Advanced Packaging

Next Generation Metrologies & Fault Detection Methods

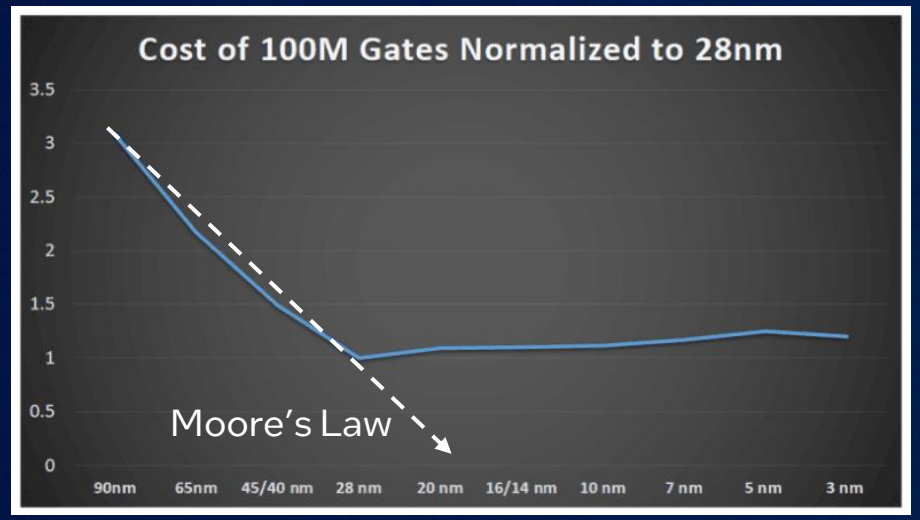
Pooya Tadayon
Intel Fellow, Director of Assembly & Test Pathfinding

Executive Summary

- The era of 3D integration and advanced packaging is upon us, but the ecosystem is not ready
- Fine pitch features in advanced 3D packaging require metrologies to detect defects at all levels – surface and buried
- Innovative solutions are needed to enable non-destructive, sub-micron resolution, and high-speed metrologies

Advanced Packaging Technology Drivers

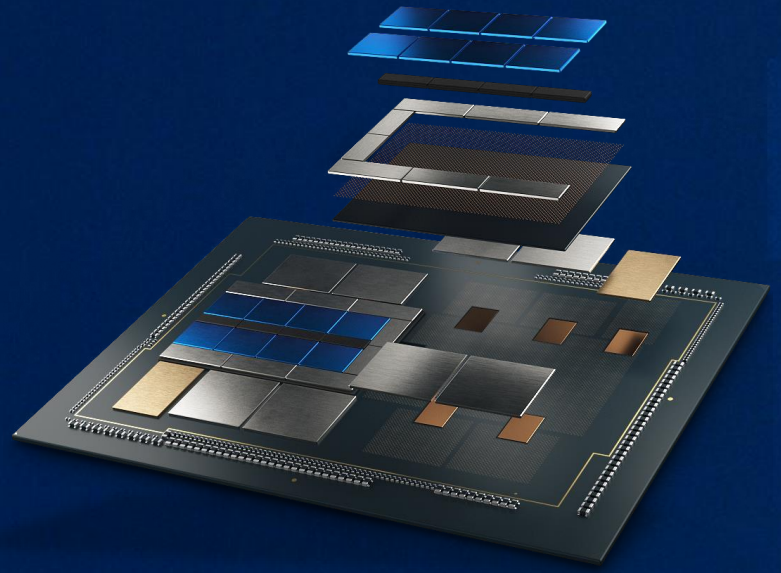
COST



Source: Google, IEDM23, SC1.6

Higher wafer cost drives disaggregation

PERFORMANCE/SCALING



Need for complex sizes that exceed the reticle limit

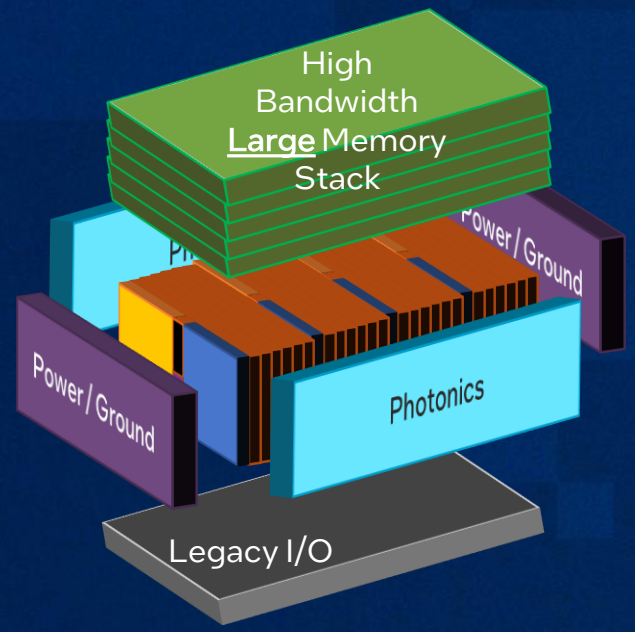
Advanced packaging is required to re-aggregate chiplets and build complexes larger than the reticle limit

