CMP Technological Paradigm Shift To Surface Cleaning

Hong Jin Kim

Advanced Module Engineering, GLOBALFOUNDRIES

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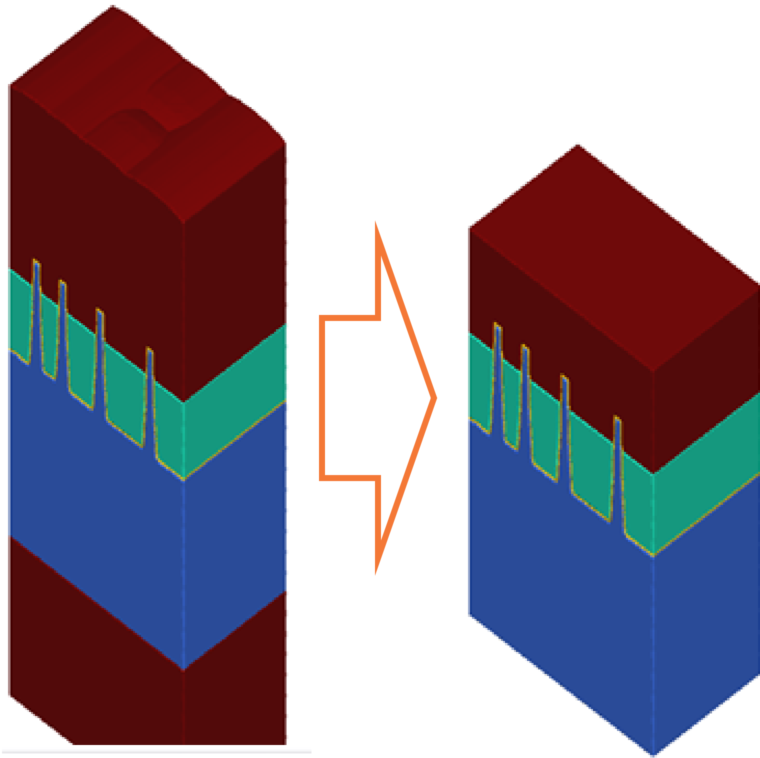
Presentation Focus On..

CMP-induced Defects:

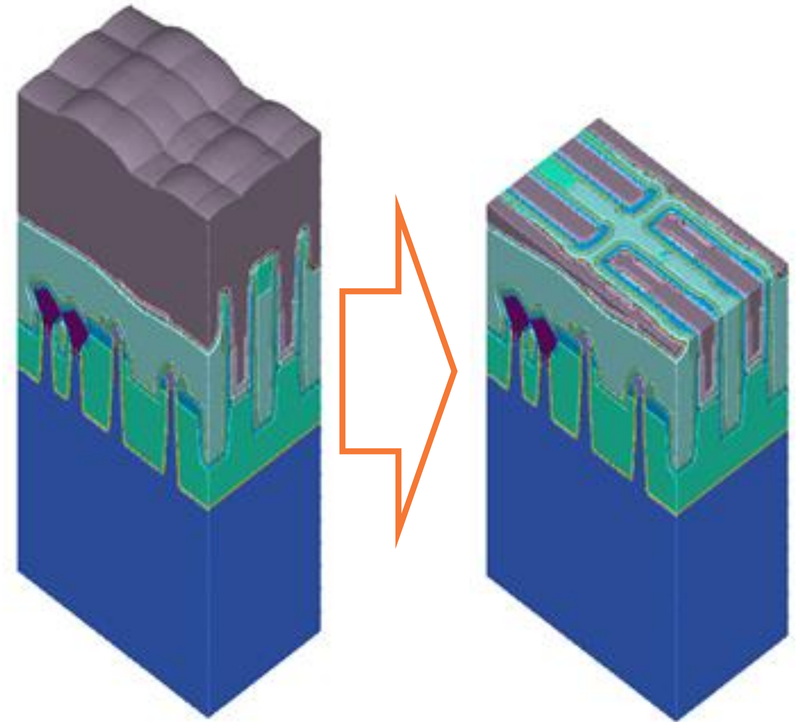
- -. CMP Process
- -. Role and Effect of CMP in-situ Cleaning
- -. Brush Cleaning
- -. Examples of CMP-induced Defects and Their Removal

