# Dry etching and defect repair of TaGeN absorber layer for EUVL mask

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# Back ground

- **ASET and DNP are collaborating for EUV mask technology development**

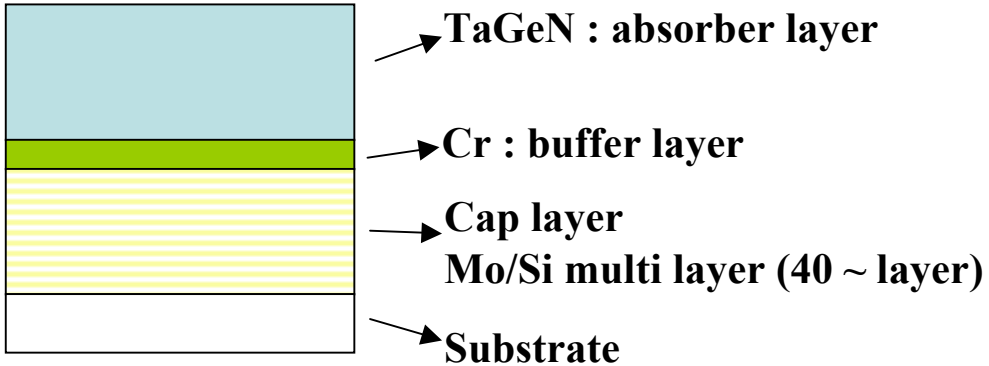
  ASET: EUV mask blank development
  - •Mo/Si multi layer, absorber and buffer layer

  EUV mask evaluation
  - •Reflectivity measurement and wafer print

  DNP : EUV mask process development
  - •Patterning and defect repair.

- **ASET developed TaGeN absorber layer and Cr buffer layer**

Advantages of TaGeN :
- •Low stress
- •Amorphous structure
- •Good chemical durability
- •High EUV absorbance



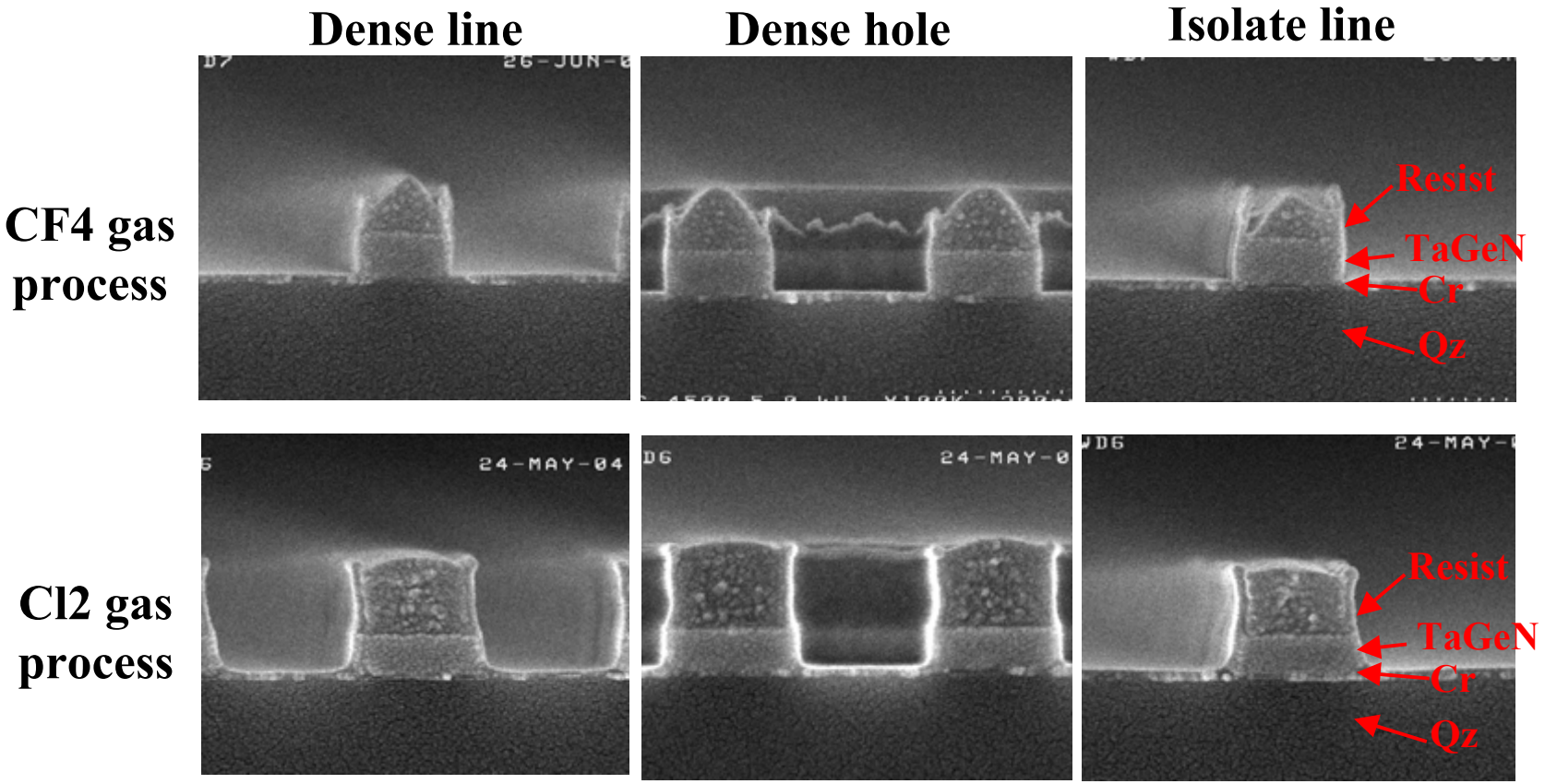

**ASET EUV mask blank structure**

- **DNP evaluated TaGeN absorber layer dry etching and defect repair**
- **ASET evaluated EUV mask fabricated by DNP**

# Absorber layer (TaGeN) dry etching

- Dry etching process — CF4 gas process
  Cl2 gas process
- Sample plate — TaGeN(88nm) + Cr(12nm) on 6025Qz
  w/ or w/o Mo/Si multilayer
- Patterning — PCAR with 50kV EB
- Evaluation tool — CD-SEM, Cross-section SEM
- Evaluation item — Resist damage, Cross section of TaGeN
  Etch bias uniformity and linearity

