



CONNECTS

Heterogeneous Integration for
Connectivity and Sustainability

Sharper scans, faster ramp up - How a leap forward in X-ray resolution can drive development and boost yield in advanced packaging

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excillum

Pilot Lines

Pilot Line 1 RF Electronics HI

Lead: FBH

- HI for high-speed broadband & RF electronics based on InP on BiCMOS, incl. thermal management.
- Photonic and electronic heterogeneous integration.

Pilot Line 2 Photonic Components for HI

Lead: IMEC

- Next gen. photonics components and Si photonics based on HI platform development.
- High-Speed Lasers and Photodetector.

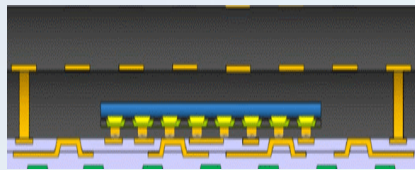
Pilot Line 3 Advanced Packaging

Lead: 3DiS

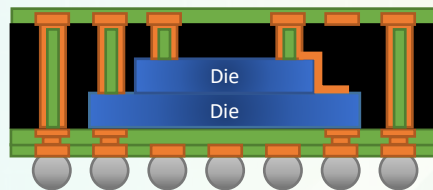
- 3D-Fan-Out Wafer Level Packaging, pivotal for antenna in packages, and 5G/6G packages (beyond 100 GHz).
- Next gen. interconnects based on glass interposer.

3D-RDL & HDc-TPV platforms: enabler of 3D WLP for RF applications

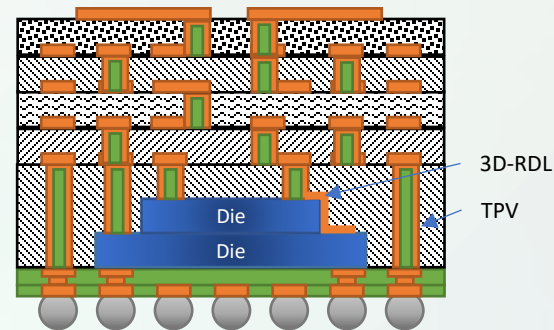
Advancing beyond State-of-the-Art for high-performance advanced wafer-level packaging of RF & mmWave applications



Current State-of-the-Art (2.5D)



Current State-of-the-Art (3DiS)



Beyond State-of-the-Art (3DiS)

Smaller features
Buried structures,
Denser interconnects
Tighter tolerances
Etc...



3D non-destructive metrology



The challenge in X-ray inspection and failure analysis

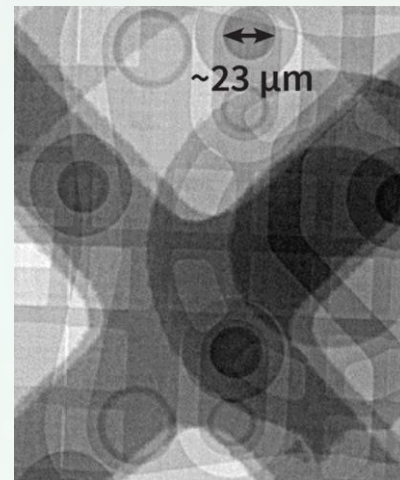
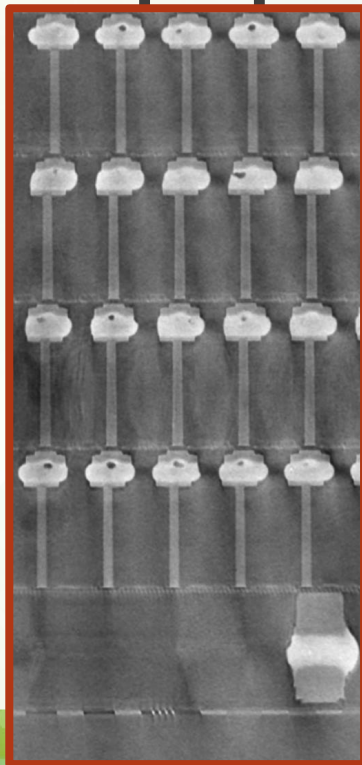


From Lab to Fab sharing the same challenges!

- Faster measurements
- Lower dose
- Better resolution

Improved X-ray source for Sharper scans – faster ramp up

Improved x-ray inspection to
drive development and boost
yield



The source for X-ray innovation

Entirely devoted to advanced
microfocus and nanofocus X-ray
sources

Based in Stockholm, Sweden

Established 2007

80+ colleagues
>40 in R&D
>10 nationalities



Chapter

01

Basics of high resolution X-ray
imaging

Resolution limit: spot size and penumbral blurring

- Achievable resolution limited by size of the X-ray spot
- Rule of thumb: $\frac{1}{2}$ spot size (FWHM)