Cleaning Perspective of CMP Process

CMP: Planarization Technology



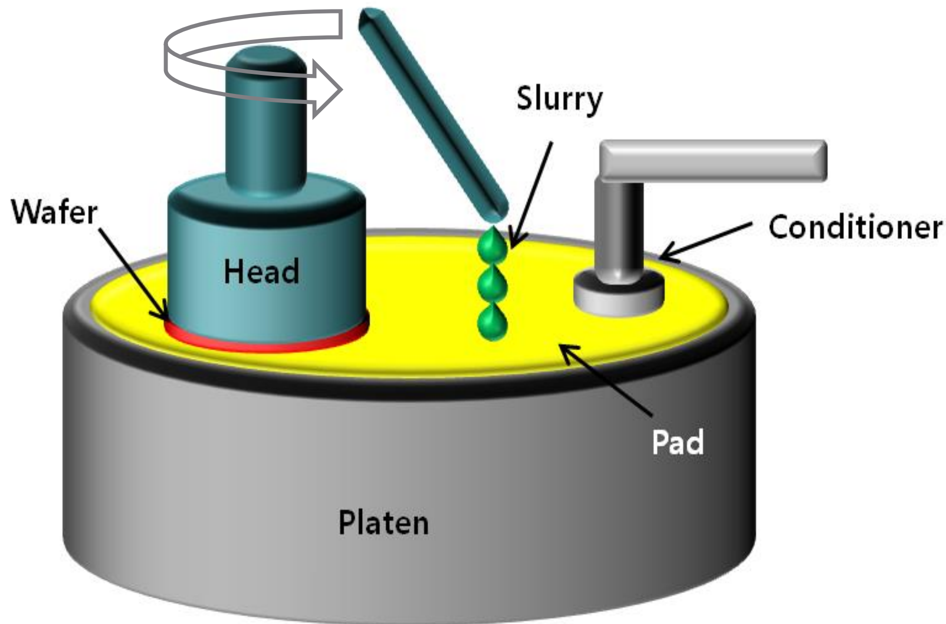
Planarization & Polishing



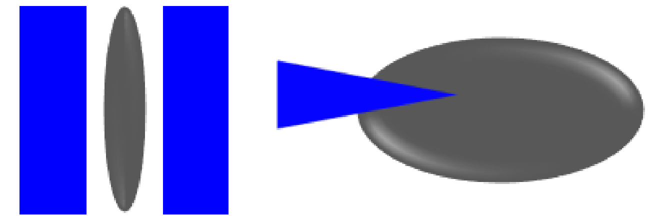
Material Removal & Separation

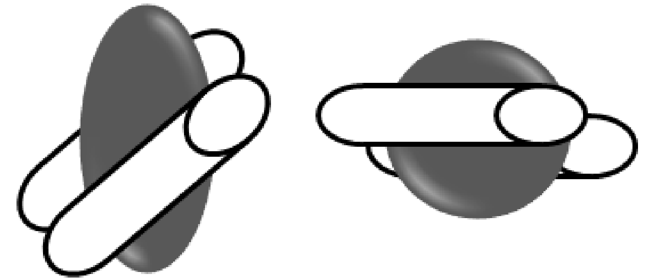
CMP Equipment: Polisher and Cleaner

Polisher



Cleaner

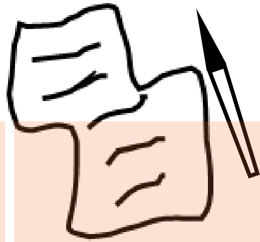




Non-Contact Cleaning (ex. fluid jet)

Polishing and cleaning are in-situ process: polishing → cleaning at the same equipment

Historical CMP Technology Development



1927, Preston published glass polishing theory

1972, Raytheon, first practice CMP for planarization

1983, IBM first planarized Pb-silicate glass for STI

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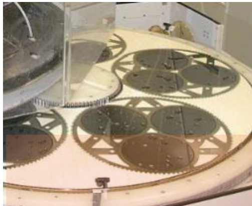
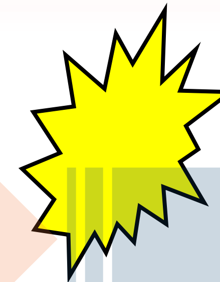
1986, CMP developed in IBM, called FRED



1987, CMP development begin at IBM

1989, oxide/Al/W CMP implemented
1991, IC pad born
1995, 1st ph.D for CMP
1997, 1st CMP textbook

2000, 300mm CMP setup in industry for manufacturing



2000 - 2010, CMP developed explosively in materials, consumables, tools and functions

2017, Core process in the semiconductor manufacturing

Michael Fury, "You want to do what to my wafer", Korea CMP User Group Meeting 2014
Gautam Banerjee and Robert L. Rhoades, "Chemical Mechanical Planarization: Historical Review and Future Trend", ECS Transactions, 2008
Images from google

ITRS Roadmap

Physical gate length (nanometers)

25, 20, 15, 10, 5, 0

2013 Report
2015 Report

2013, 2015, 2017, 2019, 2021, 2023, 2024, 2025, 2027, 2028, 2030

Year

http://spectrum.ieee.org/semiconductors/devices/transistors-could-stop-shrinking-in-2021

Transistor Scaling:

