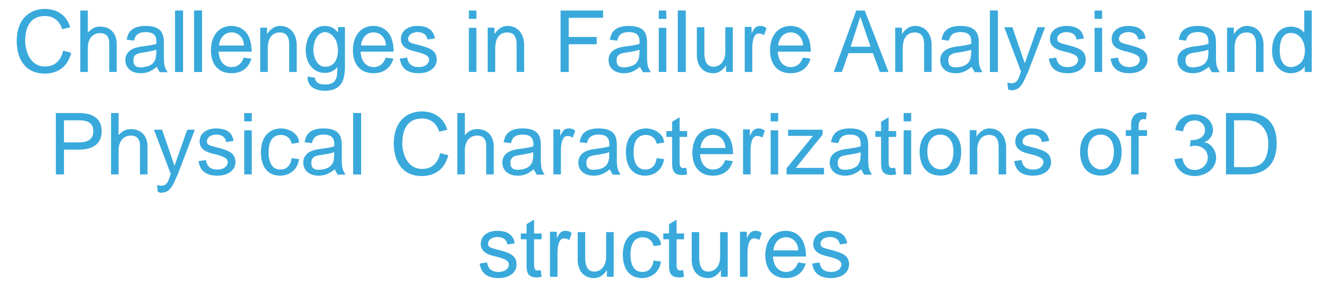

Challenges in Failure Analysis and Physical Characterizations of 3D structures

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3DAM Workshop,

Minatec - Grenoble

15/03/2019

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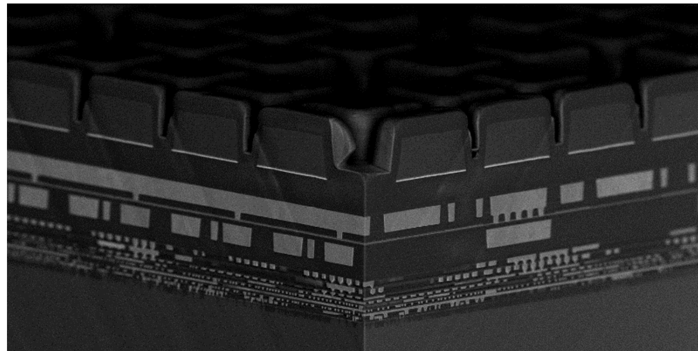
Outline

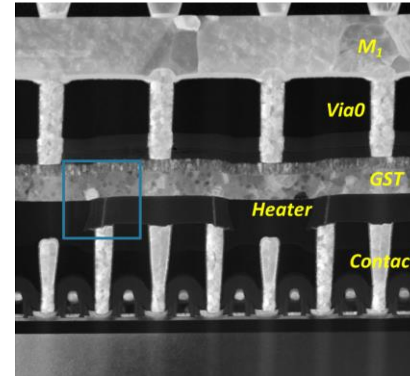
- 3D sample management for physical failure analysis
- FIB/SEM tomography for 3D metrology
- E-tomography for nm scale 3D imaging

About ST Physical charac. Lab @ Crolles

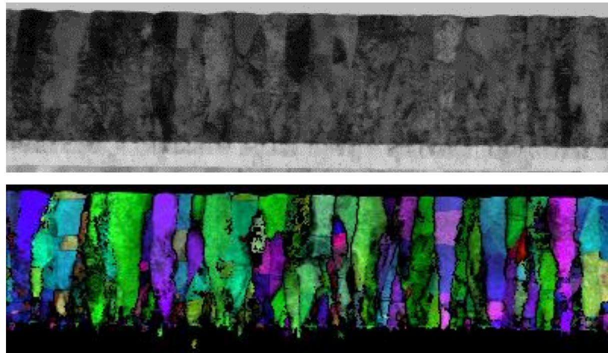
large portfolio for routine analysis



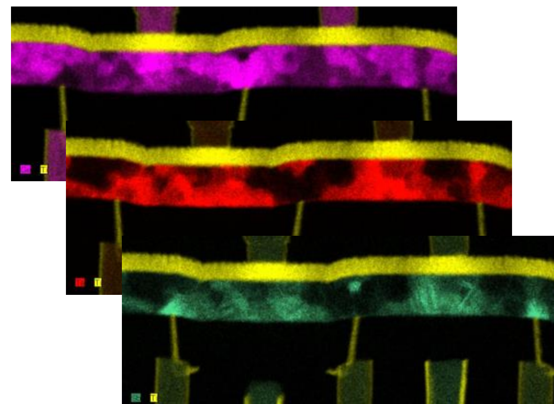
SEM imaging - 28FD stack



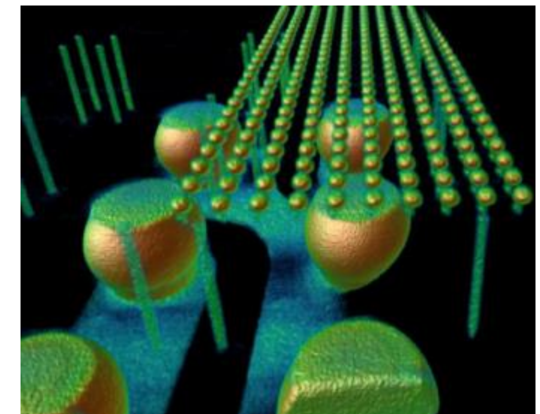
STEM imaging – PCM stack



Texture analysis in TEM



Chemical mapping STEM/EDX
PCM



X-ray tomography
Package (TSV & solder bumps)

