New Scanning Acoustic Microscopy Technologies Applied to 3D Integration Applications

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Outline

1. Potential of SAM

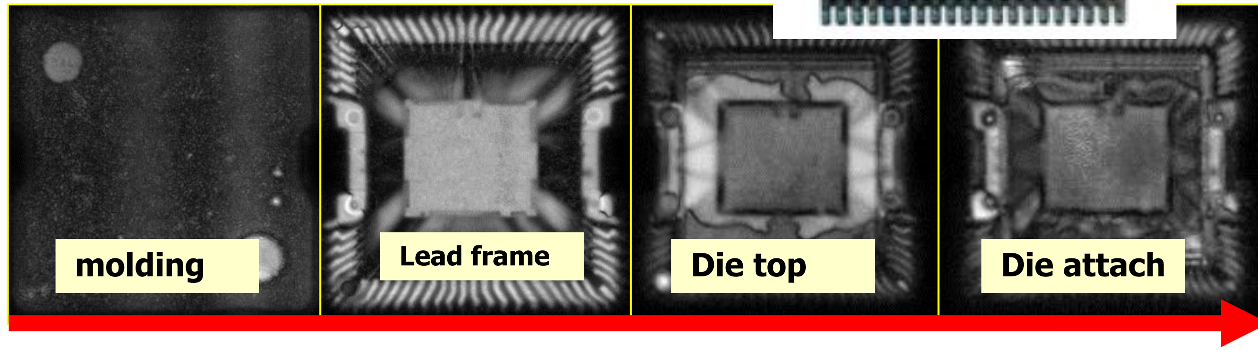
2. SAM analysis set-up

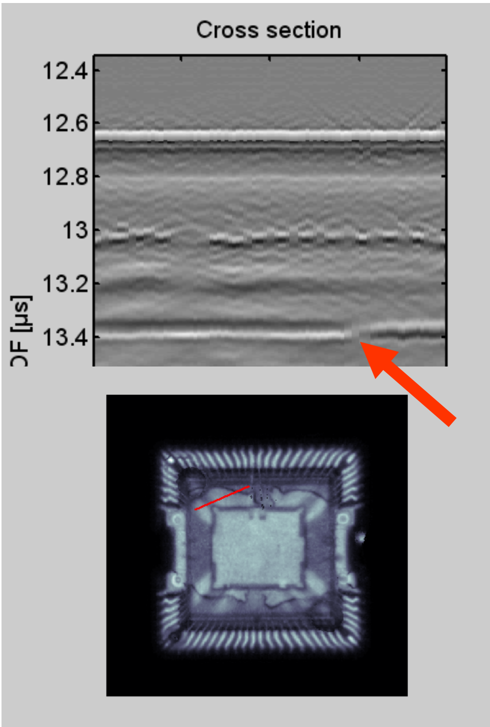
3. SAM analysis examples:
   Stack dies, micro bumps, c4 bumps
   FC/PBGA: chip underfill-underfill/laminate/ILD delam
   TSV`s, FIB cross sections

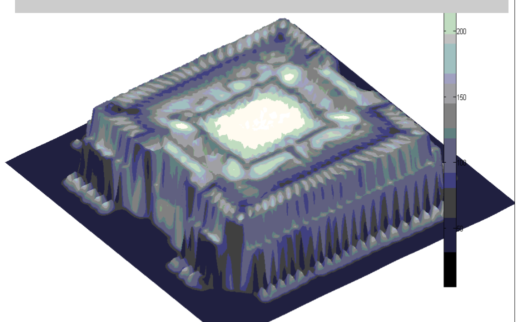
4. Summary

1. Potential of SAM (Scanning Acoustic Microscopy)

Potential of Scanning Acoustic Microscopy



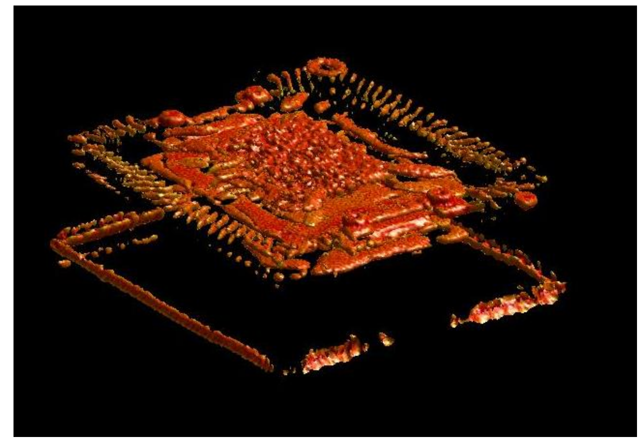




-non-destructive investigations from top to bottom

- non-destructive cross-sectioning
- high axial- and lateral resolution, depending on frequency
- **fast 3D-imaging and analysis**

-estimation of E modulus, G modulus and Poission ratio



2. SAM analysis set up

Transducer manufacturing equipment: Improve resolution and image quality

HF- sputter equipment,

-Turbo pump 750 l

-Start vacuum 1x10-6 mbar

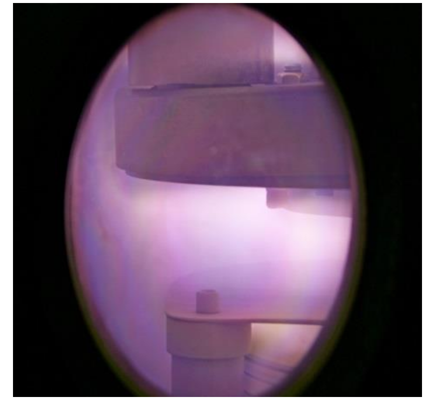
-Sputter rate 1 µm/h

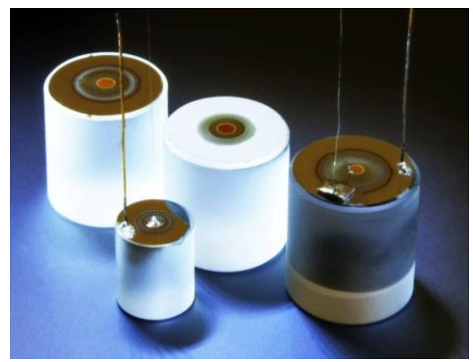
-Process gas Argon/ dioxyn

-Target ZnO 4 zoll

-Sputter capacity 0-500 Watt

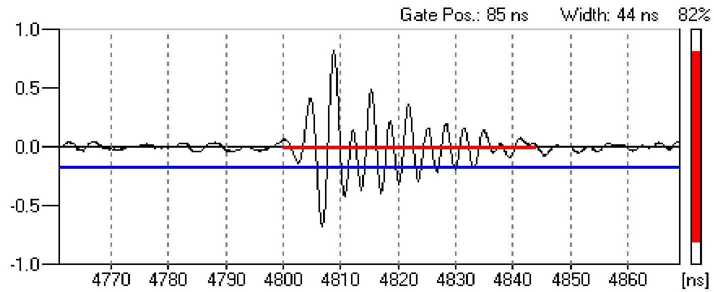
-Process parameters programmable

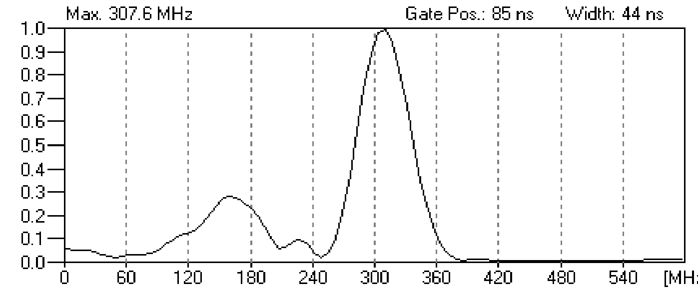




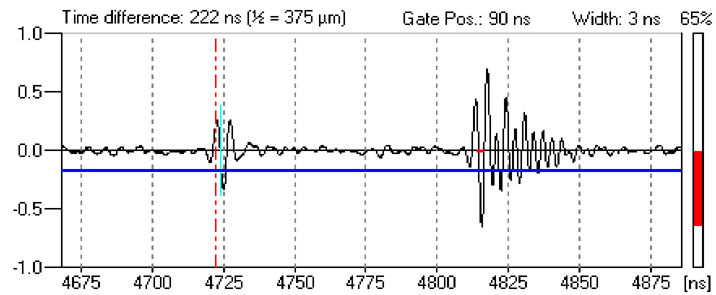
Spectral response from the different interfaces of a 370 µm die (thickness)

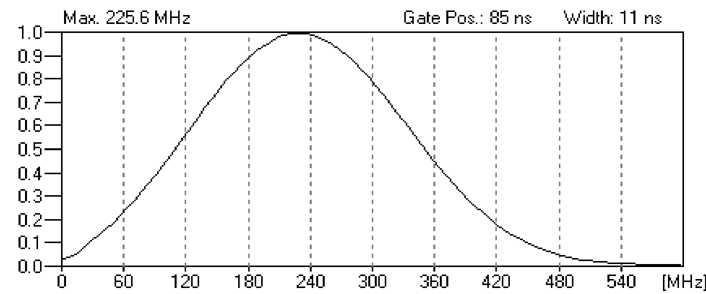
Spectrum of the full signal: 1st and 2nd interface



