Mo/Si multilayer(ML) mirror deposited with ion beam sputtering using Kr gas

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Abstract

We studied about the influence of sputtering gas in ML mirror deposition for EUV which used IBS.

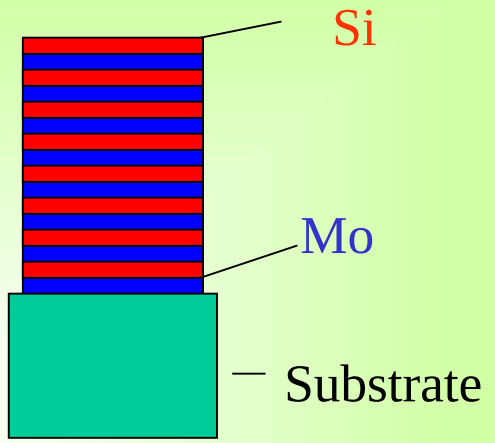
If Ar is used for sputtering gas, since the pressure at the time of deposition is high, an ion beam will be diffused, and then impurities will be supplied into a film by sputtering other parts them the target.

Moreover, when Ar was used for sputtering gas,while Ar ion reflected on the target had high energy, in order to reach the substrate in deposition, the interface interdiffuse layer of ML will be made to increase.

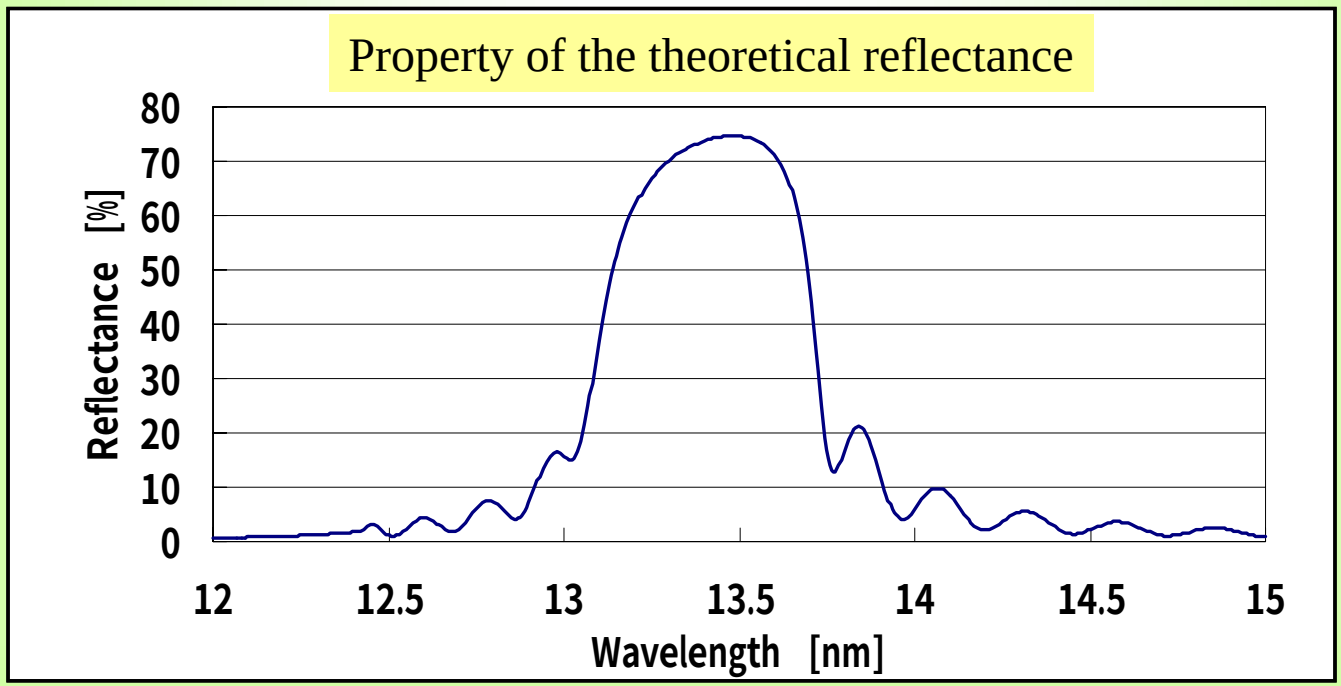
A high reflectance ML mirror has not been created by IBS by these results at deposition using Ar. We found out that these problems were solvable by using sputtering gas Kr instead of Ar.