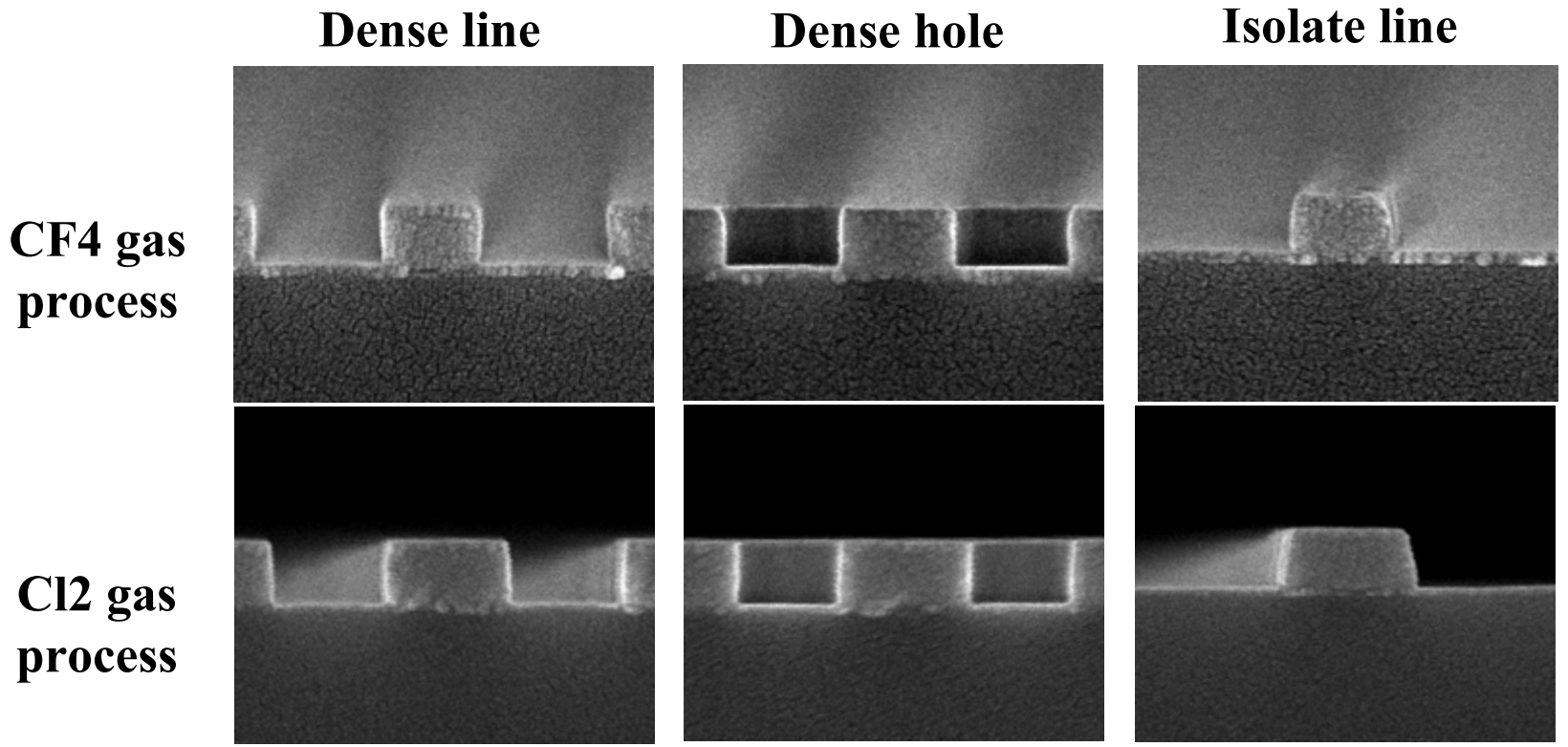
# Cross section profile of post dry etching resist




**Pattern size 300nm**

**•Resist damage of CF4 gas process was larger than Cl2 gas process**

# Cross section profile of TaGeN




Pattern size 200nm

- Vertical side wall were obtained in both gas process
- Cr buffer layer damage of Cl2 gas process was larger than CF4 gas process