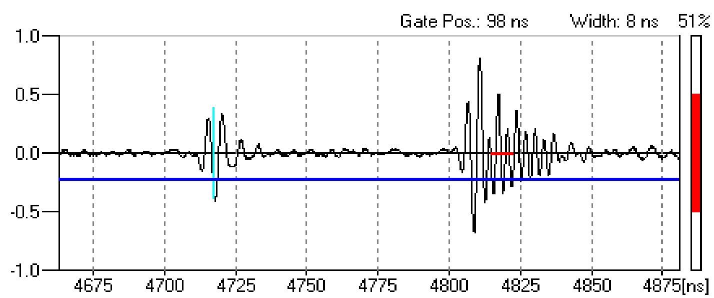


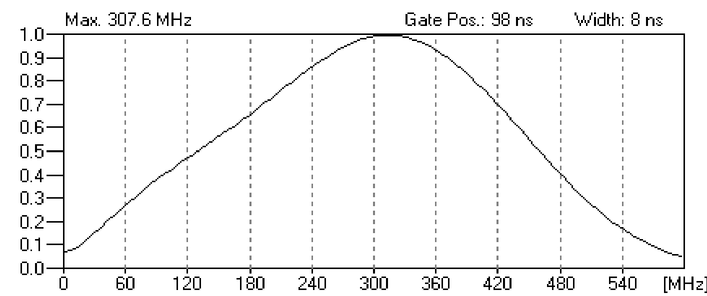
Spectrum of the 1st interface



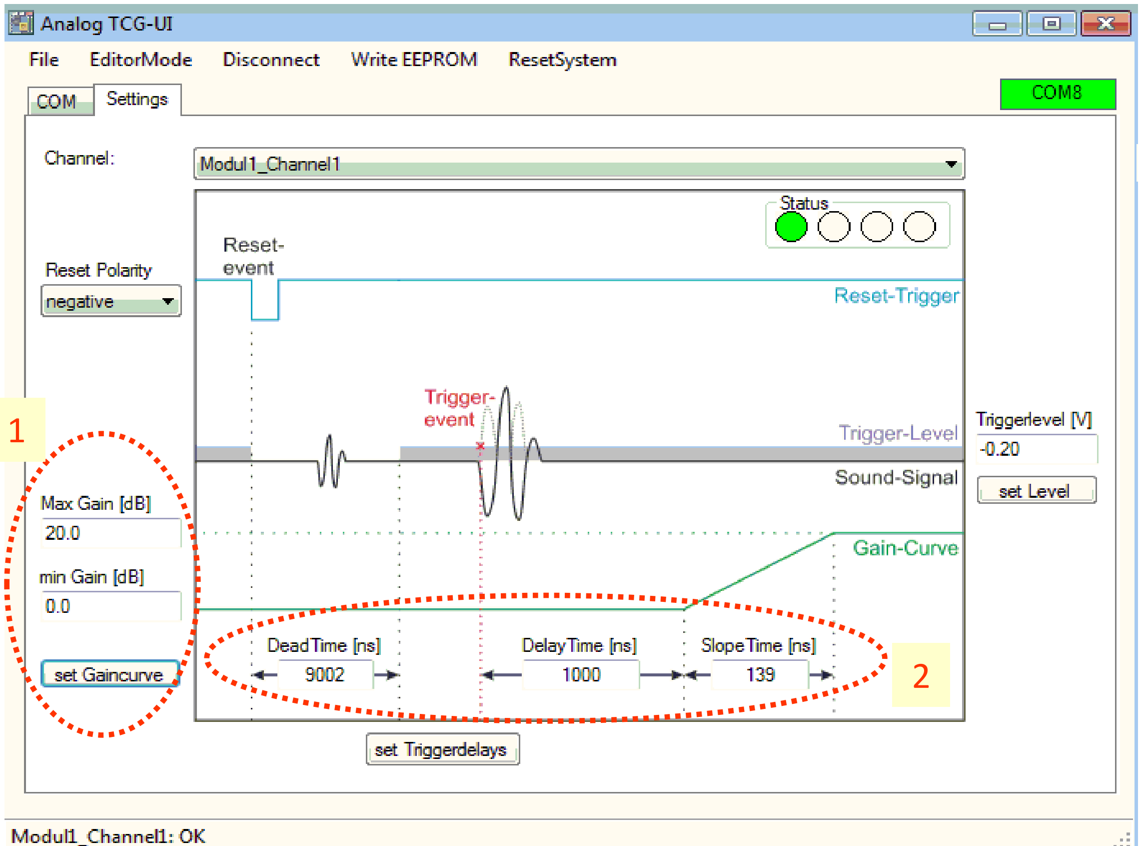


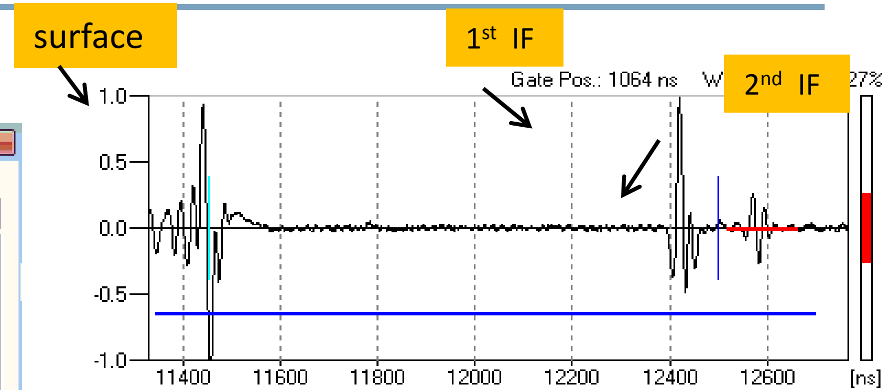
Spectrum of the 2nd interface





TIME CORRECTED GAIN (TCG): Increase depth resolution for stack dies

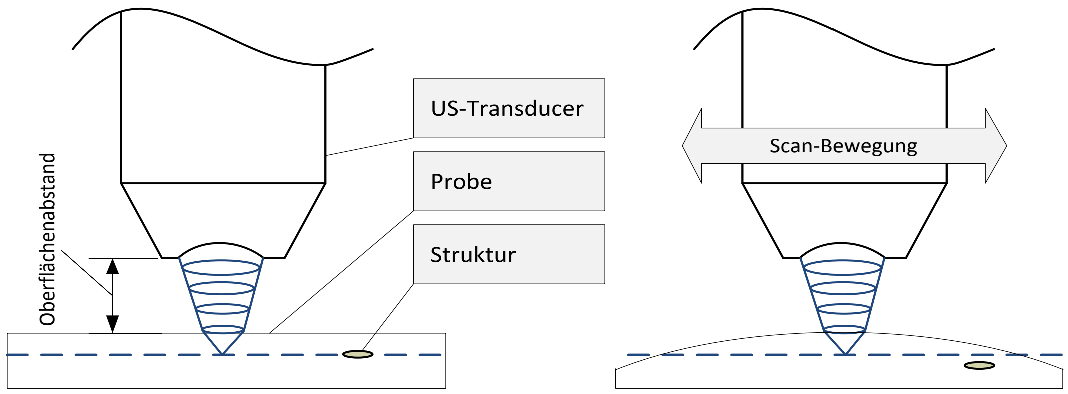




Time corrected gain (TCG) is used to amplify the reflected signal depending on its time-of-flight (TOF). For example, to be able to perform a simultaneous scan of the 1st and 2nd interface (G-scan), the intensity of the 2nd IF needs to be significantly increased. Using TCG the gain can be adjusted for the 2nd peak, avoiding the 1st IF to become oversaturated.

HiSA – task: compensate image artefacts in case of surface bow/ warpage

Current technology

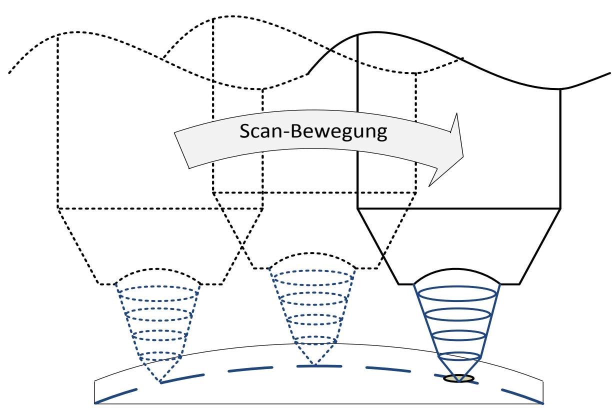


Linear Scanning:

