Leading the Next

Stabilization of Mo/Si multilayer for extreme ultraviolet lithography

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Introduction

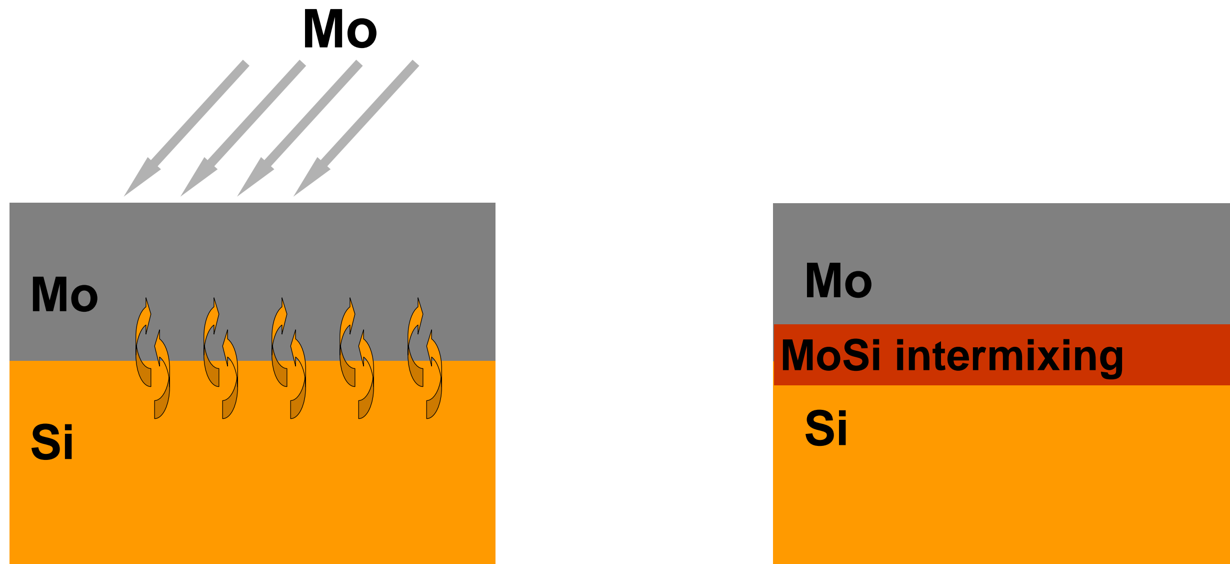
From the point of reliability of EUVL blank masks, the stability of the properties is a very important issue in order to commercialize them. In Mo/Si multilayer mirror, inter-mixing of Mo and Si is a critical problem which degrade the properties. The layer is formed during the normal deposition process and also when it is being used.

The formation of inter-mixing layer affects the stress of multilayer as well as the reflectivity. Stress generated in the multilayer can cause the substrate to bend and the pattern to distort. Finally it distorts the reflected image on the wafer.

In this study, we investigate the formation of inter-mixing layer using TEM and the stress measurement. New process to suppress the formation of inter-mixing layer is proposed.

Background

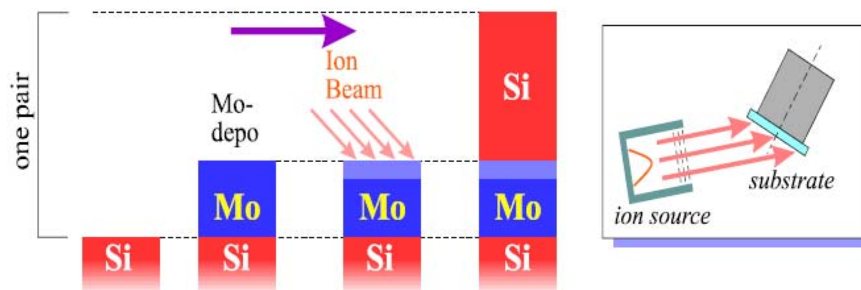
Formation of $MoSi_x$ inter-mixing layer



- Si atom easily diffuses into growing α-Mo film.