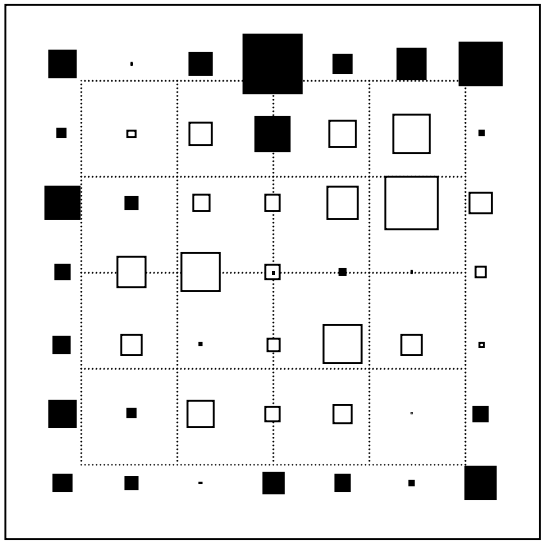
# Etch bias uniformity

Exposure tool : 50kV EB  Measurement tool : CD-SEM

Area size : 122 X 122 $mm^2$  Pattern : 400 nm Iso-Space

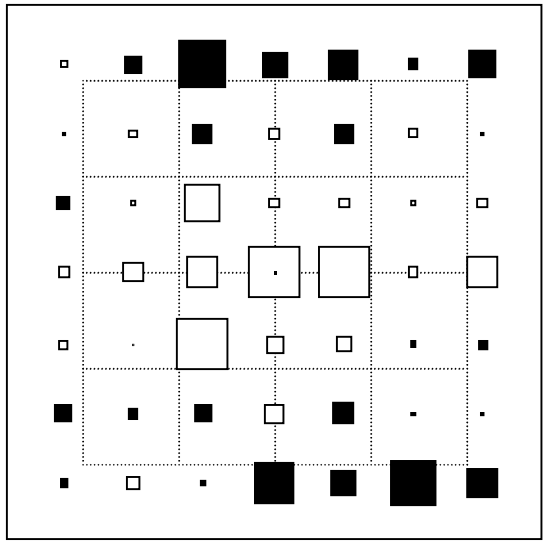
■ +5nm  □ -5nm

**CF4 process (high power)**



Mean : 2.05nm
Max : 9.31nm
Min : -4.31nm
3sigma : 9.95nm

**Cl2 process (low power)**

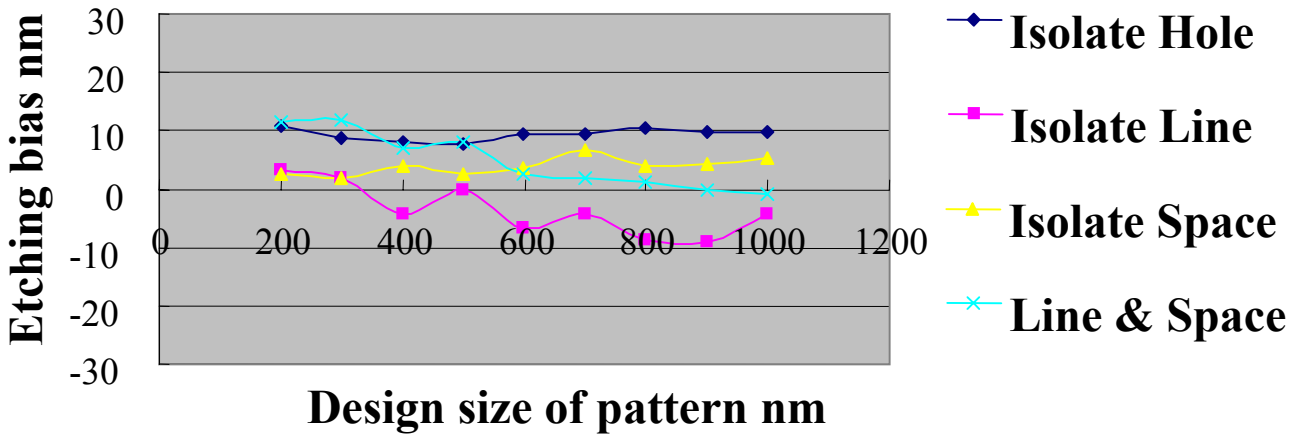


Mean : -27.3nm
Max : -21.62nm
Min : -33.71nm
3sigma : 8.36nm

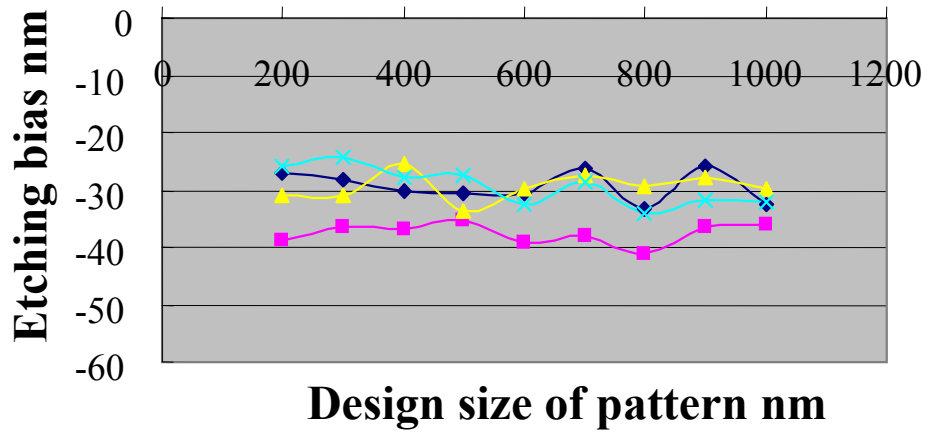
# Etching bias Linearity

Measurement tool : CD-SEM

CF4 process




Cl2 process



# Summary of absorber layer dry etching

| | CF4 gas process | Cl2 gas process |
|---|---|---|
| TaGeN cross section | Vertical | Isolated line : 80degree<br>Other pattern : Vertical |
| Resist profile of post TaGeN etching | Large top corner damage | Rectangle shape |
| Etch bias uniformity | 3s 9.9nm (122x122mm) | 3s 8.6nm (122x122mm) |
| Etch bias linearity | Range 10nm @ 200-1000nm | Flat @ 200-1000nm |
| Buffer layer selectivity | > 30 | ~6 |

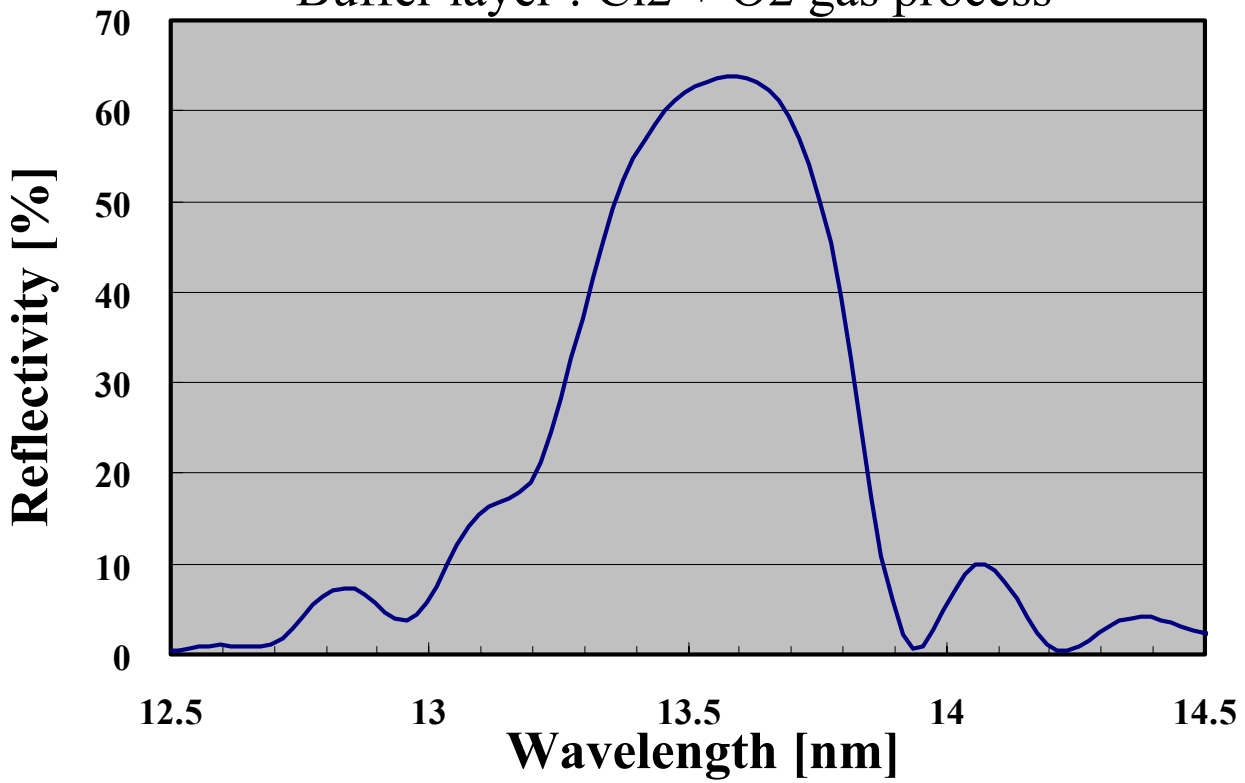
☆ Because of small Cr buffer layer damage, CF4 gas process was selected for EUV mask sample fabrication

