The repair performance comparison for EUV mask

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Contents

I. Introduction

- **Next generation repair for EUV mask**

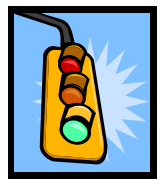
Previous matter

- Edge placement error minimization
- Substrate damage free

➔ Guarantee of wafer process window

EUV repair technology

- No more prolongation of current technology
- There are many obstacles to mass production
- Need to choose the best candidate among variable repair technology



Variable repair technology for EUV mask

- **FIB : Familiarity, Substrate damage caused by ion implantation**

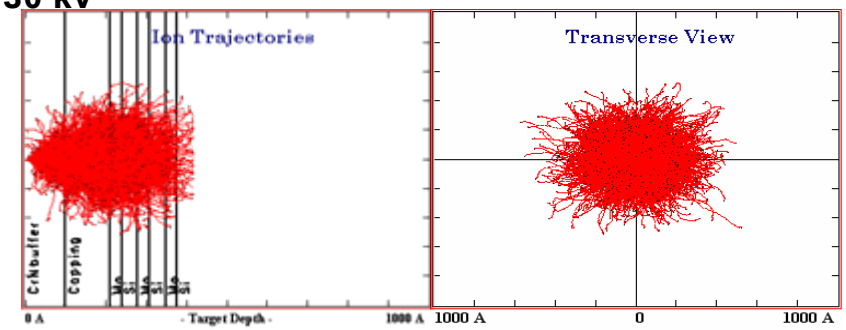
  ➔ **Confirm of problems with 30 kV FIB**

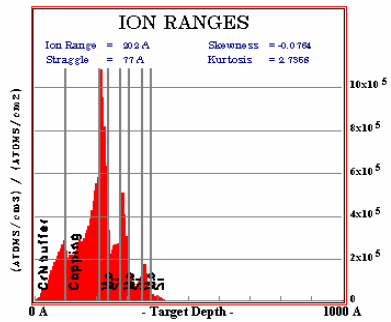
  Capability of low accelerating voltage

TRIM* simulation

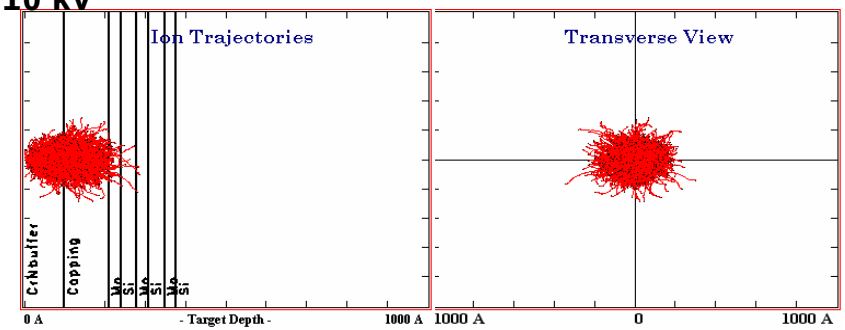
*TRIM : the Transport of Ions in Matter. http://www.srim.org

