EUV mask and blanks development at HOYA

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Outline

- **EUV mask structure at Hoya**
- **Technical issues of EUV blanks and mask**
- **Blanks characteristics**
  - **Multilayer defect**
  - **Absorber stack properties**
- **Mask characteristics**
  - **Dry etching damage to multilayer**
  - **Absorber repair**
  - **Absorber stack patterning**
  - **DUV inspection images**
  - **EUV contrast**
- **Summary**

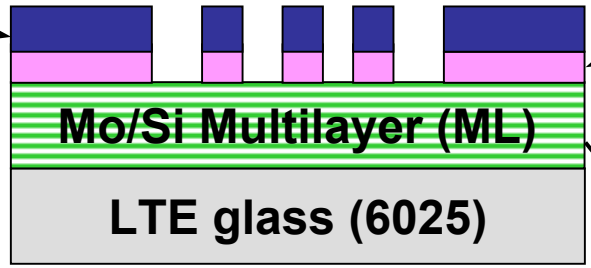
HOYA EUV mask

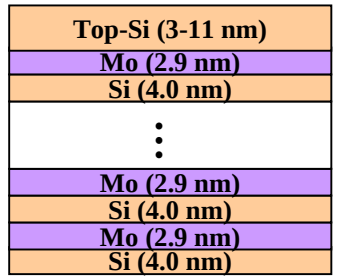
LR-TaBN absorber

LR: Low Reflectivity

Amorphous material
High stress stability
High EUV absorption

CrN buffer layer





40 bi-layers

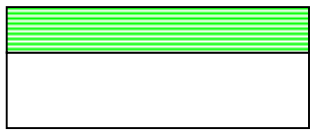
Structure of EUV mask

- **LR-TaBN absorber**
  - **The continuous layer with low optical reflectivity layer**
  - **Low reflectivity of 5% at 257 nm to obtain higher inspection contrast**
- **CrN buffer layer**
  - **Acts as etch stop layer during absorber etching and protect layer during absorber repair process**

Some technical issues must be solved.

Technical issues of EUV blanks

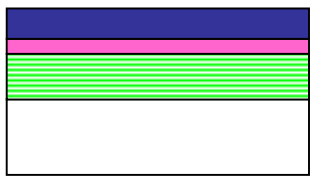
Process flow



ML (40 bi-layers) and Si capping layer deposition (by IBD)

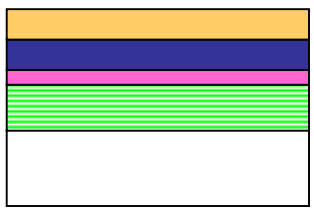
Reflectivity: NewSUBARU BL10

Cleaning & inspection



CrN buffer and LR-TaBN absorber deposition (by magnetron sputtering)

Cleaning & inspection



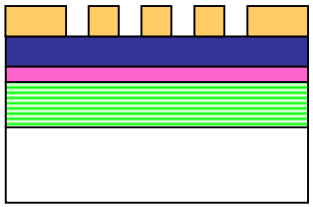
EB resist coating and baking

Technical issues

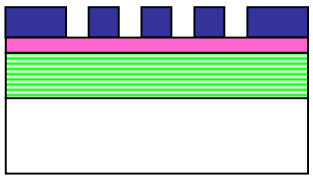
- Zero defect ML (for 50 nm sizes)
- High EUV reflectivity: >65%
- Low stress: <200 MPa
- High cleaning durability

Technical issues of EUV mask

Process flow

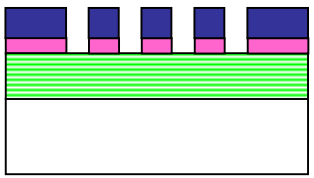


EB writing and
resist developing



Absorber etching with Cl_2
gas and resist stripping

Mask inspection (DUV/257 nm)
Absorber repair (FIB, EB etc.)



Buffer layer etching with
Cl_2/O_2 mixed gases

Mask inspection (DUV/257 nm)

