A New Type of TSV Defect Caused by BMD in Silicon Substrate

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Outlines

- TSV Process and Integration
- Silicon Fin Defect at TSV Bottom
- Defect Inspection Methods
- Root Cause Investigation
- Summary
- Acknowledgment

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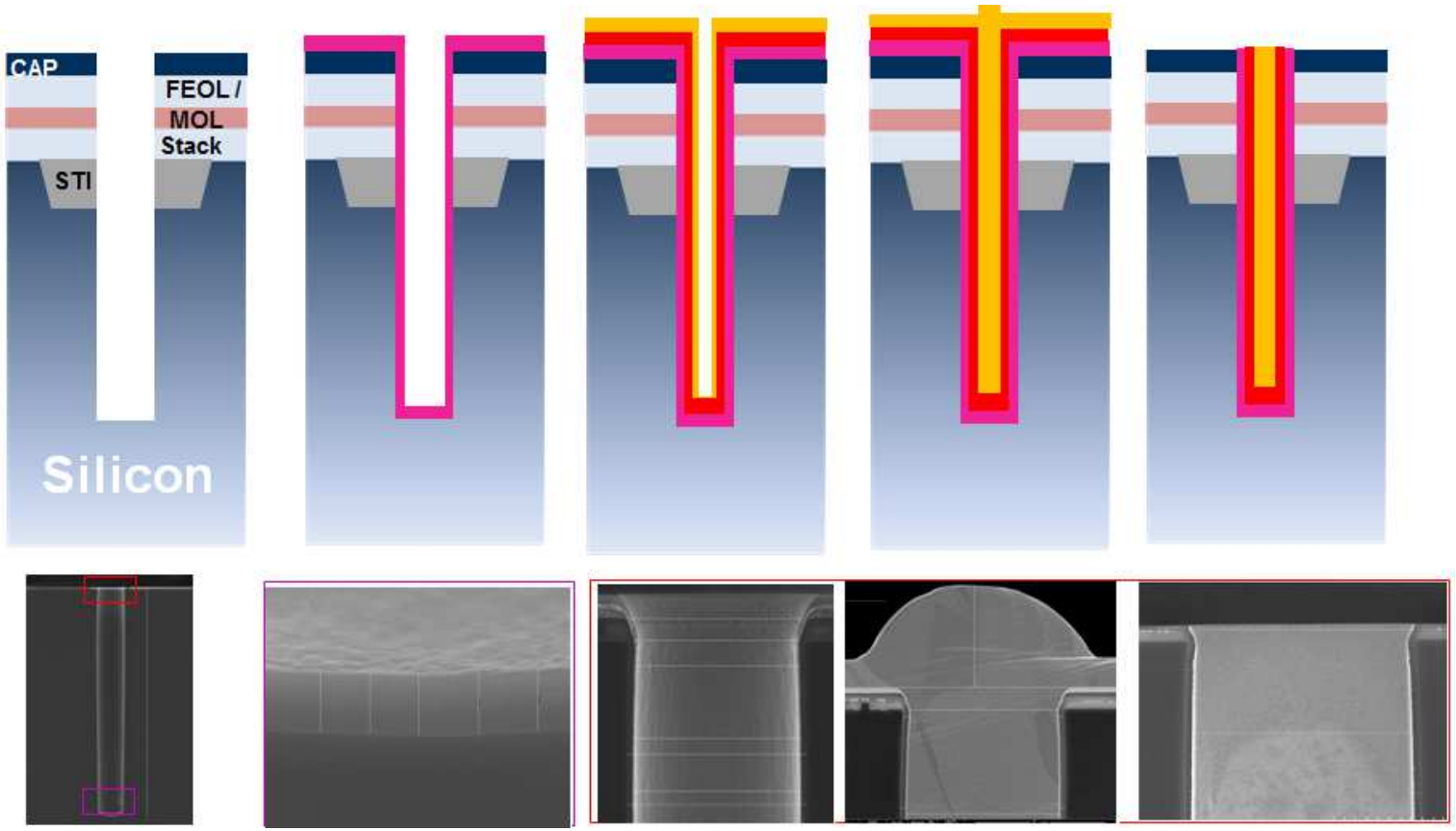
TSV Process and Integration

