Effect of chemical composition on cleaning durability of EUV mask capping layer

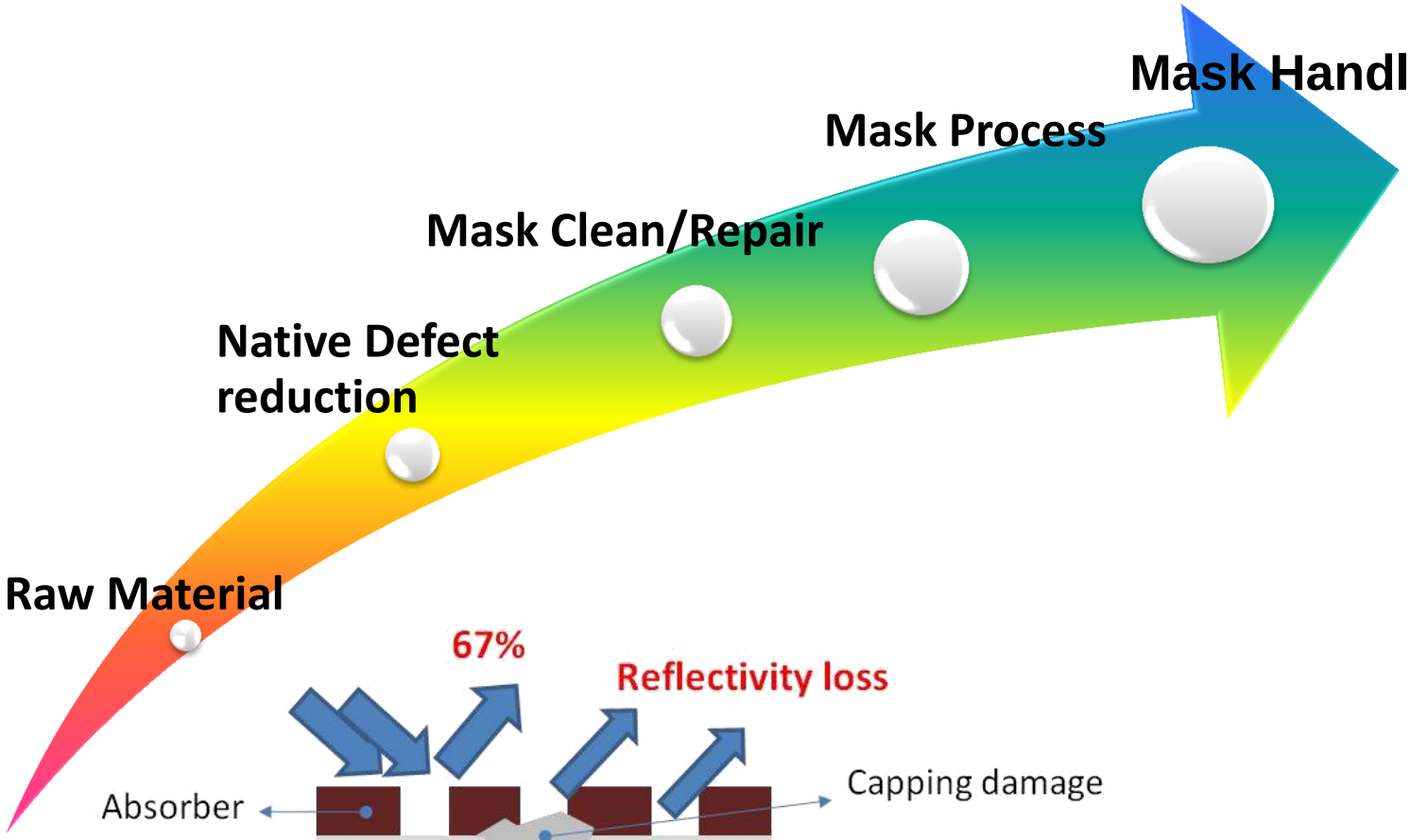
Yun-Yao Lin, Wen-Hung Liu, Jia-Jen Chen,
Shin-Chang Lee, and Anthony Yen