Background

Stress control using Ion Beam Polishing (IBP)



IBP is carried out on all Mo-layer surfaces after each deposition of Mo-layer. (Ar ion beam)

- Acceleration Voltage : 600V
- Acceleration Current : 30mA

Nikon NSR

T. Yamaguchi, 5th Next generation Lithography Workshop

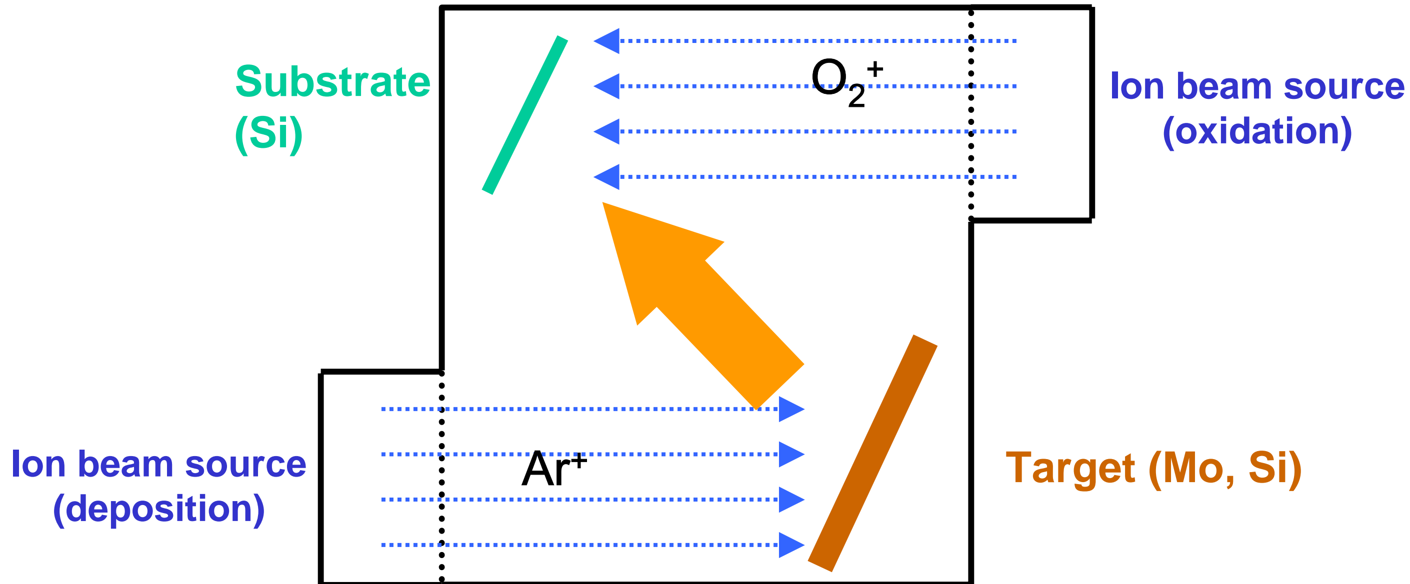
- T. Yamaguchi successfully controlled the residual stress by IBP.
- IBP densifies and stabilize the film surface

Objectives

- ***Stabilize the residual stress of Mo/Si multilayer and suppress the formation of inter-mixing layer.***
- ***Propose new or improved process to fabricate stable Mo/Si multilayer mirror.***

Experiments

- **Mo/Si multilayer deposition** : **Ion Beam Sputtering system**
- **Structure of mirror** : **Si / (Mo/Si)×40 / Si substrate**
- **Analysis** : **XRR, TEM, EUV reflectomery**