Limited focus due to bending, surface trigger limited to ~600µm bow

⇒ **Certain areas out of focus**

Active Z movement during scan

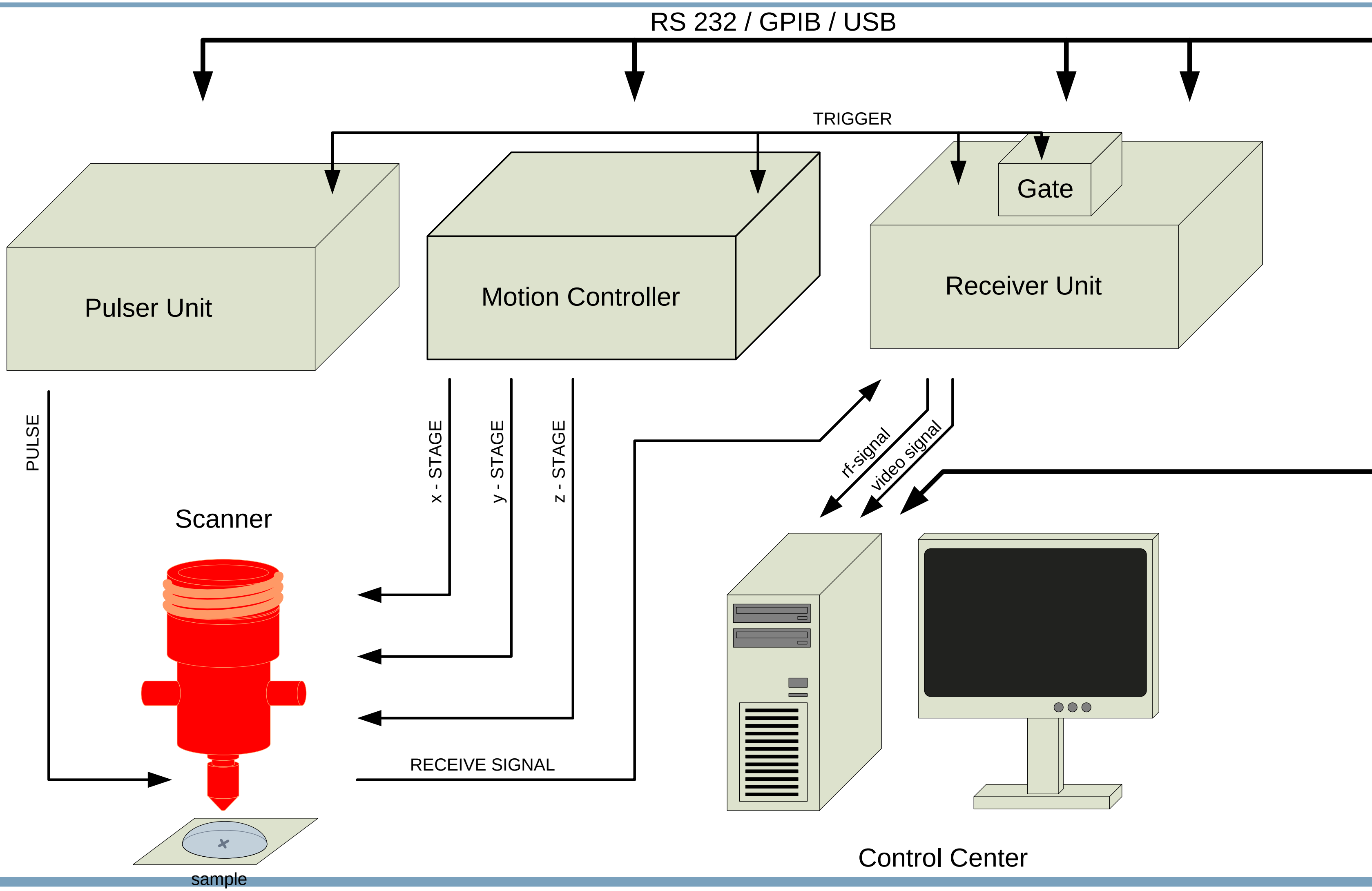


HiSA-System controls active the focus distance

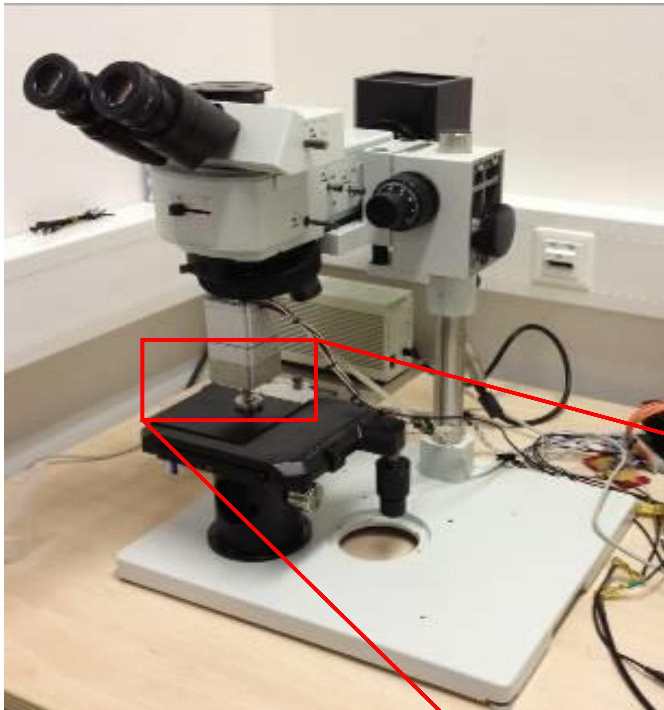
=> Sample always in focus

Bow: 2 mm

Hardware development GHz SAM:100 MHz-2000 MHz

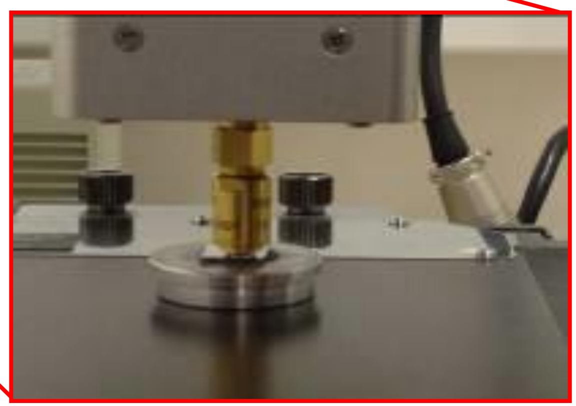


GHz imaging of real small µ-Bumps



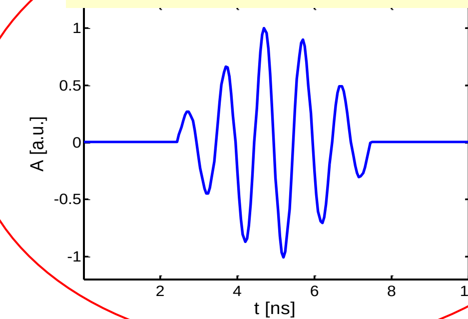
GHz-SAM

The pulser is driving the lens with tone burst signals. This improves the signal intensity and signal to noise ratio.

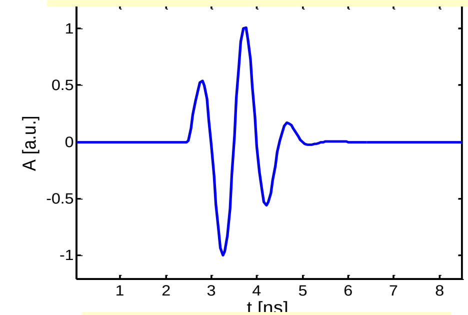


Scanning head with 1GHz 100° lens

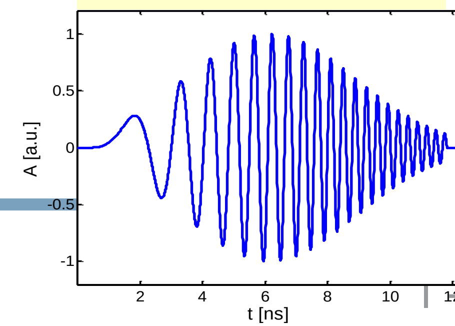
- Tone burst excitation



- Broad band excitation



- Chirp excitation



3. SAM analysis examples:

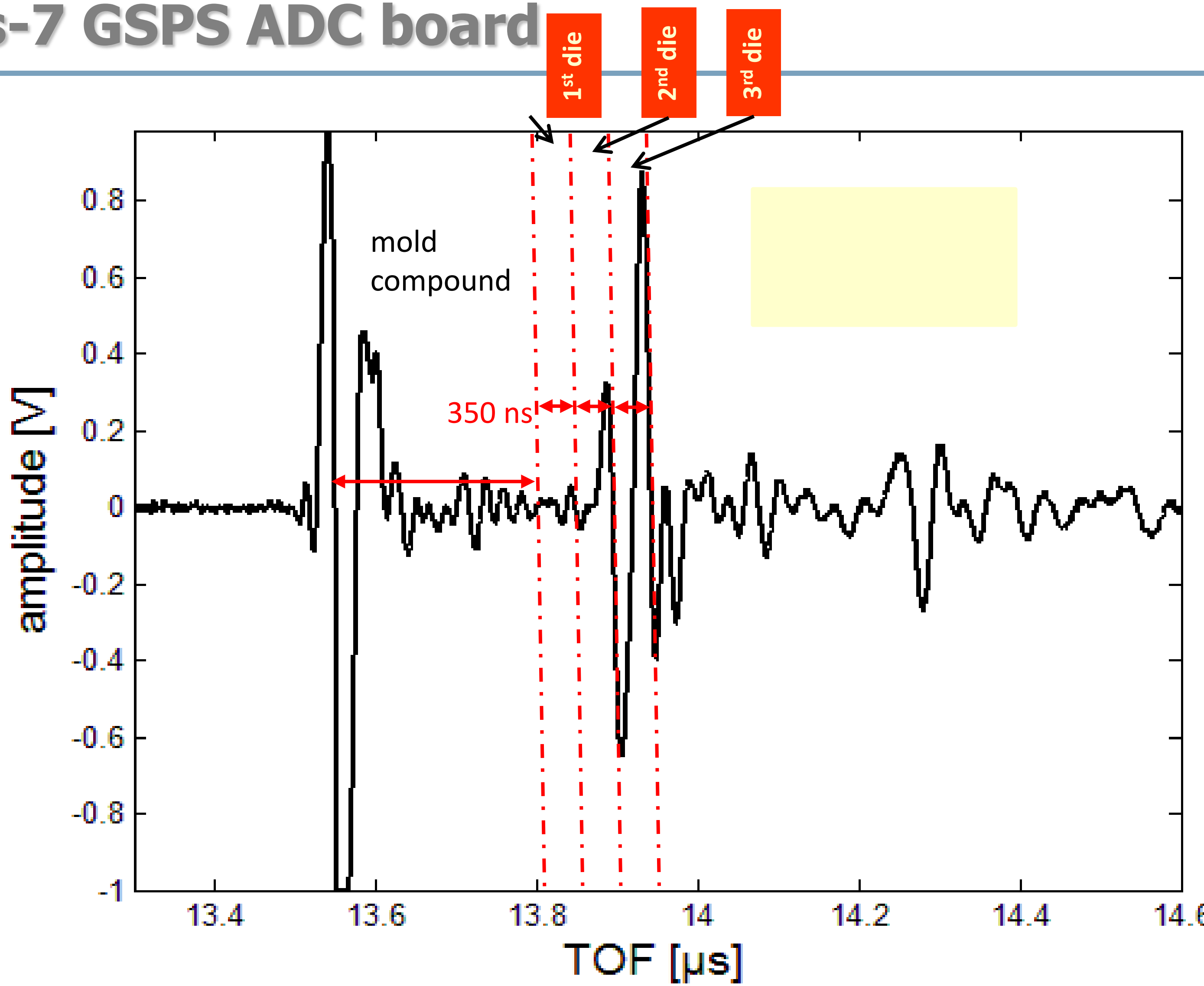
Stack dies

FC/PBGA: chip underfill-underfill/laminate/ILD delam

TSV`s

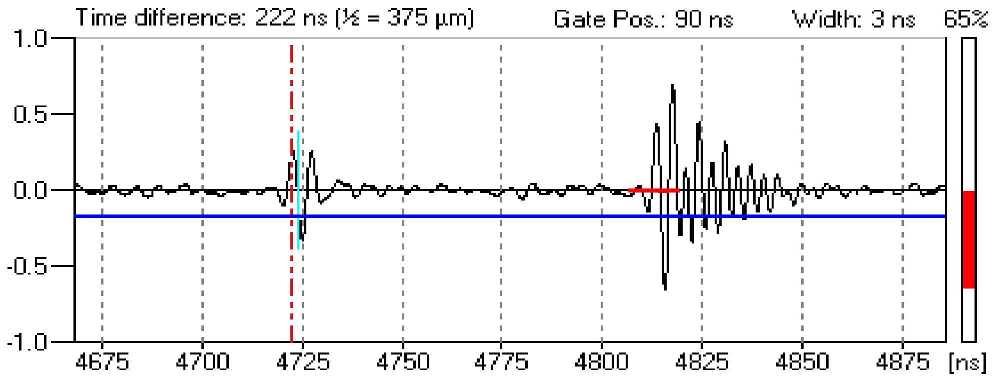
4 x 3 dies stack: A Scan plot: smalles data gate size: 140 ps-7 GSPS ADC board

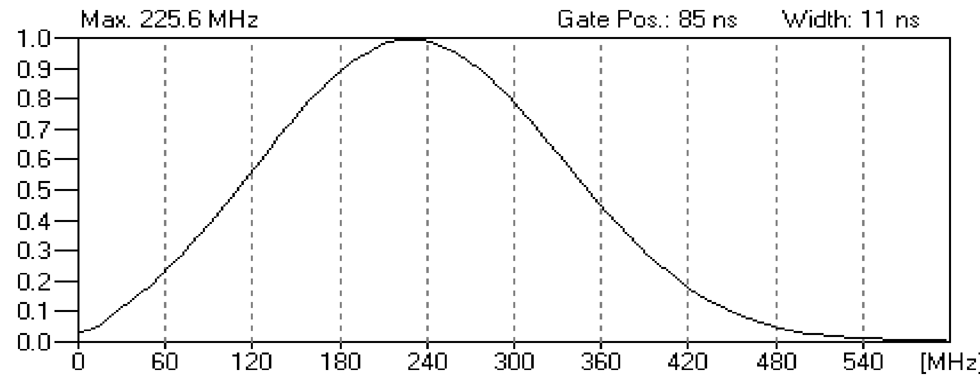
A-Scan



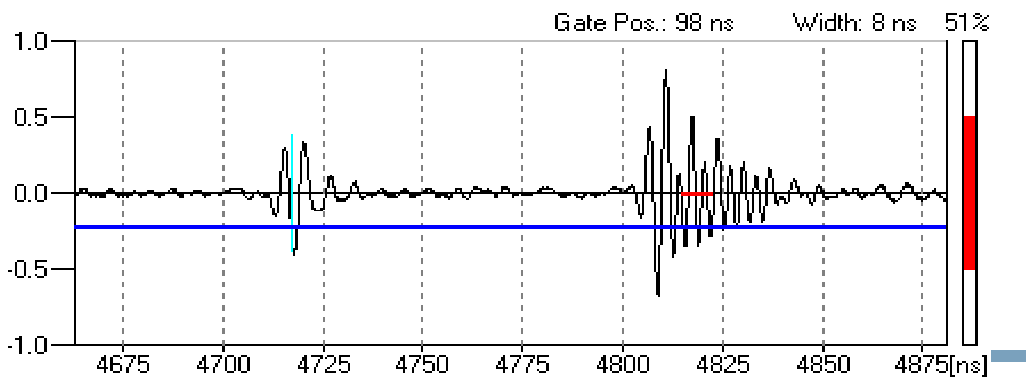
Transducer requirements for µ-bumps analysis

