Optimization of Edge Clean Using Non-visual Defect Inspection

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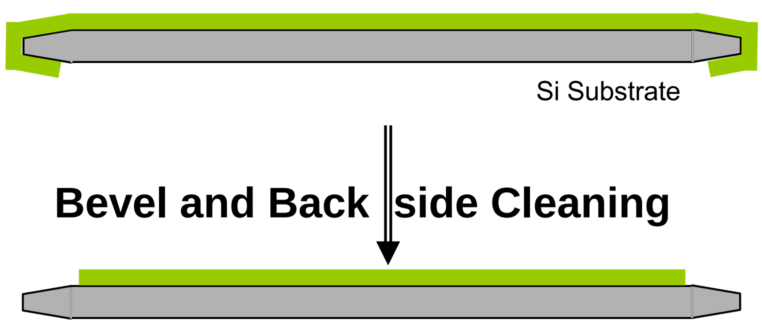
Outline

1) Motivation

Trend : more backside and edge cleans in advanced processes

- New technologies such as 3D integration, Through Silicon Via (TSV)
- New materials and metals for FE, BE up to packaging, so more types of contamination
- Many applications on the same tool - chuck / handler cross-contamination
- Shared carriers in fab / contact point cross-contamination

Metal Film Deposited on Front Side and Bevel with Backside Bevel and Partial Backside Coverage

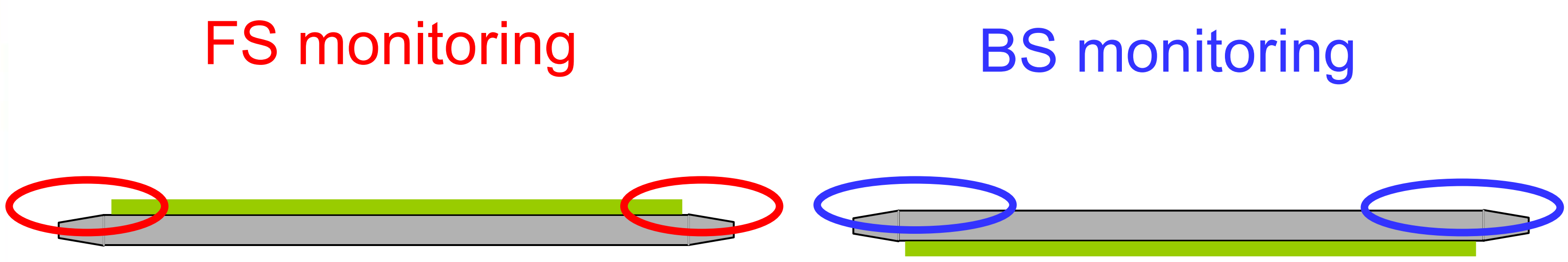


=> Efficient Cleans required to avoid cross contamination

1) Motivation

Need : Inspection technology for monitoring of bevel edge area

- To detect presence of residues in the bevel edge area
- To detect incursion of chemistry or residues into the wafer interior, where active devices are



Question : to what extent can the ChemetriQ technology provide an easy to perform, non-destructive, and reliable bevel edge control for front side and back side monitoring?

2) ChemetriQ Technology

Technology : Surface Potential Difference (SPD) Imaging

- Probe-to-wafer voltage is proportional to difference in work functions
- Changes in work functions on wafer surface causes probe voltage changes

Probe: metal with WF1

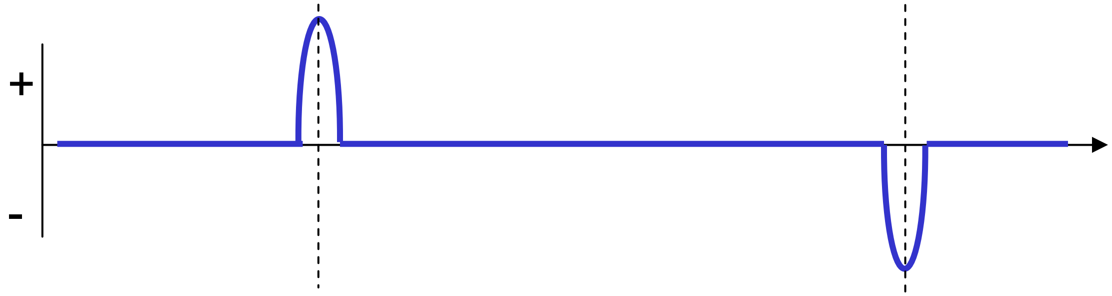
Chemical non-uniformity: WF 3 (≠ WF 2)

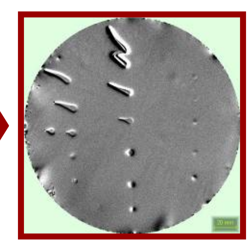
Wafer: WF 2 (≠ WF 1)

The probe scans the wafer and software creates an image proportional to work function variations

ChemetriQ SPD Signal

$$\propto \frac{\mathrm{dWF}}{\mathrm{dt}} \propto \frac{\mathrm{dV_{SPD}}}{\mathrm{dx}}$$



