Advanced process for Mo-Si multilayer formation using assisted ion beam for EUVL mask blanks

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1. Introduction

1.1 Background

* High-reflectivity and low-defect-density mask blanks are required for fabrication of LSIs by EUV lithography.
* Important specifications for multilayer mask blanks

Semi P38-1102 specification

Table 5 Peak EUV reflectivity of multilayers

Class	Mean peak reflectivity
A	> 67 %
B	65 - 67 %
C	63 - 65 %
D	60 - 63 %

We have achieved class *B* specification with 40 Mo-Si bilayers

K. Hiruma, et al., SPIE vol. 6151, 61511V-7.

Semi P38-1102 specification

Table 13 Defect count of multilayers

Class	PSL equivalent size range (nm)	Maximum defect count
A	> 25	0
B	> 30	0
C	> 40	0
D (Test)	> 60	Agreed upon between user and supplier

Defect count as low as 1 defect/cm^2 @70 nm has been achieved for 40 Mo-Si bilayers

H. Yamanashi, et al. 2nd EUVL Symposium, Antwerp, Belgium, 30 Sep.-2 Oct. 2003.

1.2 Contents

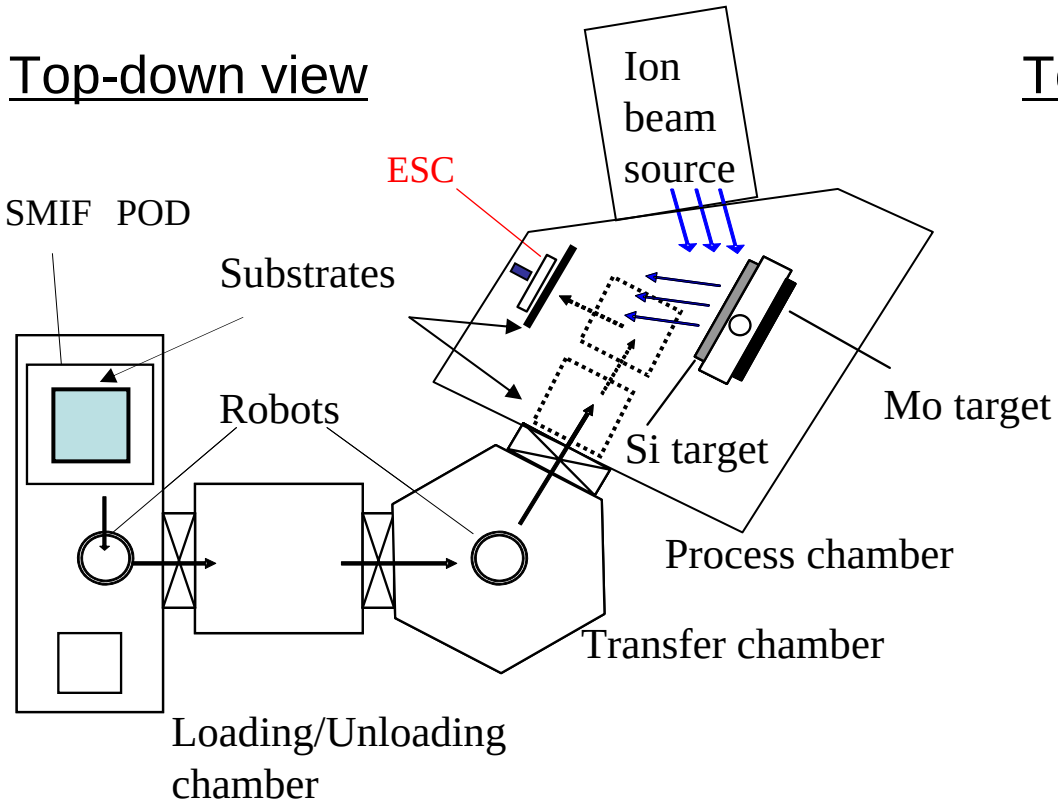
To improve performance of Mo-Si multilayers for mask blanks,

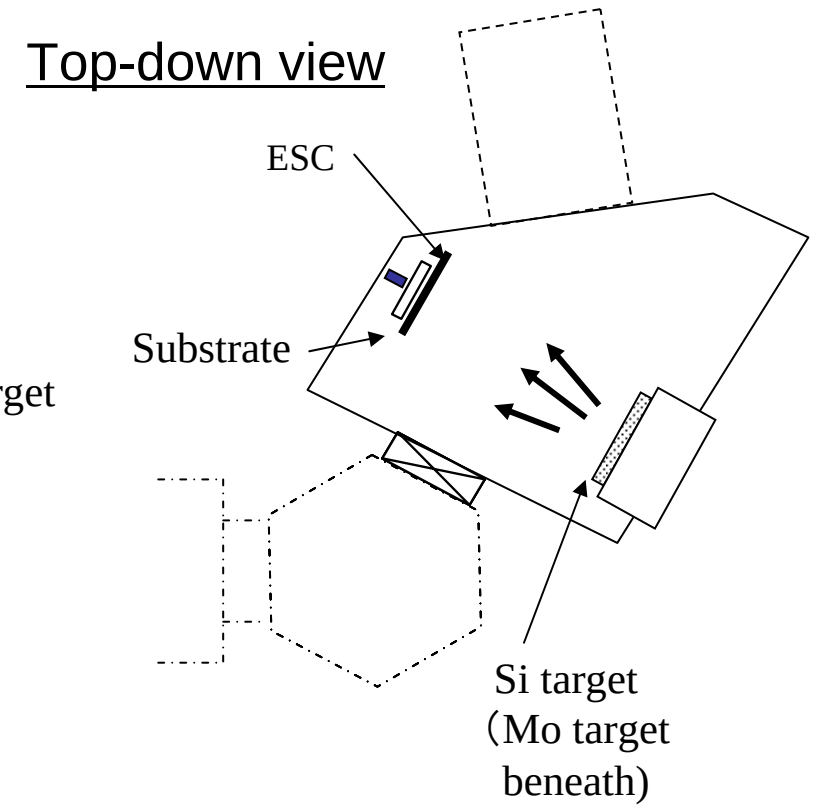
1) Analyze the interface of Mo-Si multilayers grown by using ion-beam and magnetron sputterings
2) A new surface treatment during coating process to decrease the interface layer thickness and maintain smooth interface

2. Mo/Si multilayer growth system

Ion beam sputtering (IBS)

Magnetron sputtering (MS)