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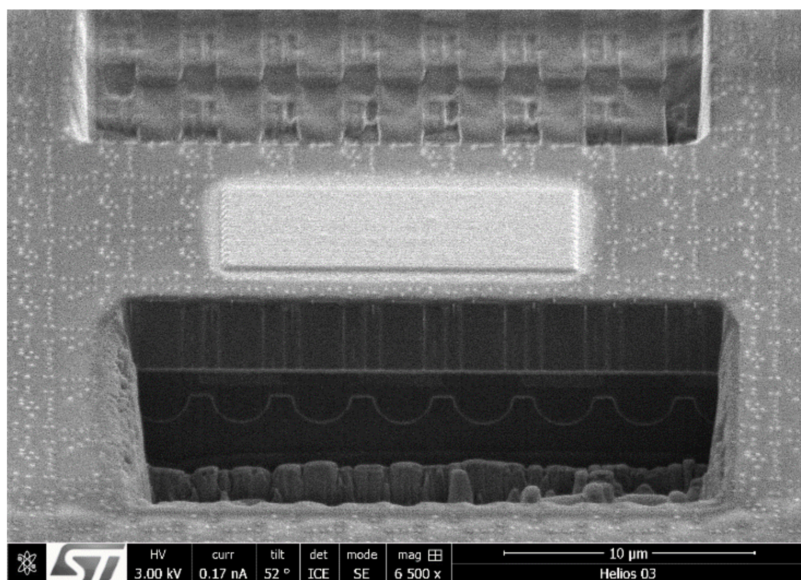
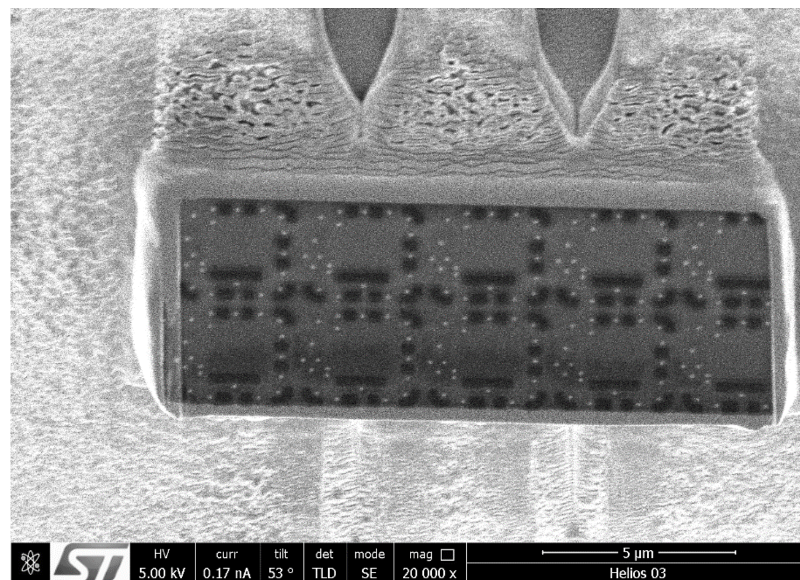
Multiple orientation analysis & combined analyses *case of dopant issue*

- Starting point : known failing device localization from FA (nanoprobing)
- Sample prep. : sample lifted excavated from wafer & top-down lapping with FIB