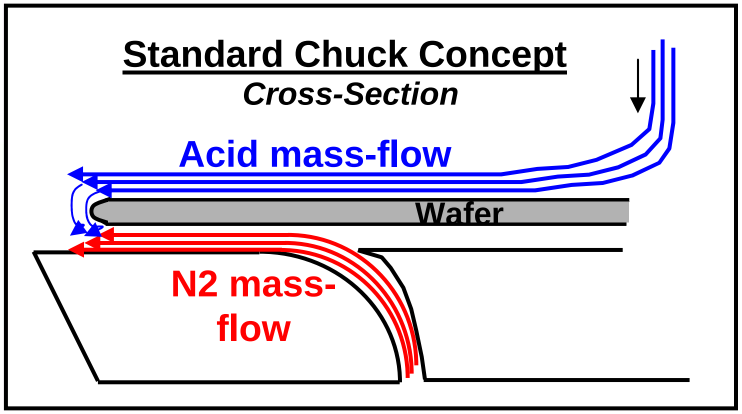


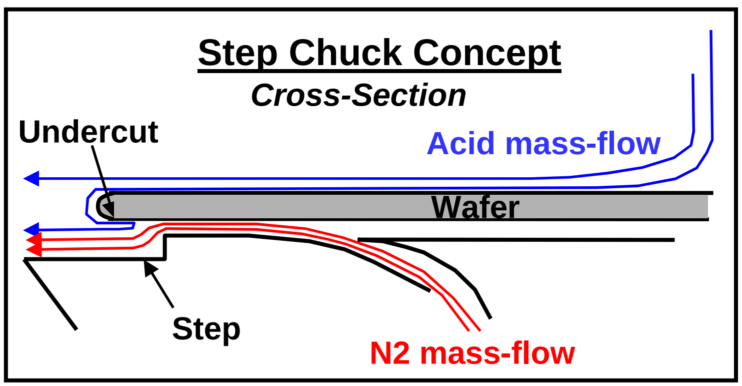
ChemetriQ Image

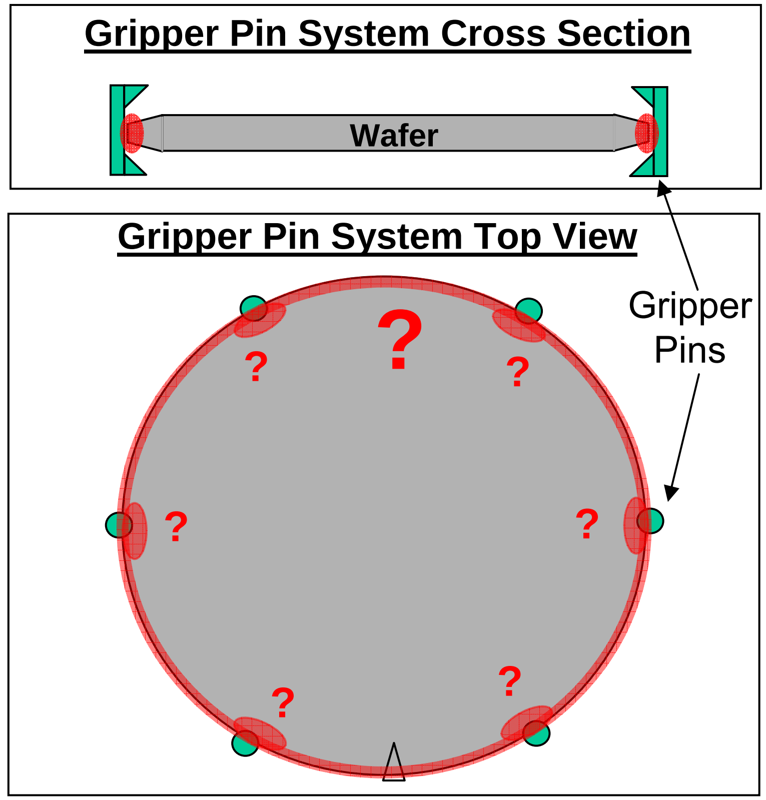
2) Experimental Overview

Clean tool description:

- Single wafer tool, "spin etcher" type
- Standard or step chuck concept
- Gripper pins to hold wafer by edges







2) Experimental Overview

Experimental Split:

- Speed of rotation: 400 vs 1200 rpm
- Gripper Handling: Wafer shift vs no wafer shift
- Chuck Type: Standard vs Step
- Process Chemistry: Hard HF/ Oxidant base & Soft HF/ Oxidant base, Aqua Regia
- Substrate: Si vs SiO_2

First:

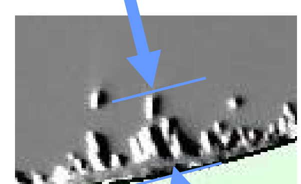
- Experiments using simple film stacks

Then:

- Experiments using complex Under Bump Metallization film stack

Measured Results:

- Backside: Residue removal efficiency
- Frontside: Radial incursion distance (mean and max)



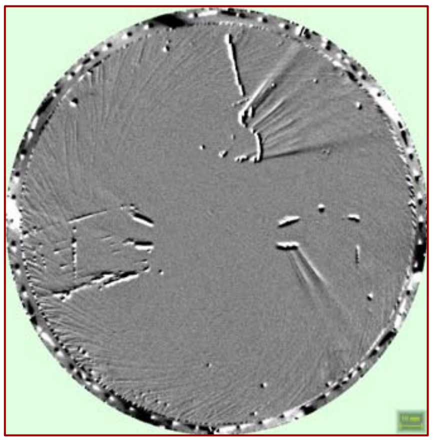
Radial incursion distance

3) Results Using Simple Film Stacks

BS monitoring:

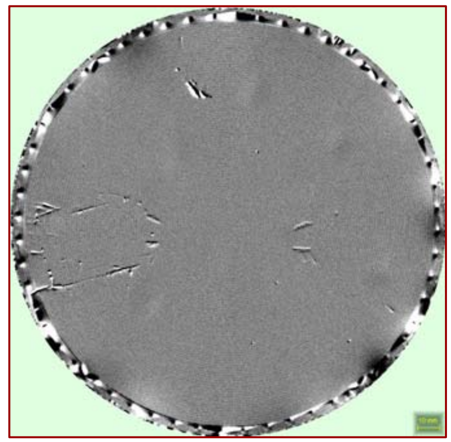
- **Film stack: Mo/ SiO_2**
- **Correlation with Zero Edge Exclusion (ZEE) TXRF results**

