



CONNECTS

Heterogeneous Integration for
Connectivity and Sustainability

Advanced Packaging industry trends driving the need for new eBeam based metrology and inspection solutions

Dr. Ralf Schmid

Applied Materials – General Manager ICT

Semicon Europe 2024

Applied Materials External Use

AGENDA

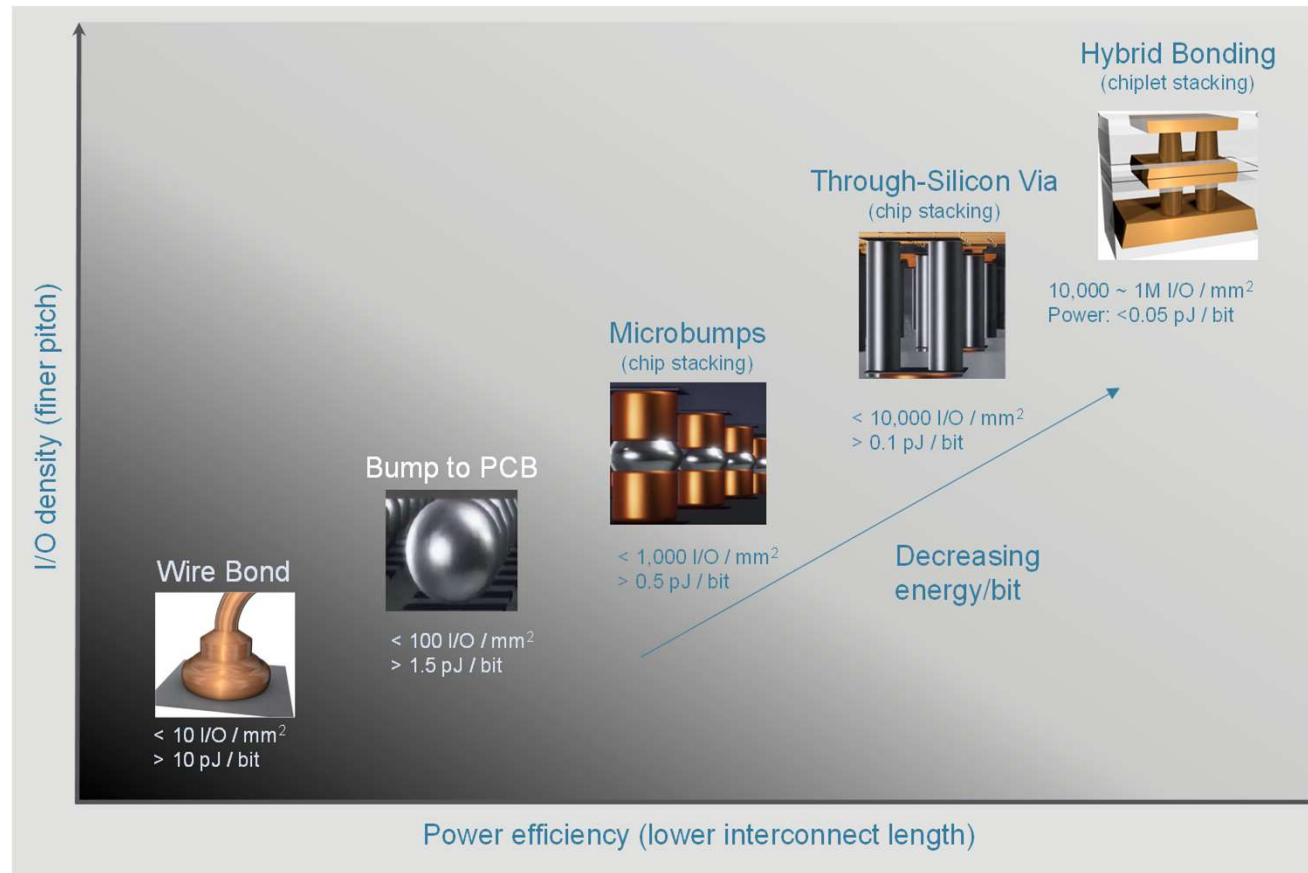
Advanced Packaging M&I Challenges

Electron Beam Solutions