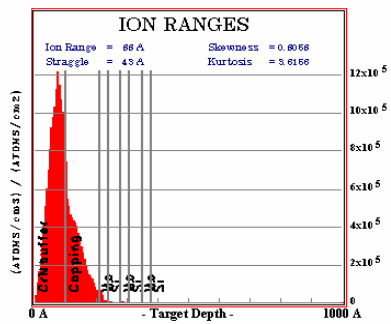
30 kV





10 kV



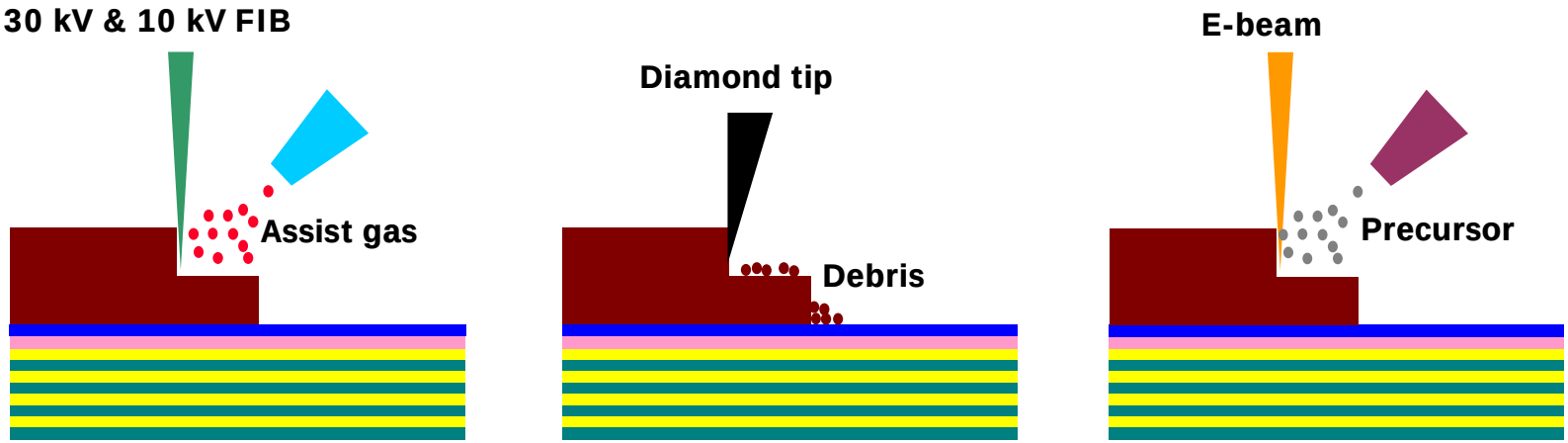


Ion trajectory **Probability distribution**

Serious multi layer damage is predicted @ 30 kV FIB.
A little ion penetration to multi layer @ 10 kV ➔ Small ML damage, higher potential than 30 kV

- Nanomachining : Low substrate damage, surface roughness on repaired area
  Limitation of pattern geography, Throughput and tip life time
- E-beam : High etching selectivity, Low substrate damage
  reaction between Absorber layer and precursor
  ➔ Scan damage on absorber

Comparison & analysis of each repair technology
➔ Selection of an optimal EUV repair technology or combination
Evaluation of capability



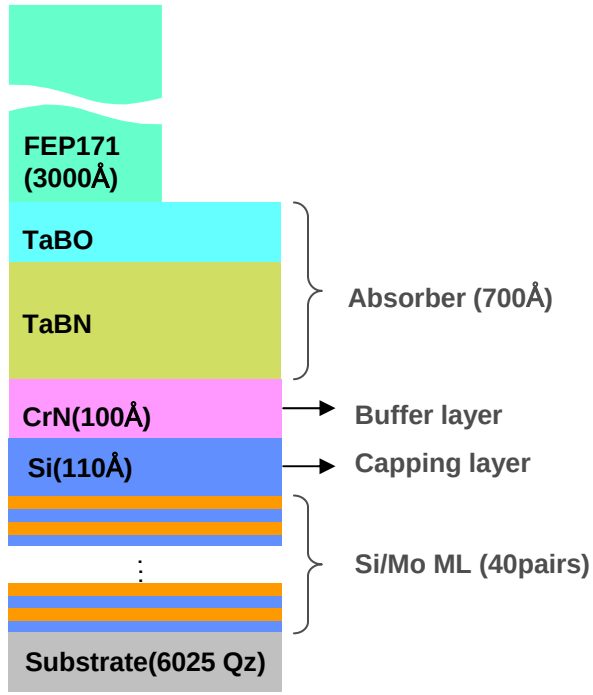
II. Experimental conditions

1. Mask repair conditions

- Blank : HOYA EUV blank
- Repair tool
  - FIB : SIINT - SIR7000(30 kV) & SIR-7 (10 kV)
  - Nanomachining : RAVE LLC – nm650
  - E-beam : Carl Zeiss – MeRiT mg

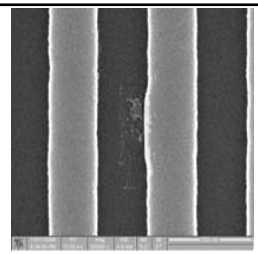
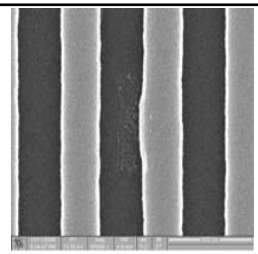
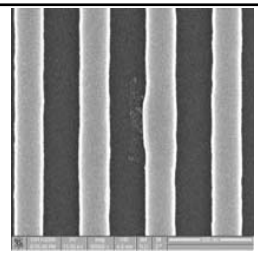
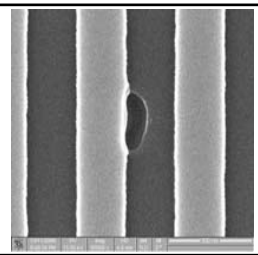
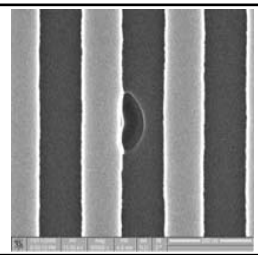
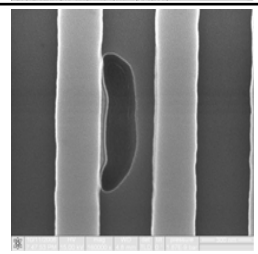
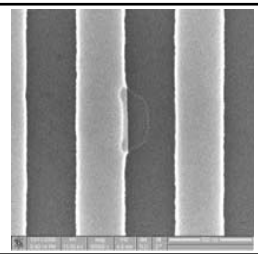
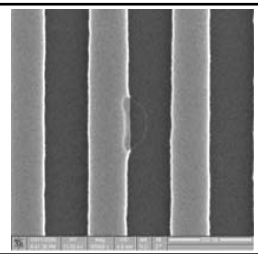
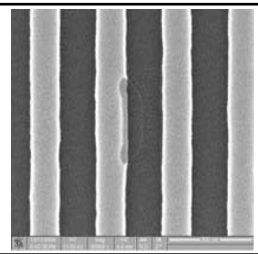
2. Wafer Exposure conditions