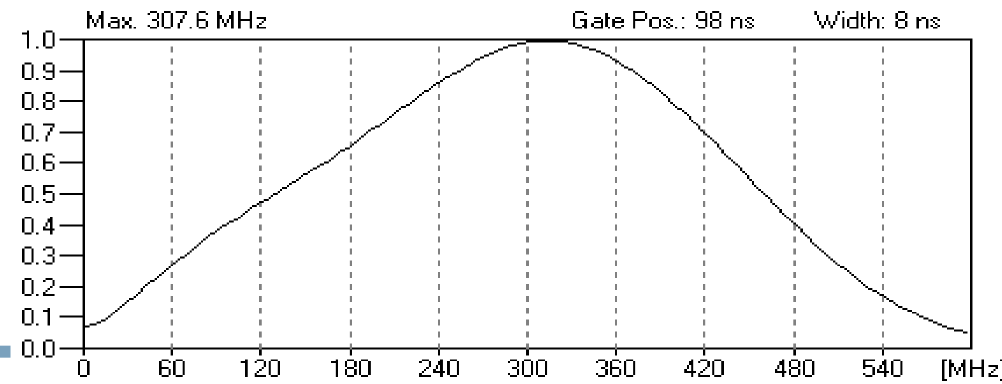
Spectrum of the 1st interface: µ bump area





Spectrum of the 2nd interface: c4 bump area





GHz investigations

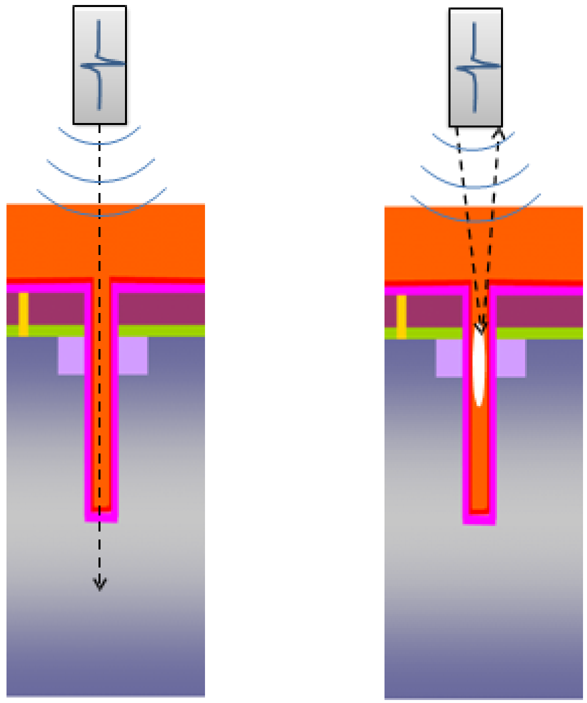
Image & analysis modes

-v(z) scans
-v(z) curves
-B (z) curves
-maximum value image
-mean value image

GHz imaging of real small µ-Bumps

- **GHz SAM: System Features and Performance**
  - Combined rf-chain for acoustic frequencies between 100 MHz and 2 GHz
  - High acoustic resolution (>1 µm @ 1GHz)
  - Quantitative evaluation of local elastic coefficients possible
  - 30 µm x 30 µm-2 mm x 2 mm lateral scan range with 50 nm scan resolution
  - 50 Hz scan-line repetition frequency (fast imaging)
  - V(f) and V(z) inspection method: quantification of SAM data
  - Small and compact Scanner: it can adapted to any other imaging device:
    - (optical microscopes - table top or inverted, large field scanners for
    - SAMs)

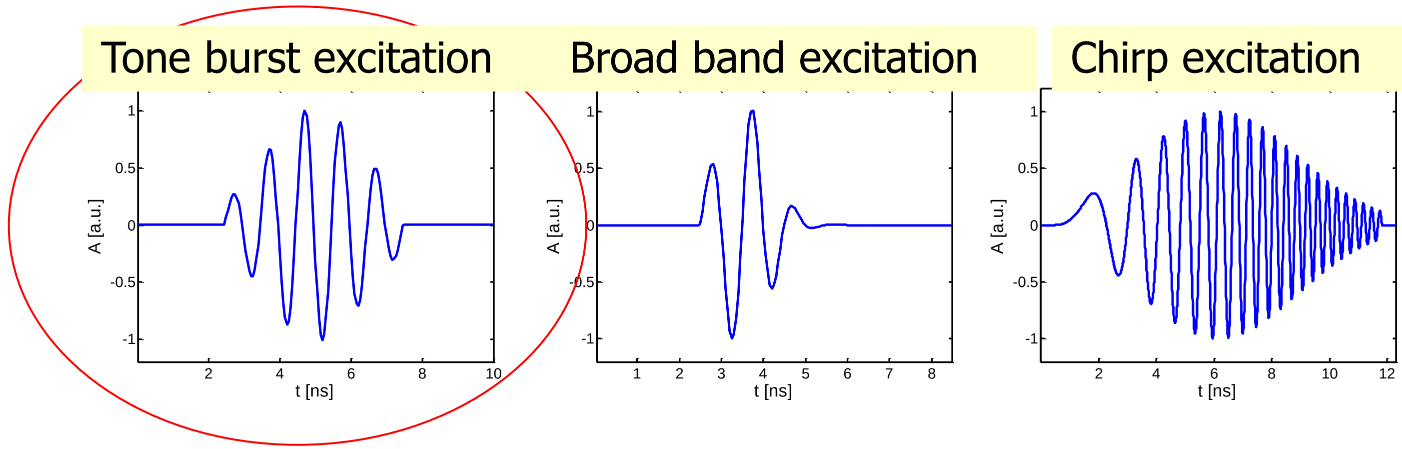
SAM inspection for TSV



Interface	Γ
Copper-Air	100%
Copper-Water	93%
Copper-Silicon	35%

Acoustic reflection coefficient for different boundary interfaces with Cu

Different lense excitation modules available



-Sound velocity in Cu: 4700 m/s, TSV depth of 50 µm: reflection recorded <20ns would indicate the presence of defects within the TSV.

-Stronger signal reflection compared to filled TSVs:

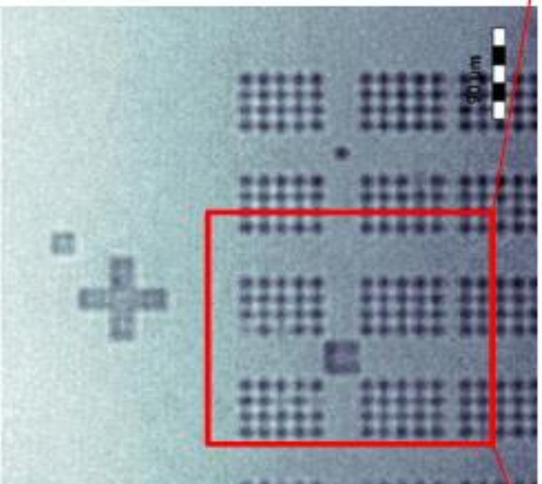
>90% for voids vs 35% for completely filled vias

- Signal frequency up to 2 GHz

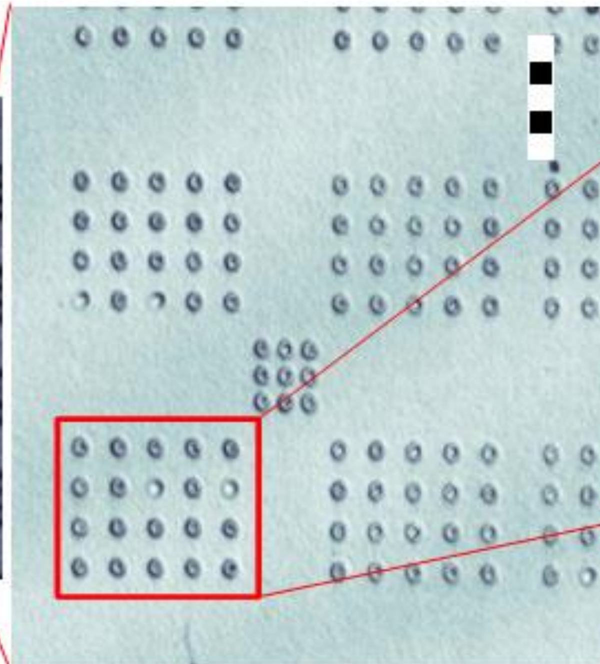
- PRF => 500 kHz @ 2 GHz (pulser repition frequency)

- monochromatic signal (tone burst)

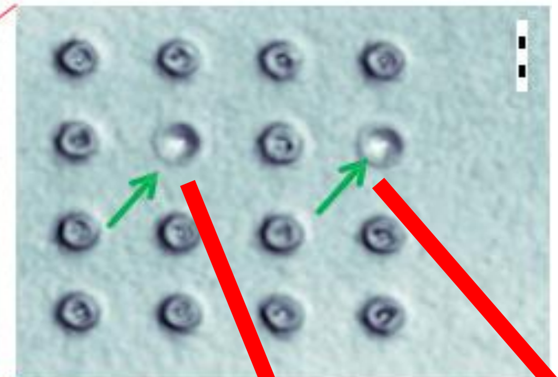
TSV inspection (5 µm diameter, depth 50 µm)

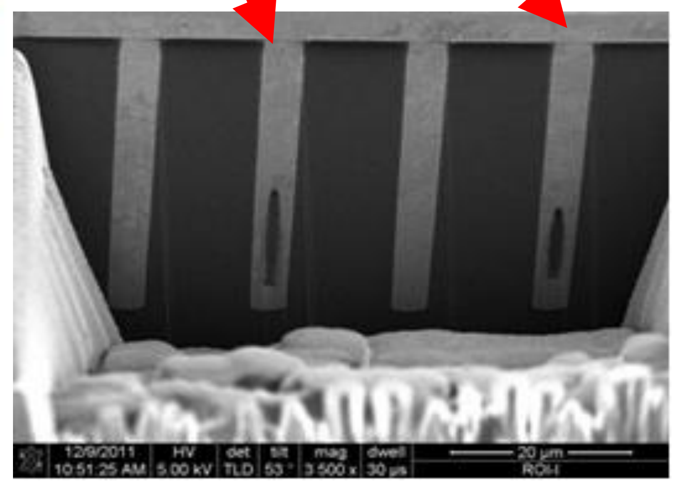


- f=200 MHz



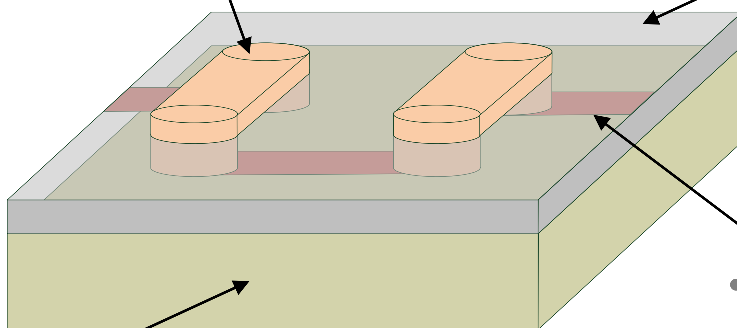
- f=1 GHz, good detail
- resolution





•A perfect correlation
•has been obtained
•between the FIB and
•SAM analysis.