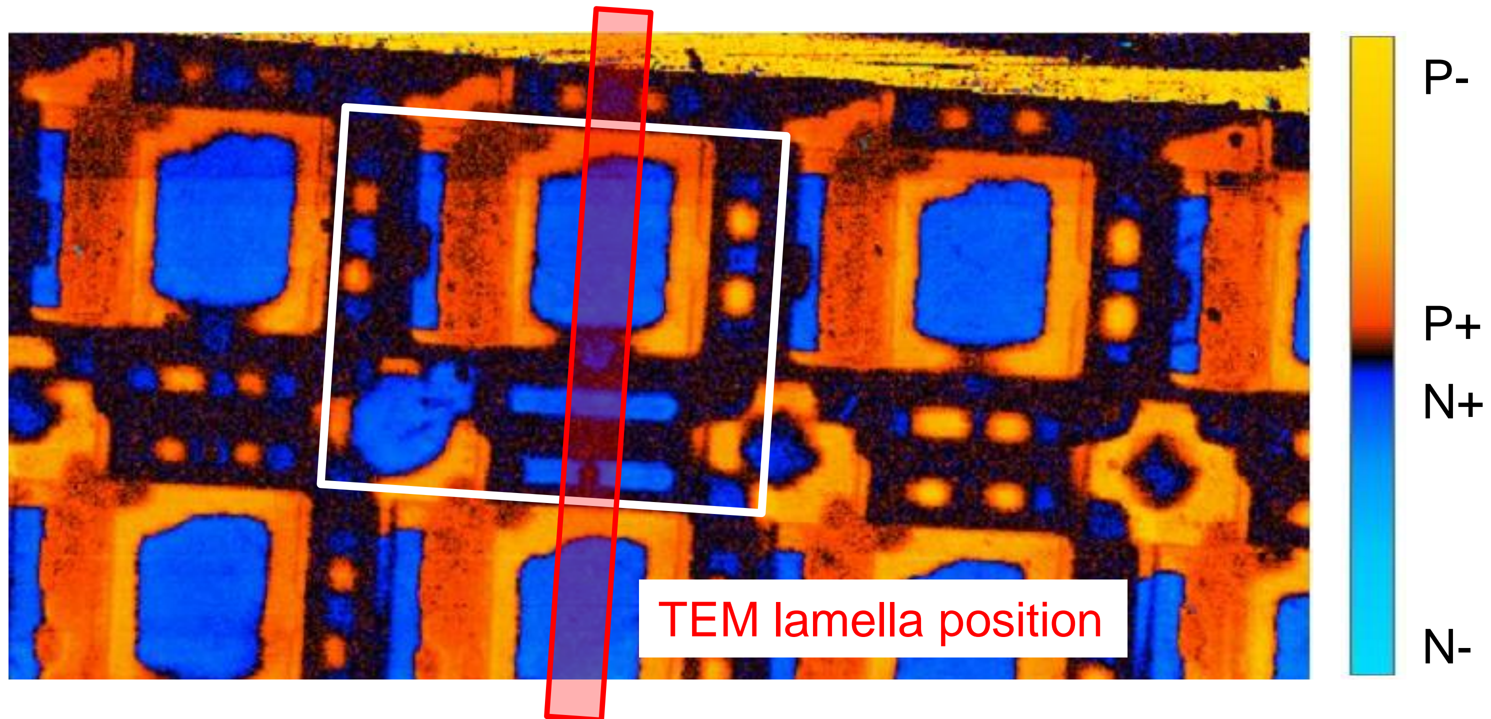
Region of interest extraction



FIB lapping down to Silicon

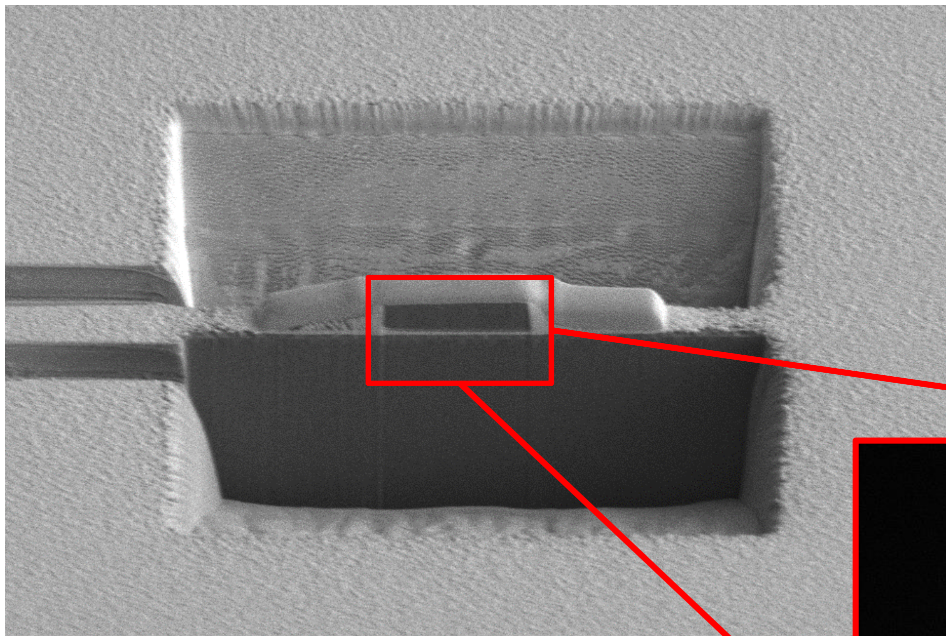
Multiple orientation analysis & combined analyses
case of dopant issue

- Dopant mapping performed using SCM (AFM based technique)



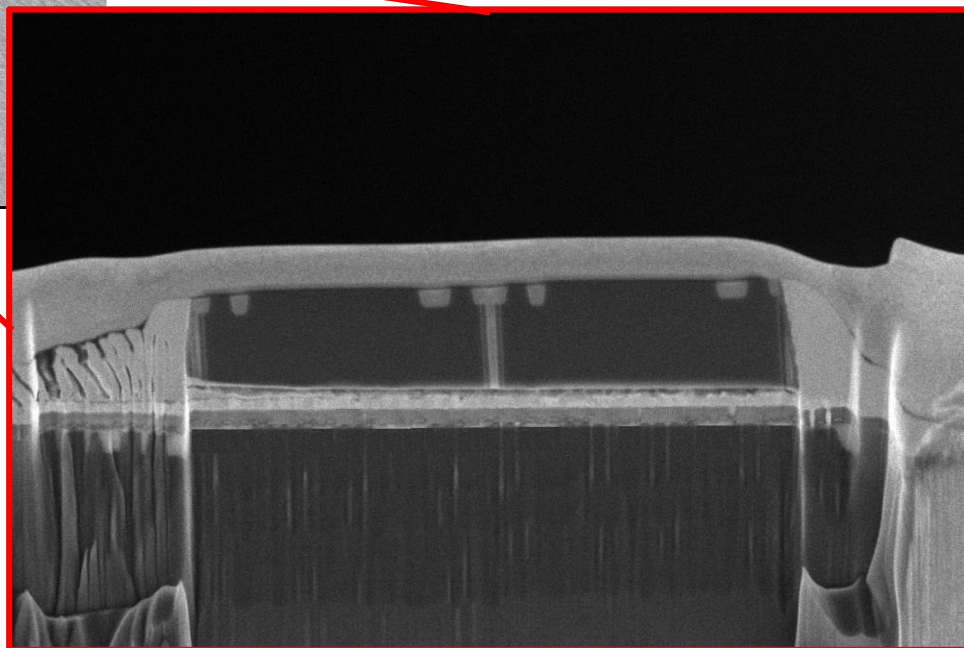
- In plane analysis not sufficient for root cause understanding
  ➔ need transverse analysis