ChemetriQ

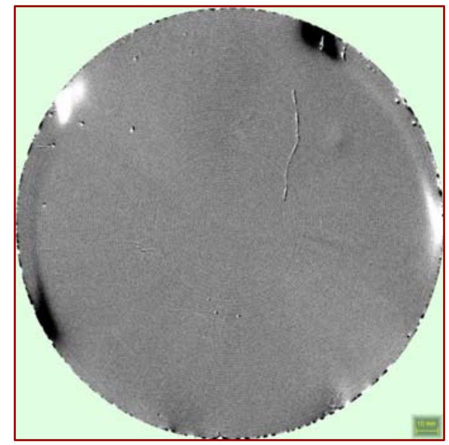


No Clean

BS clean ⇒

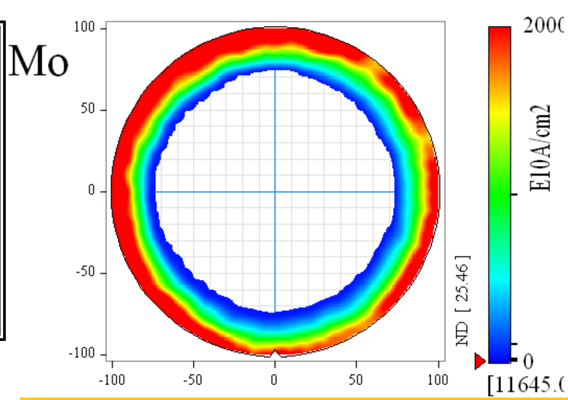


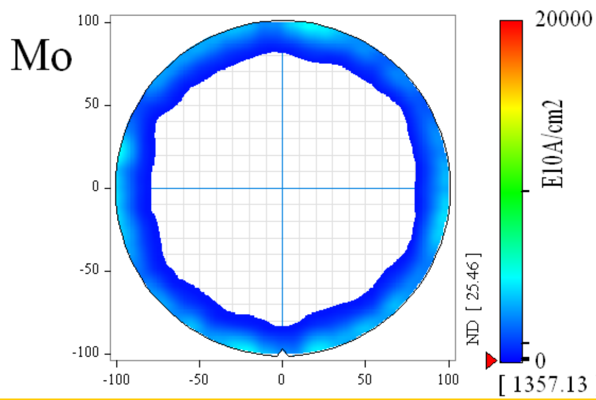
Soft Clean

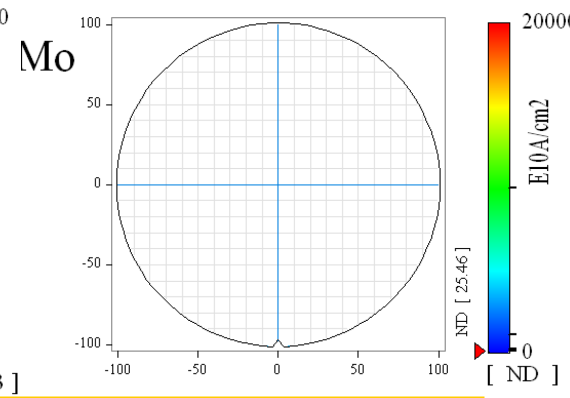


Hard Clean

ZEE TXRF







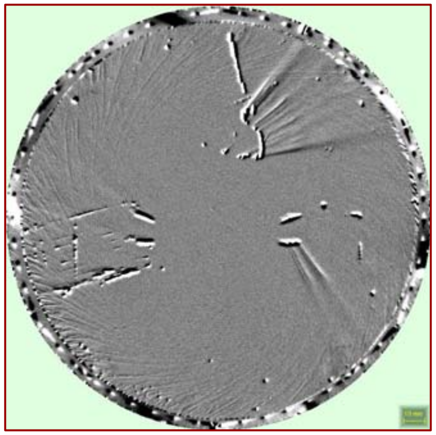
⇒ ChemetriQ shows efficacy of Hard Clean and correlation to ZEE TXRF

3) Results Using Simple Film Stacks

BS monitoring

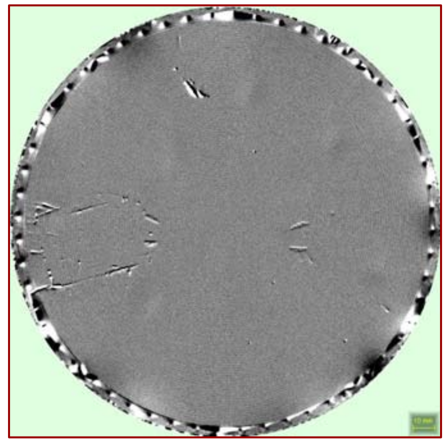
- **Film stack: Mo/ AlN/ SiO_2**
- **Correlation with Zero Edge Exclusion TXRF results**