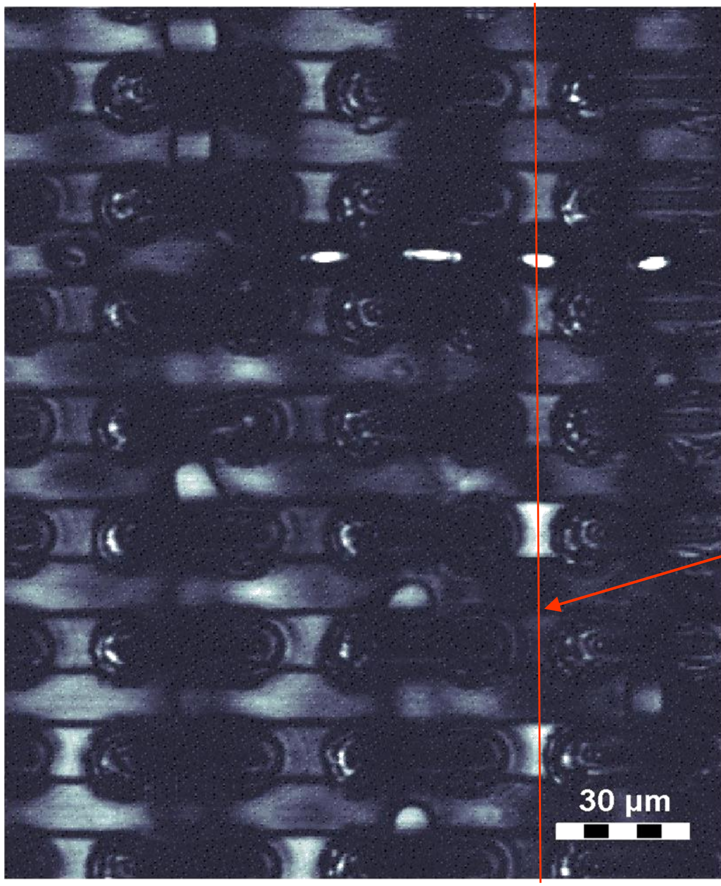
Real small µ-Bumps



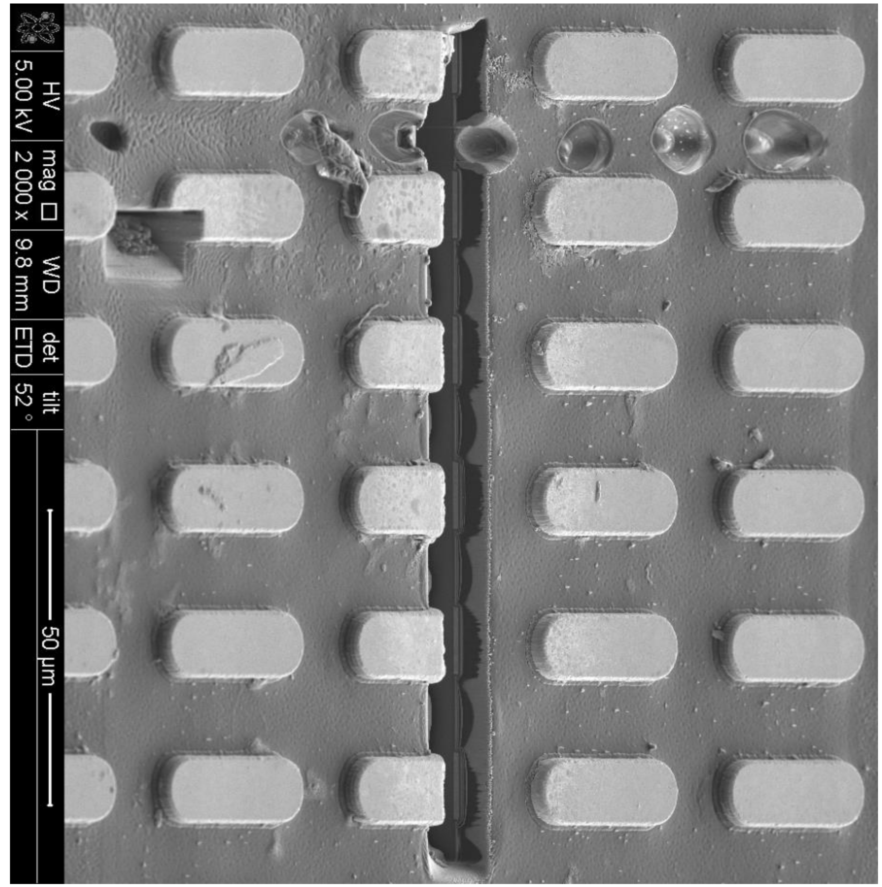
- Investigations of µ-bumps for micro voids, delaminations, cracks
- delamination between wiring and BCB layer

Small µ-Bumps

•Acoustic Inspection at 1 GHz (through 5µm of BCB)



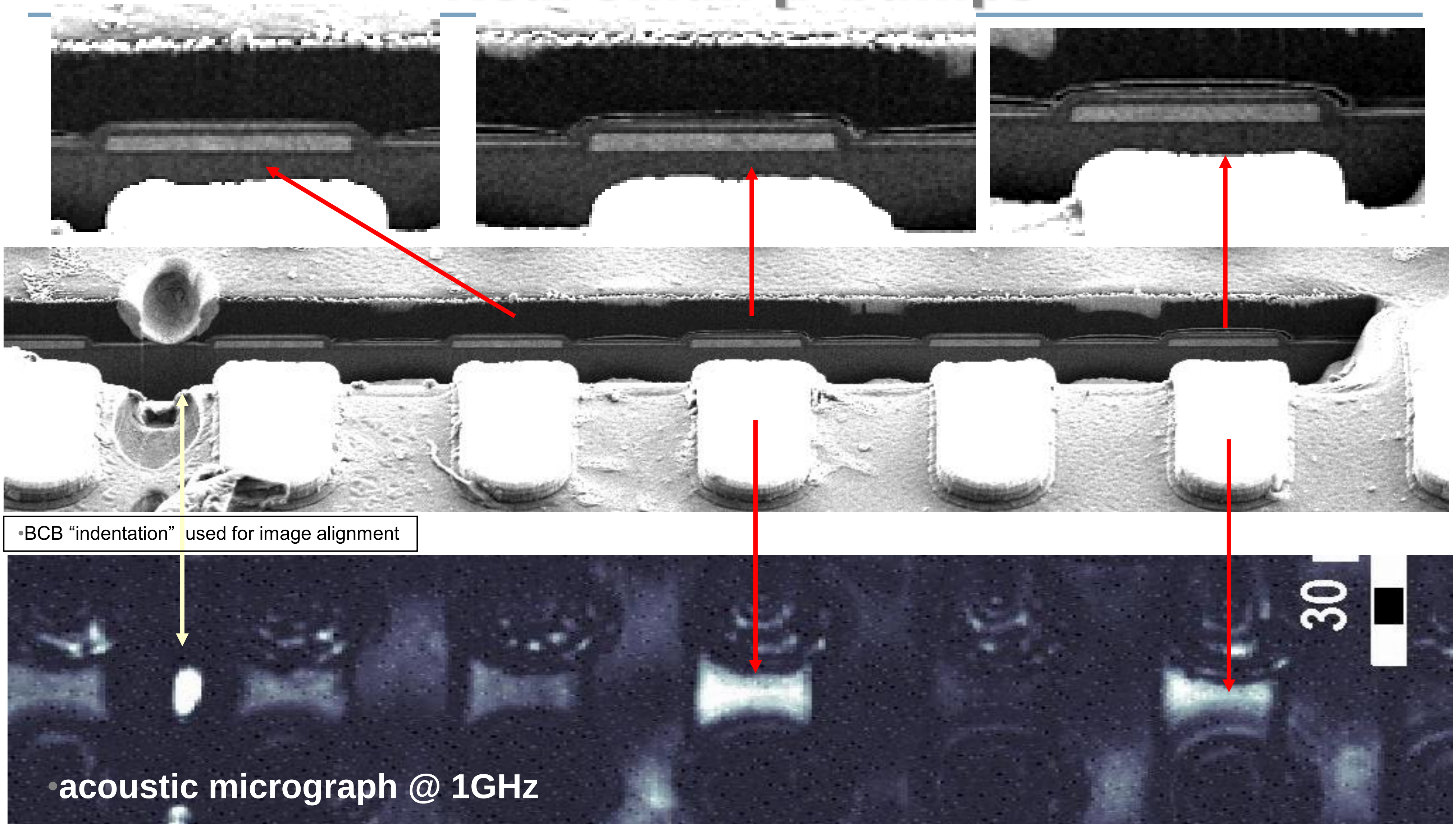
•Position for
•FIB cut



•SAM C-scan, f= 1GHz

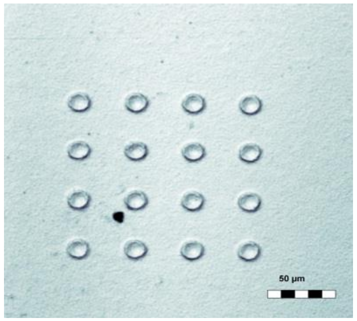
•FESEM, 5 kV

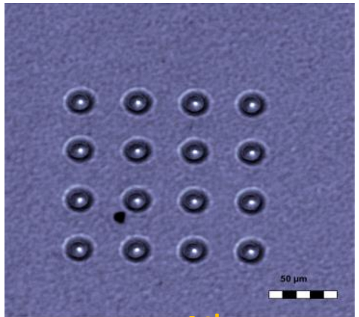
Real small µ-bumps



1 GHz SAM-analysis

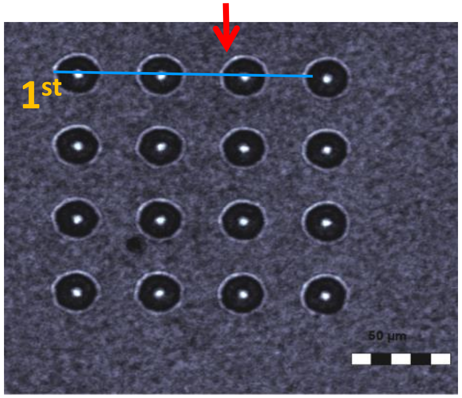
Imaging modes : maximum value imaging, mean value imaging, defocused imaging, B(z) analysis