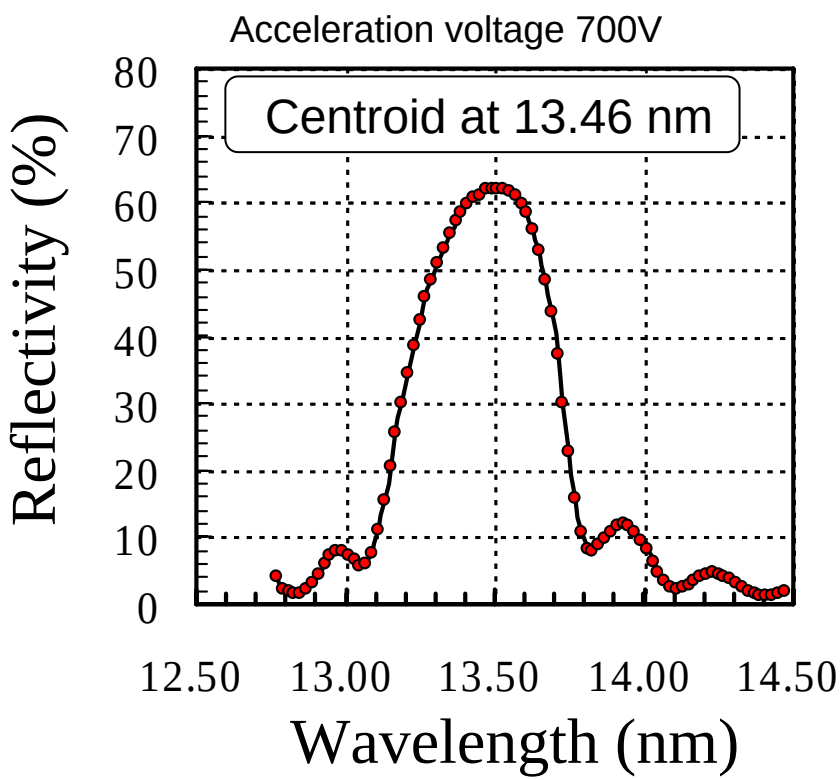


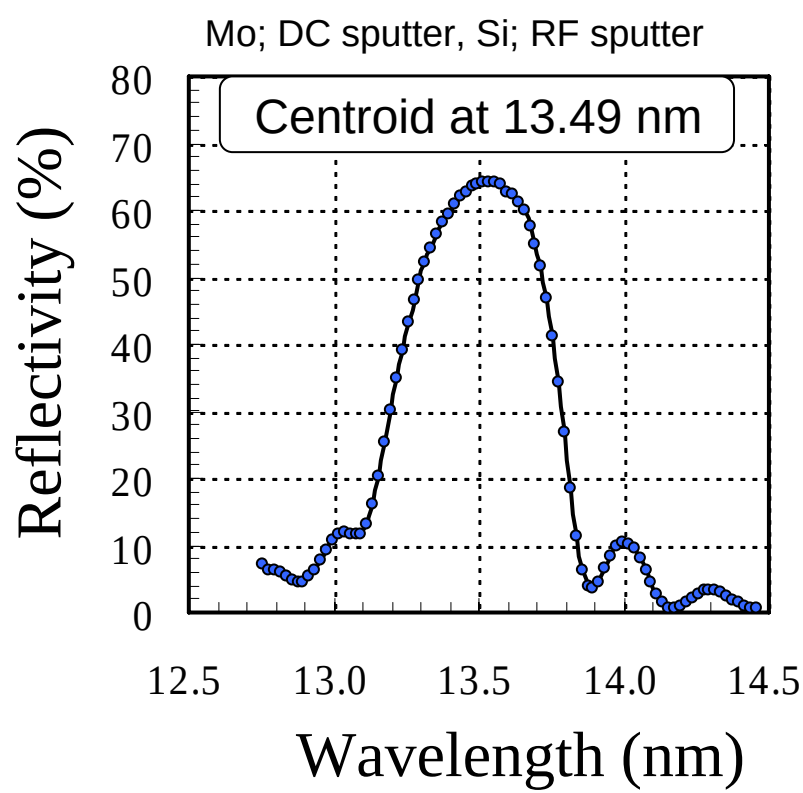


3. EUV performance

IBS: 40 Mo-Si bilayers

MS: 40 Mo-Si bilayers





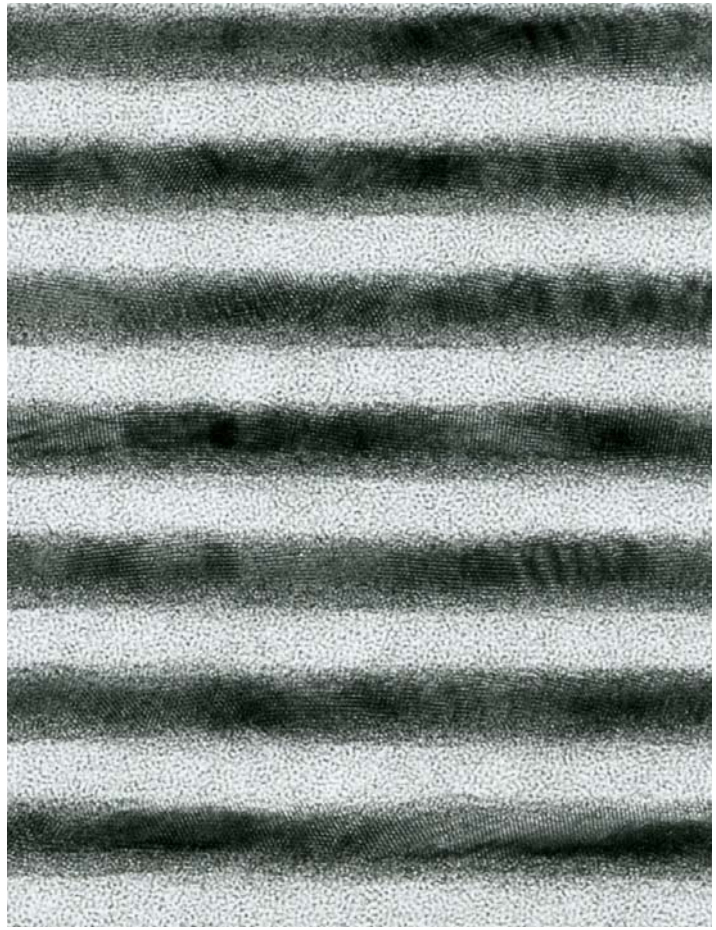
K. Hiruma, et al., SPIE vol. 6151, 61511V-7.