SEM-FIB for Packaging

Summary

Packaging System Interconnect Scaling Roadmap



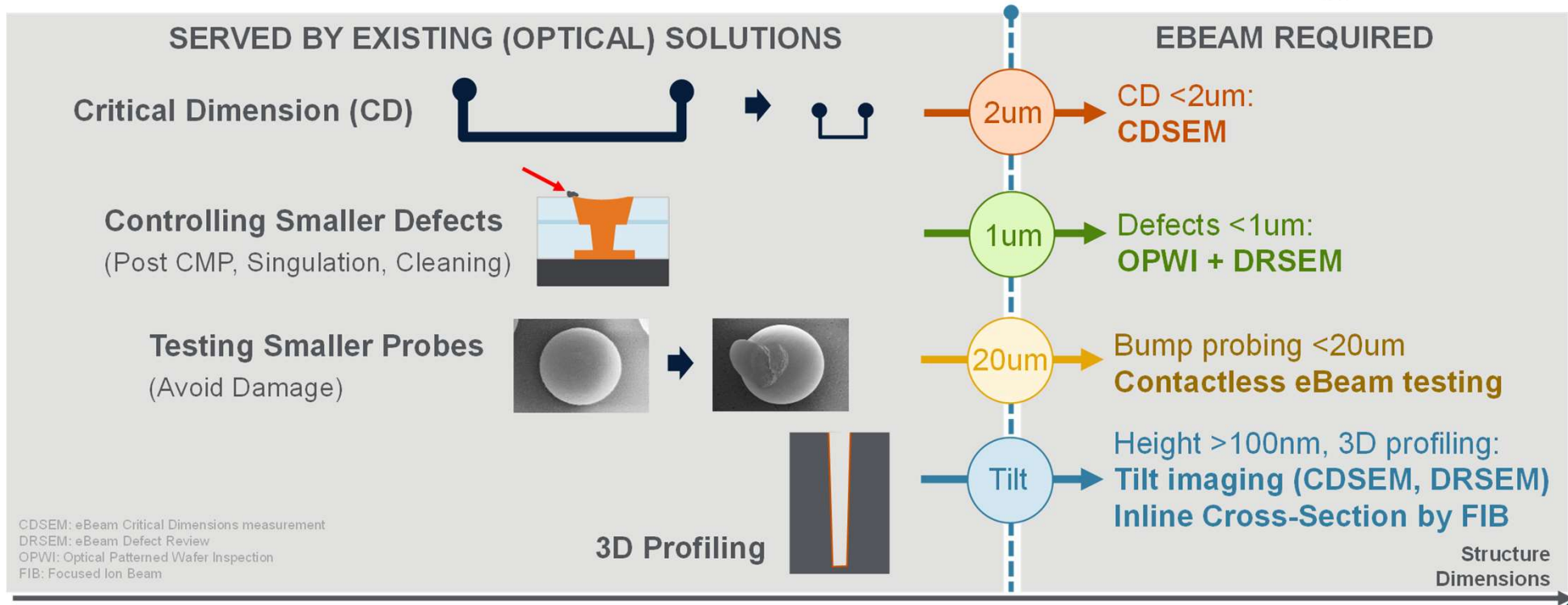
Better power efficiency
w/ finer pitch, shorter
lengths

Hybrid bonding
reduces lengths to
micron scale

Future integration:
Logic + Memory +
PMIC

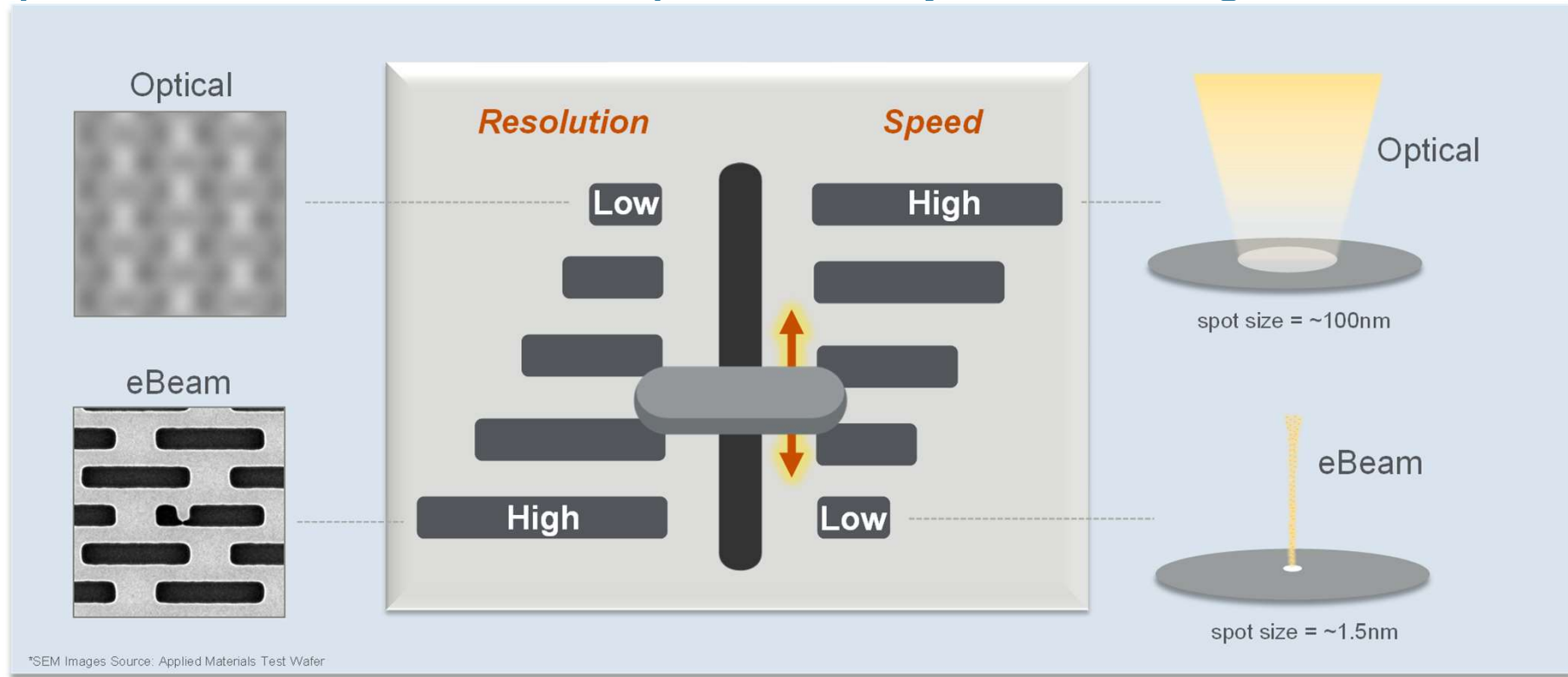
Heterogenous Integration Brings Optical Process Control To Its Limits