MOL TSV Process Flow



- An example of MOL TSV process
- High Aspect Ratio > 10

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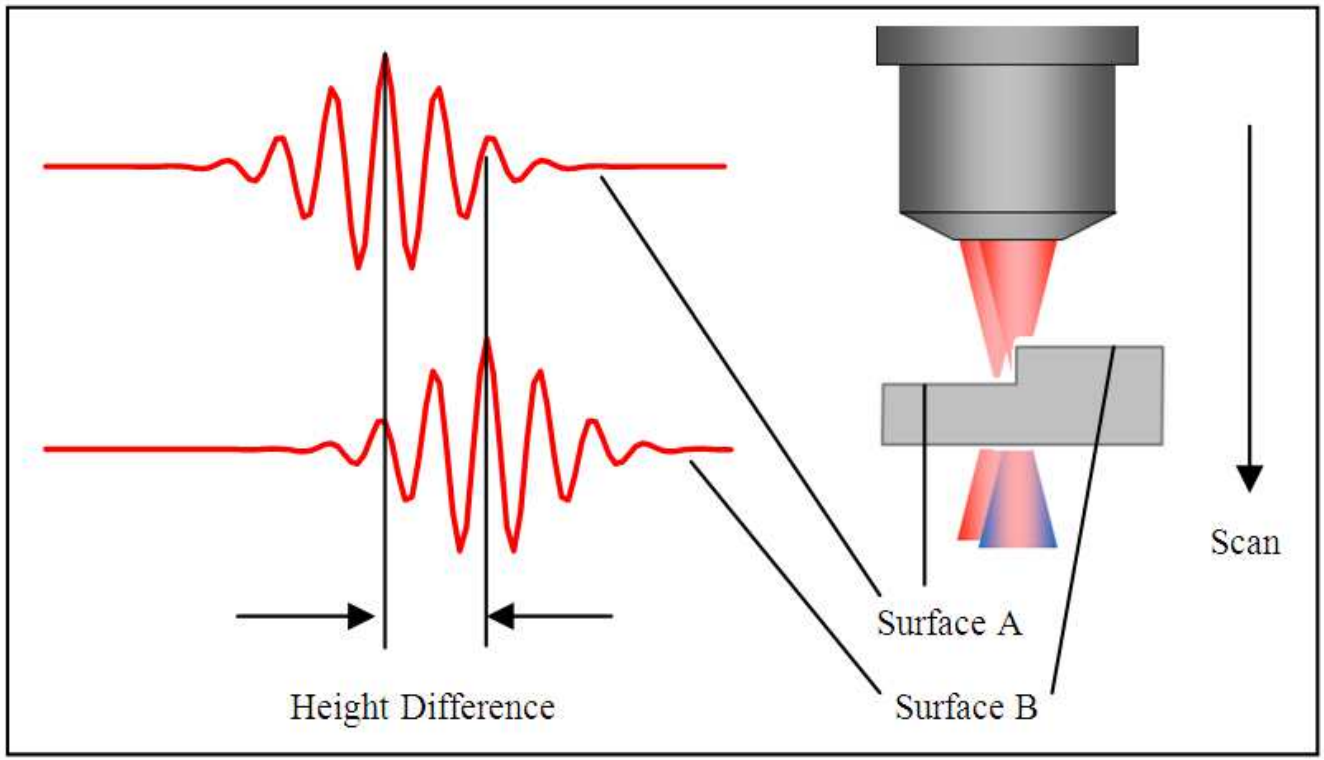
TSV Metrology



- White Light Interferometer Measurement of TSV profile including TCD/BCD/Depth
- Not capable of catching defect deep in TSV

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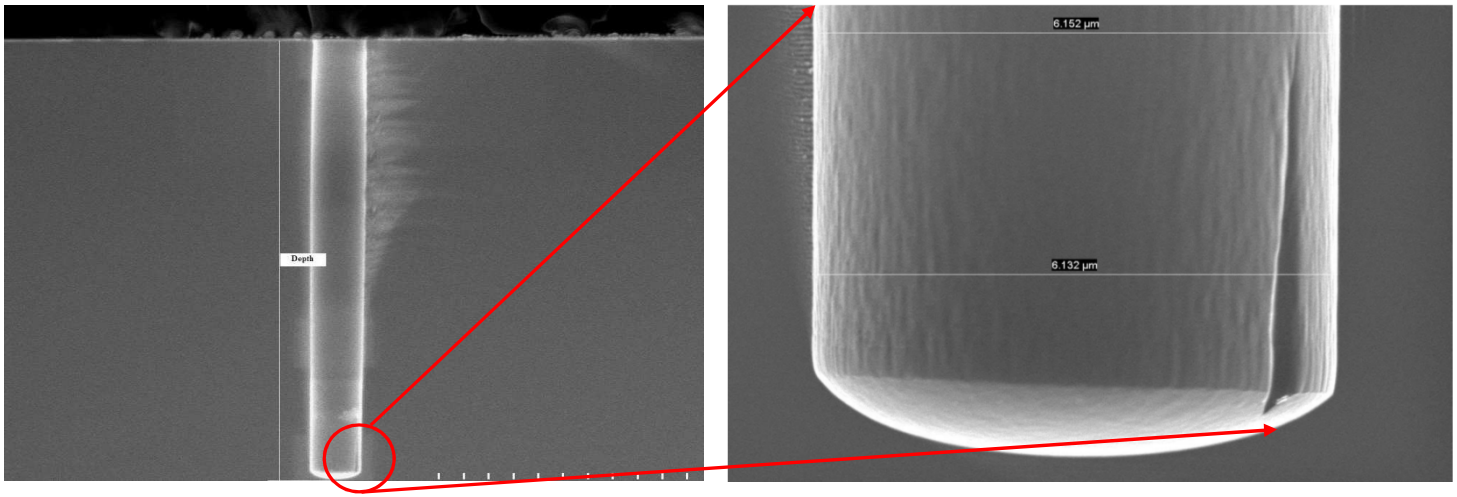
Silicon Fin Defect at TSV Bottom