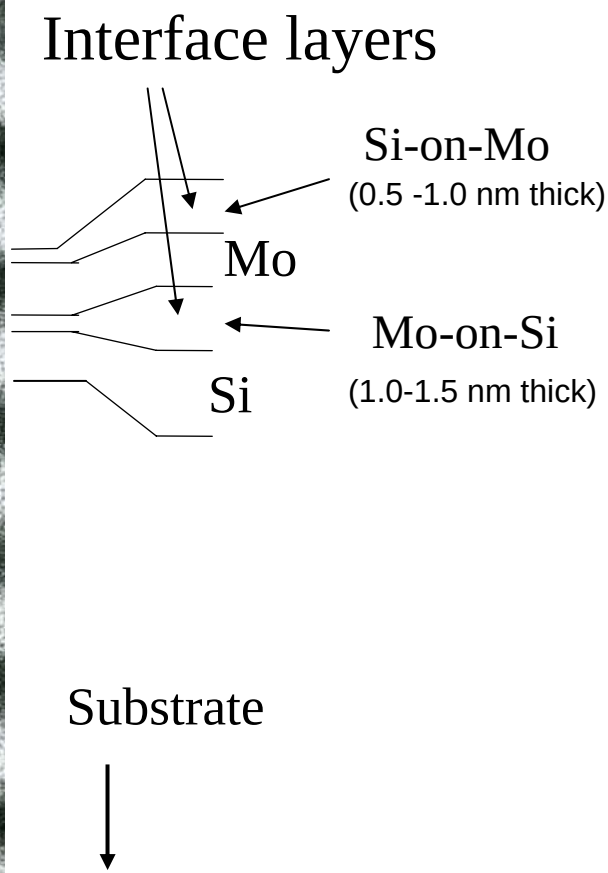
4. Analysis of Mo/Si interfaces

4.1 TEM analysis

MS

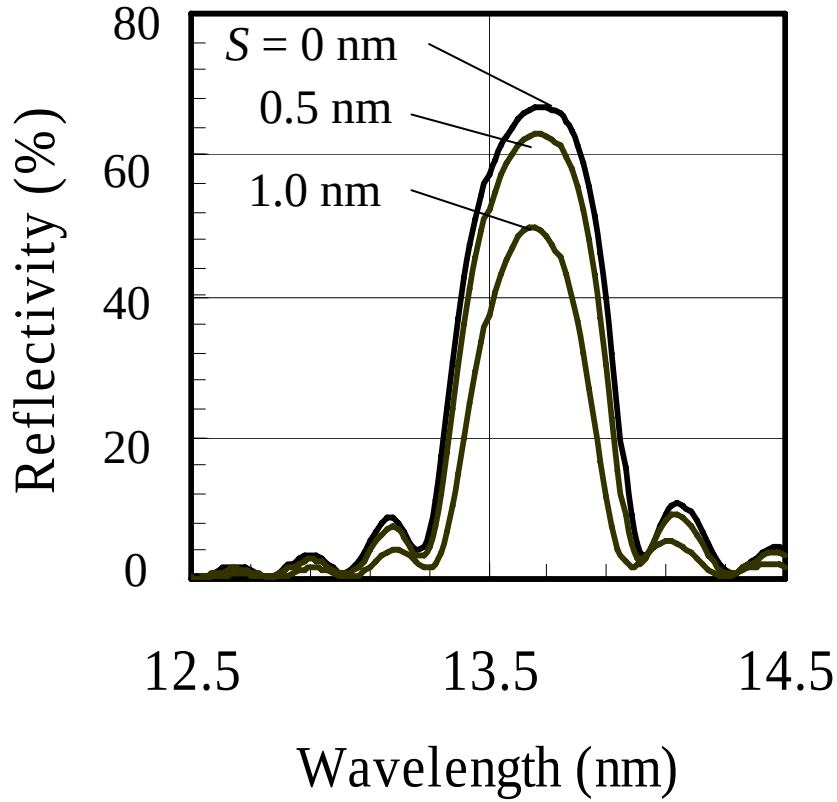
40 Mo-Si bilayers





10 nm

Effect of interface layer thickness on EUV reflectivity



To understand the experimental results on EUV reflectivity,
we should take following parameters into account

Parameters used for calculation

Ar impurity 1.0 at % (RBS)

Mo = 8.0 g/cm^3, Si = 2.3 g/cm^3 } (GIXR)

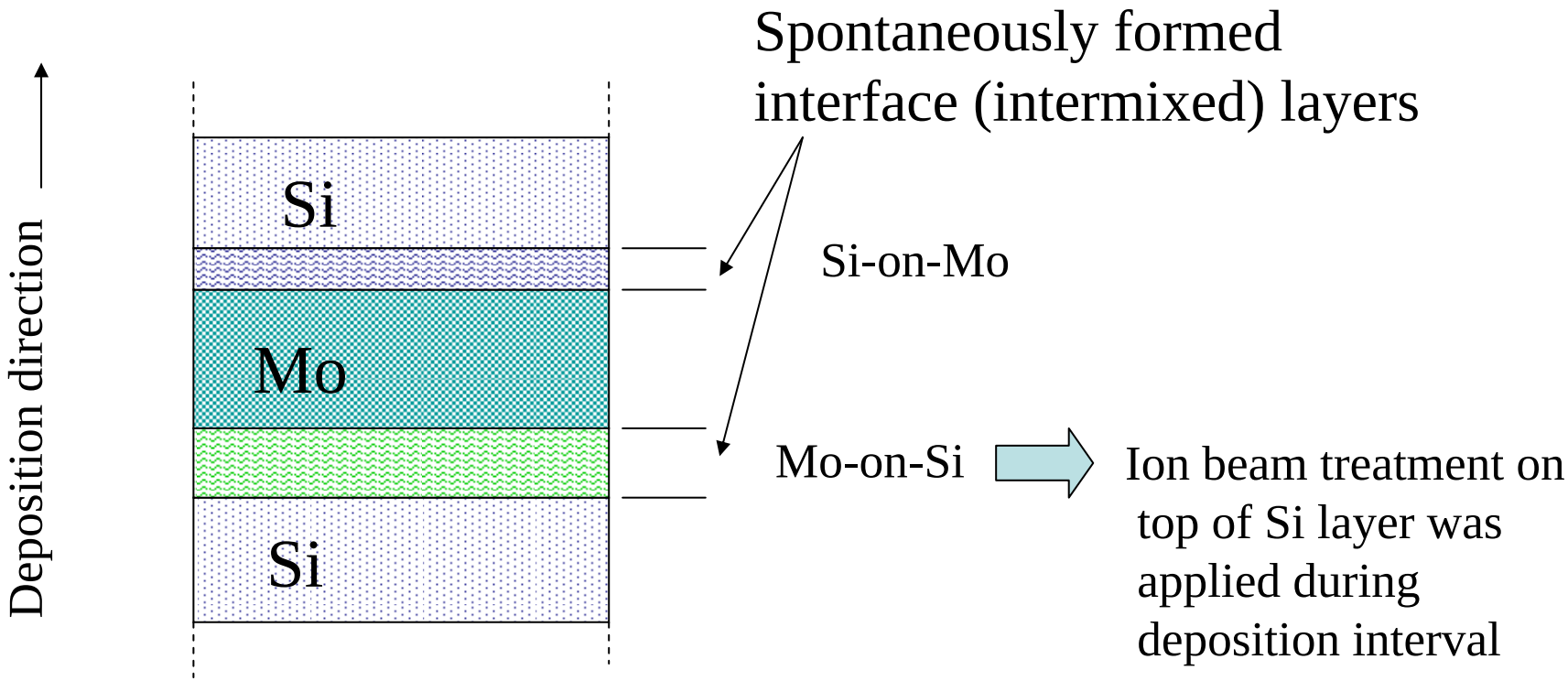
The thickness of interface layers, at Mo-on-Si and at Si-on-Mo, are considered to be equal in this model.