Evolution of Advanced Packaging

Package main function:
provide power and signaling from motherboard to die

Added package value:
high density interconnects that enable larger die complexes from multiple process nodes

Evolution of 3D Packaging



Memory

Logic

Logic

Logic

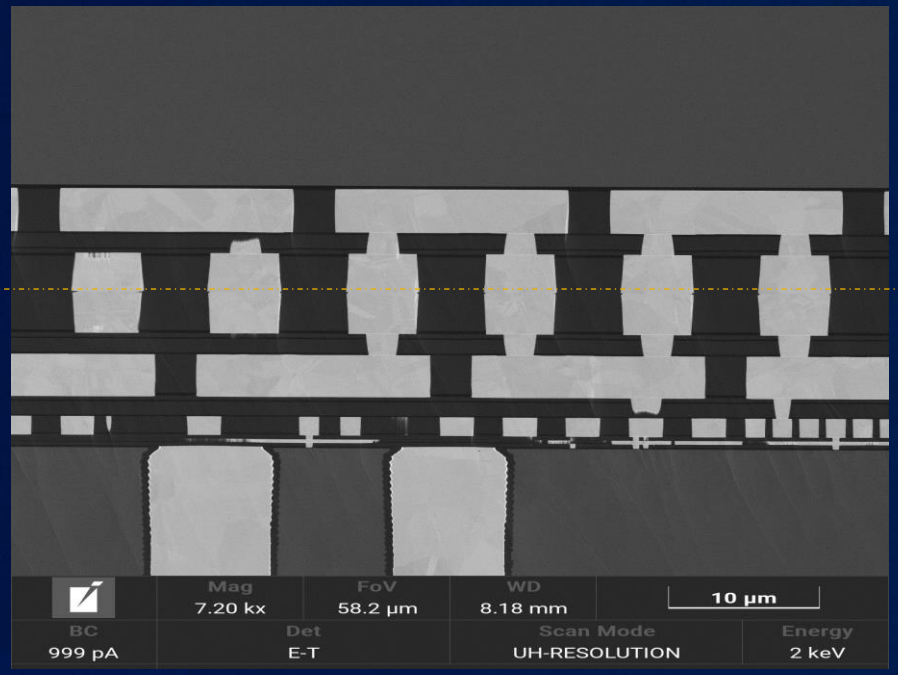
3D today
"planar"

3D future
"cube"

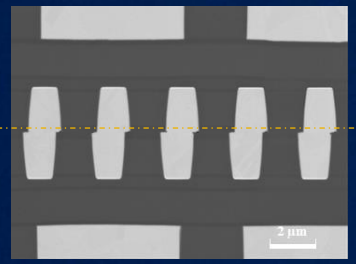
3D stacking will evolve to enable more complex and integrated devices