“Standard optical solutions are failing to meet new HI requirements...”



Smaller structures and defects drives for emerging eBeam solutions

Optical and eBeam: Complementary Technologies



- Optical provides lower resolution imaging at faster speed
- eBeam provides higher resolution imaging at slower speed

High Resolution is Critical for Effective Defects Characterization

SD (480p)



30x

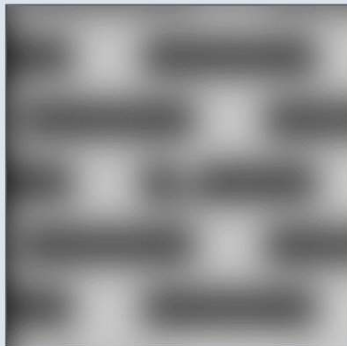
UHD (4K)



Optical Resolution

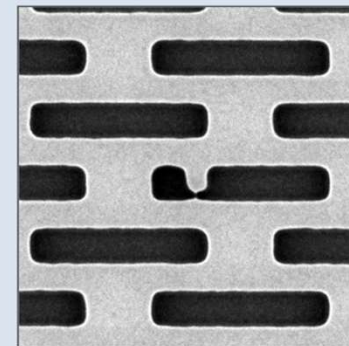


Optical



50x

eBeam Resolution

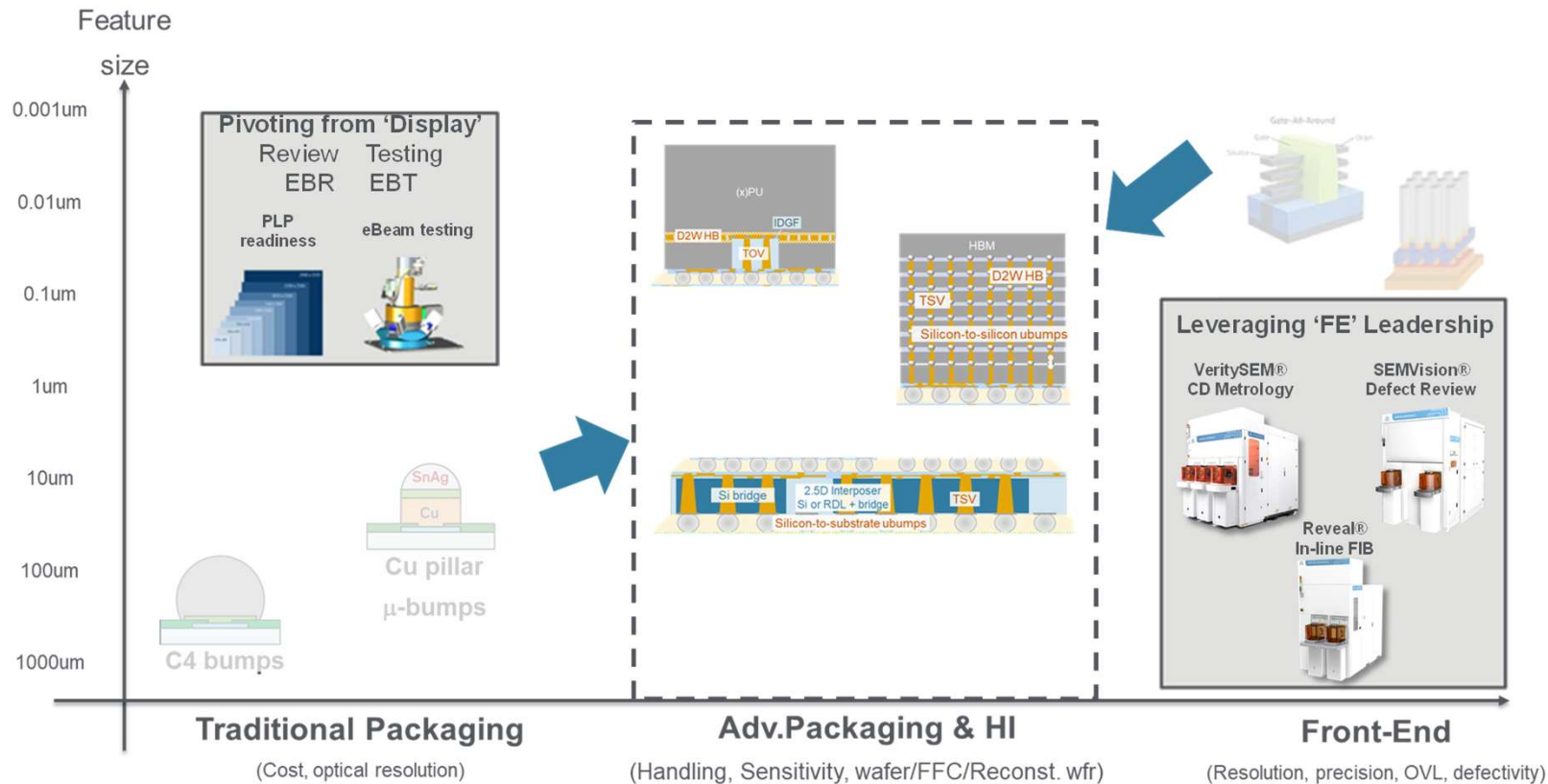


eBeam



*SEM Images Source: Applied Materials Test Wafer

Heterogenous Integration Requires Advanced Metrology & Inspection

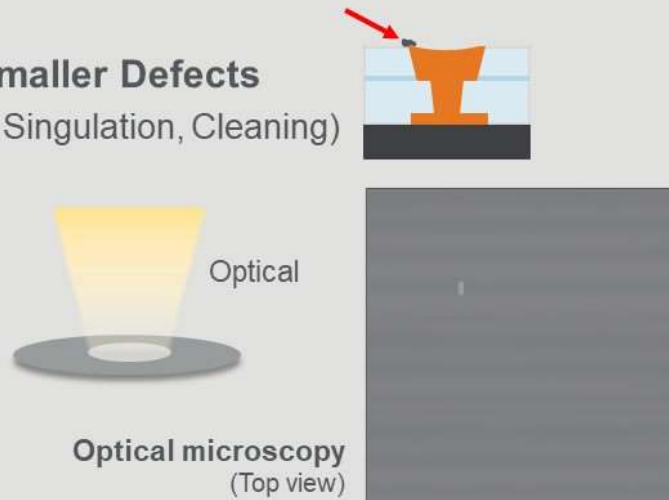


Applied as eBeam market leader, is engaging with leading customers to address emerging HB challenges

Defects are Getting Smaller

SERVED BY EXISTING (OPTICAL) SOLUTIONS

Control Smaller Defects
(Post CMP, Singulation, Cleaning)



CDSEM: eBeam Critical Dimensions measurement
DRSEM: eBeam Defect Review
OPWI: Optical Patterned Wafer Inspection
FIB: Focused Ion Beam

