

Apparatus for Contamination Control Development in EUVA

Extreme Ultraviolet Lithography System Development
Association (EUVA) Contamination Research Group

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EUV light exposure in

H₂O containing condition

C_xH_y containing condition



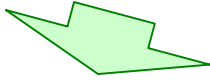
Mirror surface oxidation

Mirror surface carbon deposition

Hard to recover

Reflectance reduction

Possible recovery



- 👎 Shorter tool life time
- 👎 Lower throughput

TARGET

March 2006: $\Delta R \leq 3\%$

Need to Study

Oxidation and carbon deposition mechanism

Examination of dependency to EUV intensity, dose, contaminants partial pressure, ...

- **Capping Layer (Resistant to Surface Oxidation)**
 - Optimization of Si/Ru cap coating conditions
 - Listing up capping/anti-diffusion material candidates
 - Material screening by EUV/E-beam irradiation
 - Examining dependency of oxidation speed to light intensity, dose, H₂O partial pressure, ...
- **Mitigation of Carbon Deposition/
Cleaning of Carbon Film**
 - EUV+O₂, UV (172nm)+O₂ cleaning
 - Evaluation of surface roughness, oxidation after cleaning
 - Examining dependency of removal speed to light intensity, dose, O₂/C_xH_y partial pressure, ...

Research Sites

- Himeji (Univ. Hyogo/Himeji Institute of Technology)
- Sagamihara (Nikon)
- Utsunomiya (Canon)