Key Trend: Pitch Scaling

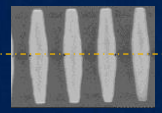
9 um pitch



3 um pitch



1 um pitch

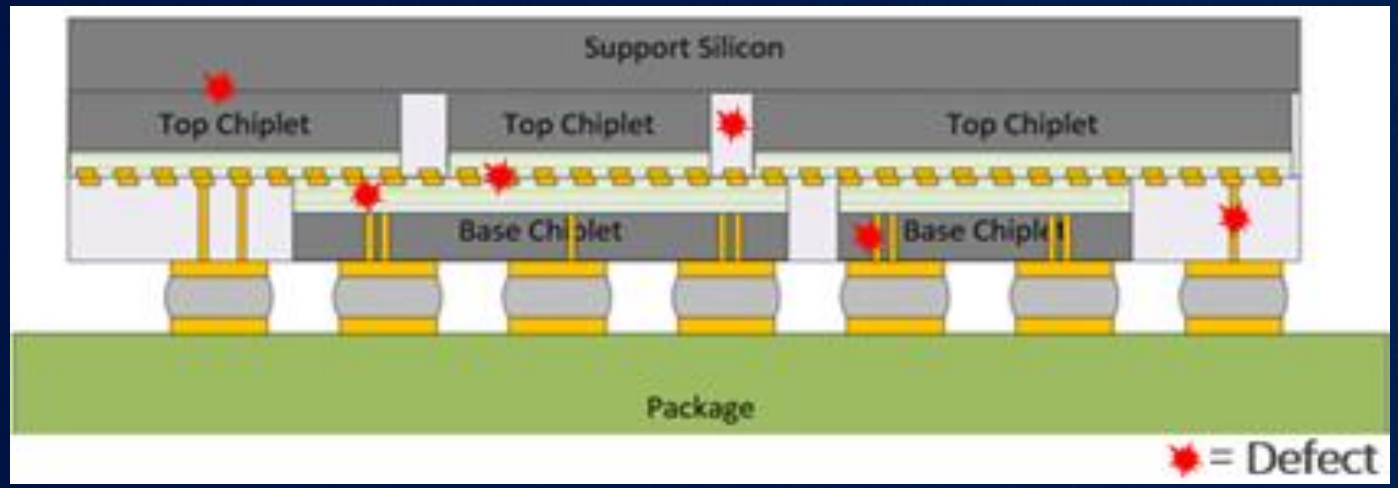


0.4 um pitch

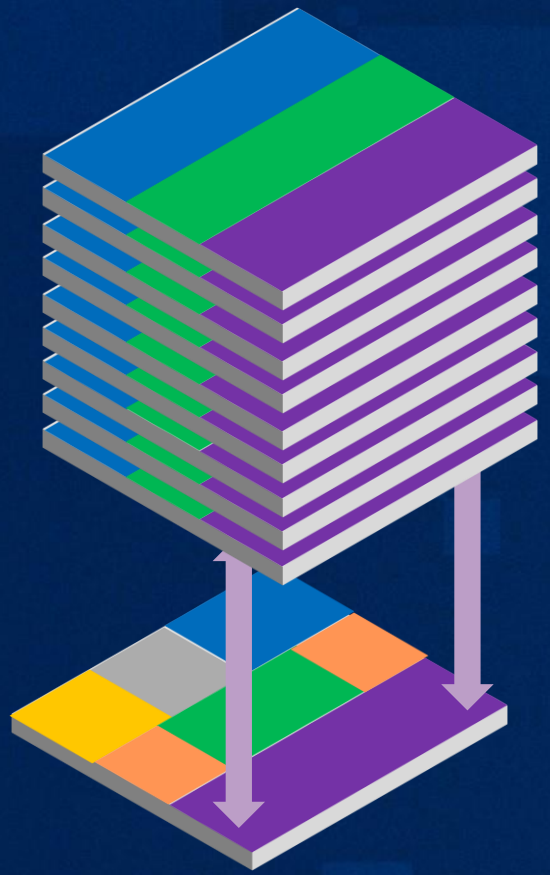
time

Cu-Cu hybrid bonding enables aggressive pitch scaling to ≤1 um

Key Challenges: Defect Isolation in Stacks

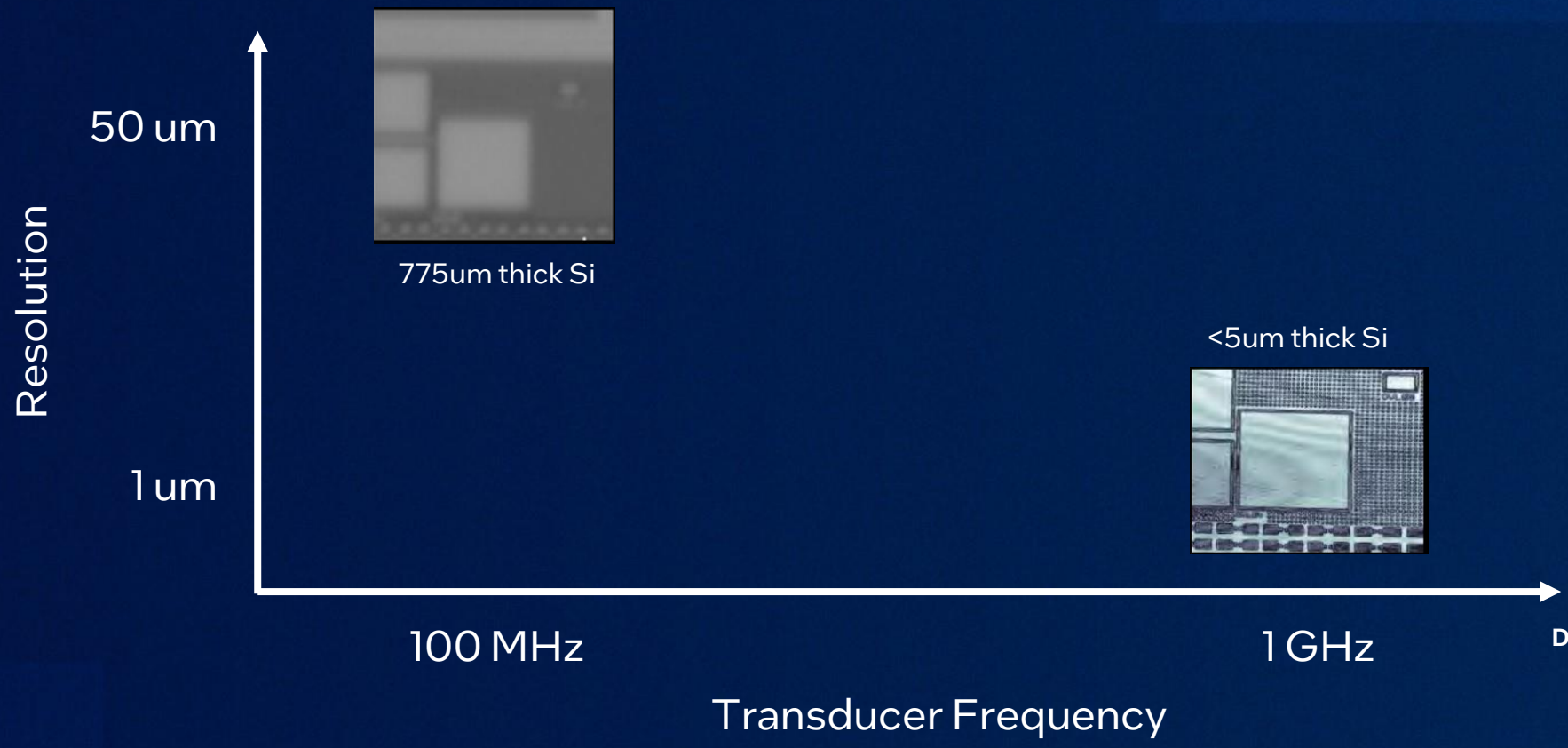


>>10 die stack



As devices become more complex with reduced dimensions, more advanced defect isolation methods are required to pinpoint location of defects in buried structures

Key Challenges: High Resolution CSAM

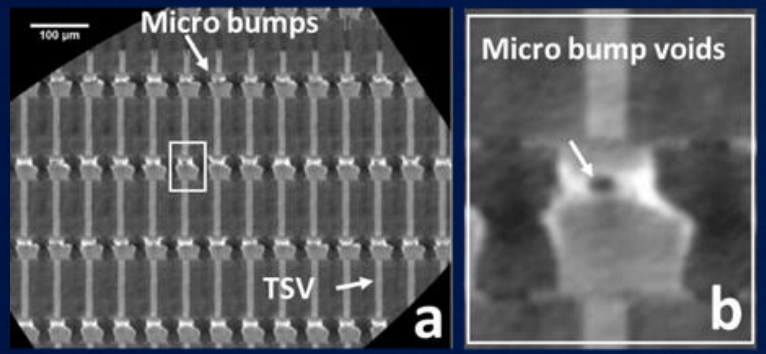


De Wolf et. al, ISTFA 2019

CSAM is a critical metrology, but higher resolution requires sample prep/die thinning that is not always possible with 3D stacked structures

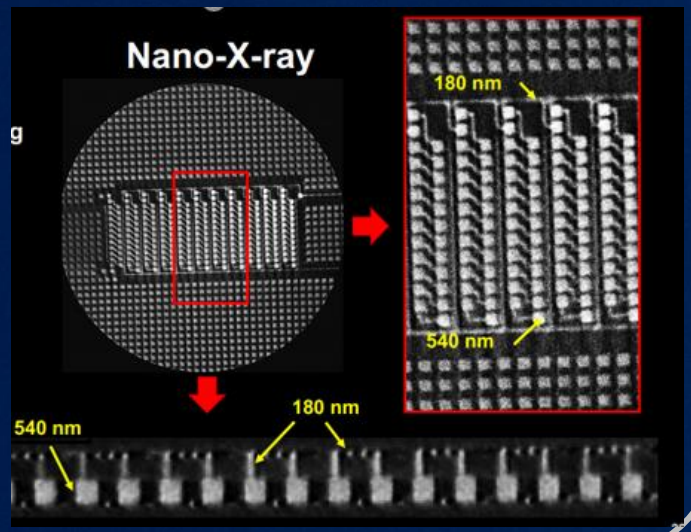
