

Evaluation of TaSix Absorber Stack with a Novel Buffer for EUV Mask

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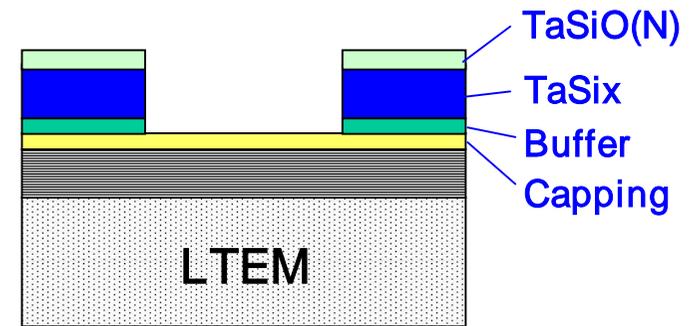
Summary

About TaSix-based absorber – Introduction –

Note) Here, “x” implies Si little addition to Ta.

We optimized TaSix absorber.

Consequently, followings were confirmed;
(Ref; SPIE6283, pp.0J)

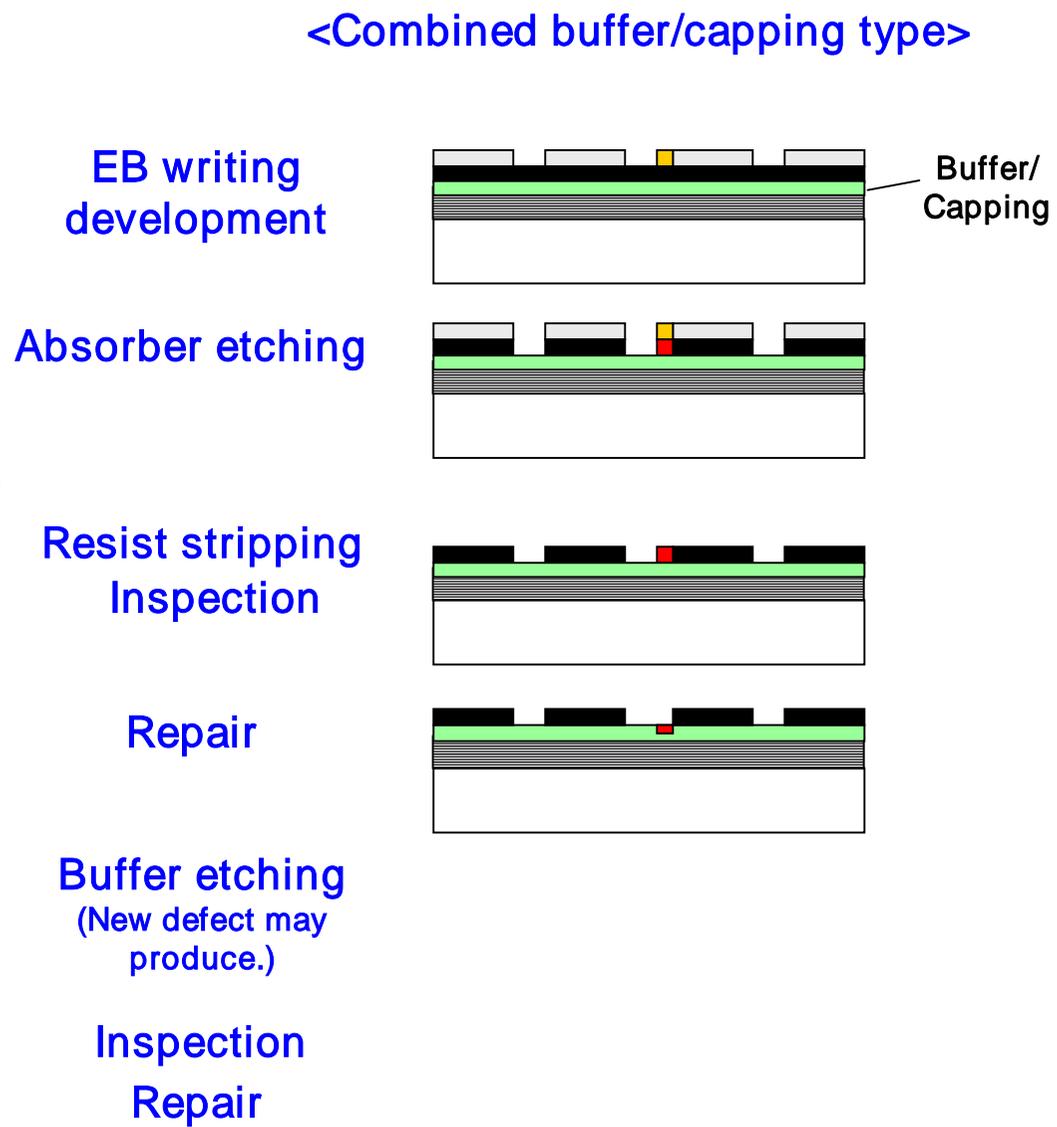
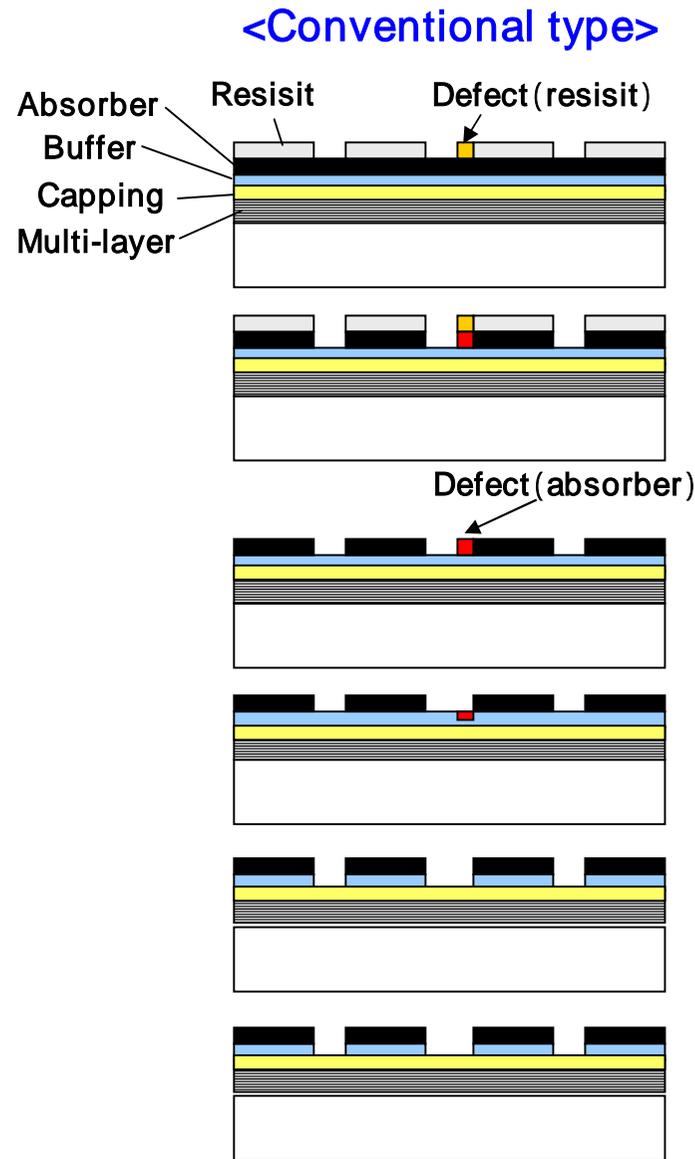


- It has amorphous structure with smooth surface, and high dry-etching rate for Cl-based gas.
- It satisfies high inspection contrast by TaSix bi-layer absorber stack with optimized anti-reflective layer .
- We confirmed experimentally that TaSix has comparative value (absorption factor @EUV) with other Ta-based materials.

