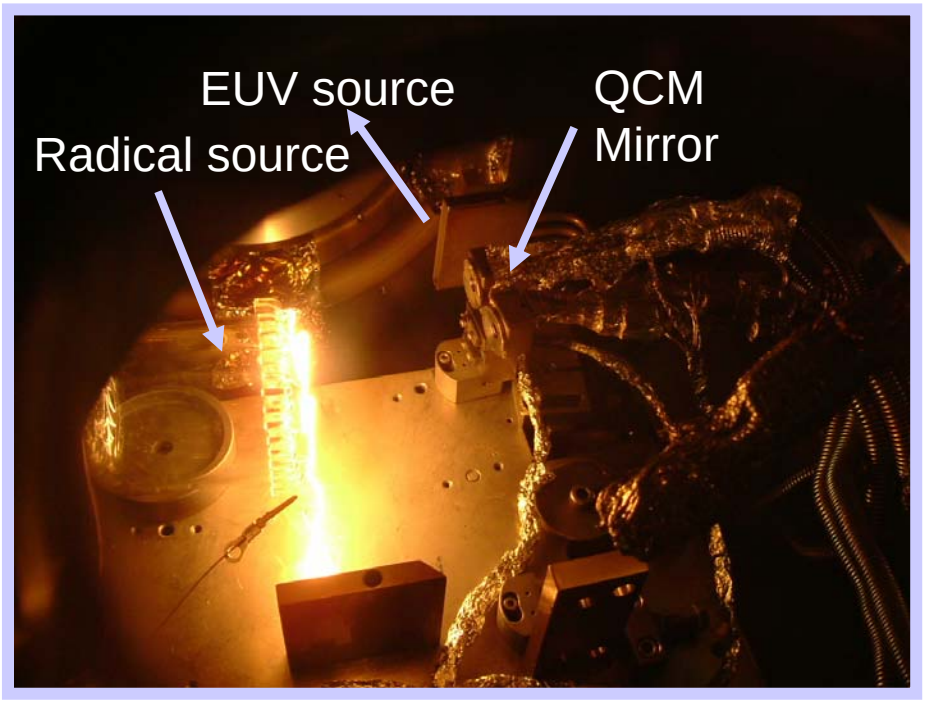



Sn contamination rate was **1.0 x $10^{-6}$ nm/pulse** with the foil trap. Sn contamination rate was **3.2 x $10^{-8}$ nm/pulse** with the foil trap and gas flow control. The experimental condition was 1 kHz of pulse repetition rate, 10 sec/set, polished QCM-crystal with Ru layer.