# EUV mask reflectivity

EUV reflectivity after buffer layer dry etching

Absorber layer : CF4 gas process

Buffer layer : Cl2 + O2 gas process

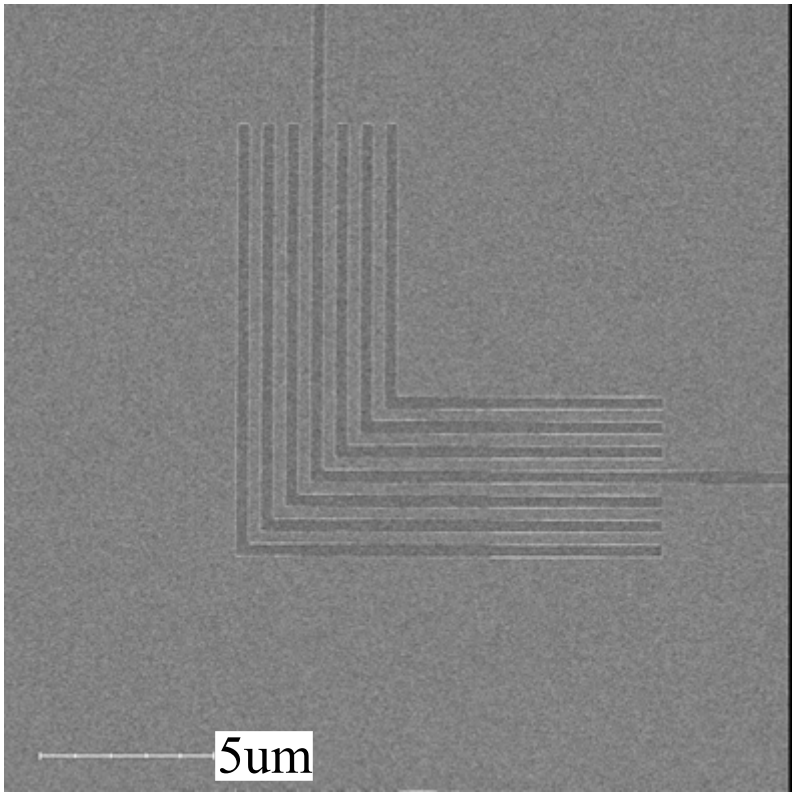



•Centroid wavelength : 13.54nm

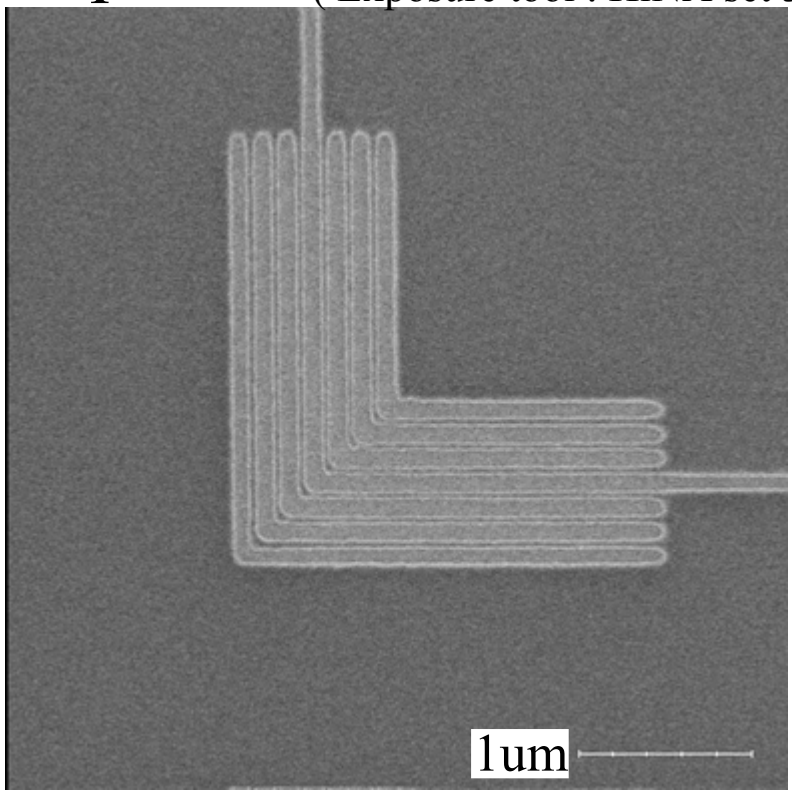
•Peak reflectivity : 63.8%

# EUV mask pattern and wafer print result

70nm line and space pattern ( Exposure tool : HiNA set 3)




Mask pattern




Wafer pattern

70 nm line and space was successfully fabricated

# TaGeN absorber layer defect repair

Evaluated repair technique

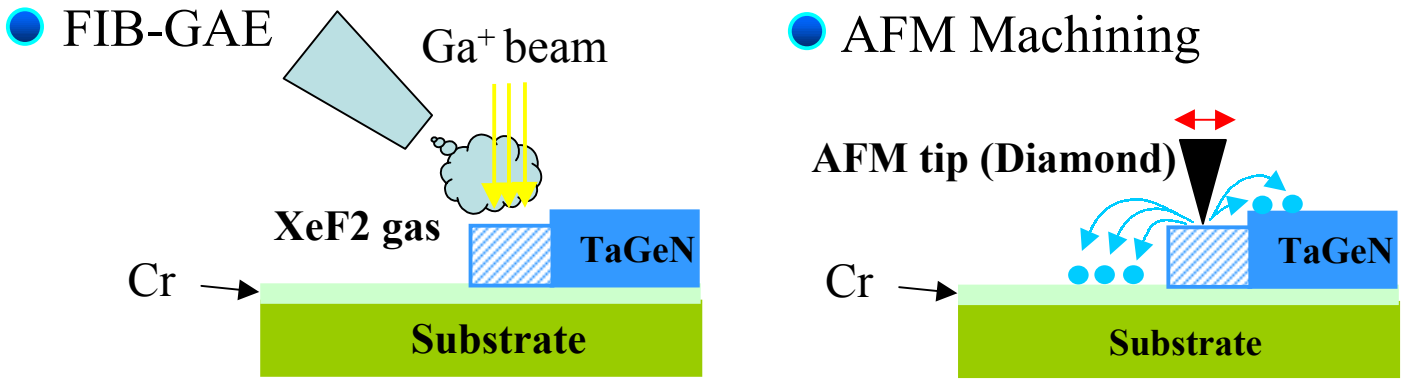
- FIB-GAE (Gas Assist Etching)
- AFM Machining

Evaluation tool

- CD-SEM
- AFM

Sample

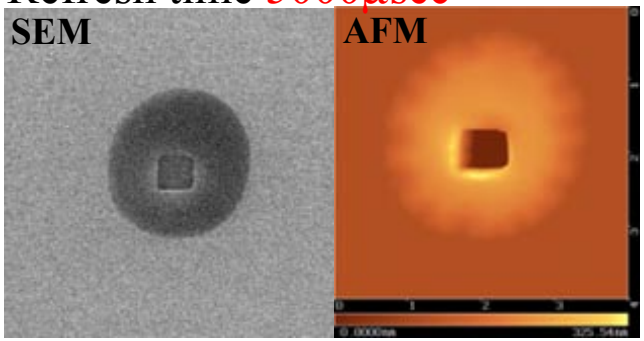
- TaGeN / Cr on 6025Qz → FIB-GAE
- TaGeN / Cr / MoSi multilayer on 6025Qz → AFM machining

