The dry etching performance of EUV mask absorbers

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1–1. Motivation (1)

- Extreme Ultraviolet Lithography (EUVL) is considered as a candidate to fabricate LSI devices for 22 nm node and beyond. To make finer EUV absorber patterns, thinner EB resists are desired in mask making process.

- The current EUV absorber is composed of bi-layer of tantalum (Ta) based film, and the dry etching mechanisms of its upper layer and lower layer are different.
  In general, the etching process of the EUV absorber is divided into two steps to acquire the high selectivity ratio to the EB resist.

We aimed to find the simplified etching condition that was able to achieve the high selectivity ratio.

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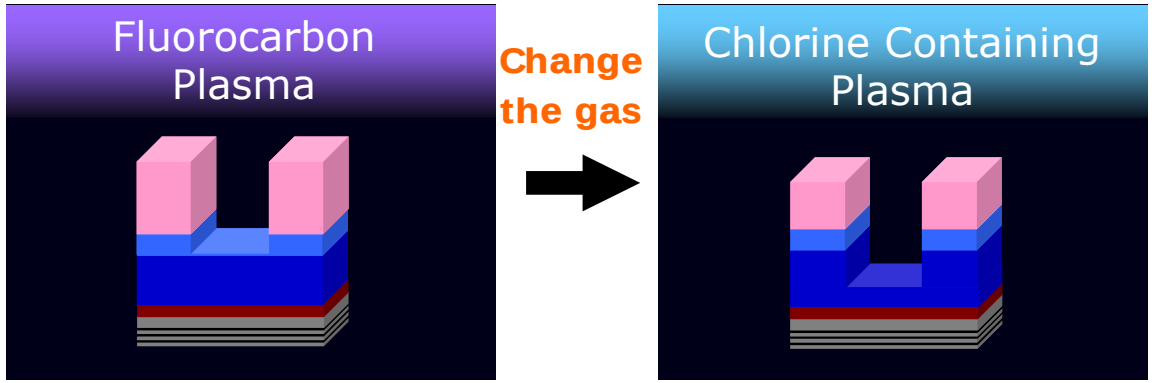
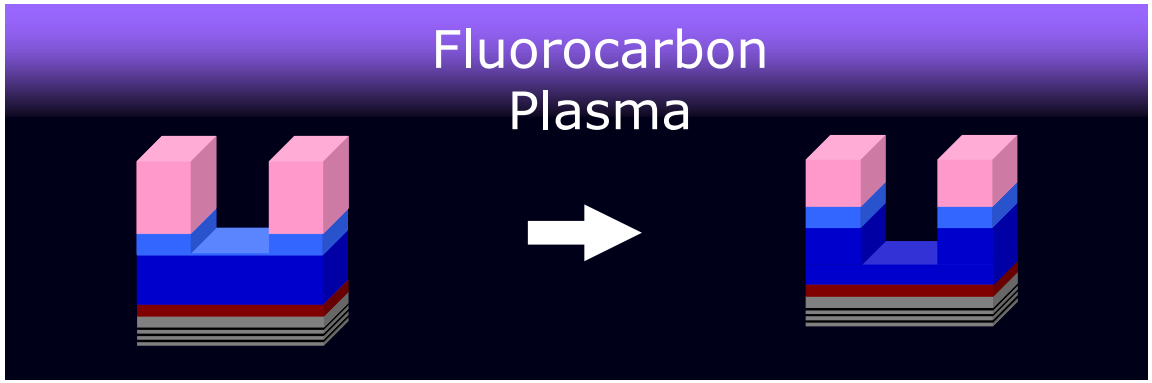
Two steps etching process



Pros.;
High selectivity to resist

Cons.;
Complex process

One step etching process; using only fluorocarbon plasma



Pros.;
Simple process

Cons.;
Low selectivity to resist

We try to develop "One step" process as well as high selectivity.

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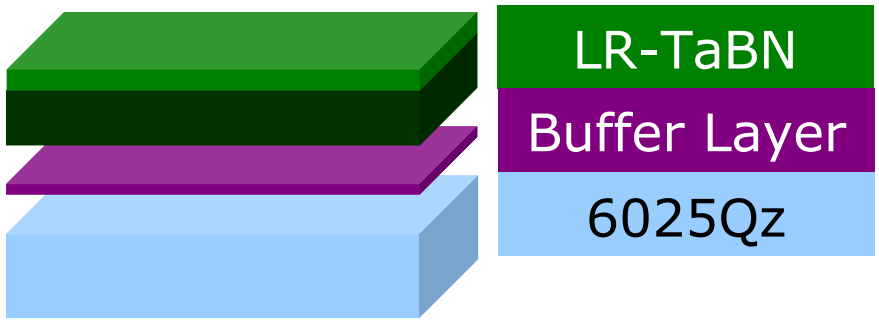
Absorber materials

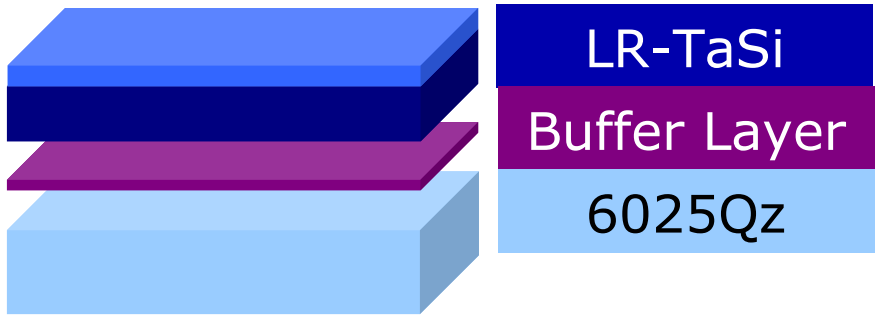
Type A LR-TaBN absorber is designed low reflection at 257 nm wavelength.

Type B LR-TaSi absorber is designed low reflection at from 193 nm to 257 nm wavelength.

Type A: LR-TaBN Absorber



Type B: LR-TaSi Absorber



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1–2. Experiments (2)

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Experimental Conditions

- EB Resist: Posi CAR, 170 nm thickness
- EB Writer: Vac.=50 kV, VSB
- Dry-etcher: ICP type
  - Gases; Fluorocarbon-based mixture gases
- CD Measurement tool: CD-SEM

Evaluation items

- Etching Bias Linearity
- Etching Bias Uniformity
  - 128 nm Dense-Clear Pattern @ 121 mm square
- Cross sectional SEM