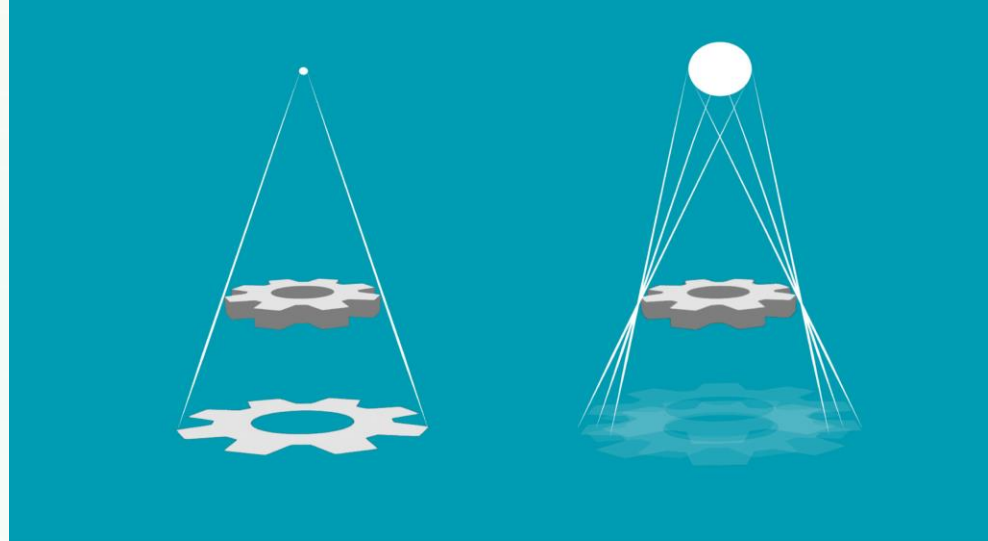
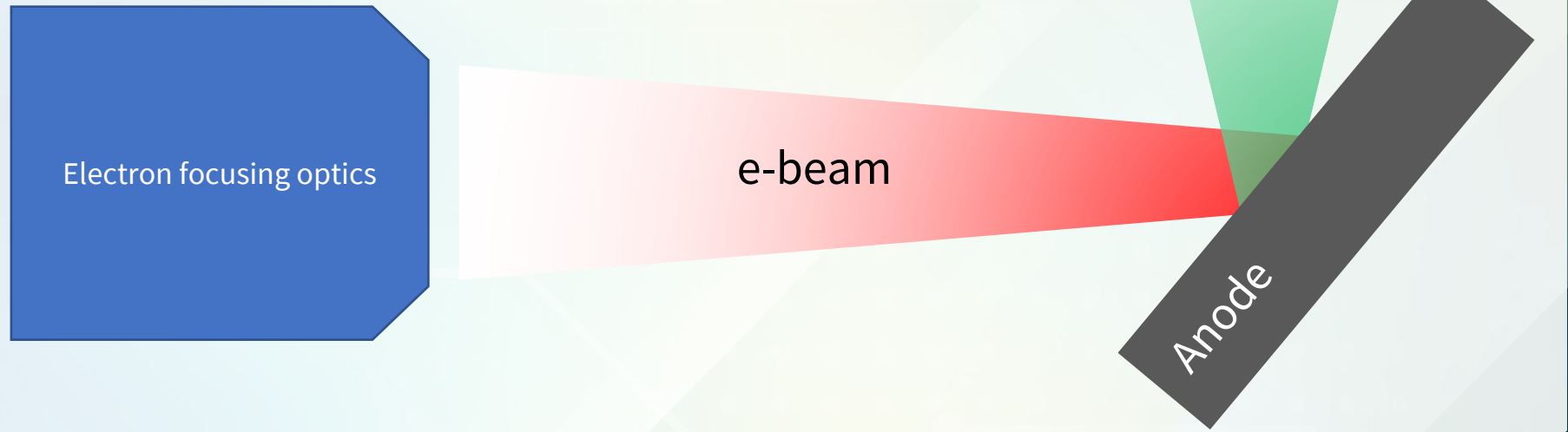
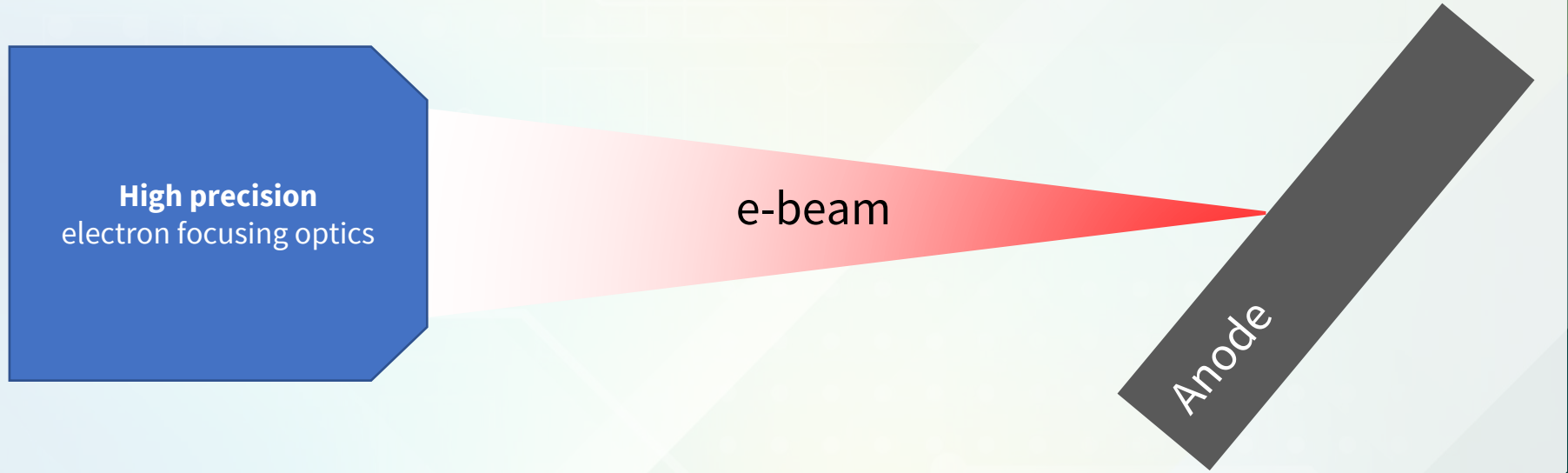


Figure from: J. Hållstedt "Brightness as key performance metric for X-ray tubes and benchtop X-ray sources", Excillum AB, 2024
<https://www.excillum.com/brightness-as-key-performance-metric/>