- 6X55um example
- Always at bottom, attaching to sidewall
- ~10um high, 1um wide
- Killer TSV Defect

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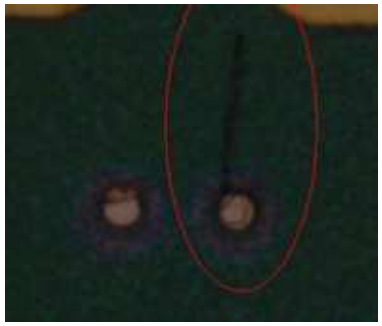
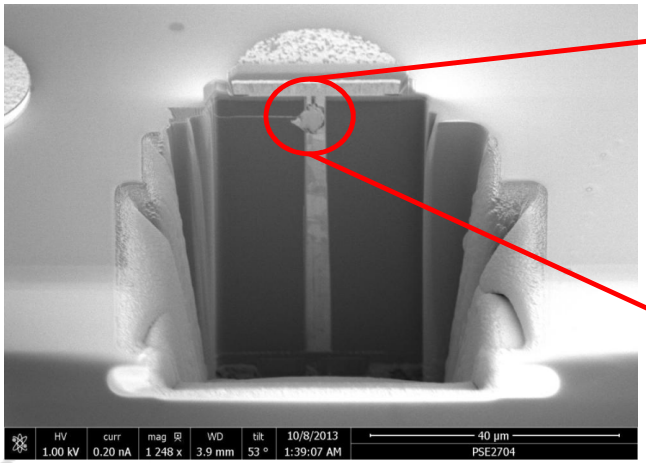
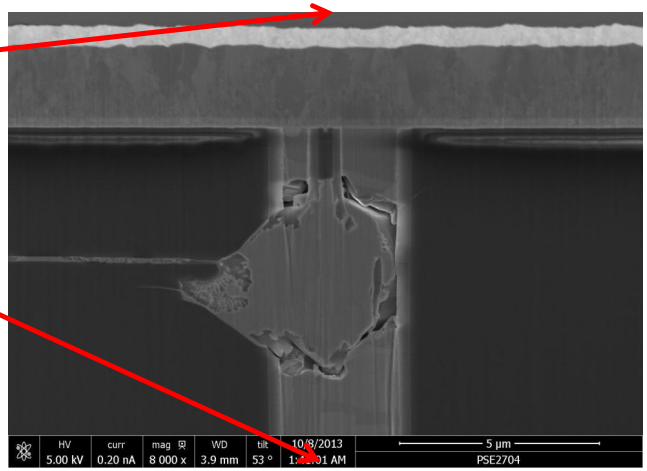
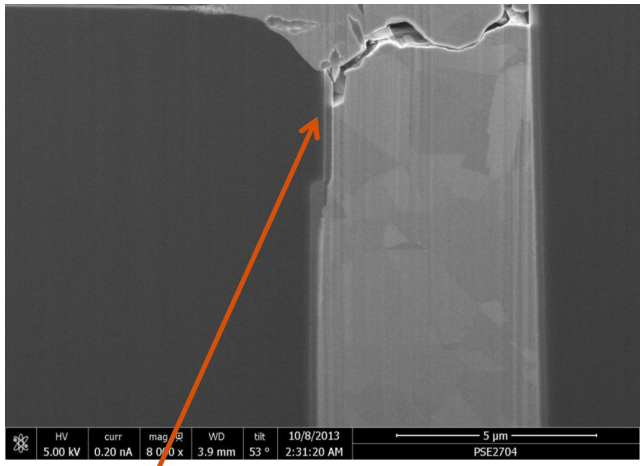
Killer TSV Defect