- Resist condition
  - Resist thickness : 100 nm
  - HMDS treatment, without ARC
- Exposure Conditions
  - Exposure tool : LBNL MET
  - NA 0.3, 5X,
  - Incident angle : 3.6˚
  - Annular, sigma 0.30/0.55

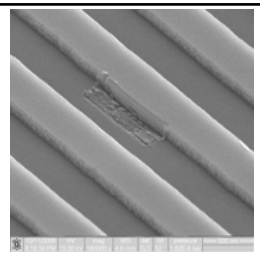
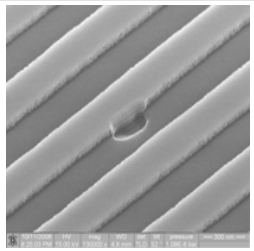
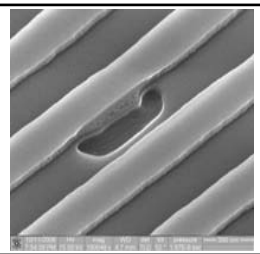
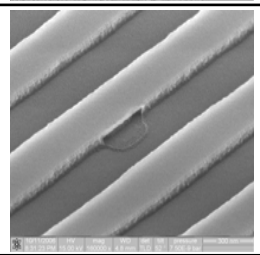


III-1. Results – Mask repair

[1] SEM image – top view

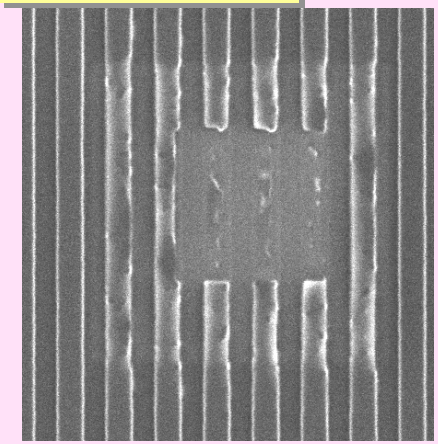
(1X)		60nm	50nm	40nm
Nanomachining				
FIB	10 kV			N/A
	30 kV		N/A	N/A
E-beam				

[2] SEM image _ tilt view

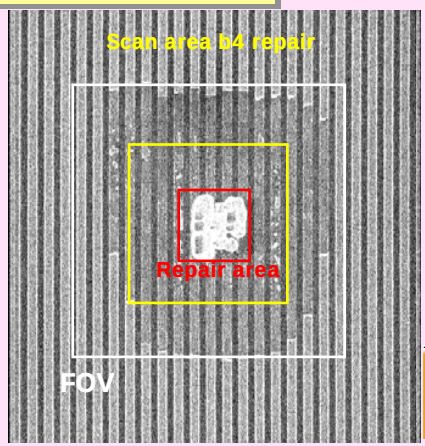
		image	
Nanomachining			◆Morphology on surface ◆Over-offset → capping layer damage
FIB	10 kV		◆Small substrate damage comparing to 30 kV
	30 kV		◆Large substrate damage
E-beam			◆Minimum substrate damage ◆Undercut at Boundary between defect and pattern