1. Geometrical Scaling (~ 2003)
2. Equivalent Scaling (~ 2021)
3. Power Scaling (~ 203x)

P. Gargini, SPCC2016

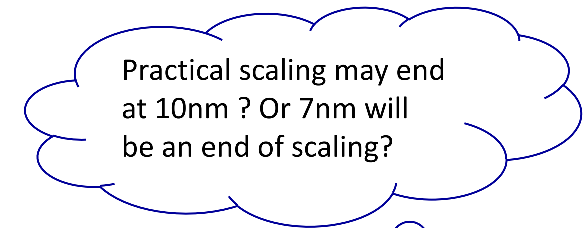


Image from google

Post CMP in-situ Cleaning

CMP: is known as the most defect generated process in semiconductor fabrication

However, **CMP is also *highly* favorable process condition for cleaning aspect**

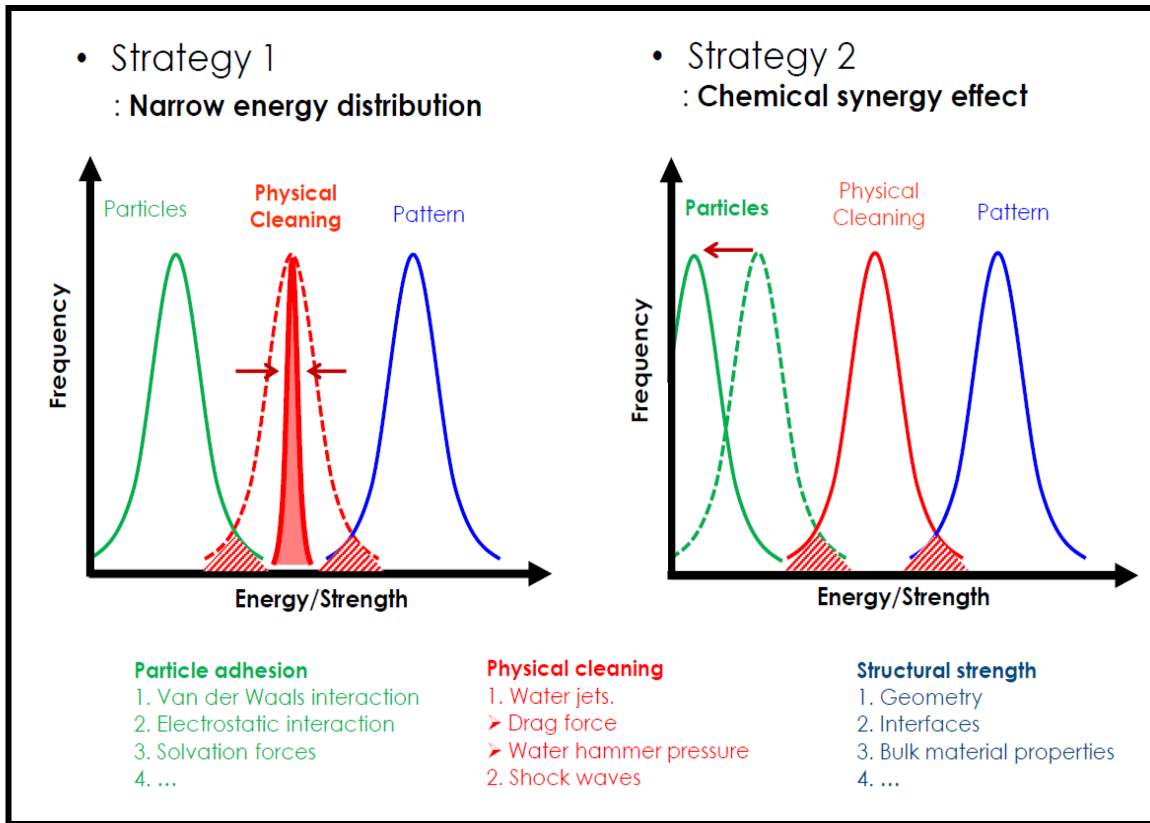
cf. Challenges of wet cleaning (ex-situe): pattern damage, strong adhesion of small particle (at dry surface state) to wafer surface

CMP (pros and cons as cleaning perspectives):

- In-situ process
- Flat surface: no pattern damage → strong physical cleaning acceptable
- Single wafer process
- Wet process: weak adhesion between particle and wafer surface
- Sufficient material undercut
- No standard method to estimate particle removal efficiency
- Variation in incoming wafer surface and defect level is very high
- Limited cleaning chemical available for manufacturing (HF, SC-1, NH4OH…)