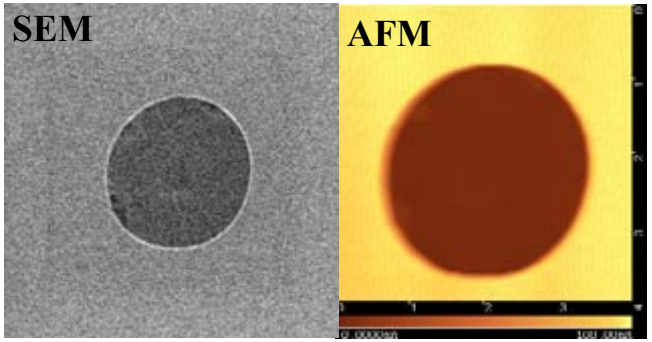


# FIB- GAE test results (assist gas : XeF2)

XeF2 pressure 1.0Torr

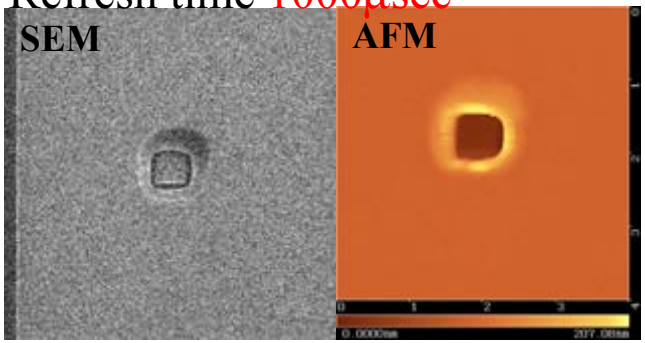
Refresh time 5000μsec

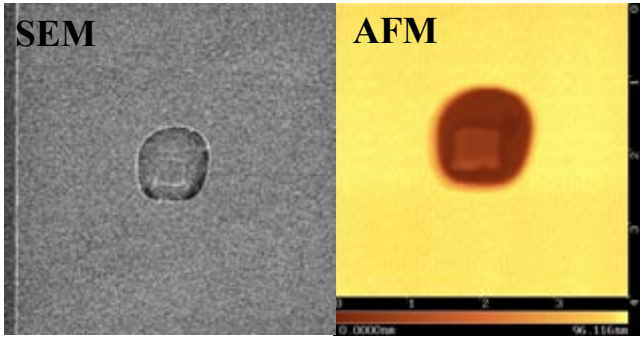



Wet Cleaning

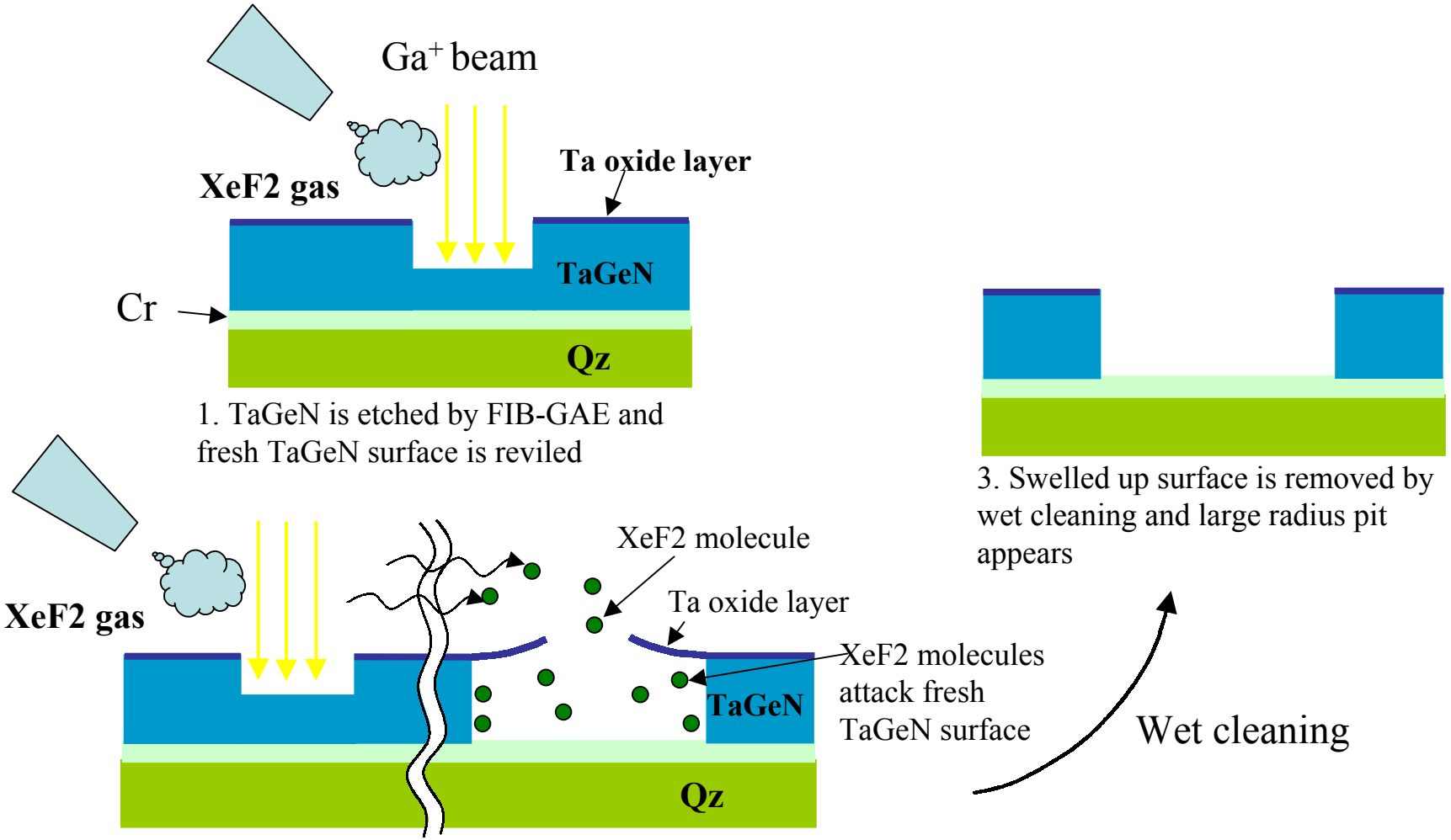
Refresh time 1000μsec




Buffer layer surface was swelled up around the etching area. The surface was removed by wet cleaning and large pit was appeared. The side etching amount was changed by gas assist condition.