- Irregular TSVs after backside TSV reveal







- Cu diffusion into Si at irregular TSV
- Silicon fin defect observed

TSV topside down

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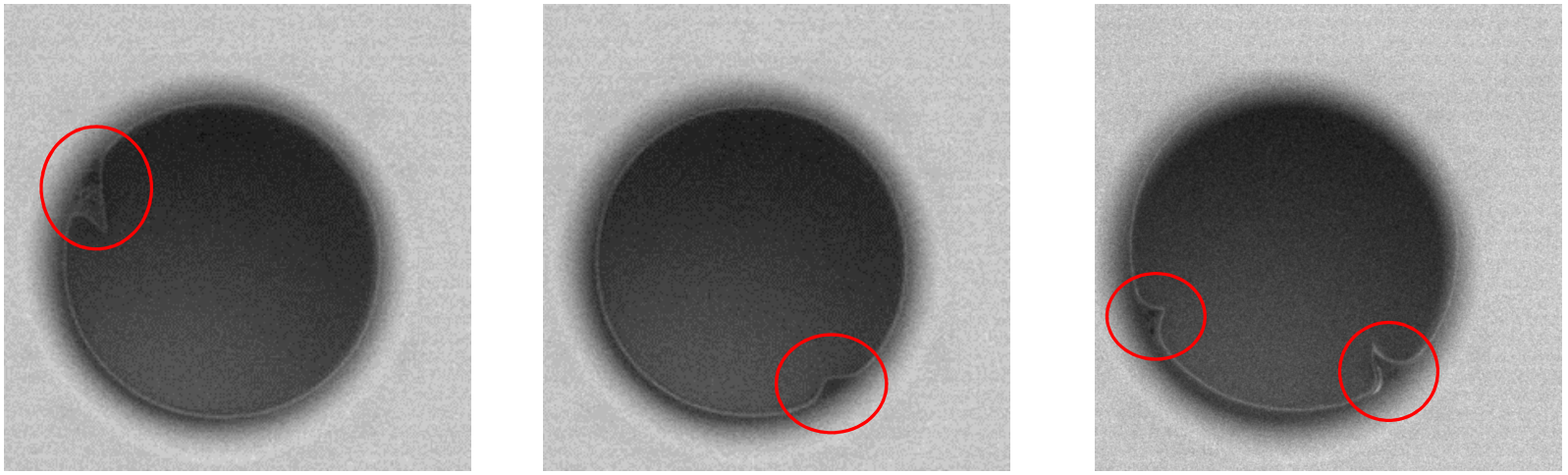
Inspection Method

SEM Automatic Process Inspection (API)



- Top-down SEM imaging of the defects at the bottom of high-aspect-ratio (HAR) structure
- Post etch before PR strip/clean
- Special working point with high depth of focus (DoF) and contrast
- Non-destructive, good throughput

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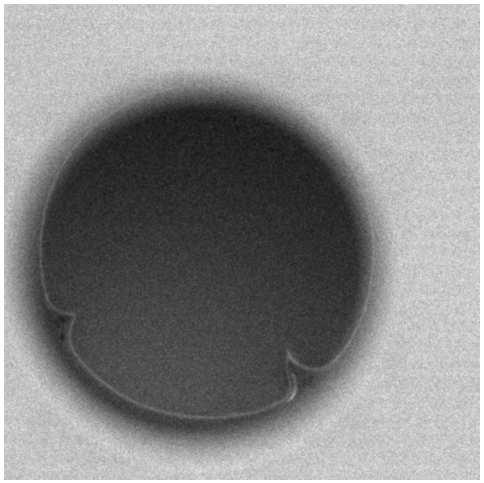
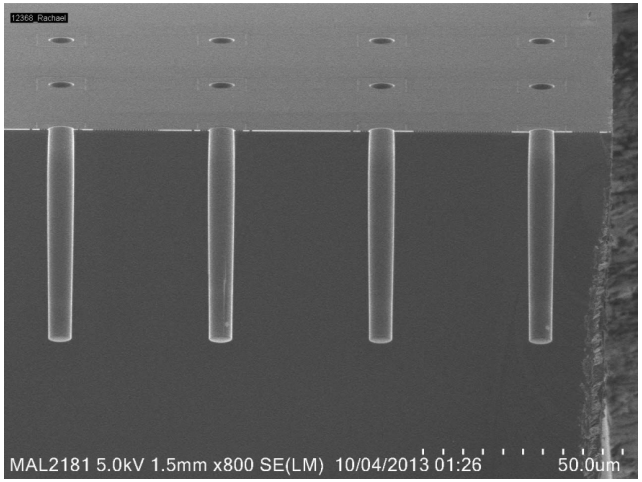
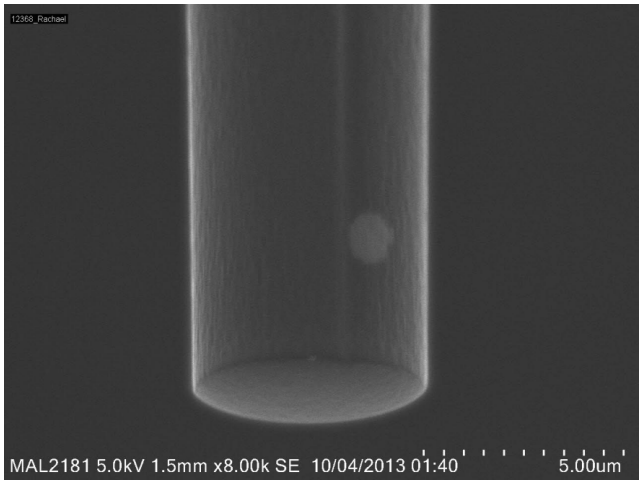
Inspection Verification