Strategy for Post CMP In-situ Cleaning

Wet Cleaning Strategy for the Next Generation

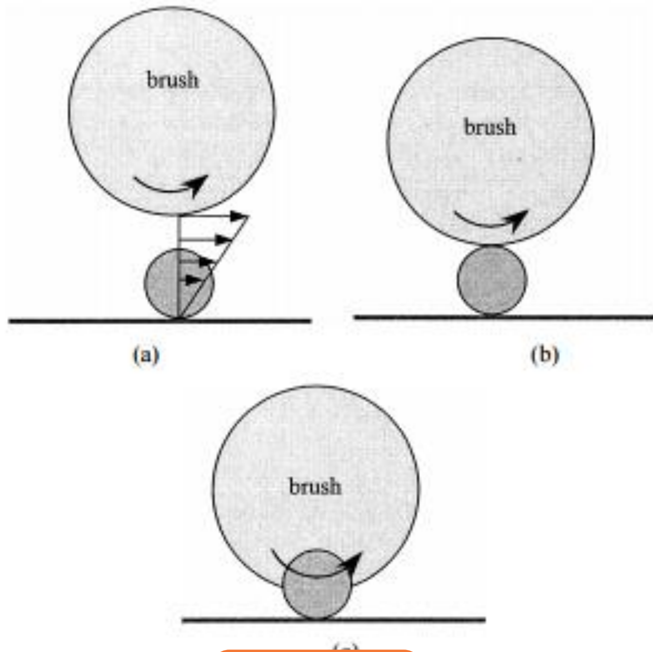


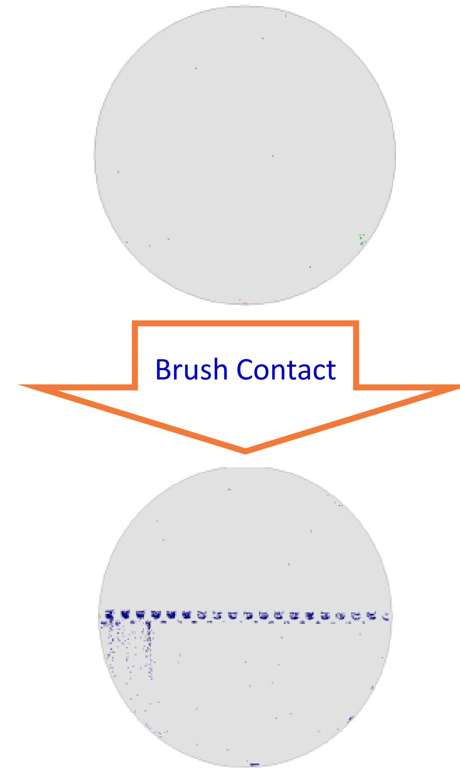
Hyosan Lee, "Next Generation Particle Cleaning", Semicon Korea 2015

What is the known CMP in-situ Cleaning Strategy?

- Cleaner
- Clean chemical
- Dryer
- **Brush, Brush**
- …..

Particle Removal vs Contamination





Particle removal: drag force > adhesion force

f (brush RPM, brush gap…): higher brush RPM → high particle removal

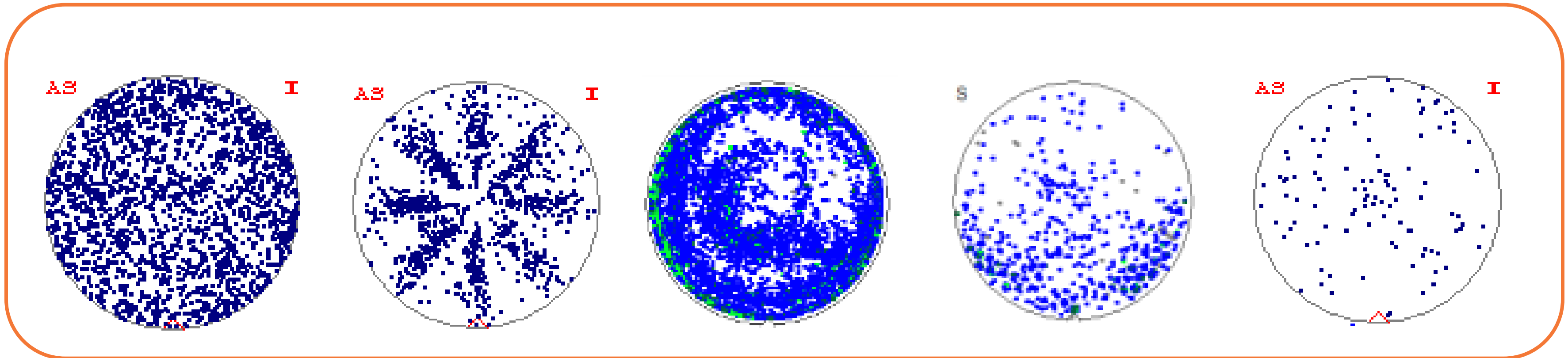
Wafer contaminated by brush cleaning → more contact, more particle