[3] 30 kV FIB : Scan damage with respect to assist gas

Before cleaning



After cleaning



XeF_2

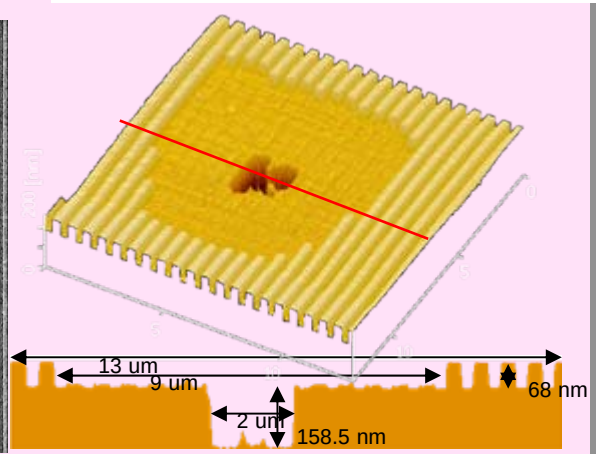
High scan damage with XeF_2

➔Amplification of damage after wet cleaning

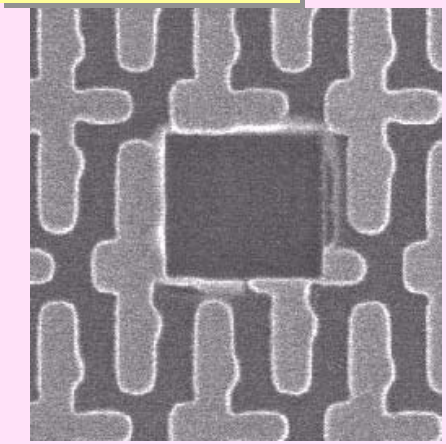
➔ Difference of etch rate between TaBO and TaBN made T top profile of absorber layer.

➔ This weaken absorber structure which can be easily damaged by wet cleaning process.

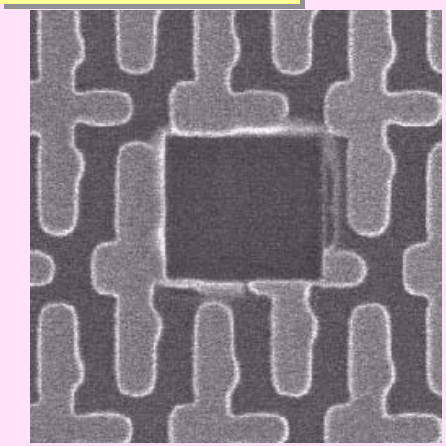
No scan damage with ß gas



Before cleaning

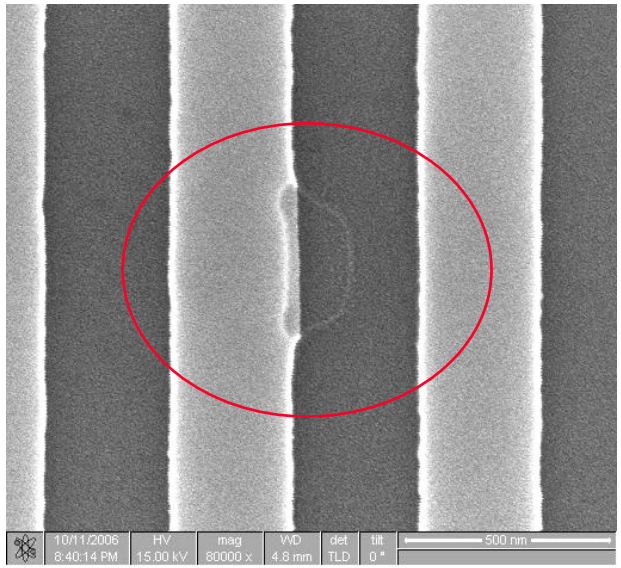


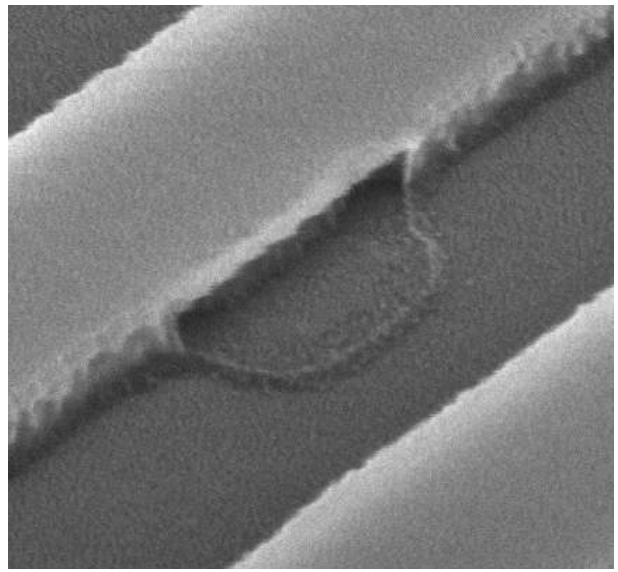
After cleaning



ß gas

[4] e-beam : T-top profile & scan damage free

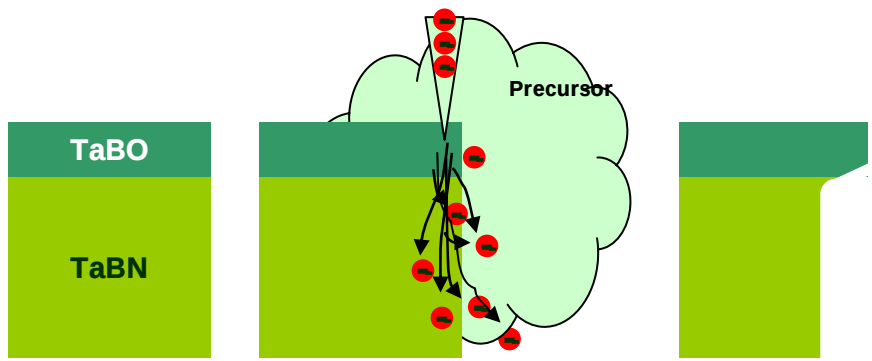




High corrosiveness of precursor, XeF2

- **➔T-top profile was caused by etch rate difference between TaBo and TaBN**
- **➔Weakness of pattern structure**
- **➔Pattern damage could be induced by wet cleaning process.**