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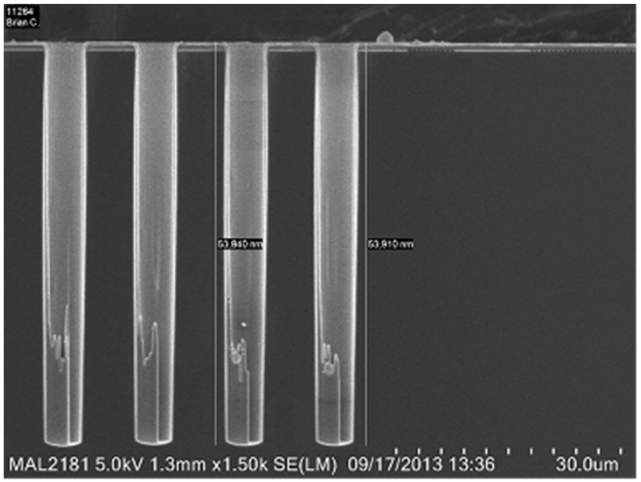
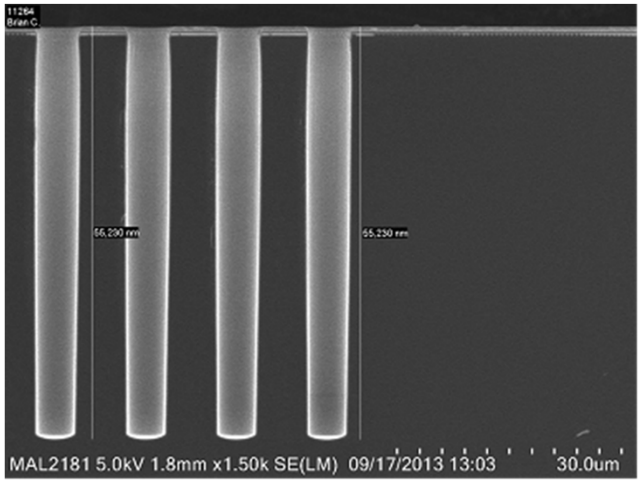
Root Cause Investigation

- TSV density micro-loading effect – Not observed (fin defects found on both dense and iso TSV area, wafer center and edge)
- Resist residue caused defect starts from TSV top surface, instead of mid via



wafer with scumming



wafer with optimized focus and dose

- Wafer substrate impact: no defect found on p-test wafer

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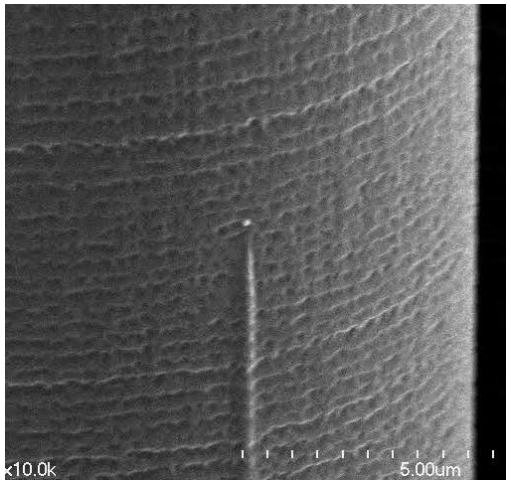
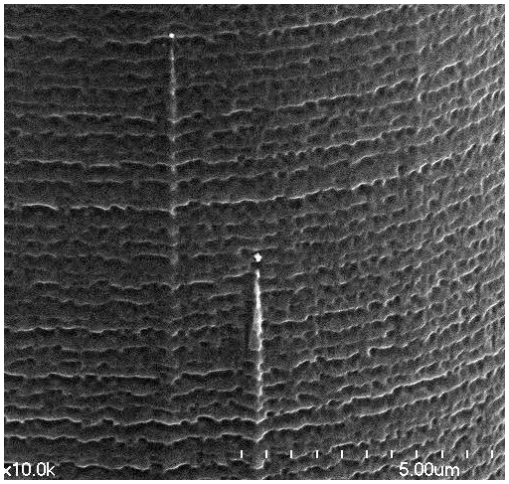
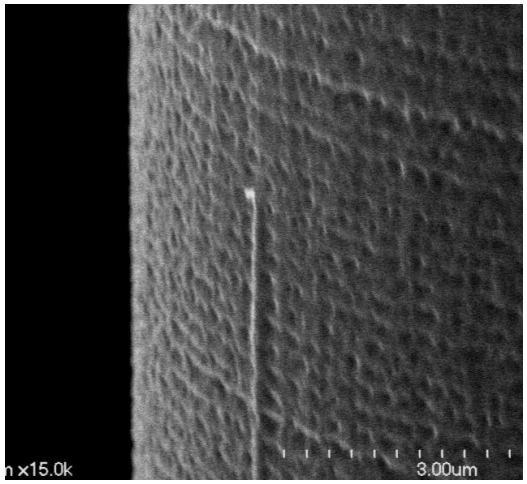
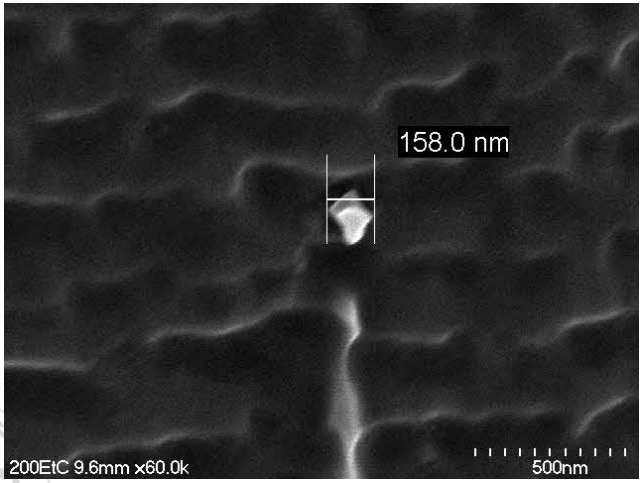
Bright Particles above Defects