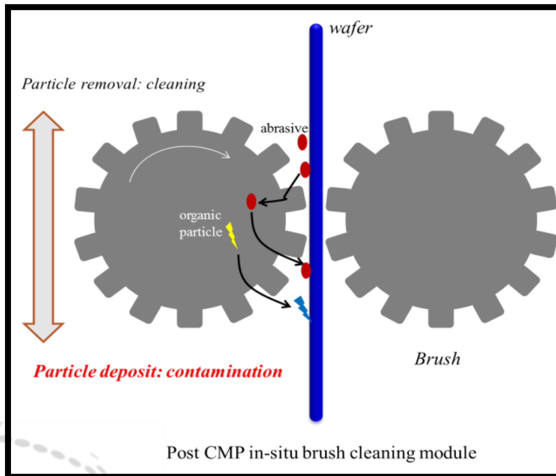
Ref.) Ahmed A. Busnaina, IEEE TRANSACTIONS ON SEMICONDUCTOR MANUFACTURING, VOL. 15, NO. 4, NOVEMBER 2002, pp. 374 - 382

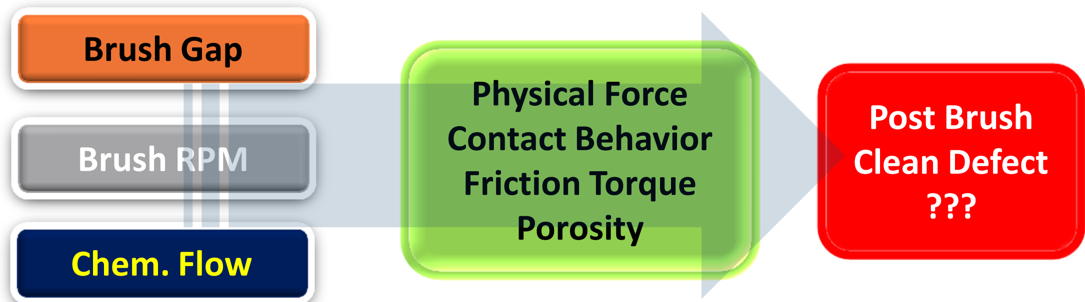
Ref.) H-J Kim et.al., MICROELECTRONIC ENGINEERING 136, 2015, PP.36-41