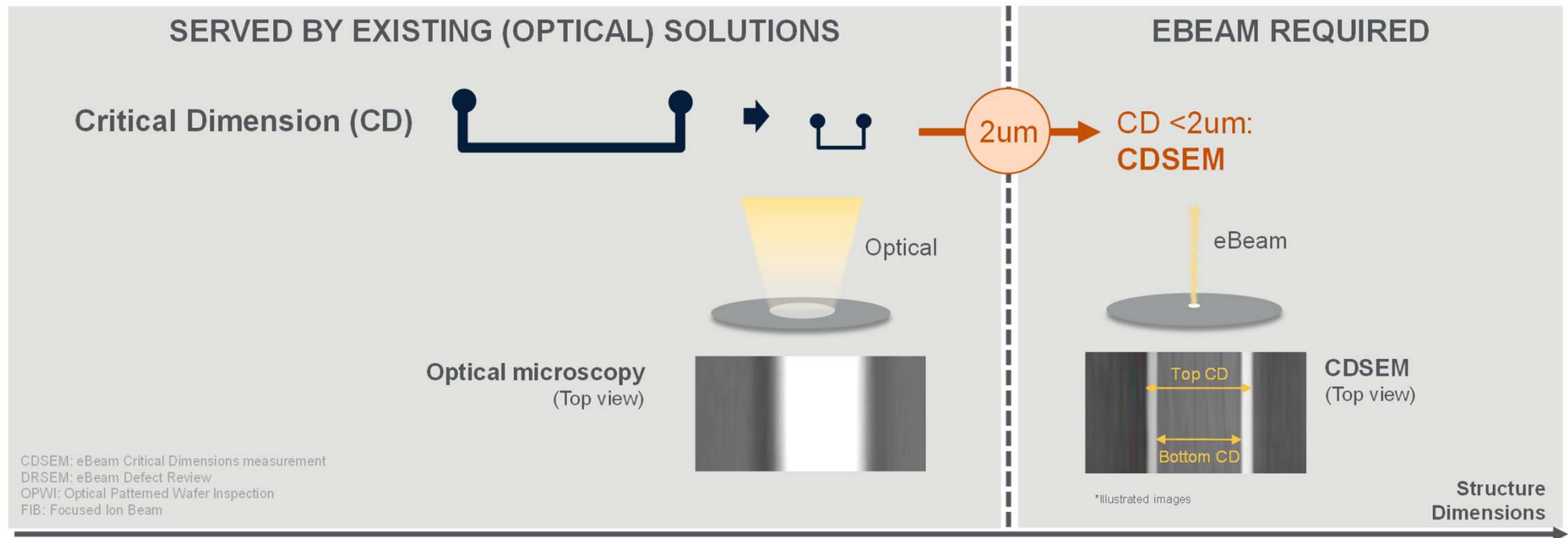
EBEAM REQUIRED



*Illustrated images

High resolution is critical for effective defects characterization

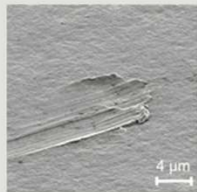
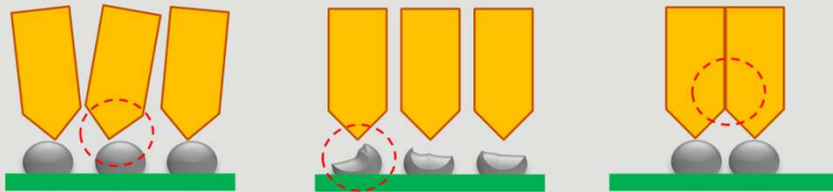
Critical Dimensions are Getting Smaller



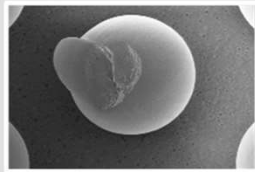
Smaller structures require better resolution for precise CD measurements

Contact-less eBeam Testing

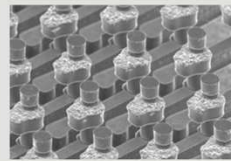
SERVED BY EXISTING (PROBING) SOLUTIONS



Needle Shift



Bump Damage

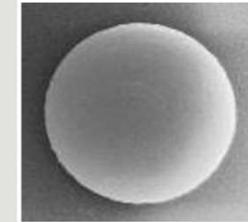
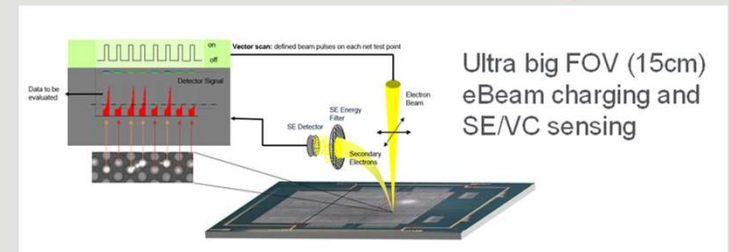