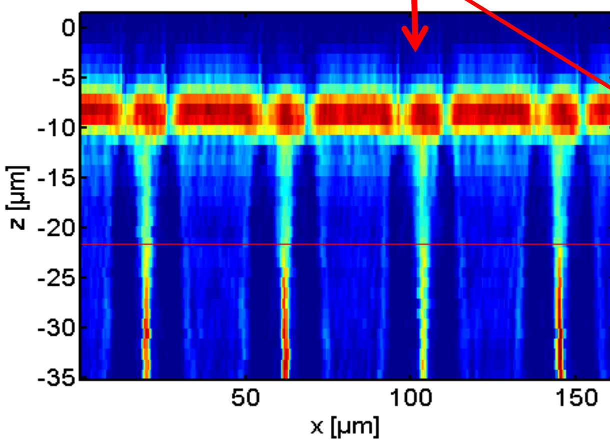




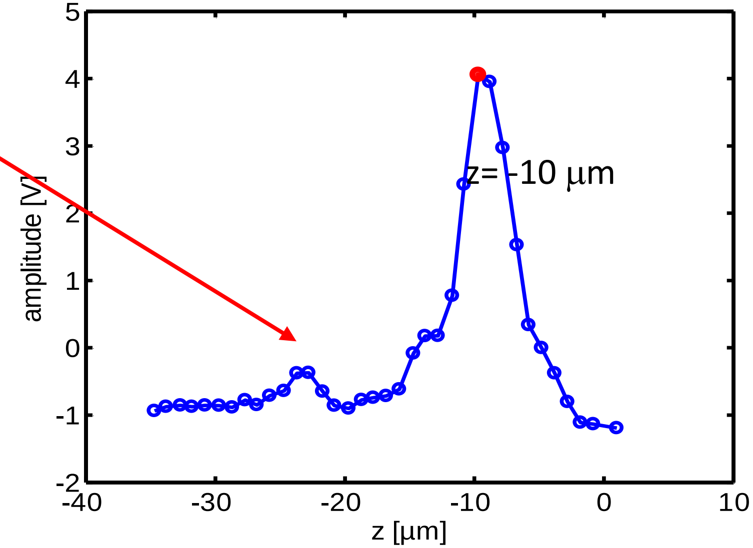
- the image on the left was taken at the z-position with the highest V(z)-amplitude (z= -10 μm)
- this position corresponds to the focus on top of the TSVs

1st





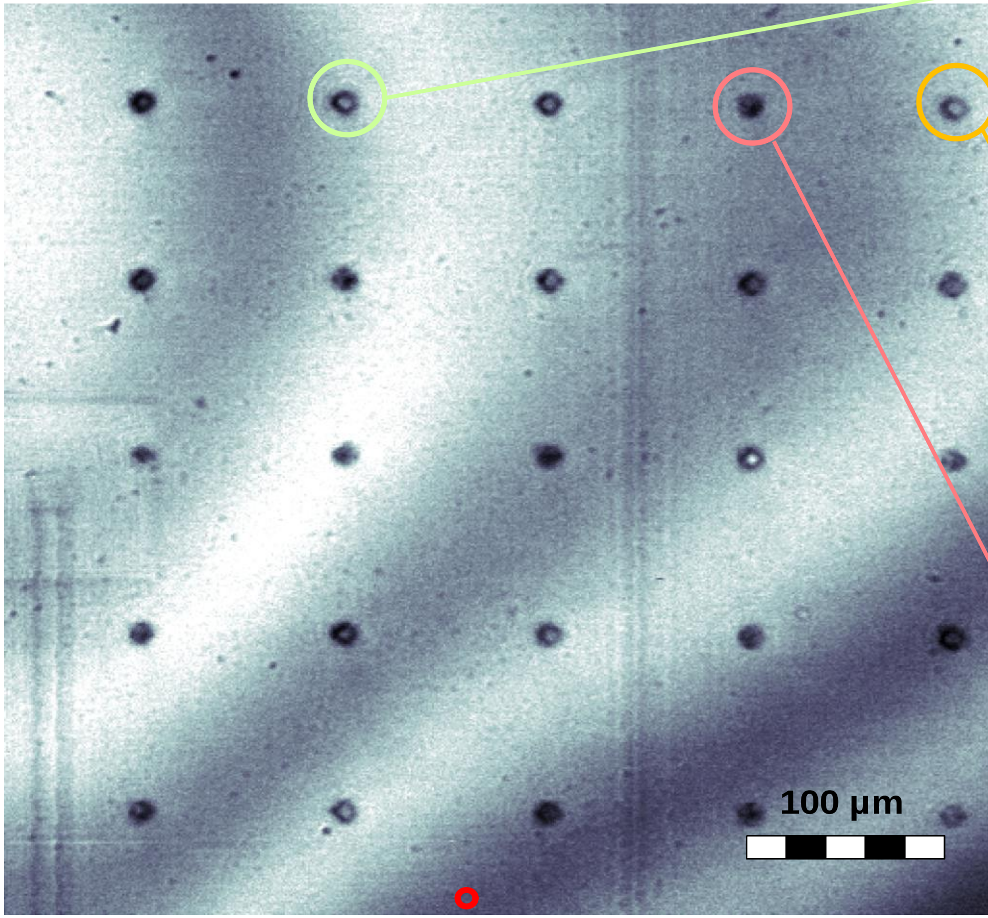
V(z) curve:

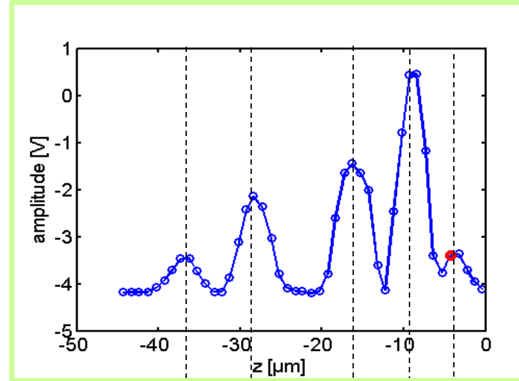


- **B(z)-signatures show uniform intensity for the surface (1st peak) and only slightly intensity deviations for the 2nd peak-respective to v(z) curve (see red arrows): mechanical properties of the TSVs are almost equal, no defects observed**

V(z)-curves @ 1 GHz: increase through put for TSV inspection

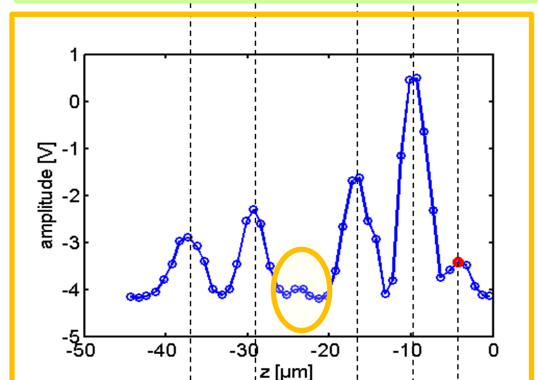
Defocus 4 μm





A) Type 1

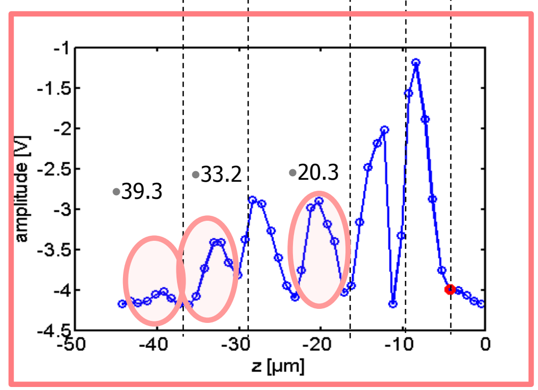
- -1st peak @ 4 μm
- -2nd peak @ 9.3 μm
- -3rd peak @ 16.3 μm
- -4th peak @ 28.4 μm
- -5th peak @ 35.3 μm