- * Courtesy: Lam Research

- Every silicon fin defect has a bright particle above it
- Particles not seen if the sample is stripped

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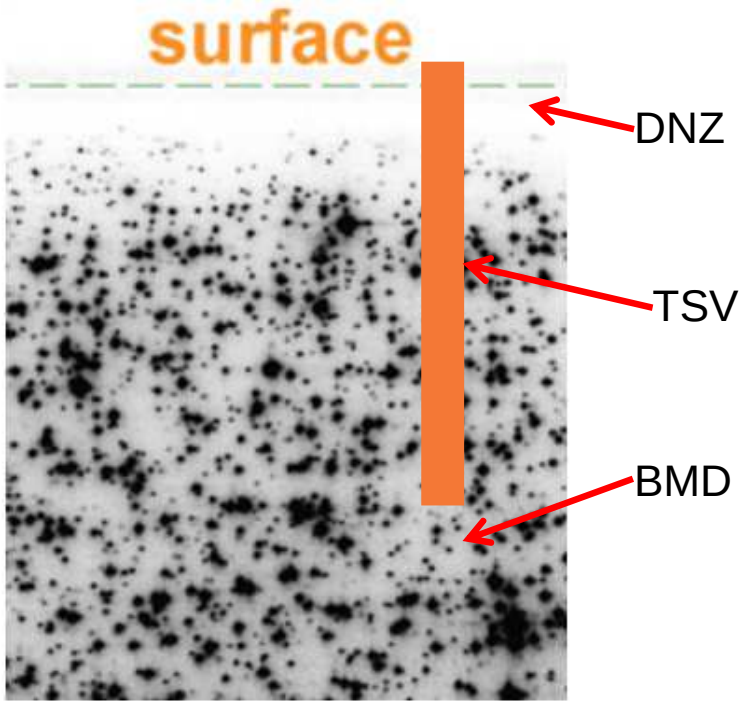
Bulk Micro Defect (BMD)



- * Courtesy: SEMILAB

- Commonly refer to oxygen precipitates in silicon (in fact could be any imperfections including oxygen precipitates, voids, inclusions, slip lines, etc.)
- Act as gettering sites at which impurities tend to concentrate
- The profile of BMDs is often controlled via a complex series of high temperature processes, to create a “denuded zone,” so that the surface layer silicon, where the MOS transistor action takes place, is free of oxygen precipitates (oxygen precipitates in the underlying silicon that acts as a gettering site to keep impurities away from the MOS transistors)
- Imperfections in the lattice of a semiconductor and impurities create energy states in the bandgap, decrease carrier lifetime, and increase junction leakage