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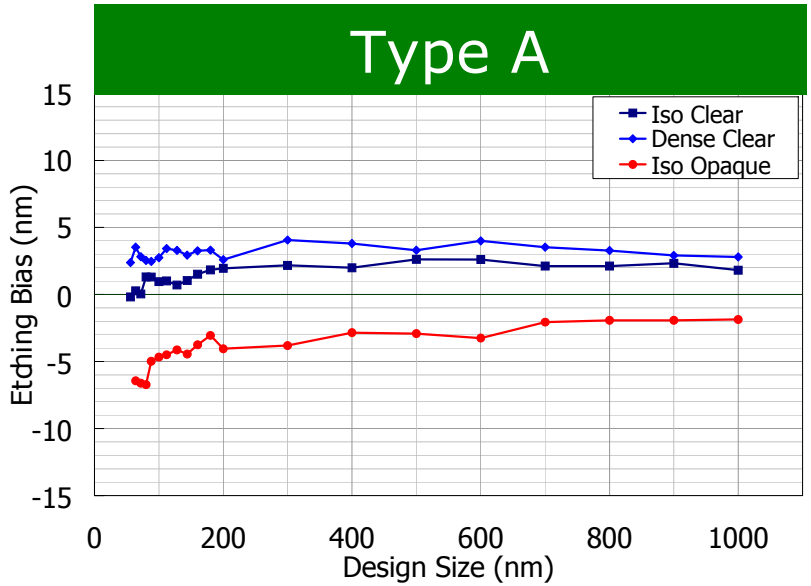
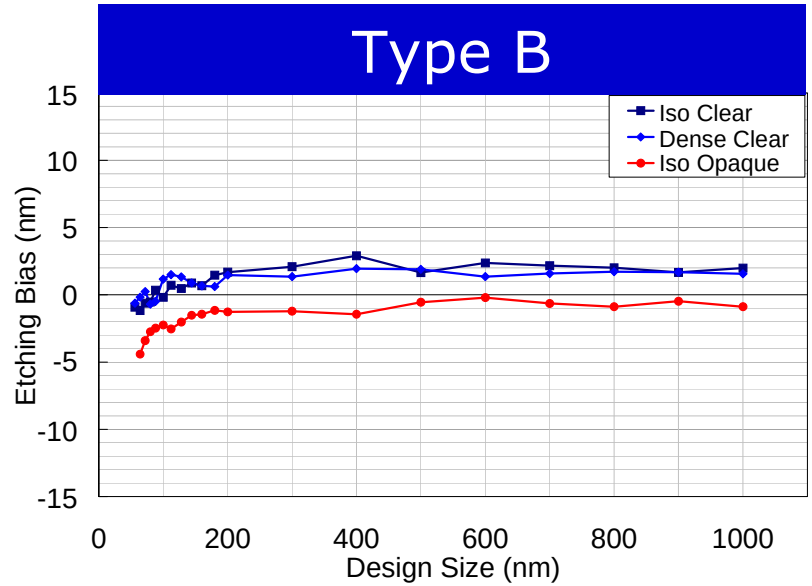
Etching bias linearity





Iso Clear: 1.07 nm
Dense Clear: 0.87 nm
Iso Opaque: 1.08 nm

Iso Clear: 1.75 nm
Dense Clear: 1.61 nm
Iso Opaque: 1.08 nm

* This value was calculated between 88 nm and 500 nm.

These results suggest that the CDL of etching bias is sufficient for both of absorber etching.

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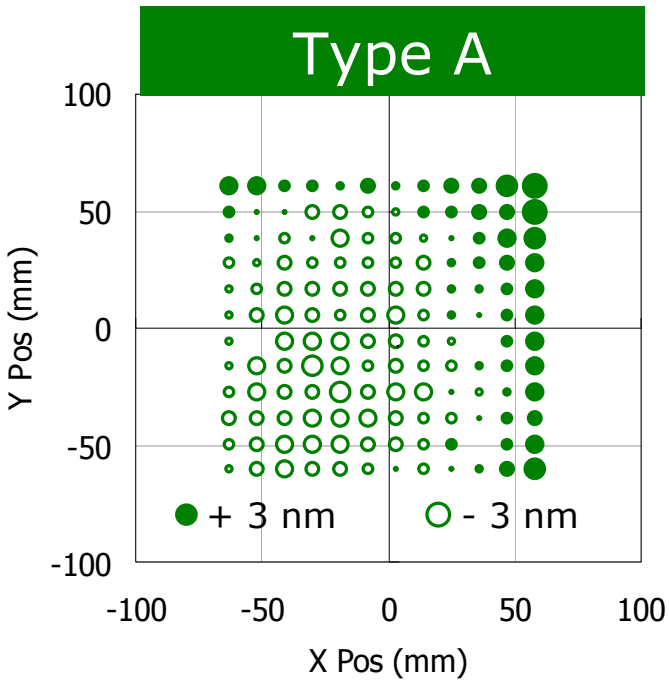
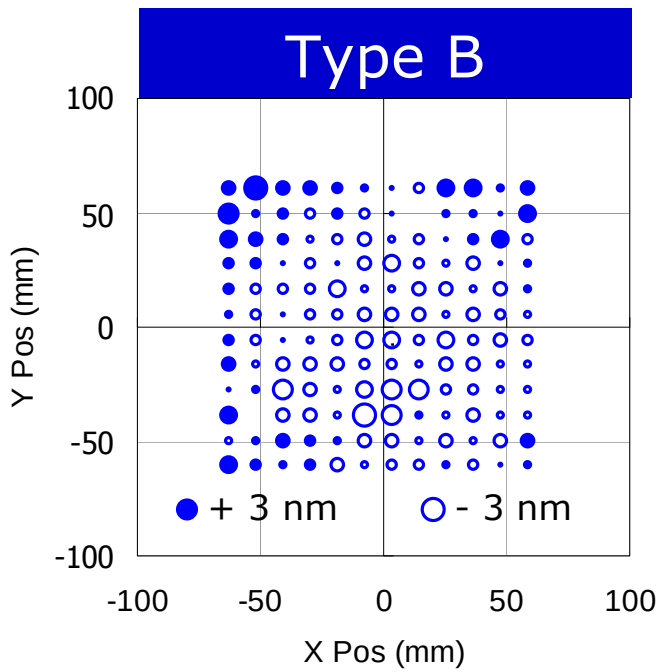
Etching bias uniformity



Range: 6.58 nm

3σ: 3.93 nm



Range: 5.87 nm

3σ: 2.72 nm

CDU of Type A and Type B are different tendency.

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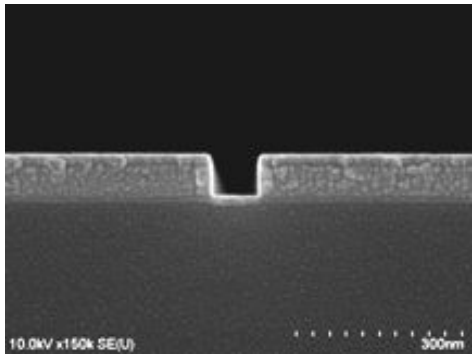
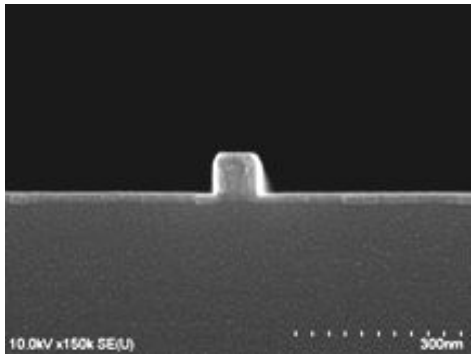
Cross sectional SEM (Design: 88 nm)