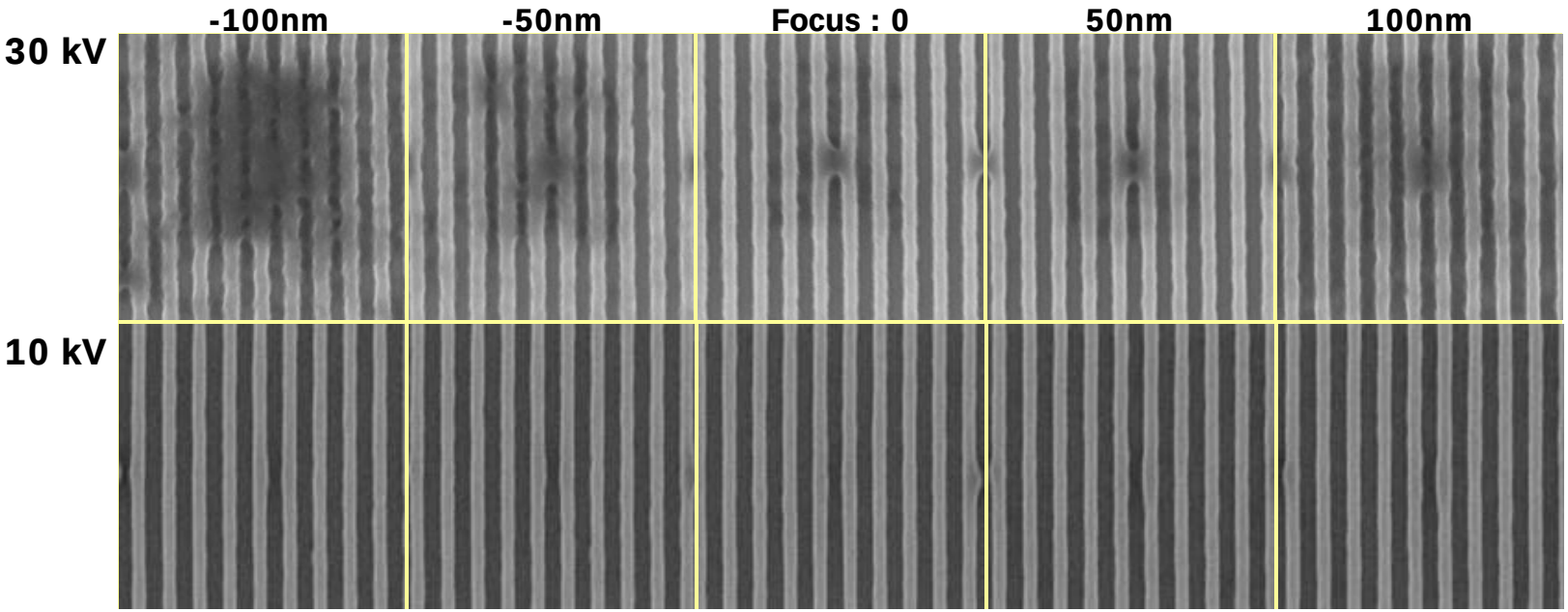
Scan damage free : pretreatment was applied to protect scan damage