# Hydrogen radical cleaning system

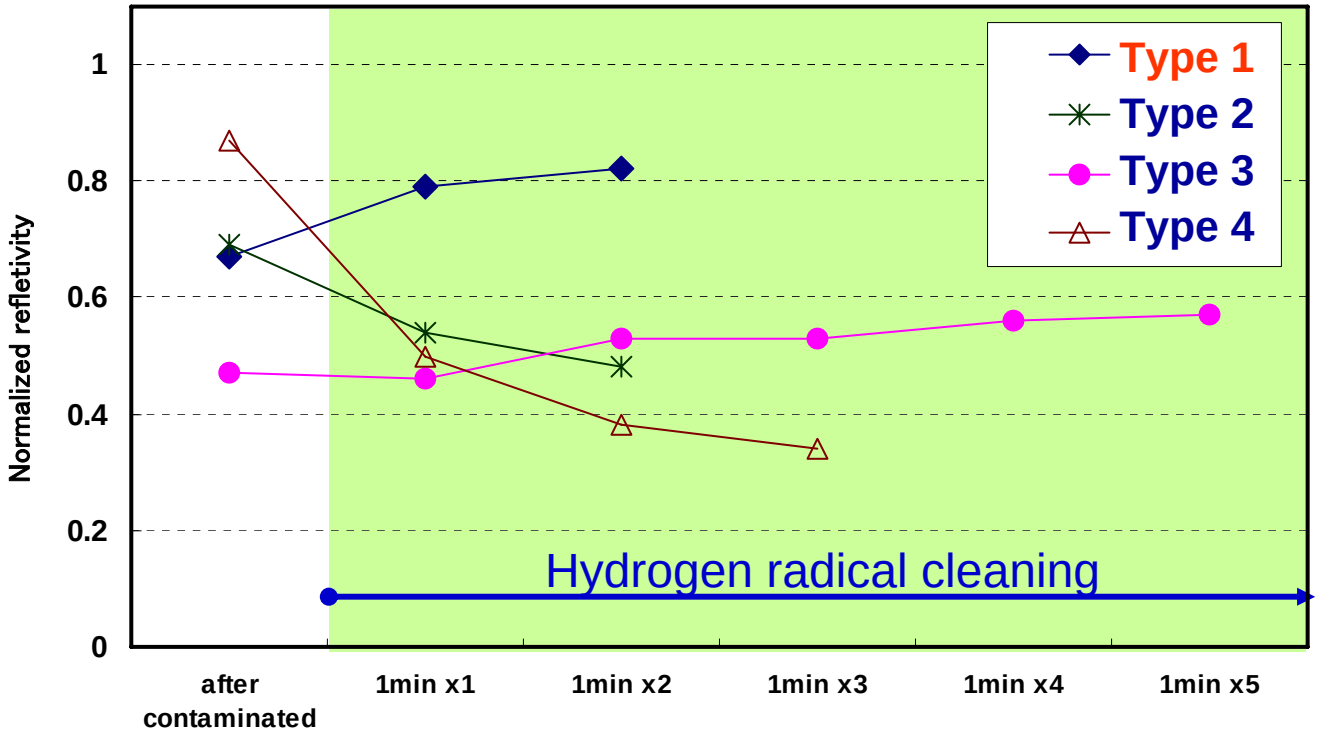
Radical source : Hot filament



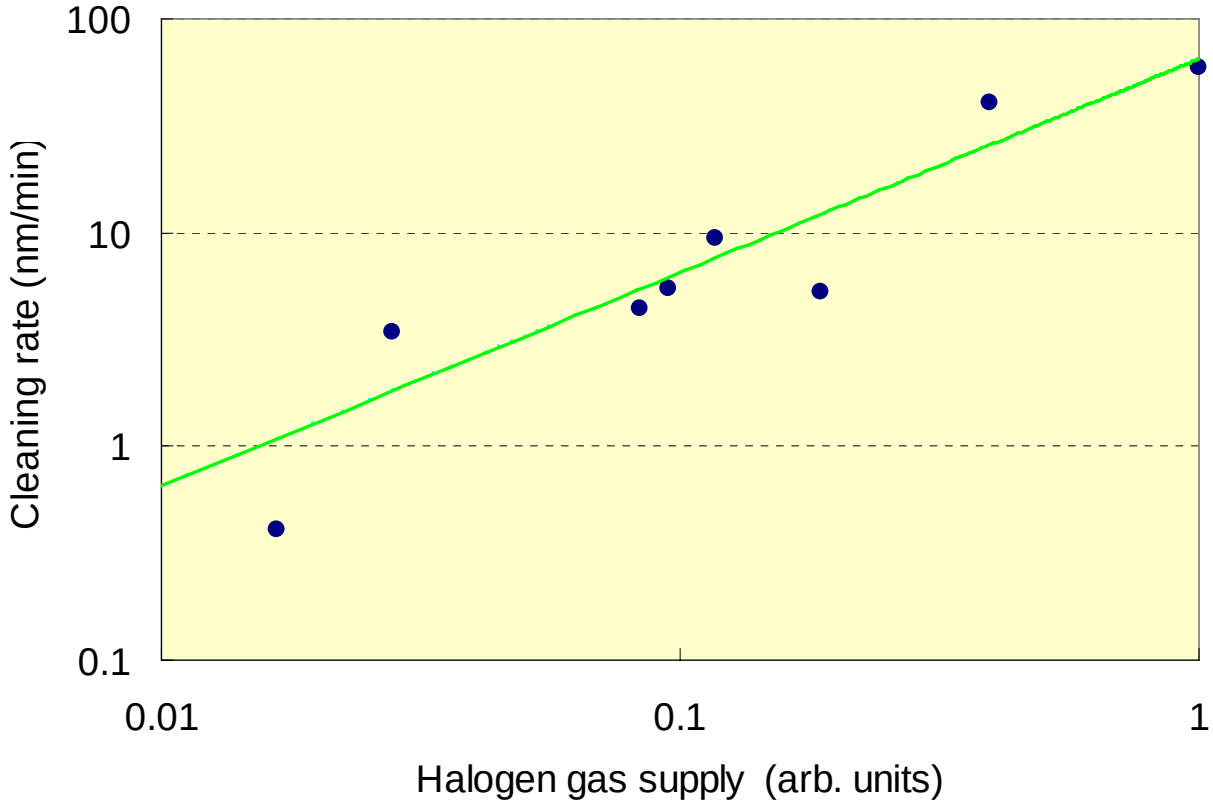

Sn thickness and cleaning rate were measured by QCM and normalized reflectance. Hydrogen radical density was more than $10^{16}$ $cm^3$.