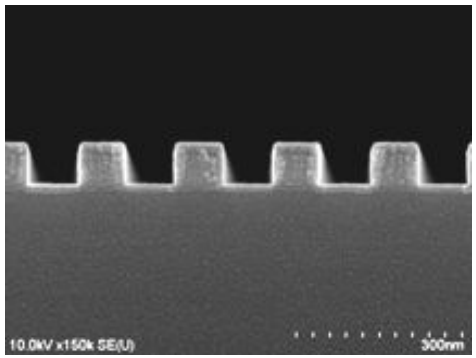
Type A



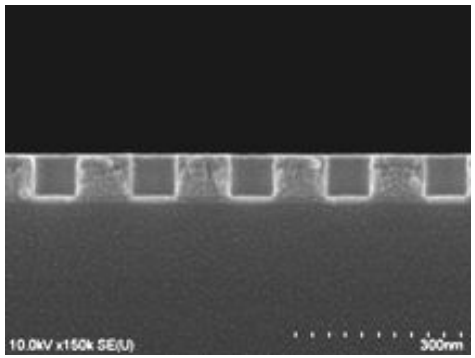
Iso Clear



Iso Opaque

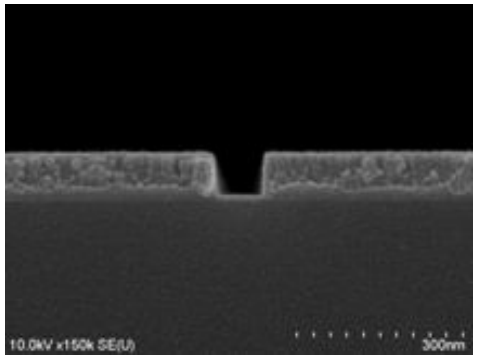


Dense

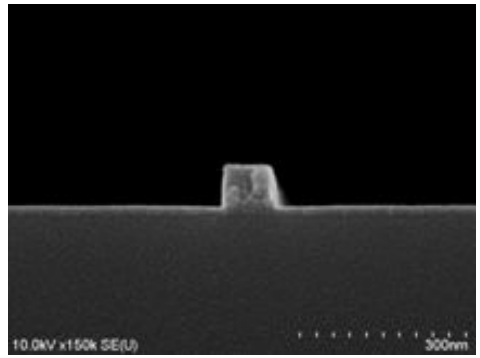


Dense Hole

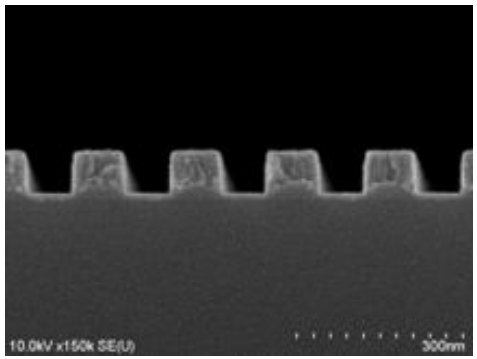
Type B



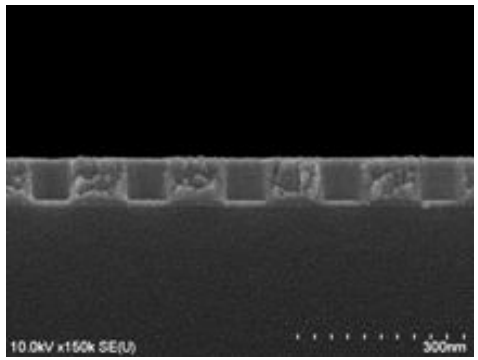
Iso Clear



Iso Opaque



Dense



Dense Hole

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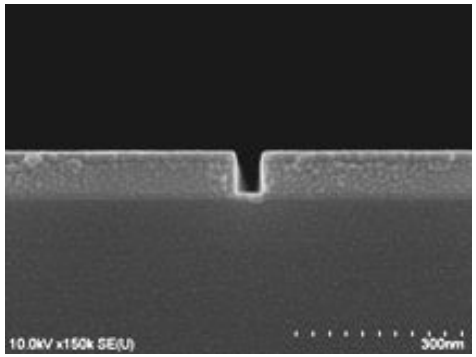
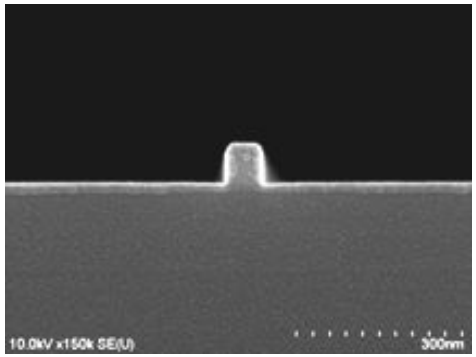
Cross sectional SEM (Resolution Limits)