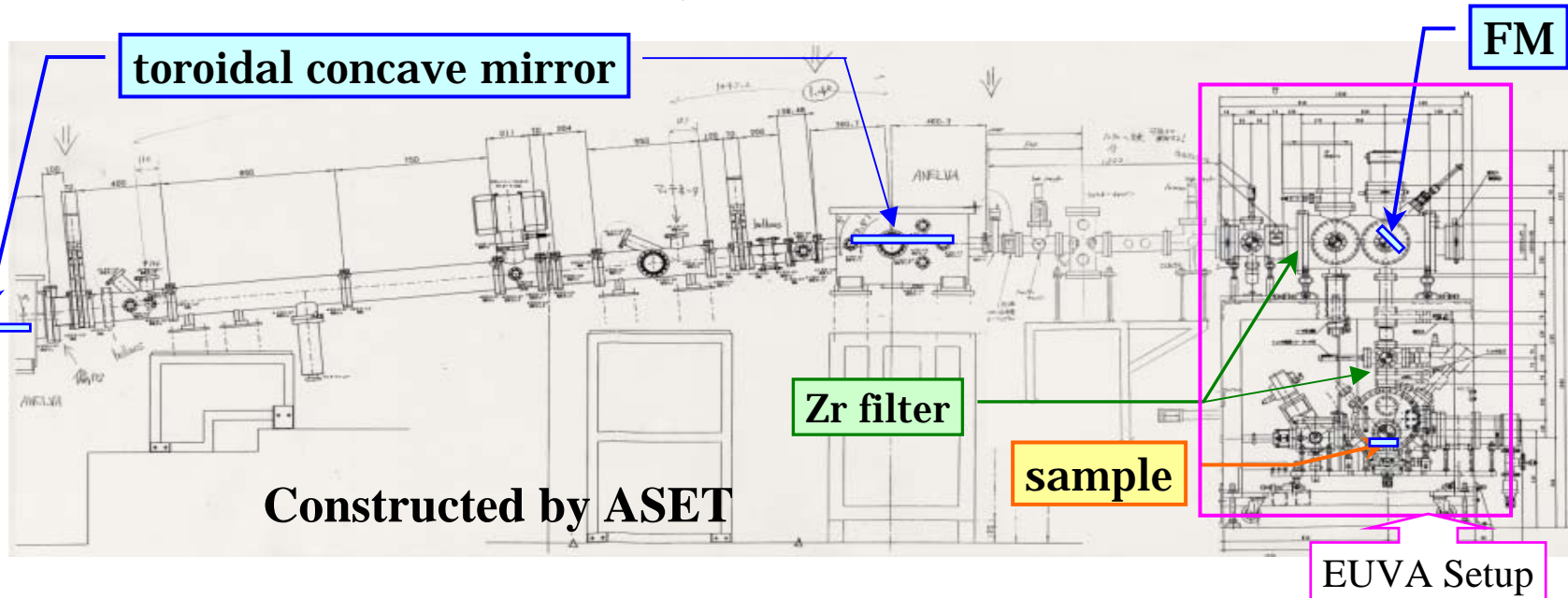
Research Laboratories

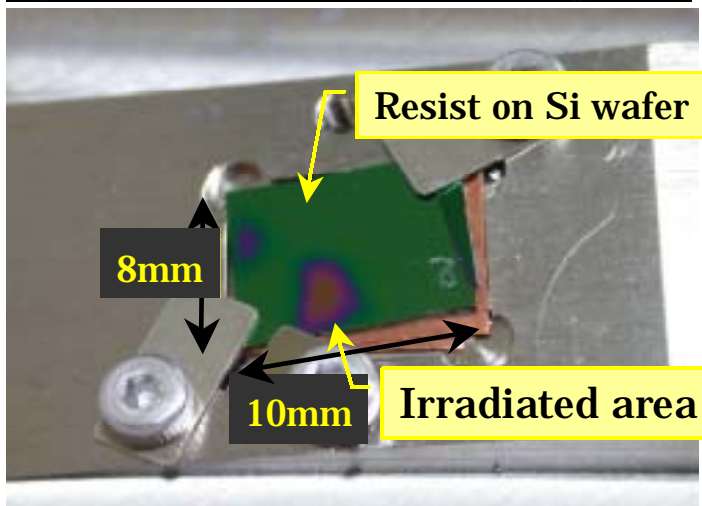
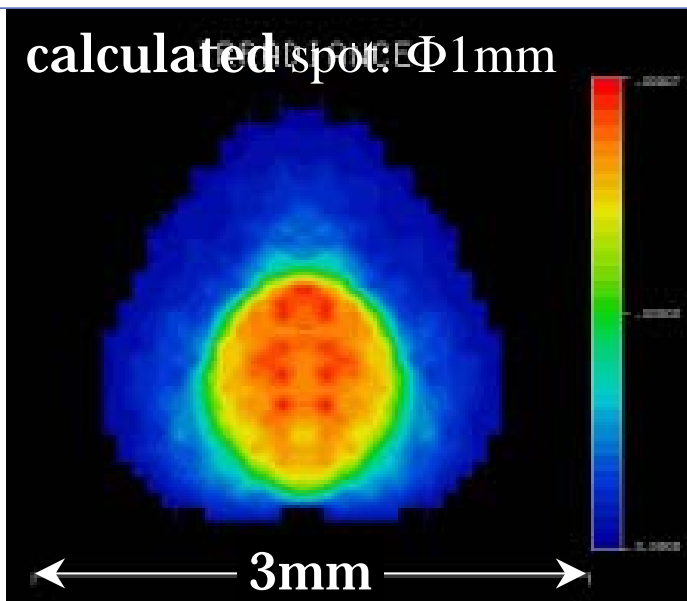
- **SR “Super-ALIS” in Atsugi (NTT)**
 - light intensity/dose dependency test
 - H₂O/C_xH_y partial pressure dependency test
 - cleaning test
- **SR+Undulator “NewSUBARU” in Himeji (Univ. Hyogo)**
high power irradiation (Undulator)
 - accelerating experiments
 - material screening

See the poster by Kakutani *et al.*
and Takase *et al.* for more details.

- ✓ Two grazing-incidence and concave mirrors with toroidal shape
- ✓ Water-cooled folding multi-layer mirror (FM) with 45 degree angle to irradiate EUV light to test piece.
- ✓ A couple of thin Zr membranes for not only monochromatic and/or neutral density filter but also bulkhead.

Calculated EUV beam intensity is about 16 mW/mm^2 (see next page)