Fine Pitch $\leq 40\mu\text{m}$

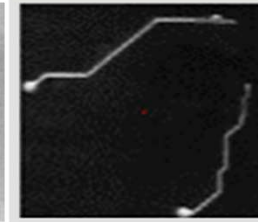


EBEAM REQUIRED

Contact-less eBeam testing



Damage free

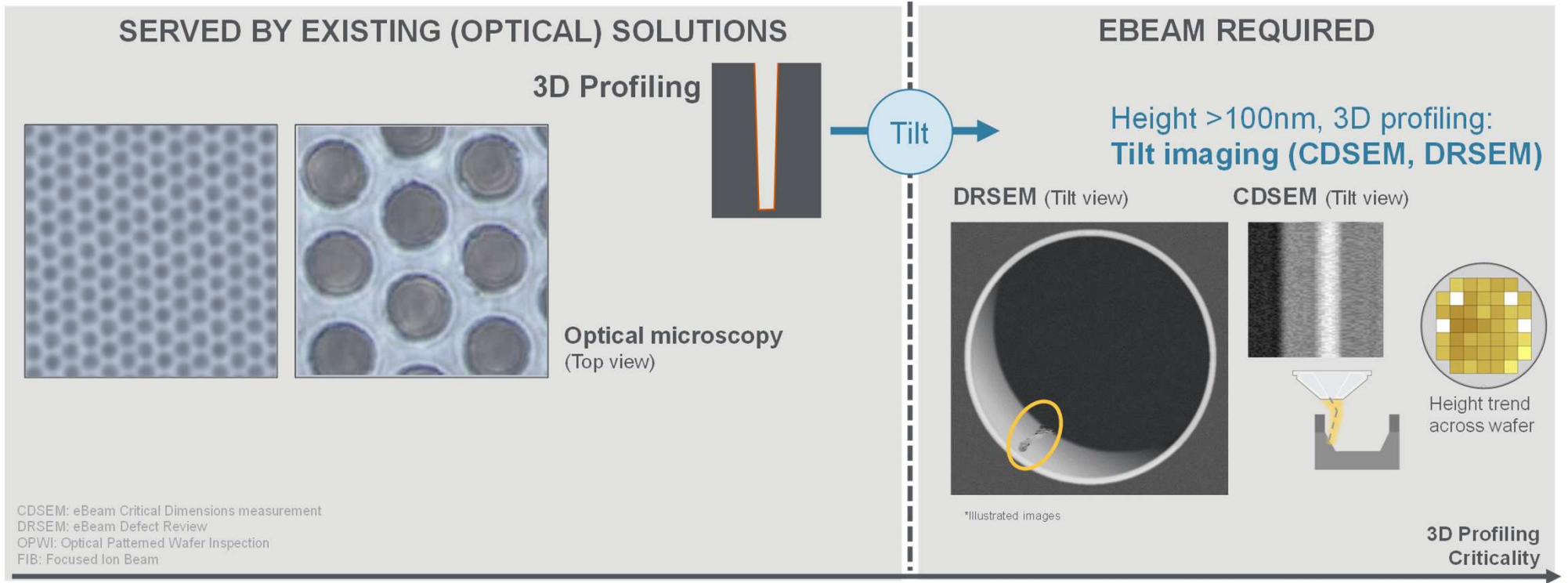


RDL charging

IO density &
Bump pitch

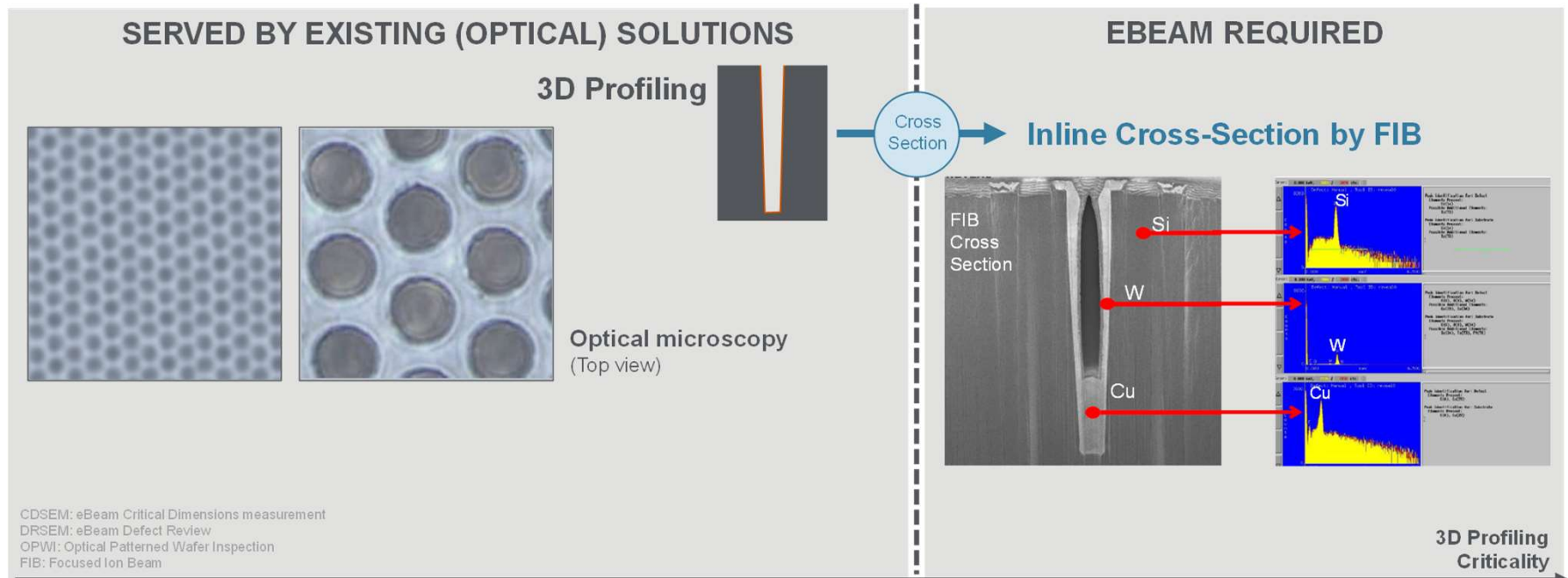
eBeam probing and VC sensing enable RDL connectivity test w/o damage and bump pitch limitation