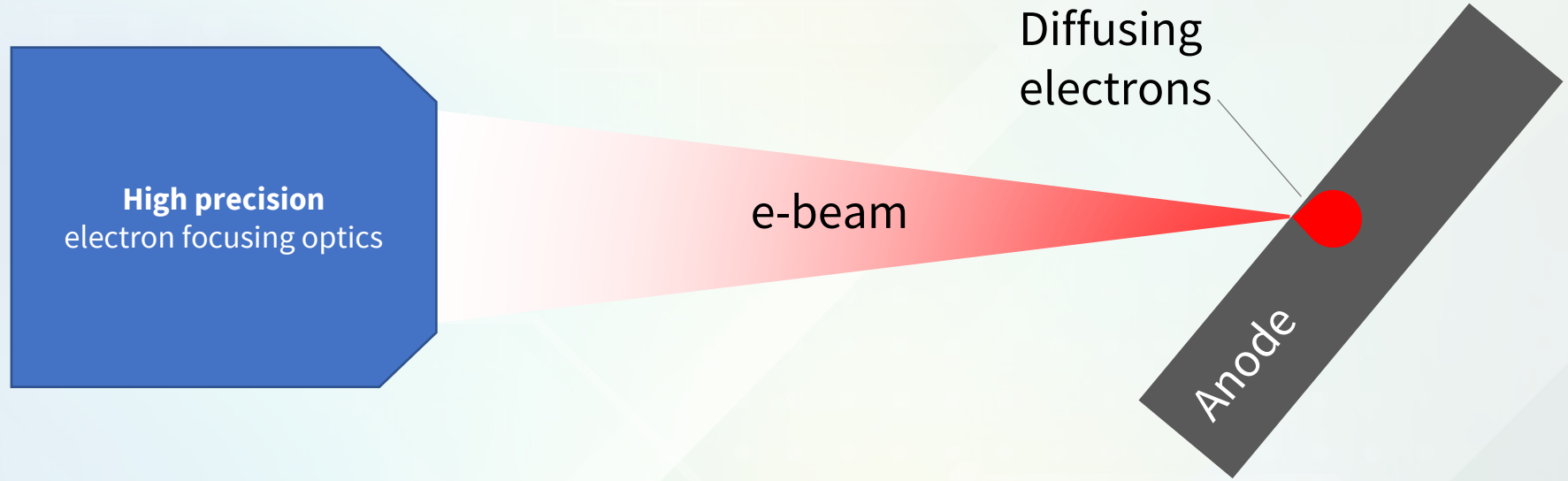
How to achieve small X-ray spots



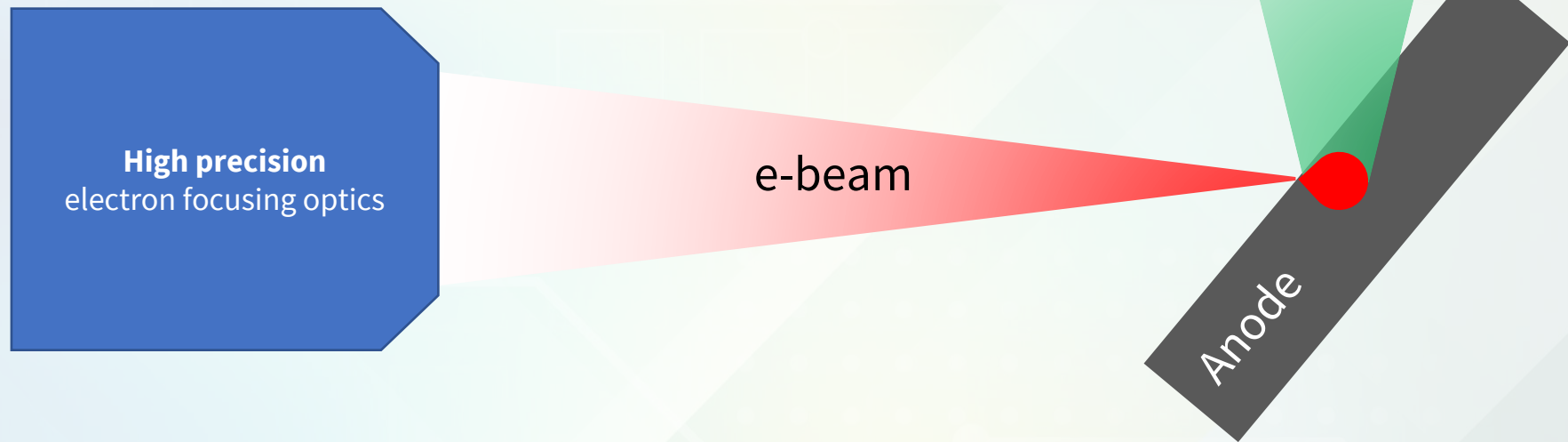
How to achieve small X-ray spots



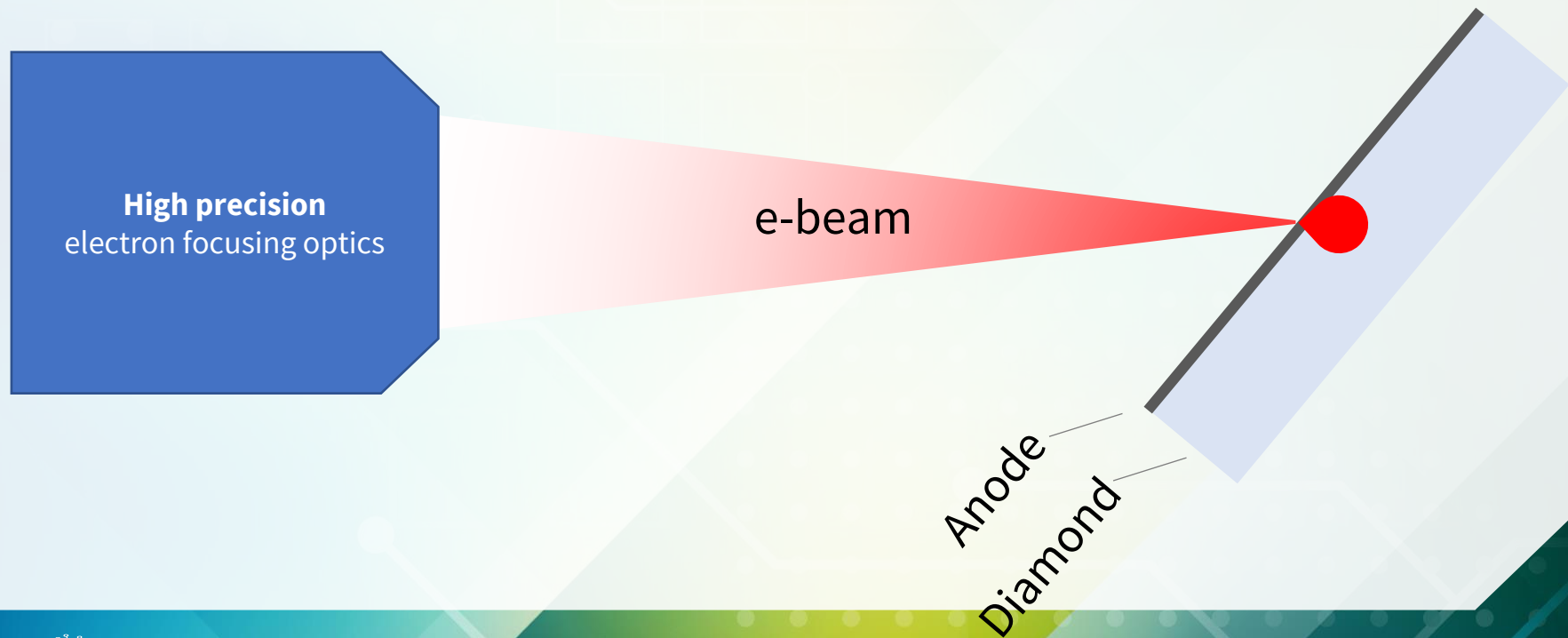
How to achieve small X-ray spots



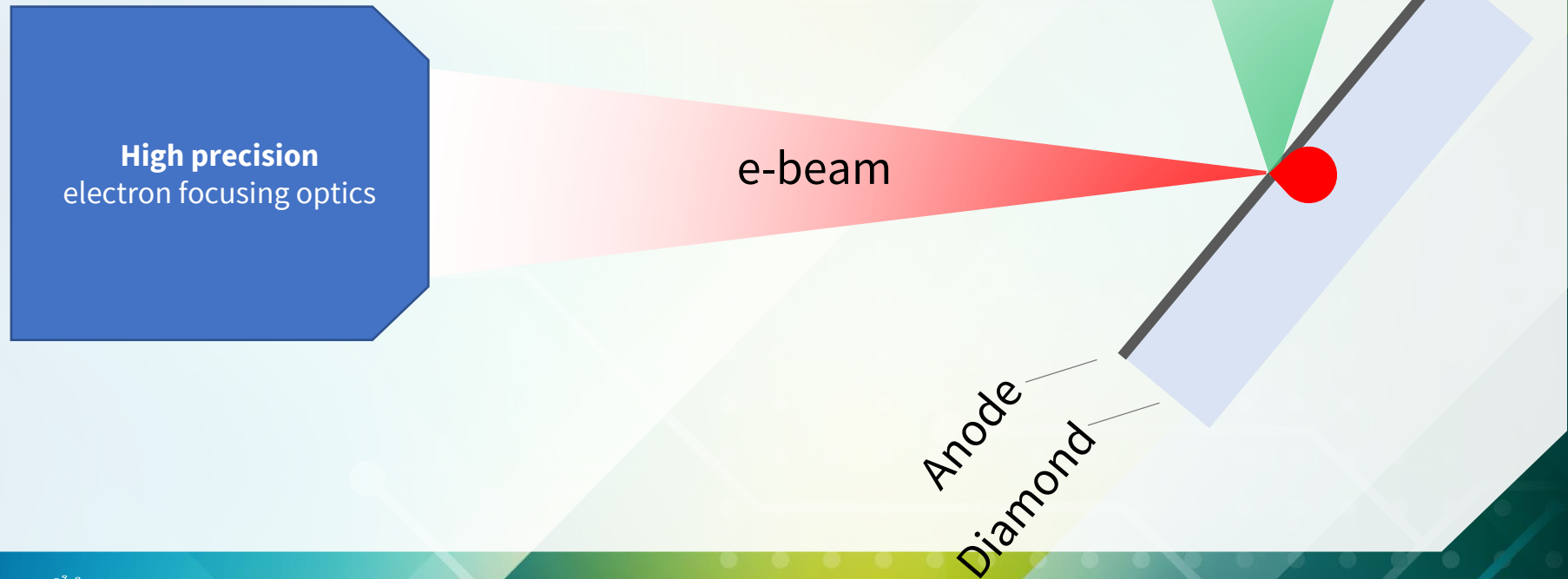
How to achieve small X-ray spots



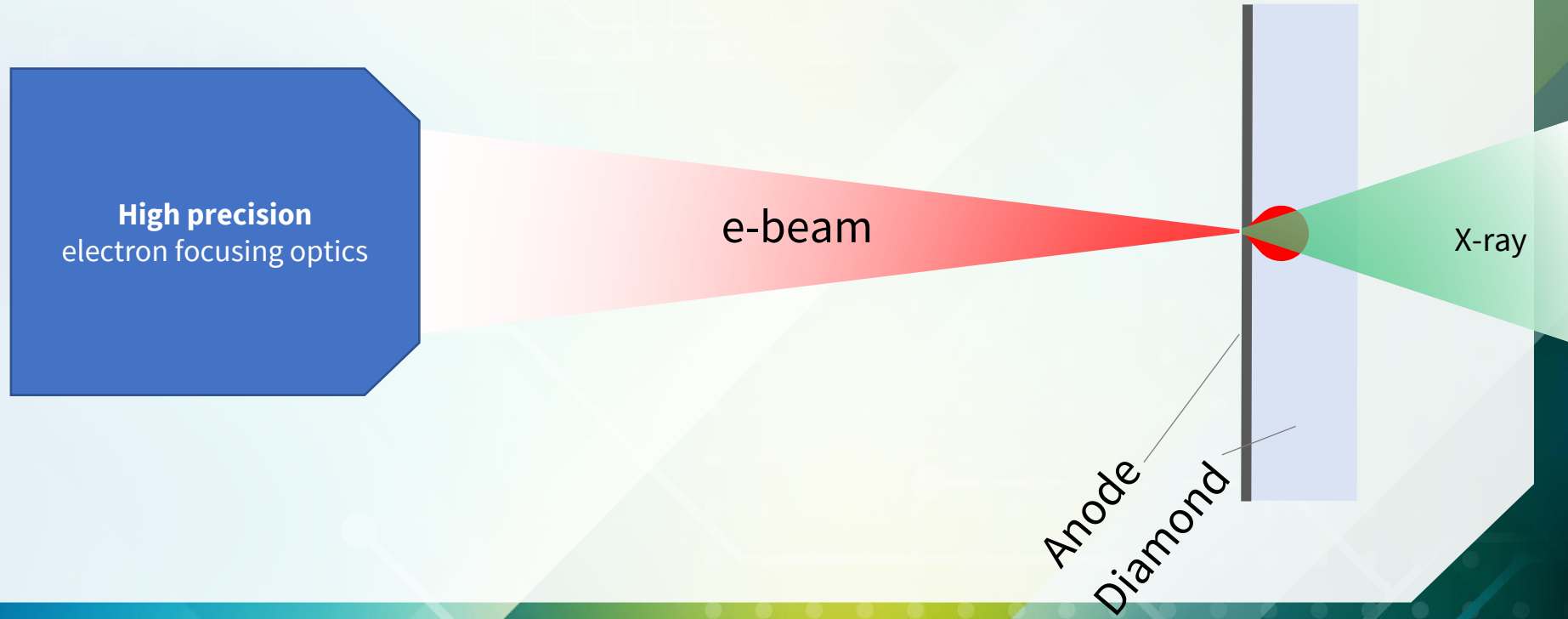
How to achieve small X-ray spots



How to achieve small X-ray spots



How to achieve small X-ray spots



Measurement speed

How to achieve fastest measurement speed/throughput?:

- Diamond target excellent heat transfer
- High precision electron optics to minimise tails and stray electrons



maximum power to be applied on desired spot size

Minimizing absorbed dose in sample

X-ray source parameters:

- Well defined spot - aim for round gaussian shape (minimize tail and fringes (i.e. parasitic X-rays))
- Minimize secondary radiation (i.e. parasitic X-rays)
- Beam blanking (fast switching (on/off) of X-ray source) – Only have X-rays on when you measure.