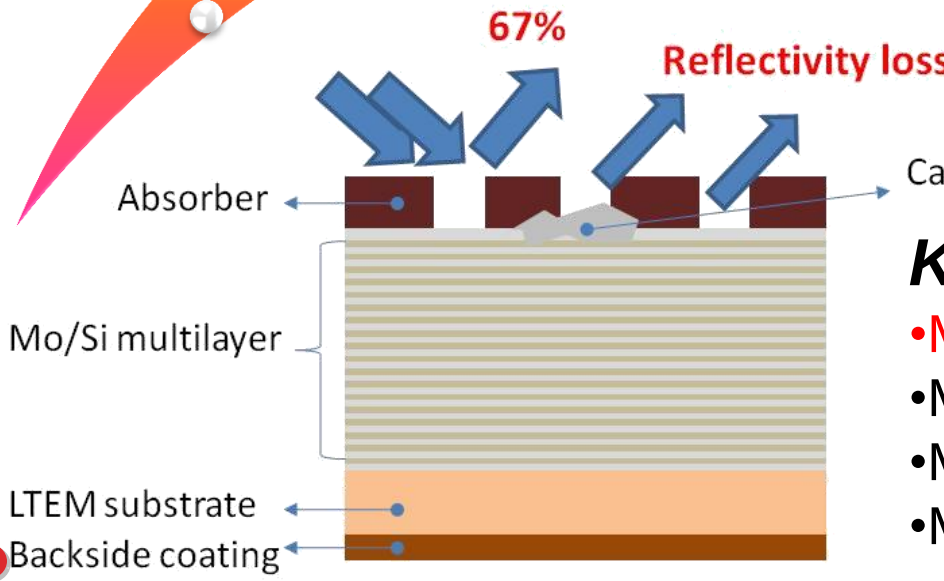
***A**dvanced **M**ask **F**rontend **T**echnology Dept.*
NPT Division, Taiwan

Outline

- ***Ru capping layer damage***
  - ***The importance and challenge of capping layer***
- ***Motivation***
  - ***From fundamental material study point of view***
- ***Experiment***
  - ***SEM/AFM/XPS/TEM***
- ***Simulation model***
  - ***Ab initio simulation***
- ***Summary***

Outline-*toward EUV lithography for Production*





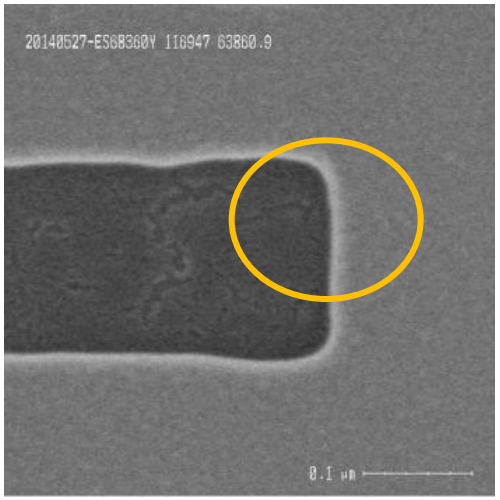
Key factor:

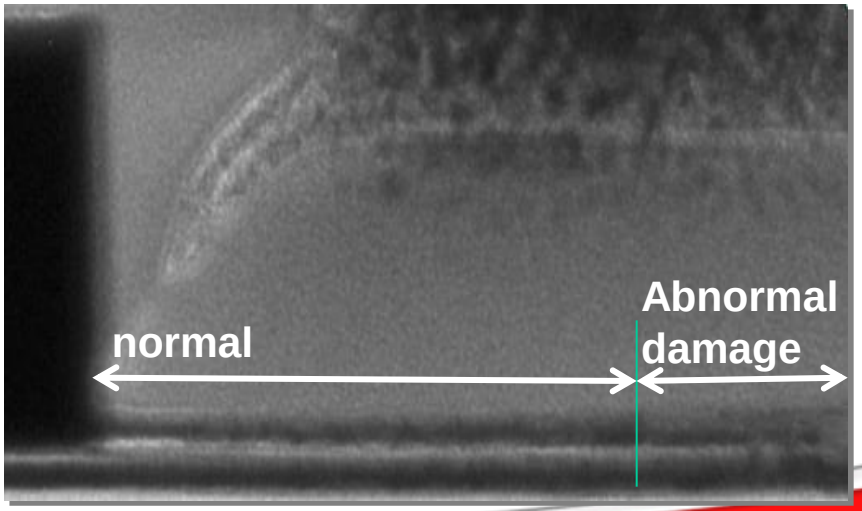
- Material reliability(Ru capping layer)
- Mask process optimization
- Mask defect control
- Mask repair capability