The ML mirror for EUVL

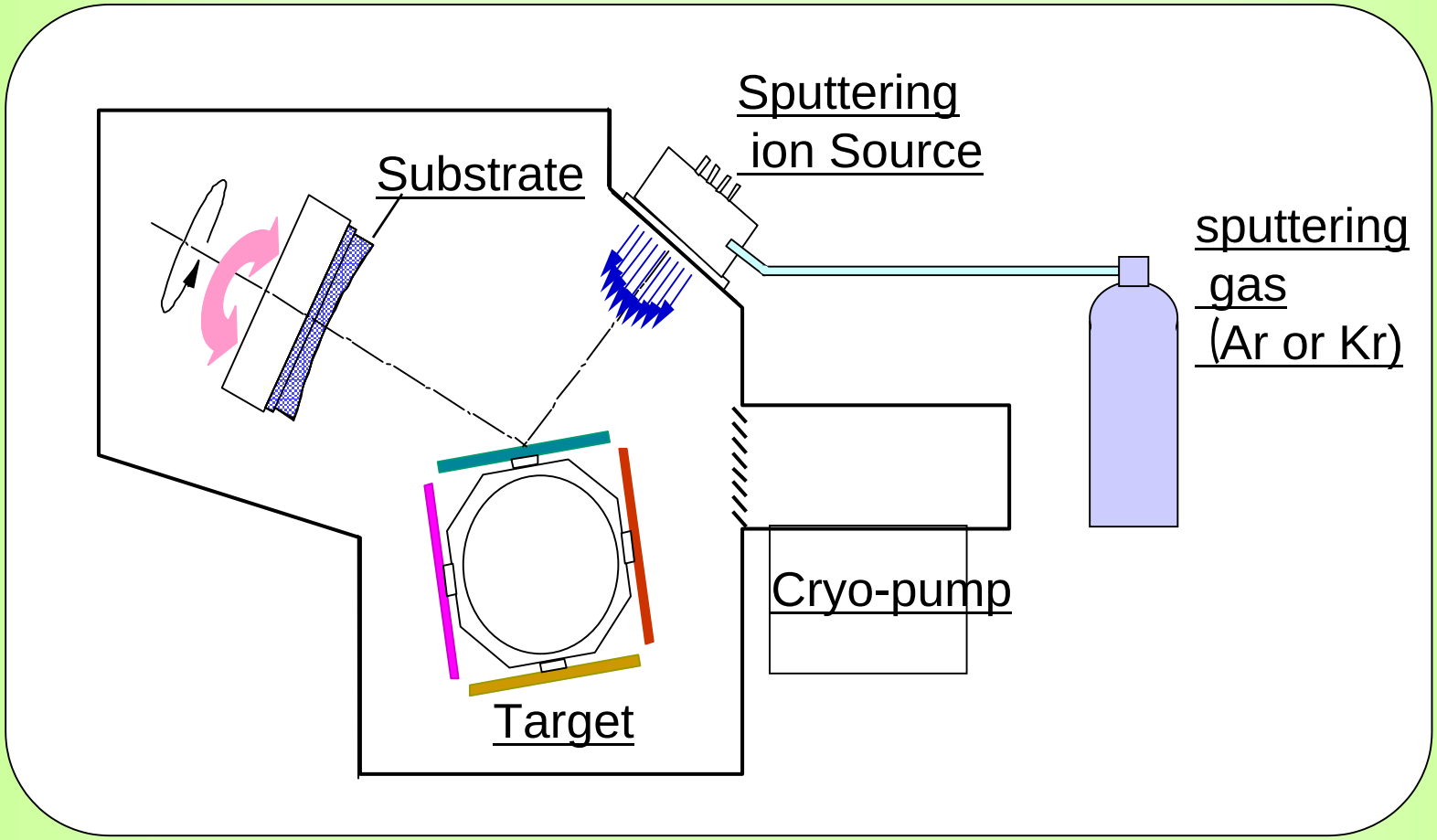
- Center wavelength：13.5 nm
- ML structure：Mo（2.76nm）/Si(4.14nm)
  (50 pairs)



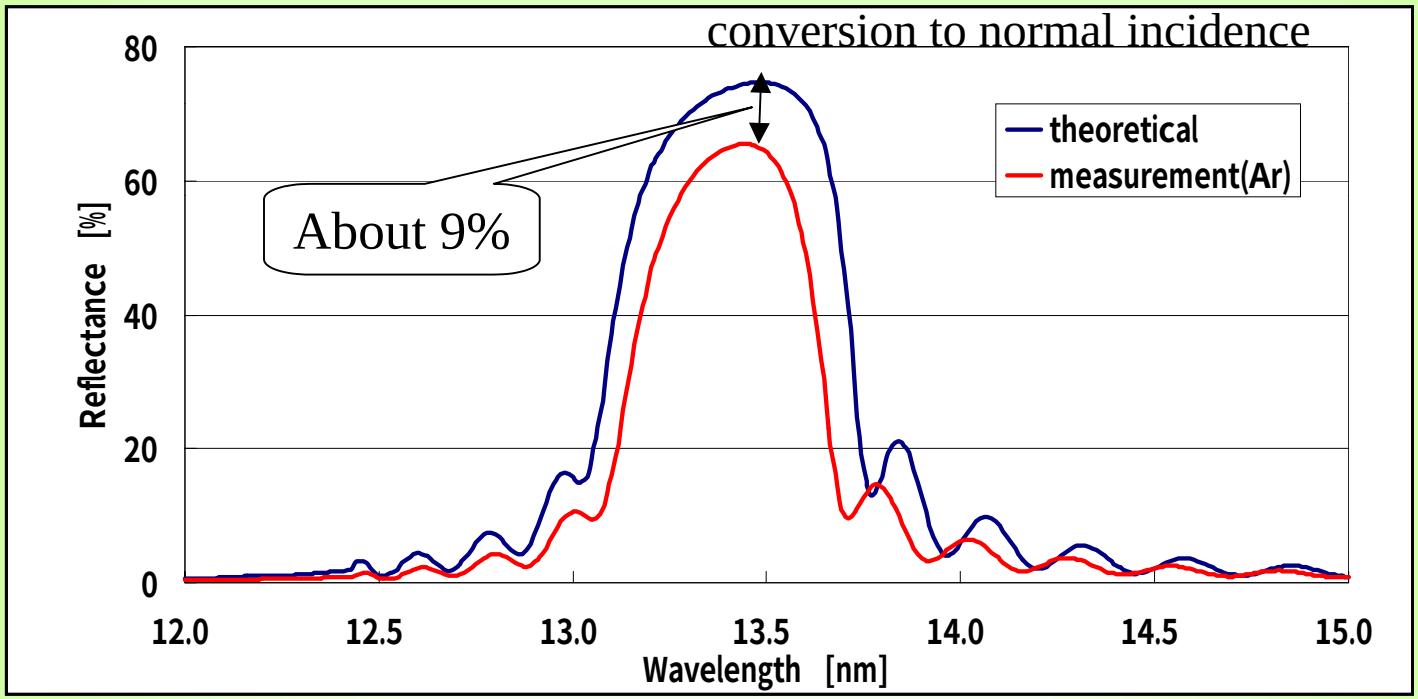
Incident angle:0 deg



The IBS equipment figure



Spectra of ML mirror reflectance deposited with IBS using Ar gas



The causes of decrease in reflectance

1)The absorption by impurities in the film.