Multiple orientation analysis & combined analyses
case of dopant issue



FIB prep. from SCM stamp…

… to TEM lamella



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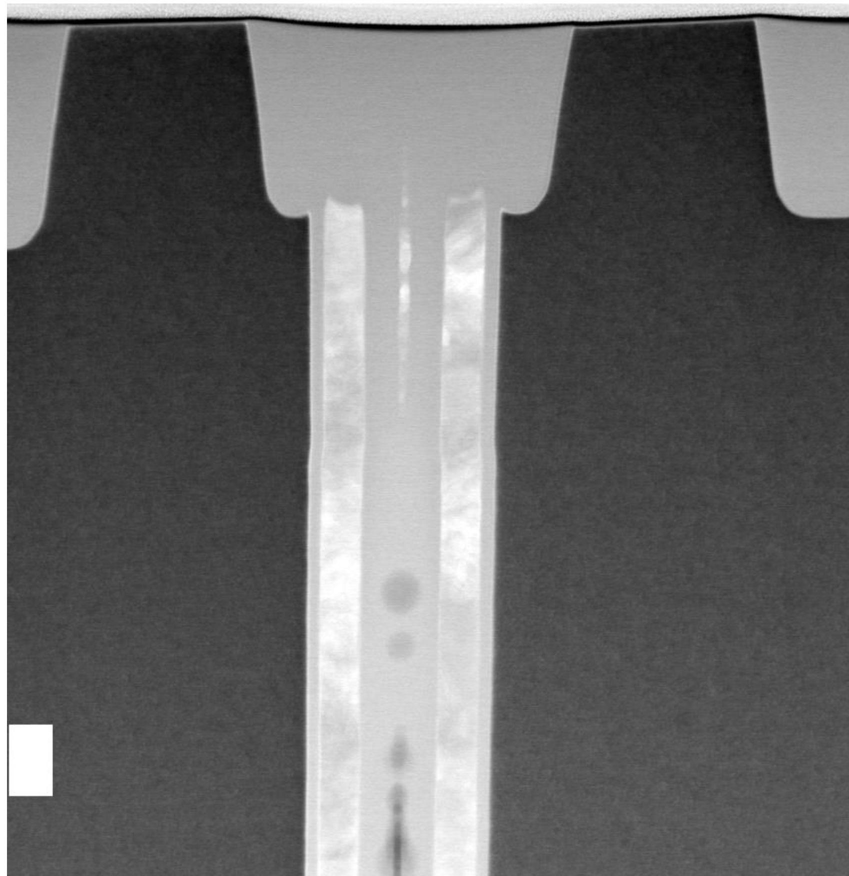
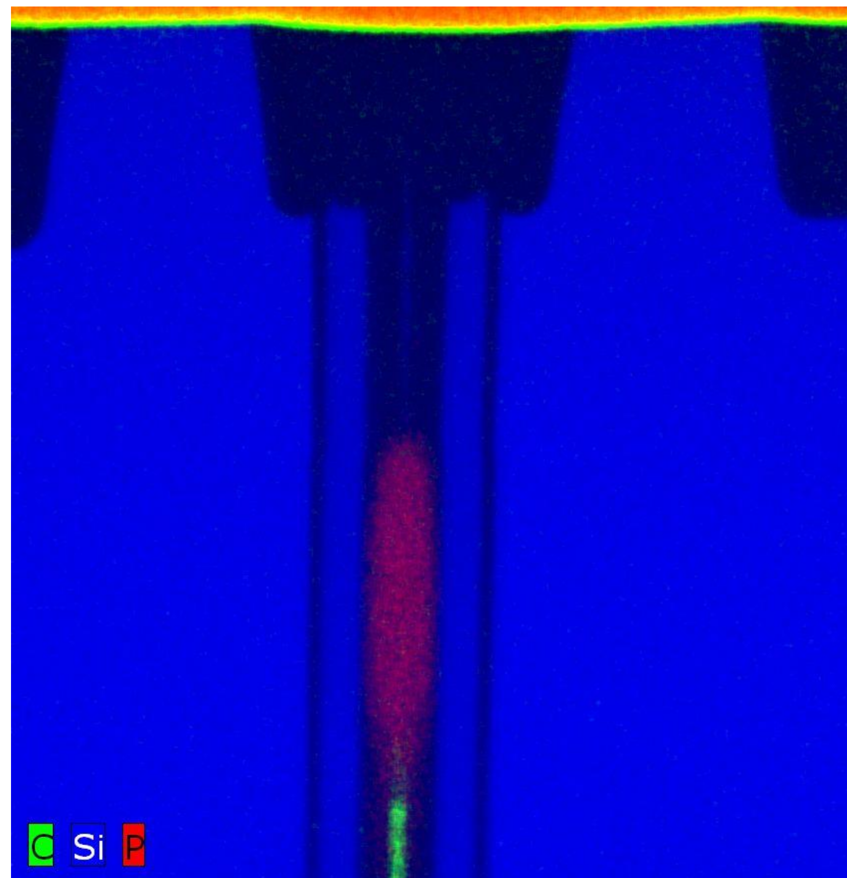
Multiple orientation analysis & combined analyses *case of dopant issue*

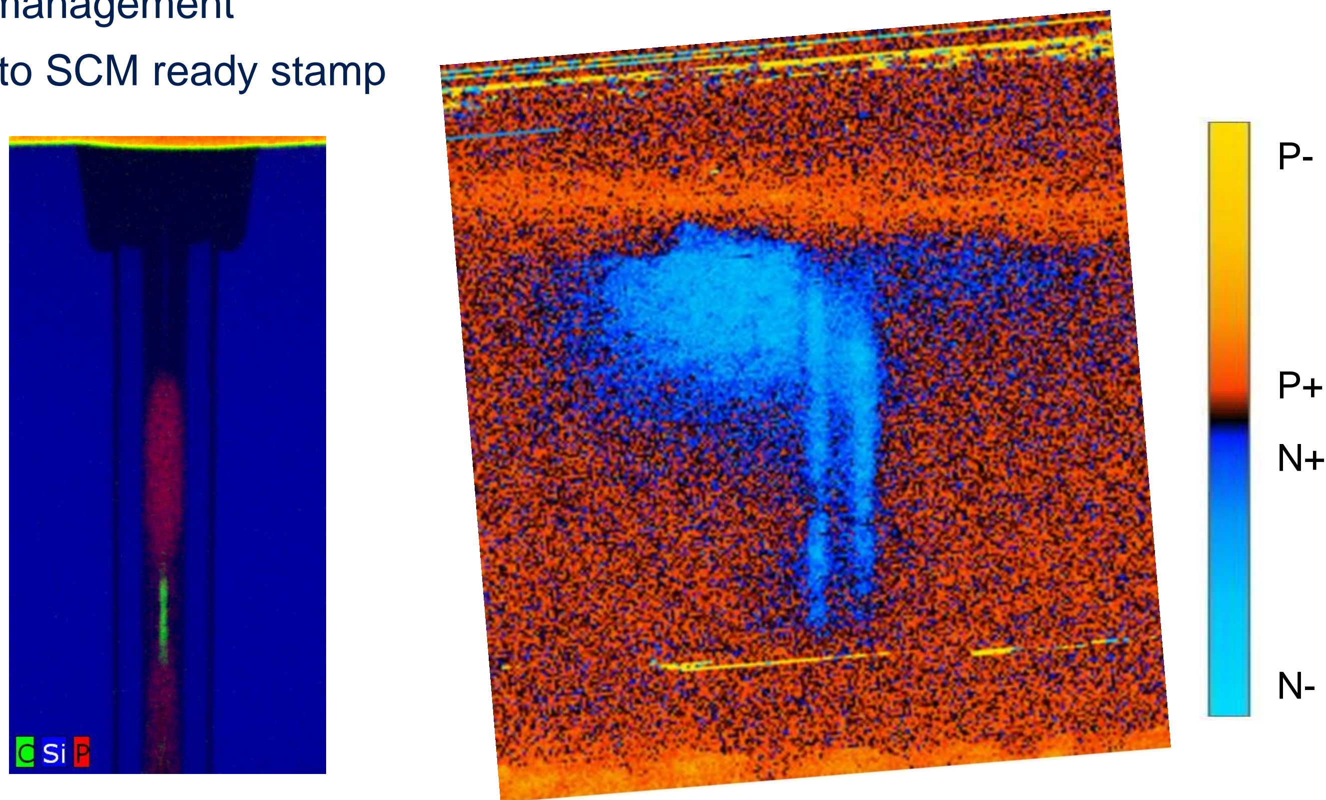




STEM EDX mapping revealing abnormal P contaminant
No electrical fail evidence yet