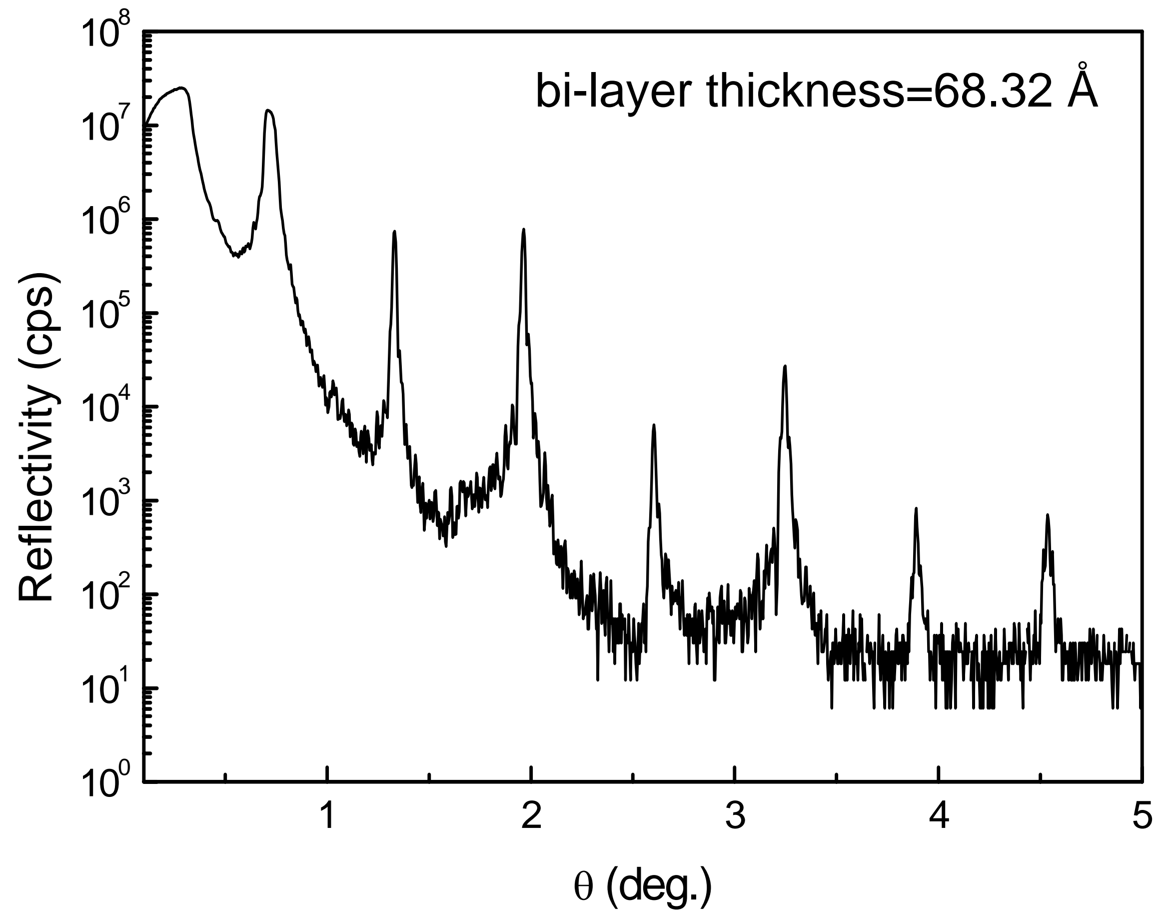


Results

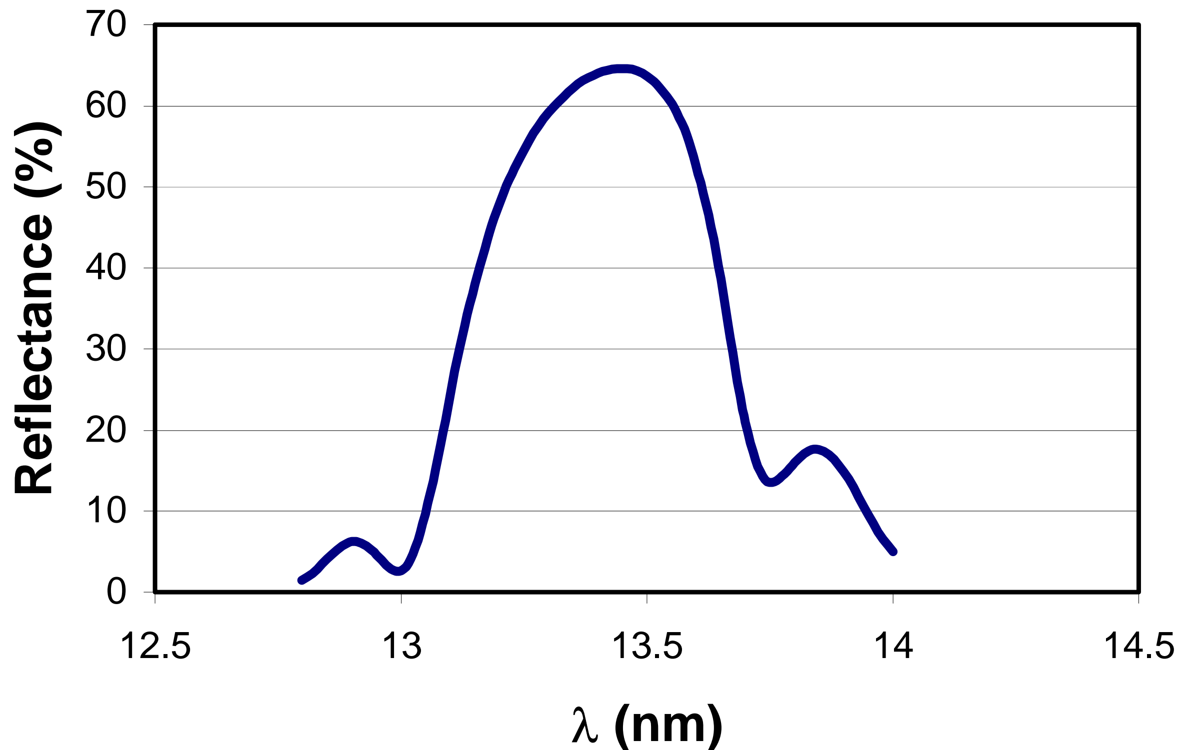
TEM image of Mo/Si multilayer

Si

X-ray reflectivity of Mo/Si multilayer



EUV reflectivity of Mo/Si multilayer



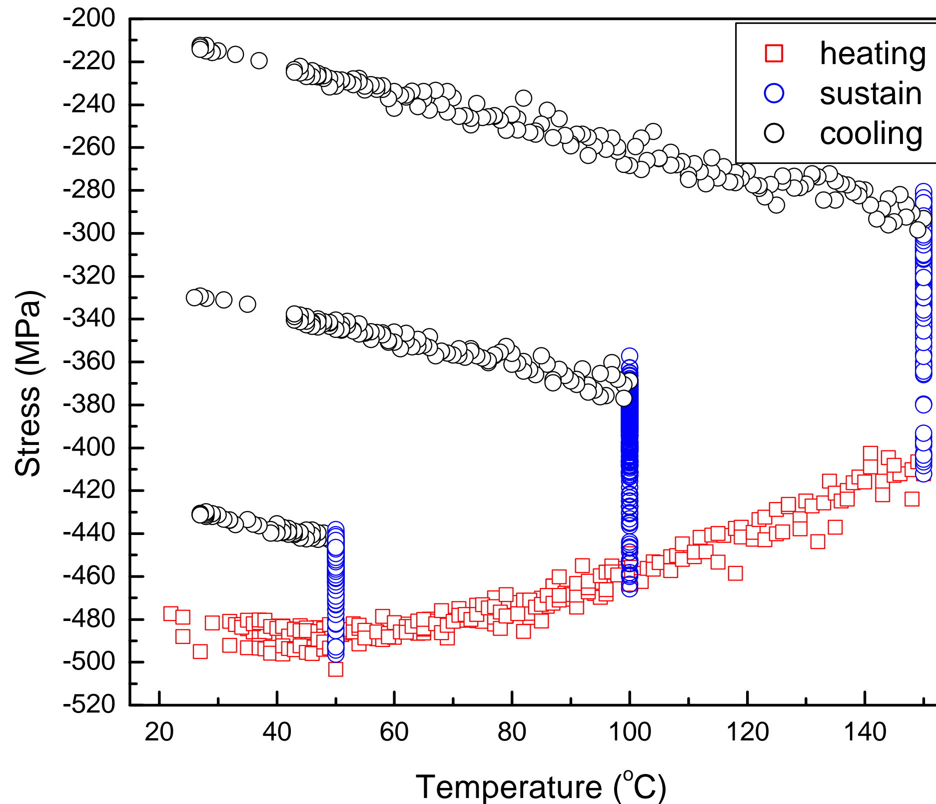