# Dependence of EUV reflectance by Hydrogen radical cleaning



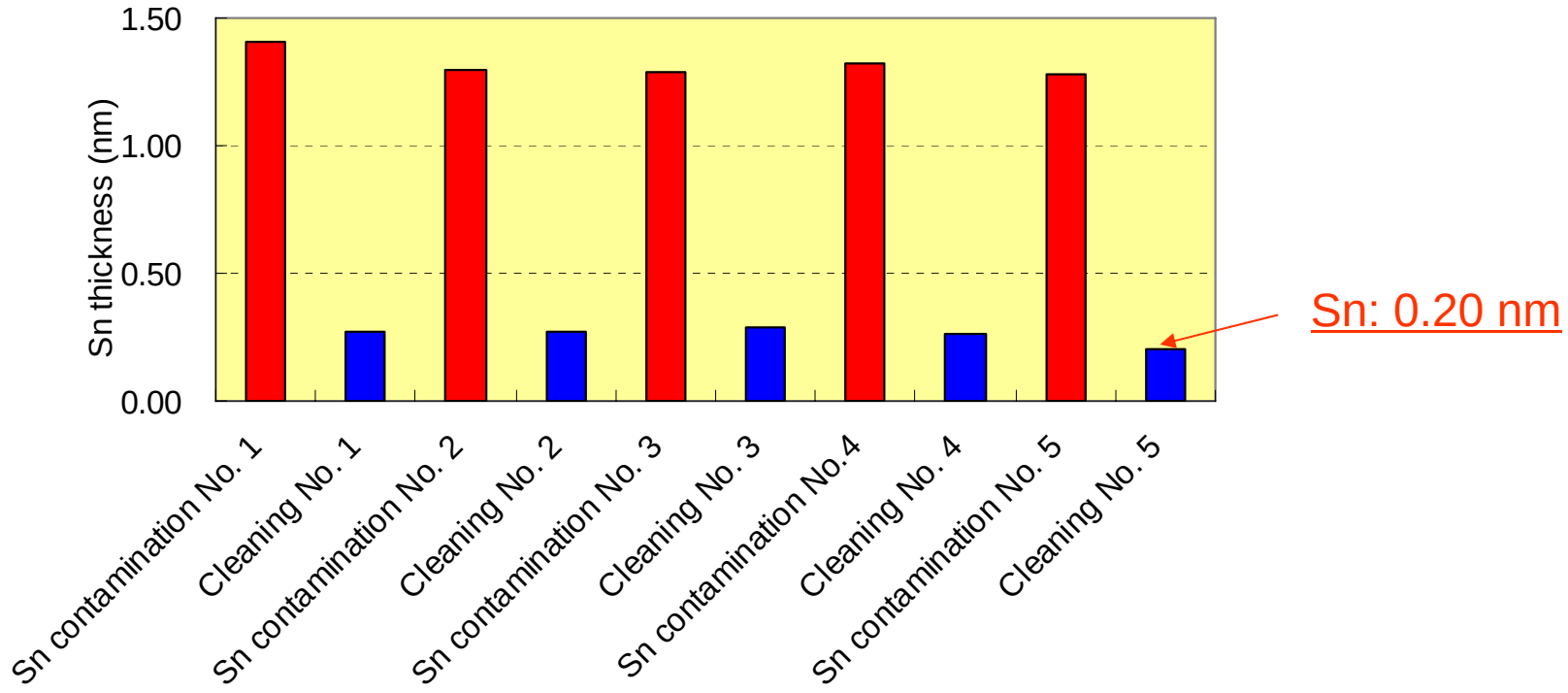

Debris of Sn contaminated the Sn-fueled discharge. Sample mirrors were different substrate and layer material. Reflectivity of the type No. 1 sample was improved by the cleaning.

# Dependence of cleaning rate by Halogen gas




Cleaning rates of sample mirrors were sufficiently high. Possibly, the cleaning processing was enabled in a short time. The cleaning rate was calculated using cleaning time and layer thickness, before/after cleaning. The Sn thickness was measured by QCM or SEM.

# Repetition of Sn contamination and cleaning




5 times of Sn contamination and Halogen cleaning were continued. Sn contamination was about 1 nm/time. Cleaning rate was 99%/time on average. After 5 cleaning, Sn thickness was 0.20 nm by QCM. The average (5 times) of Sn thickness after cleaning was 0.26 nm. The QCM was polished about 1.0 nm@Ra and was Ru layer. This QCM looked like a sample mirror.

# Summary

**Latest achievement of mirror lifetime, Debris mitigation, mirror cleaning**

**<Mirror lifetime and Debris mitigation>**

Sn contamination rate: $3.2 \times 10^{-8}$ nm/pulses

(with DMT and gas flow control)

Mirror lifetime (10% degradation): $>3 \times 10^{7}$ pulses

**<Mirror cleaning>**

**Hydrogen radical cleaning**

Reflectance recovery: from 0.67 to 0.82

**Halogen cleaning**

Possibility: short time cleaning

Cleaning rate: average 99%

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