2)The index change by formation of interdiffusion layer.

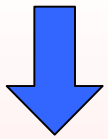
3)The scattering caused by interface roughness.

The absorption by impurities in the film

The RBS analysis result about Mo and Si single layers

Impurities in the film deposited with IBS using Ar gas

Impurity	SUS (Fe+Ni+Cr)	Ar	Total impurities	Thickness ratio (in ML)	Impurities in ML
Mo film	0.78 atm%	0.58 atm%	1.36 atm%	0.35	2.89 atm%
Si film	0.96 atm%	2.76 atm%	3.72 atm%	0.65	

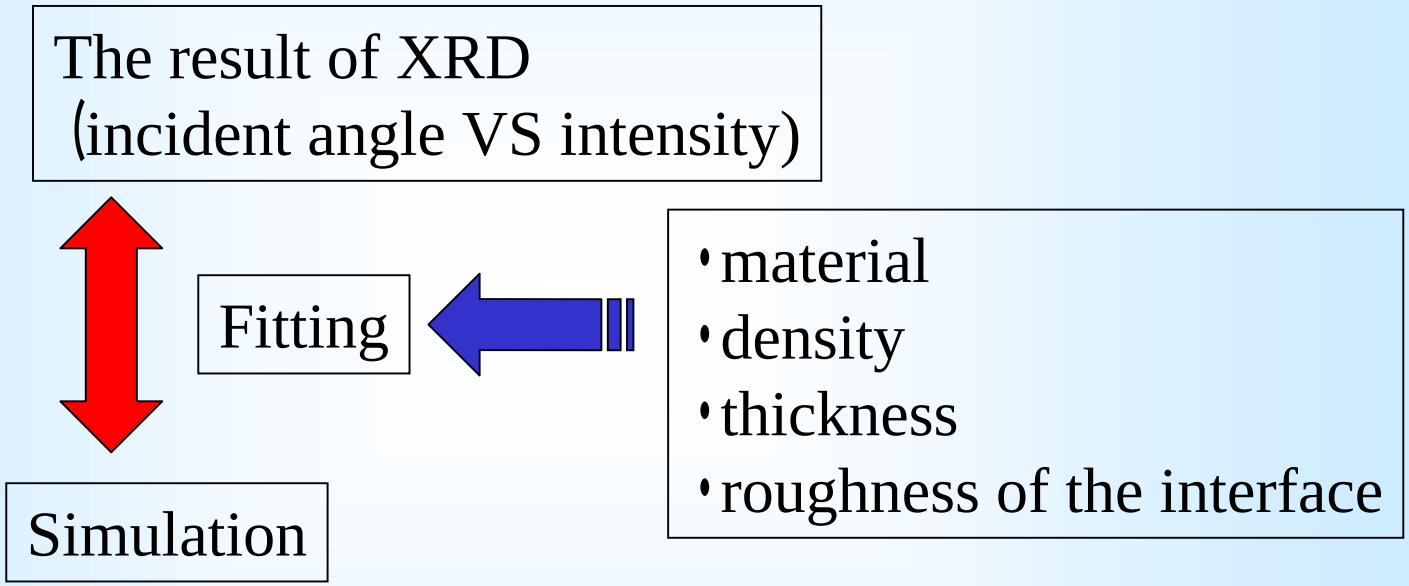


The estimated value of absorption for ML mirror by impurities in the film at the wavelength of 13.5nm.

2.6%(conversion to Mo/Si 50pair)

The analysis of interdiffusion layer thickness

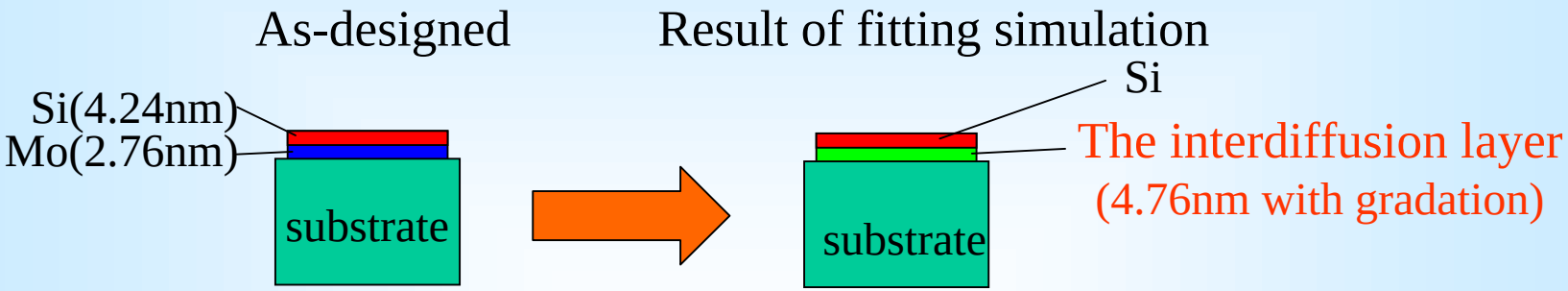
Identified by fitting of the measurement result of XRD in a simulation