# TaGeN FIB-GAE using XeF2 gas



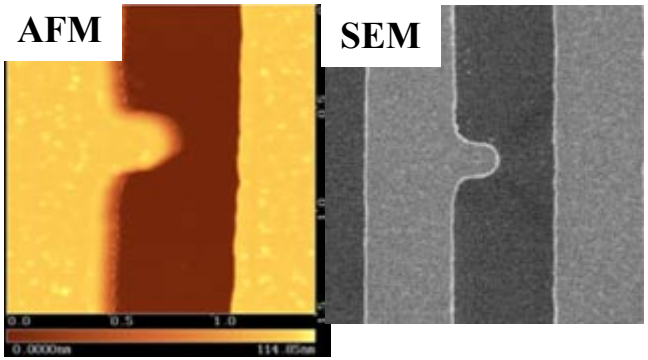

1. TaGeN is etched by FIB-GAE and fresh TaGeN surface is reviled

2. XeF2 molecules attack fresh TaGeN surface of former repaired pattern. Ta oxide layer swells up by its stress

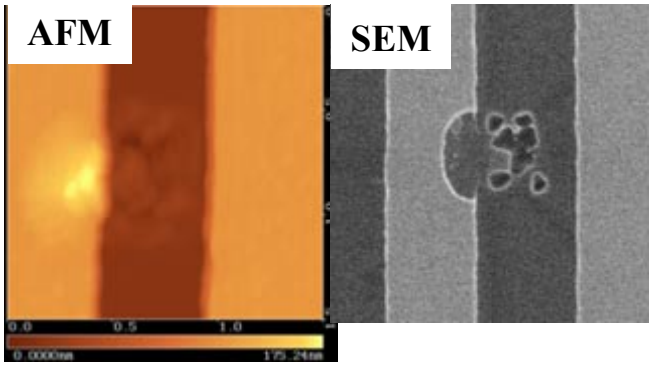
3. Swelled up surface is removed by wet cleaning and large radius pit appears

# XeF2 GAE designed defect repair test result

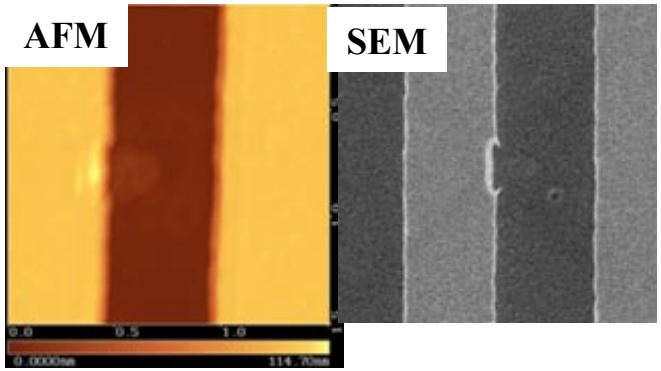
**Reference**
0.6µm L&S
Defect size
280nm




**Repair test1**
XeF2 pressure
1.0Torr
Refresh time
1000µS
Dose
0.04nC

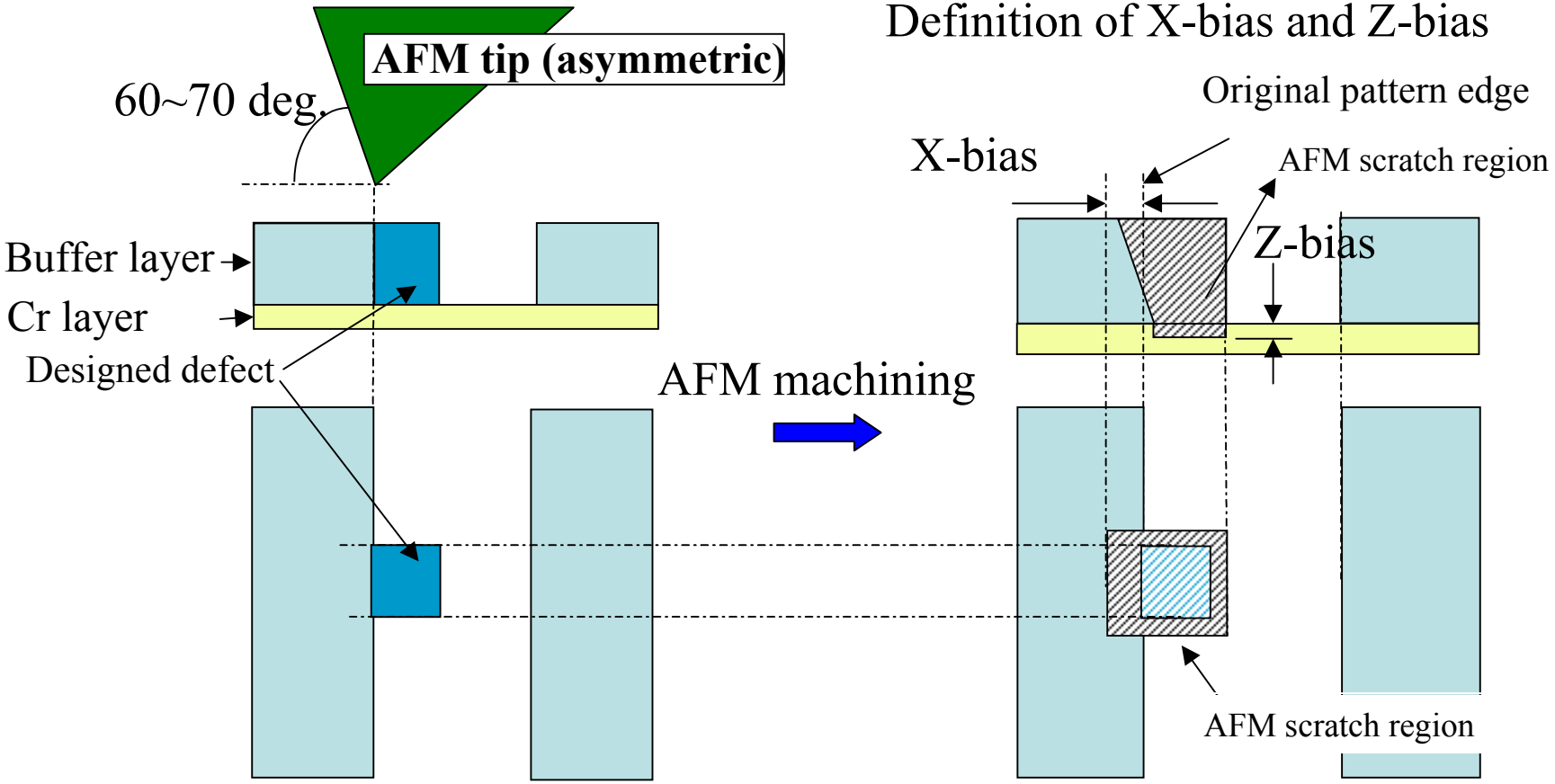



**Repair test3**
XeF2 pressure
1.0Torr
Refresh time
5000µS
Dose
0.015nC




Refresh time 1000µsec condition caused Cr layer damage around the designed defect area. Refresh time 5000µsec condition did not caused Cr layer damage. However, this etching condition caused large side etching at a former repaired pattern (see repair test1).

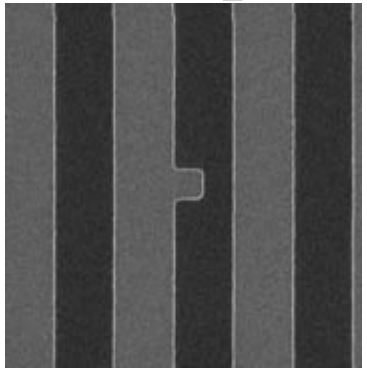
# AFM machining defect repair




AFM tip (asymmetric tip) angle is 60 - 70 degree, so side wall of repaired pattern become tapered shape and some scratched material is pushed into substrate. Therefore X-bias and Z-bias are needed for AFM machining repair technique.