(*s*: interface (intermixed) layer thickness at Mo-Si interface)

calculated using CXRO web-based simulator

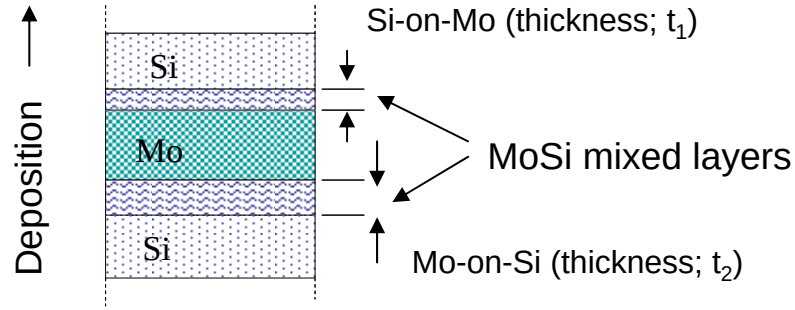
5. Interface treatment during sputtering

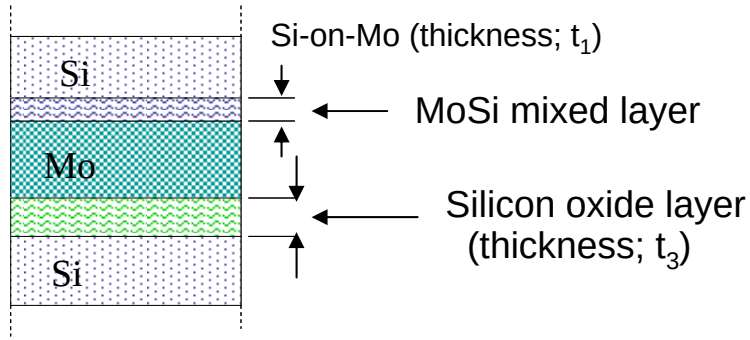
To reduce the thickness of the interface layer, ion beam treatment was carried out.