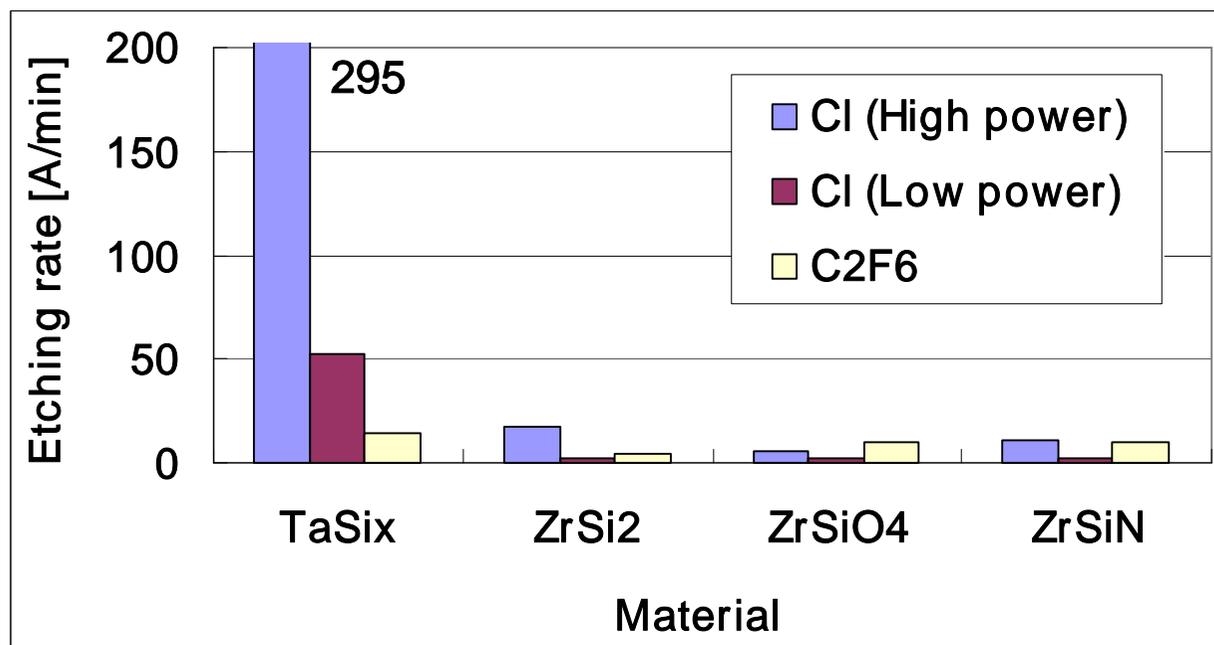
Motivation of this study

Need to practical evaluation with buffer layer resistant to Cl etching, such as mask accuracy, repair ability, printing performance

EUV Mask process flow – Introduction –

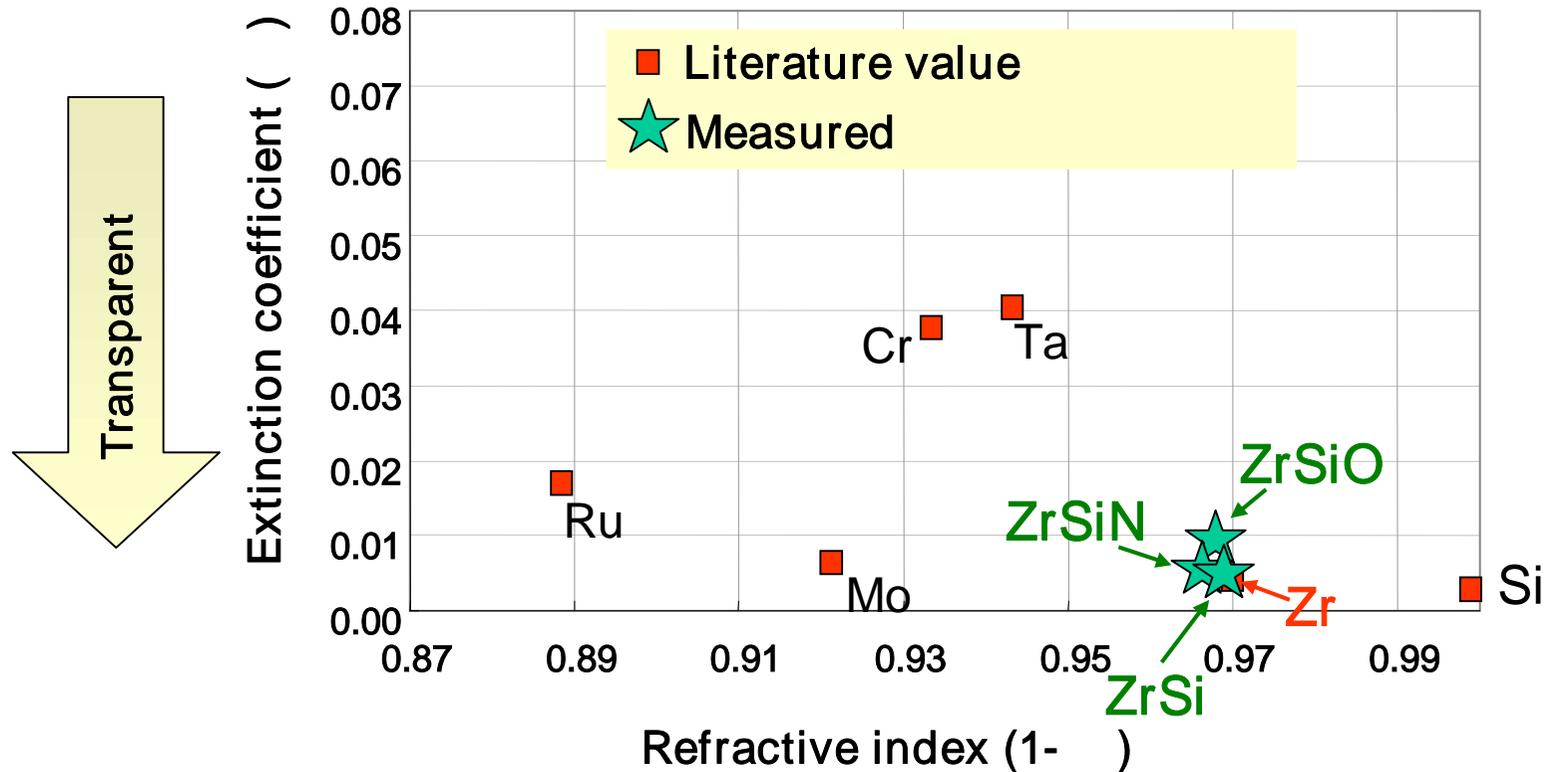


Dry-etching property of ZrSi-based buffer



- ZrSi-based films have high dry-etching resistance to both chlorine-based and fluorine-based gases.
- Especially, ZrSi-based films has possibility to become good buffer film for Cl-based etching of Ta-based absorber.

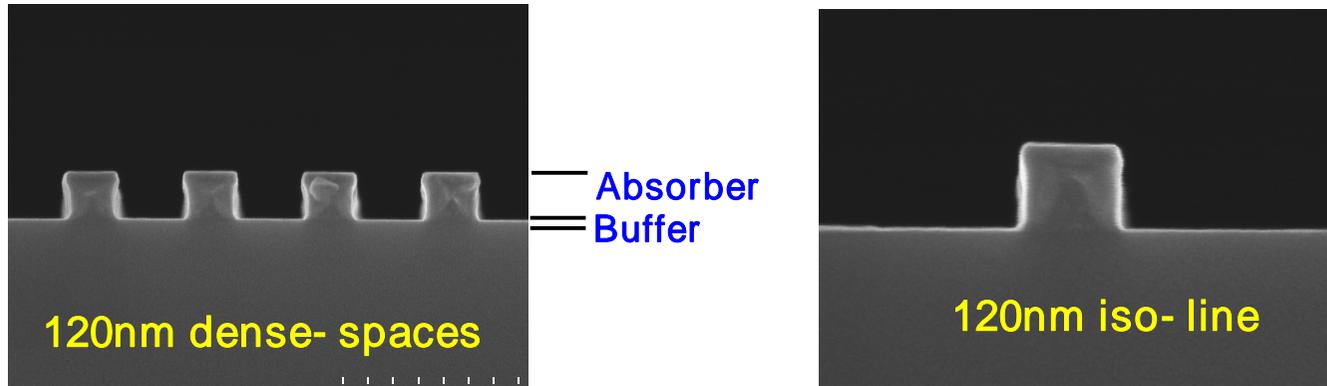
Optical property@EUV of ZrSi-based buffer



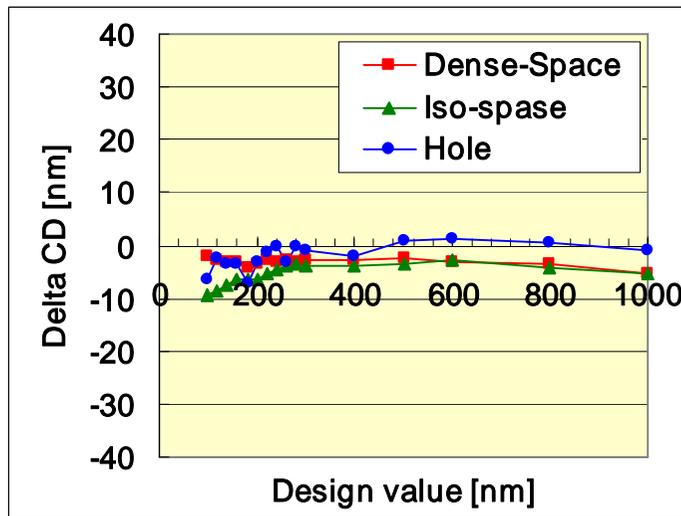
- ZrSi-based film is comparably transparent to Mo, Si, therefore its defect productivity is low.
- ZrSi-based film has potentiality to work as a buffer needless to be stripped after absorber repair.