Multiple orientation analysis & combined analyses *case of dopant issue*

- Additional sample management
- From TEM lamella to SCM ready stamp



- Evidence of electrical fail issue

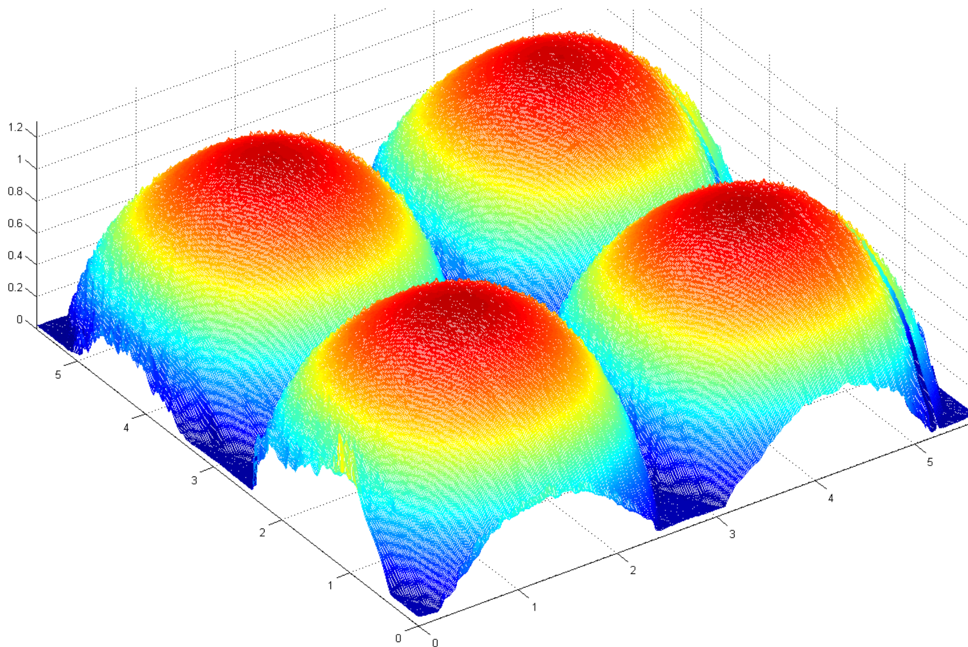
- **Need for a 3D approach/specimen mgt for root cause understanding**

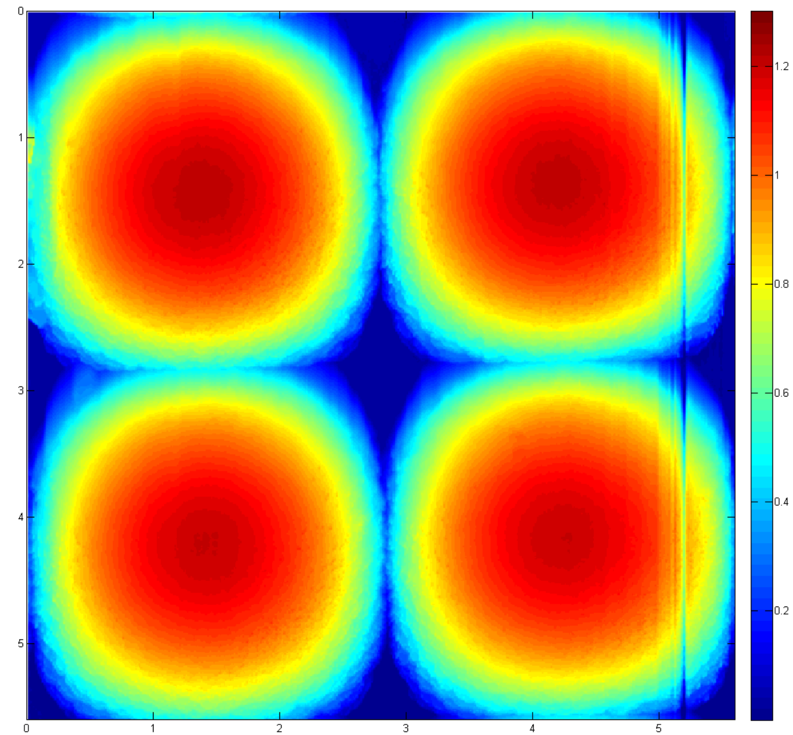
FIB/SEM 3D for 3D metrology

case of microlenses

- Microlenses
  - in imaging/pixel architecture
  - Shape of importance to determine photons path
  - Conventional technique for topography: AFM