Mechanism of T-top profile

III-2. Results – Wafer printability

[1] 30 kV FIB vs. 10 kV FIB (60 nm) _ β gas



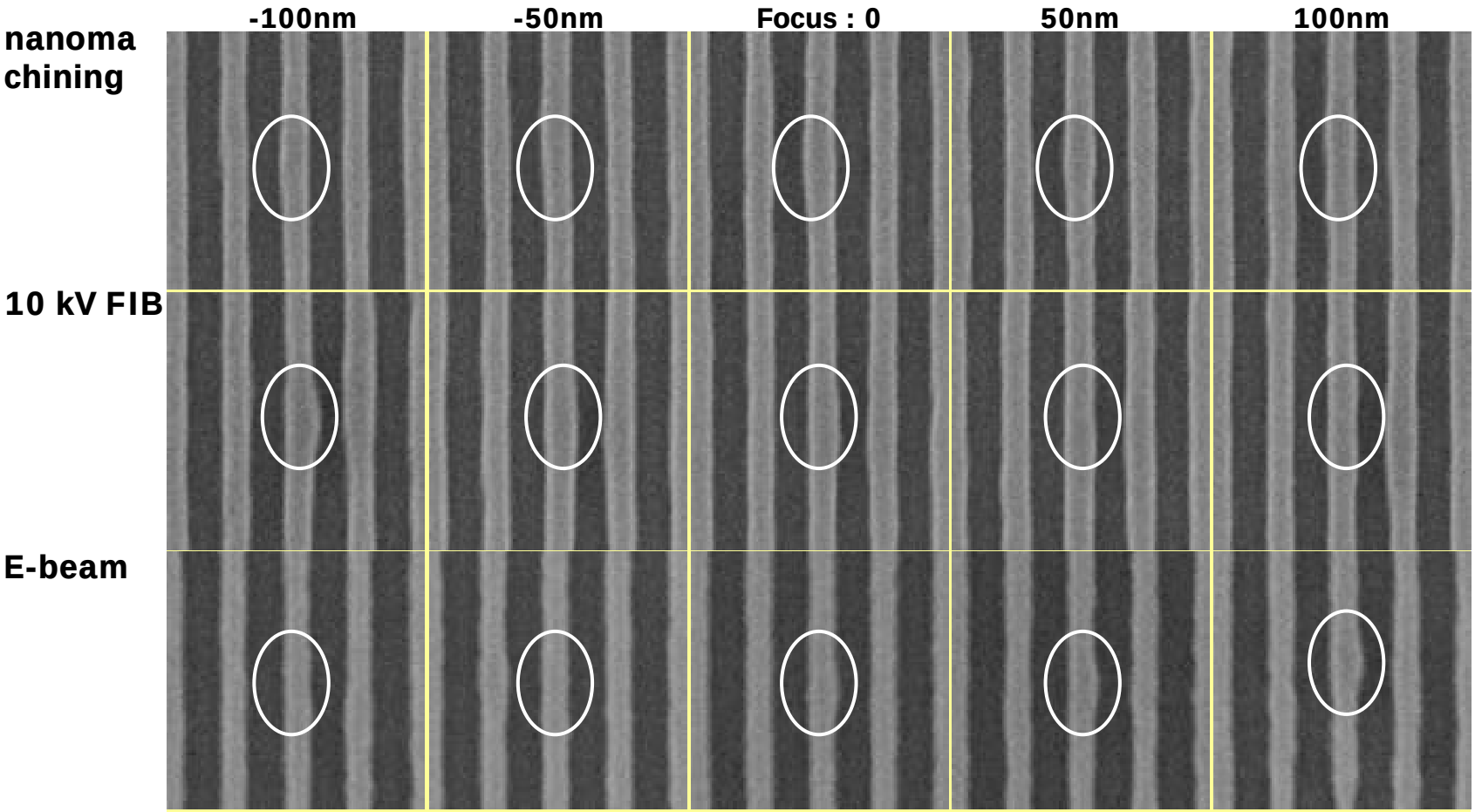
30 kV : Reflectance change of multi layer by ion implantation during scan ➔ Serious edge roughness and bridge

Multi layer damage by over etching in repaired area ➔ failure of repair

10 kV : No scan damage

Small reflectance change was observed in repaired area although multi layer damage was showed from SEM image.

