Post CMP in-situ cleaning for 14/7nm transistor scaling: a crucial process for yield enhancement at advanced node device fabrication

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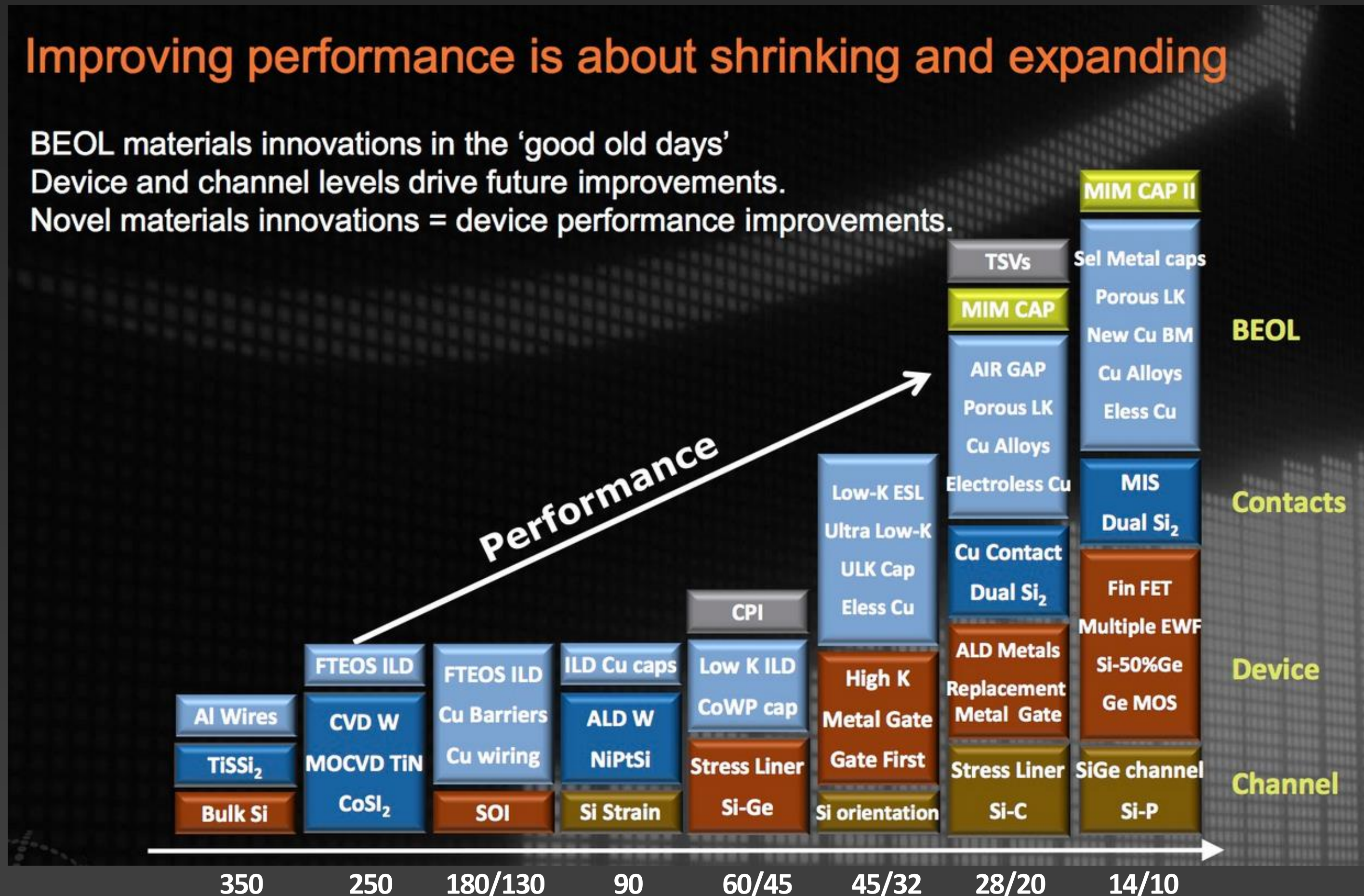
GLOBALFOUNDRIES®

CMOS Transistor Scaling & New Device Platform



Materials Innovation of Technology Node. Source: Bartlett, GLOBALFOUNDRIES, SEMI Strategic Materials Conference