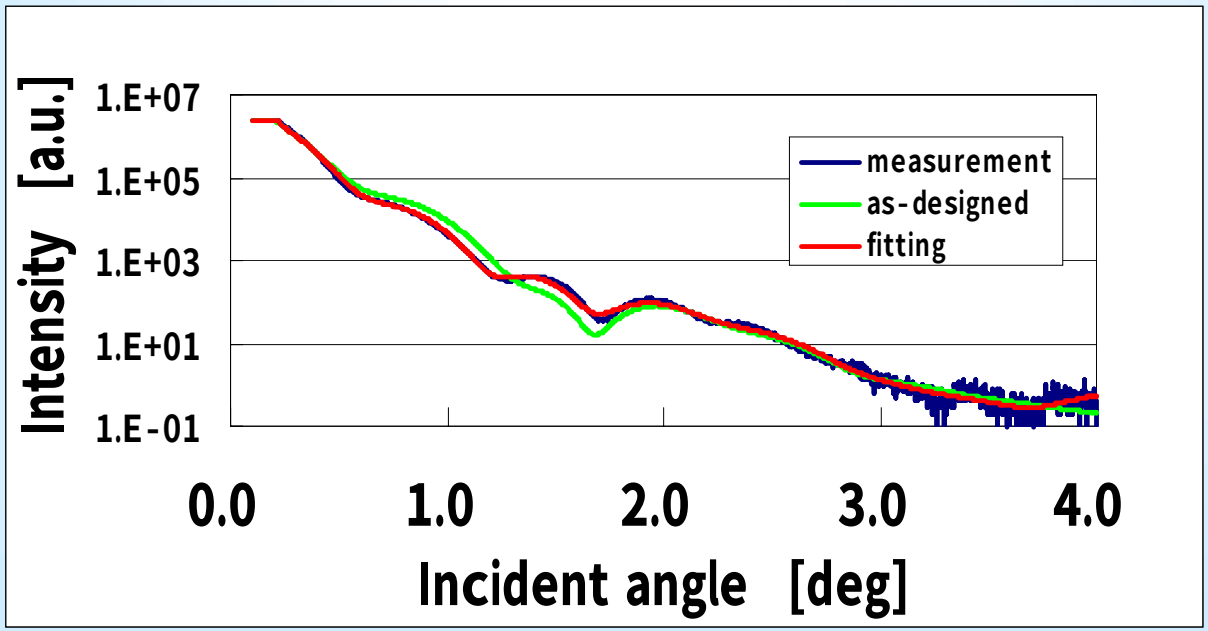
In order to simplify a simulation model,
the film composition is simplified(1-2pairs).

The interdiffusion layer with IBS using Ar gas

(The result of XRD analysis)



The interdiffusion layer is very thick



Influence of Ar gas sputtering

1) The absorption by impurities in the film

⇨ mid(2.6% ⇩)

2) The index change by making interdiffusion layer.

⇨ big (9.0% ⇩)

3) The scattering caused by interface roughness.

⇨ small (0.16nm rms：1.5% ⇩)

1)for impurity ⇒ low-pressuer deposition

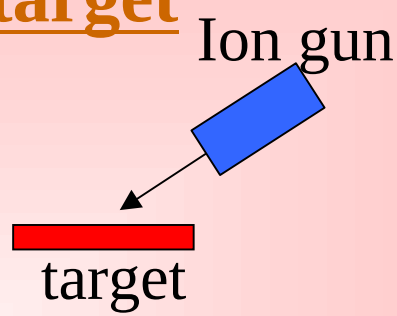
2)for interdiffusion layer ⇒ low-damage deposition

Change the sputtring gas

Ar ⇒ Kr

Ion beam current distributions on the target

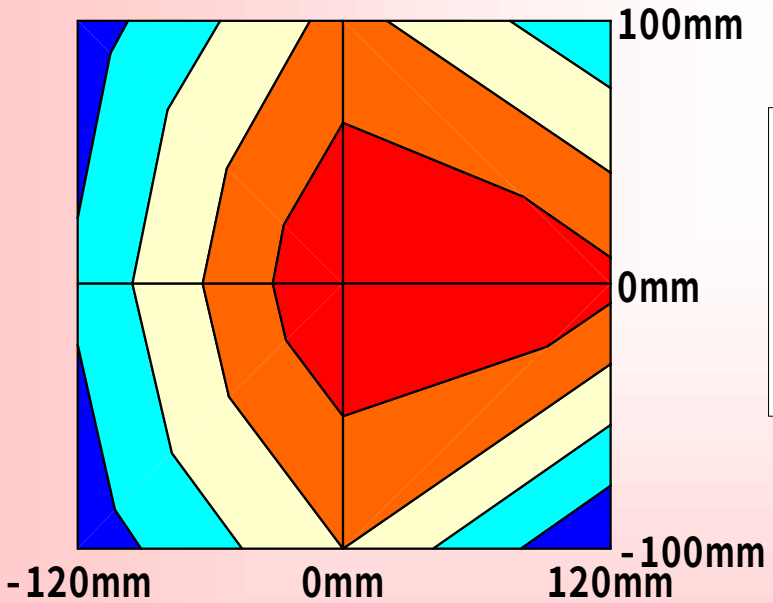
(standardizes at current value on the target center)