- Fast switching and accurate acceleration voltage setpoints for optimised spectrum

External parameters:

- Filters (remove spectrum not contributing to image)
- Collimators to confine beam into region of interest (ROI) minimize parasitic.
- Efficient detector (e.g. photon counting)

Development in HiConnects

- Better and faster calibration
- Power increase
- Smaller spot size



Faster measurements
/higher throughput



Better resolution



Lower dose

How to achieve a 250 nm X-ray spot

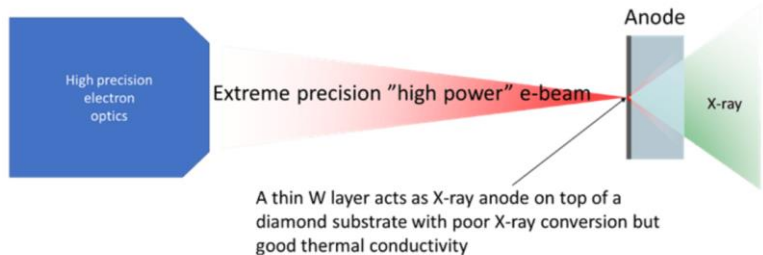


Figure 27 Excillum BSOTA XRAY source to enable 125nm X-ray resolution with 250nm X-ray spot

From Amendment No AMD-101097296-12

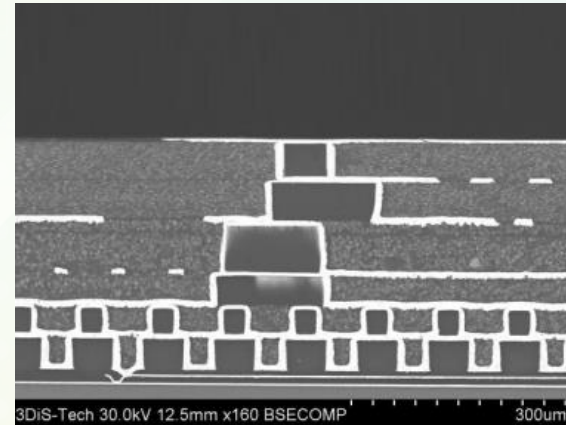
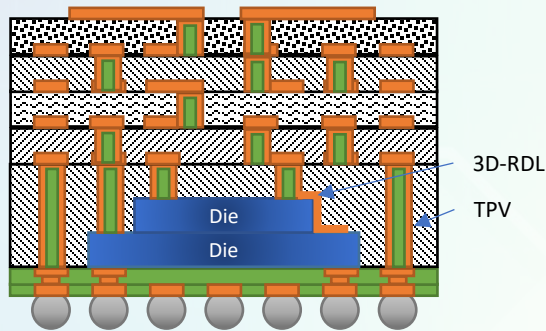
Chapter

02

Results -
Advanced packaging

3DiS - 3D-RDL & HDc-TPV

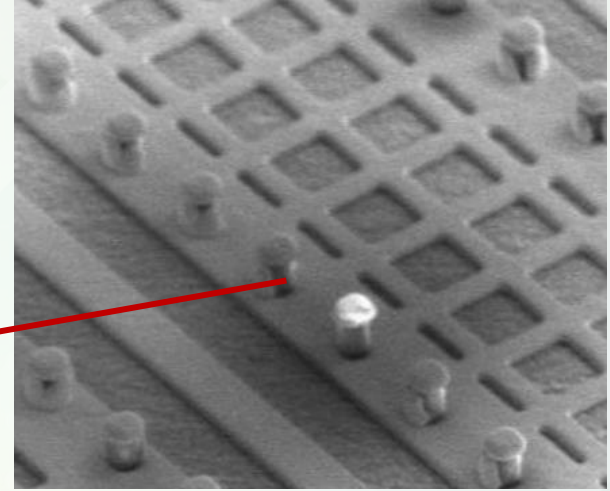
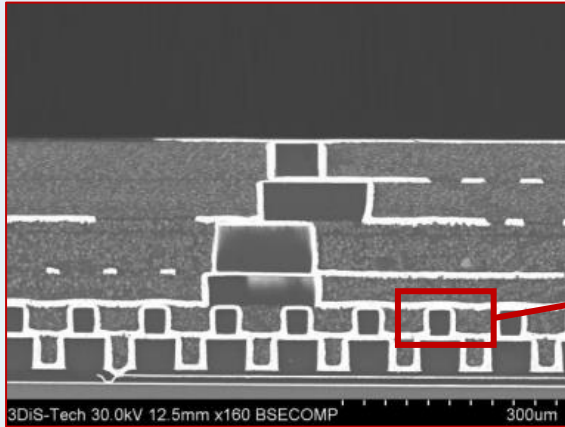
Schematic and cross section SEM of similar example