Topography map obtained with AFM





- Questions about AFM results accuracy;
  needed for photons path simulation

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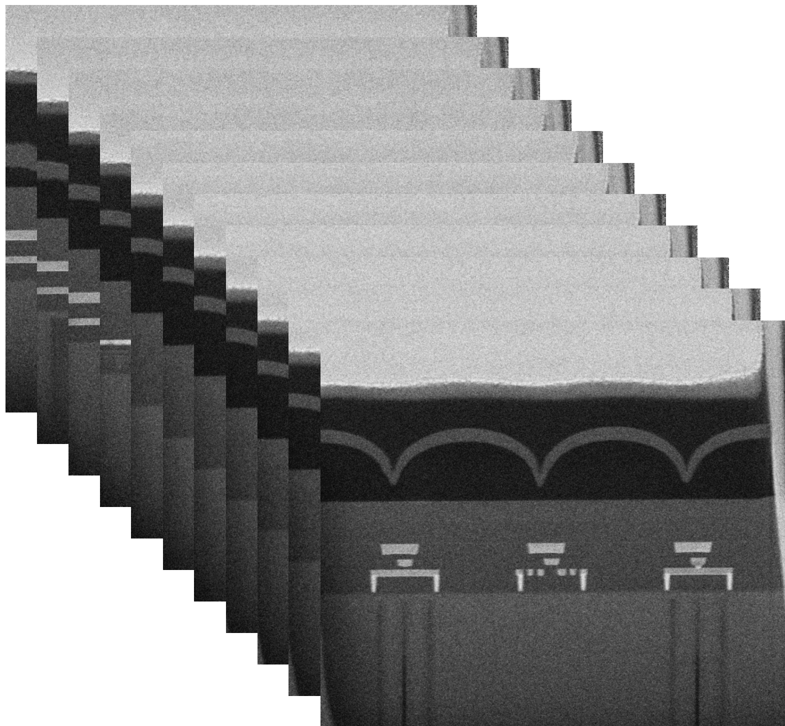
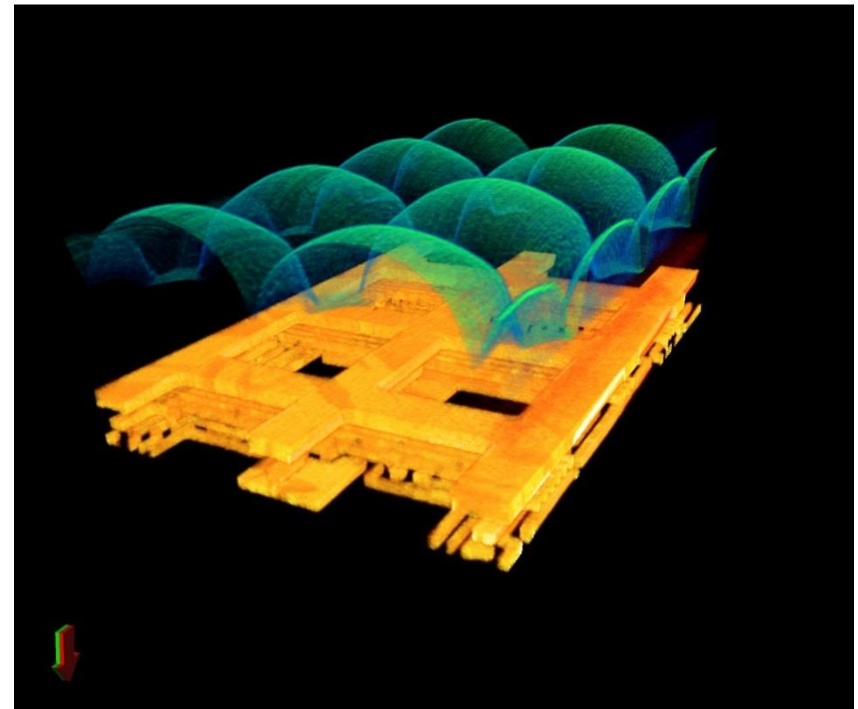
FIB/SEM 3D for 3D metrology

case of microlenses

µ-lens slicing and SEM imaging



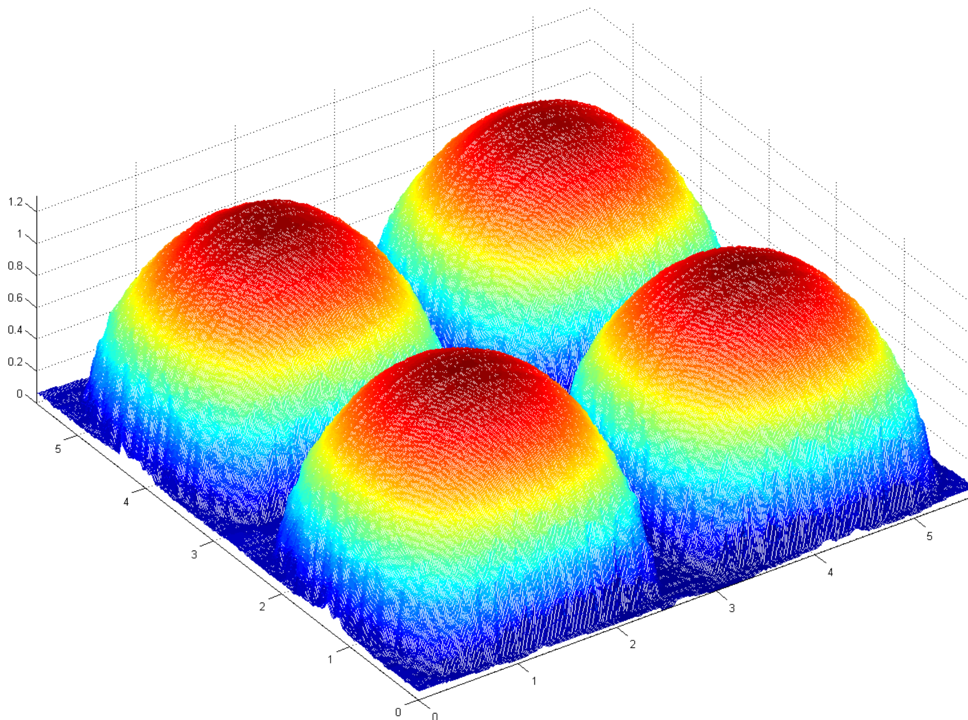
Pixel architecture volume rendering

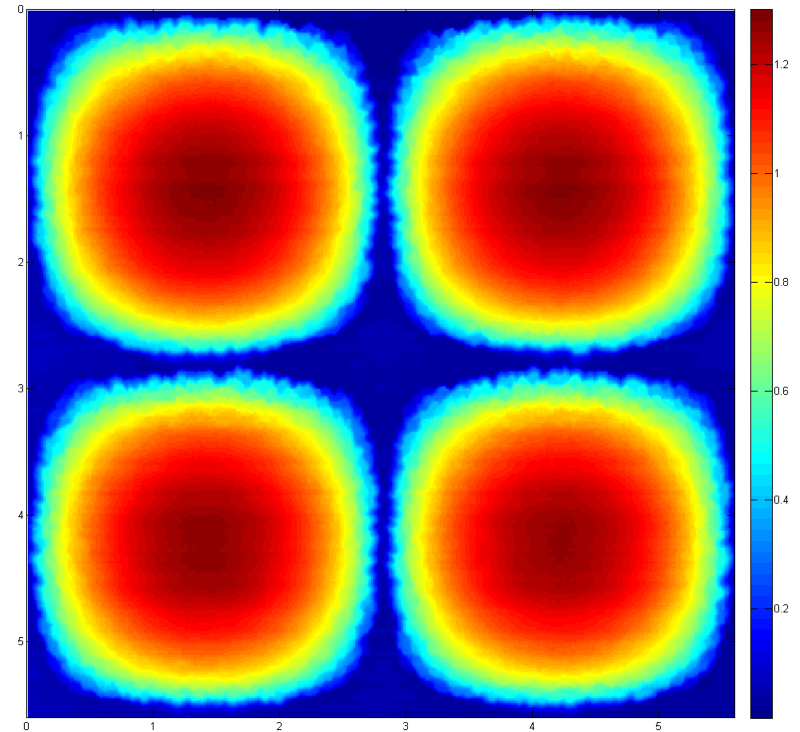


F/S3D acquisition : in routine analysis
Deployment to team

FIB/SEM 3D for 3D metrology
case of microlenses

- Elevation mapping from FIB/SEM 3D
  - Obtained after segmentation
  - Script to provide AFM format results