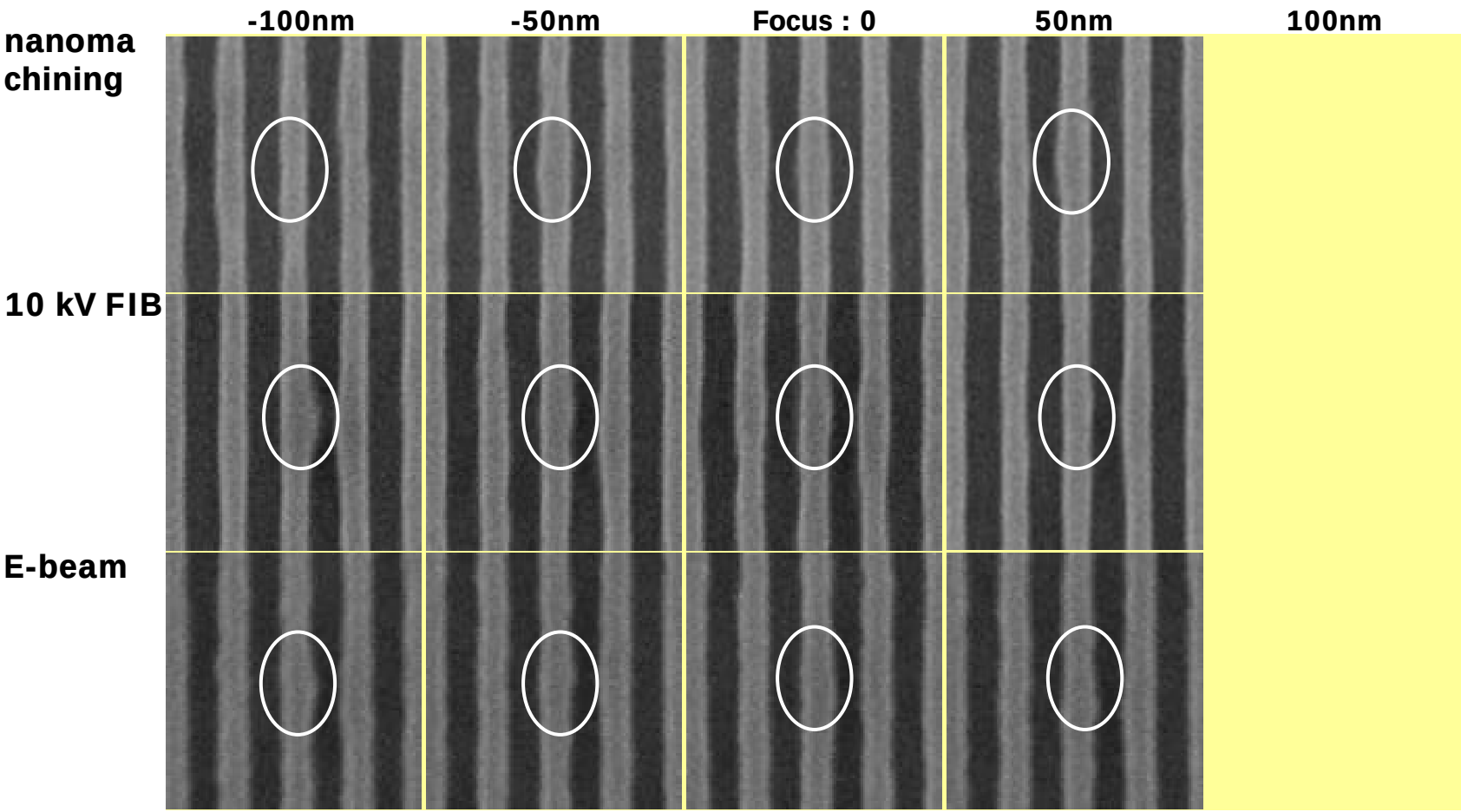
[2] 60 nm L/S



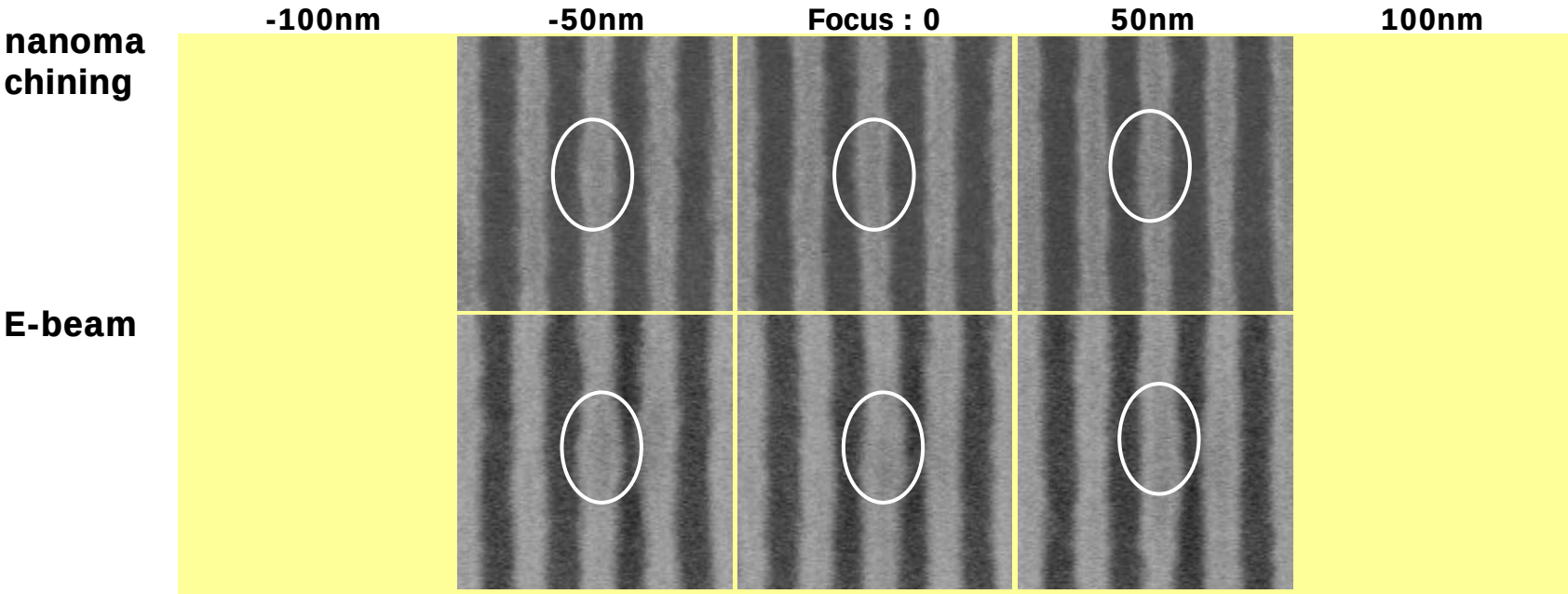
10 kV FIB : Reflectance error of ML by FIB repair