Key Challenges: High Resolution Imaging

Typical 3D X-ray for interconnect defects; no sample prep is needed



Cheryl Hartfield et. al. DOI: 10.1109/IPFA.2018.8452551

Nano 3D X-ray with <1um res.; sample preparation is needed



Christian Schmidt, Lorenz Lechner, Ingrid DeWolf, Soon-Wook Kim, Eric Beyn ECTC 2018

Sample prep and long scanning time needed to reach high resolution for fine pitch features will slow down yield learnings and impact time to market

Need innovation in imaging to quickly detect subtle defects buried under multiple interfaces non-destructively

Key Challenges: High Resolution Imaging

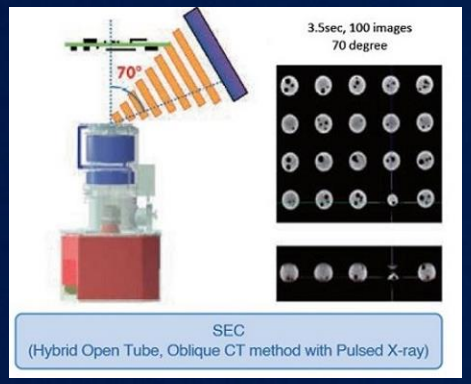
Fast/Automated

- Sub-micro resolution
- Fast scan
  - High speed detectors
  - Large FOV
  - Fast data processing
- AI & deep learning