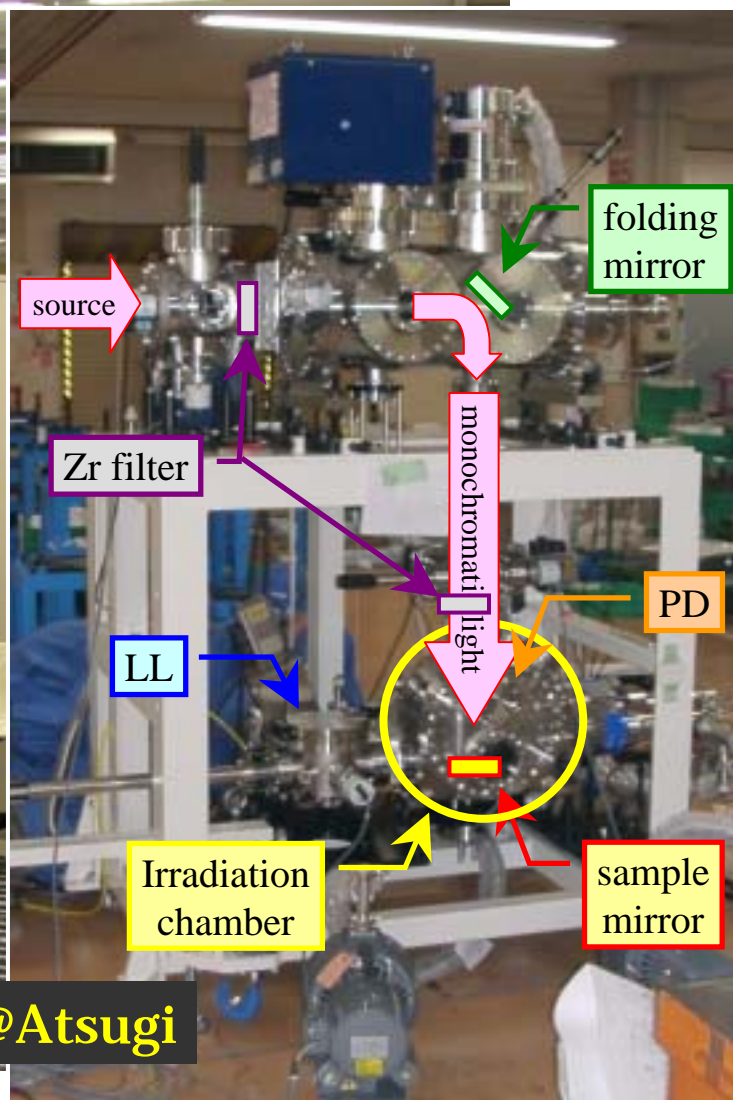
Estimation of EUV intensity on TP

- Light source: $\Phi 1.6\text{mm}$
- Solid angle: H35mrad, V1mrad
- SR Current: 500 mA
- Electron energy: 0.6 GeV
- Two grazing-incident mirrors
- One multi-layer folding mirror
- Two Zr filters for band restriction

16 mW/mm²

40 times greater than those
on exposure tool mirror surface

Intensity measurement has not made yet.



Super-ALIS beam-line & Apparatus @Atsugi

- ✓ System is constructed with UHV components and has no plastic components to mitigate the $\text{H}_2\text{O}/\text{C}_x\text{H}_y$ outgassing.
- ✓ Reflectance can be evaluated with photo-diode (IRD SXUV). Direct EUV light can be also monitored with the identical PD.
- ✓ Cryo-sorption pump is mounted to mitigate H_2O pressure.
- ✓ Water vapor partial pressure control: $1\text{E}-6\sim 1\text{E}1$ Pa
- ✓ Load-lock chamber is attached to put in or take off test pieces.
- ✓ EB irradiation, UV lamp and $\text{H}_2\text{O}/\text{C}_x\text{H}_y$ gas introduction sub-systems can be mounted.