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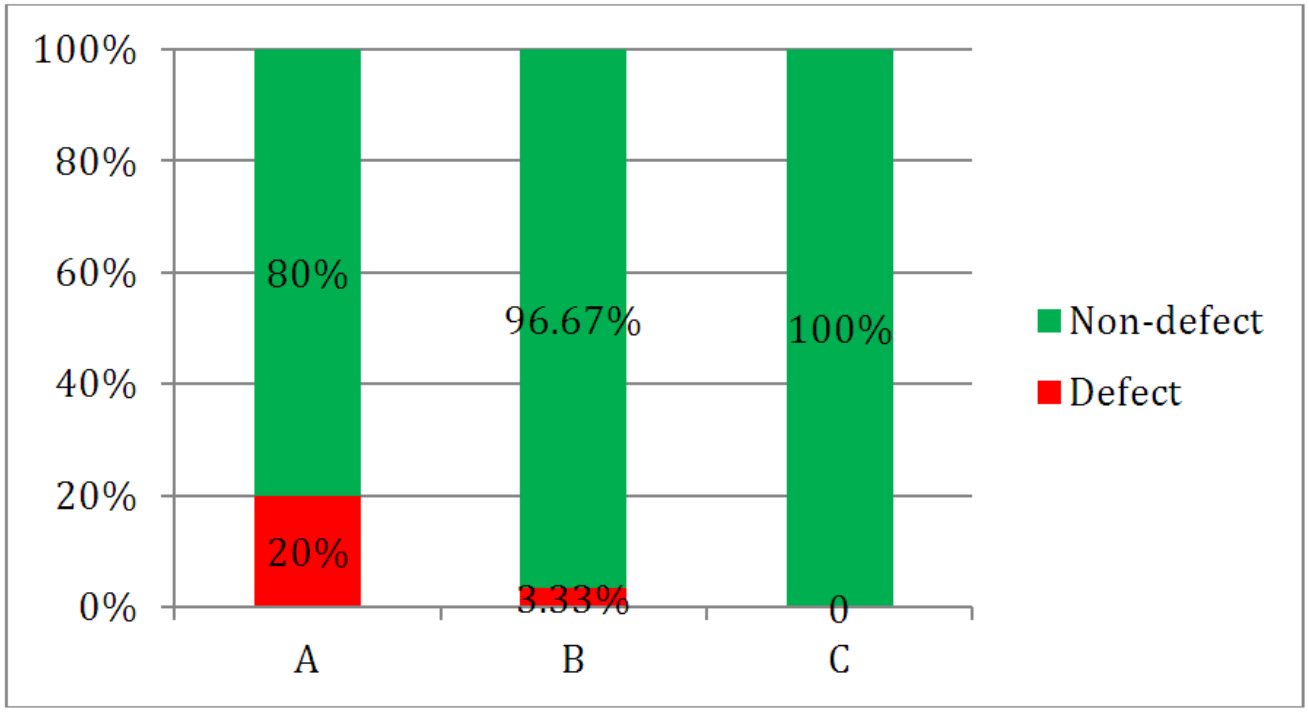
Substrate Impact on Defect Rate



- Various wafer substrates: A, B, and C
- Same process and TSV floorplan
- Inspected by SEM API , sampling across wafer

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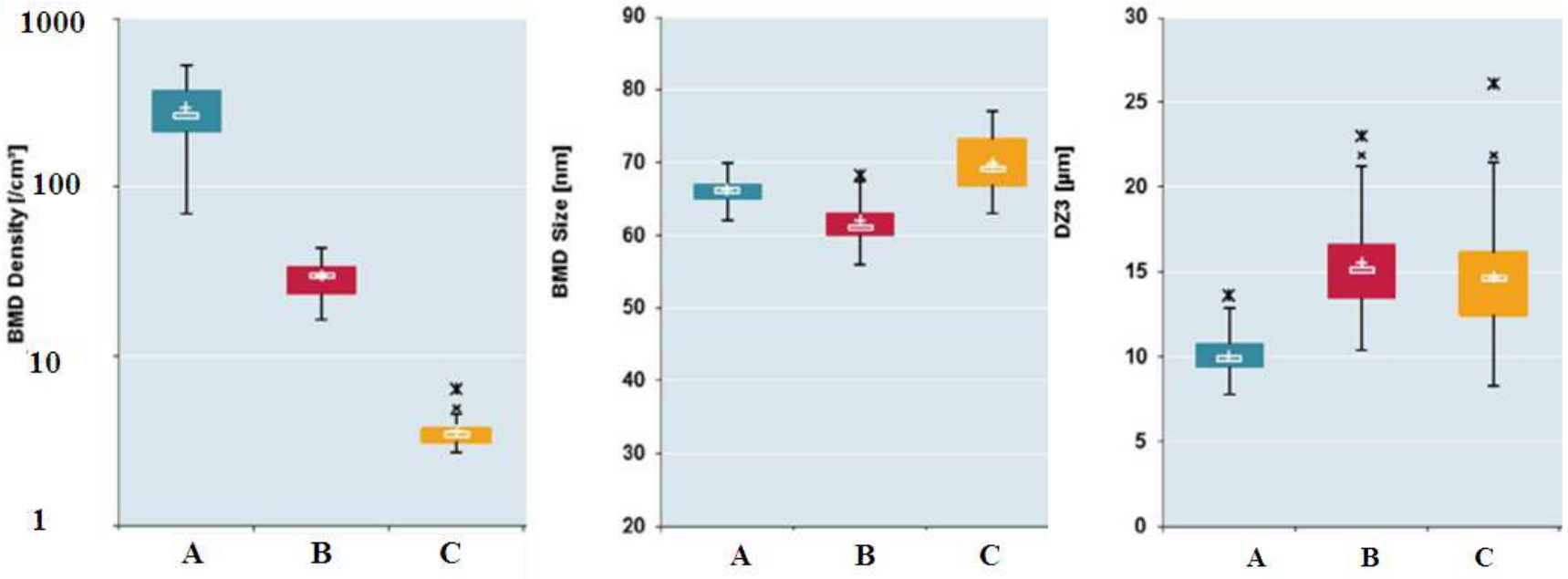
BMD Simulation