Why capping layer damage is so important for EUV masks??

- **Wafer printing perspective:** EUV reflectivity degradation if capping layer is damaged or surface is roughen.
- **Mask process perspective :** Unstable patterning process and weak cleaning stability.
- **Mask repair perspective :** complicated repair process

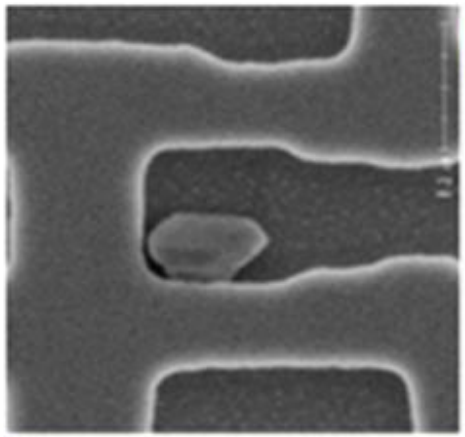
Study of surface chemical reaction on capping layer is important to the improvement of EUV mask quality



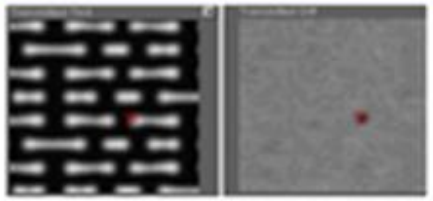


Material stability challenge for EUV mask

Frequent cleaning (> 100 cycles) may be required due to lack of pellicle or backside contamination.



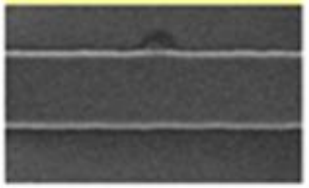
Particle removal



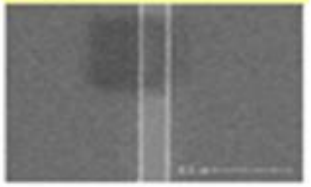
Lower ← **Physical force** → Higher

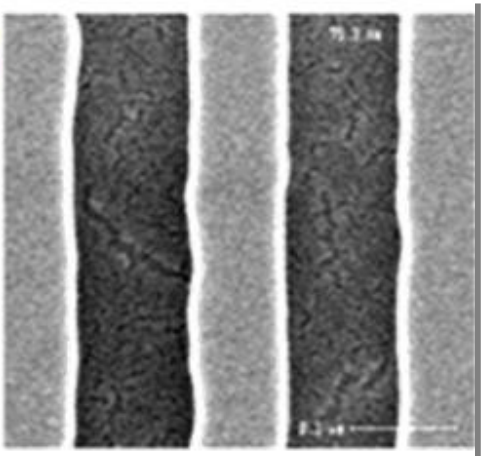
Chemical force

Haze growth ??



Carbon growth ??