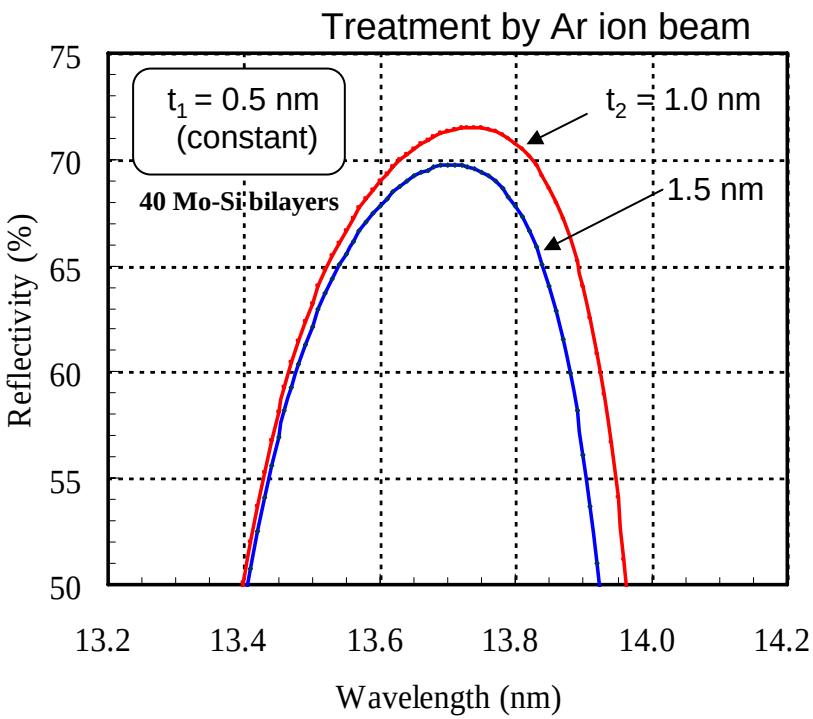


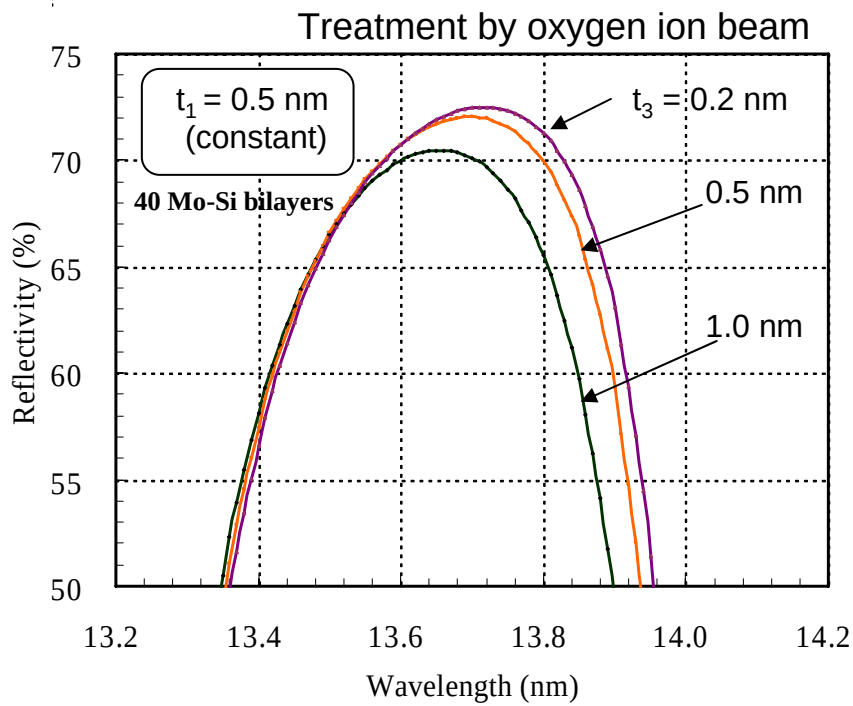
5.1 Model calculation*

* Impurity in Si or Mo, low density of Mo are not considered in the calculation for simplicity