Technical issues

Mask performance
IP and CD

Damage less repair
process

Absorber repair with
high etch selectivity

→ Thinner buffer

Mask inspection with
high contrast

Absorber patterning
with vertical side wall

High dry etching durability to ML

→ High EUV reflectivity on mask

ML defects reduction

Total defects on ML blanks measured by M1320

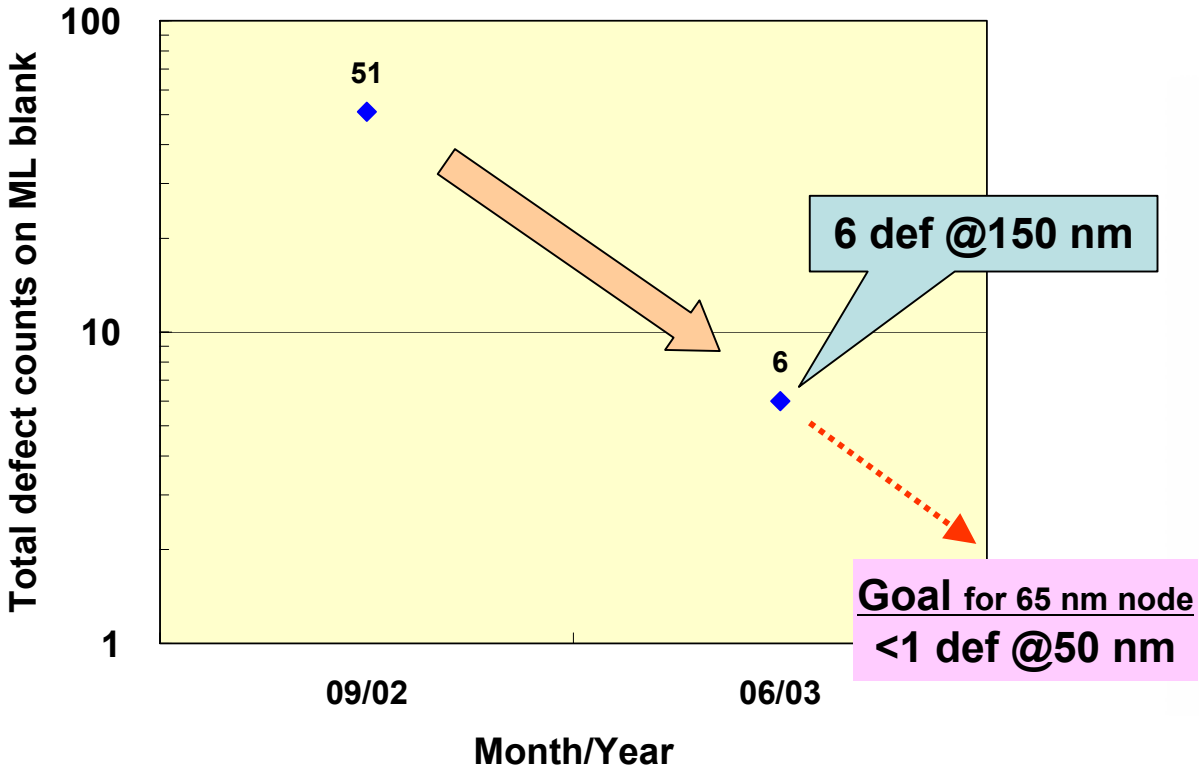


Fig. Progress in ML defect reduction

0.03 def/cm² @150 nm

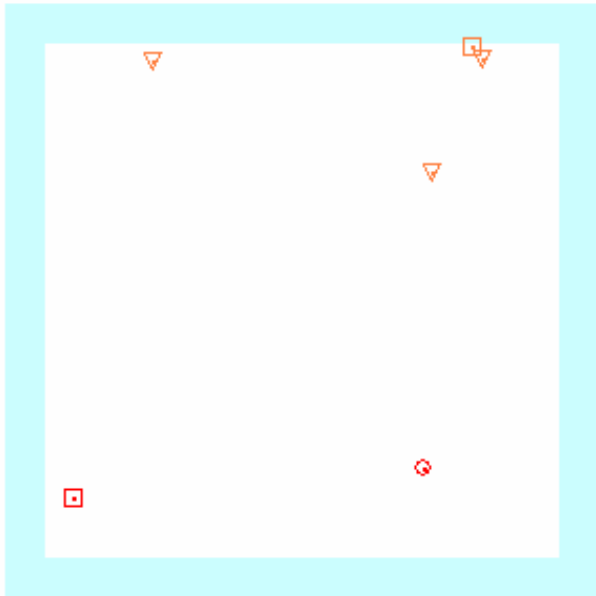


Fig. Defect map of ML blank

Further reduction in ML defects will be performed.

Properties of LR-TaBN/CrN blanks

Stress and roughness of the blanks

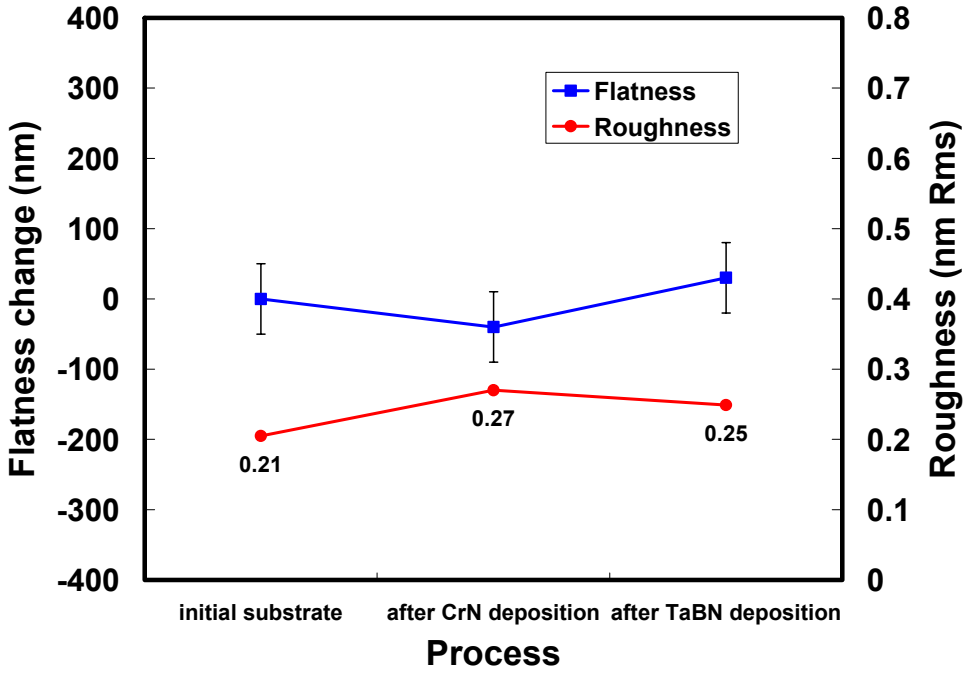


Fig. Flatness change in 142-mm sq. and roughness in 10 μm after CrN deposition and then after LR-TaBN deposition.