B) Type 2

- peak positions are **the same, intensities differ**

- **one peak onset @ 29.3 μm**



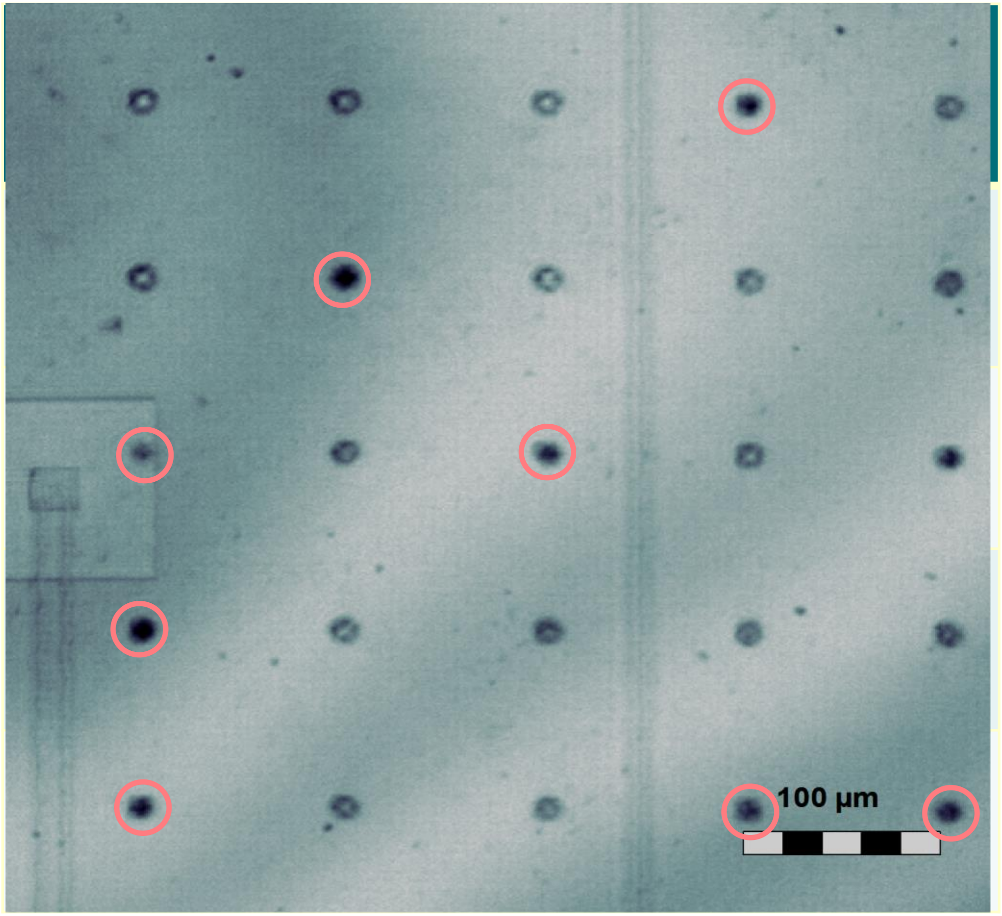
C) Type 3

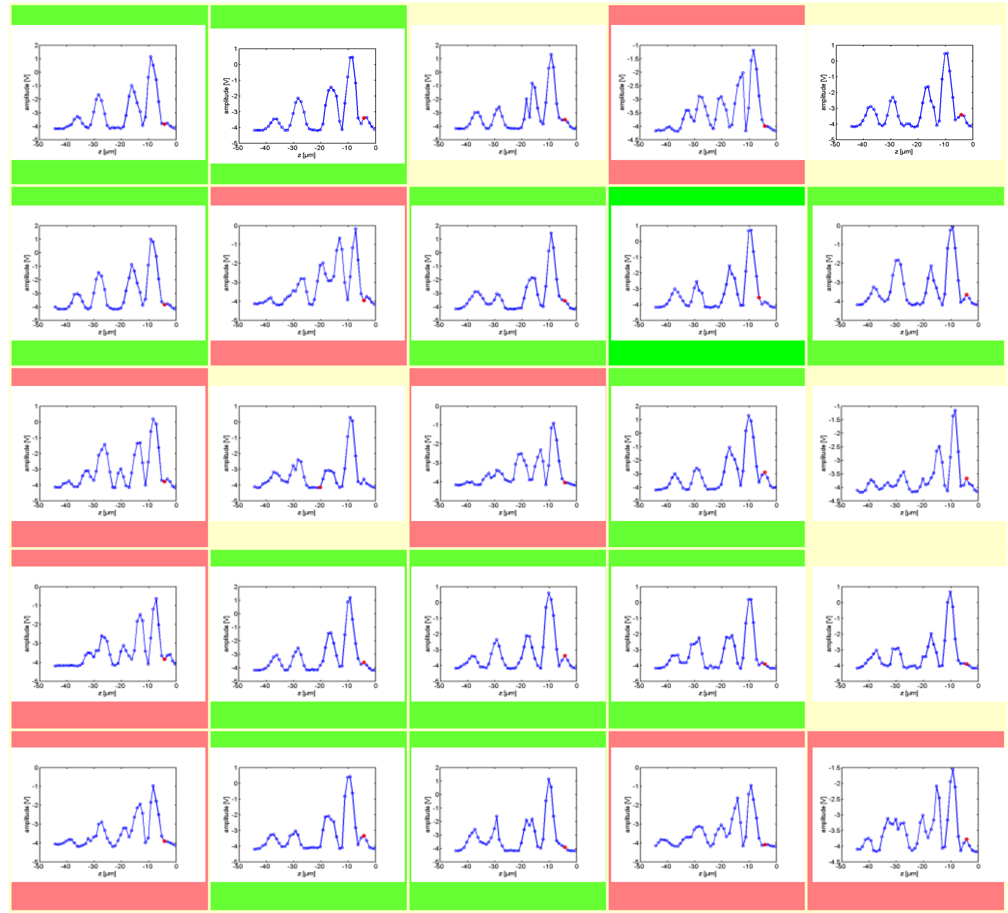
- - 3rd peak shifted
- to 14.3 μm
- - 5th peak shifted
- to 40-42 μm
- **2 additional peaks (strongly pronounced) @ 20.3, @ 33.2 μm**