Thanks to Ayad Ghannam of 3DiS for providing the sample and SEM images

3DiS - 3D-RDL & HDc-TPV

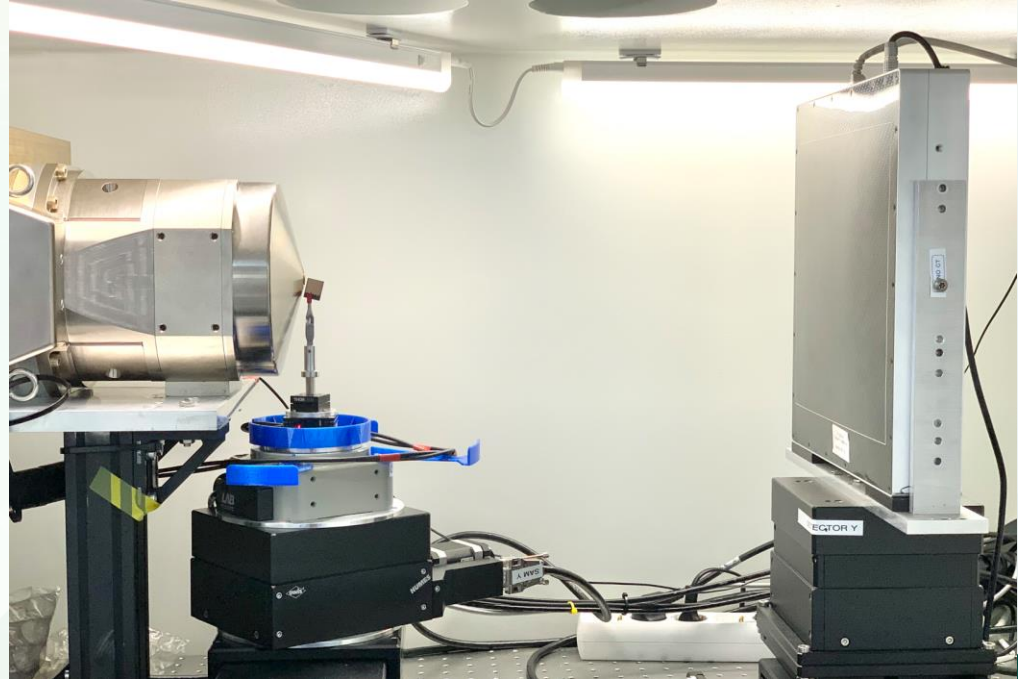
SEM image of one of the layers



Thanks to Ayad Ghannam of 3DiS for providing the sample and SEM images

3D X-ray setup

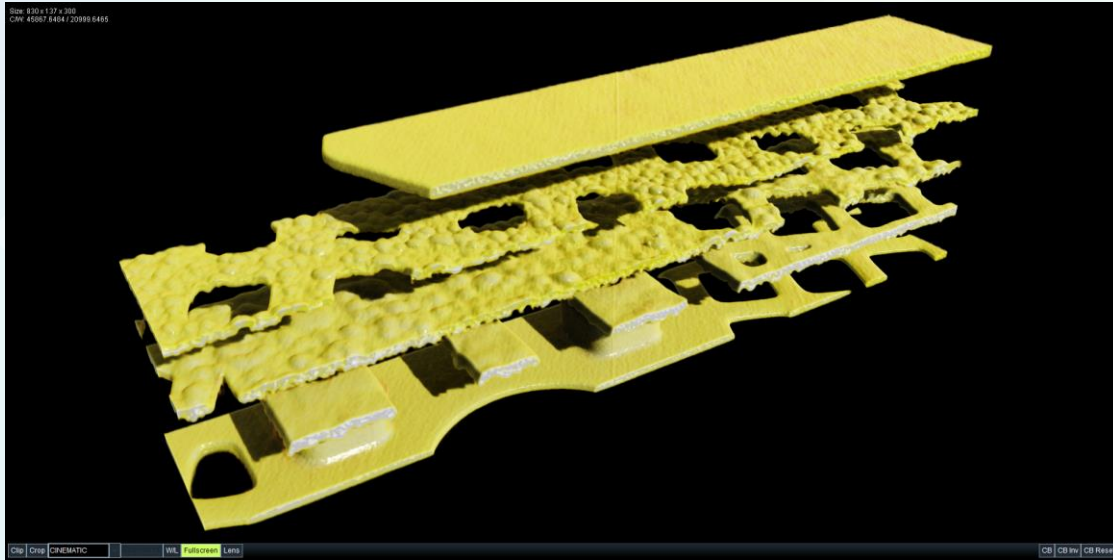
- Source: Excillum N3
 - 40-160 kV
 - 300-2000 nm spot size
- Detector: Spectrum Logic 2844HS
 - CMOS flat panel
 - 600 μm CsI scintillator
 - 100 μm pixel size
 - 2803 x 2401 sensor size
- Rotation stage: LAB RT100S
 - Precise air bearing stage