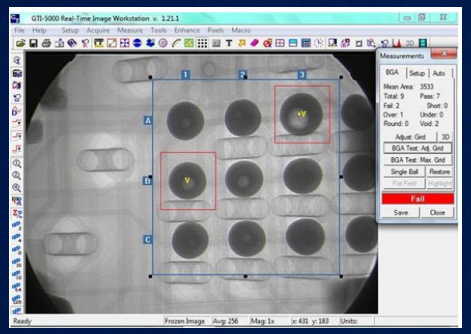
Low resolution → **High resolution**

Slow/Manual

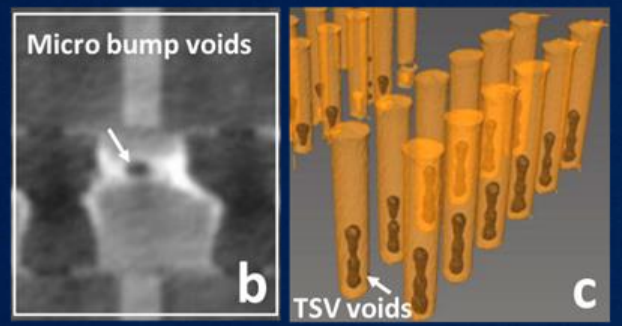
1



2

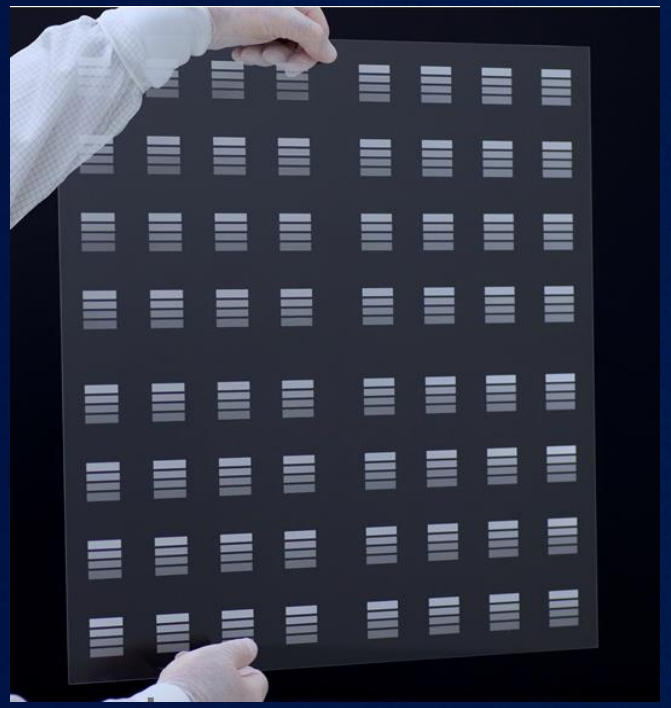


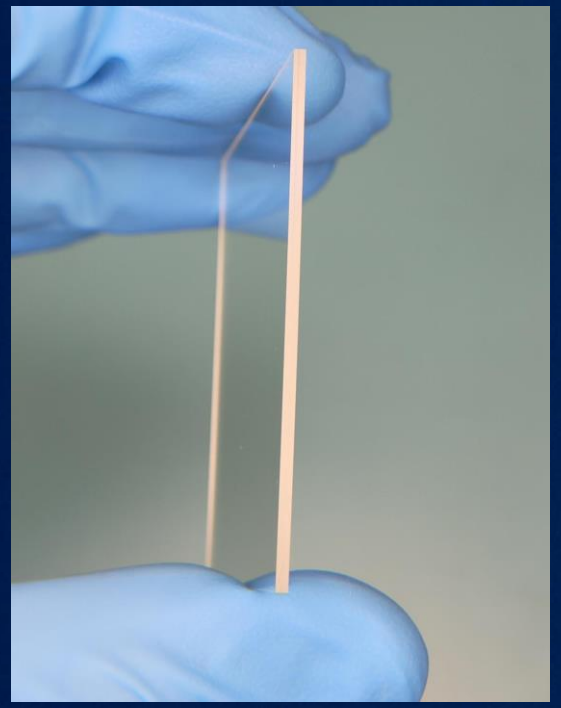
3

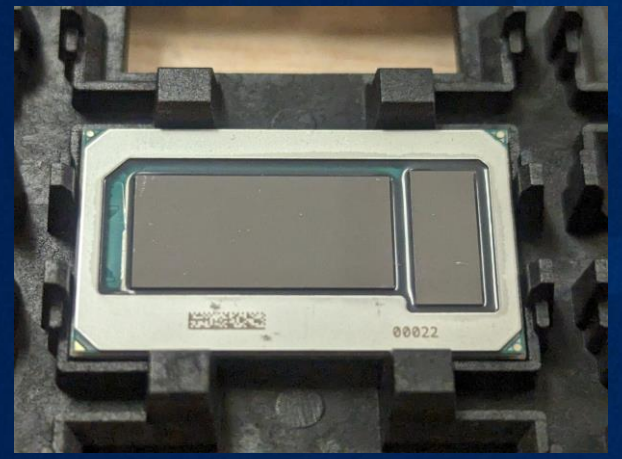


1. https://smtnet.com/news/index.cfm?fuseaction=view_news&company_id=54743&news_id=24997
2. https://www.glenbrooktech.com/x-ray-inspection-system-rentals/bga-inspection/
3. Yan Li and Deepak Goyal, "3D Microelectronic Packaging: From Architectures to Applications", 2nd edition, Springer, 2021, ISSN 1437-0387