64.57% @ 13.38 nm

$MoSi_x$ inter-mixing layer

- Inter mixing is very severe when Mo grows on Si films.
- Mo is amorphous when it's very thin so Si easily diffuse into Mo.

- In order to suppress the formation of inter mixing layer, Si diffusion to Mo should be controlled.

Variation of residual stress at elevated temperature.



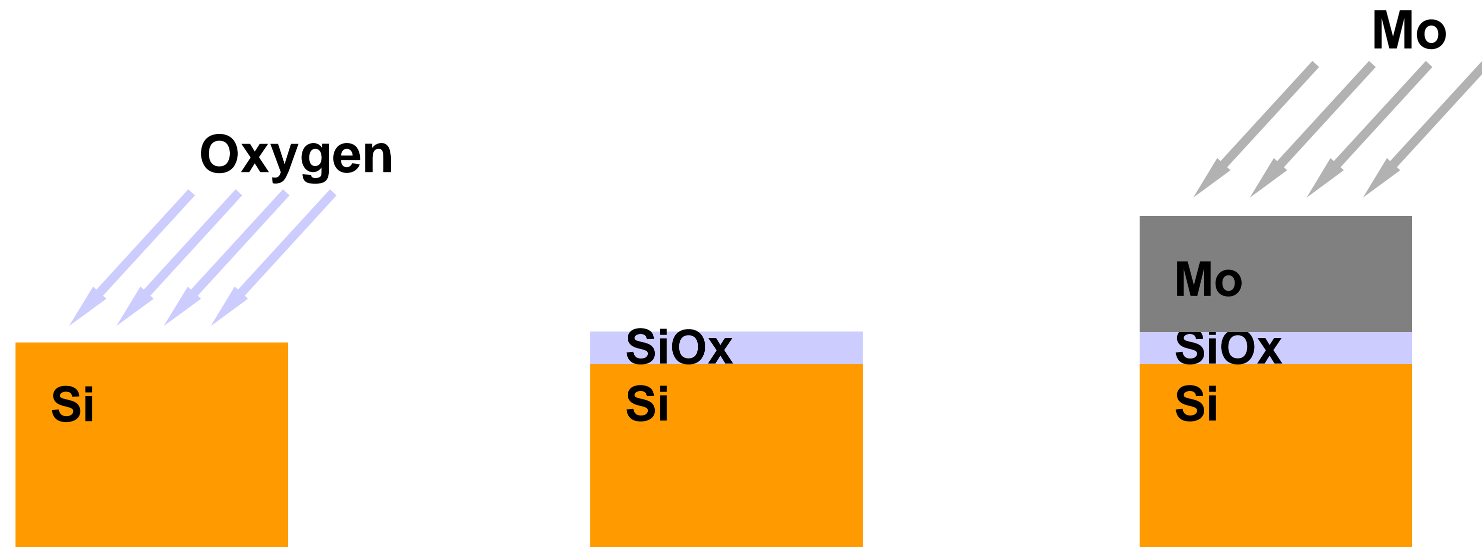
- The residual stress changes with time even at 50°C.
- It means the reaction between Si and Mo is continuously preceeded.