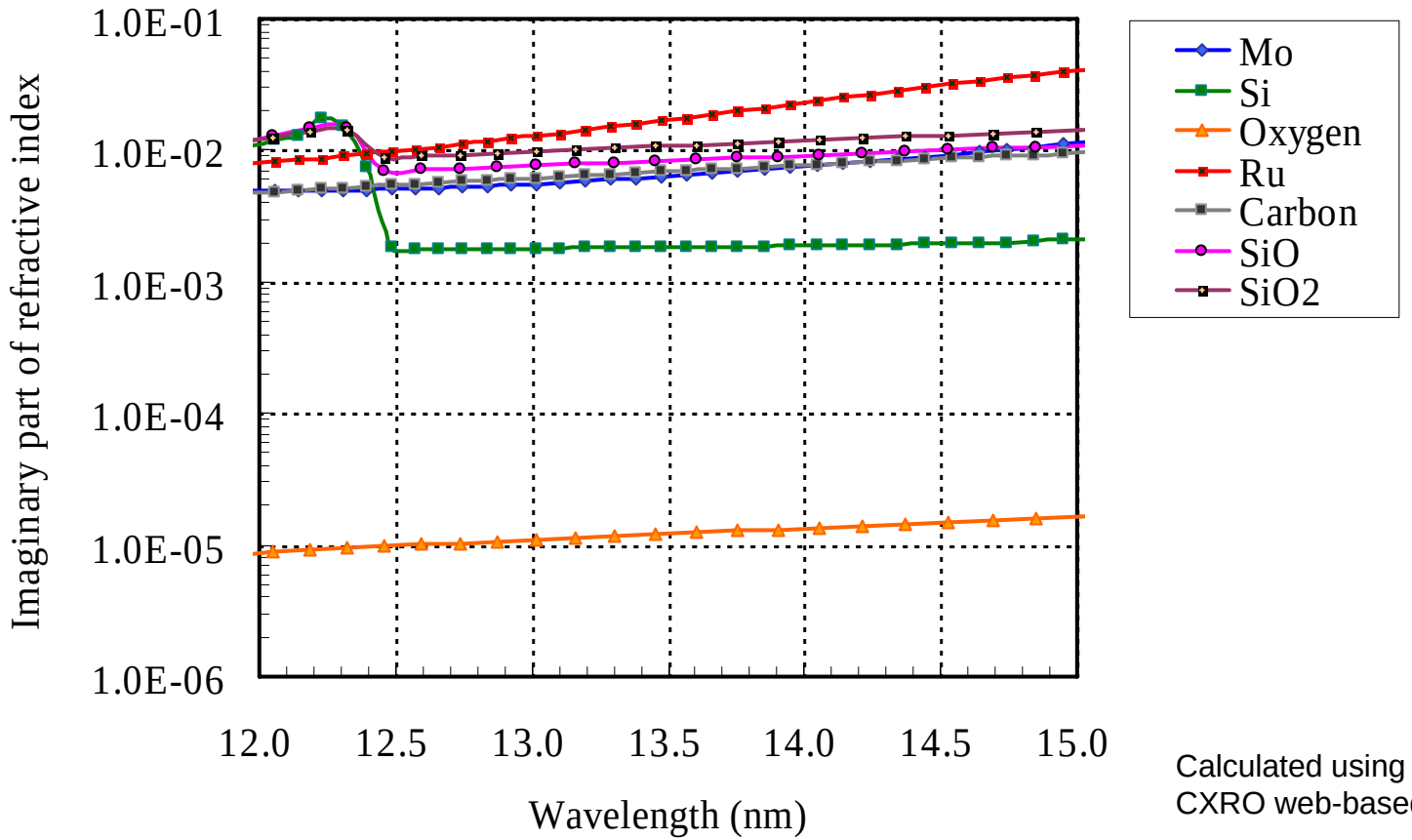






Consideration of optical absorption

Imaginary part of refractive index for related materials



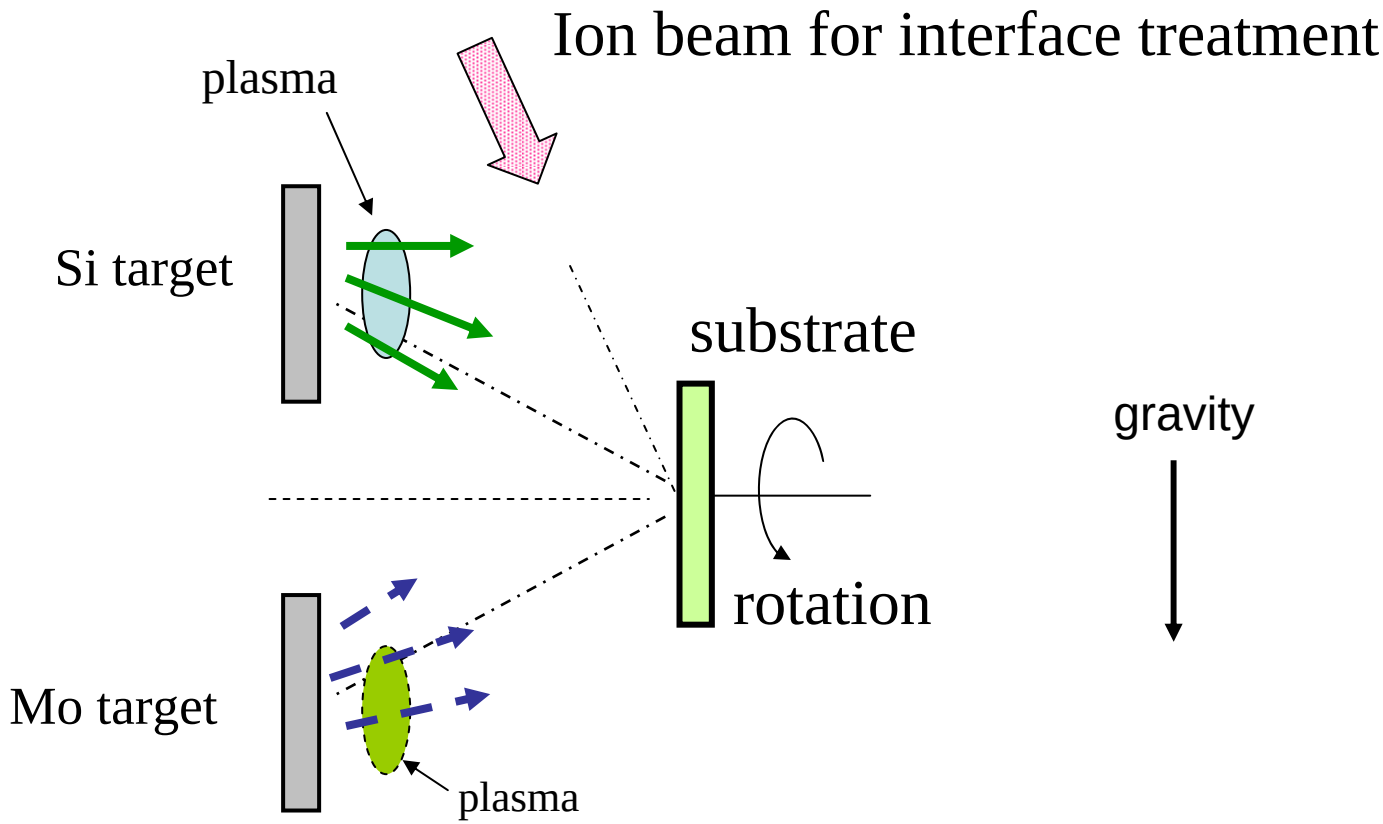
Calculated using
CXRO web-based simulator

EUV Process Technology

5.2 Improved coating system

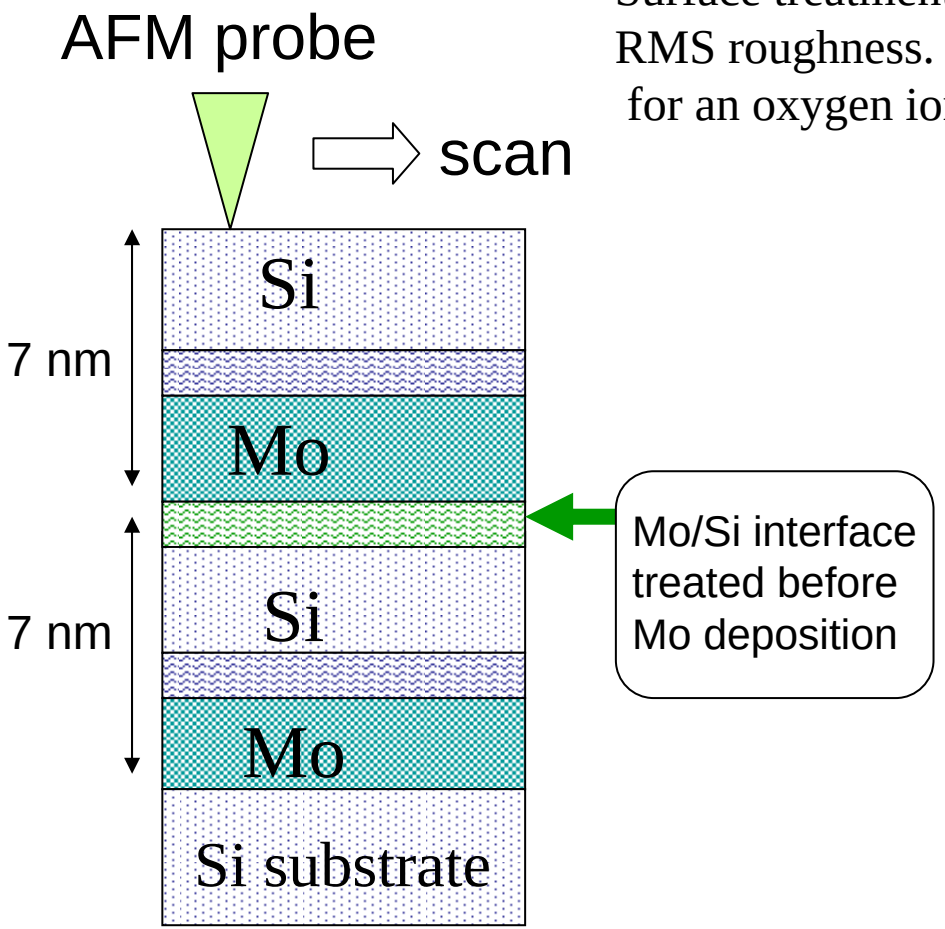
Magnetron sputtering in combination with interface treatment by ion beam