TaSix patterning example on ZrSi-based buffer

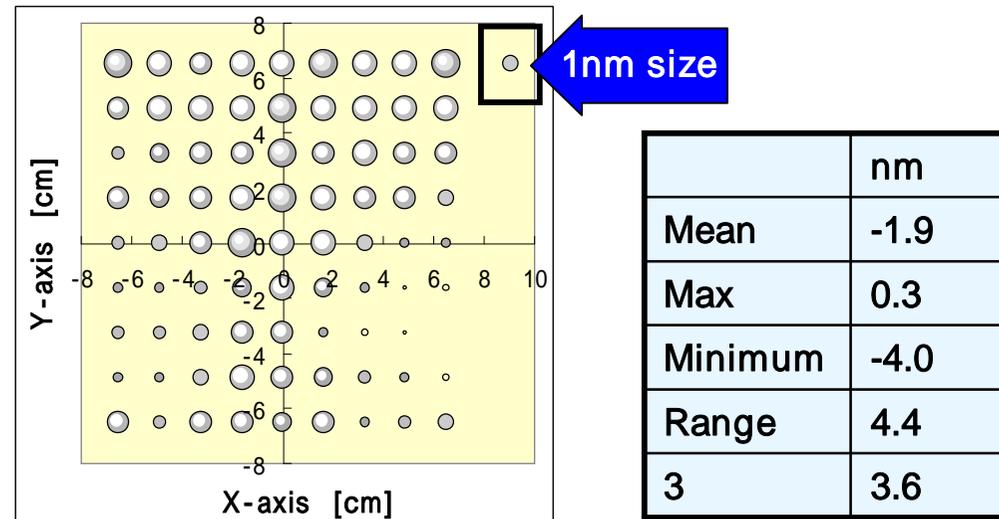
<Cross-sectional profile>



<CD linearity of etching bias>



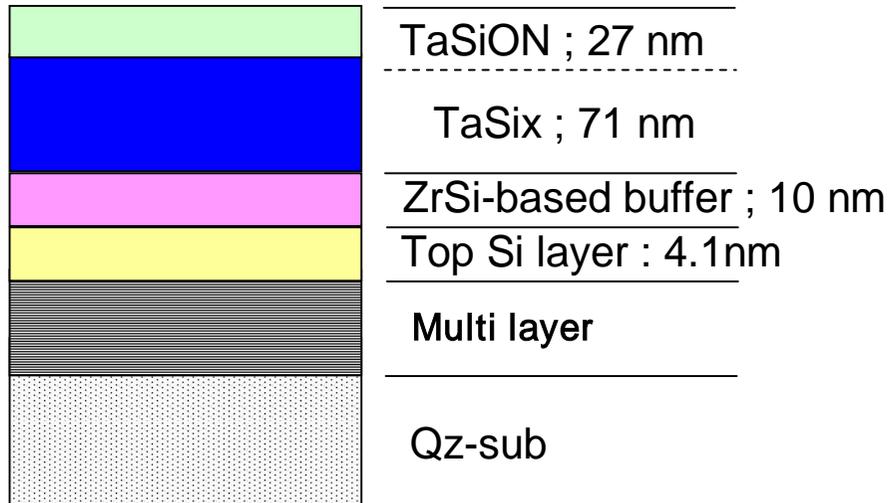
<CD uniformity of etching bias>



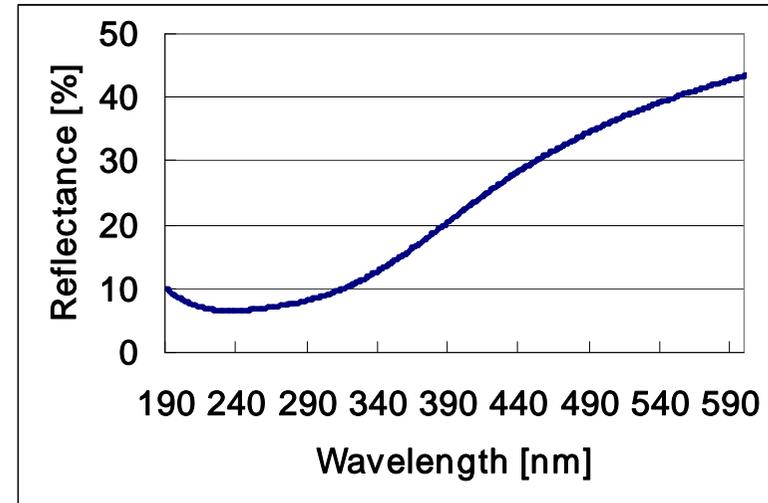
120nm dense-spaces

Mask making for printing test

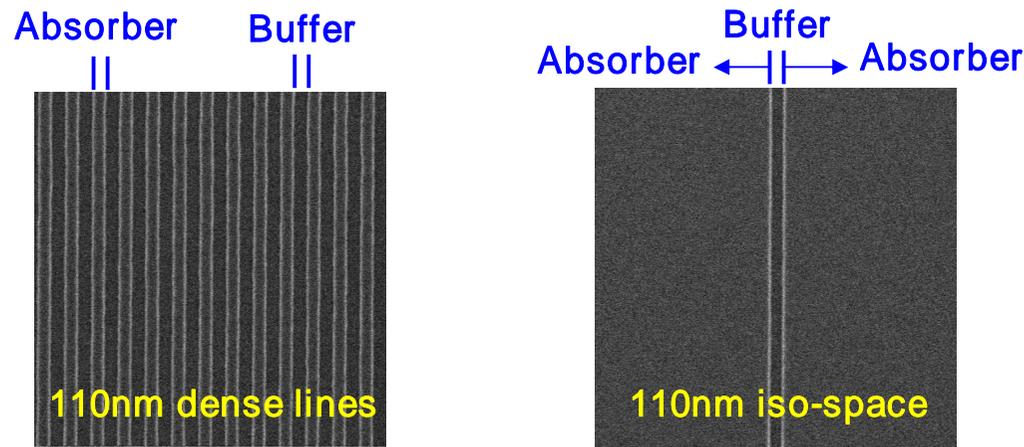
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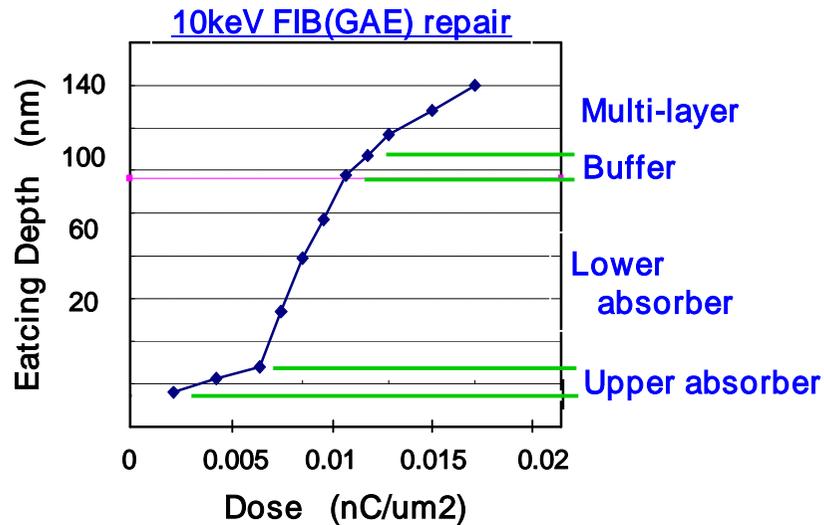
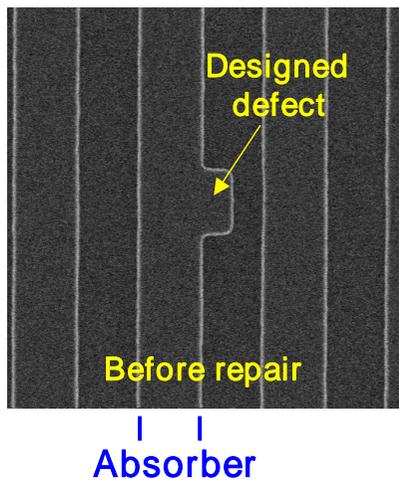
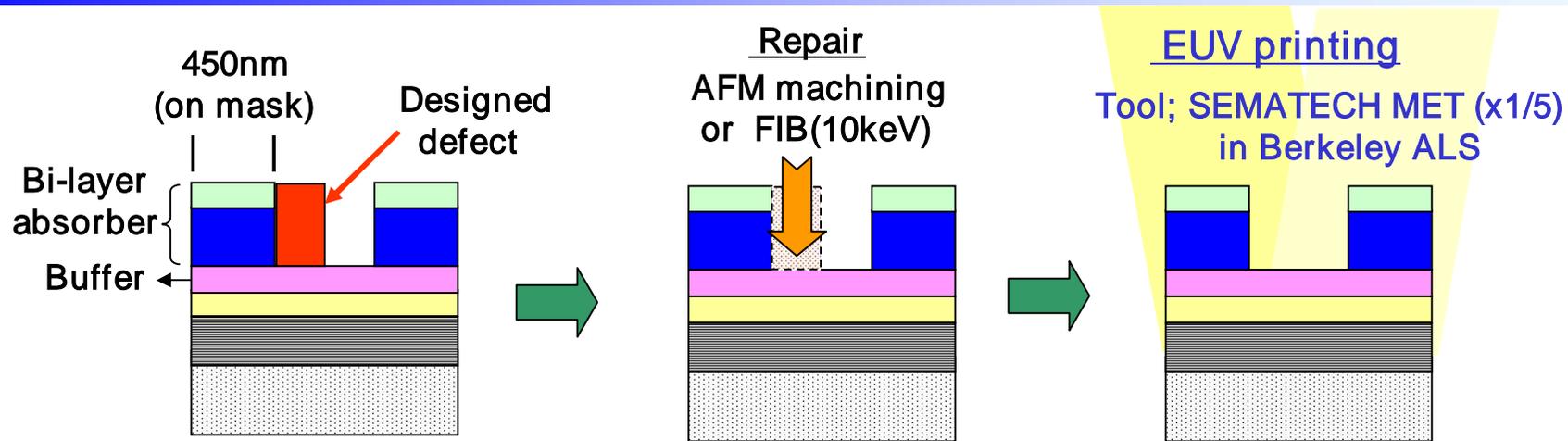
<Spectroscopic reflectance>