Cleaning durability of LR-TaBN

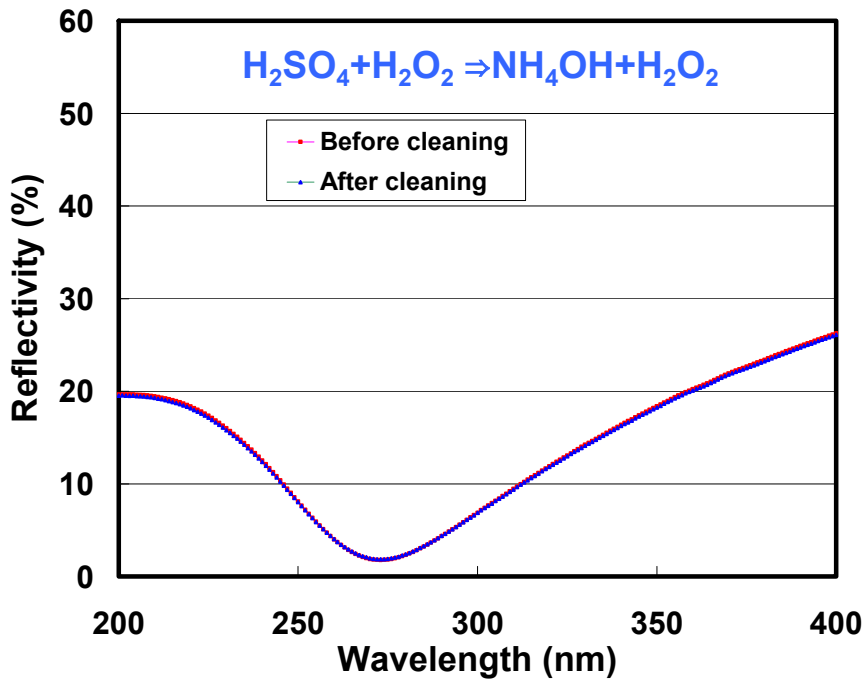


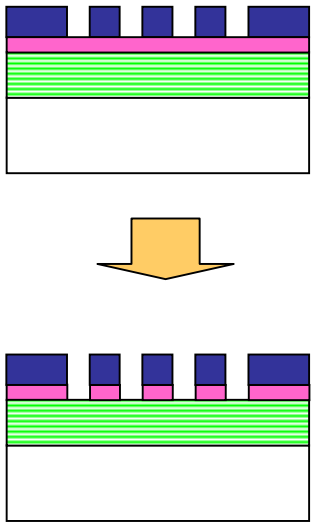
Fig. Optical reflectivity spectra of LR-TaBN film before and after the cleaning process.

Low stress: <200 MPa
Smooth surface: 0.25 nm Rms

High cleaning durability against conventional cleaning

Dry etching damage to ML blanks
--Reflectivity change--

Dry etching selectivity of CrN buffer to Si capping layer is nearly infinite



CrN buffer layer etching with Cl_2/O_2 mixed gases

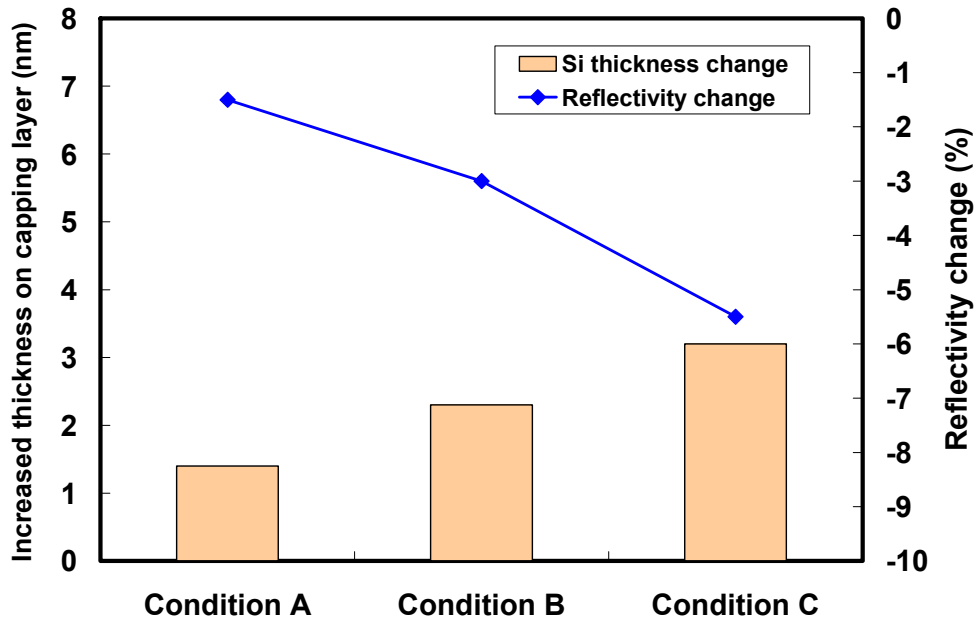
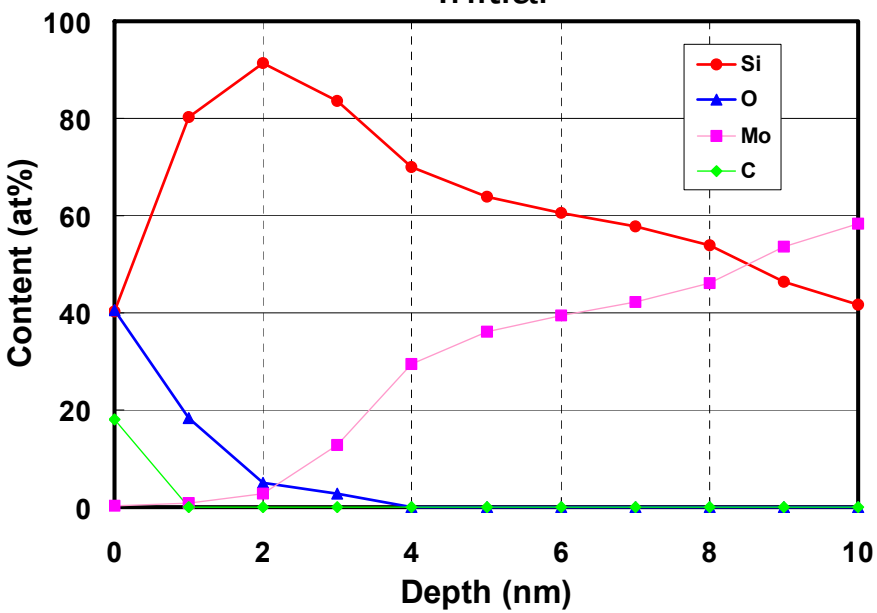