3D Profiling Becomes Critical – Tilt SEM Imaging



eBeam is required for TSV sidewall imaging, and accurately measure heights

3D Profiling Becomes Critical – Inline SEM-FIB Solution



*Source: "Silicon Carbide wafers yield enhancement with SEMVision® G3MAXFIB application at STMicroelectronics production line," 2023 34th Annual SEMI Advanced Semiconductor Manufacturing Conference (ASMC), Saratoga Springs, NY, USA, 2023, pp. 1-5, doi: 10.1109/ASMC57536.2023.10121147.

Inline SEM-FIB can image and measure pre- and post-metallization deep structures with ~50% failure analysis cycle time reduction and without wafer scrap

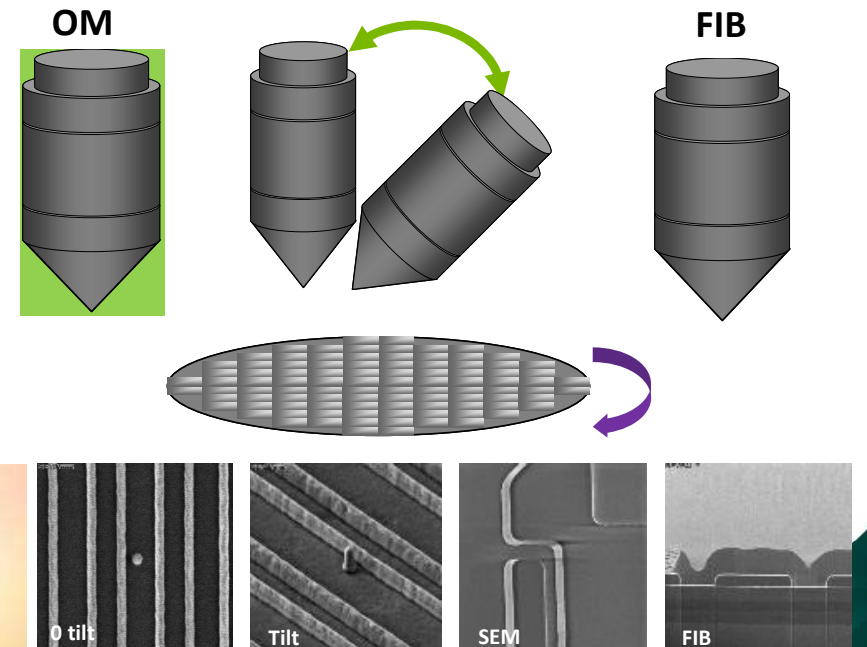
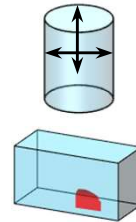
REVEAL™ – In-line SEM-FIB Capabilities for Packaging Applications

REVEAL® SEM-FIB highlights

- In-line, production worthy metrology tool supporting process development, pilot lines and production
- Analysis and monitoring of process integration challenges
- 3D metrology on critical features
- Deep buried defects root cause analysis