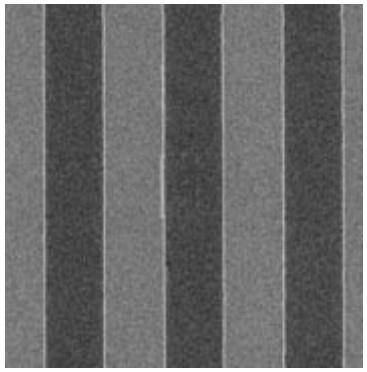
# SEM images of AFM machining defect repair results

- **Before buffer layer dry etching** Reference

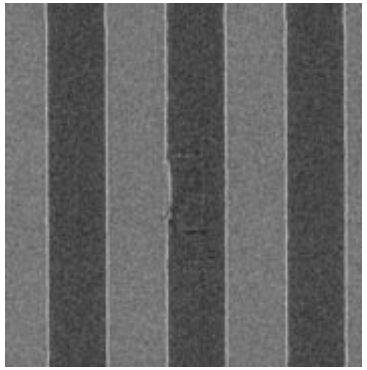


**•Main pattern 1um line and space**
**•Defect pattern size 0.5 um**

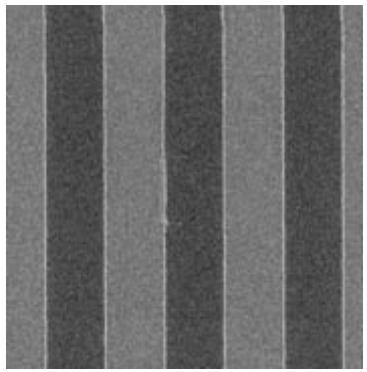
TEST 1-1
X bias 40nm
Z bias 5nm



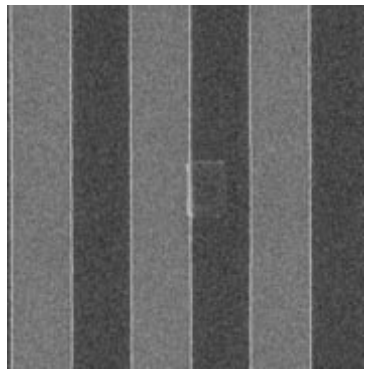
TEST 1-3
X bias 0nm
Z bias 5nm



TEST 1-2
X bias 20nm
Z bias 5nm



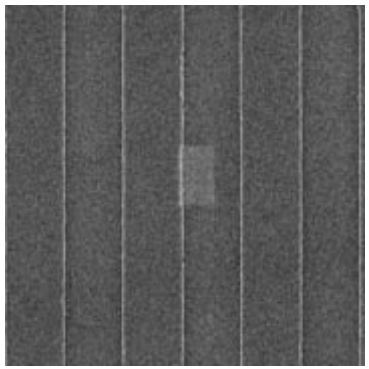
TEST 2-2
X bias 20nm
Z bias 0nm



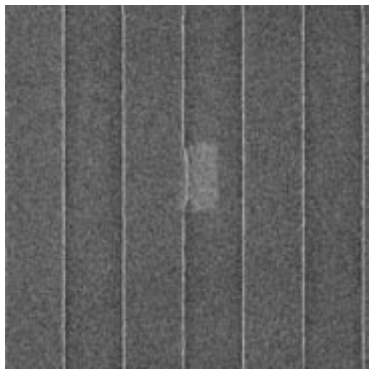
# SEM images of AFM machining defect repair results