Thanks to Ayad Ghannam of 3DiS for providing the sample and SEM images

3DiS - 3D-RDL & HDc-TPV

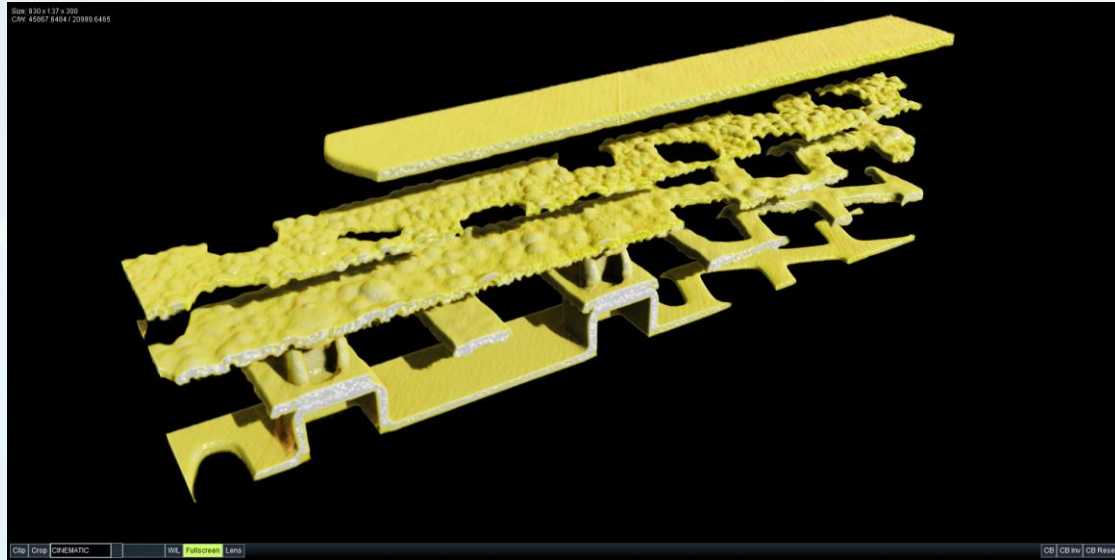
Non-destructive 3D X-ray



Thanks to Ayad Ghannam of 3DiS for providing the sample and SEM images

3DiS - 3D-RDL & HDc-TPV

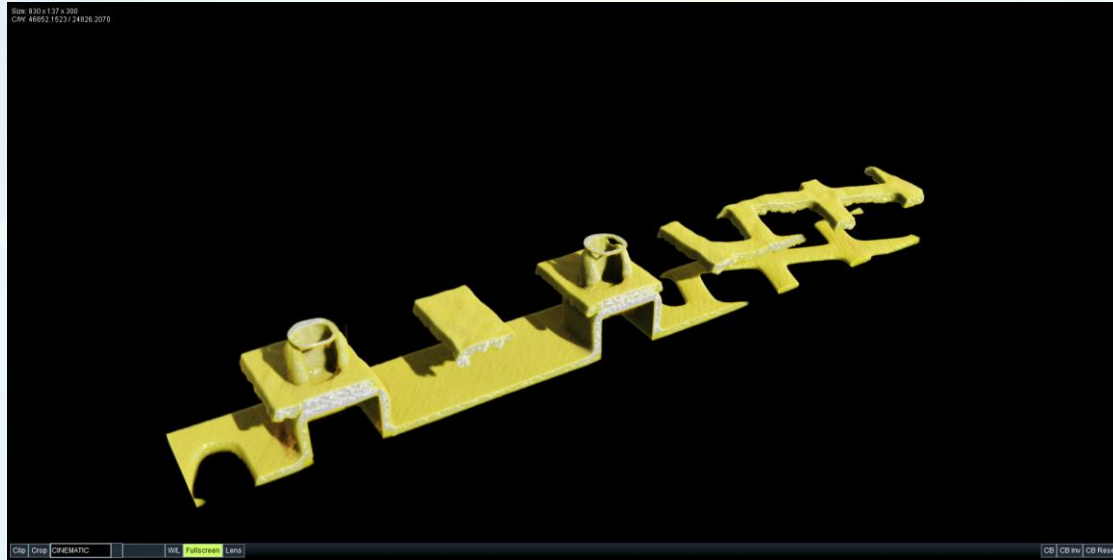
Non-destructive 3D X-ray



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3DiS - 3D-RDL & HDc-TPV

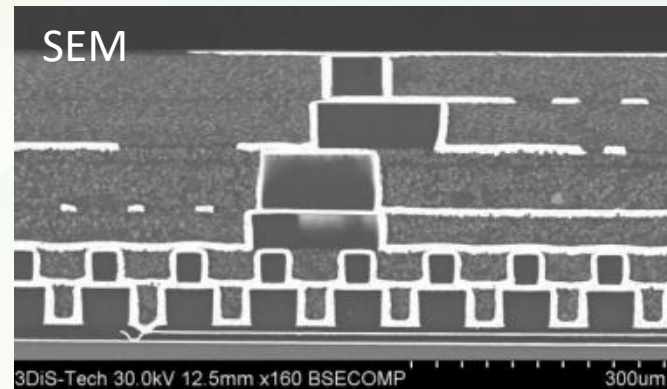
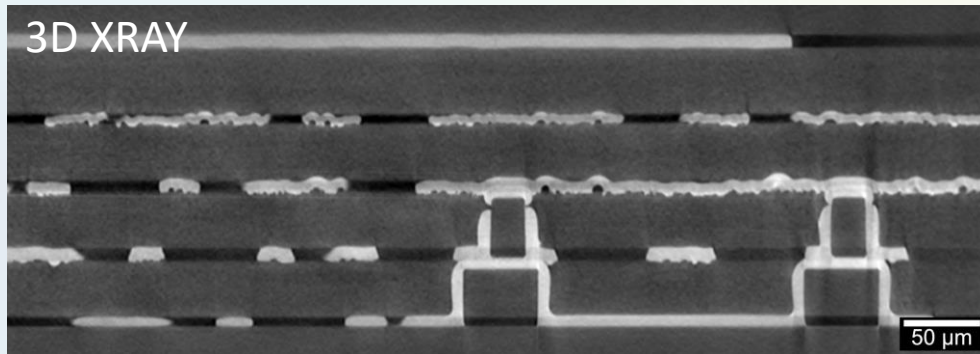
Non-destructive 3D X-ray



Thanks to Ayad Ghannam of 3DiS for providing the sample and SEM images

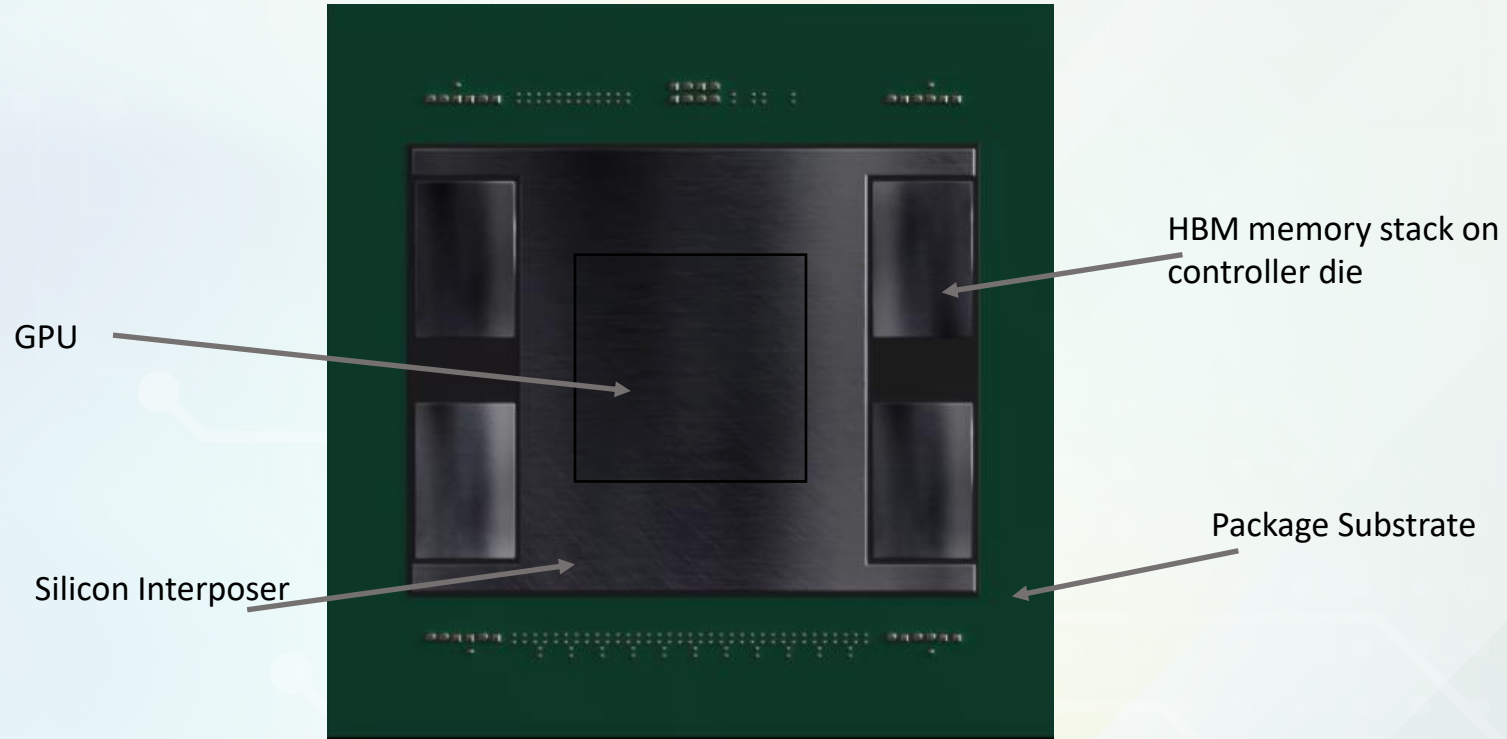
3DiS - 3D-RDL & HDc-TPV

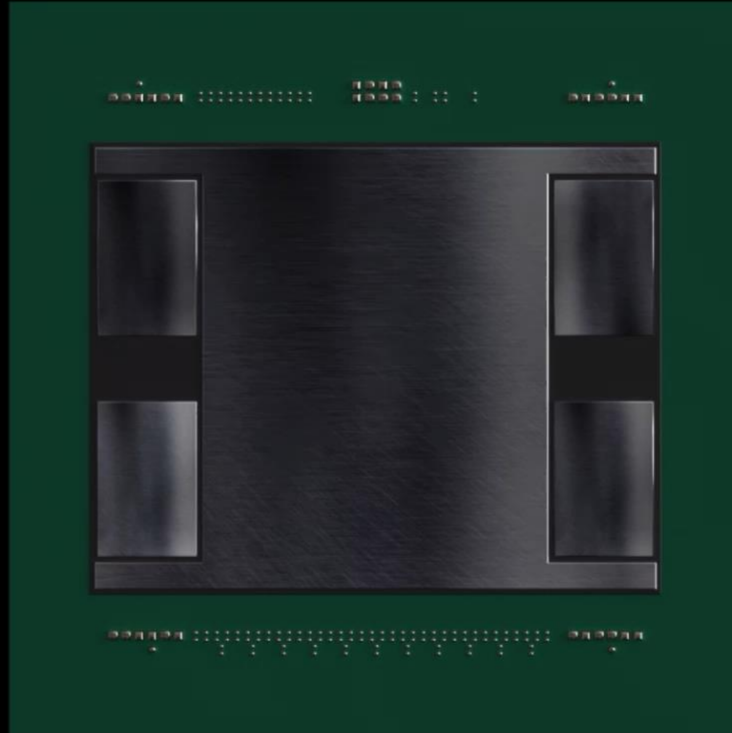
Non-destructive 3D X-ray (virtual slice) and SEM comparison