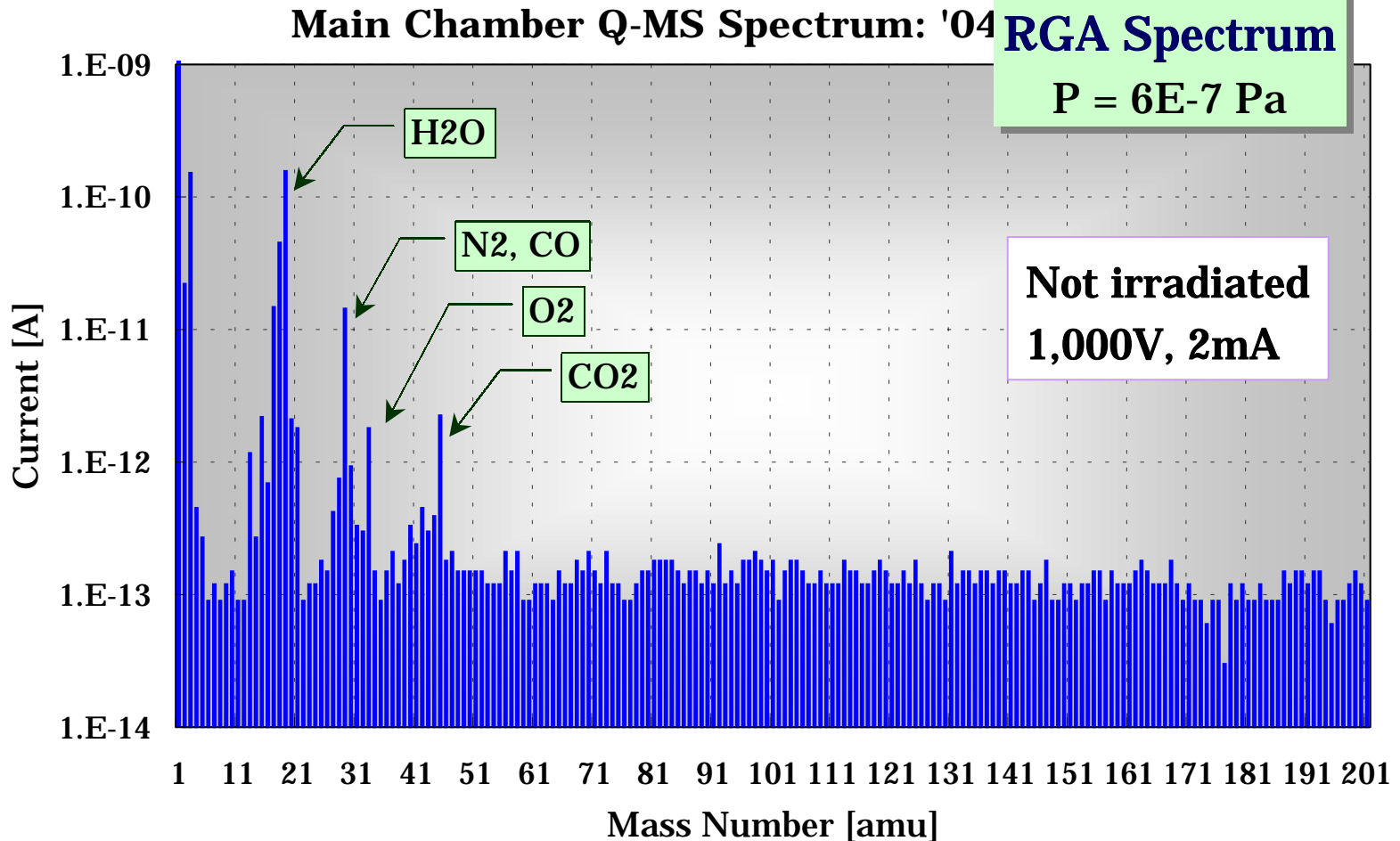
Degree of vacuum
 $5\text{E}-7$ Pa ($3\text{E}-9$ Torr)
is achieved after
23 hours baking.

Test Piece

- ✓ Si/Mo 50 pairs on Si wafer.
- ✓ With/without Si, Ru & other capping layer
- ✓ Anti-diffusion layer

Analysis

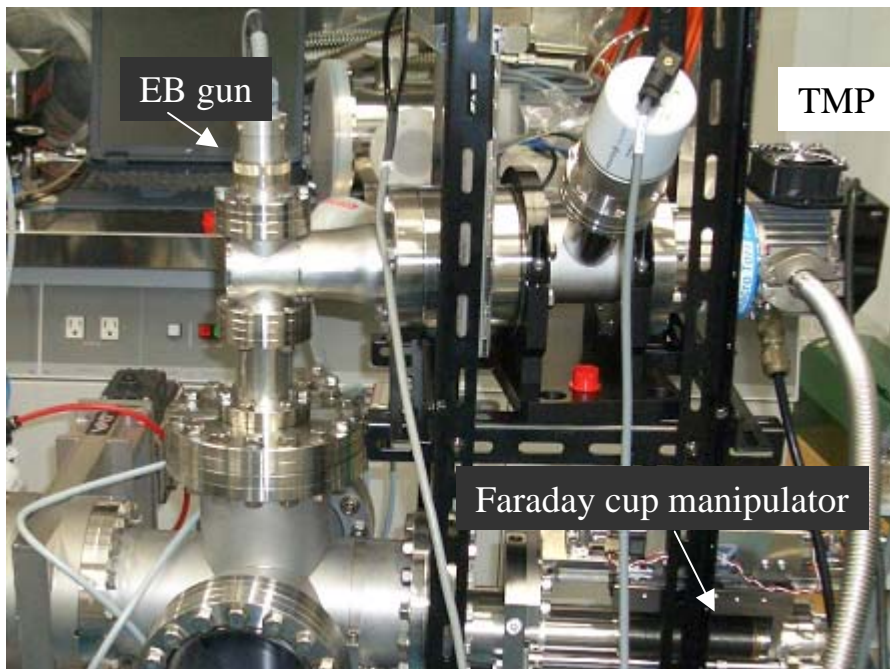
- ✓ On-line (in-situ) analysis
EUV reflectance evaluation
- ✓ Off-line (ex-situ) analysis
Surface analysis with XPS
(AES), SIMS, AFM, ...