<CD-SEM image of patterned TaSix bi-layer absorber>



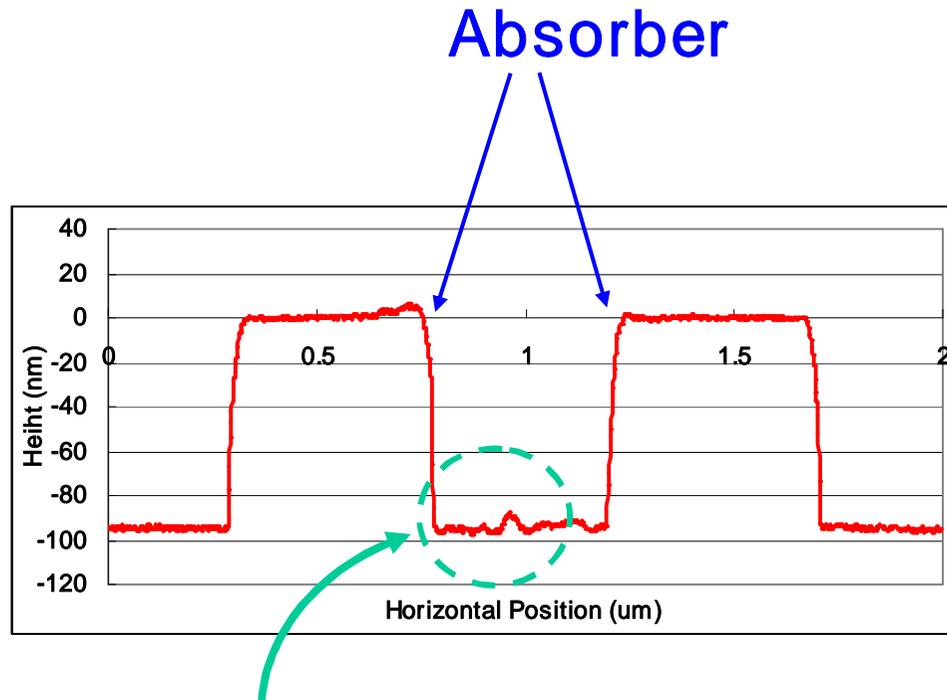
Process flow of repair evaluation



Remark) EUV printing was performed without ZrSi-based buffer stripping for evaluating its possibility as a buffer needless to be stripped.

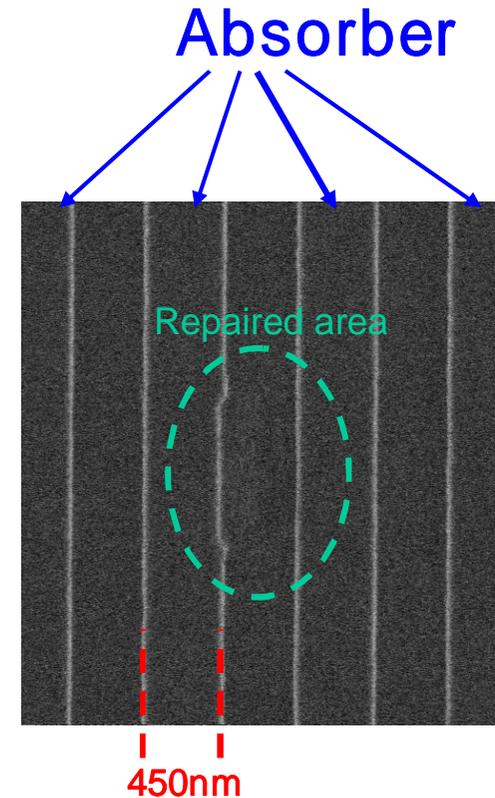
AFM machining 90nm Opaque repair (1)

AFM profile



Repair to Z-direction is almost stopped on the surface of buffer.

SEM image



Repair bias to X-direction is about 50nm.

Printed resist pattern incl. AFM repair (1)