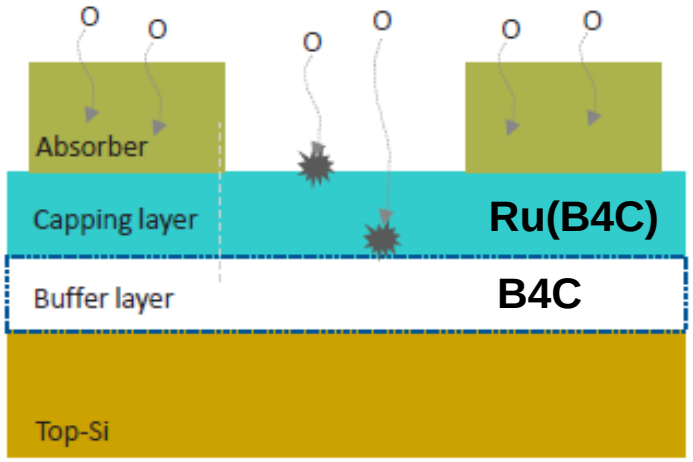


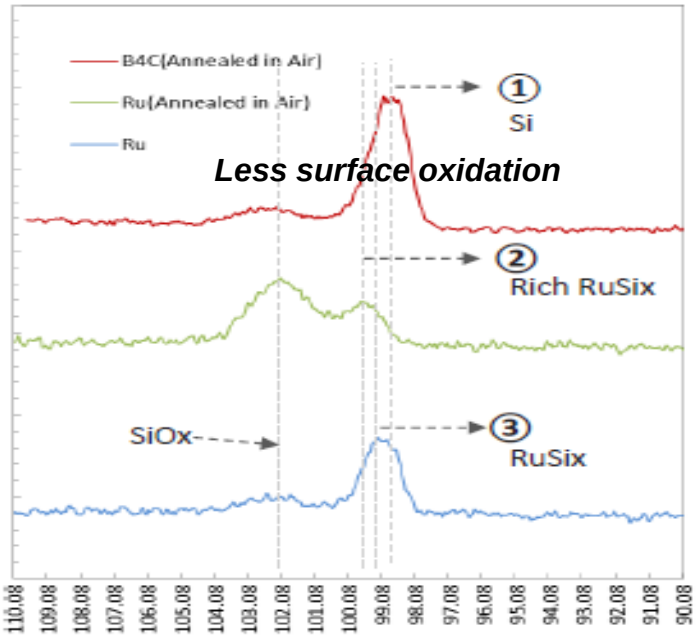
Ru damage

Need to balance PRE(particle removal efficiency) and capping layer damage

Motivation

Develop new alternative material or??