BMD Density, Size and Location



- After simulation of thermal processing cycles
- BMD Density: A>B>C
- Similar BMD size and DNZ location
- Good agreement with inspection results

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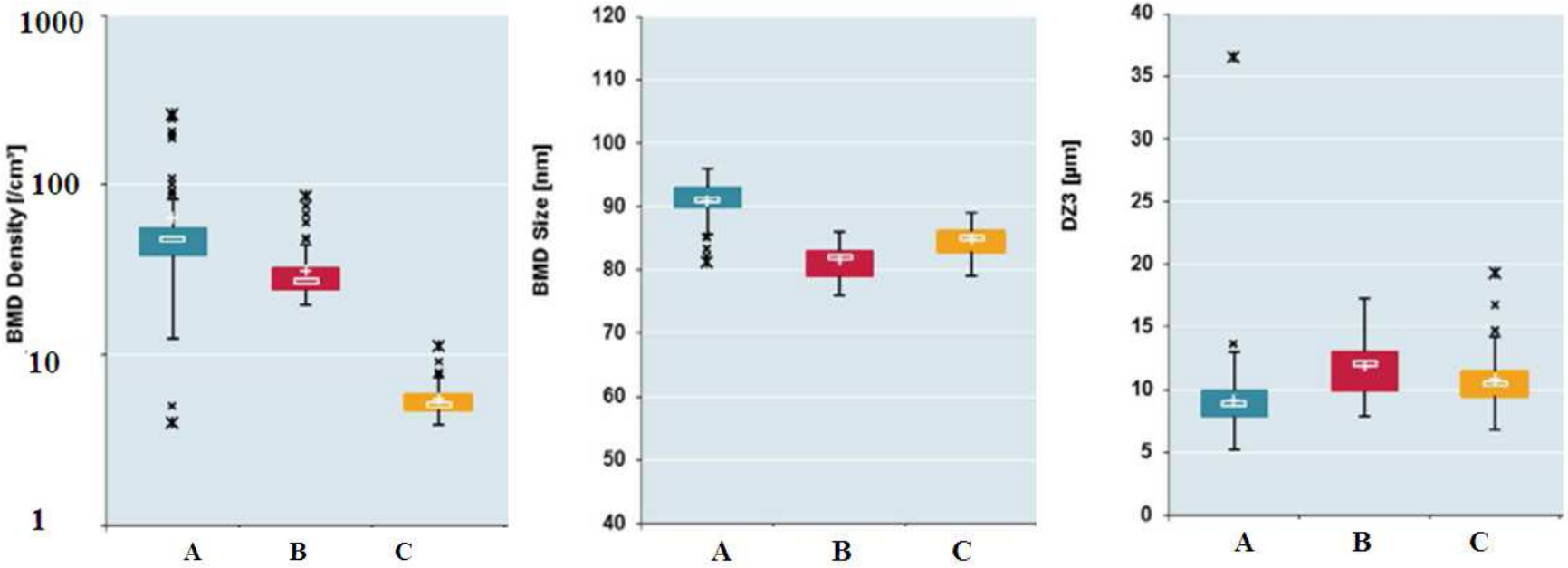
BMD Benchmark Result

BMD Density, Size and Location



- Test on wafers after thermal simulation
- BMD Density: A>B>C
- Similar BMD size and DNZ location
- Good agreement with simulation and inspection results

- * Courtesy: Siltronics AG

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Summary

- Silicon fin defect was found at bottom of TSV and has been identified as a killer TSV defect
- A post RIE non-destructive inspection approach is established and proven to be effective
- BMD in silicon substrate can serve as micro-mask during RIE process and results in silicon fin defect at TSV bottom
- Both simulation result and benchmark result shows that higher BMD density with same BMD size and denuded zone depth leads to higher silicon fin defect rate
- A low BMD substrate and/or reduced thermal budget is recommended

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Acknowledgment

The authors would like to thank Siltronics AG for providing BMD benchmarking test during this work.

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