## After buffer layer dry etching

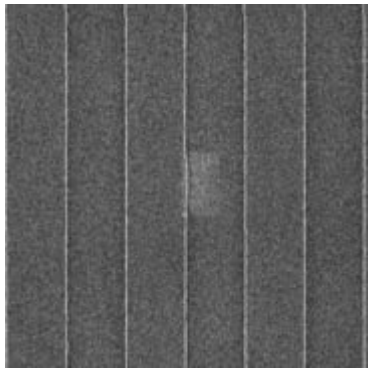
TEST 1-1
X bias 40nm
Z bias 5nm



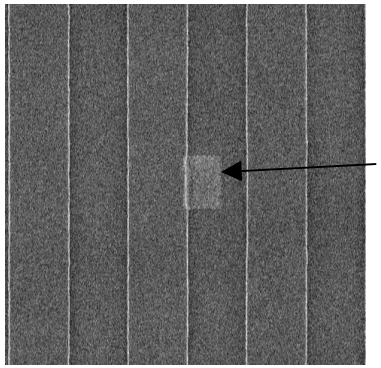
TEST 1-3
X bias 0nm
Z bias 5nm



TEST 1-2
X bias 20nm
Z bias 5nm

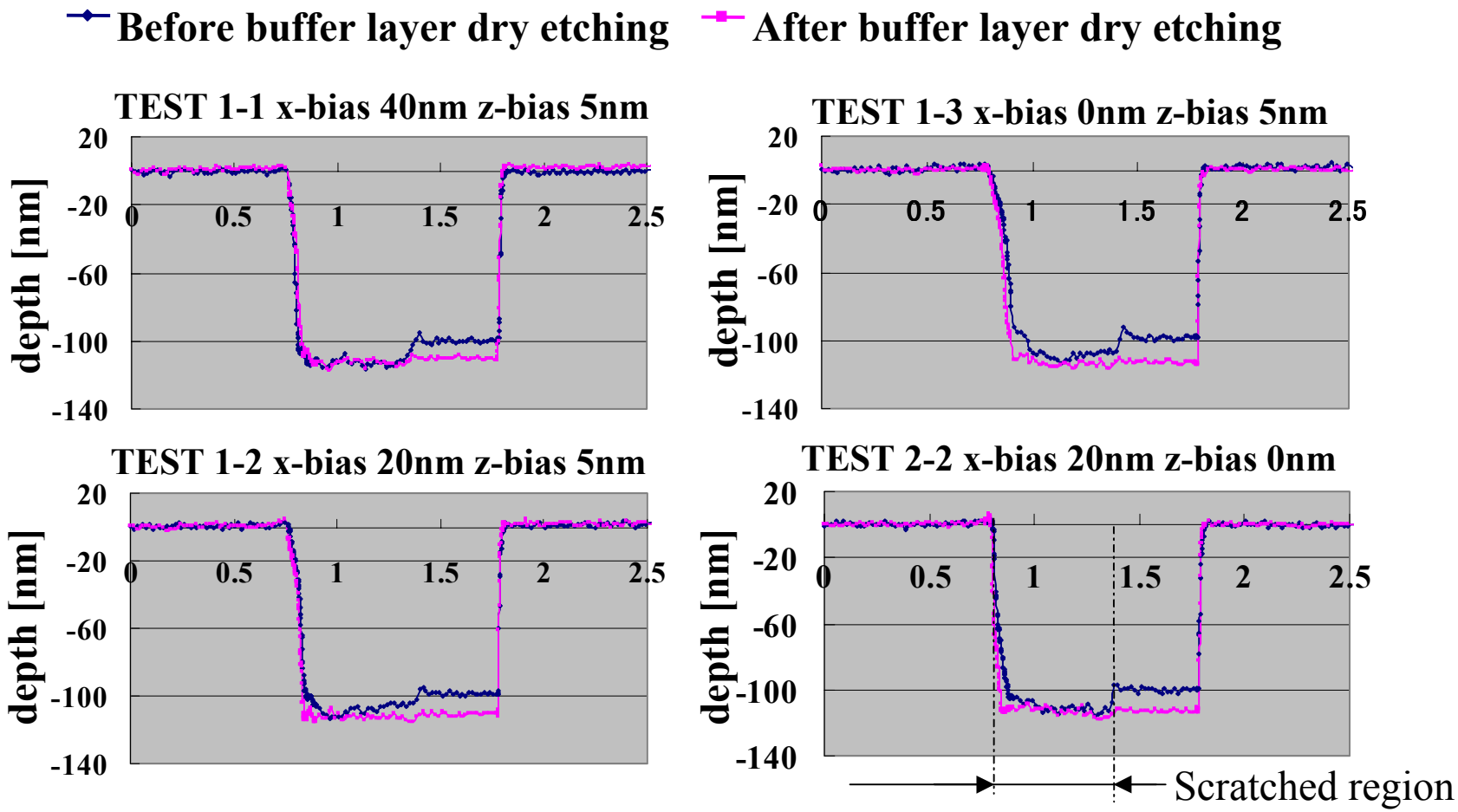


TEST 2-2
X bias 20nm
Z bias 0nm



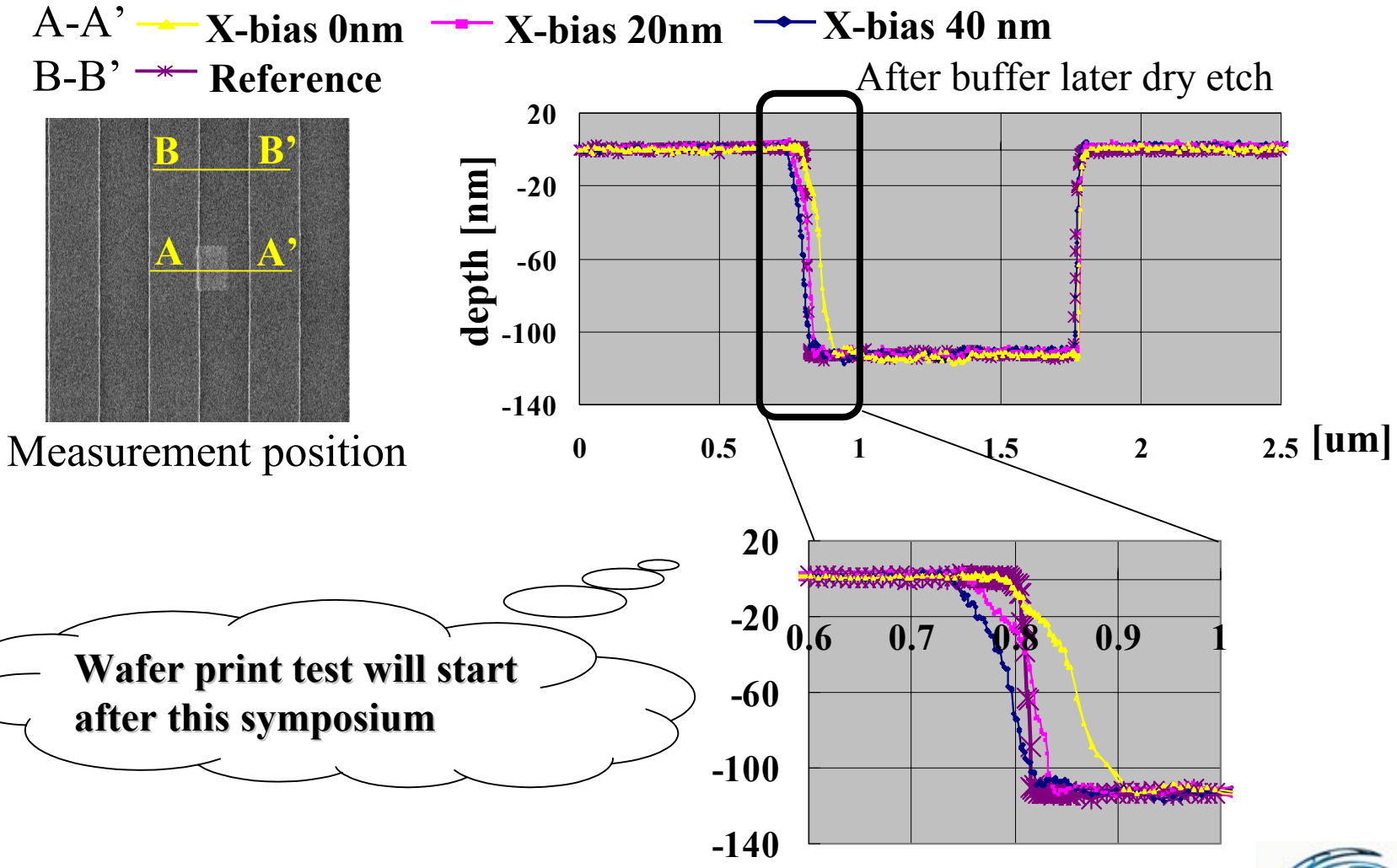

Contrast difference was observed between scratched region and unscratched region.

# Cross section of AFM scratched region 1




Scratched depth was 5~10nm deeper than target depth. After the buffer layer dry etching, some roughness remained on the scratched surface and the depth was 1~1.5nm deeper than unscratched surface.

# Cross section of AFM scratched region 2



# Summary

- Absorber layer dry etching process were evaluated
  - CF4 gas process
    - Advantage : High Cr selectivity (>30)
    - Disadvantage : Large resist damage
  - Cl2 gas process
    - Advantage : Better resist selectivity than CF4 gas process
    - Disadvantage : Low Cr selectivity (about 6)
  - Each gas process achieved vertical cross section and small etch bias
  - Because of small buffer layer damage, CF4 gas process was selected for EUV mask sample fabrication
  - Peak reflectivity of 63.5% and centroid wavelength of 13.54nm was obtained
  - Wafer print test was demonstrated
- Defect repair of TaGeN absorber layer was evaluated
  - Good selectivity between TaGeN and Cr layer was obtained with XeF2 gas. However, XeF2 gas causes large side etch at TaGeN layer
  - AFM machining defect repair was evaluated

# Acknowledgement


- This work was supported by the New Energy and Industrial Technology Development Organization (NEDO)
- HiNA set-3 projection optics were developed and provided by Nikon Corporation.