ChemetriQ

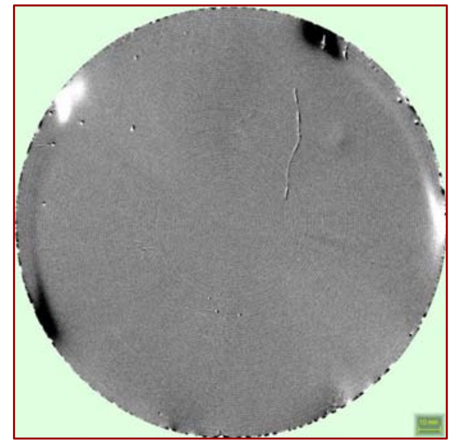


No Clean

BS clean

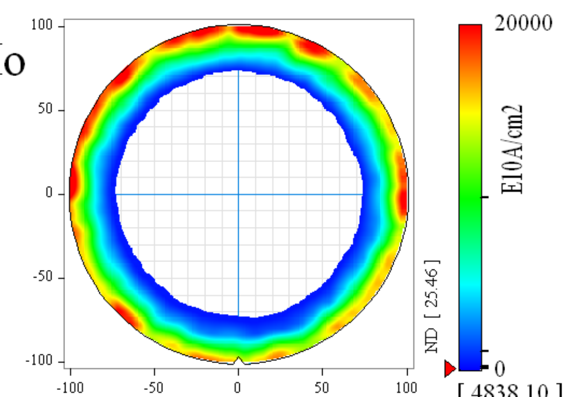


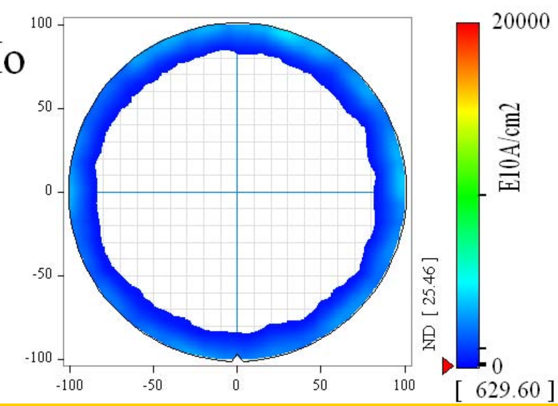
Soft Clean

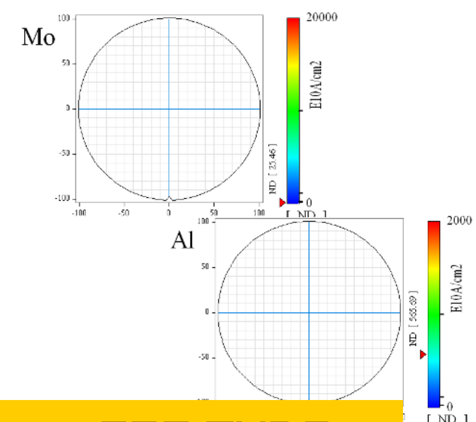


Hard Clean

ZEE TXRF





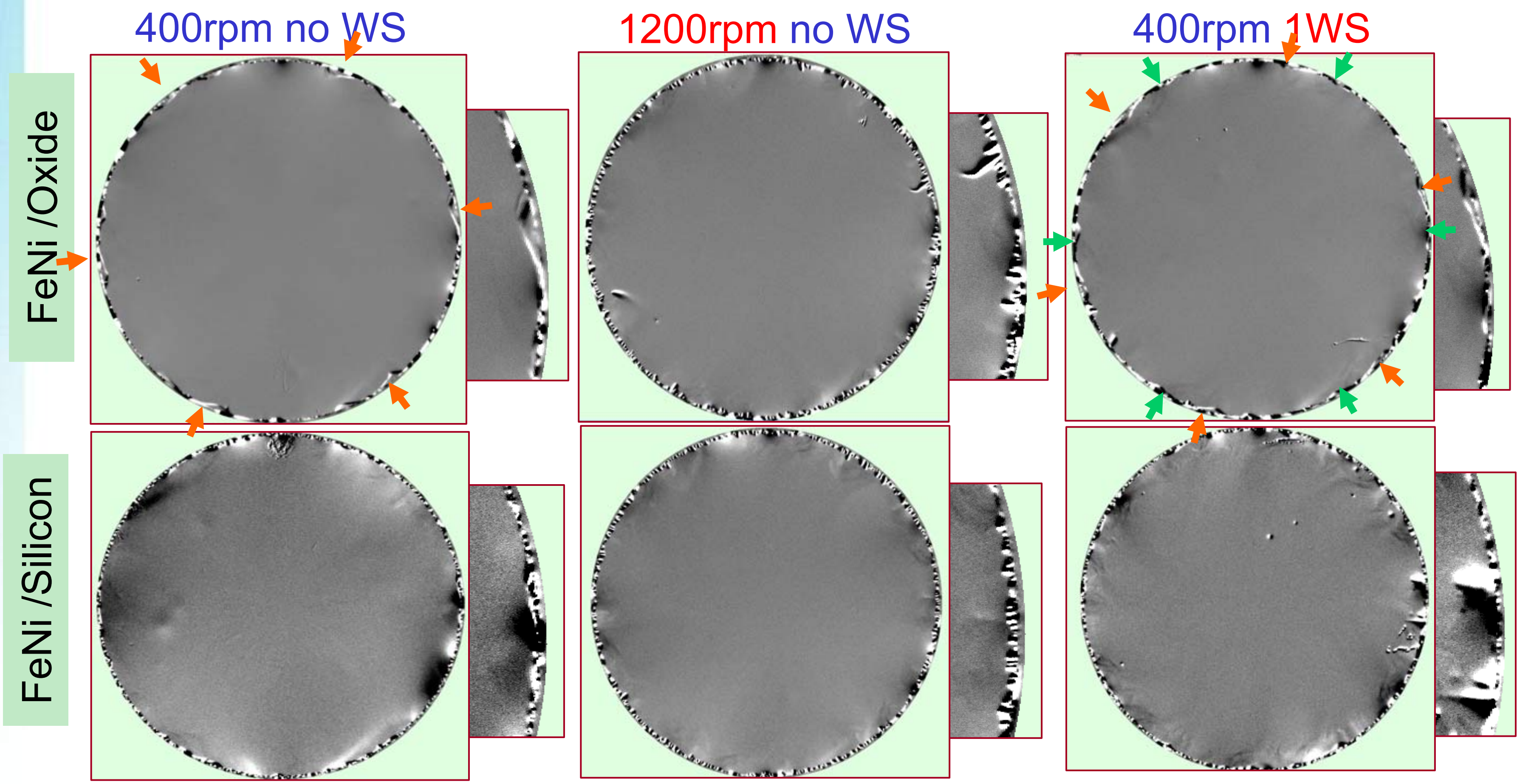


⇒ Again, shows efficacy of Hard Clean and correlation to ZEE TXRF

3) Results Using Simple Film Stacks

FS Monitoring

- **Film stack: FeNi/ SiO_2 & FeNi/ Si; Chemistry: hard clean**
- **Process parameters change: speed rotation/ wafer shift**