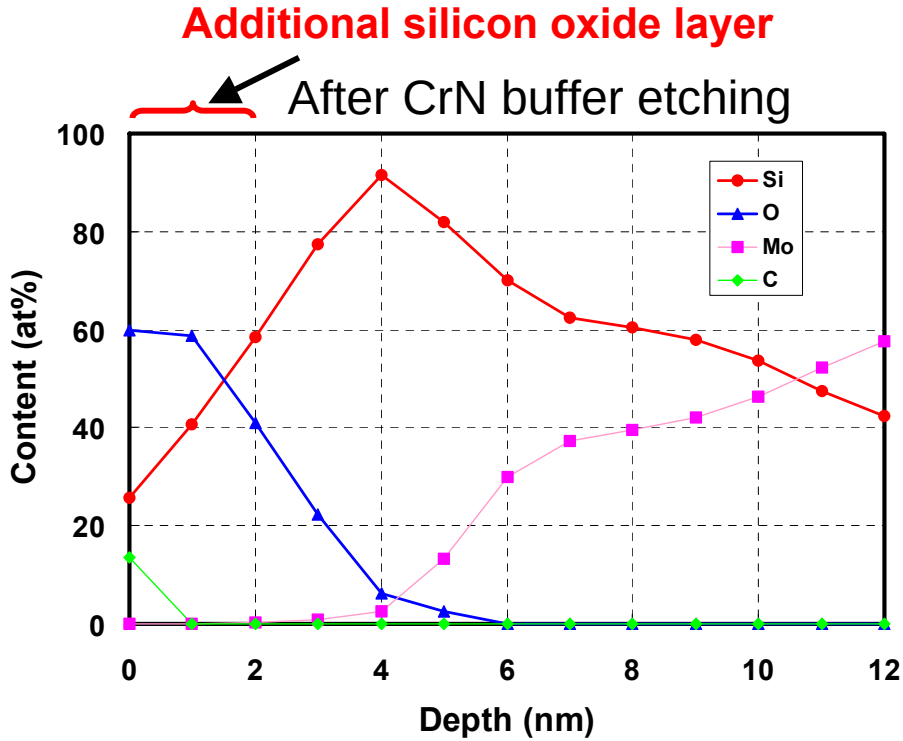
Fig. Relationship between the increased thickness on the capping layer and reflectivity change after three etching processes.

The mask featured reflectivity loss of 1.5-5% due to an increase of the capping layer.

Dry etching damage to ML blanks
--Compositional analysis of Si capping layer--



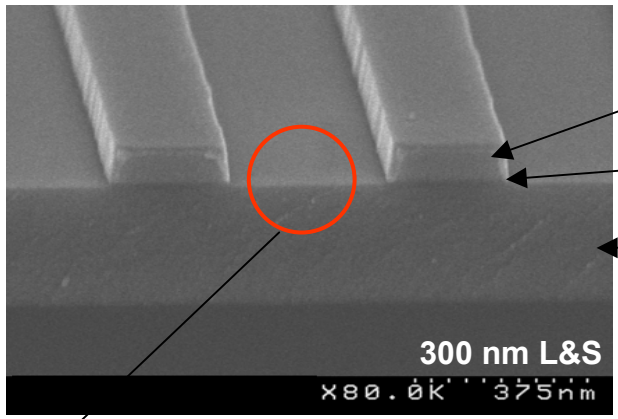
(a) XPS depth profile of original Si capping layer



(b) XPS depth profile of Si capping layer after CrN buffer etching

SiO_2 layer is formed on the original Si capping layer during CrN buffer etching.

Dry etching damage to ML blanks
--TEM analysis on Si capping layer--



TaBN absorber (90 nmt)

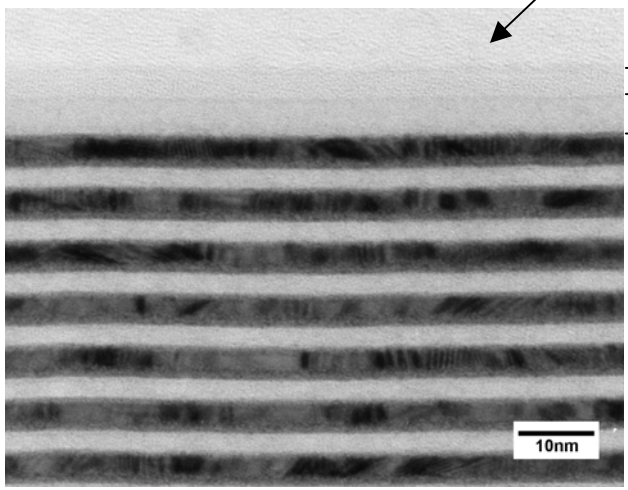
CrN buffer layer (10 nmt)

Mo/Si multilayer

After CrN buffer etching

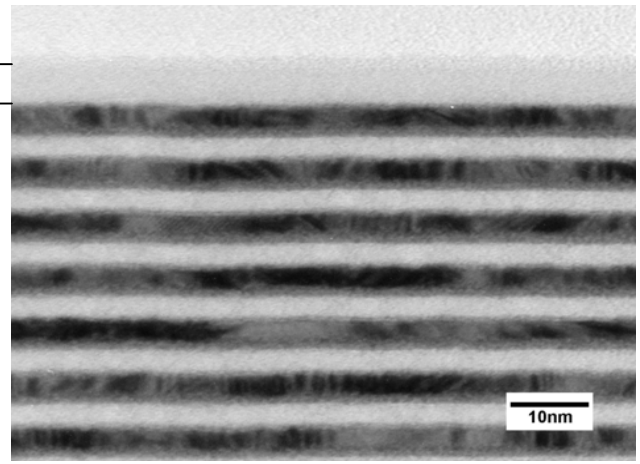
Additional oxide layer (3 nmt)

After HF treatment



Cap-Si (7 nmt)

In a diluted HF for 120 sec.



The additional SiO_2 layer is removed without structural damaging by HF treatment.

EUV mask reflectivity

ML blank (40 bi-layers) → **CrN buffer etching** → **HF treatment**

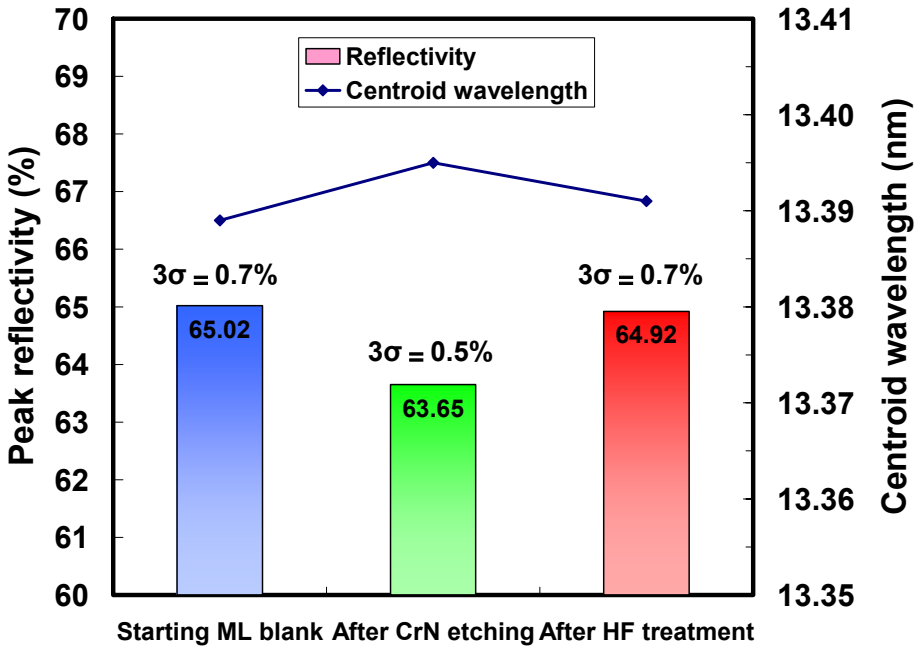


Fig. Peak reflectivity, reflectivity uniformity and centroid wavelength for starting blank and mask after buffer layer etching and HF treatment.