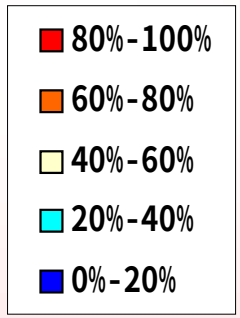


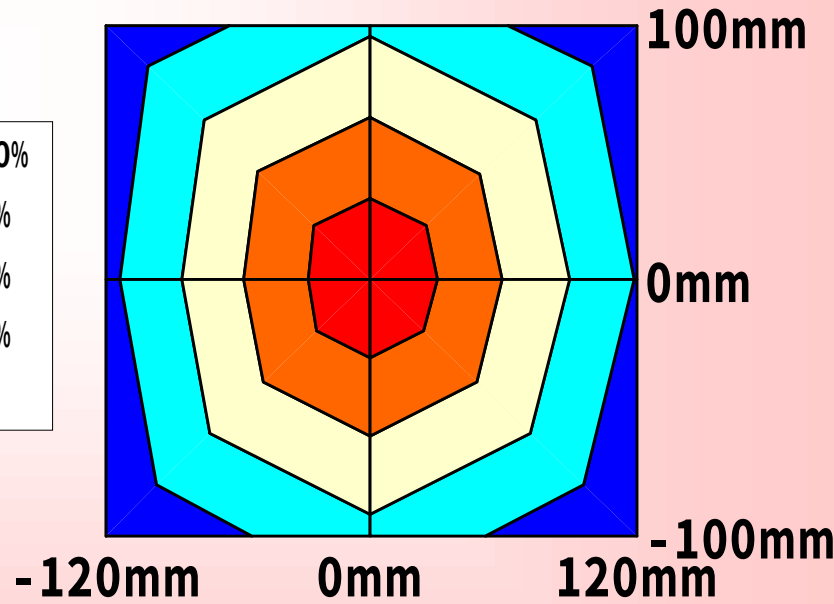
2×10^{-2} Pa
300 V

Pressure
accelerating voltage

5×10^{-3} Pa
300 V







Ar ion beam

Kr ion beam

Target size：480mm×250mm

Effect of impurities in films by the sputtering gas change

Sputtering gas	Accelerating voltage	Pressure	Total impurity	Decrease of reflectanc*2)
Ar	300 V	2e-2 Pa	2.89 atm%	2.6 %
Kr(1)	300 V	5e-3 Pa	0.89 atm%	1.1 %
Kr(2)*1)	300 V	5e-3 Pa	0.68 atm%	1.0 %

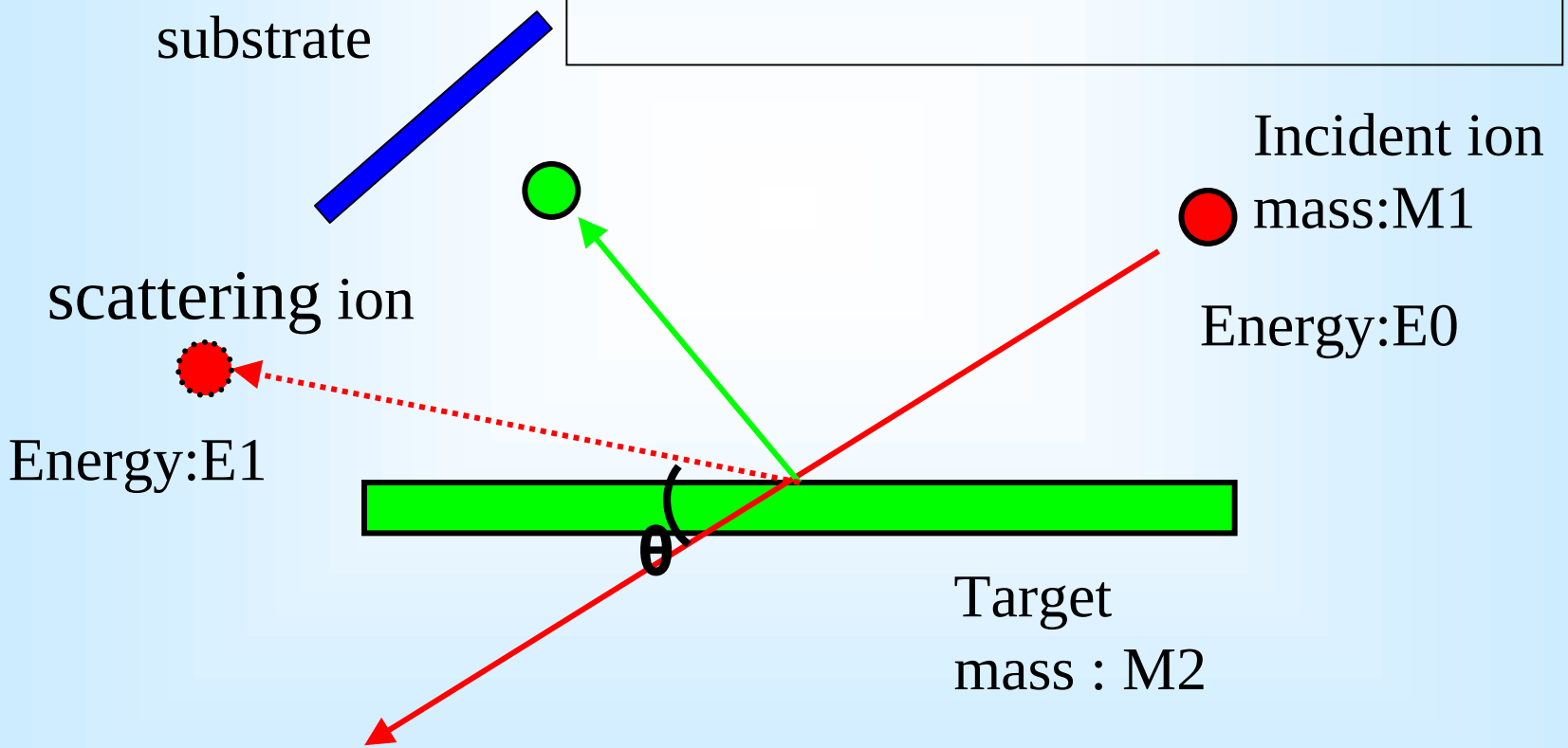
*1)Kr(2):tilted substrate to 30deg from Kr(1)

*2)The calculated value of absorption for ML mirror by impurities in the film at the wavelength of 13.5nm.