Clean chemicals

Radiation damage

Fundamental material property & mechanism

Heating effect

Etching chemicals

- **Capping layer damage**

→**From under layer diffusion??**

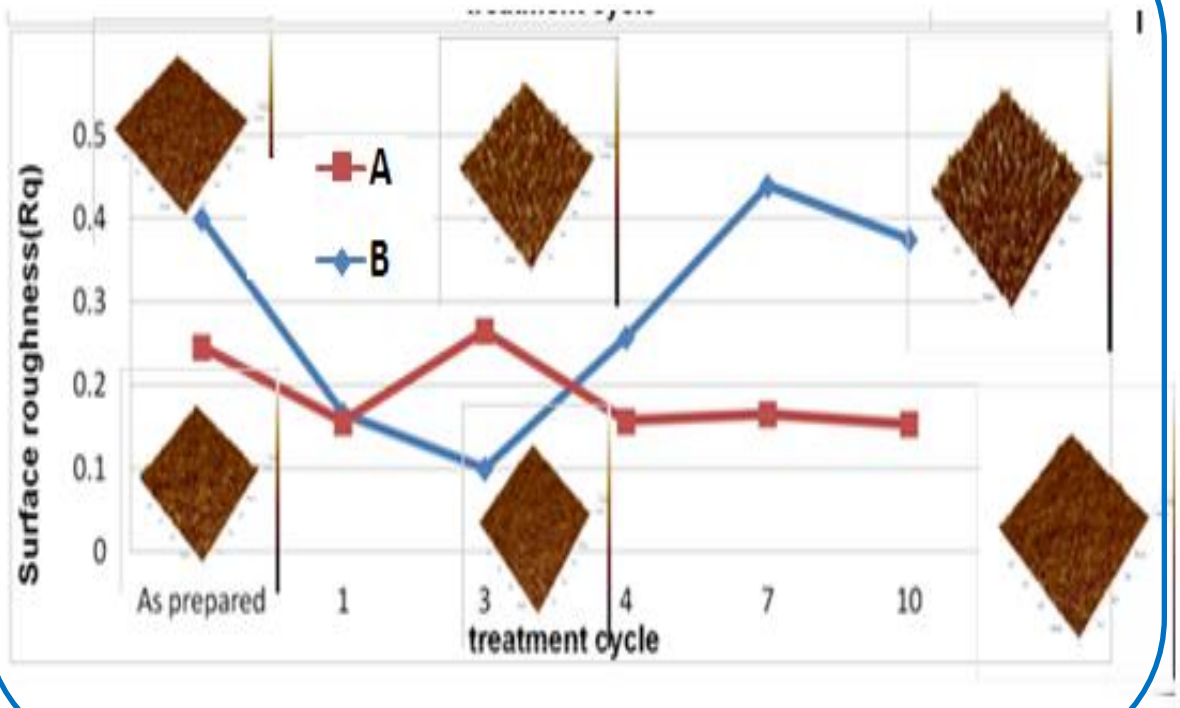
→**Process chemicals interaction??**

Outline

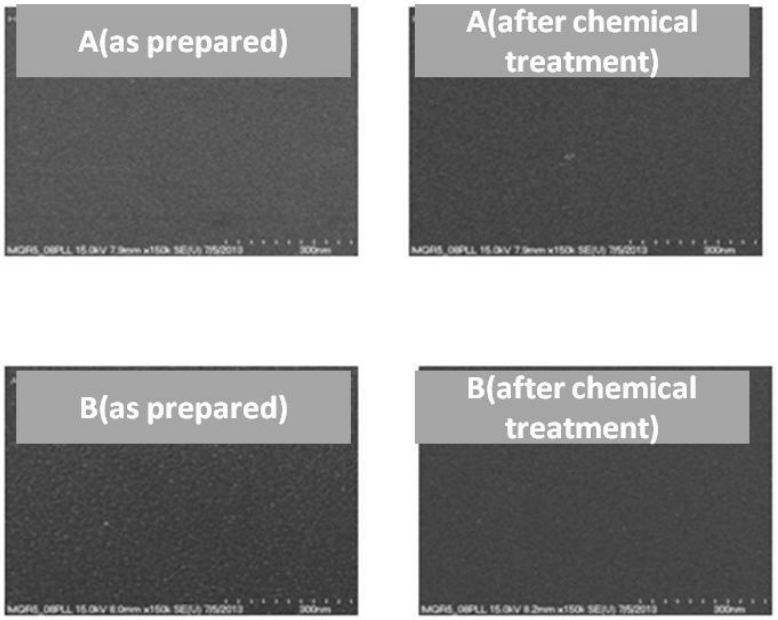
- *Ru capping layer damage*
  - *The importance and challenge of capping layer*
- *Motivation*
  - *From fundamental material study point of view*
- ***Experiment***
  - ***SEM/AFM/XPS/TEM***
- ***Simulation model***
  - ***Ab initio simulation***
- ***Summary***

