# Characterization of capped multilayer mirror using XPS and AES

Extreme Ultraviolet Lithography System Development Association (EUVA) contamination research group
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# Background

•It is necessary to find out how to accelerate the change of reflectance by oxidation because the oxidation rate is low.

• The effect of atmosphere being introduced $H_2O$ and powerful EUV light from a long undulator at NewSUBARU of the University of Hyogo for such above acceleration were investigated.

• The sample with carbon layer at the surface of mirror was characterized by X-ray photoelectron spectroscopy (XPS) and Auger electron spectroscopy (AES).

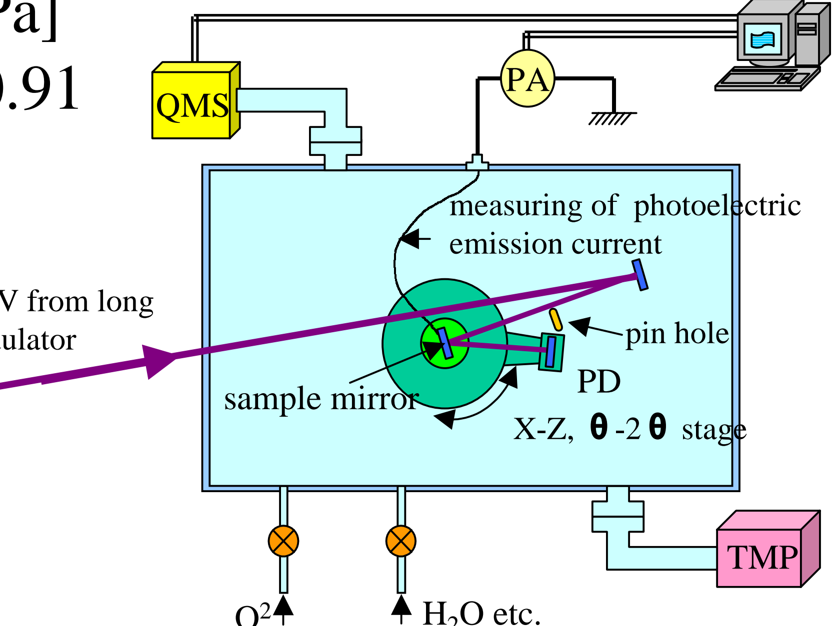
# Purpose

- To estimate surface composition and chemical states of Si and Mo.
- To clear how much of multilayer was oxidized by irradiation.
- To clear how much of carbon was removed and whether carbon was taken into oxide layer under coexistence of activated species of carbon and oxygen or not

# Sample and experimental condition

Sample : C/ Si(4.2nm)/ [Mo(2.8nm)/Si(4.2nm) ]50pairs / Si
carbon was deposited by EUV irradiation.

Beam line : NewSUBARU BL9 (long undulator)
EUV intensity : 60mW/mm$^2$
EUV dose : 630J/mm$^2$
$H_2O$ partial pressure : 1.3 x 10$^{-3}$ [Pa]
$C_xH_y$ partial pressure : 3 x 10$^{-8}$ [Pa]
Final relative reflectance ($R/R_0$) : 0.91
( initial relative reflectance is 1.0)



# XPS/AES analytical condition

**XPS**

Instrument : Quantum2000 (PHYSICAL ELECTRONICS)
X-ray:Al-kα 25W  analyzed area:100μmφ
detected photoelectron : $Si_{2p}$, $Mo_{3d}$, $O_{1s}$, $C_{1s}$

**AES**

Instrument : PHI-680 (PHYSICAL ELECTRONICS)
acceleration voltage: 10kV  current: 10nA
detected Auger electron : $Mo_{MNN}$, $Si_{LMM}$, $C_{KLL}$, $O_{kLL}$
ion sputtering:
ion species: $Ar^+$  acceleration voltage: 1kV
sputter rate: 0.2nm per min for $SiO_2$

# Change of surface composition after EUV irradiation

x10³

initial C O

Intensity: 2.5, 2, 1.5, 1, 0.5

1000 800 600 400 200 0 -200

Binding energy (eV)

x10³

irradiated O Mo Si C

Intensity: 6, 5, 4, 3, 2, 1

1000 800 600 400 200 0 -200

Binding energy (eV)

XPS indicated Carbon reduced from 83% to 19% and oxygen increased from 13% to 53% under EUV irradiation under $1.3 \times 10^{-3}$ Pa of $H_2O$. The finally remained carbon was little more than one of fresh sample without deposition of carbon.

# Chemical state of Si after EUV irradiation

x10$^3$
3.5
3.0
2.5
2.0
1.5
1.0
0.5
Intensity
initial
$Si_{2p}$
metal
oxide
115 110 105 100 95
Binding energy (eV)

x10$^3$
3.0
2.5
2.0
1.5
1.0
0.5
Intensity
irradiated
$Si_{2p}$
oxide
metal
115 110 105 100 95
Binding energy (eV)

XPS indicated Si capping layer was composed of 99% $SiO_2$ and 1% Si even after irradiation under $1.3 \times 10^{-3}$ Pa of $H_2O$.

# Chemical state of Mo after EUV irradiation

x10^3
initial
3.0
2.5
2.0
1.5
1.0
0.5
Intensity
240 235 230 225
Binding energy (eV)

x10^2
irradiated
$Mo_{3d}$
12
11
10
9
8
7
6
Intensity
240 235 230 225
Binding energy (eV)

XPS indicated irradiated $Mo_{3d}$ was able to be fit in same parameter as initial, so Mo seemed to be stable even after irradiation under $1.3x10^{-3}$ Pa of $H_2O$.

# Depth profile of C, O, Si, Mo

initial

3nm

C

Si

Mo

O

Atomic concentration (%)

Sputter time (min)

irradiated

0.3nm

3nm

O

Mo

C

Si

Atomic concentration (%)

Sputter time (min)

AES indicated almost carbon was removed and the removed carbon seemed not to be taken into the Si oxide. Si oxide layer grew up to 3nm thickness.

# Analysis of chemical state of Si in AES

Sample No.5
AES Depth profile
Processed data ( TFA analysis )

Mo
O
C
Si
( Oxide Si? )
Si
( Metal Si? )

Derivative Peak Height

Sputter Time ( min. )

Distribution of Si oxide and Si metal was derived from AES depth profile by Target Factor Analysis (TFA) in trial. Si metal was detected at the interface of Si oxide and Mo layer.

# Summary

- Change of surface composition and chemical states of Si capping multilayer mirror, on which carbon was deposited in EUV, was characterized after irradiation of high power EUV under $1.3 \times 10^{-3}$ Pa of $H_2O$.
- Si metal still remained in Si capping layer and Mo seemed not to be oxidized even after irradiation under $1.3 \times 10^{-3}$ Pa of $H_2O$.
- Almost contaminated carbon was removed, but the removed carbon seemed not to be taken into the oxide layer while oxide grew up in irradiation.

# Acknowledgement

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