Trends: Glass Substrates

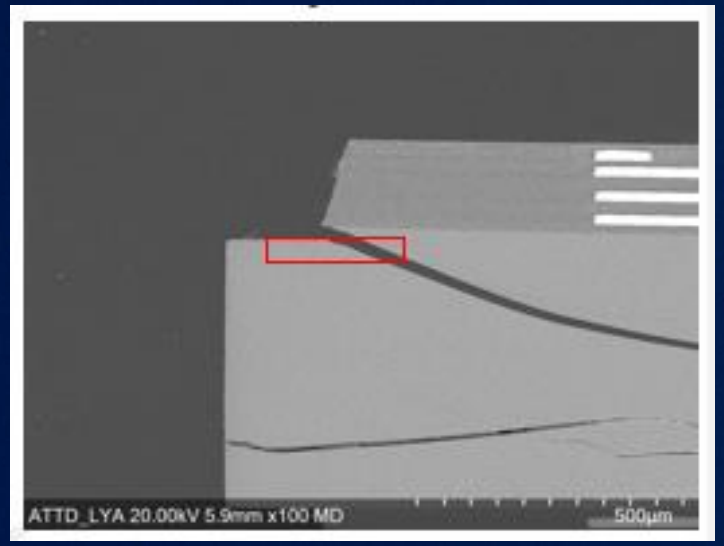






Glass offers improved material properties resulting in better dimensional stability and ability to scale