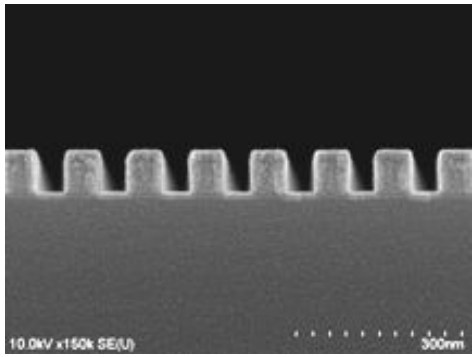
Type A



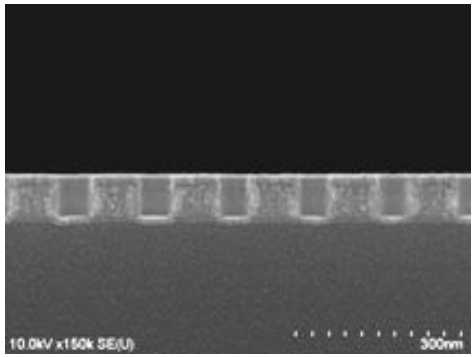
Design: 52 nm
Meas.: 51.7 nm



Design: 64 nm
Meas.: 58.7 nm

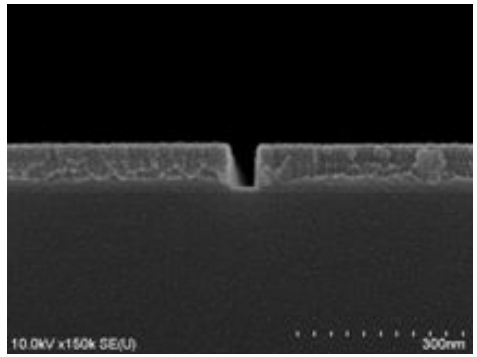


Design: 56 nm
Meas.: Clear 54.2 nm
Opaque 58.5nm

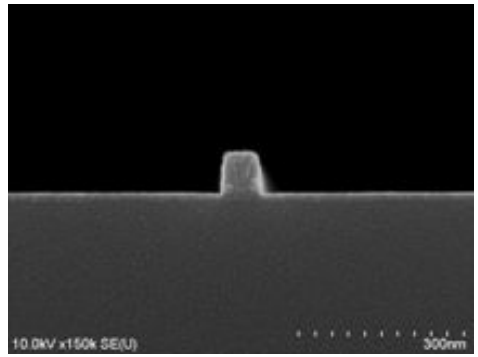


Design: 72 nm
Meas.: 54.4 nm

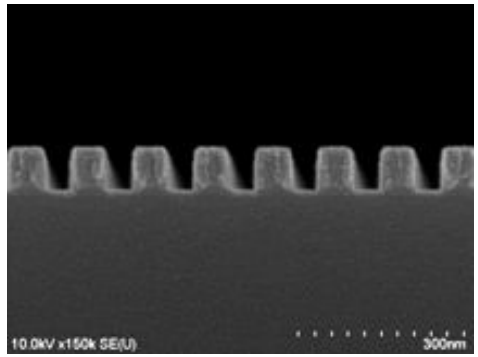
Type B



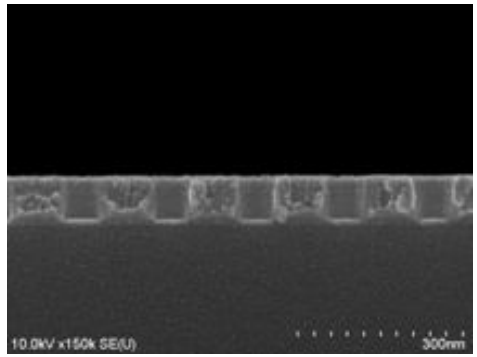
Design: 52 nm
Meas.: 46.1 nm



Design: 64 nm
Meas.: 57.4 nm



Design: 56 nm
Meas.: Clear 46.0 nm
Opaque 66.8 nm



Design: 80 nm
Meas.: 61.0 nm

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1–4. Summary

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	Type A	Type B
Stack Structure	LR-TaBN / Buffer / Qz / Backside coating	LR-TaSi / Buffer / Qz
Selectivity to Resist	0.97	1.16
Etching Bias Linearity	Iso Clear: 1.07 nm Iso Opaque : 1.08 nm Dense Clear : 0.87 nm	Iso Clear: 1.75 nm Iso Opaque: 1.08 nm Dense Clear: 1.61 nm
Etching Bias Uniformity 128 nm Dense Clear 121 mm square, 3σ	Dense Clear: 3.93 nm	Dense Clear: 2.72 nm
Resolution Limit (Actual Size)	Iso Clear: 51.7 nm Iso Opaque : 58.7 nm Hole: 54.4 nm	Iso Clear: 46.1 nm Iso Opaque : 57.4 nm Hole: 61.0 nm

1. Optimized "One step etching" process with the high selectivity to resist was obtained.
2. These results suggested backside coating has some impact for etching bias uniformity.

Next, we investigated the influence of backside coating on dry etching performance.

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2–1. Preliminary Test (1)

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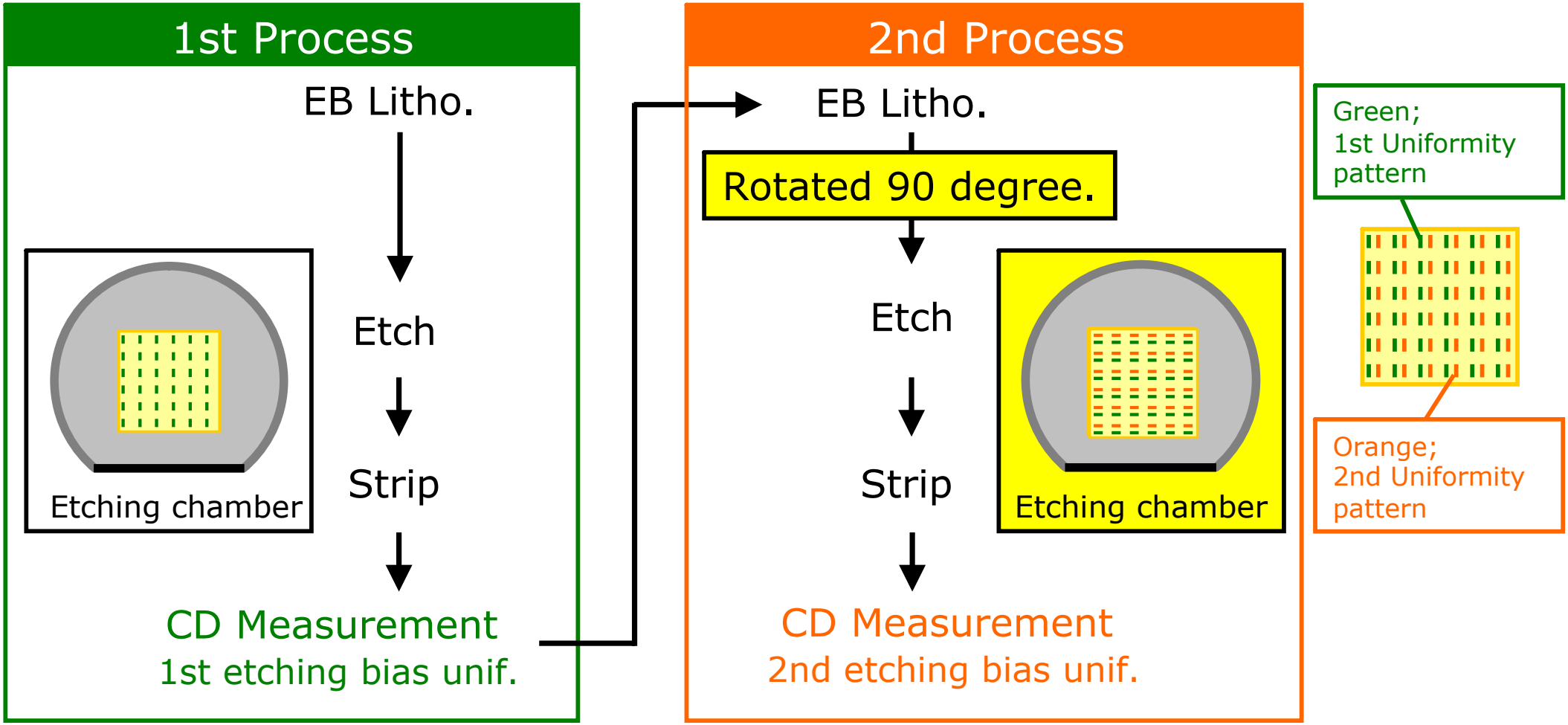
As for the Previous result, etching bias uniformity had tendency.

We confirmed which material or plasma was the cause of signature.



