COVALENT METROLOGY

Welcome

covalentmetrology.com

COVALENT METROLOGY

SEEING IN SOUND

ULTRASONIC IMAGING WITH SCANNING ACOUSTIC MICROSCOPY

GUEST SPEAKER:

Lisa Logan

Applications Manager, SAM from PVA TePla

Aug 20, 2020 11am PDT

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PVA TePla



COVALENT ACADEMY

Advancements in Instrumentation Webinar Series

Covalent Metrology



- **Founded 2016**
- Testing, measurement & characterization **Platform**
- **30 team members** (11 PhDs)
- **9,500 ft² lab in Sunnyvale, CA**
- **1-Stop-Shop Source for Answers**
  - 30 instruments in-house
  - 6 partnerships with instrument manufacturers
  - 11 partner labs
  - 6 corporate “tool shares”
- **More than 300 customers** (80 % repeat)

Covalent Technical Groups and Organization

hello@covalentmetrology.com

Electron & Scanning Probe Microscopy

SEM / TEM, AFM, EDS, EELS, Nanoindentation, Acoustic Microscopy

Surface Analysis

XPS, Auger, TOF-SIMS, d-SIMS

Optical Microscopy & Spectroscopy

Laser Confocal, White Light, Chromatic Aberration, Spectral Ellipsometry, UV-Vis-Nir Spectroscopy