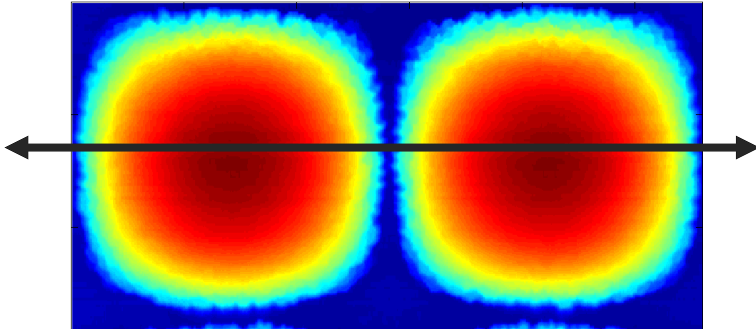




FIB/SEM 3D for 3D metrology

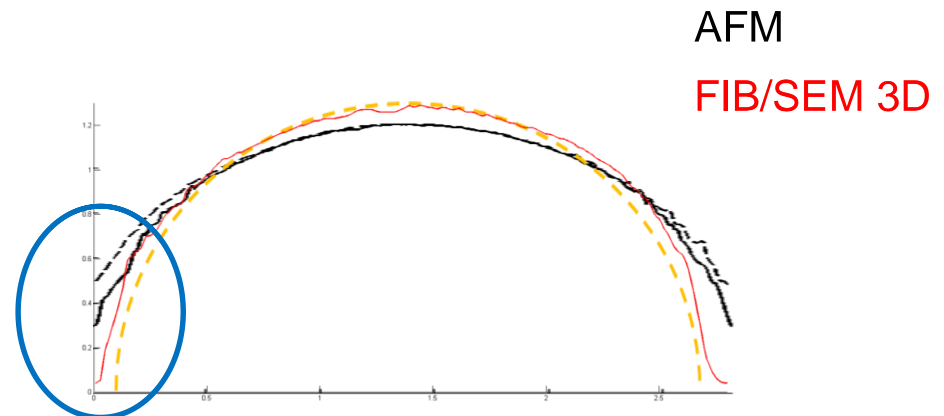
case of microlenses

- AFM to FIB/SEM 3D comparison



AFM

FIB/SEM 3D

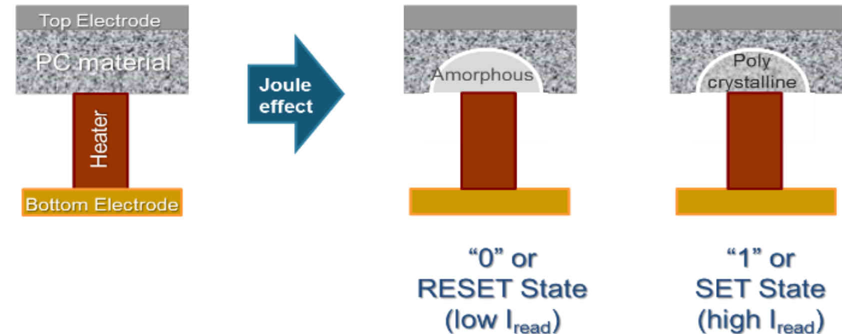


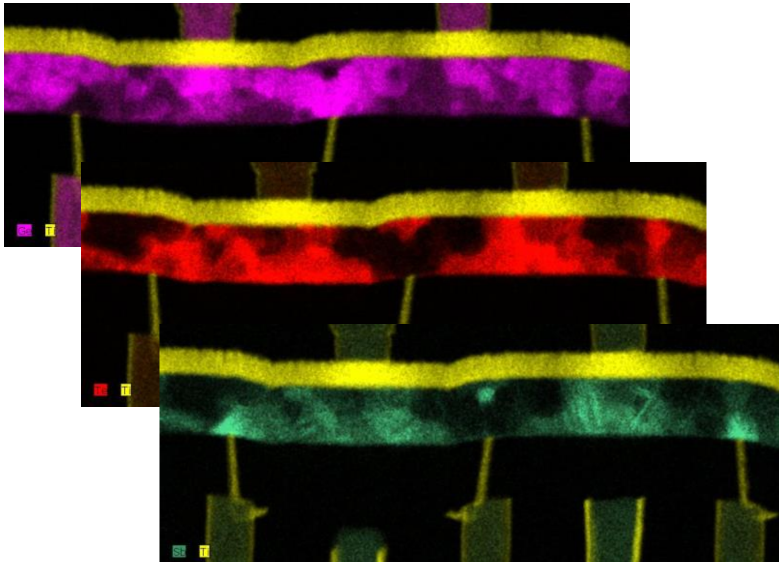
- Improvement of topography definition between lenses

- Need for 3D metrology
- 3D approach required for charac. accuracy

E-tomography for nm scale 3D imaging
case of GST compound density variation

- PCM architecture
  - Material with 2 distinct resistive states



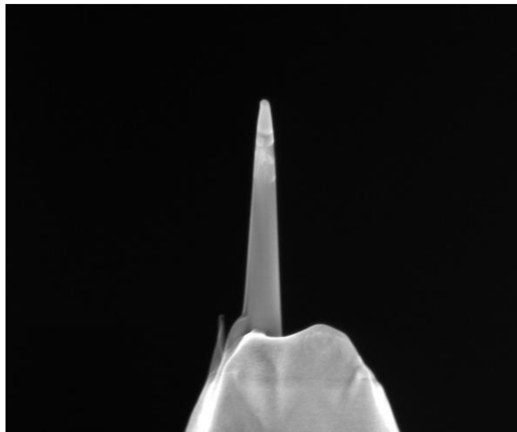


- Layer
  - $Ge_xSb_yTe_z$
  - Poly-crystal sample
  - Grains size & distribution ➔ influence on device behaviour properties