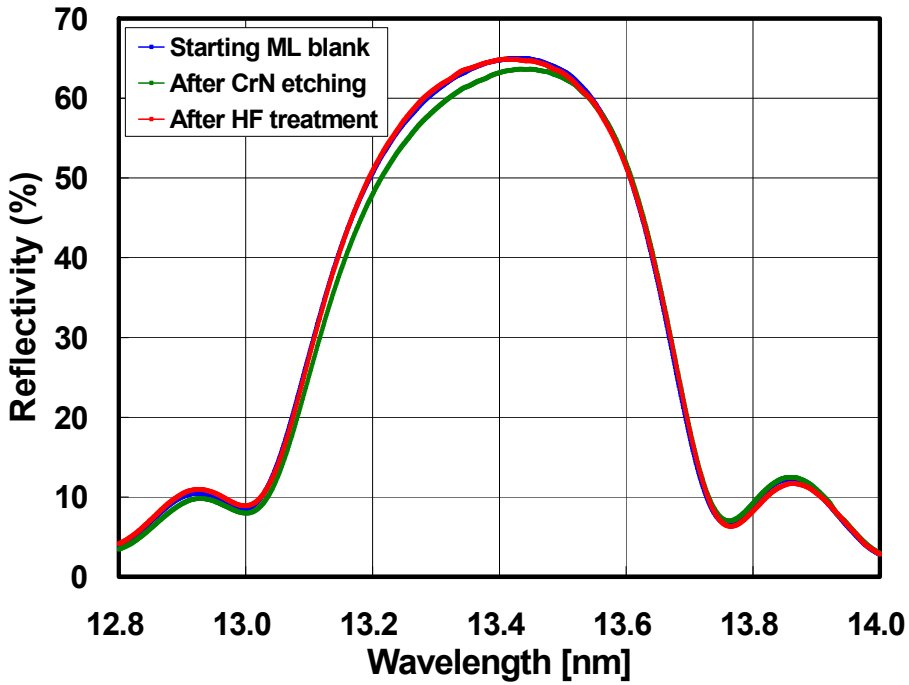


Fig. Reflectivity spectra for starting blank and mask after buffer layer etching and HF treatment.

Peak reflectivity of around 65% was obtained on the mask.

New capping layer
with higher dry etching durability

New capping layer

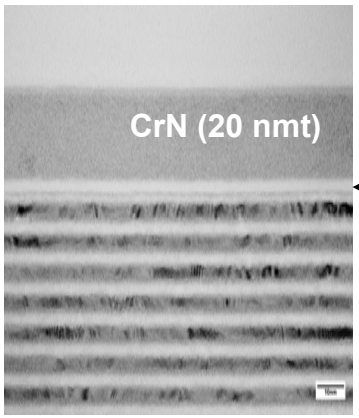


Fig. TEM image of ML blanks with new capping layer.

- **Simple ML structure**
  - Produced from only Si and Mo targets.
- **High durability against CrN etching**