<u>Two Processes demonstrated using the same material.</u>

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2-1. Preliminary Test (2)

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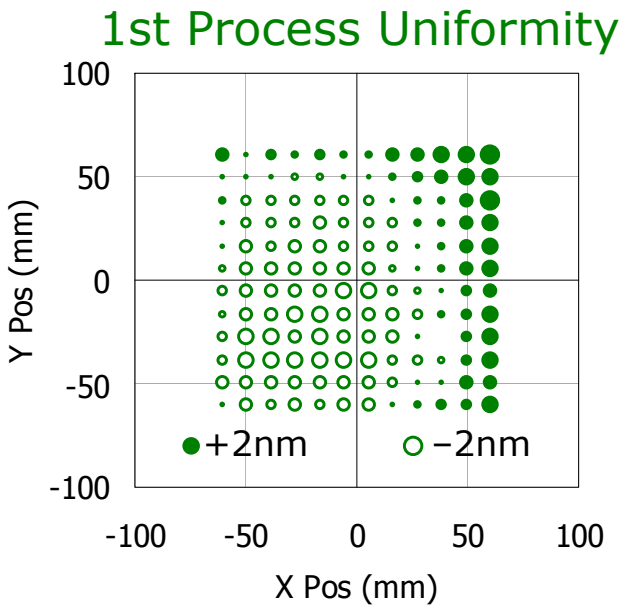
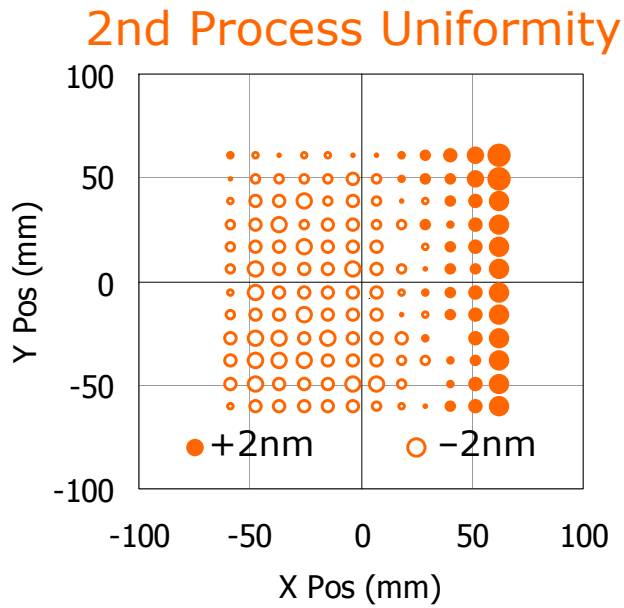
<Definition>

1. 1st = 2nd → depends on material
2. 1st ⊥ 2nd → depends on plasma distribution





* A random element was subtracted

These results indicate depending on material.

Next, we focused on the dry etching performance w/wo backside coating.

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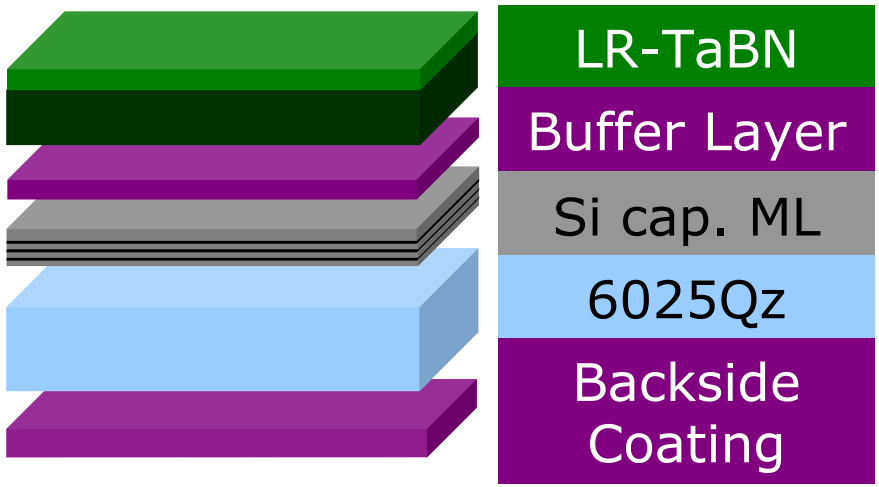
Stack structures