No significant C_xH_y peak (>45amu)

EB irradiation & differential pumping with buffer chamber

- ✓ Oxidation test with water vapor introduction
- ✓ Capping material screening
- ✓ Carbon film formation with C_xH_y gas introduction



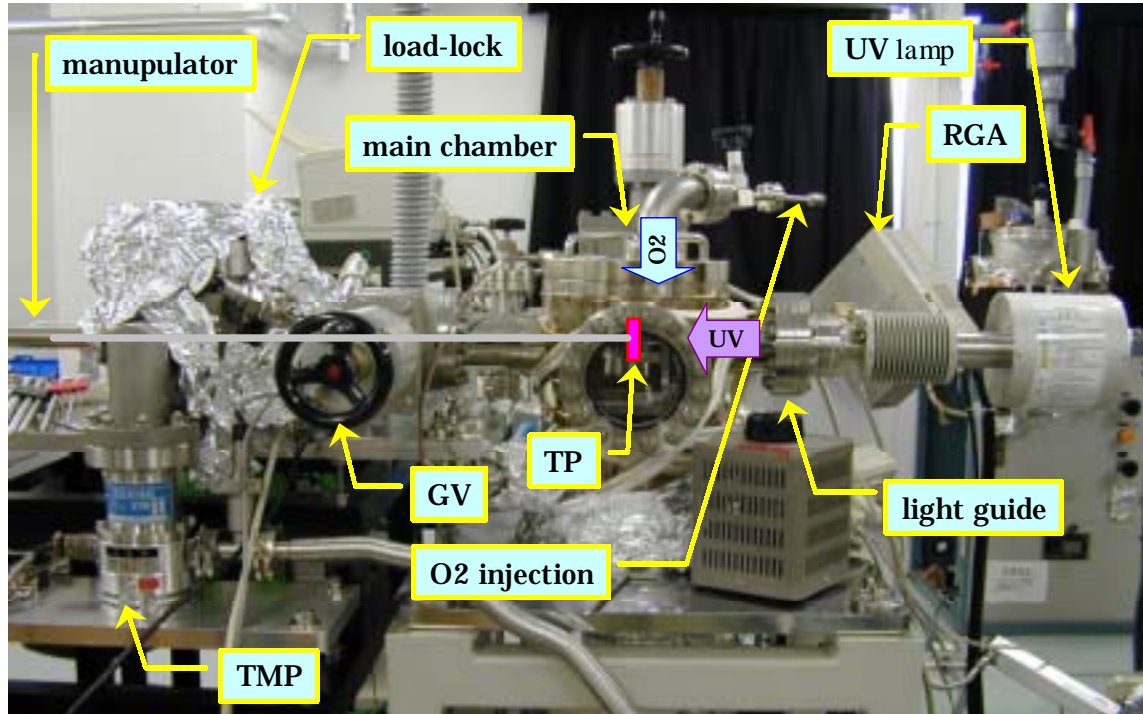
Performance

- Accel. Voltage: 1 kV (max)
- Beam size: $\Phi 400 \mu\text{m}$
- Current Density: under measurement.
- Scanning available

Just completed
Under inspection

Removing carbon film with UV exposure under O_2 containing condition

- ✓ Estimation of cleaning speed and surface damage
- ✓ Dependency to O_2 partial pressure, light intensity, dose, cap material (Ru/Si)

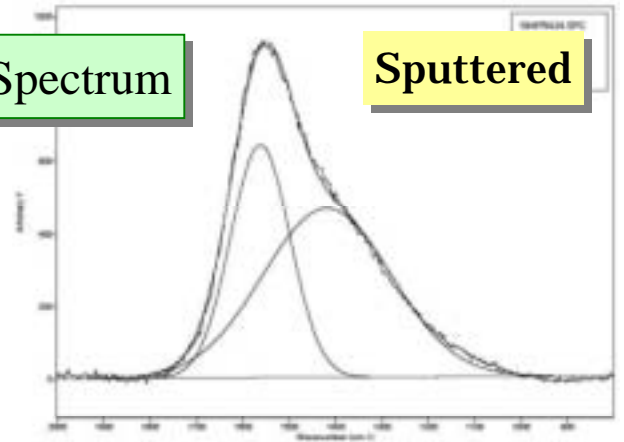


Performance

- Xe_2 excimer lamp (172nm)
- Intensity: 50 mW/cm² (max)
- Residual gas pressure: 2E-6 Pa
- O_2 pressure: 1E-1~1E3 Pa