Brush Cleaning and Defect Signature

Defect Signature by Brush Cleaning

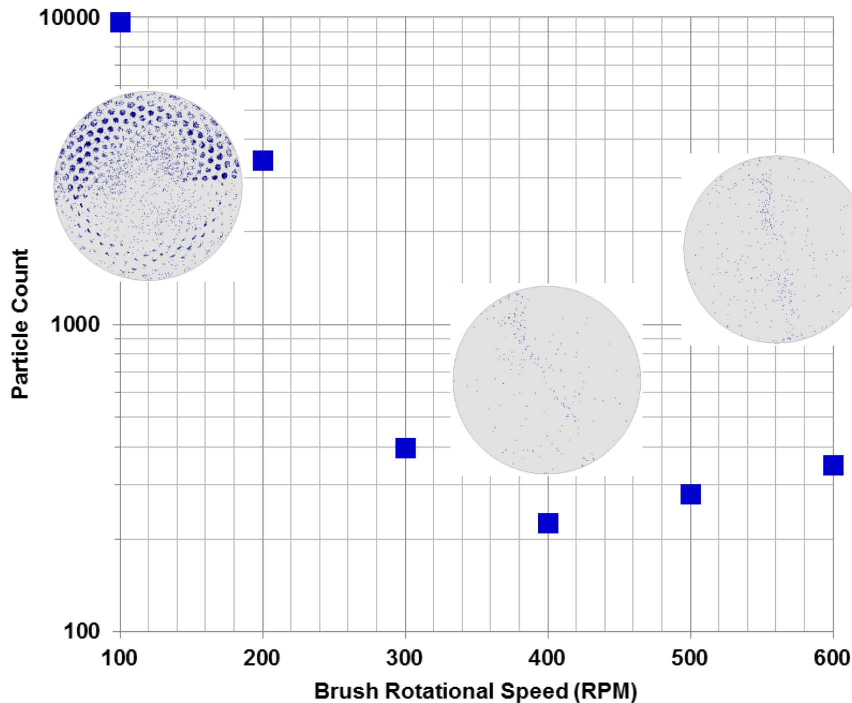


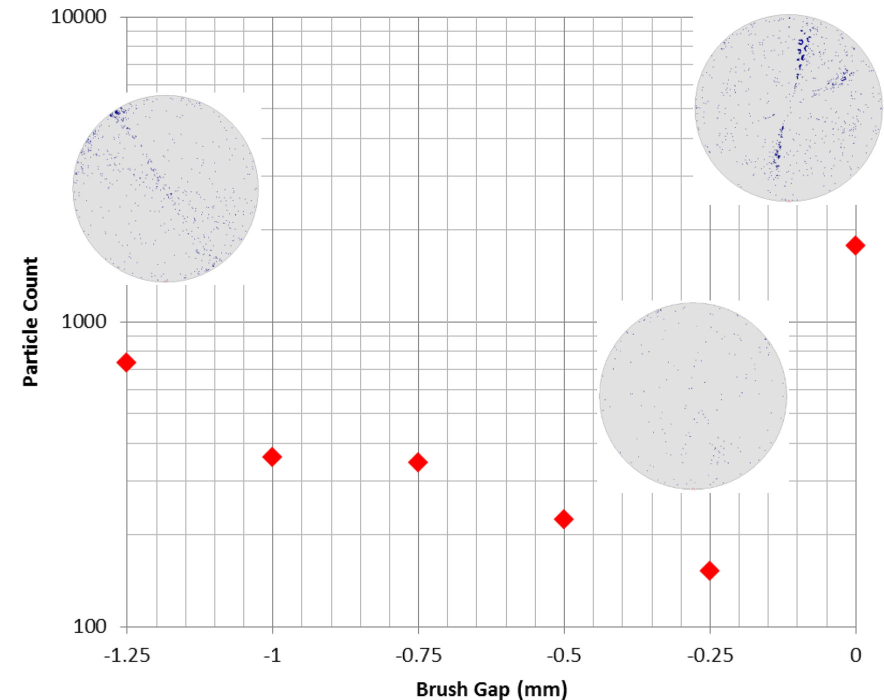




Brush Cleaning is NOT ONLY clean the wafer BUT ALSO contaminate wafer → **PRE vs C.C.**

Effect of Brush Recipe on Cross Contamination





Low RPM → longer contact duration → high cross contamination

Optimum RPM → high PRE & optimum duration → lowest cross contamination

High RPM → high contact frequency → increase cross contamination

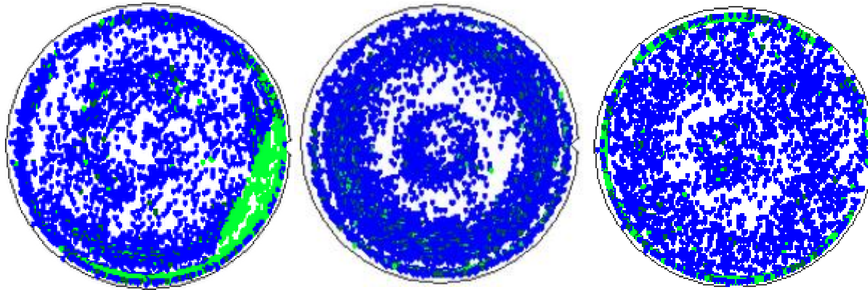
Negative brush gap → high down force → increase contact area → high cross contamination

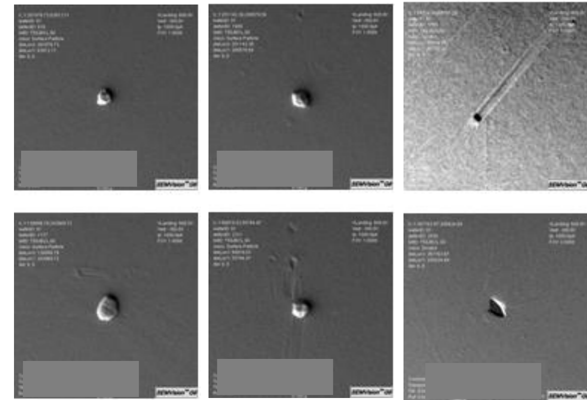
At 0 gap → nodule non-uniformity → high cross contamination/ low PRE

Effect of Brush Lifetime

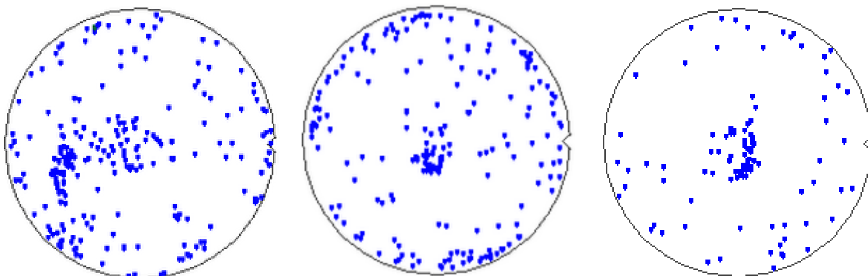
Effect of Slurry – Incoming Wafer Effect