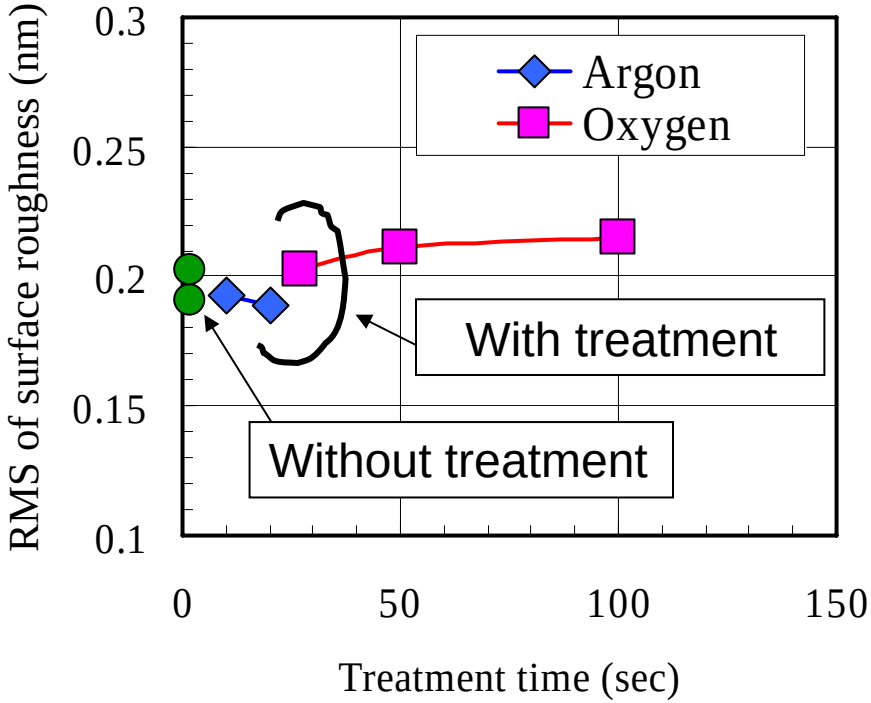
<u>Side view</u>



5.3 AFM measurement

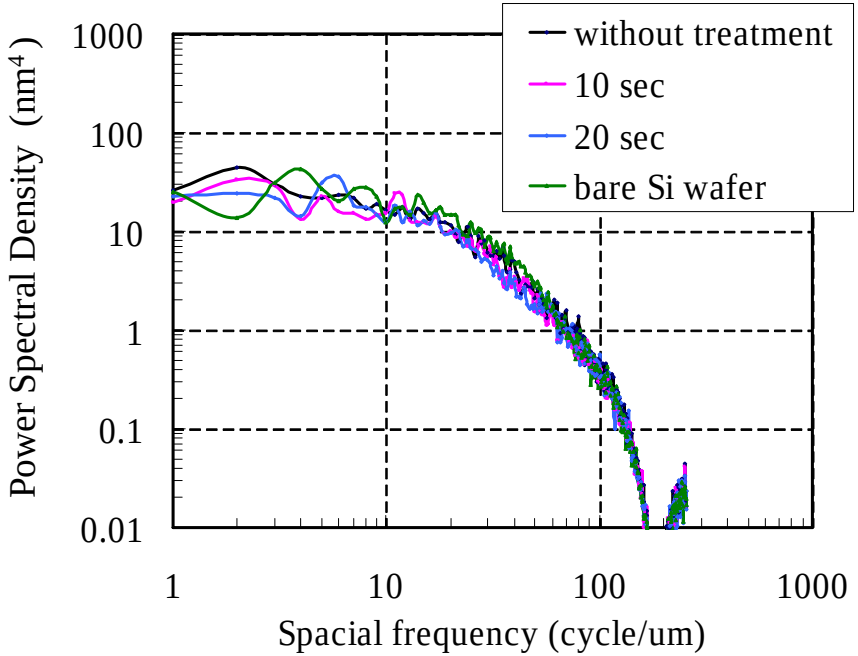
2 Mo-Si bilayer surface was measured by AFM. Surface treatment by Ar ion beam showed no degradation in RMS roughness. But the roughness was increased up to 5-10 % for an oxygen ion beam treatment.