⇒ Larger incursion seen with higher spin speed/ gripper system detected

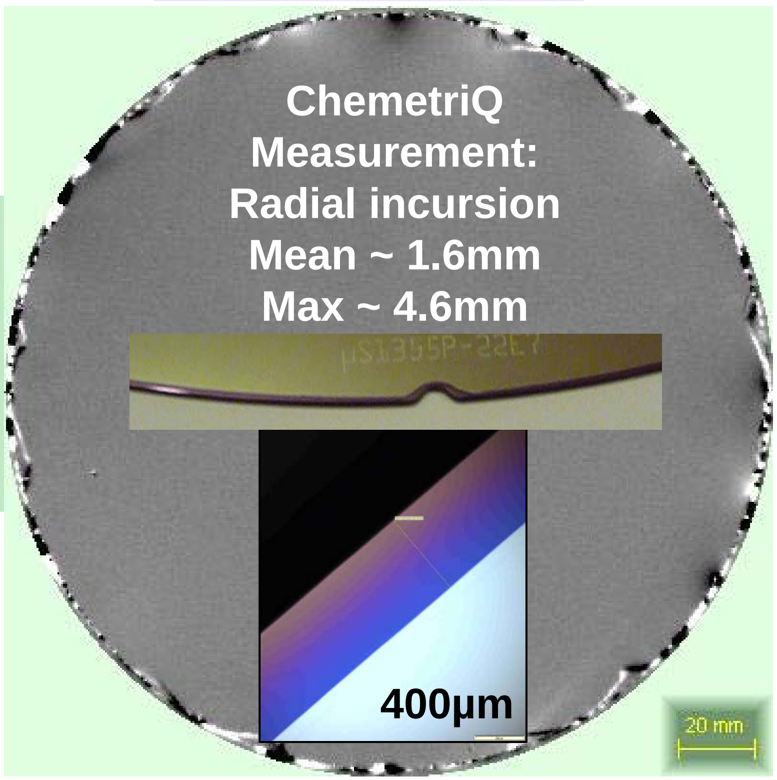
3) Results Using Simple Film Stacks

FS Monitoring

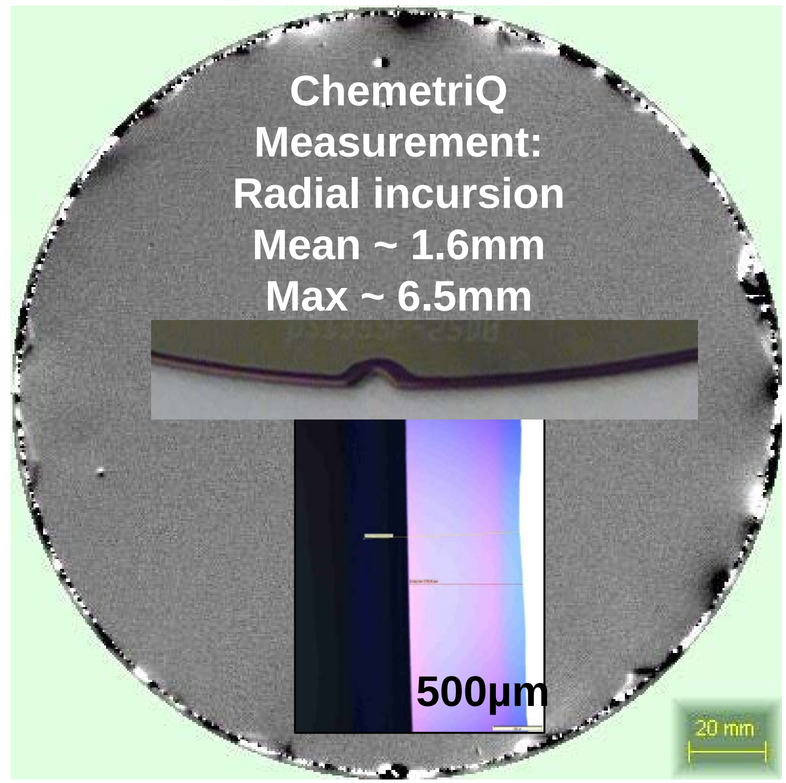
- **Film stack: FeNi/ SiO2**
- **Chuck impact**

