

# Characteristics of Ru capping and optimization of EUV mask absorber stack

SeungYoon Lee, TaeGeun Kim, ChungYong Kim, ByungHun Kim, and Jinho Ahn<sup>+</sup>

Dep. of Materials Science and Engineering, Hanyang University, Seoul 133-791, Korea

<sup>+</sup>Contact author : jhahn@hanyang.ac.kr

## Introduction

• Finding optimized combination of absorber stacks is very essential

### Anti-reflection coating

To improve DUV contrast for inspection

- Low DUV & EUV reflection
- Low sheet resistance for e-beam writing
- $Al_2O_3$ , SiON, LR-TaBN

### Absorber layer

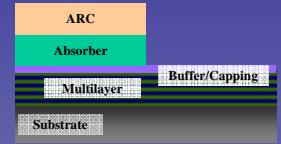
To absorb EUV for image formation

- Patterning characteristics
- EUV contrast to ML >100:1
- TaN, TaBN, TaSiN, TaSi

### Buffer/capping layer

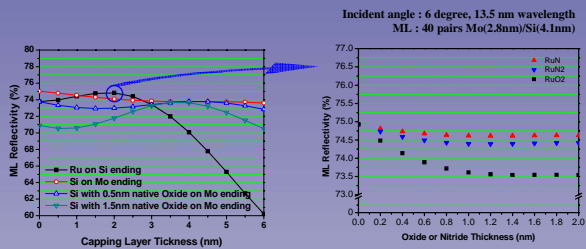
To protect ML from absorber-etch damage and from the unexpected oxidation

- High etch selectivity to absorber
- Oxidation resistance
- Ru,  $TiO_2$ , Nb,  $B_4C$



## Capping issue

• Ru and Si capping layer – oxidation & nitridation



- Ru capping layer degrades EUV reflectivity significantly with >2 nm thickness  
 - Ru oxidation reduces EUV reflectivity further ( $RuO_2$ )  
 - Ru nitride shows a stable EUV reflectivity characteristics

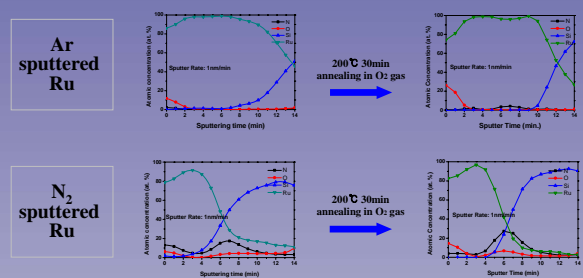
• Ru capping layer – Ar vs  $N_2$  sputtered

sample	Max. reflectivity(%) @ peak wavelength(nm)	sample	Max. reflectivity(%) @ peak wavelength(nm)
ML#418	49.9% @ 13.4nm	ML#413	49.1% @ 13.7nm
Ar sputtering	50.7% @ 13.6nm	$N_2$ sputtering	50.9% @ 13.5nm

- Ru capping deposited in Ar and  $N_2$  can improve EUV reflectivity about ~2 % and changed the peak wavelength slightly

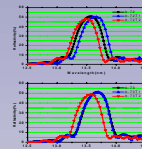
## Oxidation resistance – Ar vs $N_2$ sputtered Ru

• AES depth profile



-  $N_2$ -sputtered Ru is better than Ar-sputtered Ru in terms of oxidation resistance

• EUV reflectivity



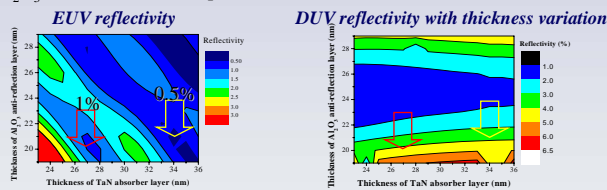
sample	Max. R.(%)@peak wavelength(nm)	sample	Max. R.(%)@peak wavelength(nm)	Annealing condition
b-72	50.7% @ 13.6nm	b-73	51.4% @ 13.7nm	-
b-72T1	50.1% @ 13.63nm	b-73T1	51.4% @ 13.7nm	100C, 30min with $O_2$
b-72T2	48.1% @ 13.5nm	b-73T2	48.9% @ 13.6nm	200C, 30min with $O_2$

- Ru capping deposited with Ar and  $N_2$  can improve peak EUV reflectivity by ~2 %, but slight shift of the peak wavelength is observed.