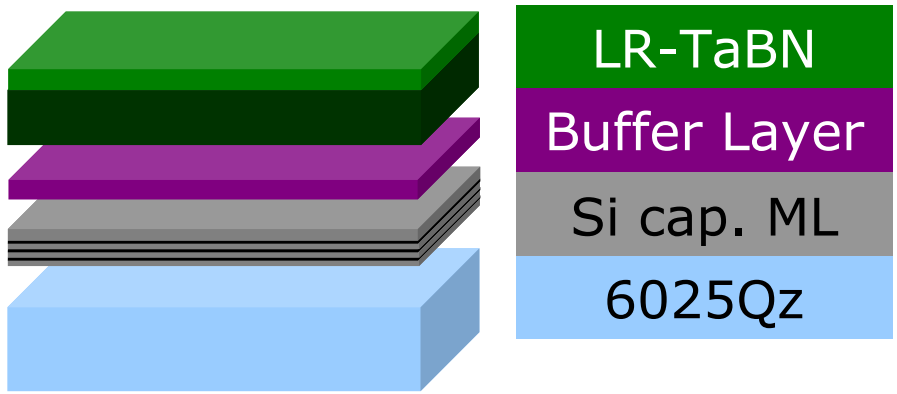
Type C → With backside coating

Type D → Without backside coating

Type C



Type D



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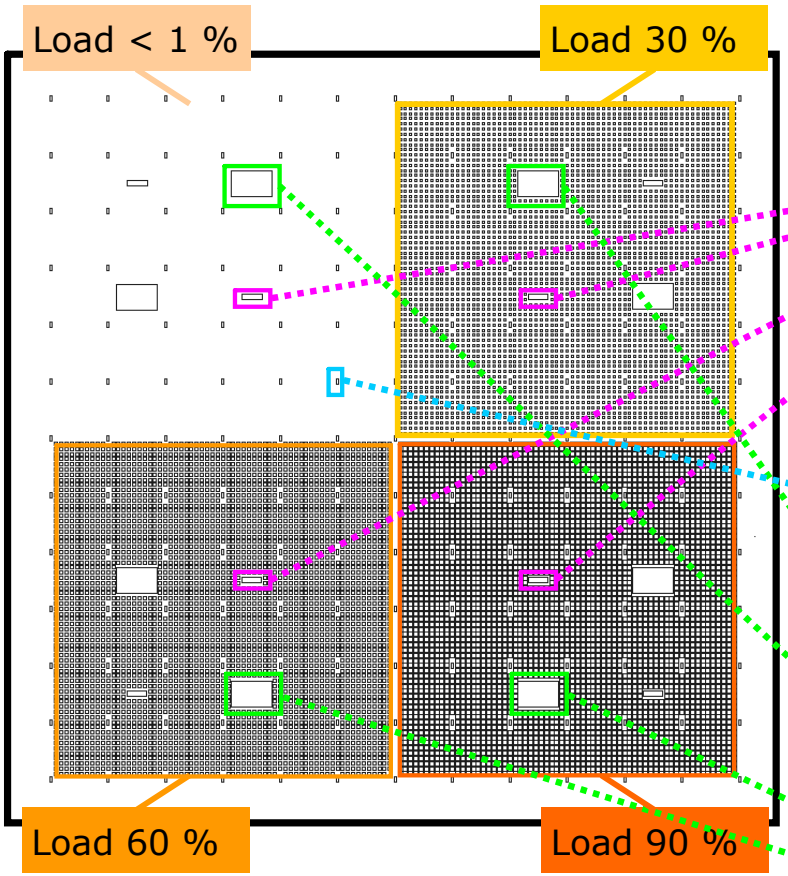
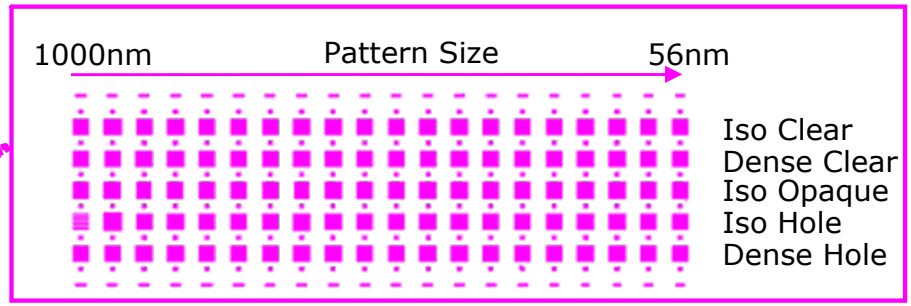
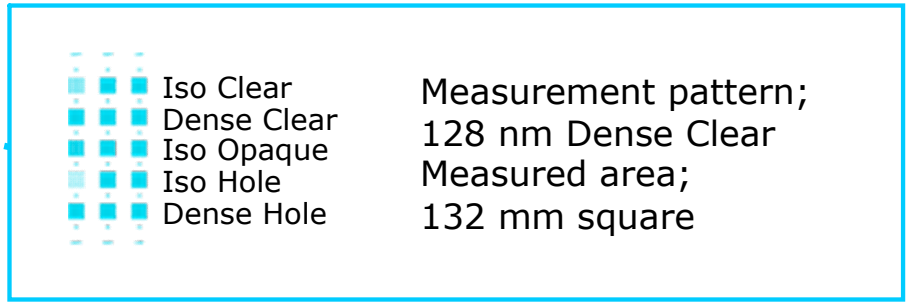
Pattern layout and evaluation items



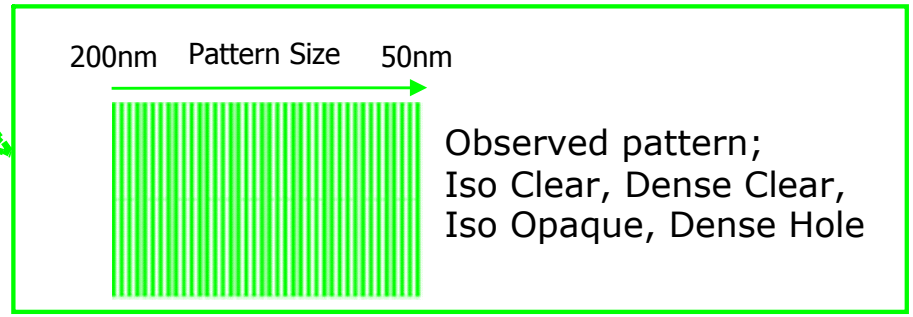
Etching bias Linearity



Etching bias Uniformity



Cross sectional SEM



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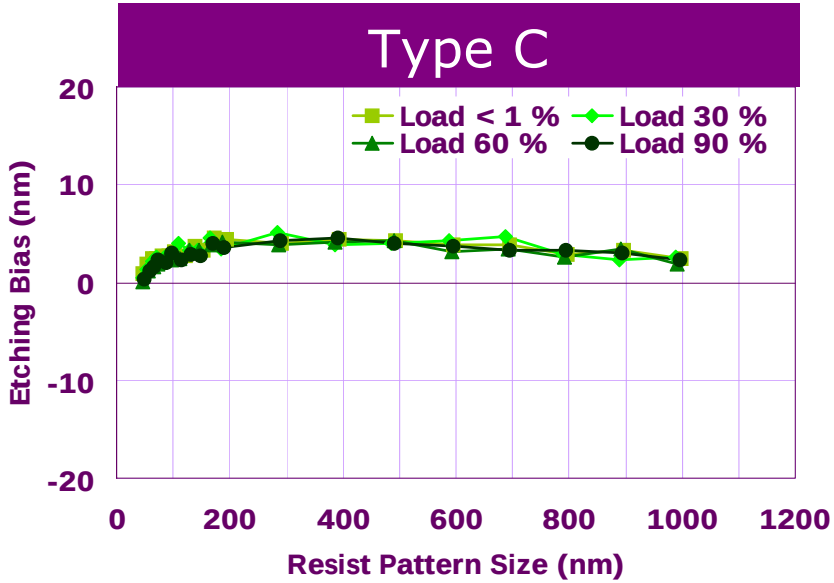
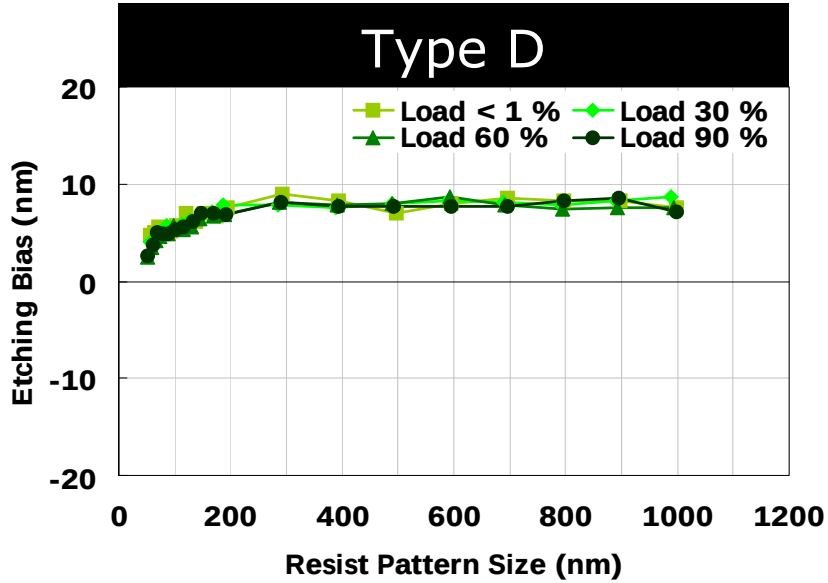
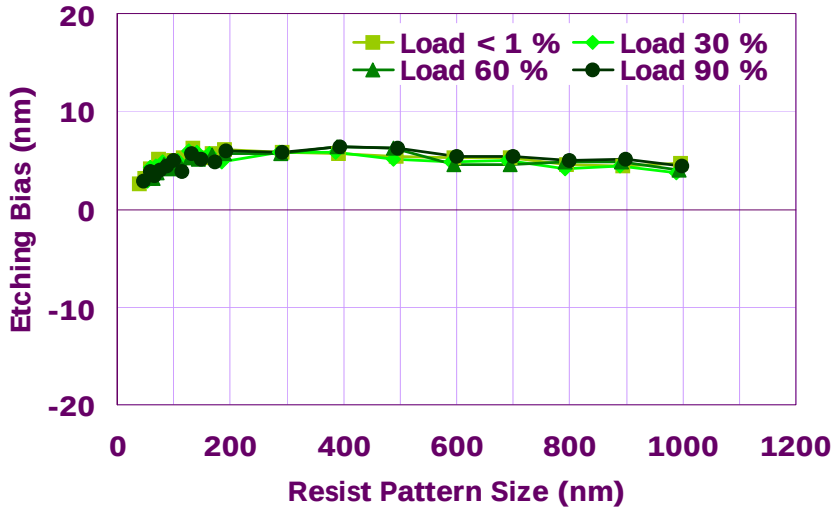
Etching bias linearity