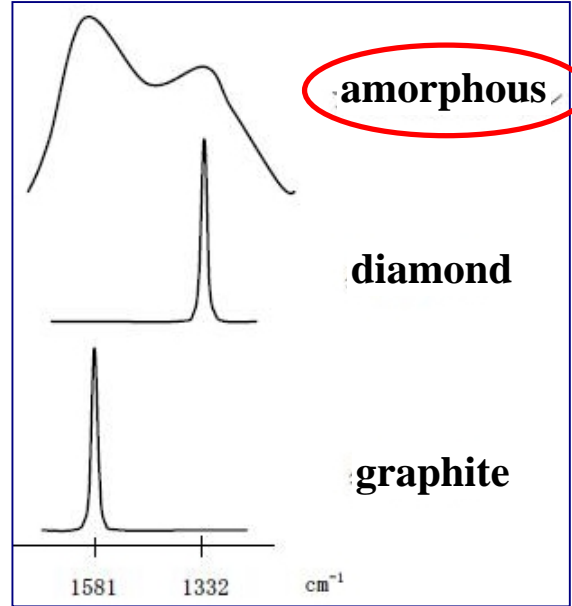
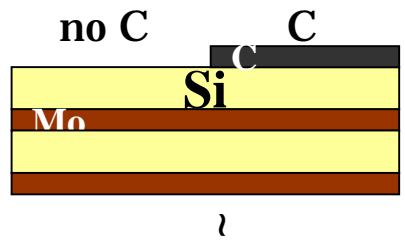
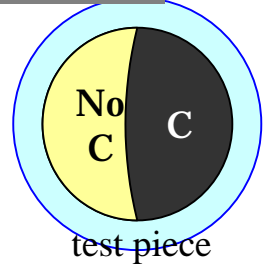
Cleaned C film	sputtered: 1nm
O ₂ pressure	100 Pa
UV intensity	1.5 mW cm ⁻²