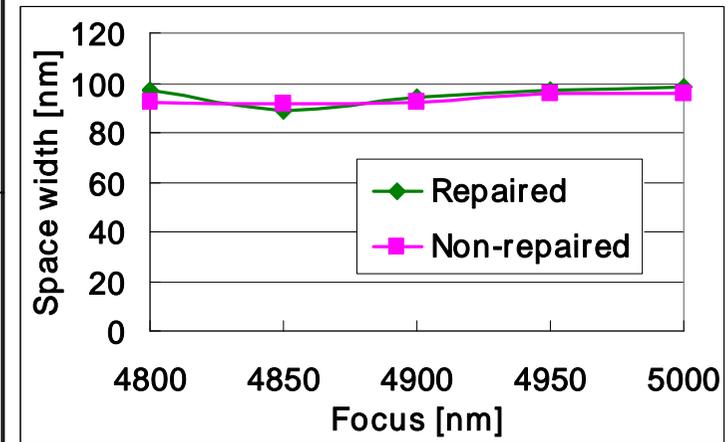
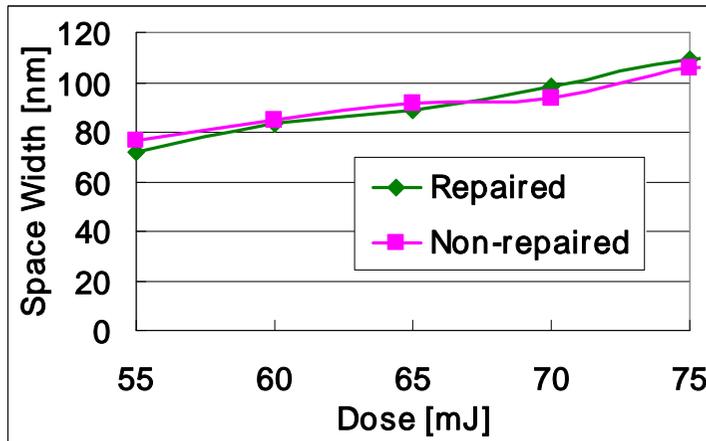
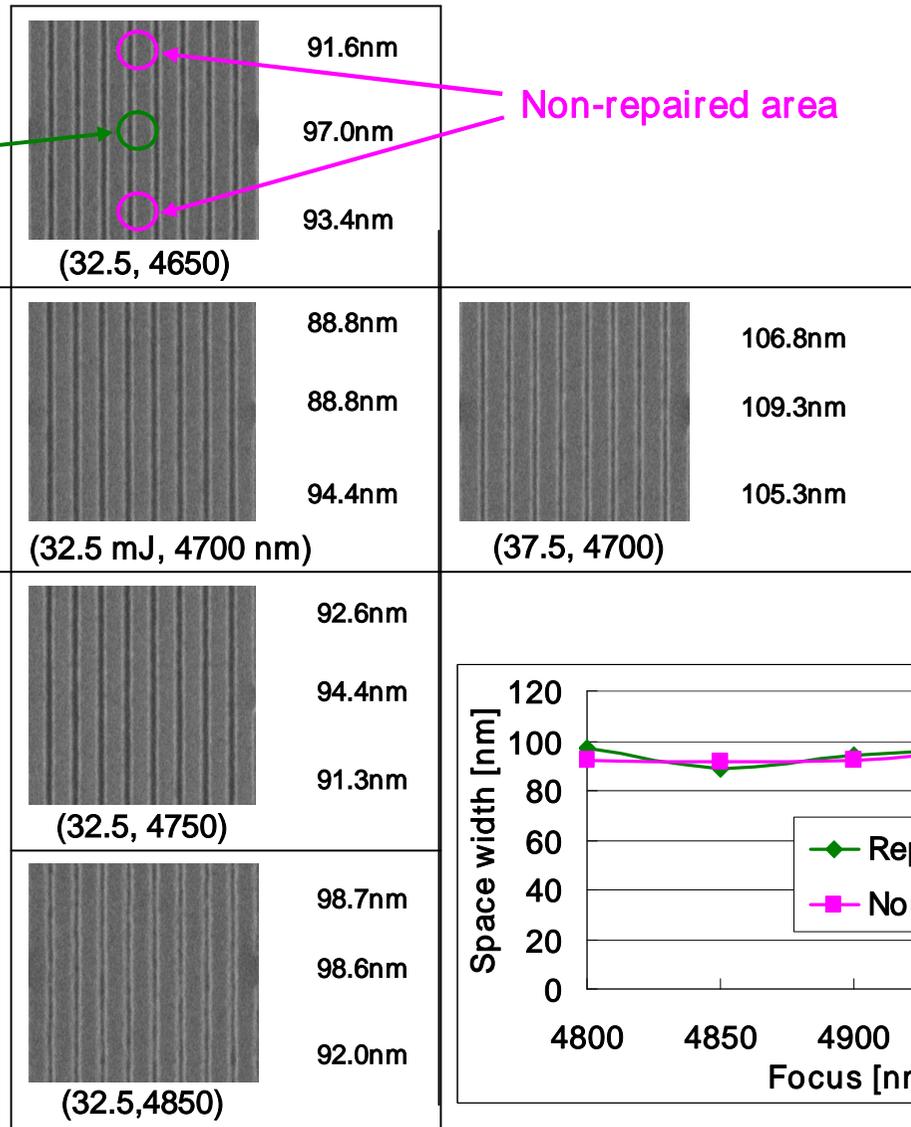
EUV Exposed resist pattern

Resist: ; positive-type

Repaired area

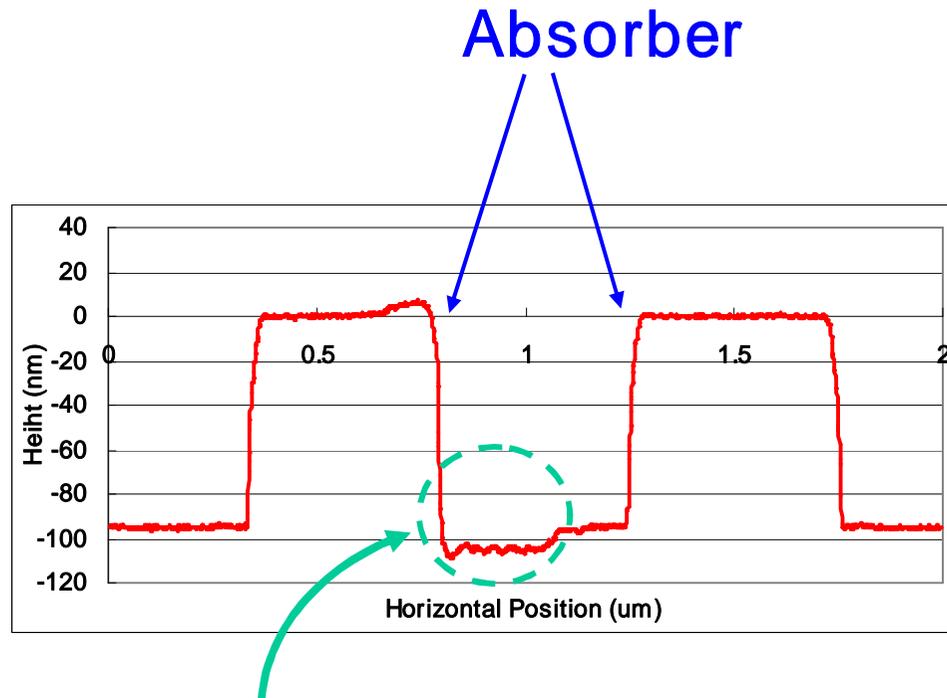
Space width

(Dose [mJ] , Focus [nm])



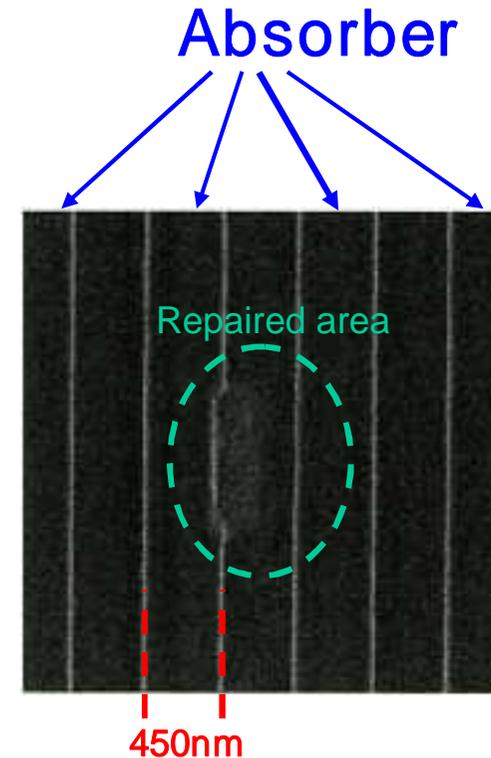
AFM machining 90nm Opaque repair (2)

AFM profile



Repair bias to Z-direction is about 10nm. Which is nearly equal to buffer thickness.

SEM image



Repair bias to X-direction is about 80nm.