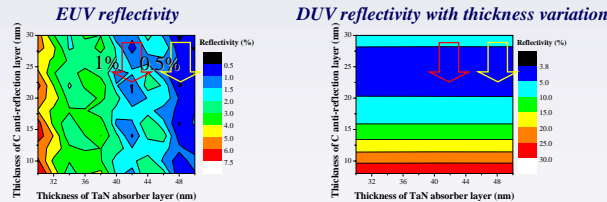
## Mask absorber stack : ARC-absorber combination

• EUV (at 13.5 nm wavelength) and DUV (at 257 nm and 199 nm wavelength) reflectivity simulation contour with the thickness variation of ARC and TaN in ARC/TaN/2 nm Ru/ML

$Al_2O_3$  ARC for 257 nm inspection

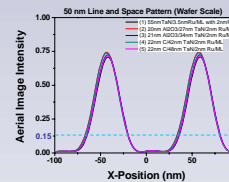


C ARC for 199 nm inspection

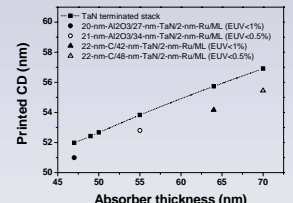


-  $Al_2O_3$ -20-nm/TaN-27-nm/Ru-2-nm/ML for 257 nm inspection  
 - C-22-nm/TaN-42-nm/Ru-2-nm/ML for 199 nm inspection

## Aerial image simulation & CD variation



The printed CD as a function of the absorber stack height for  $Al_2O_3$ -ARC, C-ARC, and TaN terminated stack



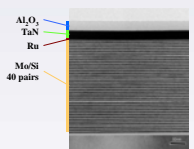
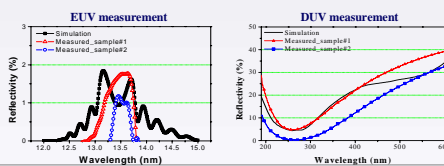
The printed CD depends on the absorber stack materials as well as the geometrical stack height.

No	1	2	3	4	5
ARC	Non	$Al_2O_3$	C		
$R_{EUV}$ (%)	0.2	0.97	0.38	0.95	0.43
Absorber stack thickness (nm)	56.5	47	55	64	70
Printed CD (nm) at threshold line of 0.15	-54	50.99	52.80	54.17	55.45

## EUV & DUV measurements of $Al_2O_3$ /TaN/Ru/ML

Proposed optimized absorber stack

$R_{EUV} < 1.0\%$  : 20 nm  $Al_2O_3$  / 27 nm TaN / 2 nm Ru / ML  
 $R_{EUV} < 0.5\%$  : 21 nm  $Al_2O_3$  / 34 nm TaN / 2 nm Ru / ML



## Summary

• Improvement of the Ru capping layer

- Ru capping layer was compared with Si capping layer by simulation  
 - Ru capped ML deposited with  $N_2$  shows a better reflectivity compared to the one deposited with Ar.  
 - Through the annealing experiment,  $N_2$  sputtered Ru surface shows a better oxidation resistance than Ar sputtered Ru.

• Optimization of the absorber stack

-  $Al_2O_3$  ARC for 257 nm inspection on TaN absorber is 47 nm thick.  
 - C ARC for 199 nm inspection on TaN absorber is 64 nm thick.  
 - Two ARCs of  $Al_2O_3$  and C show the better printed CD variations compared to TaN terminated stack.

• Verification of the final stack

- Designed absorber stack has been fabricated and checked by TEM.  
 - Optical measurements were performed for EUV and DUV reflectivity, and the results match well with the simulation data.