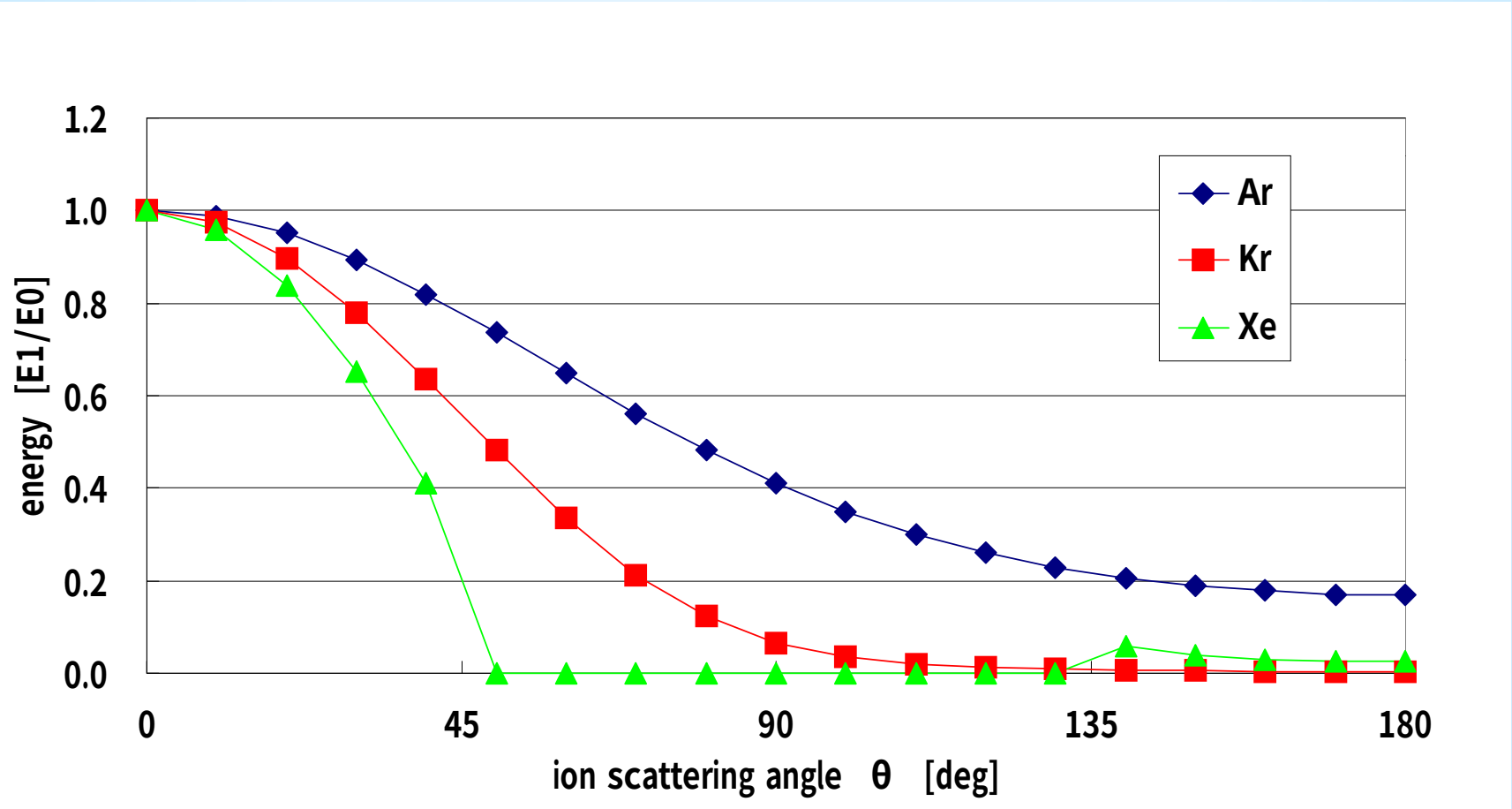
Model of the scattering ion energy

$$E1 = K \times E0$$

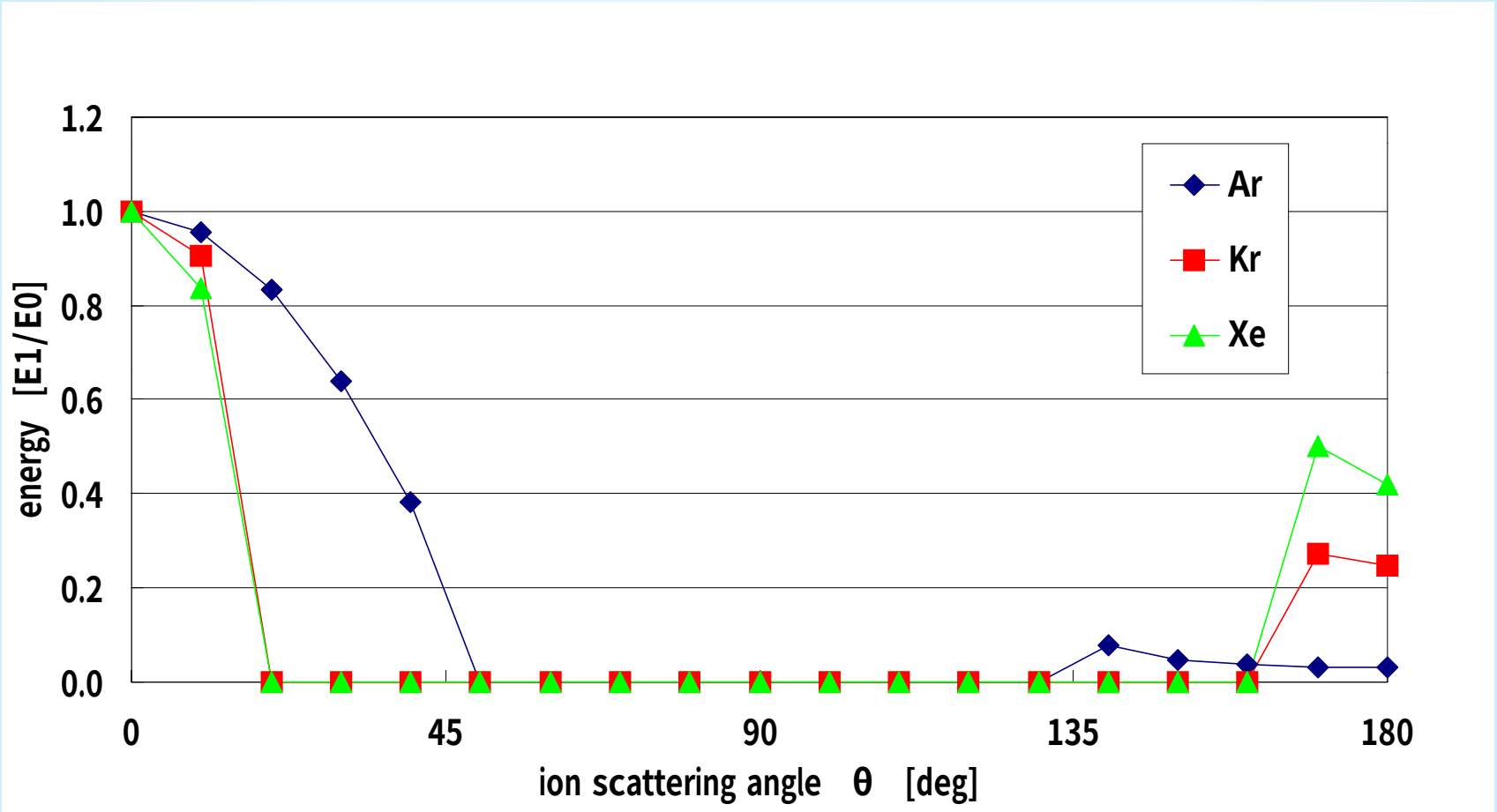
$$K = \left\{ \frac{(M1 \times \cos\theta) + (M2^2 - M1^2 \times \sin^2\theta)^{1/2}}{M1 + M2} \right\}^2$$



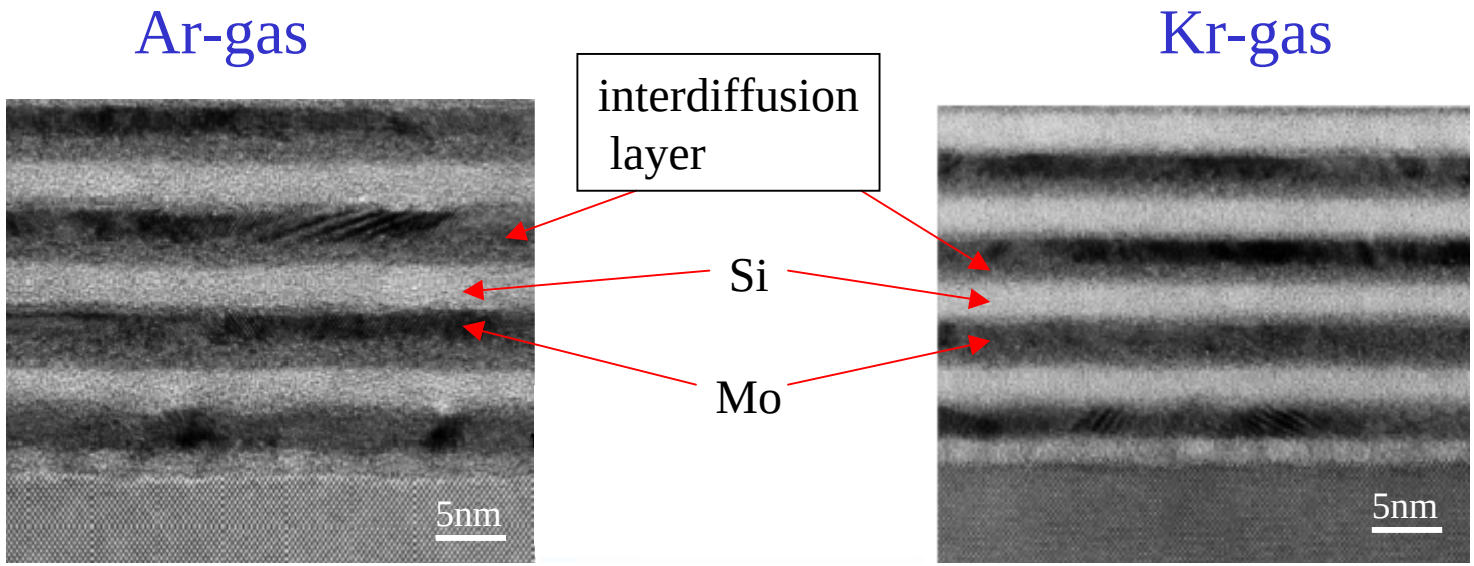
Scattering angle vs ion energy(Mo)