Wet chemical damage on different capping layer

AFM

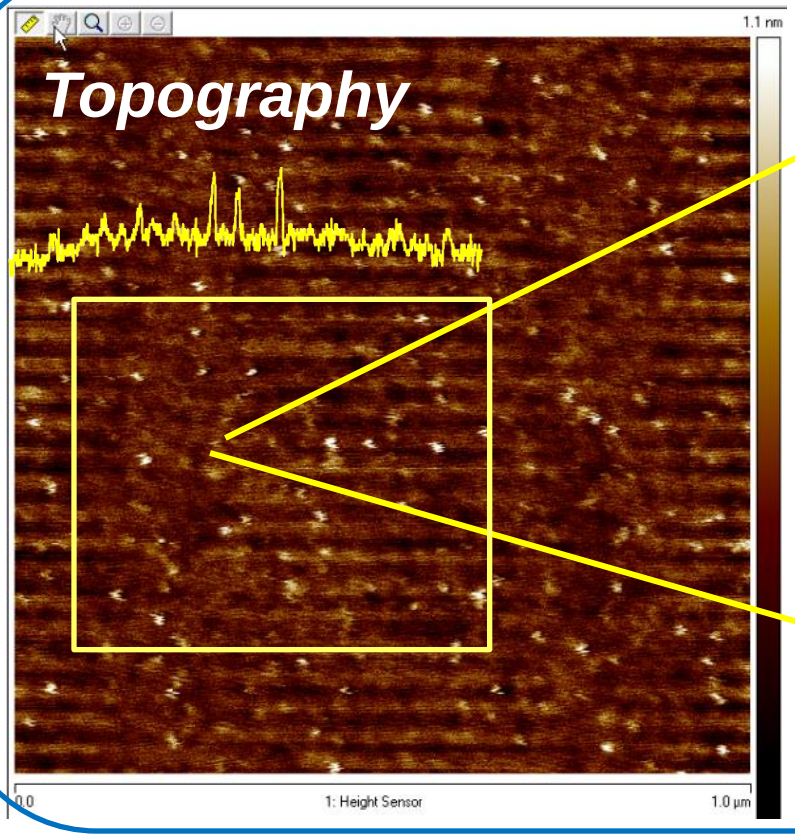


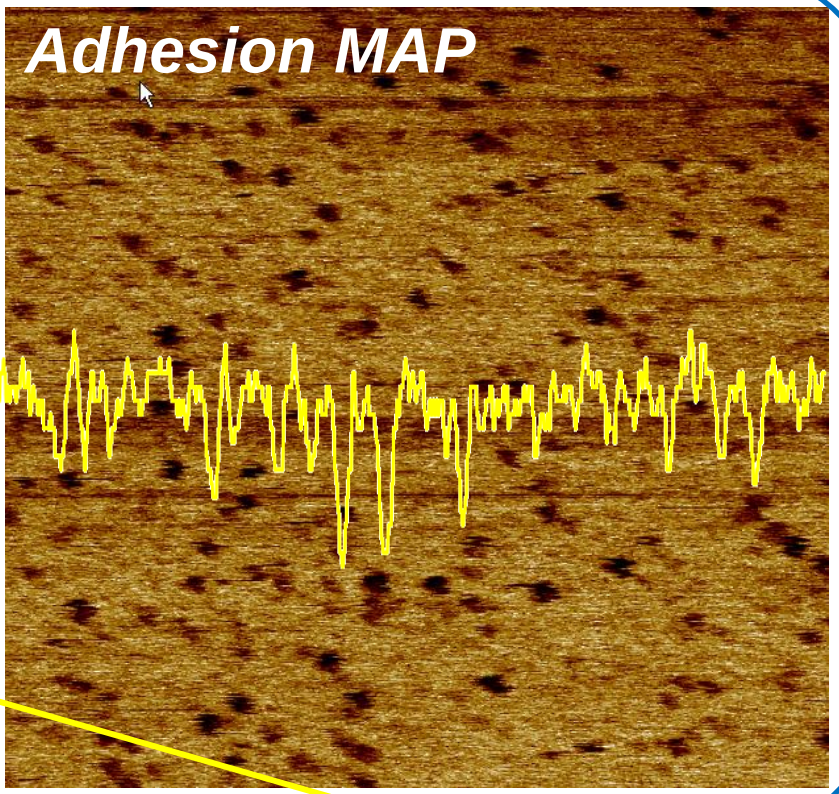
SEM



- *Design two type capping layer material compound*
- *More surface roughness increase in B type capping layer after cleaning cycles.*
- *Small tiny grains found after cleaning cycles->same material or??*