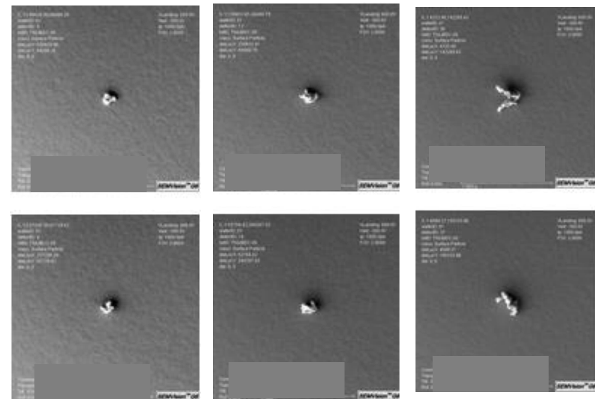
Polishing with Slurry A - Cleaner





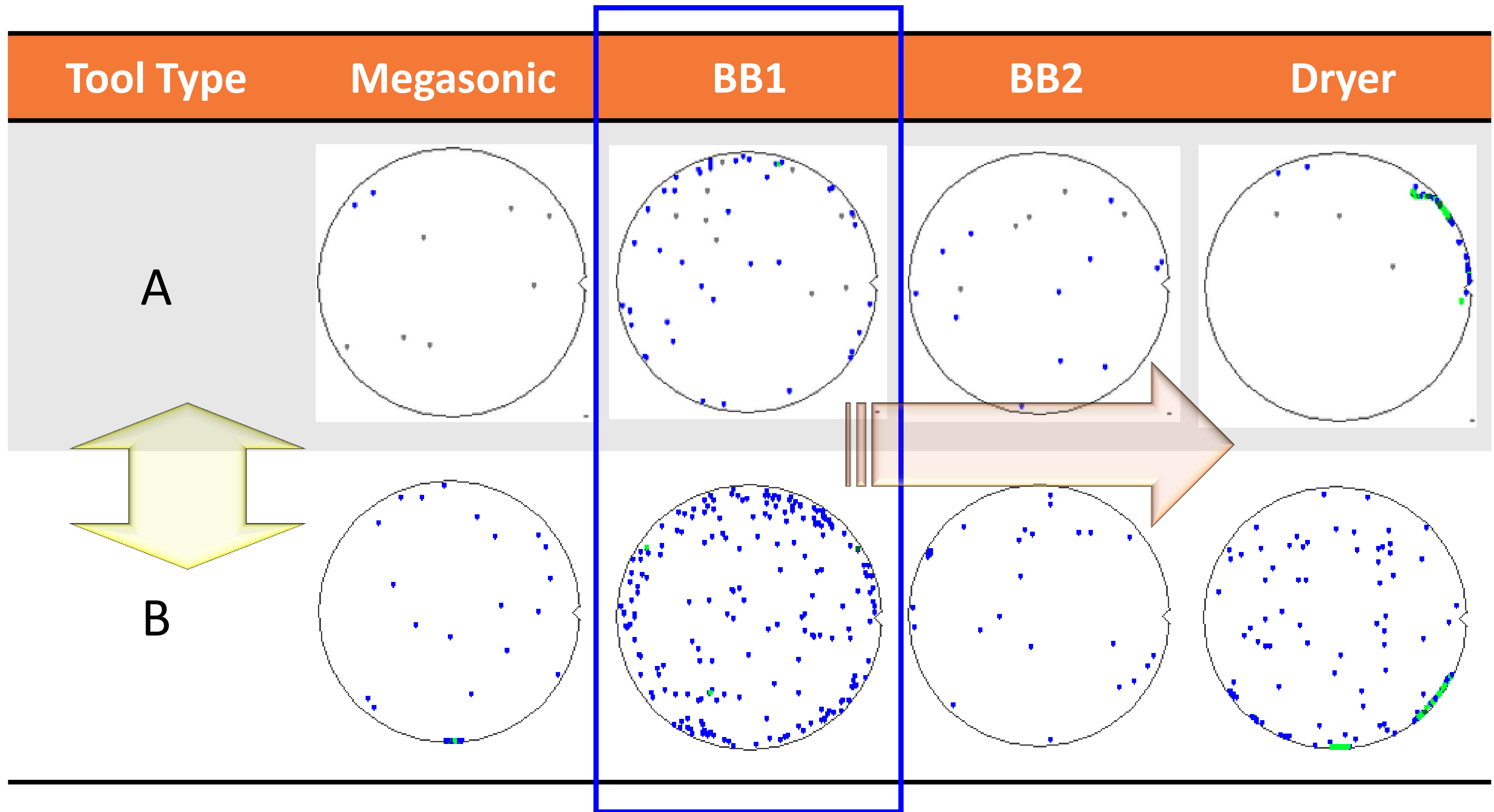
Polishing with Slurry B – Cleaner





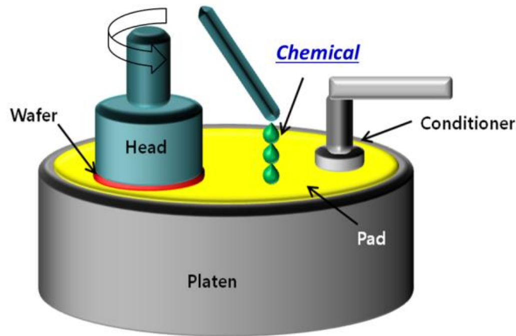
CMP cleaner performance is sensitively influenced by slurry

Effect of Cleaner Contamination

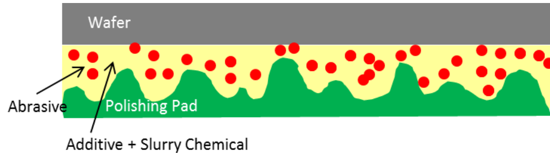


1st cleaner loaded defects more than following cleaner.
Contamination depends on tool.