Scaling continues by structural changes and new materials

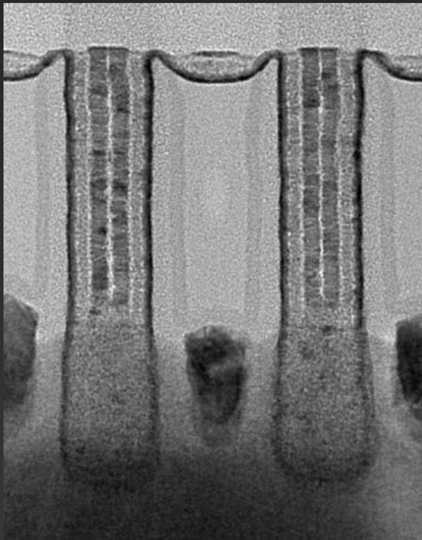
CMP Process Challenges

Updated from 2015 SEMATECH

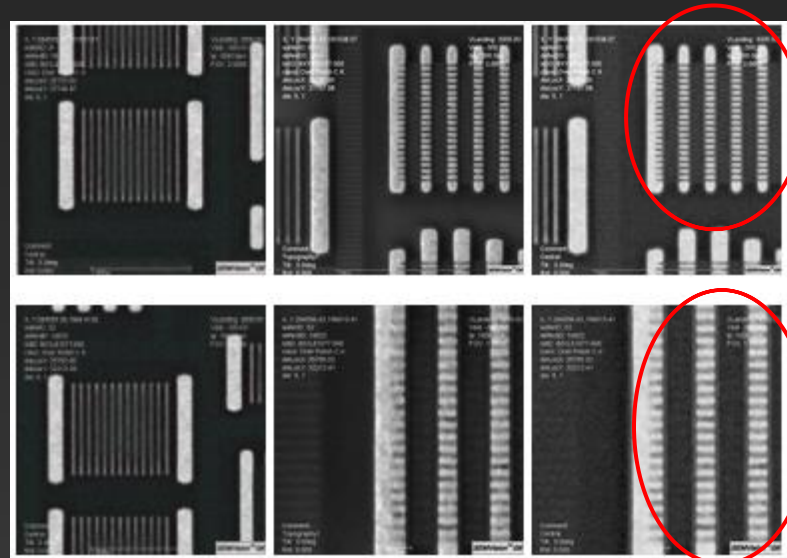
	20nm	14nm	7nm
Selectivity/ Materials	FEOL: SiN, Ox MOL: SiN, Ox, W, TiN, Al BEOL: Cu, Ta, TaN, TiN	FEOL: Si, SiN, Ox, a-Si MOL: W, SiN, Ox, poly Si, TiAl, TiC BEOL: Cu, Ta, TaN, TiN	FEOL: Si, SiN, Ox, ***low k , Lower Density*** MOL: W, SiN, Ox, poly, ***low k spacer, SiOC, Co*** BEOL: Cu, Ta, TaN. TiN, ***Ru/Co***, BDIII
Dishing/ Erosion	**Higher PD <200A**	**Higher PD <150A**	**Higher PD <100A**
Uniformity	**3sigma <120A**	**3sigma <100A**	**3sigma <80A**

- New materials expected at future nodes to meet both process and device requirements
- More than 50% newer materials at advanced technology node