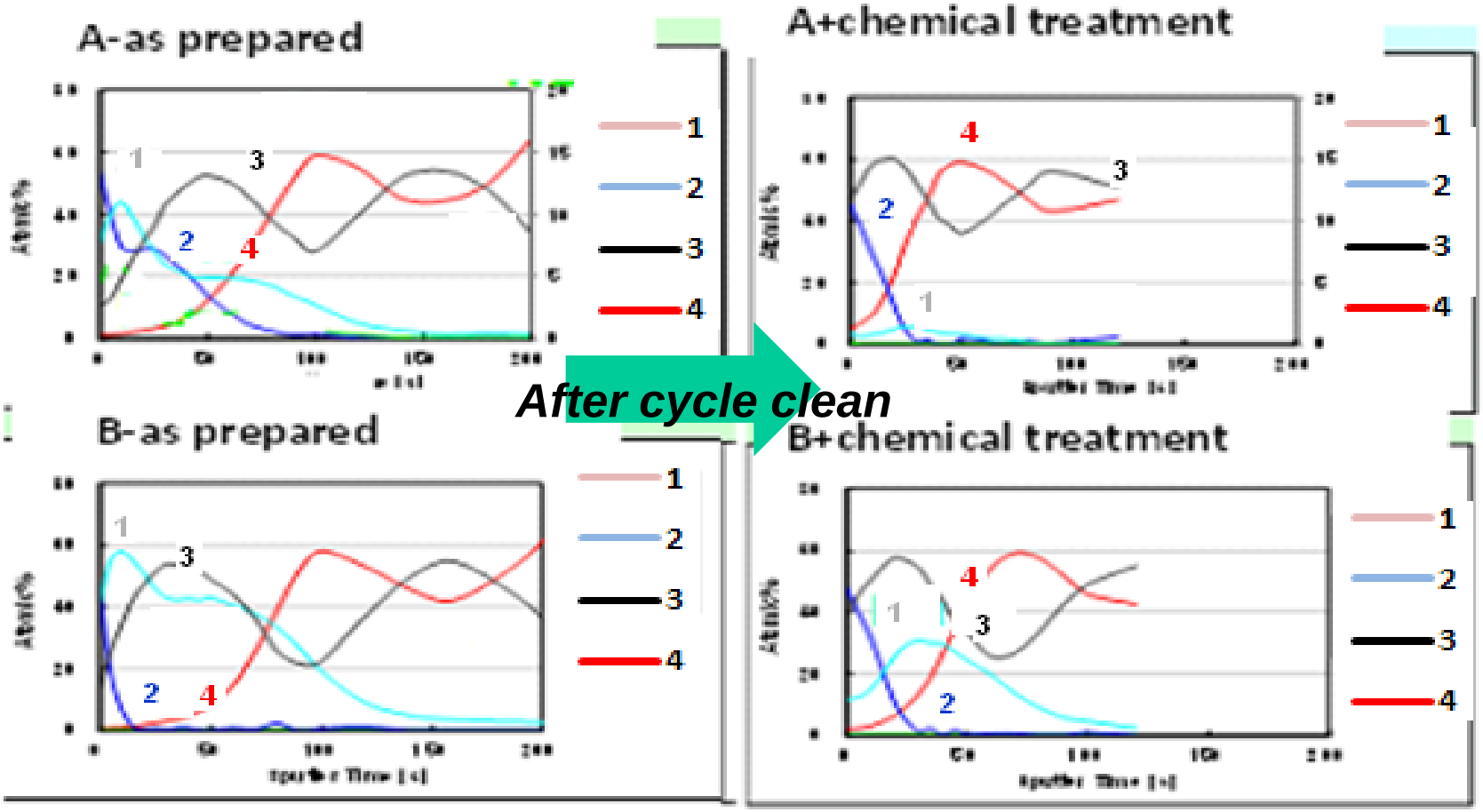
Hetero-composition formation or surface damage??