There's need to adjust repairing dose

[3] 50 nm L/S



[4] 40 nm L/S

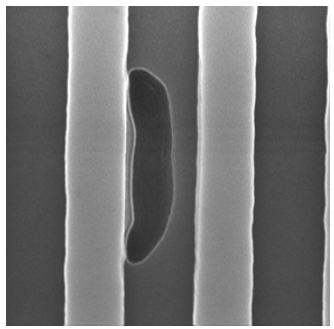


Nanomachining repair : The optimized repair condition from two pre test.

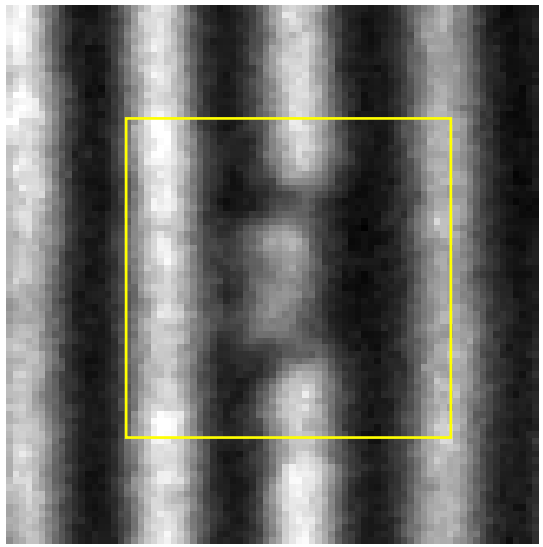
➔ Better performance than other repair methods

III-3. Actinic Inspection _ 30 kV FIB repair, @LBNL

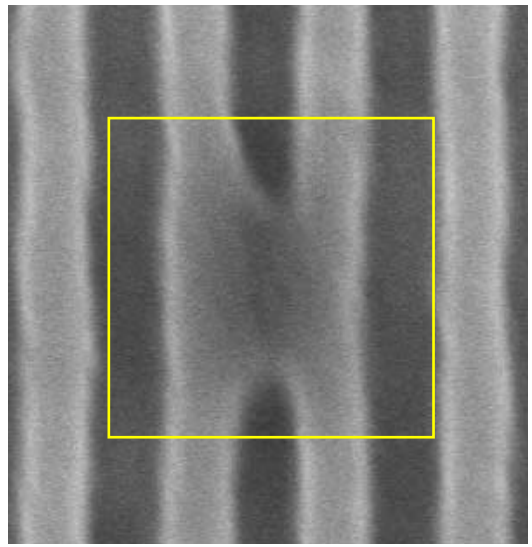
- Actinic inspection system at LBNL was used.
- The images are each 81 x 81 pixels.
- Each pixel is 28.736 nm.
- Therefore, the image is 2.327 μm wide.



Mask image



Actinic inspection image



Wafer image

- Actinic inspection result matched wafer result well.
- Requirement of actinic inspection or Aerial imaging system to dispose defect.

IV. Conclusion

- Need to choose the best candidate among variable repair technology
- Evaluation of FIB, nanomachining, e-beam repair technology

		Results	Problems
FIB	30 kV	•Multi layer damage in FIB scanned area •Multi layer damage in repaired area	•Reflectance change in scanned and repaired area by Ga implantation → No capability
	10 kV	•No scan damage •Multi layer damage in repaired area	•Repairing dose not adjusted •Need more analysis of reflectance change in repaired area
Nanomachining		•Good performance to 40 nm	
E-beam		•Pretreatment → scan damage free repair •Good performance to 40 nm •Undercut (mask)	•High corrosiveness of XeF_2 •Need development of new method to prevent undercut

- Three technology (E-beam, nanomachining, low accelerating voltage FIB) have potential enough to repair EUV mask.

- There is no single selection of repair technology, because each technology has different strong point. Selection of repair technology depends on the defect type.
- Although E-beam repair has high potential, the development of new method to prohibit from undercut phenomenon.
- The damage free issue is the most important for FIB technology.

  In the case of low accelerating voltage FIB repair, few scan damage was observed due to low corrosive beta gas.

  But Reflectance change issue in repaired area by ion implantation should be confirmed.

		Resolution	Edge placement	Multi layer damage	Removal selectivity	Geographical dependency	Throughput	Familiarity
FIB	30 kV							
	10 kV							
Nanomachining								
E beam								

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