Dry etching damage to ML

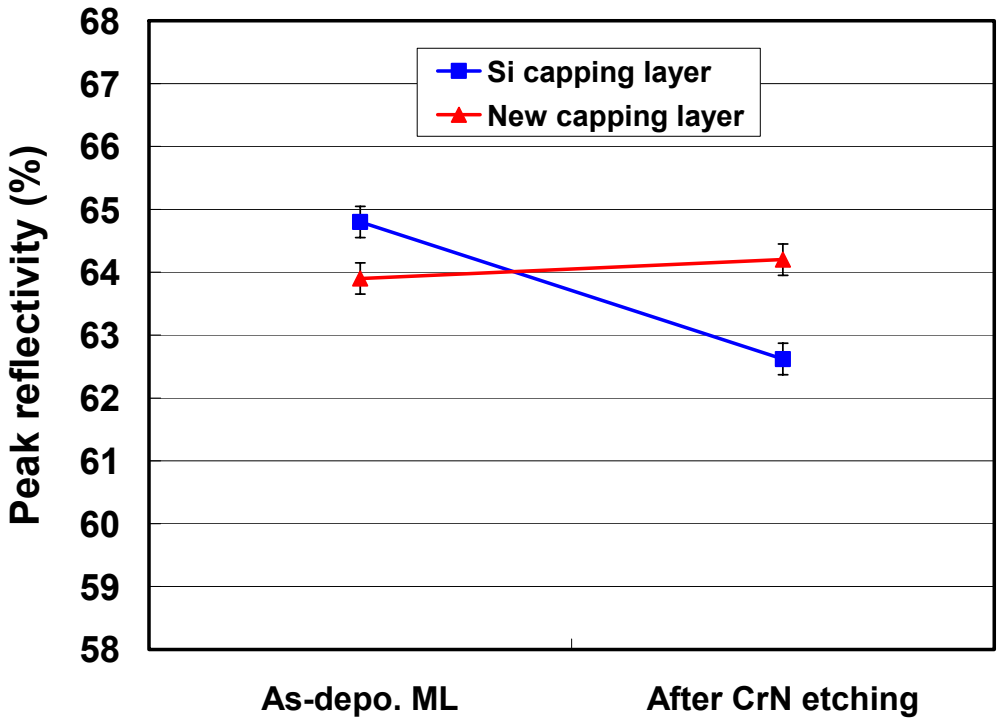
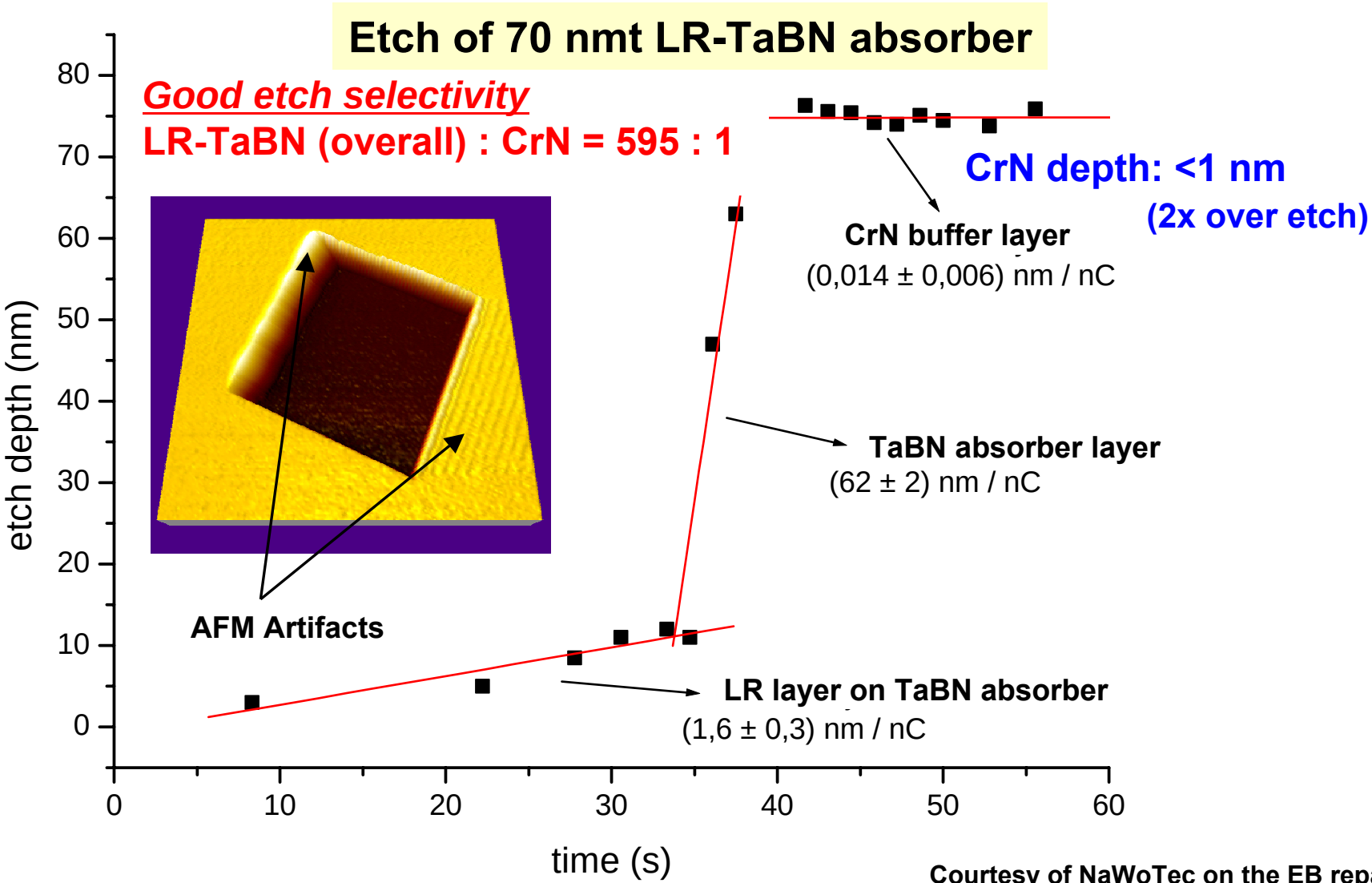


Fig. Peak reflectivity of ML with Si cap layer and ML with new cap layer before and after CrN etching.

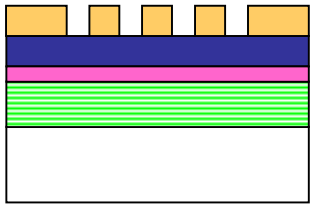
EUV mask with new capping layer showed no change in reflectivity after CrN etching process.

Etch performance in EB repair



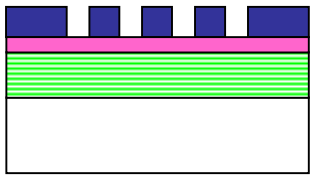
Courtesy of NaWoTec on the EB repair

Patterning process of EUV mask



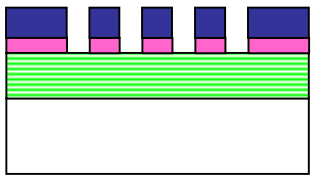
EB writing and resist developing

EB resist: Posi type CAR
LR-TaBN: 90 nmt
CrN: 10 nmt



Absorber etching and resist stripping

LR-TaBN absorber etching (by ICP-RIE)
Etching gas: Cl_2
Pressure: 0.1 Pa
Selectivity to CrN: >20



Buffer layer etching

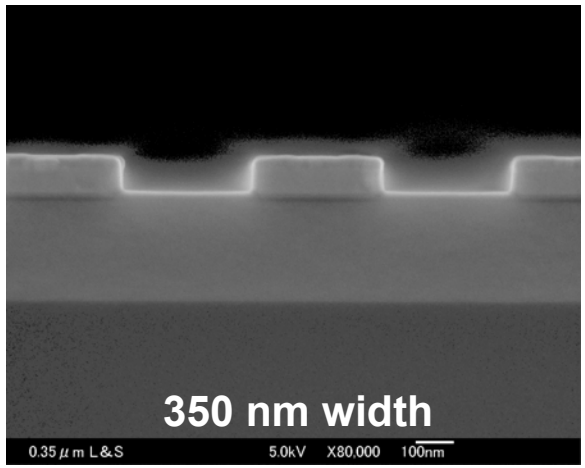
CrN buffer layer etching (by ICP-RIE)
Etching gas: Cl_2+O_2
Pressure: 0.1 Pa
Selectivity to Si: >50

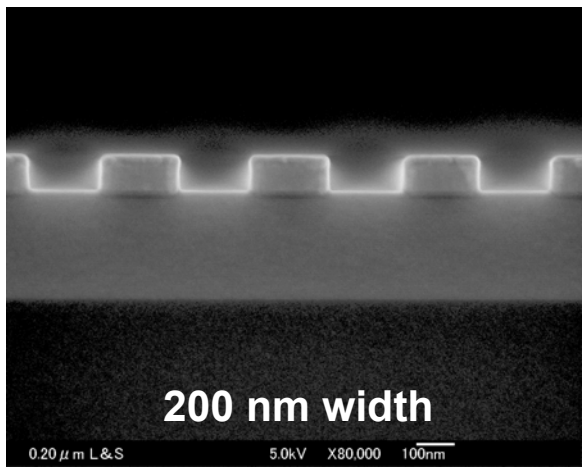
EUV masks were produced for evaluation of pattern images and mask inspection.