Key Challenges: Crack Detection

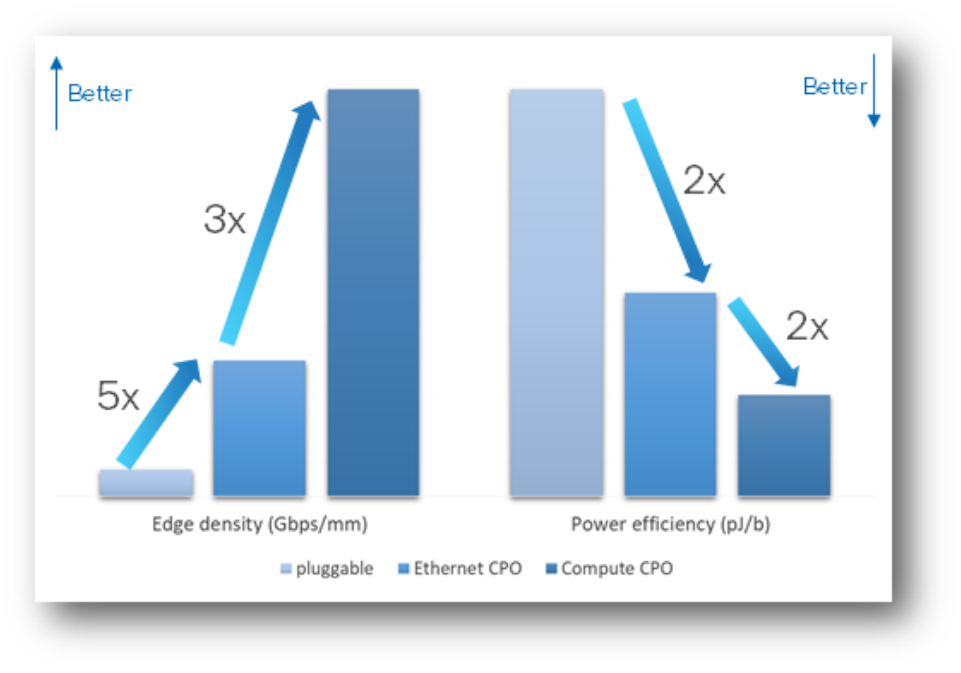


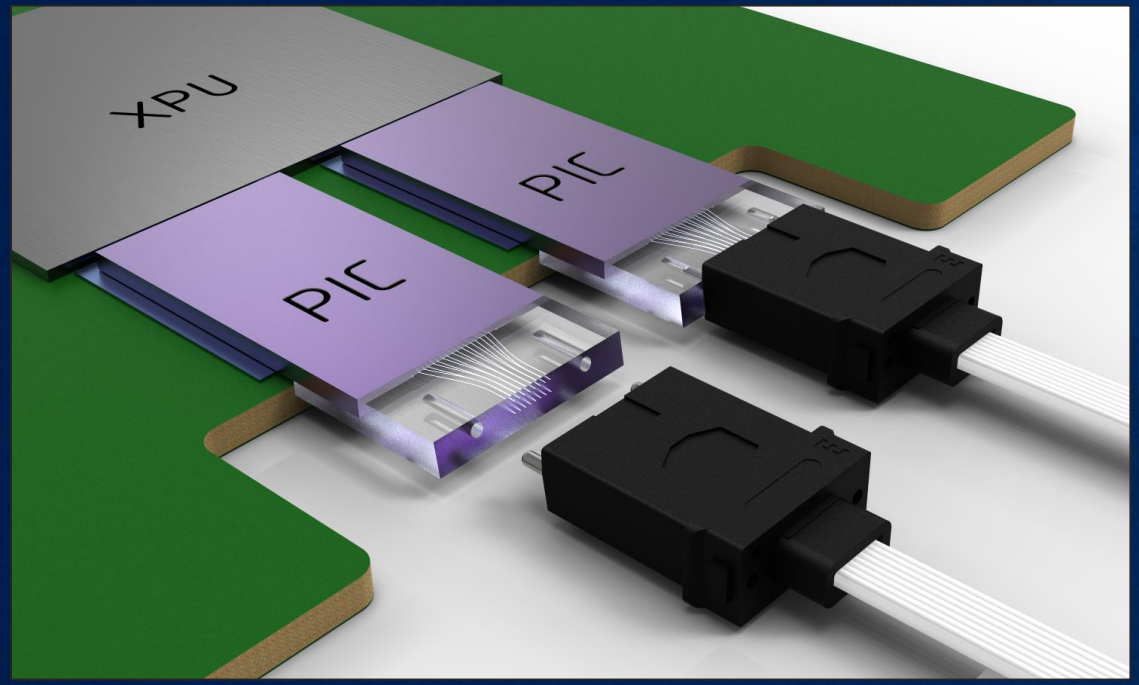
Edge defects due to singulation

Cracks that can become gross fails if undetected

New in-line metrologies required to quickly detect micron-level cracks in glass substrates