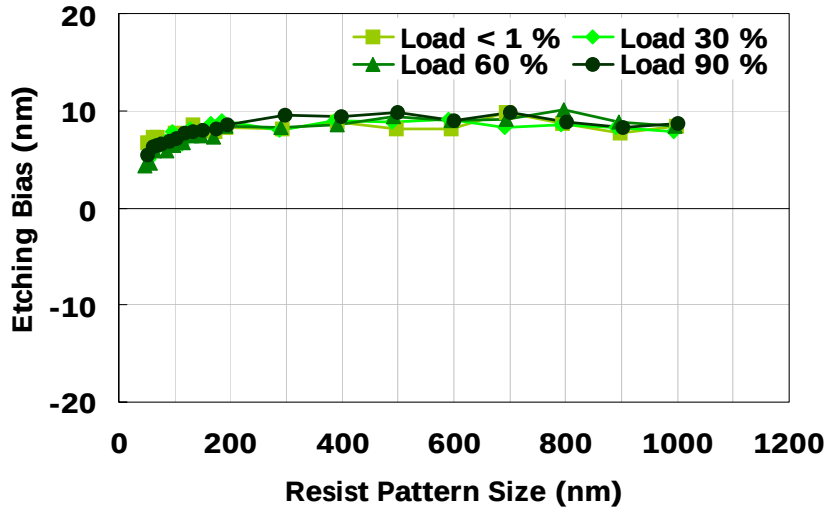


Iso Clear





Dense Clear



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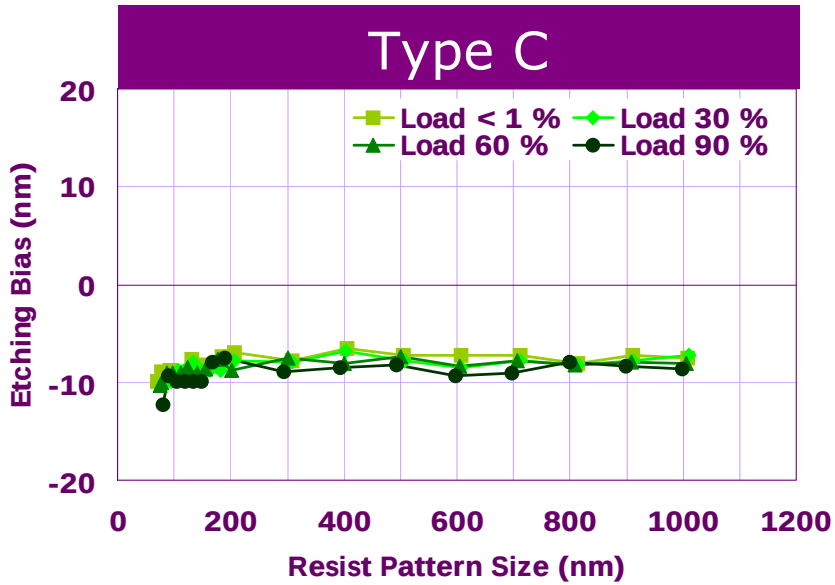
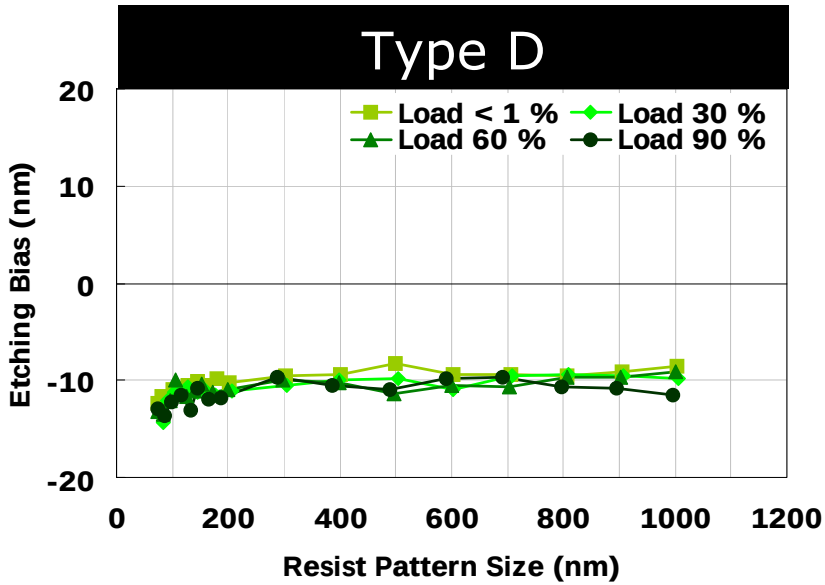
Etching bias linearity



Iso Opaque



- No difference of etching bias linearity w/wo backside coating
- No impact of load factor
- Negligible gap of etching bias w/wo backside coating