•POI 1: area 1

V(z)-curves: Unique finger print

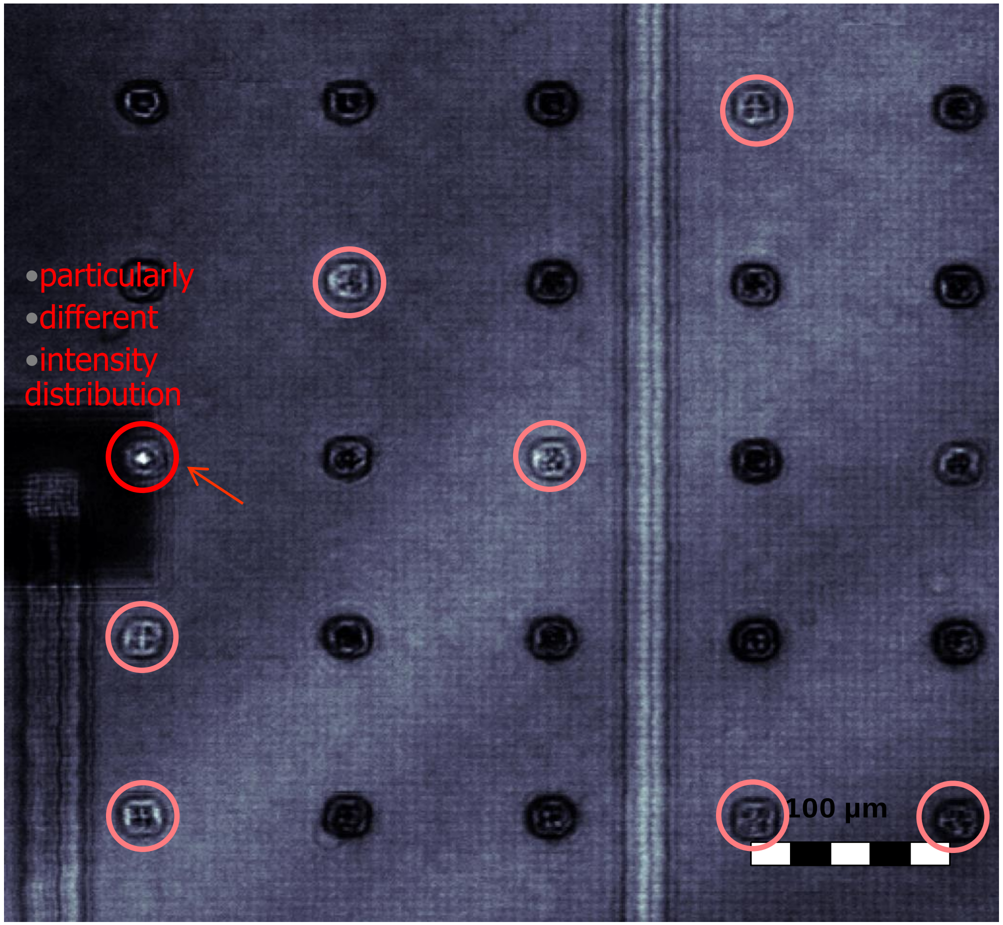
Defocus 10 μm





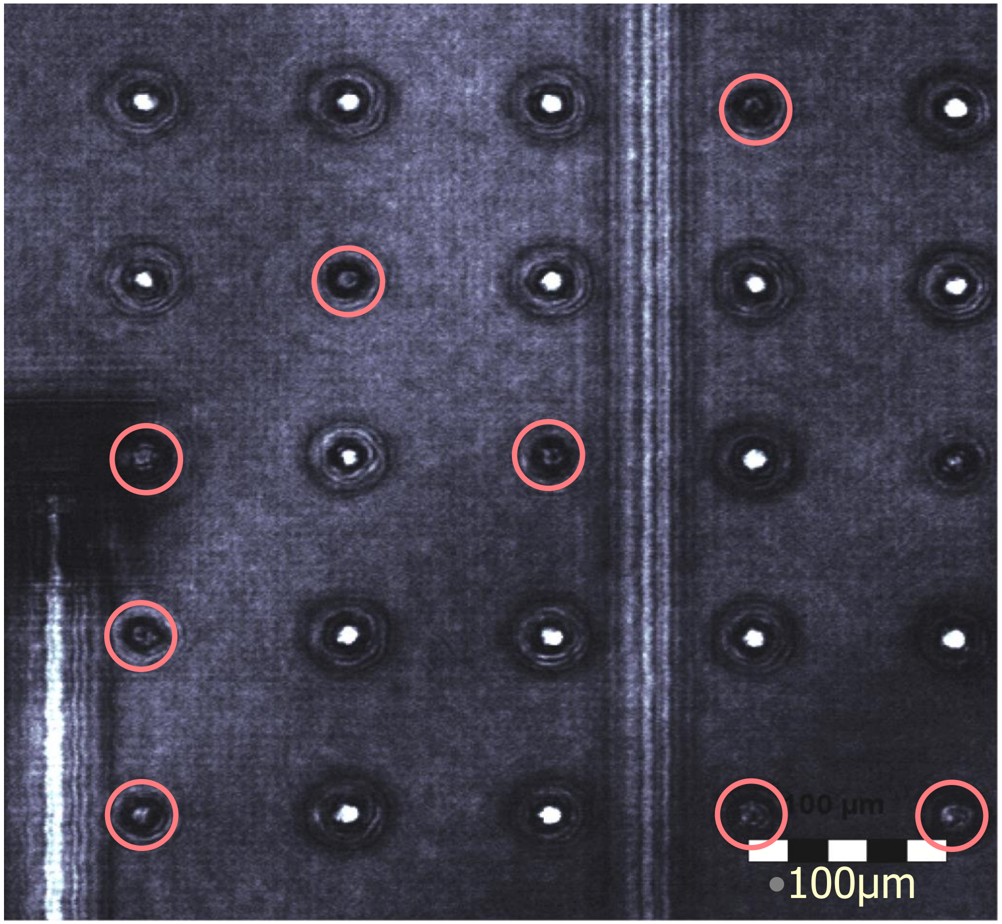
V(z)-curves: Unique finger print

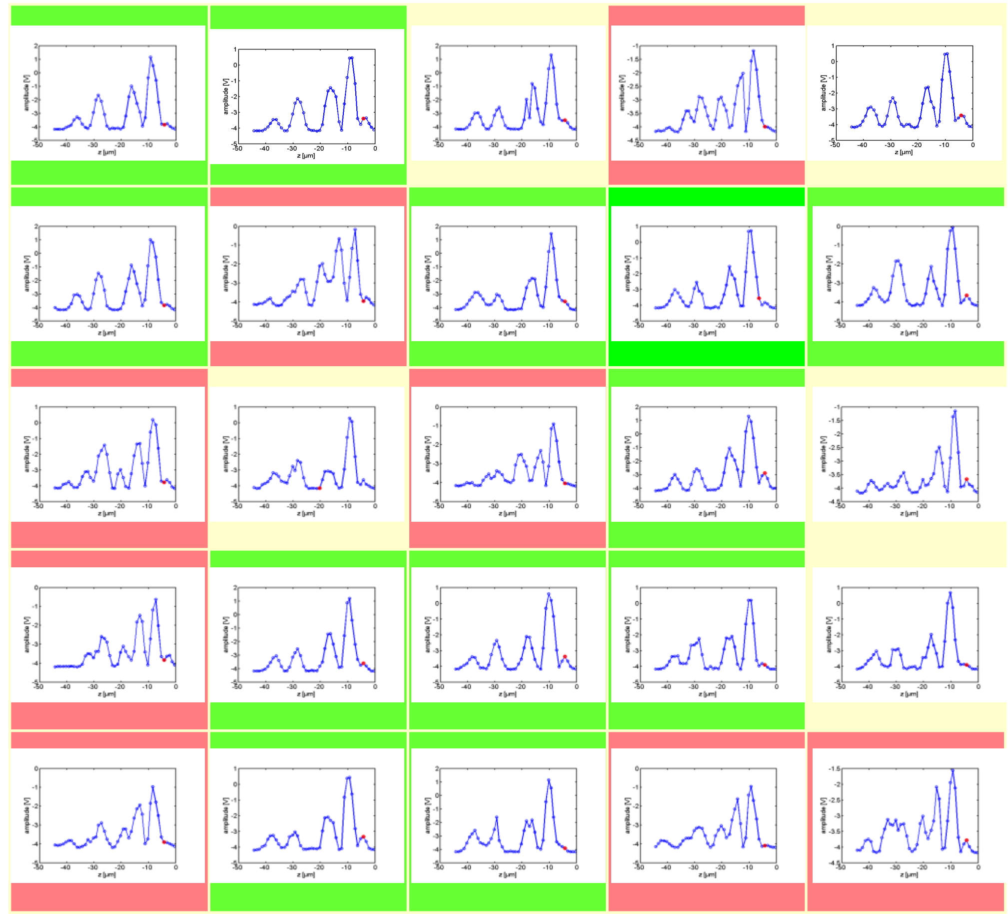
Defocus 25 µm



V(z)-curves: Unique finger print

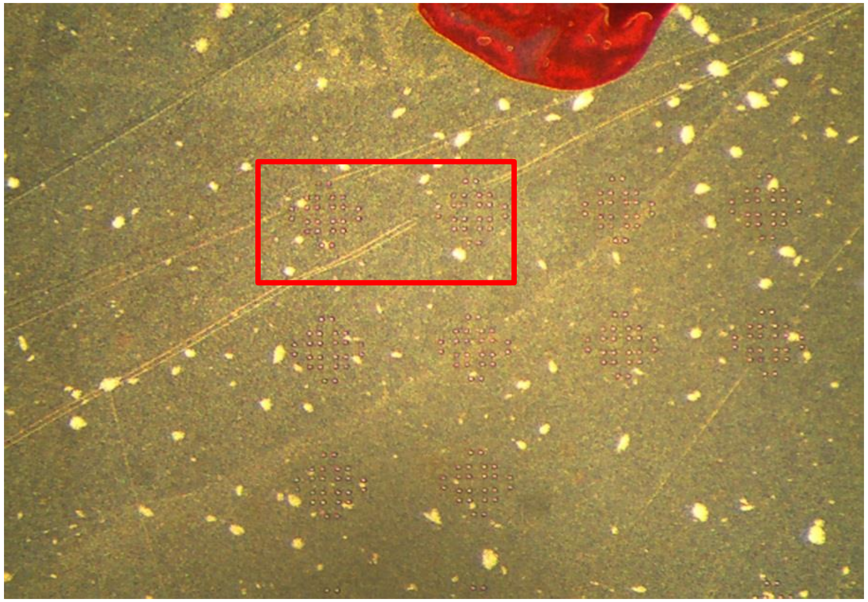
Defocus 37 μm

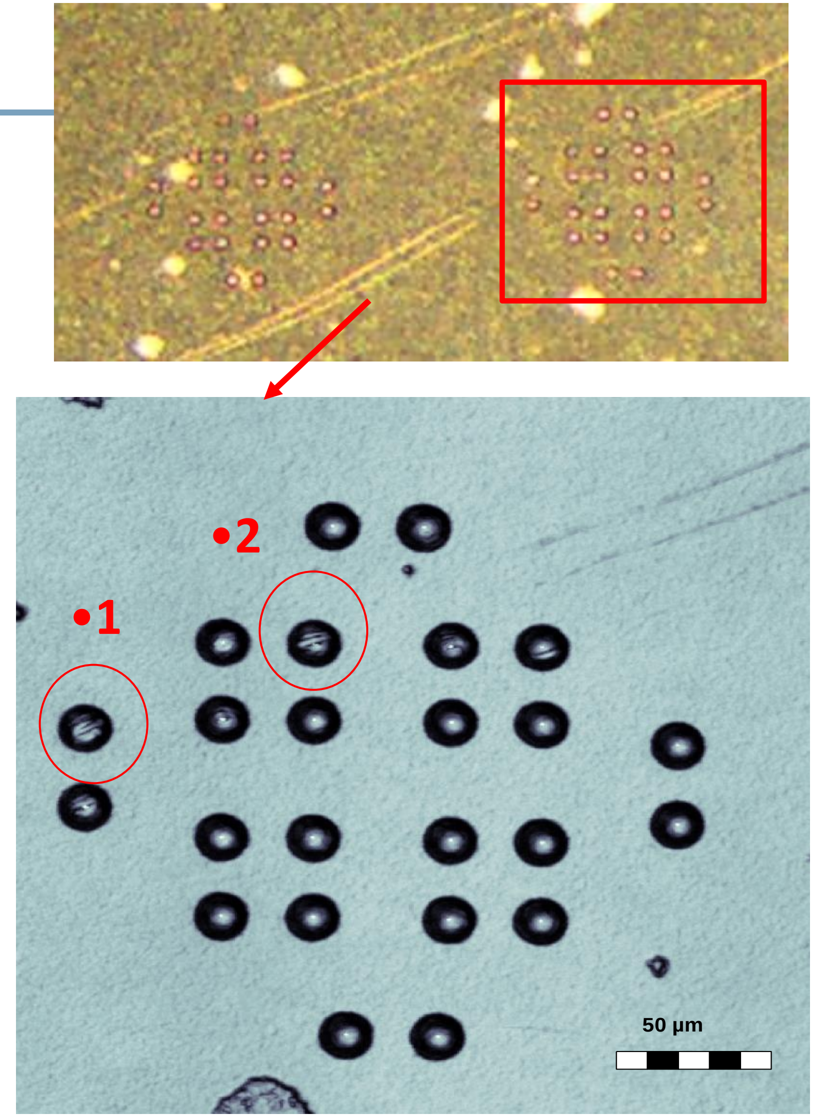




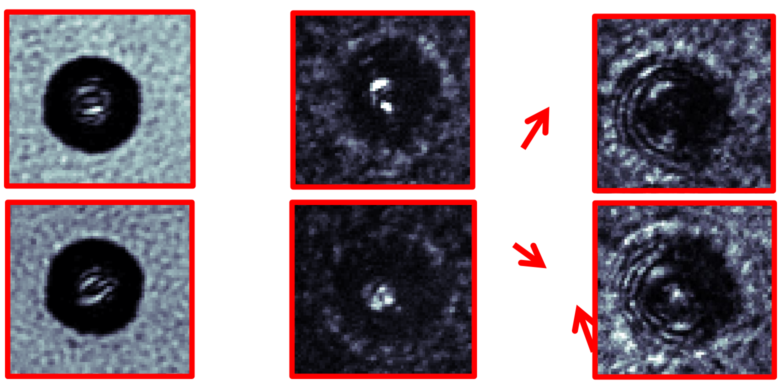
Further correlations GHz SAM-FIB based on V(z) analysis

Orientation by LM-images



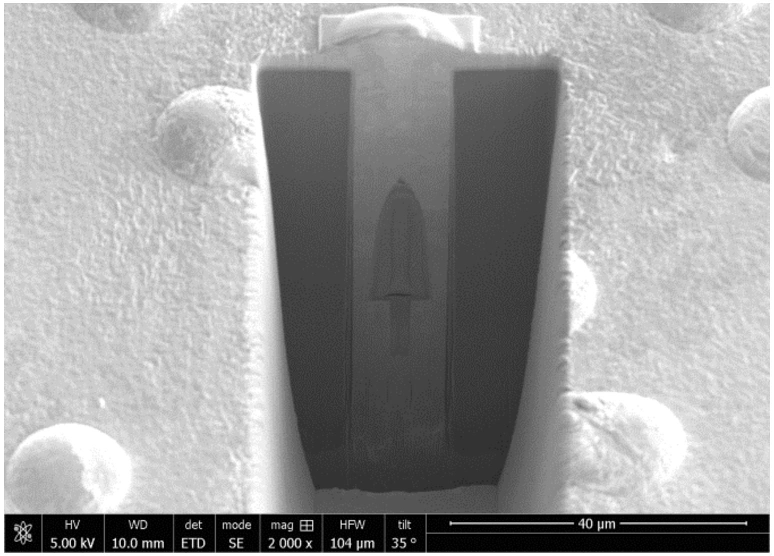


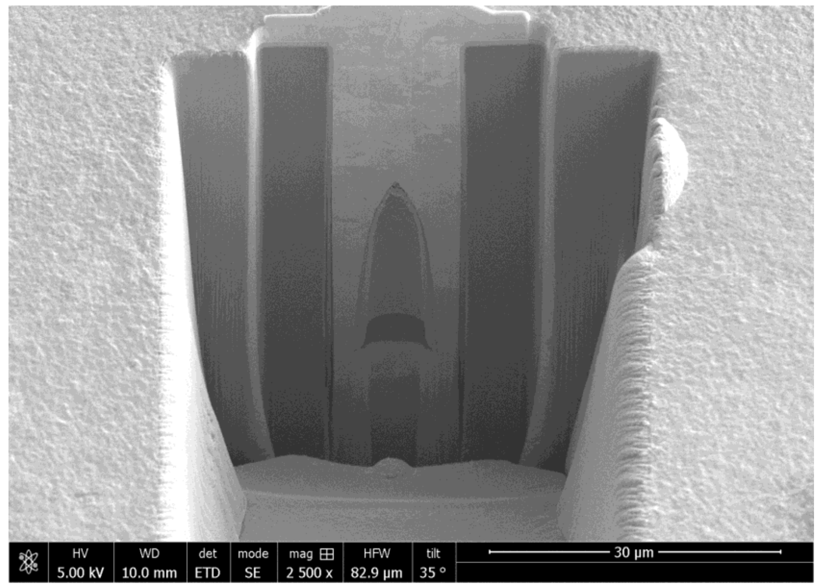
•1
•2



•1 GHz V(z)_withvoids_001

FIB cut- rotated sample Spot 1/2





Summary

1. **Improve yield and cost of ownership of F&A equipment: increase SAM resolution and depth sensitivity, sample throughput**

2. **Provide SAM defect resolution >>10 µm range**

3. **Localization and measure of defects in z- 3 D approach**

4. **Utilization of GHz SAM as new approach for semiconductor failure analysis in 1 µm range,**

   potential for in line tool TSV inspection development for complete 300 mm wafer inspection

E N D

Thank you!