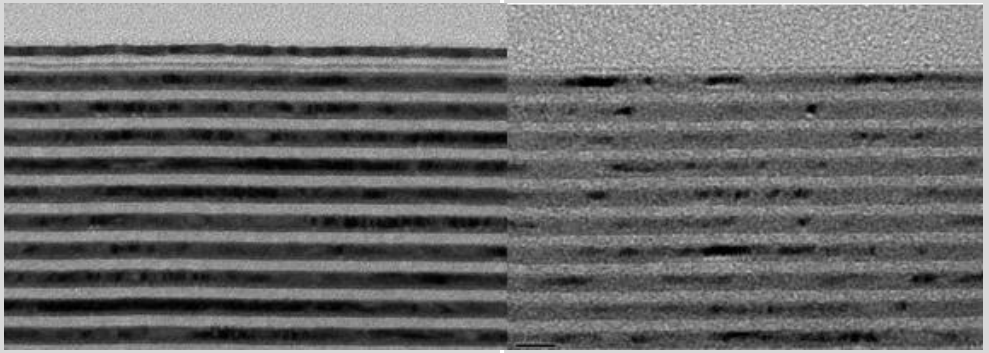
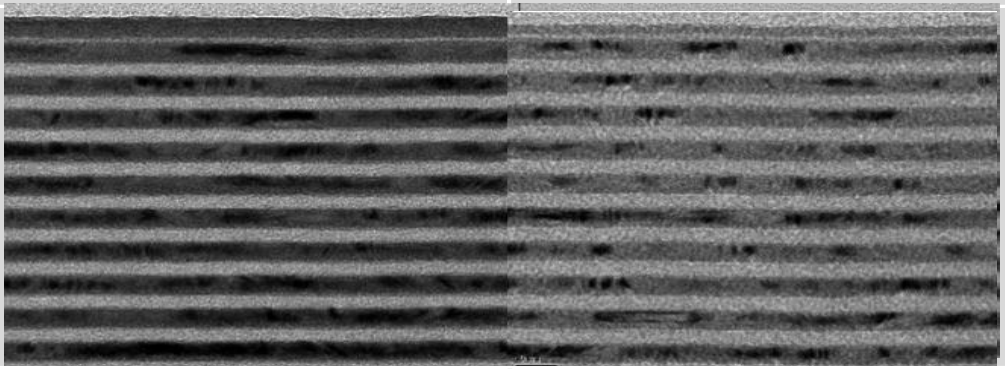
- *Both topography and adhesion maps show tiny grain formed on the surface.*
- *Composition analysis may reveal more information.*

XPS analysis for tiny grain or damage on capping layer



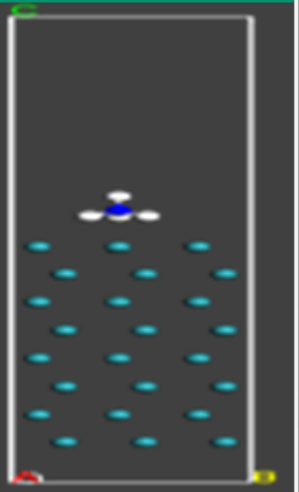
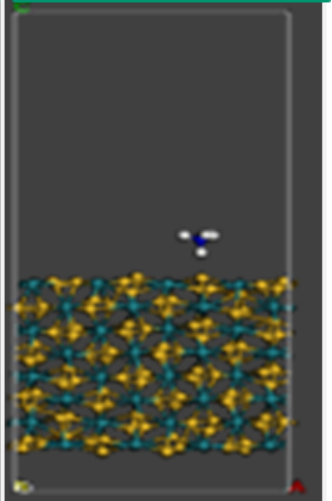
XPS data show that severe capping layer loss in A type material compared to B after cleaning cycles.

HRTEM analysis for capping layer damage

	Before	After
A		
B		

Compared to B material, the TEM image of A capping layer shows severe Ru loss after chemical treatment.

Origin of capping layer surface interaction by ab initio simulation

	BlankA	BlankB
Structure		
Binding Energy $E_{b(ionic}$ molecular C)	-7.5	10.16
Binding Energy $E_{b(ionic}$ molecular D)	-16.4	9.55

A type capping layer material shows stronger chemical reactivity with general ionic molecules

Conclusion

- Chemical treatment of EUV masks after substantial cleaning cycles leads to a marked capping layer loss and damage.
- Capping layer film loss can be effectively suppressed by Manipulating capping layer composition
- The TEM morphological changes which correlates to the surface composition evolution are also found in the XPS depth-compositional analysis.
- Clean process on EUV blanks still needs further optimization in order to reduce capping layer damage.

Acknowledgement

A**dvanced **M**ask **F**rontend **T**echnology **Dept.
***NPT Division tsmc*, Taiwan**

Wei Hung Liu,

Yi Jhih Lin

J. J. Chen,

S. C. Lee,

Dr. Anthony Yen

Thank you for your attention!