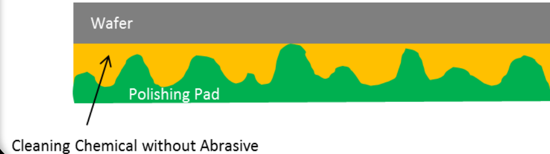
Chemical Mechanical Cleaning



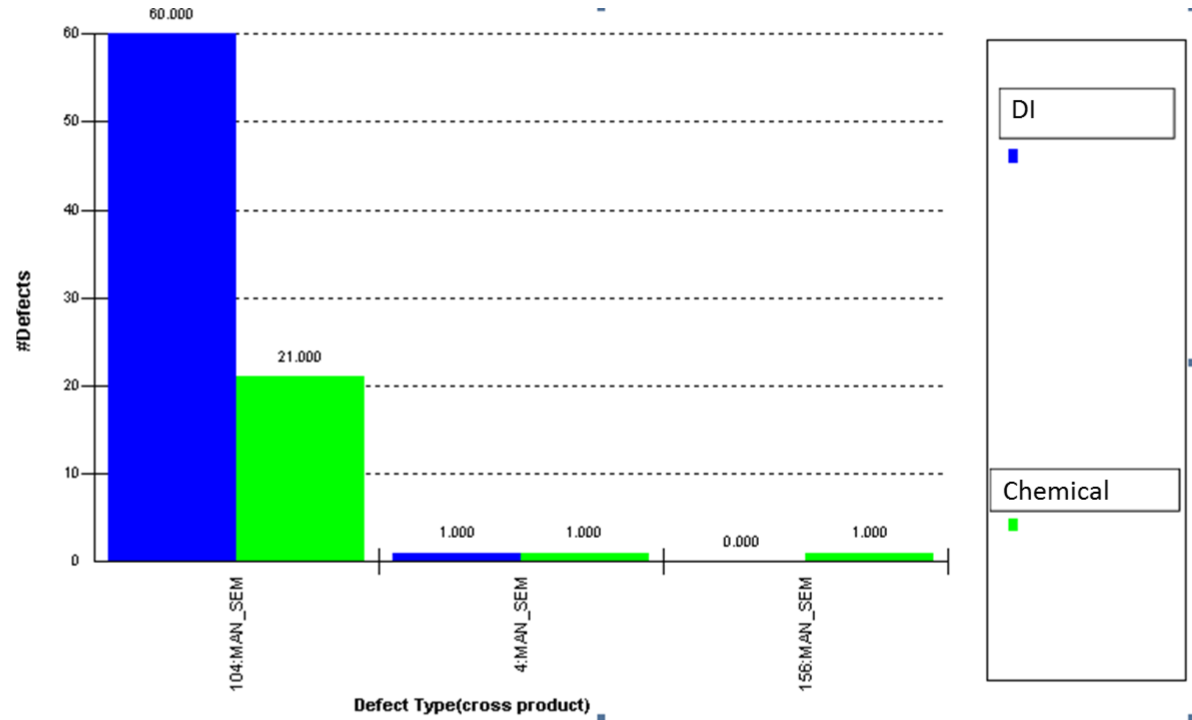
CMP



CMC



Effect of chemical buffing polishing on defects



Buff CMP with cleaning chemical: "Chemical Reaction + Physical Force" to "Wet Wafer Surface" → Effective **CLEANING** process. *No (Min.) material removal required (not matured process in industry yet)*

Challenges and Opportunities

Brush Cleaning

- Early brush defect
- Minimize cross contamination
- New design of brush and brush nodule
- Pre-broken brush
- Optimized brush properties, ex) porosity, pore size, softness

Clean Chemical

- Almost same chemicals used for more than 15 years
- High performance of particle removal associated with brush cleaning
- No material damage with multi materials exposure
- Low cost, eco-friendly chemical (in particular, for Cu CMP)

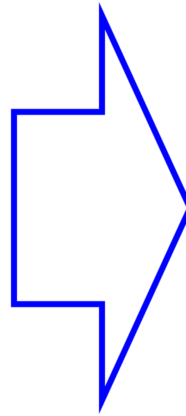
Cleaner Module

- Non-contact type cleaner module
- New design on cleaner module for advanced cleaning
- Monitoring for dryer

Summary

Paradigm need to be shifted....

Planarization /Polishing



Cleaning

CMP concept now encompasses "cleaning" in addition to traditional planarization concept. And role of cleaning becomes much more critical than previous device.

CMP → CMPC: Chemical Mechanical Polishing and Cleaning