Cross sectional pattern images

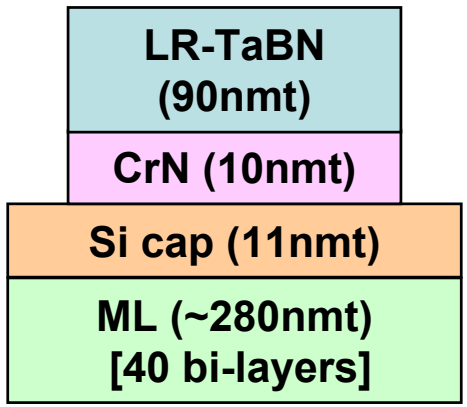
EUV test mask including L&S patterns and hole patterns

Line and space patterns

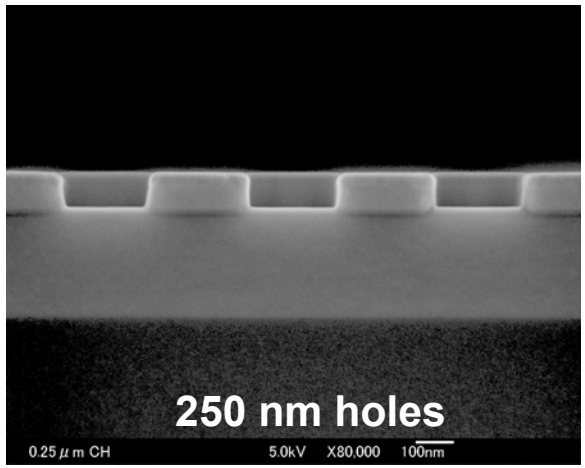


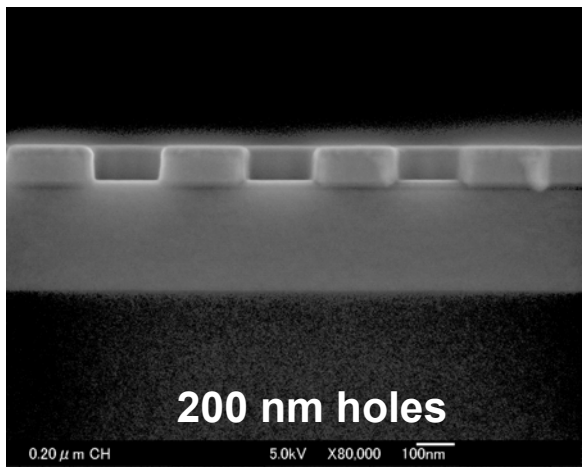


Pattern structure



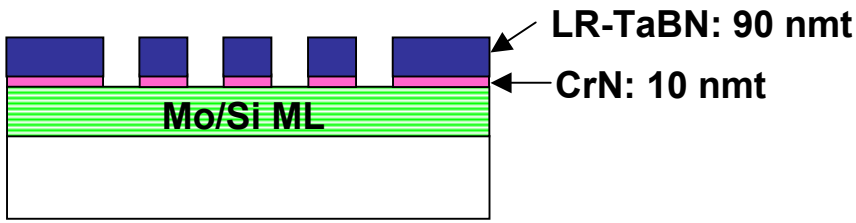
Hole patterns





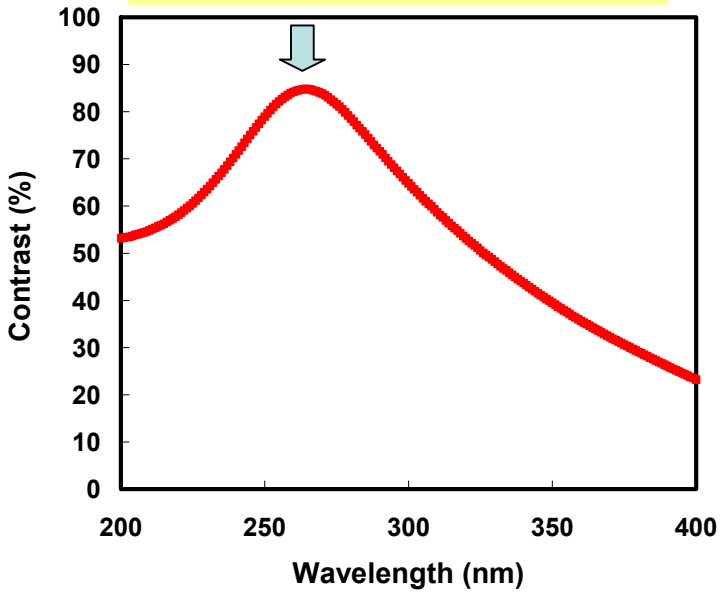
257nm DUV inspection images

EUV mask structure



Optical contrast on the mask

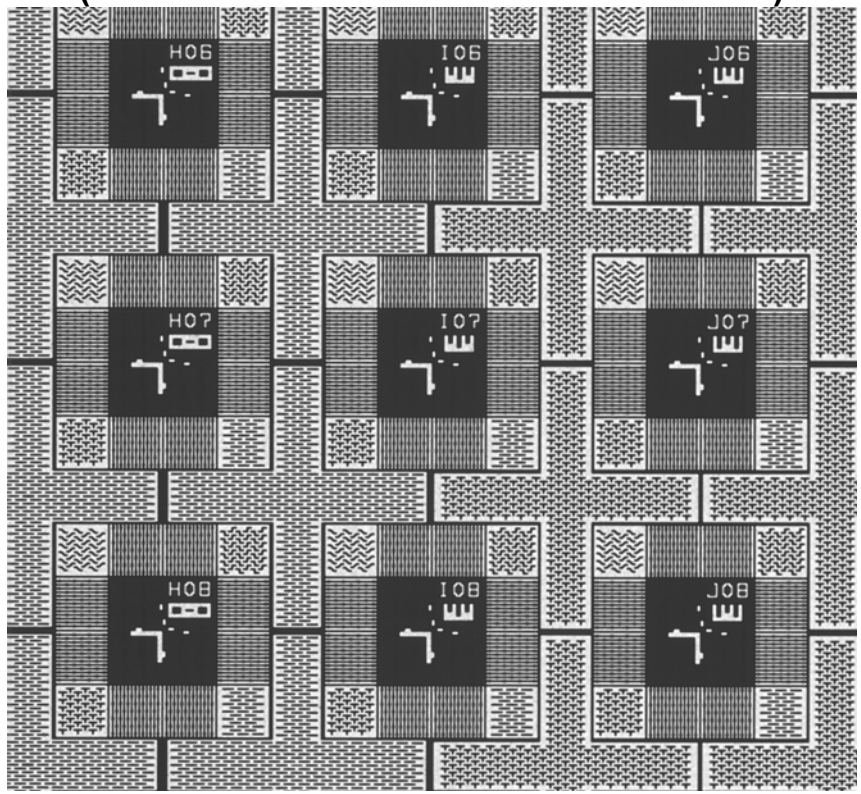
>80% contrast at 257 nm



Inspection image at TeraScan 257 nm

Programmed defect mask

(Patterns with a feature size of 240 nm)



The EUV mask showed good contrast

Courtesy of KLA-Tencor on the TeraScan DUV inspection system

EUV contrast on EUV mask

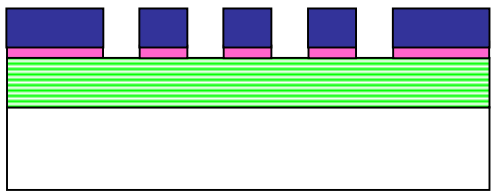
CrN buffer layer

Etch depth during EB repair: <1 nm

Etch depth during TaBN etch: <2 nm

CrN buffer: 5 nmt

LR-TaBN: 90 nmt



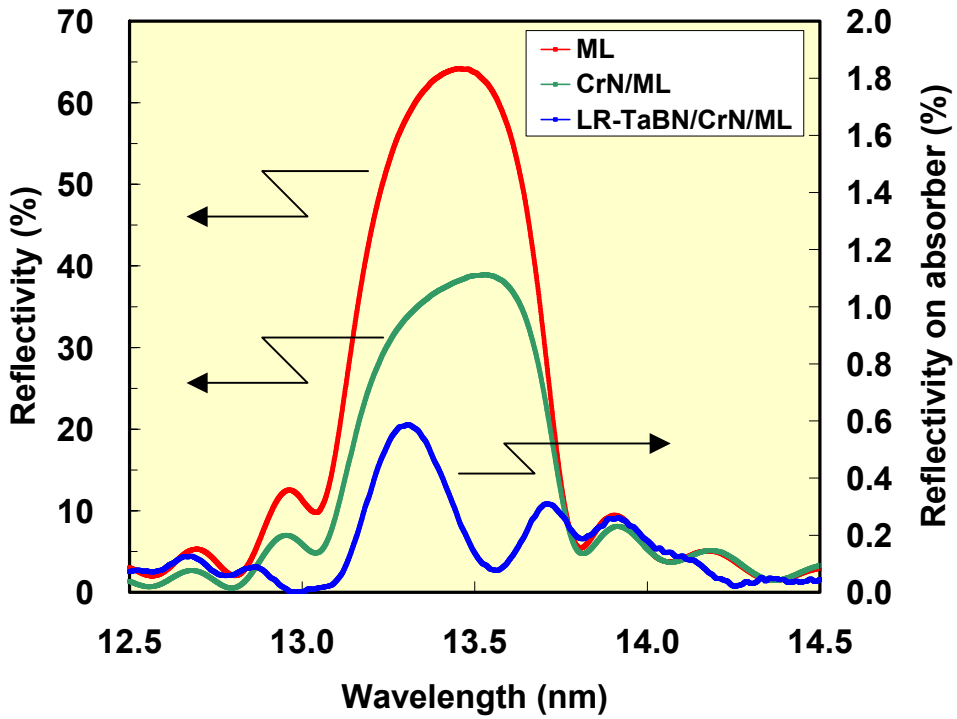
	Present mask	Target (for 45 nm node)
Mask contrast	98.2%	>97%