Gate height control – Defects



Nominal device

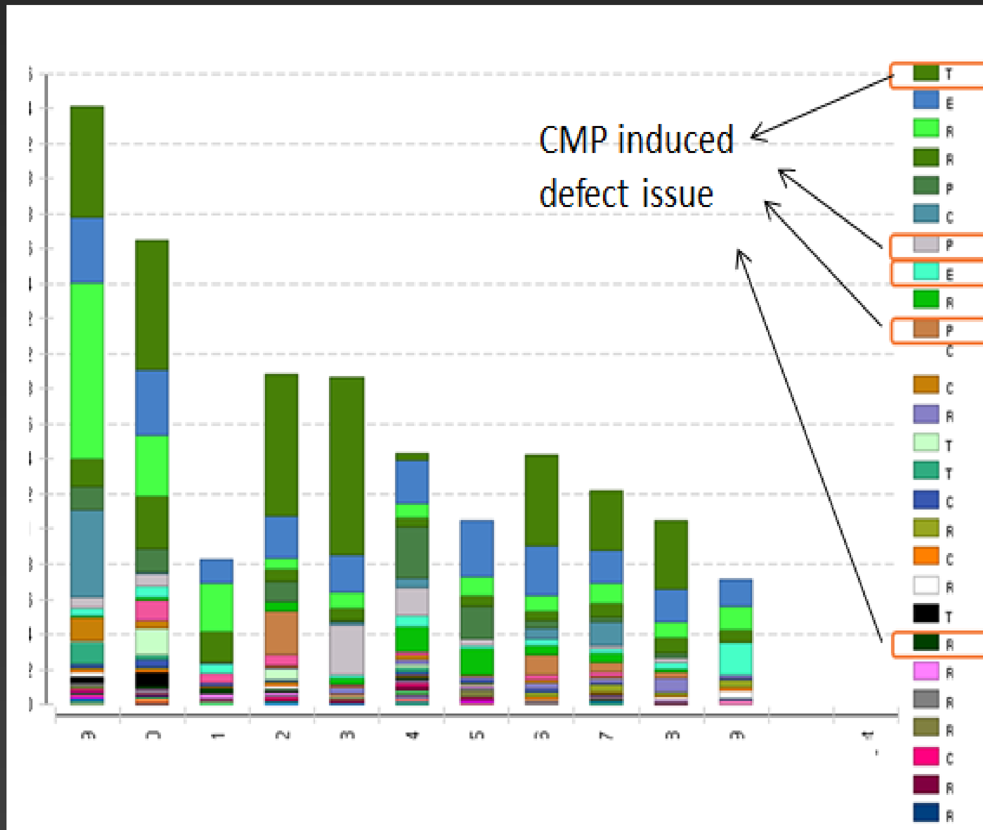


Wide gate >150nm

Taller gate → residues → potential shorts/Open
Shorter gate → Fin exposure → Opens

- Defects can be impacted by gate height control
- Residues and overpolish
  - Accumulation of topography from prior layers
  - Integration scheme
  - Selectivity between different materials
- Very narrow process window → Control is the key!!

Impacts of CMP Cleaning on Yield Detract



Defects	Failure Mode
Metallic Particle	Leakage Failure
Non-metallic Particle	Open Contact (Block Etch)
Organic Residue	Leakage Path
Microscratch	Pattern Damage
Metal Corrosion	Resistance

Post CMP cleaning becomes one of the key yield impact detractors

Challenges in CMP In-situ Cleaning

Sources	Challenges & Opportunities
Equipment (Cleaner Module)	• High performance cleaning implement (ex. spray jet) • Closed chamber for various chemical application • Tool cleanliness
Megasonic	• Control acoustic bubble motion • High physical force (ex. gigasonic) implementation
Cleaning Chemical	• Limited chemicals available (highly diluted acid, NH4OH, SC1) • Minimize surface damage (ex. roughness, charge, hydrophobicity) • Non-hazardous and cost effective
Brush	• Nodule design and control of contact area • Brush material for improved cleaning efficiency • Nodule height uniformity control at manufacturing • Pre-broken conditioned brush • Cleanliness of brush at manufacturing stage
Cleaning Recipe	• Optimize cleaning efficiency with minimize cross contamination • Minimize throughput impact
Dryer	• End point detection at drying point

Particle Removal Mechanism

Adhesion force:

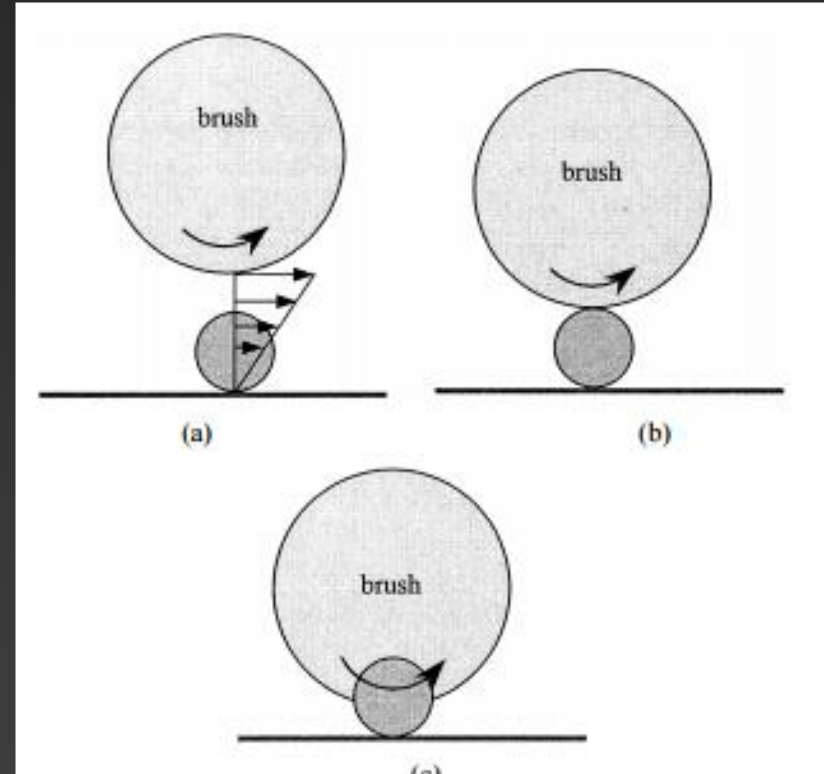
$$F_a = F_{\text{vdw}} + F_{\text{deformation}} = \frac{AR}{6z_0^2}\left(1 + \frac{a^2}{Rz_0}\right)$$

Particle drag force:

$$F_d = \frac{\pi}{8} C_D \rho_l d_p^2 u^2$$

Particle removal: drag force > adhesion force

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



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

Thank You!!

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