FeNi / Oxide

Standard Chuck



Step Chuck



⇒ step chuck had more instances of large incursions

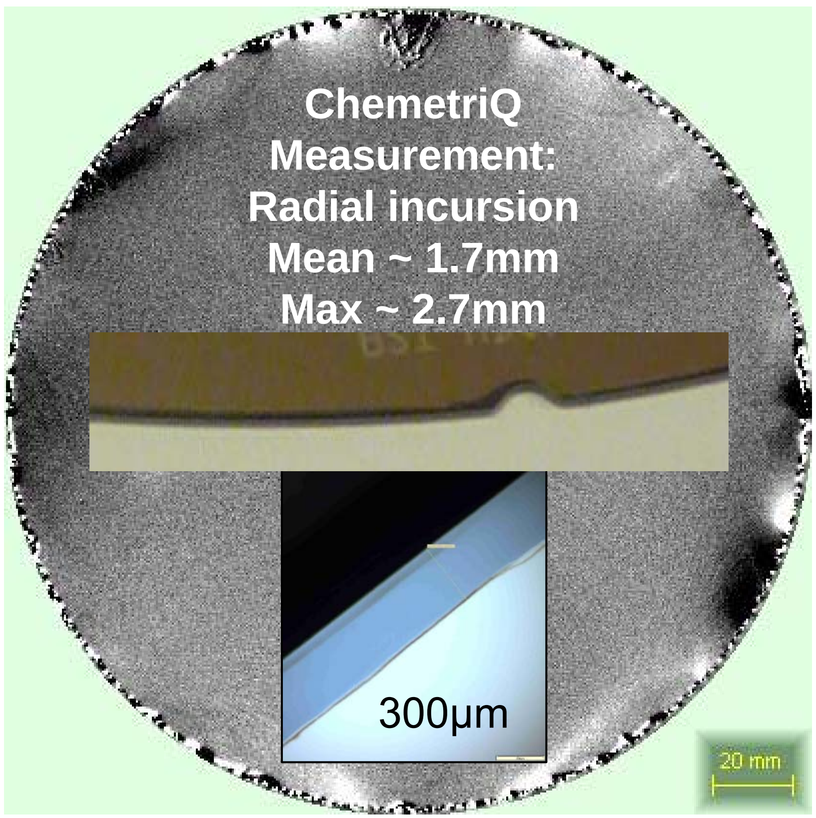
3) Results Using Simple Film Stacks

FS Monitoring

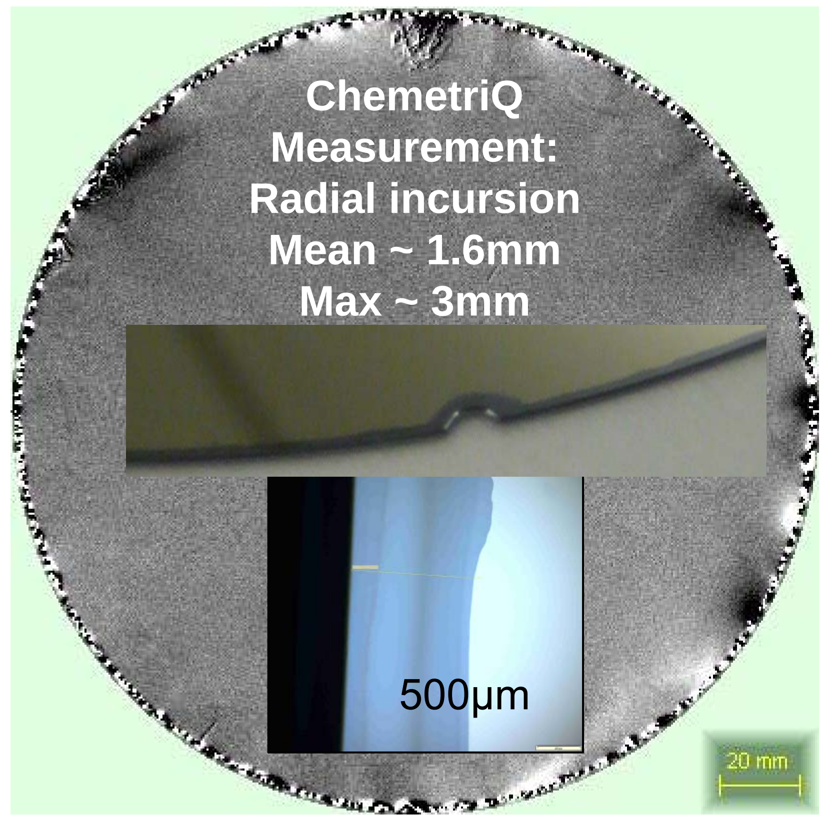
- **Film stack: FeNi/ Si**
- **Chuck impact**

FeNi / Silicon

Standard Chuck



Step Chuck



⇒ChemetriQ shows similar incursions on both; visual shows only on step chuck

3) Results Using Simple Film Stacks

Summary

BS Monitoring

- Qcept sensitivity for Mo & Mo/AlN well correlated with ZEE TXRF datas
- Full wafer scan in 3 minutes / wafer (200mm)
- Wide contaminated area (~30mm) makes this easier to see in images

FS Monitoring

- Process parameters change is detected by Qcept
- Wide clean area not correlated with visual control – Qcept detects residues that cannot be detected optically
- Edge-only FS scan can be performed in <30 seconds / wafer
- Gripper was suspected of causing the incursion, but the gripper signature was not easily separated from the rest of the signal from the liquid incursions

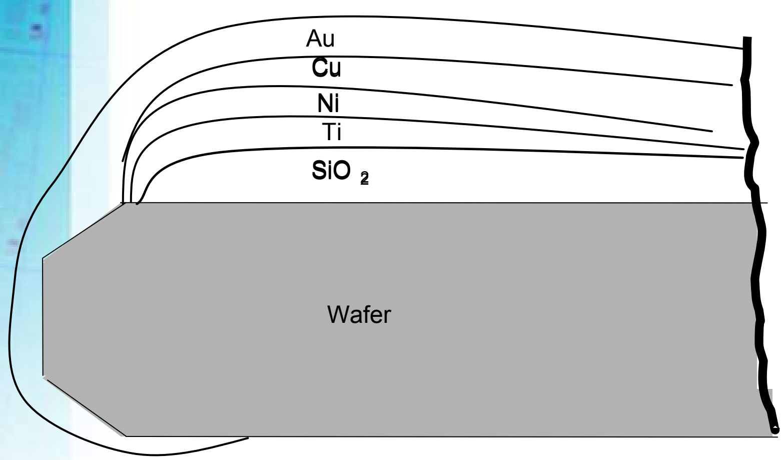
4) Results Using Complex UBM Film Stacks

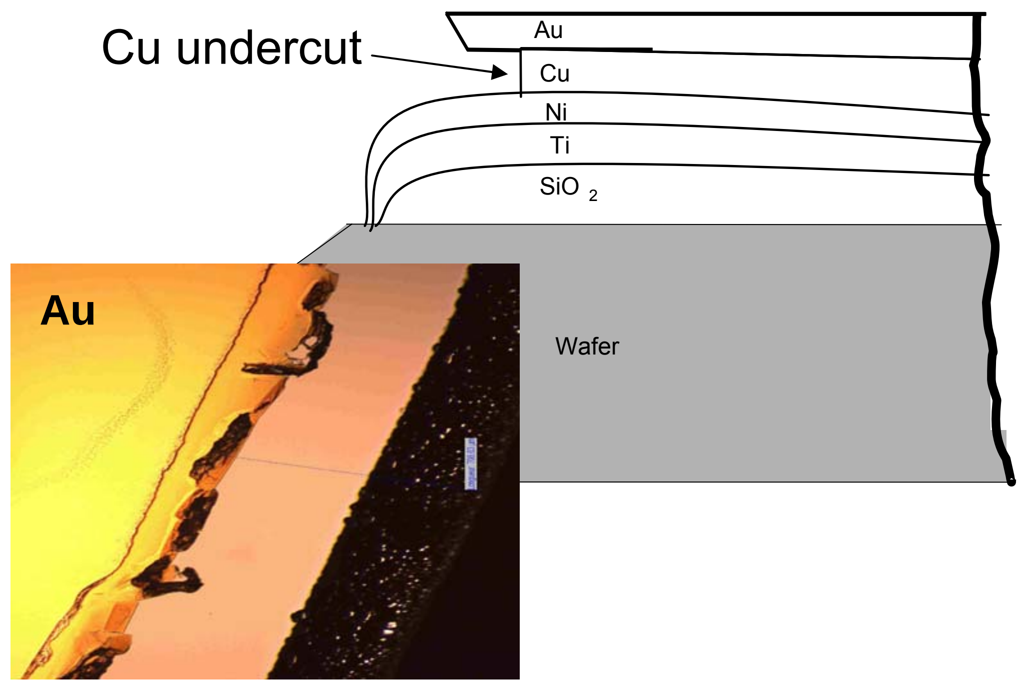
UBM stack description

- Schematic wafer cross section at the Under-Bump Metallization (UBM)
- Incursions are very expensive: these are nearly finished wafers!