Aspect ratio	0.52	<1.3

EUV reflectivity spectra

ML: 11nmt-Si/40-bilayers

CrN: 5 nmt

LR-TaBN: 90 nmt

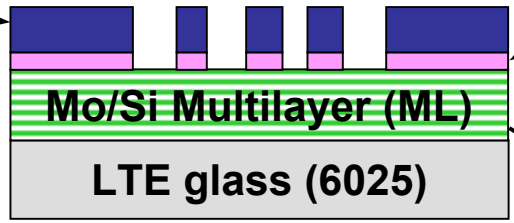


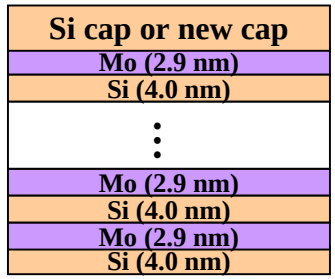
Summary

LR-TaBN absorber (90 nmt)

CrN buffer layer (5 nmt)

EB based repair
DUV mask inspection
(TeraScan/257 nm)





40 bi-layers

EUV blanks performance

- **Low reflectivity TaBN absorber:** <5% at 257nm
- **Smooth surface:** ~0.25 nm Rms
- **Low stress:** <200 MPa
- **High EUV absorption:** 95 nmt for 98% contrast
- **Fine patterning capability:** 200 nm width on mask
  - nearly vertical side wall
- **High etching selectivity (TaBN/CrN):** 595
  - using EB repair process
- **High dry etching durability to ML**

EUV mask performance

- **High inspection contrast**
- **Less LER**
- **Less IP**
- **Low aspect ratio: 0.52**
- **Precise mask (CD control)**
- **Damage less repair**
  - using EB repair process
- **High EUV reflectivity**

Next action

- **To evaluate mask IP, CD and LER**
- **To perform defect reduction in ML blanks**