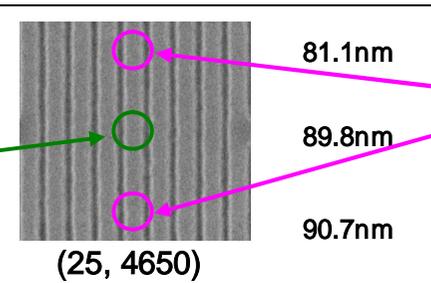
Printed resist pattern incl. AFM repair (2)

EUV Exposed resist pattern

Resist: ; positive-type

Repaired area

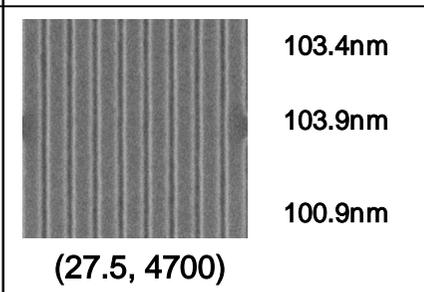
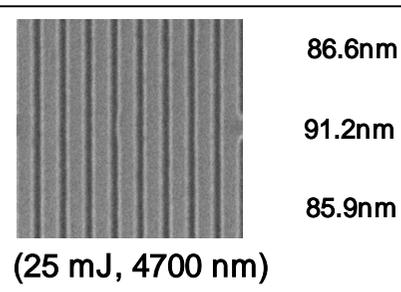
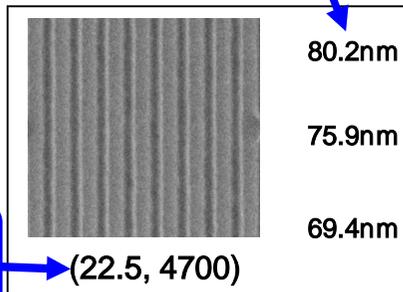
Space width



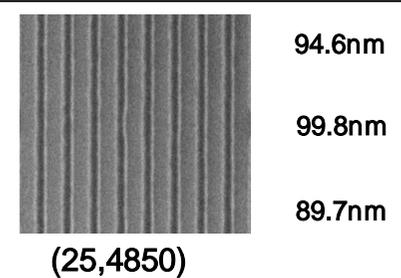
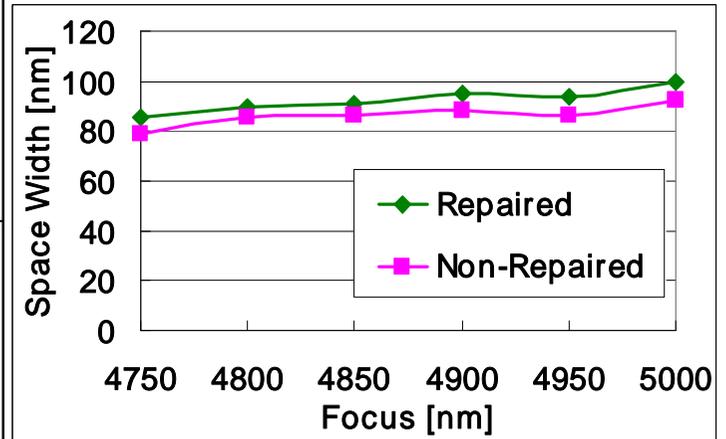
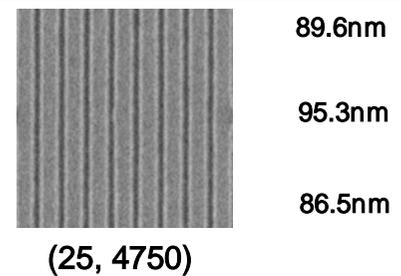
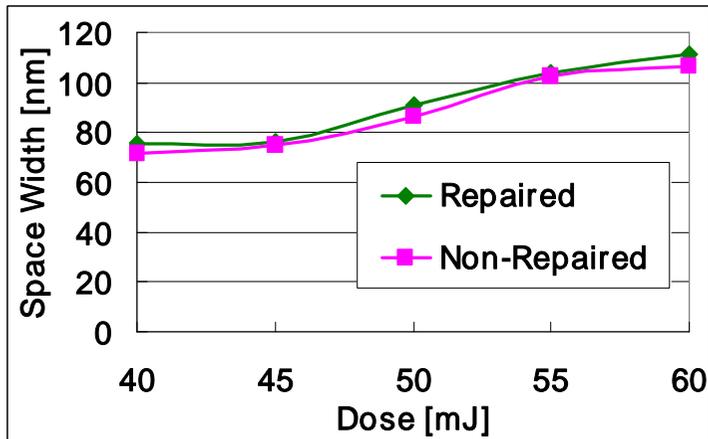
Non-repaired area

Note)

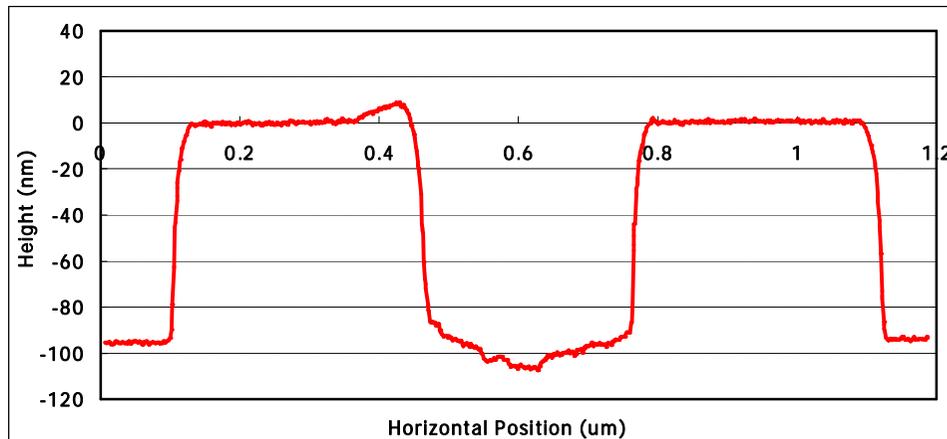
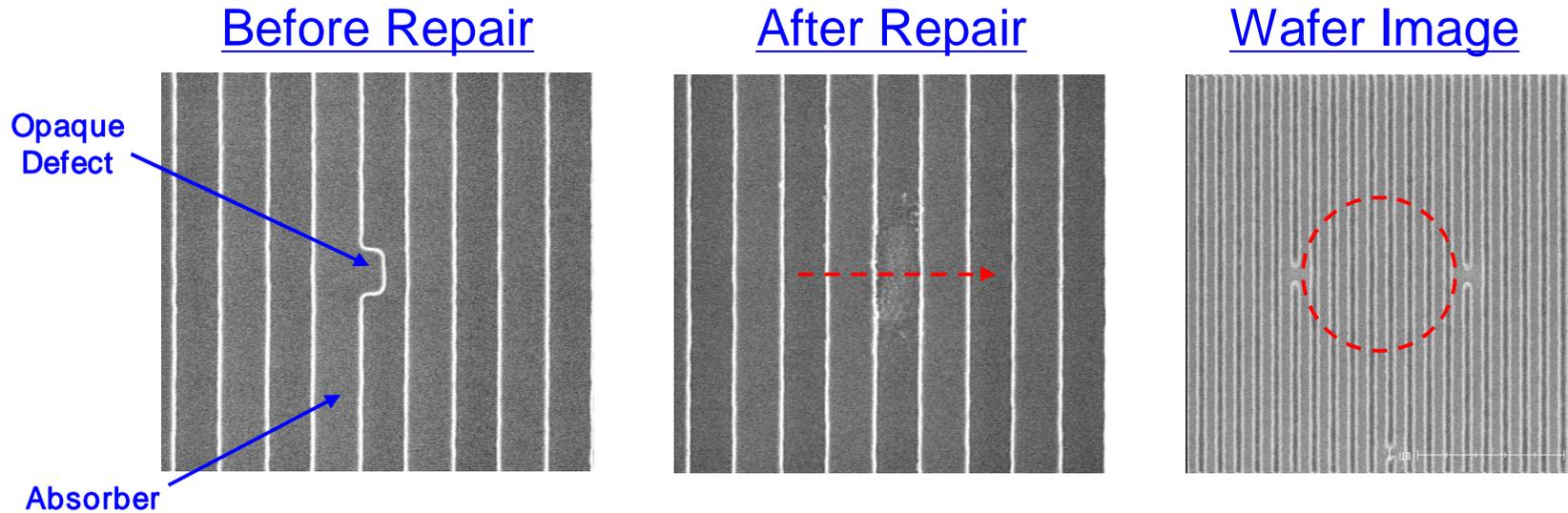
Dose deviation from center dose (25.0mJ) is due to light intensity distribution.