After Metal Deposition

After BS Clean



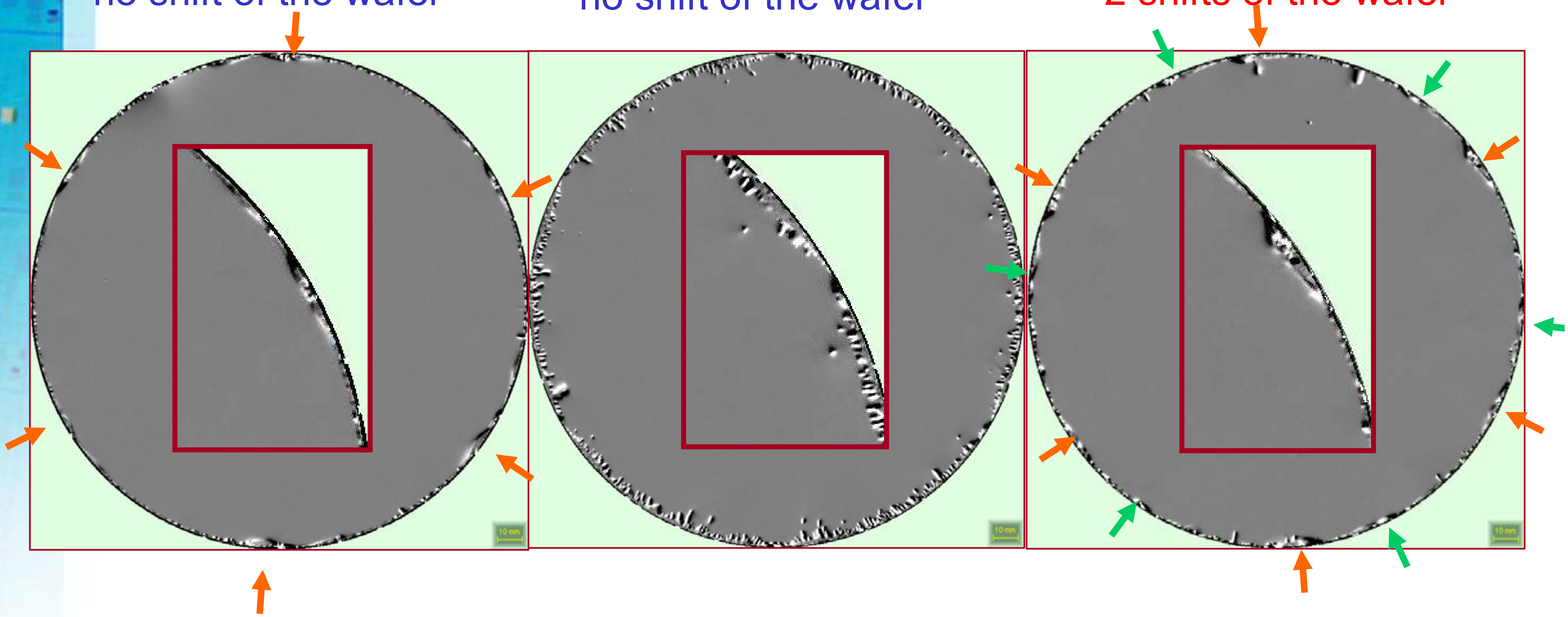


4) Results Using Complex UBM Film Stacks

BS Monitoring

- Film stack: UBM film stack; Chemistry: Aqua Regia
- Process parameters change: speed rotation/ wafer shift

400rpm	1200rpm	400rpm
no shift of the wafer	no shift of the wafer	2 shifts of the wafer

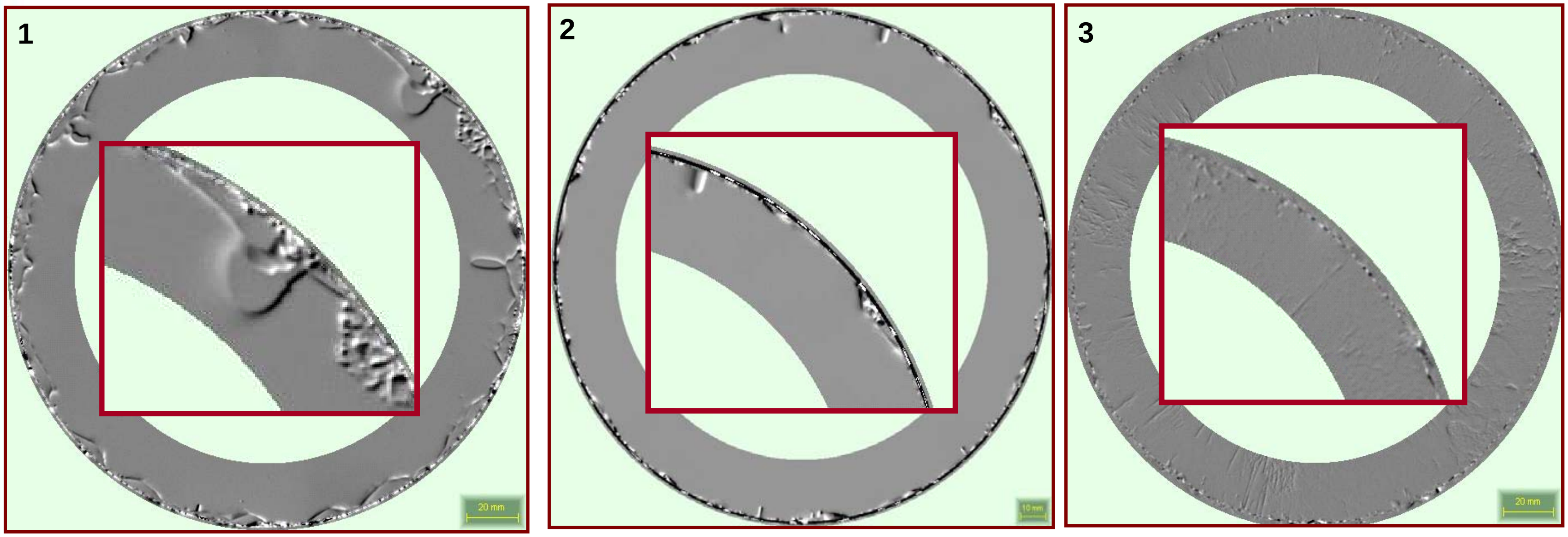


⇒ Higher spin speed and wafer shift induce larger radial incursions

4) Results Using Complex UBM Film Stacks

Recipe Optimization

Original Process | First Optimization | Second Optimization



1) Original process: significant incursions

2) With first process parameter improvement: the incursions have been reduced significantly