Thanks to Ayad Ghannam of 3DiS for providing the sample and SEM image

Commercial GPU with HBM memory stack

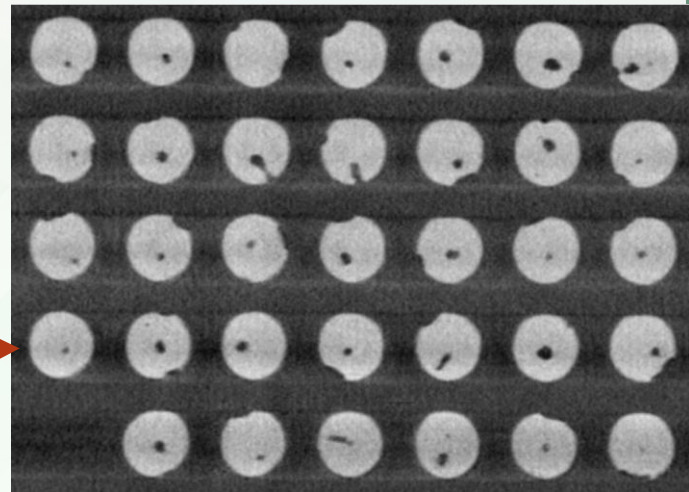
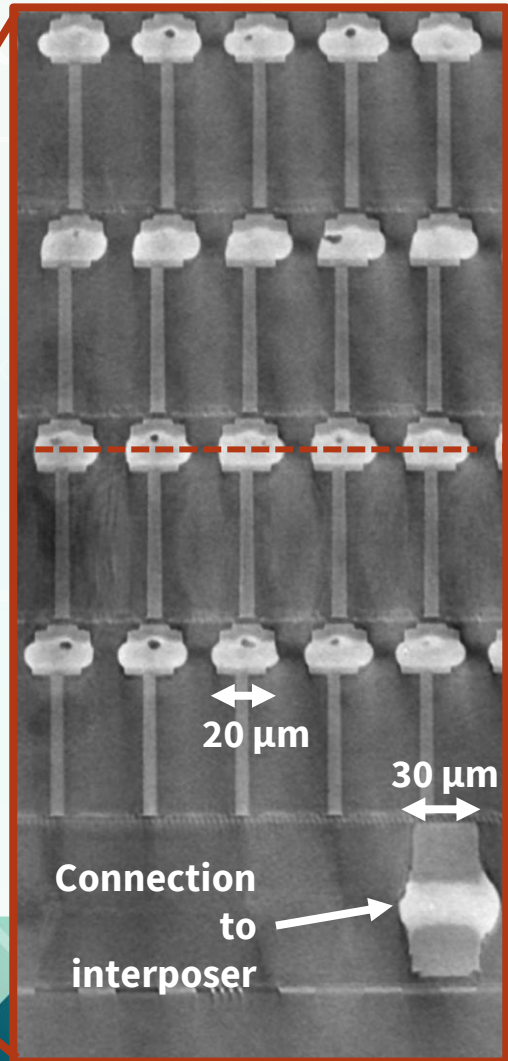
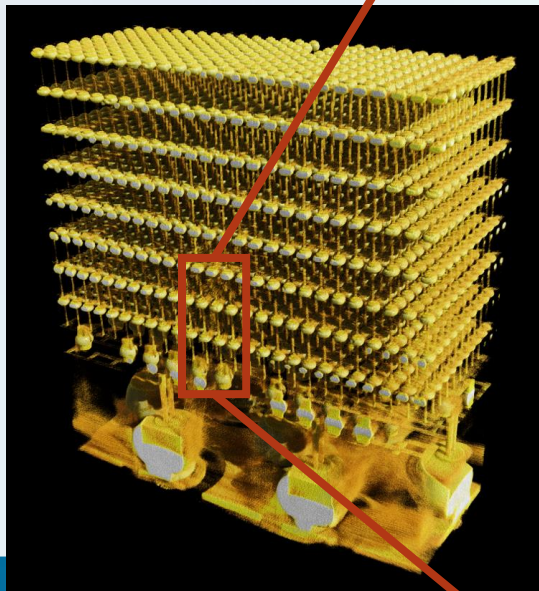




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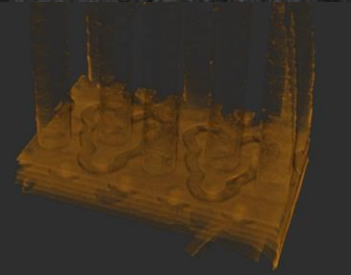
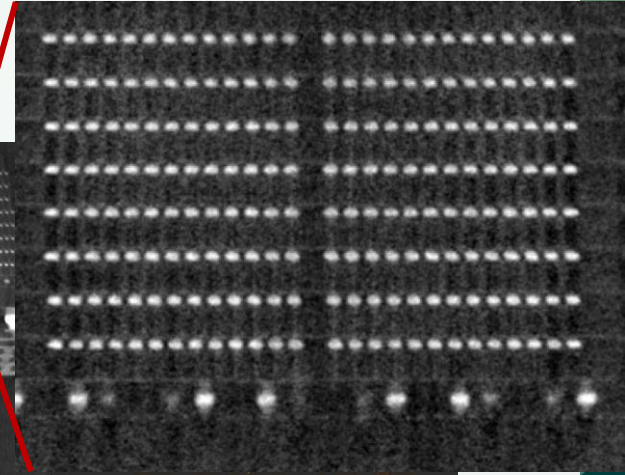
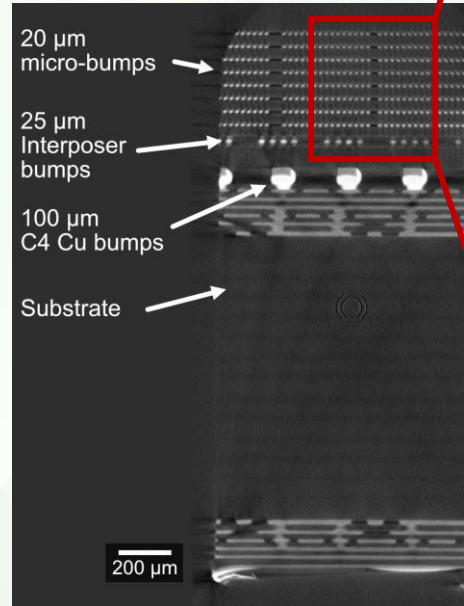
Zoom in

- 4 layers of micro bumps and 7SV in the HBM2 memory.