(Dose [mJ] , Focus [nm])



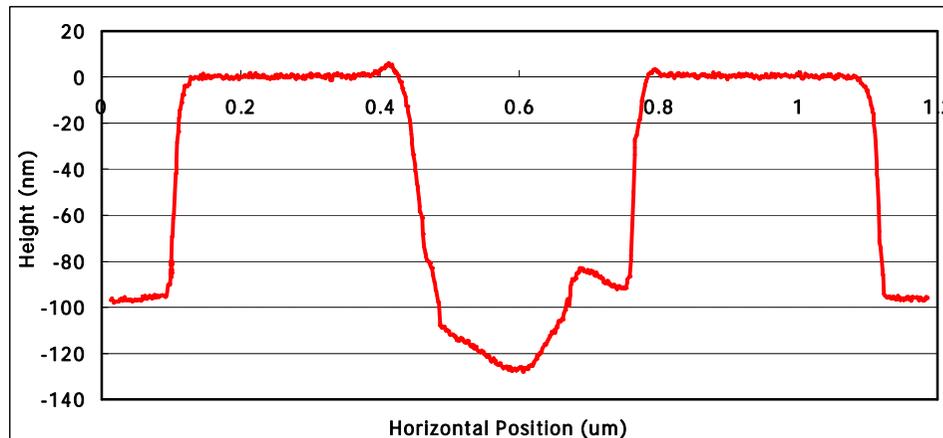
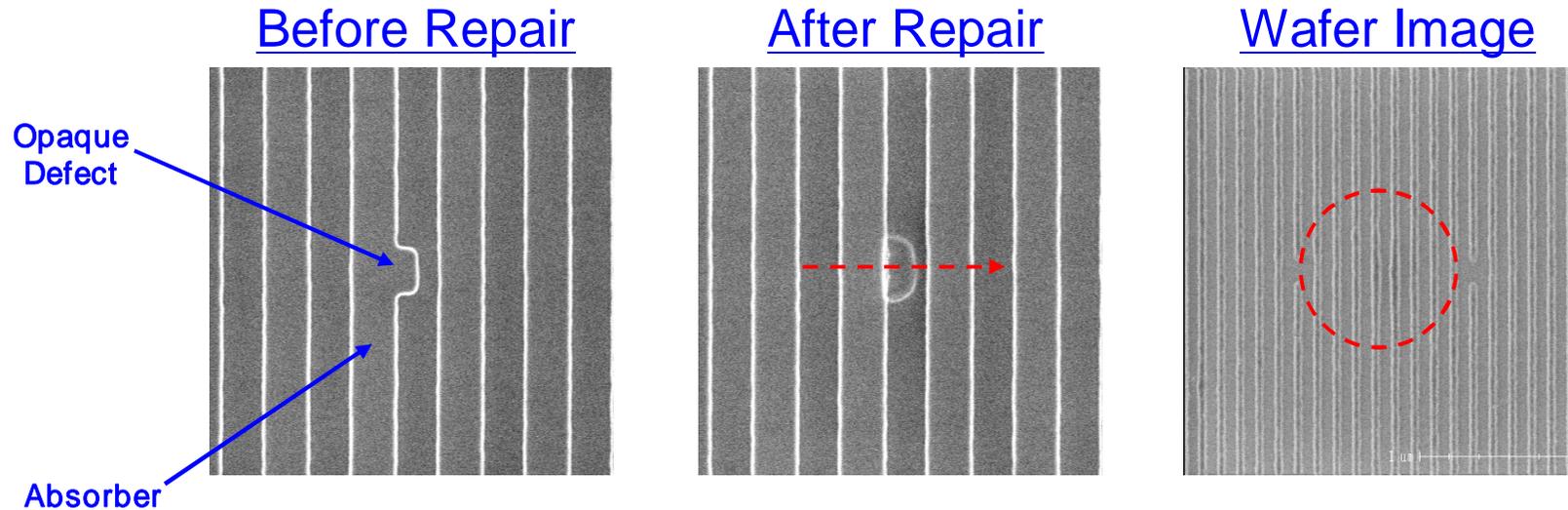
AFM machining 65nm Opaque repair



Cross Sectional Profile of Repair

- Nano-machining repair method is acceptable, like as 90nm pattern.
- Needs more analysis to estimate process capability.

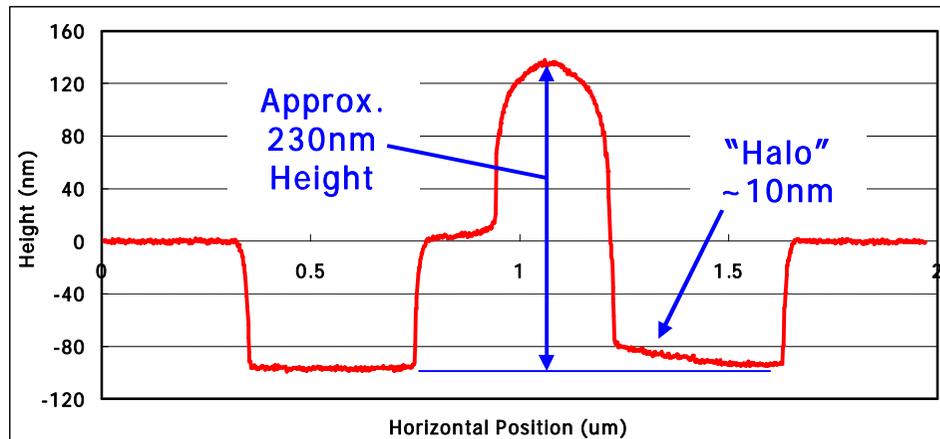
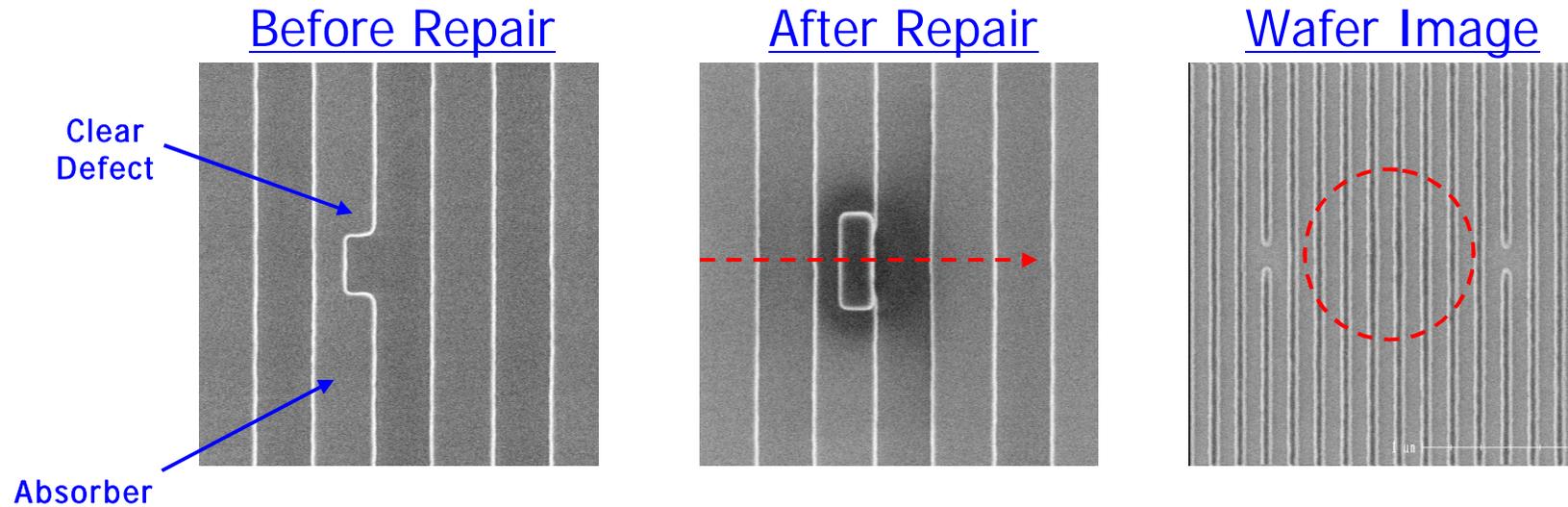
FIB-GAE(10keV) 65nm Opaque Repair



Cross Sectional Profile of Repair

- FIB based gas assist etching has potential for opaque defect of absorber.
- Needs improvement for surface profile (or selectivity)