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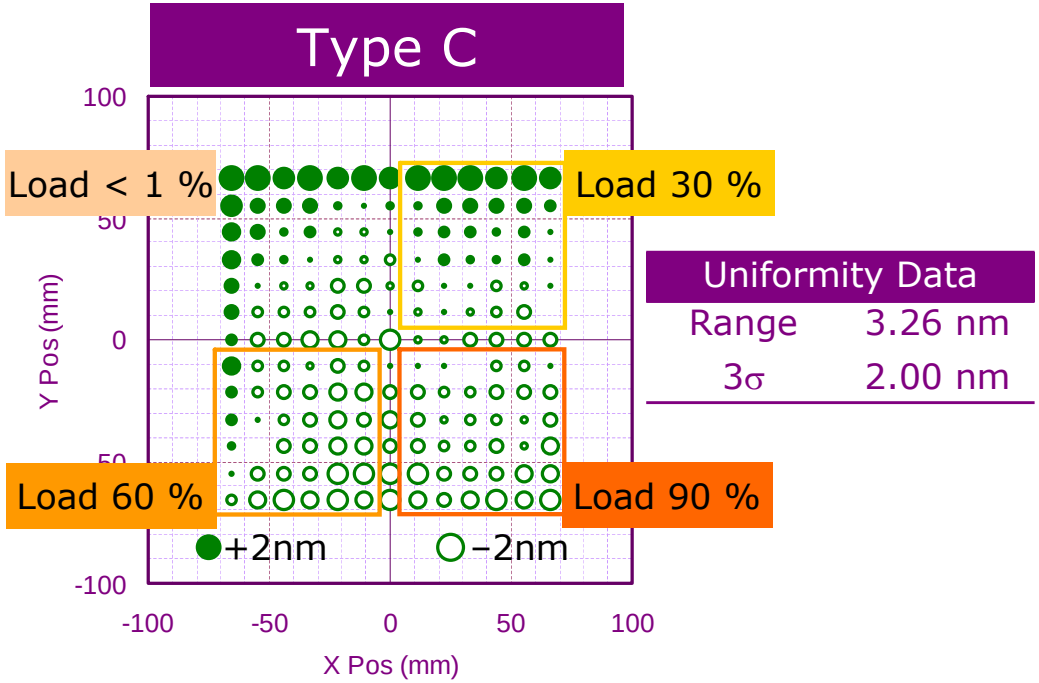
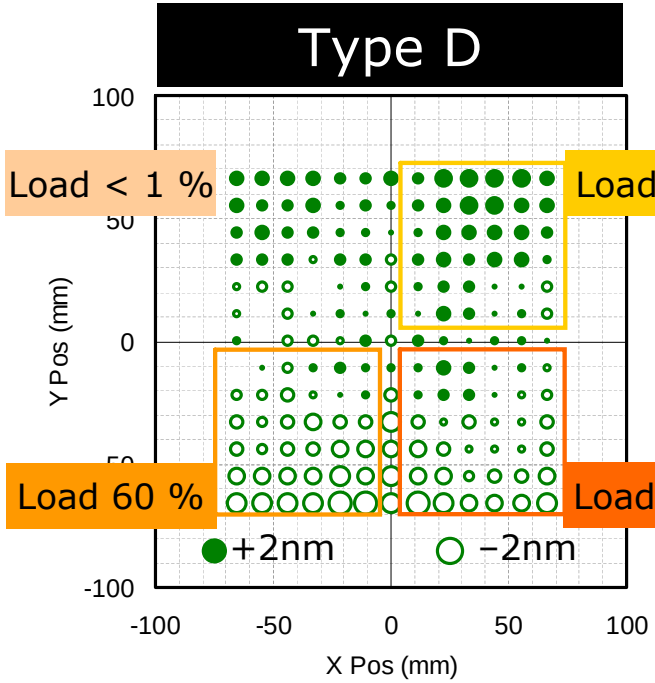
Etching bias uniformity
(128 nm Dense Clear, 132 mm square)



Uniformity Data	
Range	3.26 nm
3σ	2.00 nm



Uniformity Data	
Range	2.26 nm
3σ	1.59 nm

* A random element was subtracted

Backside coating was degraded etching bias uniformity.

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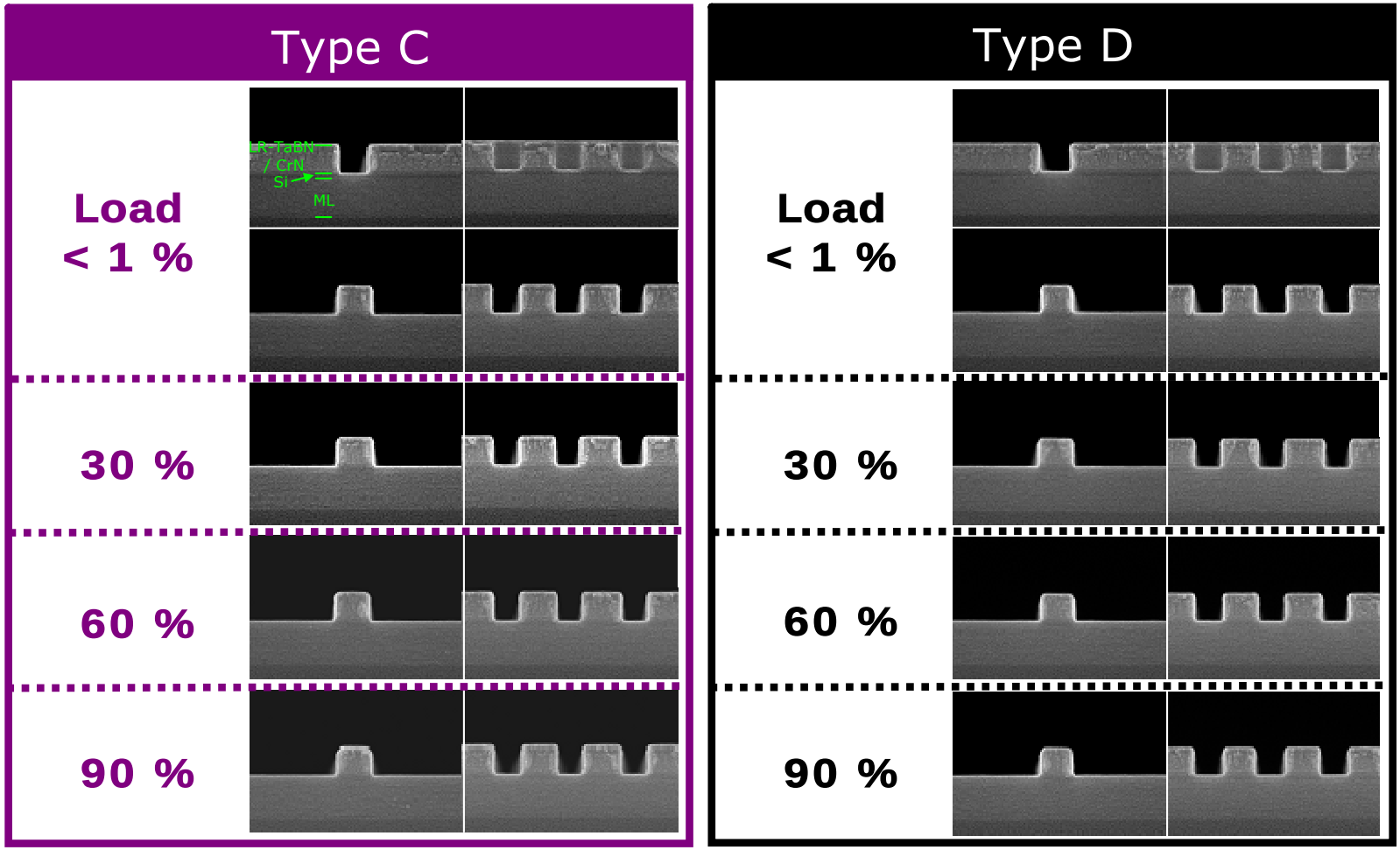
Cross Sectional SEM (Design 88nm)



Neither backside coating nor load factor influenced the pattern profile.

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2–4. Summary

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LR-TaBN performance by **one step** etching,

- Etching bias linearity
  - No influence of load factor and w/wo backside coating
- Etching bias uniformity
  - Degraded by backside coating
- Pattern profile
  - No impact of load factor and w/wo backside coating

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3. Conclusion

- We developed **one step** absorber etching process. However, systematic uniformity error has seen in etching bias uniformity.
- It was clarified that backside coating influenced etching bias uniformity.

《 Future work 》

- We will challenge to improve mask making processes to meet all ITRS requirements.
- We will investigate the factor that cause the influence of etching bias uniformity with backside coating.

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