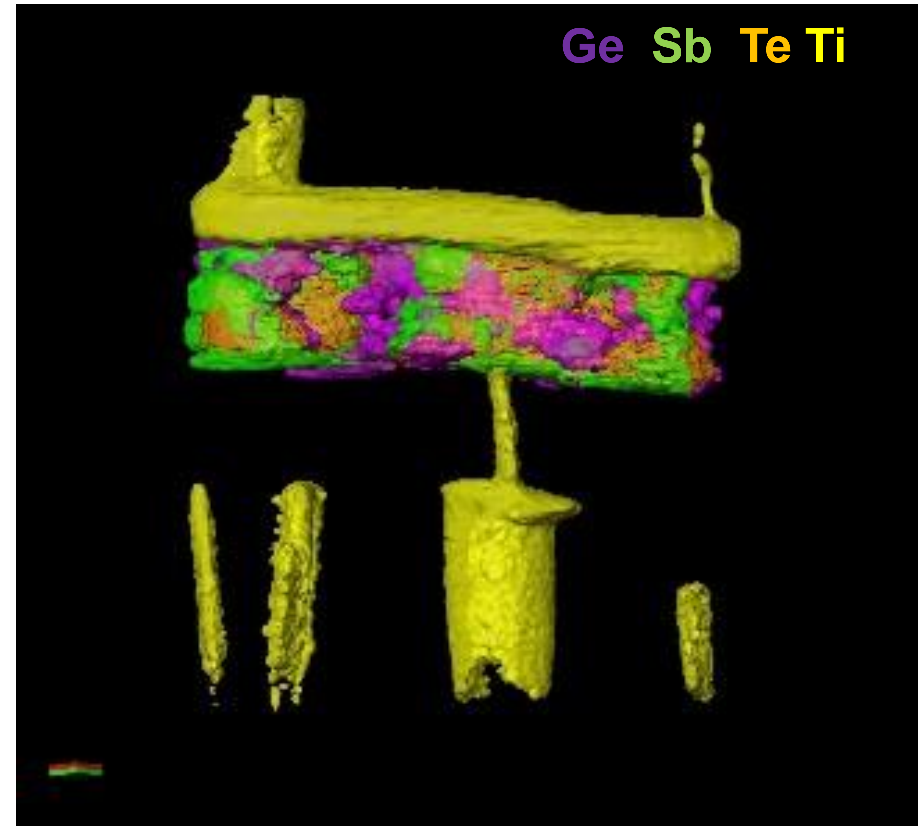
- Elemental mappings overlapping over TEM lamella thickness ➔ need for local information

E-tomography for nm scale 3D imaging
case of GST compound density variation

- FIB prepared probe

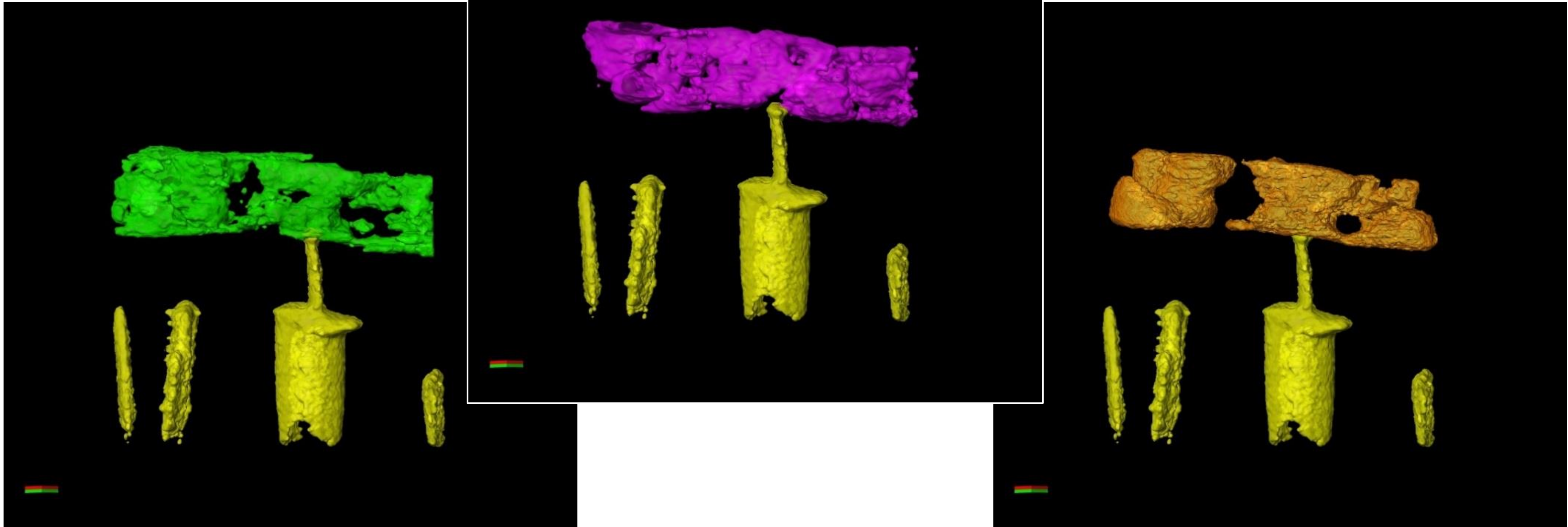


- STEM-EDX electron tomography
  - Manual mappings acquisition
  - Every 10° step, 180° range
  - Long data treatment (engineering)



Volume rendering

E-tomography for nm scale 3D imaging
case of GST compound density variation



- Individual species distribution within PCM layer can be analyzed

- 3D need for complex material analysis

conclusions

- 3D approach and/or analyses required for IC development
  - Ready for industrial support or still engineering mode
- For all techno nodes
  - From packages to µm scale device, down to advanced scale (nm) nodes
- Still complex techniques
  - Sample prep.
    - Sample management /orientation for successul analysis
    - Can become (very) difficult when dealing with a specific device
  - SW / scripting needs
    - For data acquisition, data extraction, data management