Fast measurements of HBM stacks

- Geometry
 - SOD = 5.8 mm
 - SDD = 444 mm
 - $M = 76.55 \rightarrow p_{eff} = 2.6 \mu\text{m}$
- Source
 - 80 kVp
 - 2 μm x-ray spot
- Acquisition
 - 900 projections
 - 33.3 ms exposure
 - 12 deg/s continuous rotation
- **→ 30 s scan time!**



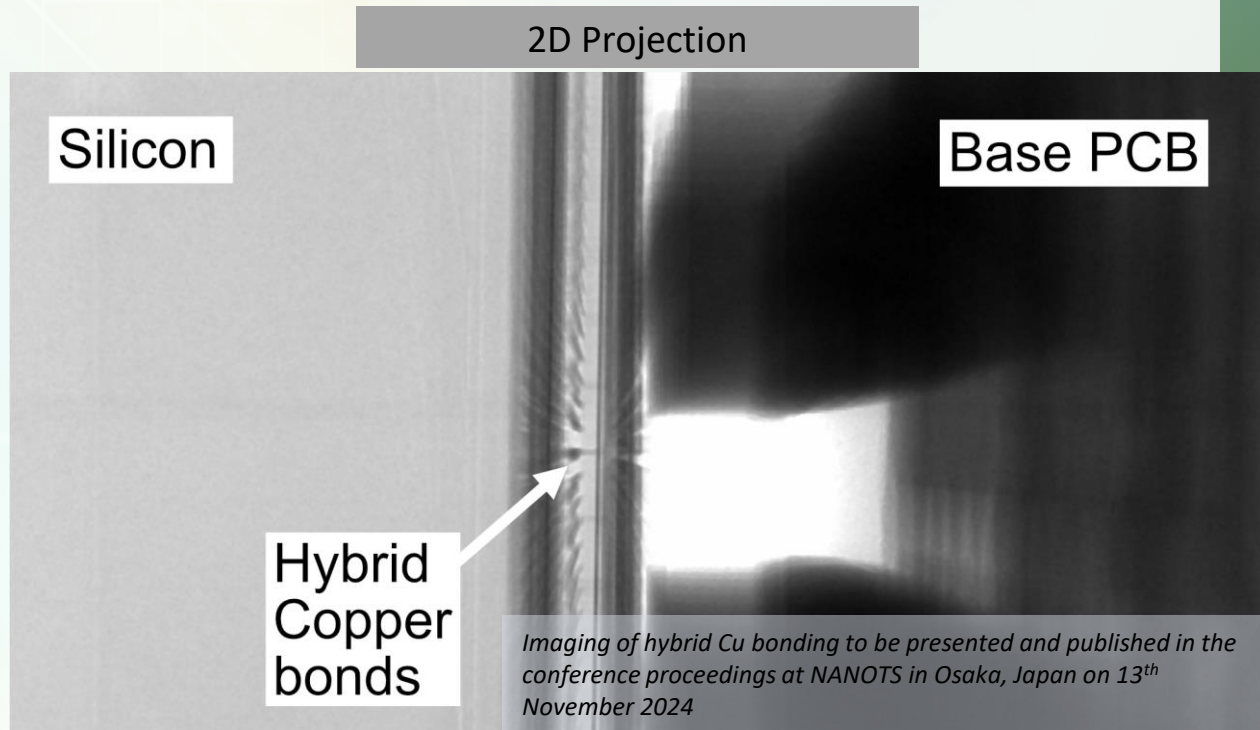
MLCC – Multi-Layer Ceramic Capacitor

0402 capacitor, 1000 pF
(400x200 μm)

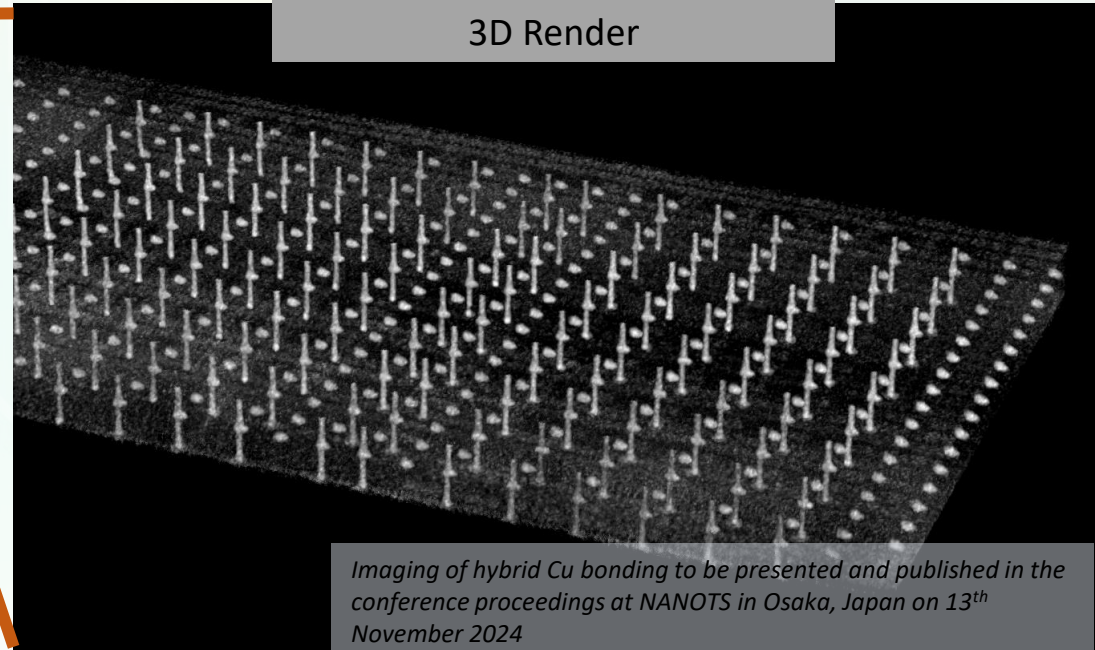
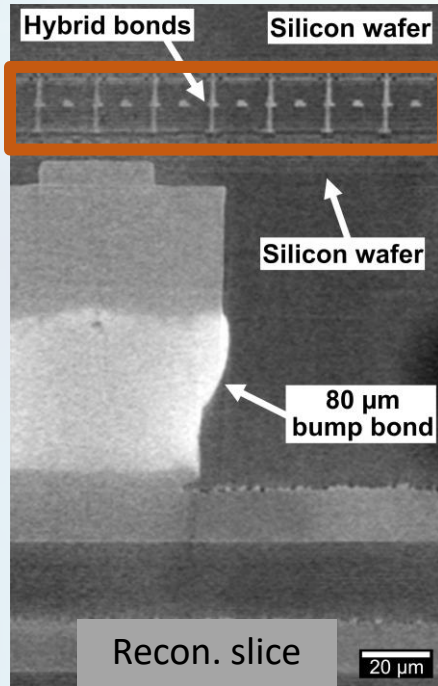


Hybrid Copper Bonding

- AMD Ryzen 7 5800X3D
- Hybrid bonds
 - 1.5 μm diameter
 - 9 μm pitch
 - 15 μm length
- CT scan
 - 300 nm voxels
 - 6 h scan time



Hybrid Copper Bonding (cont'd)



Conclusions



Highest resolution X-ray measurements



Highest power per spot size for fast measurements



Optimised X-ray source for lowest dose



Want to learn more about X-ray?

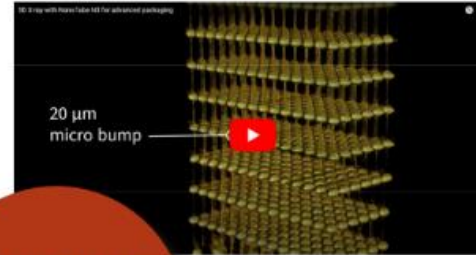
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- Articles
- User stories
- Application examples
- And more...

Watch video

3D X-ray for advanced packaging



Interested in
a demo?
Contact us!

Acknowledgement

HiCONNECTS has received funding from Chips Joint Undertaking (Chips JU) under grant agreement No 101097296. Chips JU receives support from the European Union's Horizon Europe research and innovation programme and Austria, Italy, Germany, Netherlands, Israel, Finland, Switzerland, Hungary, Sweden, Turkey, France, Denmark and Romania.



**Co-funded by
the European Union**



Thank you for your attention!

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