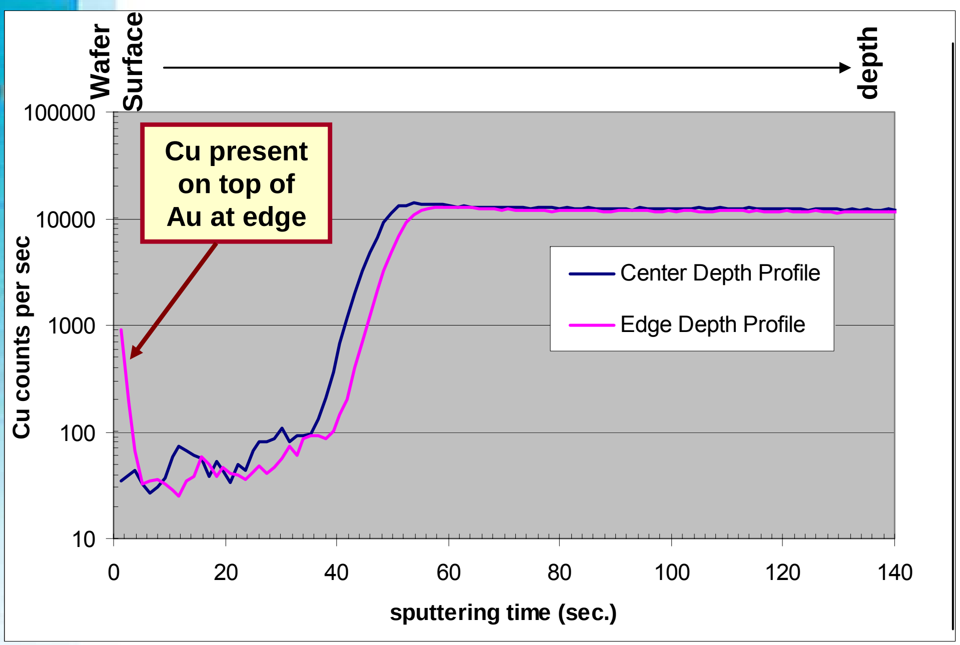
3) Final Process: Radial incursions have been substantially reduced and defects eliminated

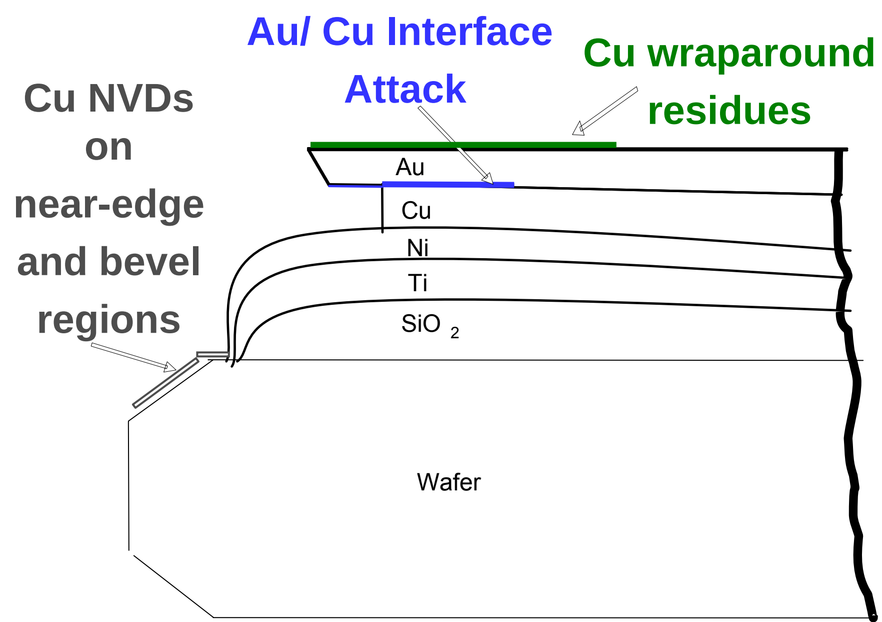
⇒ Demonstrated ability to optimize process

4) Results Using Complex UBM Film Stacks

Correlation with SIMS results

- SIMS depth profile of two points on wafer: at center and at edge location
  - at center of wafer (blue): no Cu at the surface
  - at the edge(pink): a measurable amount of Cu is present where ChemetriQ image indicated a Non-Visual Defect





Defect mechanisms during BS clean

⇒ Confirmed by SIMS characterization that the wider incursion observed on Qcept images (not seen visually), are due to Cu non-visual defects

4) Results Using Complex UBM Film Stacks

Summary

- ChemetriQ images show similar impact of process parameter change on UBM stack and simple FeNi film stack (speed rotation and wafer shift have primary impact)
- BS clean process recipe was optimized using ChemetriQ characterization
- Thanks to the tool, front side defectivity impact was reduced
- But, results did not confirm if gold residues (possible cross-contamination source) are present at the bevel edge or not, improvements in resolution are needed to confirm this

5) Conclusions

- ChemetriQ provides valuable insight, and allowed us to optimize the backside / edge clean process in ways that are not possible with other tools.

- Regarding BS monitoring, for Mo specifically, ChemetriQ has sufficient resolution to be a robust method for contamination detection.

- Regarding FS monitoring, ChemetriQ has sufficient resolution to accurately measure incursions into the active area of the wafer, but higher resolution is needed to give a definitive answer in the smaller bevel edge region. Further work should be undertaken to correlate higher-resolution ChemetriQ results to analytical results.

Acknowledgements

✓ This work was performed in the frame of a collaboration among LETI, STMicroelectronics, and Qcept Technologies

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Thank you for your attention