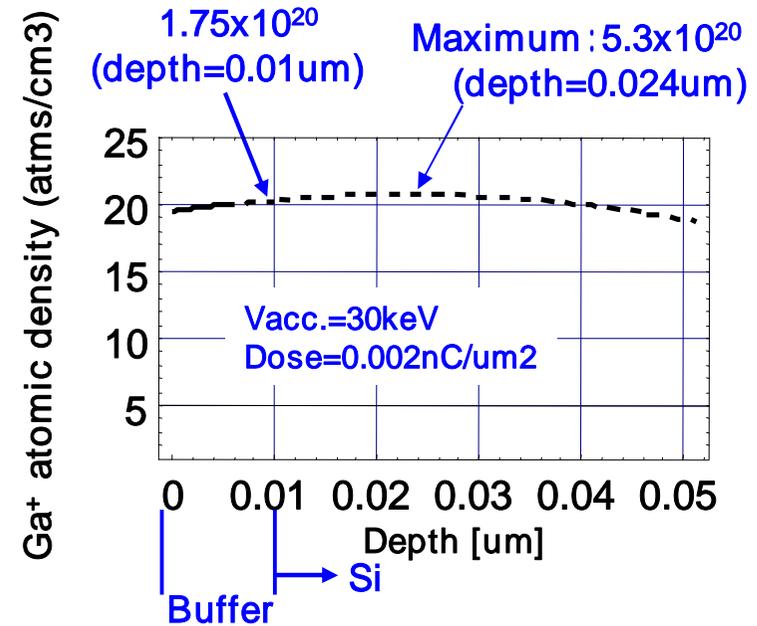
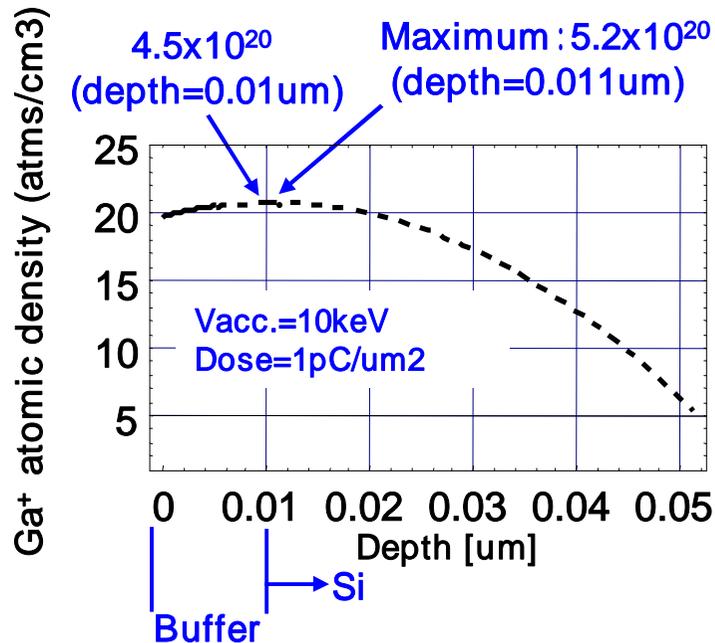
FIB-GAE(10keV) 90nm Clear Repair



Cross Sectional Profile of Repair

- Traditional carbon based FIB deposition may be used for EUV.
- Thickness control and halo reduction are also significant.

Calculated Ga⁺ distribution due to FIB scan



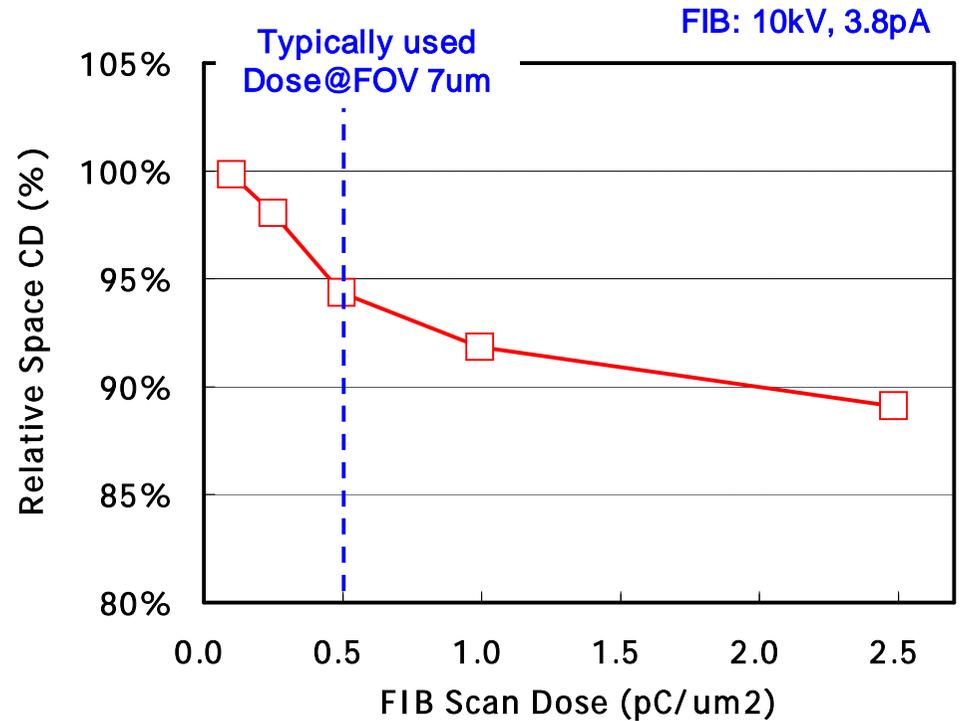
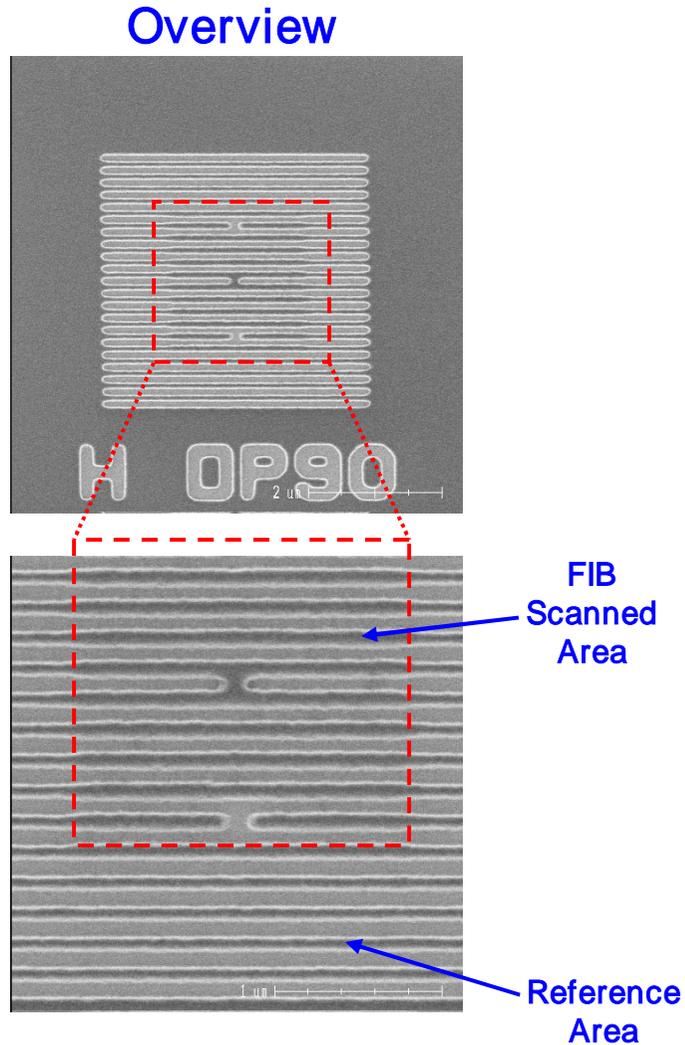
<Notes>

- Atomic density (atoms/cm³); Buffer: 4.4×10^{22} , Si: 5.0×10^{22}
(Literature value for bulk)

Needs experimental measurement for thin film

Ga⁺ atomic density is smaller than about 1% of buffer or Si density (bulk)
in cases of both 10keV and 30keV FIB.

FIB Scan Damage



- FIB scan decreases space width on wafer, according to its Dose.
- At the typical Dose, CD changes ~5%.
→ Needs improvement for production.

Summary

We evaluated TaSix absorber / ZrSi-based buffer mask, especially focusing on the possibility of buffer needless to be stripped.

- ZrSi-based buffer has both high dry-etching resistance and EUV transparency capable to work as a buffer needless to be stripped.
- TaSix bi-layer absorber patterning on ZrSi-based buffer showed good properties such as vertical-like profile, CD linearity and CD uniformity.
- AFM machining repair of TaSix bi-layer absorber on ZrSi-based buffer can be performed good profile. Printing evaluation (90&65nm) showed that over-repair into buffer layer did not affects wafer CD significantly.
- FIB(10keV) opaque repair has potential for opaque defect, and needs improvement for surface profile. Traditional carbon based deposition may be used for clear defect.
- FIB (10keV) scan will make wafer CD worse. Improvement to minimize scan dose is necessary for future production.

Acknowledgements

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