Change of multilayer structure after heating.

As deposited	48hrs @ 50°C	48hrs @ 100°C	48hrs @ 150°C

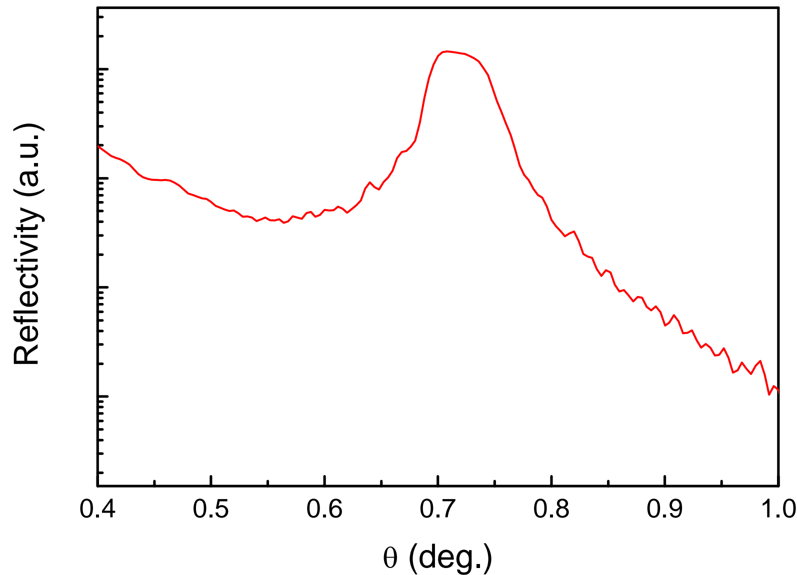
- TEM image clearly indicates that the inter-mixing layer grows.

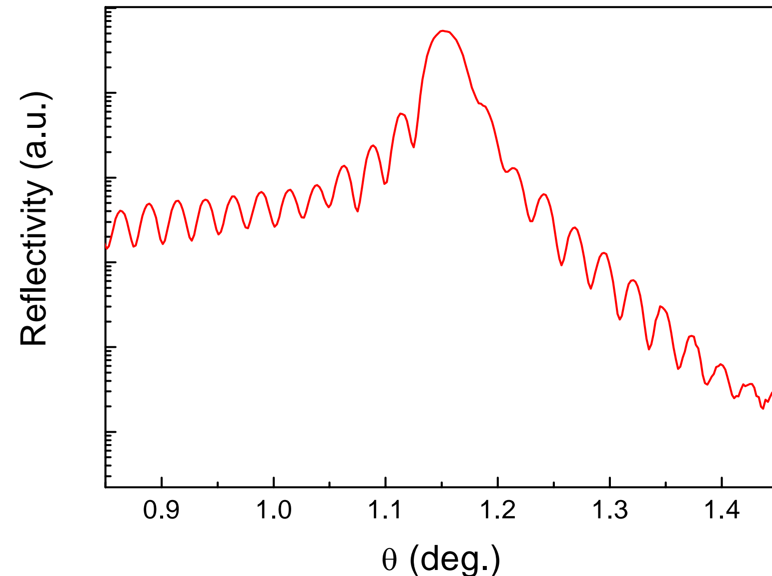
Suppression of Si diffusion by surface oxidation using Oxygen Ion Beam



- SiO_x layer is very good barrier material for Mo/Si system.

Change of 1st diffraction peak from XRR analysis





- Small fringes are shown very clearly when oxygen ion beam treatment is applied.
- This change implies that the interface roughness is decreased.

Conclusion

- *We successfully fabricated Mo/Si multilayer mirror that has 64.57% reflectivity at 13.38 nm.*
- *It was found the $MoSi_x$ inter-mixing layer grows even at very low temperature (>50°C) and it causes the residual stress change.*
- *Oxygen ion beam treatment on Si film effectively improved the problem related to inter-mixing layer.*