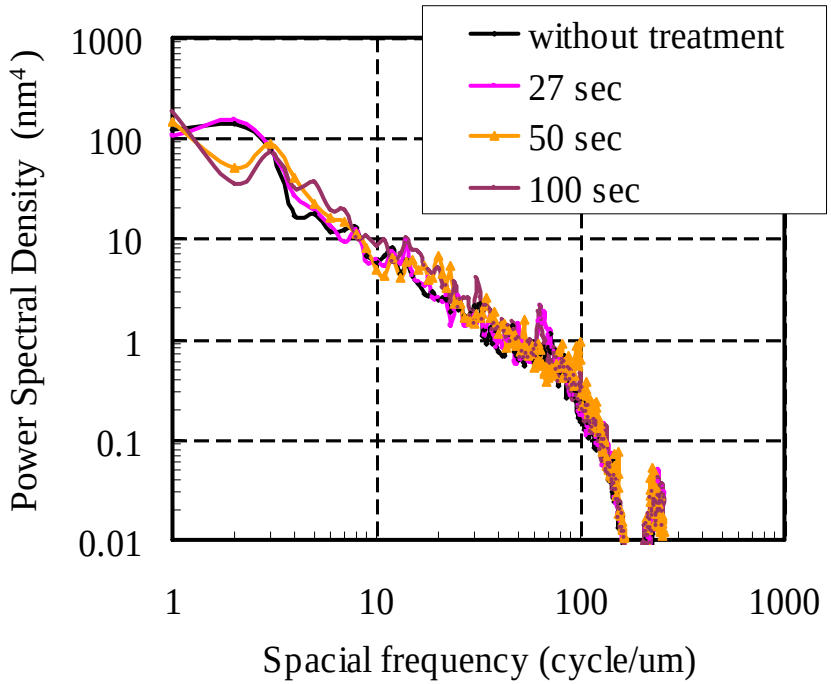


2 Dimensional isotropic Power Spectral Density (2D-PSD)

Ar ion beam treatment

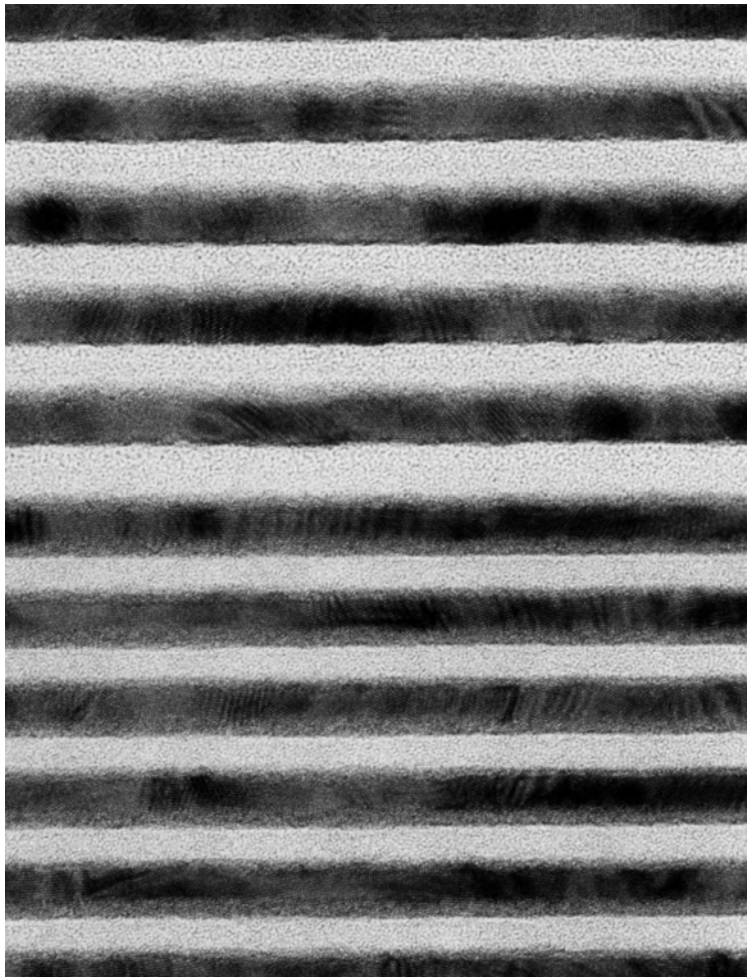


Oxygen ion beam treatment



Ion beam treatment causes no significant damage

5.4 TEM analysis of Mo-Si bilayer interfaces



Deposition direction

With treatment

Without treatment

10 nm

Mo

Ion beam treatment on Si

Interface layer (Mo-on-Si) seems to be thinned out

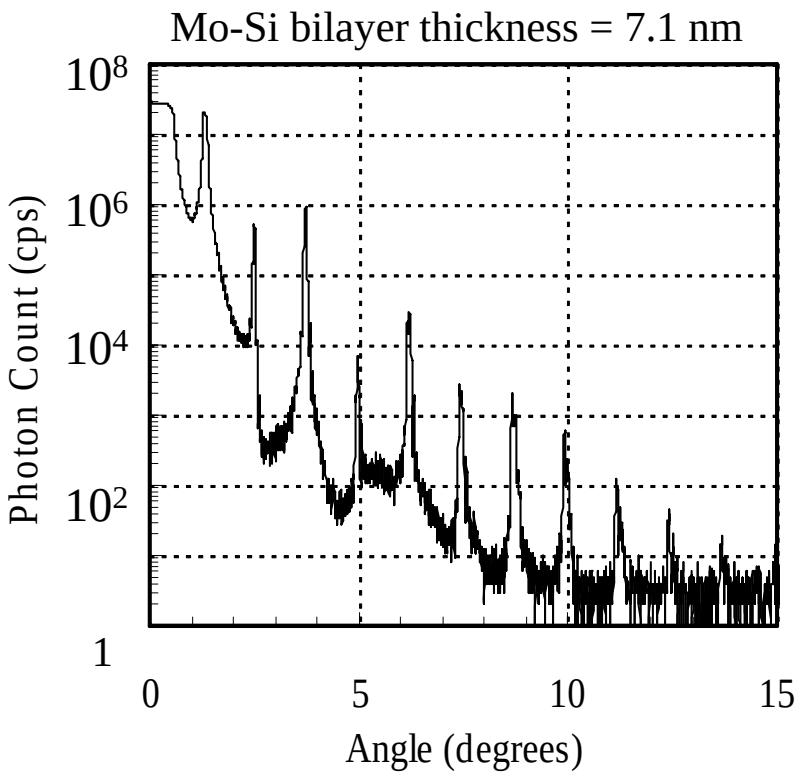
Mo

Interface layer (Mo-on-Si)

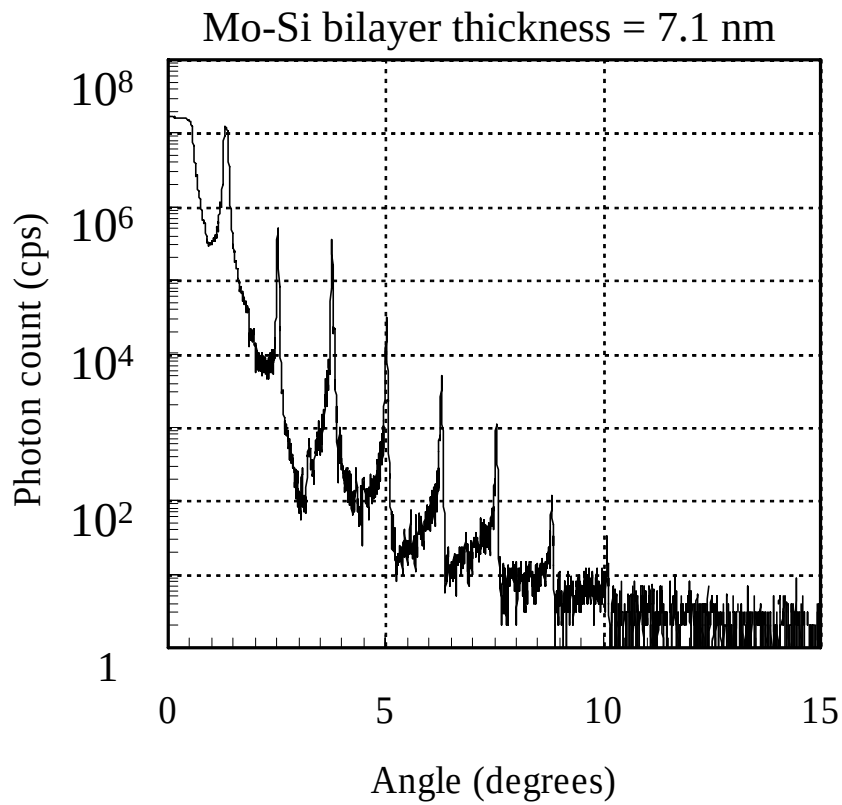
Si

5.5 X-ray diffraction (XRD) measurements for 40 Mo-Si bilayers

Without interface treatment



With interface treatment



Bilayer thickness is precisely controlled for both the bilayers with and without interface treatment

XRD peaks of Mo-Si multilayers with interface treatment are as sharp as those without interface treatment.

6. Summary

We compared the EUV performance of Mo-Si multilayers formed by magnetron sputtering (MS) and ion beam sputtering (IBS).

To reduce the thickness of MoSi intermixed layer formed during Mo deposition on Si, we adopted a new interface treatment method by using an assisted ion beam (AIB).

1. AFM measurements show little degradation in RMS roughness of ion-beam-treated Mo-Si bilayer surfaces.
2. TEM analysis shows AIB is effective in decreasing the MoSi intermixed layer thickness.
3. XRD peaks of 40 Mo-Si bilayers formed with AIB treatment are as sharp as those without AIB treatment.

We should further check EUV reflectivity.

Acknowledgement:
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