Raman Spectrum



Sputtered

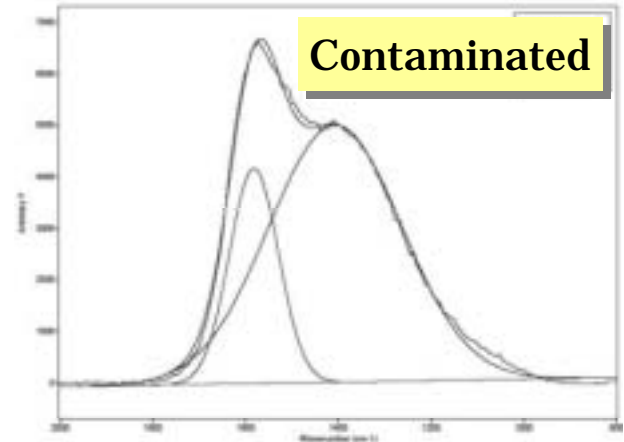
Test Piece



amorphous

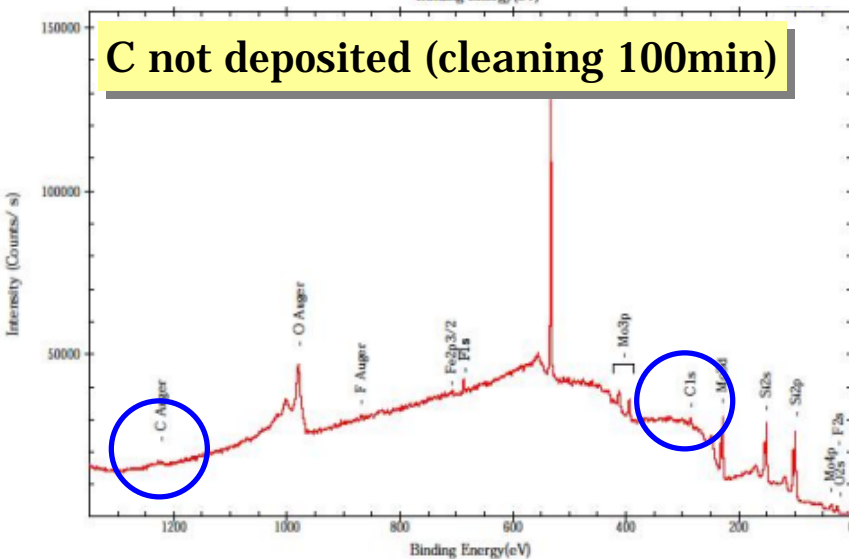
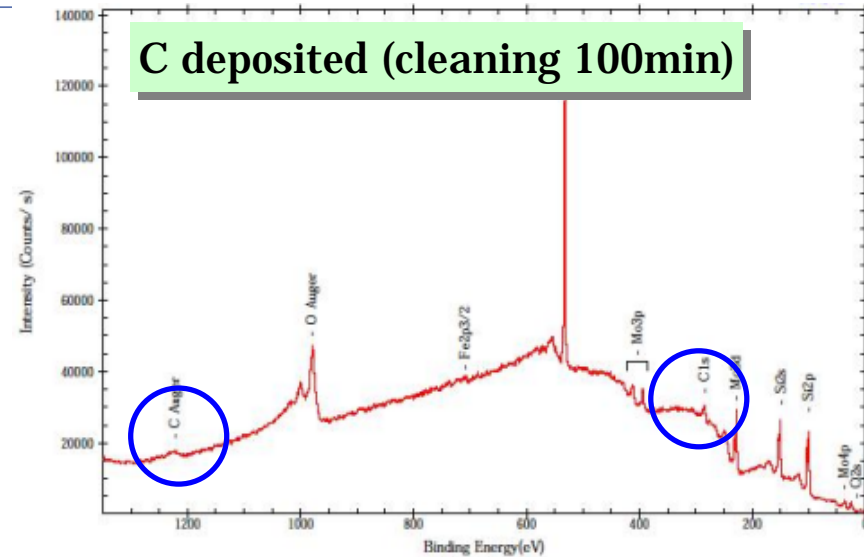
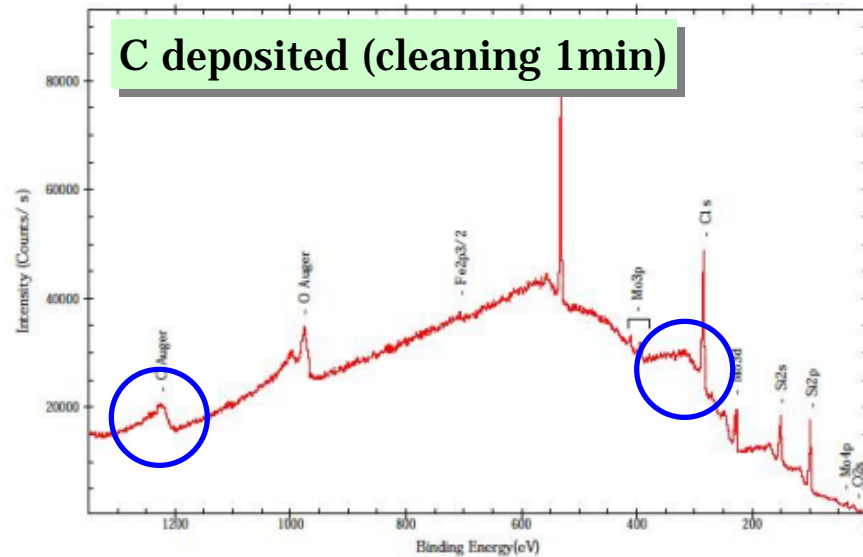
diamond