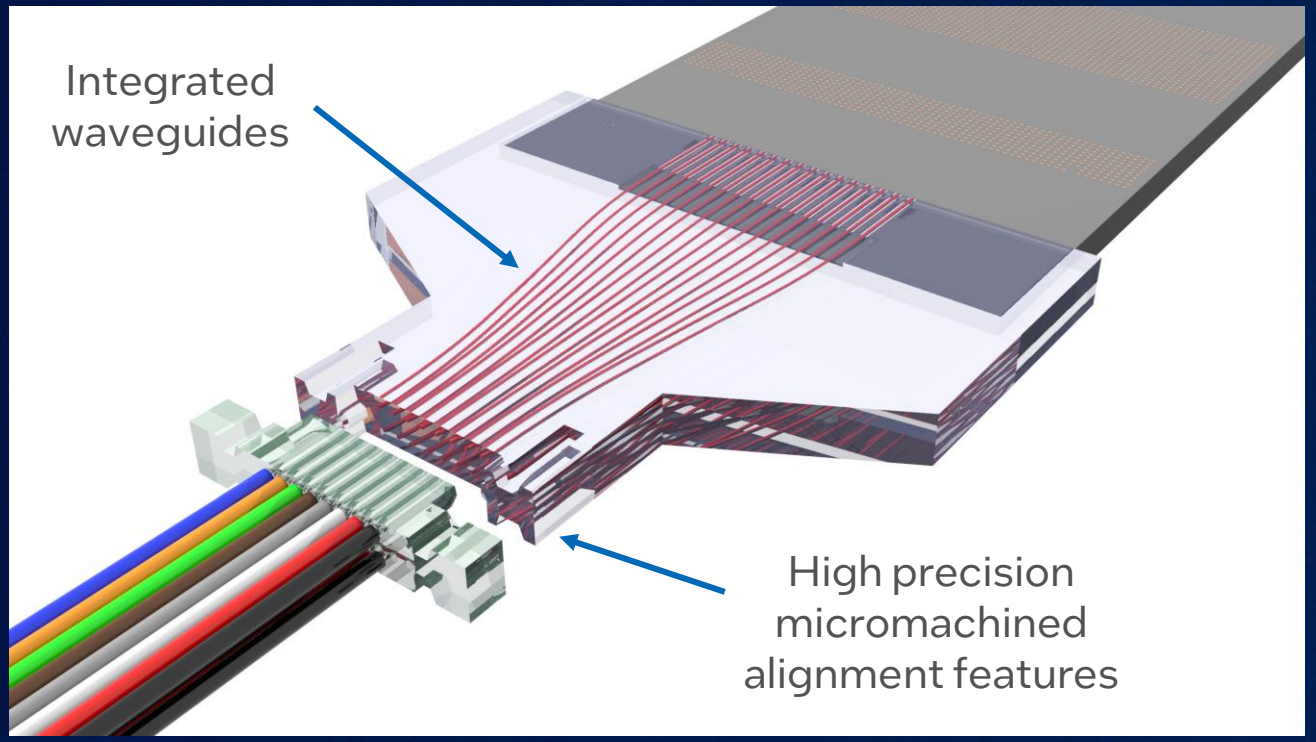
Trends: Co-Packaged Optics

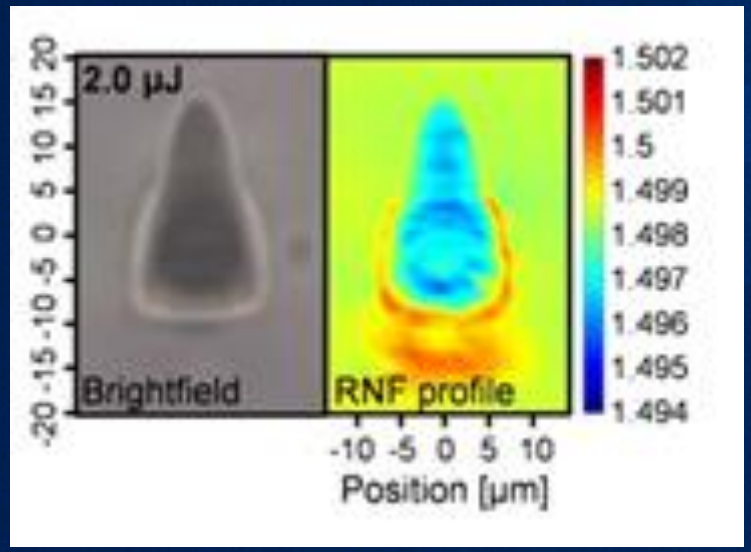




Glass bridge with integrated waveguides is key to enabling a high-volume compatible pluggable solution

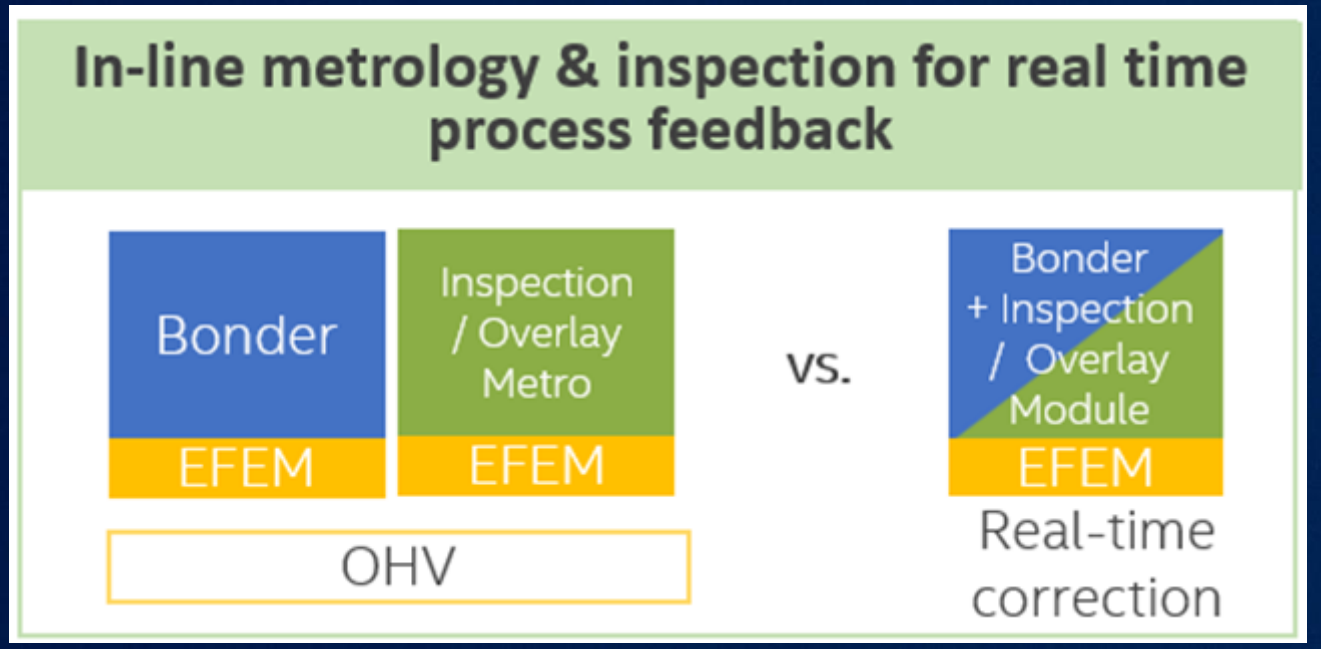
Key Challenges: Metrology





Non-destructive methods for 3D mapping of optical waveguides in glass + high accuracy measurement of fine features on a transparent substrate

Key Challenges: Metrology



Need higher level of integration of metrologies inside process tools for real-time process feedback and control

Executive Summary

- The era of 3D integration and advanced packaging is upon us, but the ecosystem is not ready
- Fine pitch features in advanced 3D packaging require metrologies to detect defects at all levels – surface and buried
- Innovative solutions are needed to enable non-destructive, sub-micron resolution, and high-speed metrologies