Basic features

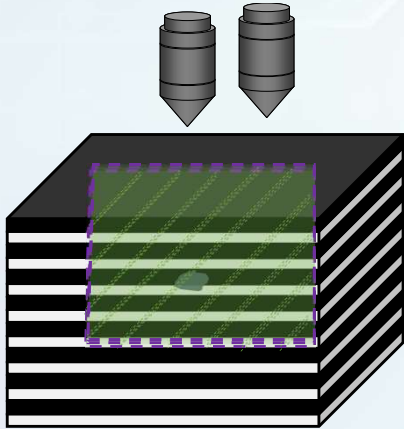
- Dual independent column
 - SEM review independent column
 - Stage rotation; SEM column tilt
 - Advanced FIB independent column
 - Wafer Cross Section for 2D information
 - Wafer Delaying for 3D information
- Material analysis EDX
- Optical microscope



REVEAL™ Cross Section and Delayering Applications

Some defects are buried inside the structure

Cross Section



Top Down



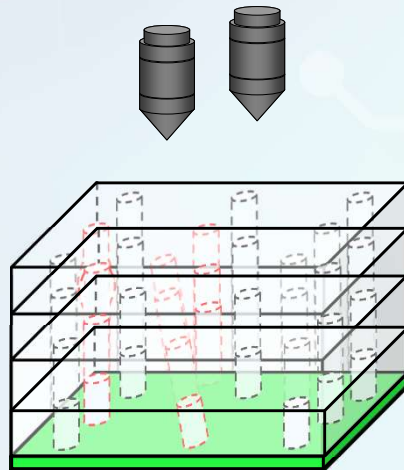
Cross Sections



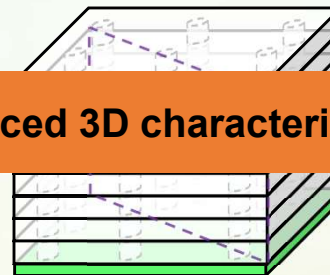
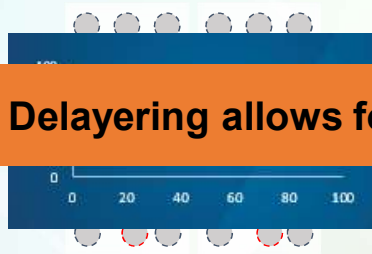
Cross Section: slice through the device to allow root cause analysis

Some devices require advanced 3 D metrology characterization

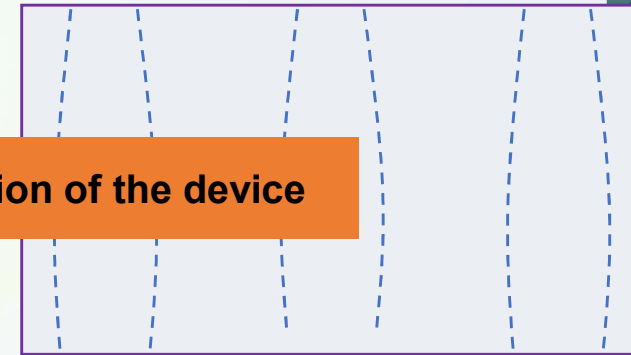
Delayering



Delayering allows for advanced 3D characterization of the device



Virtual Cross Section



REVEAL™ – Packaging Applications Challenges in HiCONNECTS

1. Wafer bow handling

- Packaging wafers are not as flat as Si wafers
- Need to handle securely highly warped/bow and high mass wafers

2. Wafer thickness handling

- Packaging wafers **exhibit** a wide range of bow and thickness
- Need to handle multiple types of wafers

3. FIB milling speed

- FIB packaging applications require very high thickness milling – high FIB milling rates and flows for acceptable throughput
- SEM imaging at deep and slanted geometries

4. SEM-FIB productivity

- Productivity and consistency – enable automated SEM-FIB applications

How Applied Solves These Problems

SEMVision™

Defect Review on Wafer



Si 500um; Dielectric 300um
RM '25-'26: Si 1mm, D: 500um on lab tool

VeritySEM™

CDSEM Metrology



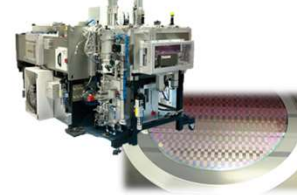
Reveal™

Inline Failure Analysis



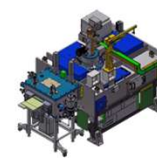
EBReview™

SEM Review Panel, tape frame



EBT

Contactless etester



AP space

Logic - HB



HBM



Interposer
WPL/PLP



Summary and Conclusions

- Hybrid Bonding enables high density die-die interconnect for higher bandwidth and lower energy/bit
- Tighter process specs drive 'Front end-like' equipment for process integration, metrology and inspection
- Traditional Metrology and Inspection are facing new challenges that can be addressed by eBeam
- Innovations in Process and Metrology Control are paving the way for HI & Hybrid Bonding enablement

Acknowledgement

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