Scattering angle vs ion energy(Si)



Cross-section HRTEM images of ML coatings



The result of XRD analysis

4.7 nm	Thickness of interdiffusion layer	2.0nm

Reflectance decrease factor analysis

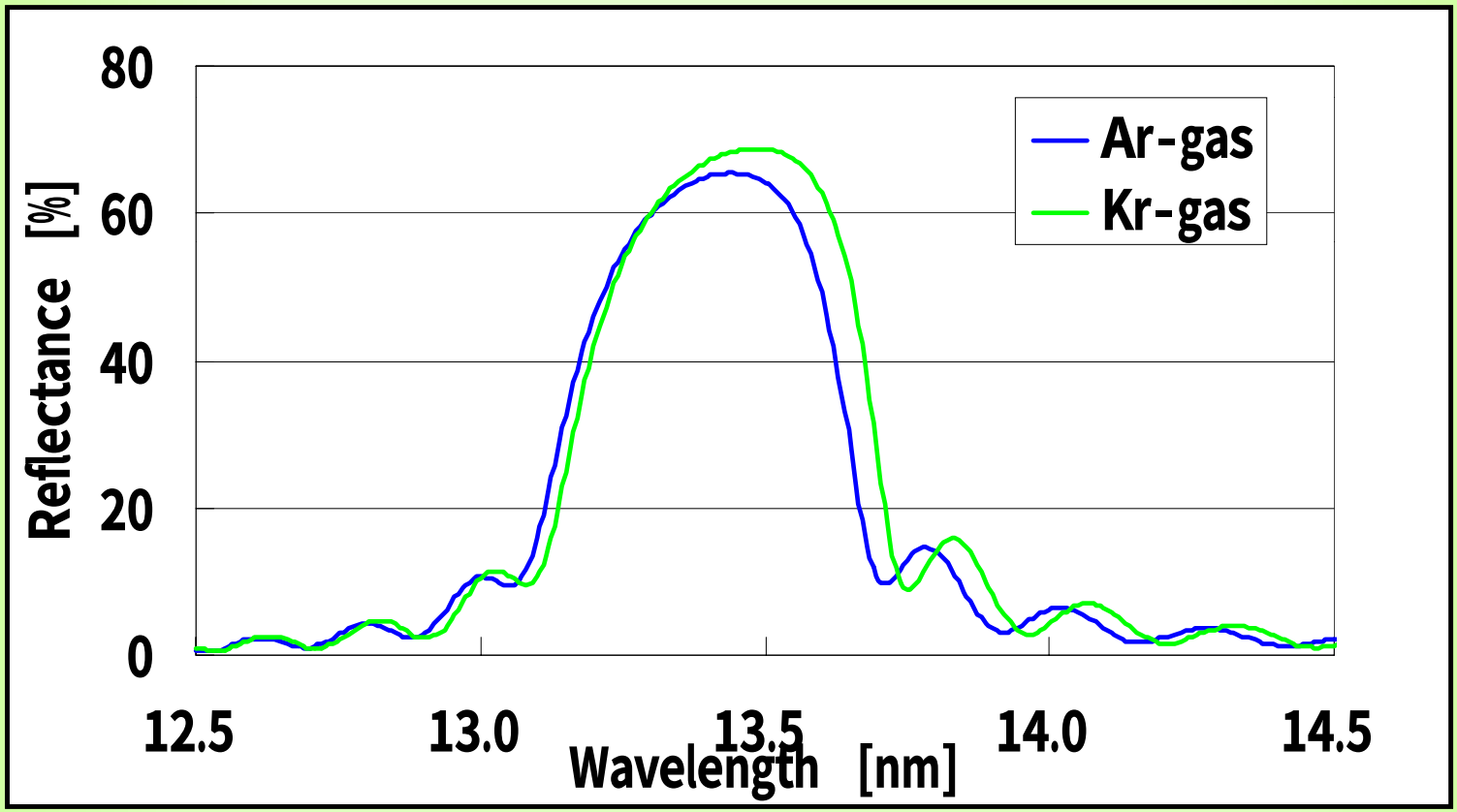
Too big estimate

Sputtering gas	Theoreti-cal (a)	Measure-ment (b)	Delta (a-b)	Impurity (c)	interdiffu sion layer (d)	Rough-ness (e)	Total (c+d+e)
Ar	74.3%	65%	9.3%	2.6%	9%・・・?	1.4%	13.1%
Kr (1)	74.3%	66%	8.3%	1.1%	5.2%	1.4%	7.7%
Kr (2) *	74.3%	69%	5.3%	1.0%	4.6%	1.4%	7.0%

*Kr (2) : tilted substrate to 30deg from Kr(1)

The spectra of ML mirror reflectance
(deposited by Ar-gas and Kr-gas)

conversion to normal incidence



Conclusion

We improved reflectivity of Mo/Si ML deposited with ion beam sputtering (IBS) by changing the sputtering gas.

By exchanging sputtering gas from Ar to Kr, We were realized to decrease impurities from 2.89 atm% to 0.87 atm%.And to decrease the thickness of interdiffusion layers from 4.67 nm to 2.0 nm.

We achieved the ML mirror with 69% of reflectivity in normal incidence at the wavelength of 13.5nm.