graphite



Contaminated

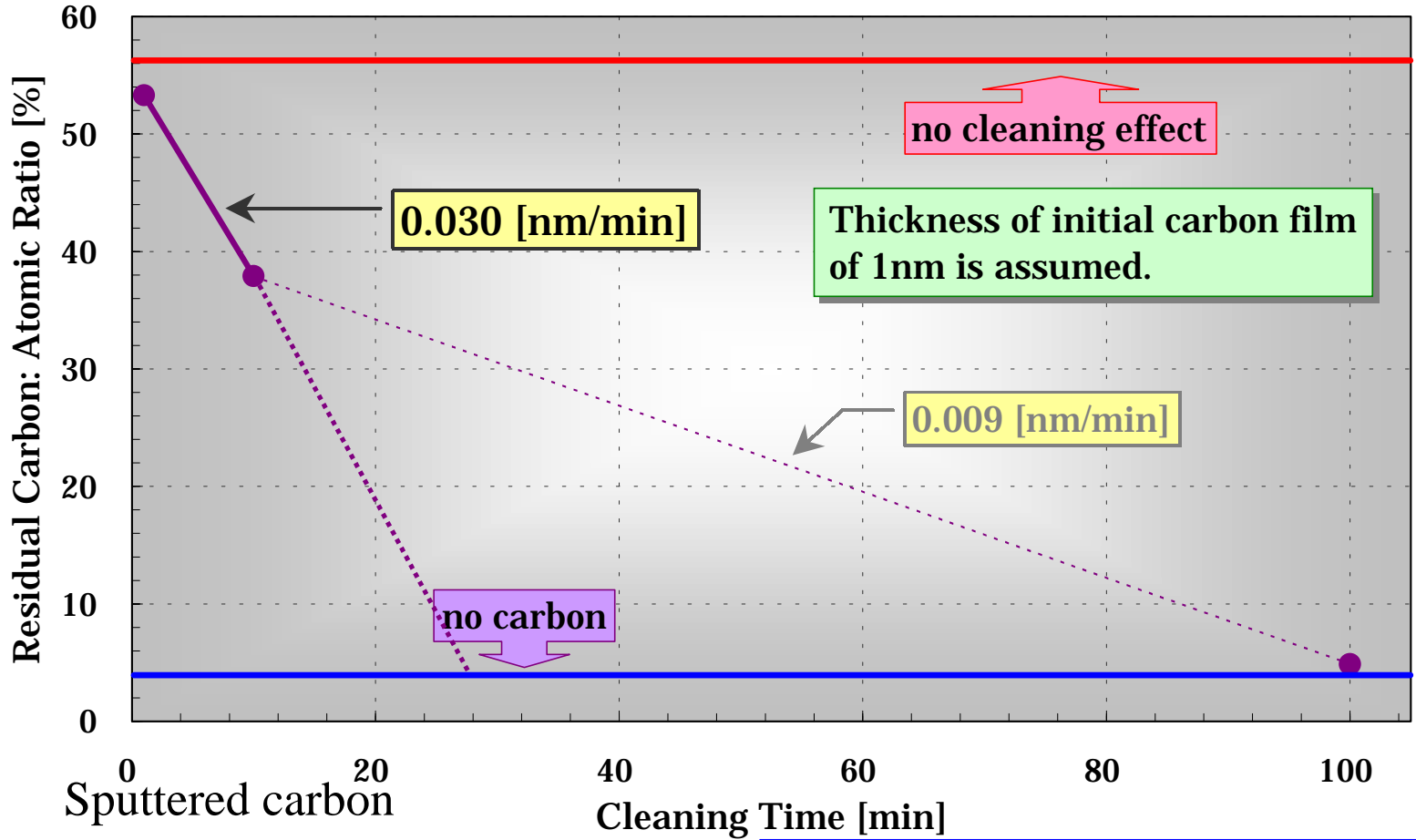
- Both of them are in amorphous states.
- Sputter carbon can be replaced to contaminated carbon.



- No significant peak on no carbon and C deposited area with 100m cleaning
- Significant peak on C deposited area with 1m cleaning

Cleaning effect is evident

UV+O₂ Cleaning Rate: Si ratio corrected



0 Sputtered carbon

O₂ pressure: 100 Pa

UV intensity: 3.9 mW/cm²



Cleaning Rate: ~0.03 nm/min

- **Capping Layer (Resistant to Surface Oxidation)**
 - ✓ Study of oxidation reduction with Si and Ru cap will be focused in near future.
 - ✓ Listing up and screening of capping layer materials will be performed within a few months.
 - ✓ Long term stability test
- **Mitigation of Carbon Deposition/
Cleaning of Carbon Film**
 - ✓ EUV light cleaning with oxygen
 - ✓ UV light cleaning with lower pressure O₂
 - ✓ Surface damage examination after cleaning

➤ **Our Apparatus was Installed onto NTT Synchrotron Facility “Super-ALIS”**



- ✓ Setting-up is almost completed.
- ✓ Preliminary experiments has just started.

➤ **Preliminary Experiments has just Started.**

- ✓ Very good degree of vacuum ($5\text{E-}7$ Pa) is achieved.
- ✓ RGA spectrum shows very low C_xH_y pressure in the chamber.
- ✓ The results indicate UV light cleaning under O_2 containing condition is effective. Cleaning rate is estimated to be about 0.03 nm/min in 100 Pa O_2 .

➤ **Future Work**

- ✓ We will concentrate on the study of oxidation using Si and Ru capped multi-layer mirror.

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