Materials / PC Board Failure Analysis

Cross Sections, Inspections, Dye & Pry Testing

X-Ray Characterization

XRD / XRR, XRF, µCT

Chemical Analysis

ICPMS, GCMS, FTIR, Raman Spectroscopy, NMR

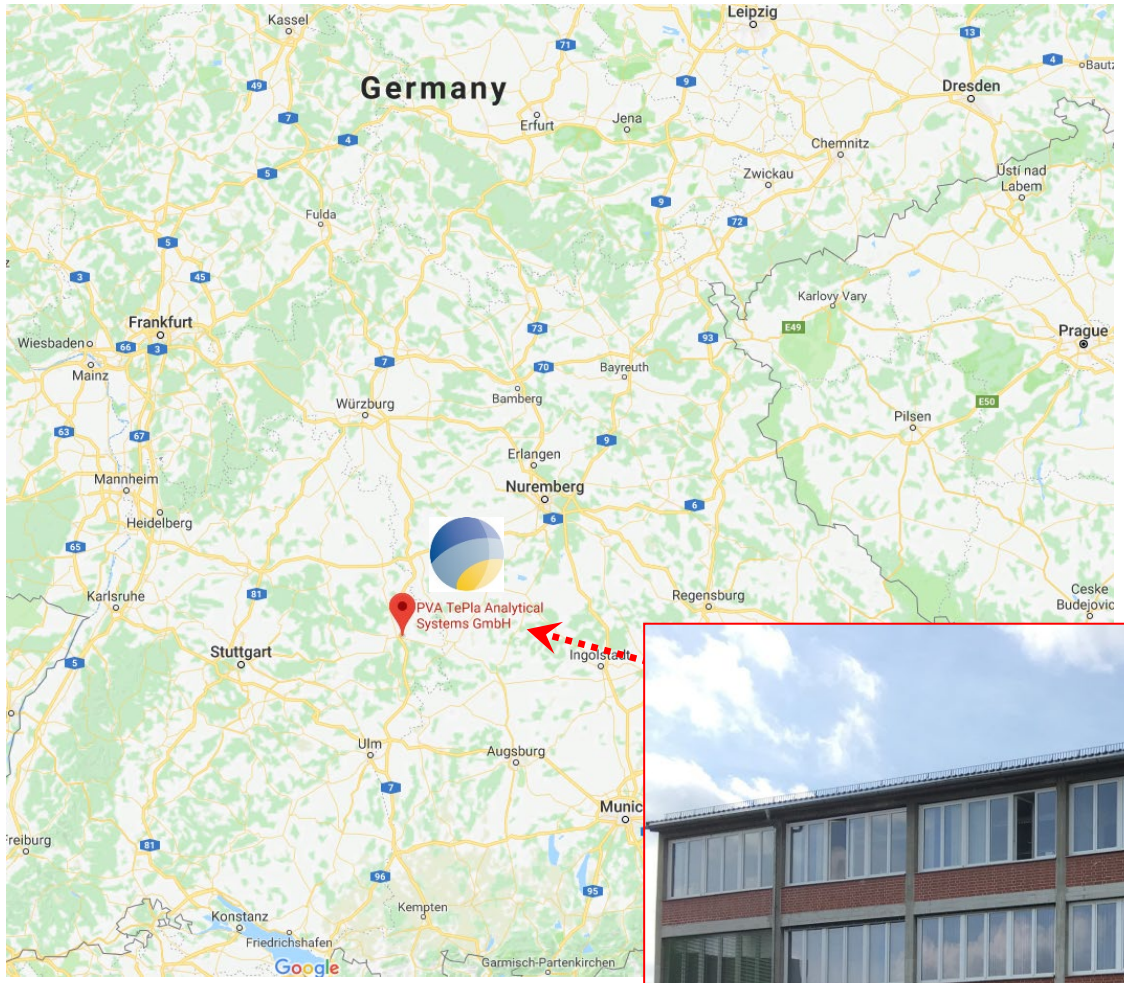
Nanoparticle Analysis

DLS, PSA, Particle Zeta Potential

Bulk Properties Characterization

DSC, TGA, DMA, Rheometry, Tensile Testing, Pencil Test, Surface Zeta Potential

PVA TePla Analytical Systems GmbH



PVA TePla

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D-73463 Westhausen
Germany

☎ +49 7363 9544 0



with worldwide Sales and Service network

Covalent Strategic Instrument Partnership

PVA TePla

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- Partnership established in November, 2019
- Several of PVA TePla's advanced Scanning Acoustic Microscopes are housed in Covalent's Sunnyvale, CA laboratory:
  - **PVA TePla 302 HD2**
  - **PVA TePla 501 HD2**
- Covalent Metrology provides **advanced analytical services and support for method and applications development** on these systems

Anton Paar

Rigaku

J.A. Woollam Co.
Ellipsometry Solutions

KEYENCE

OXFORD INSTRUMENTS
ASYLUM RESEARCH

Speaker Introduction



Lisa Logan

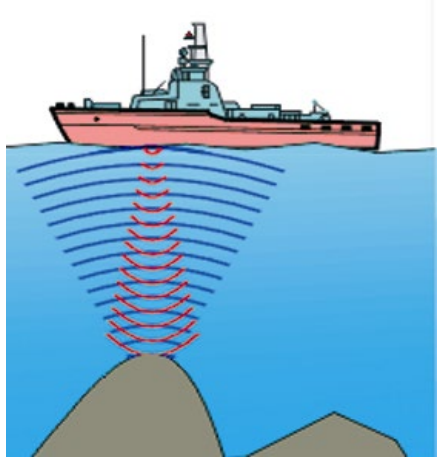
- Applications Manager, Scanning Acoustic Microscopes, for PVA TePla Analytical Systems
- 20+ years of experience in acoustic microscopy
- B.S. from Illinois State University in Physics

Ultrasonic Applications

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Feature Recognition Range

Sonar
m-cm



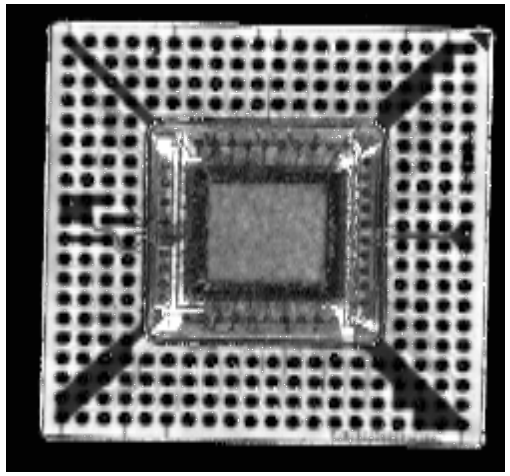
20 - 500kHz

Medical US
cm-mm



1MHz

SAM
mm-µm-nm



5MHz - 2GHz

1-20Hz = Infrasound (felt as vibration)

20-20000Hz = Audible frequencies (human ear)

>20000Hz = Ultrasound

Ultrasonic waves: f > 20 kHz
not noticeable to the human ear



Basics on Scanning Acoustic Microscopy

Ultrasonic waves: reflection/refraction at boundaries of different acoustic impedance Z

$$R = \frac{Z_2 - Z_1}{Z_2 + Z_1}$$

… reflection coefficient

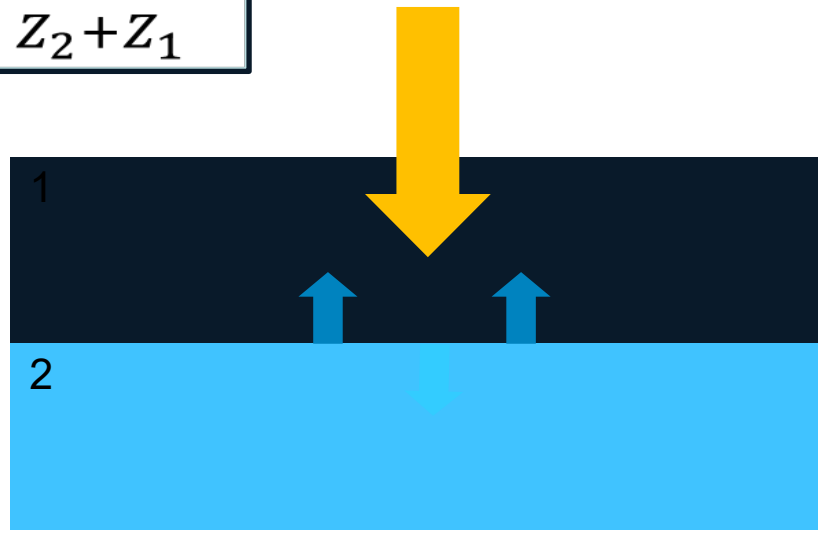
Medium 1:

$$Z_1 = \rho_1 * v_1$$

Medium 2:

$$Z_2 = \rho_2 * v_2$$

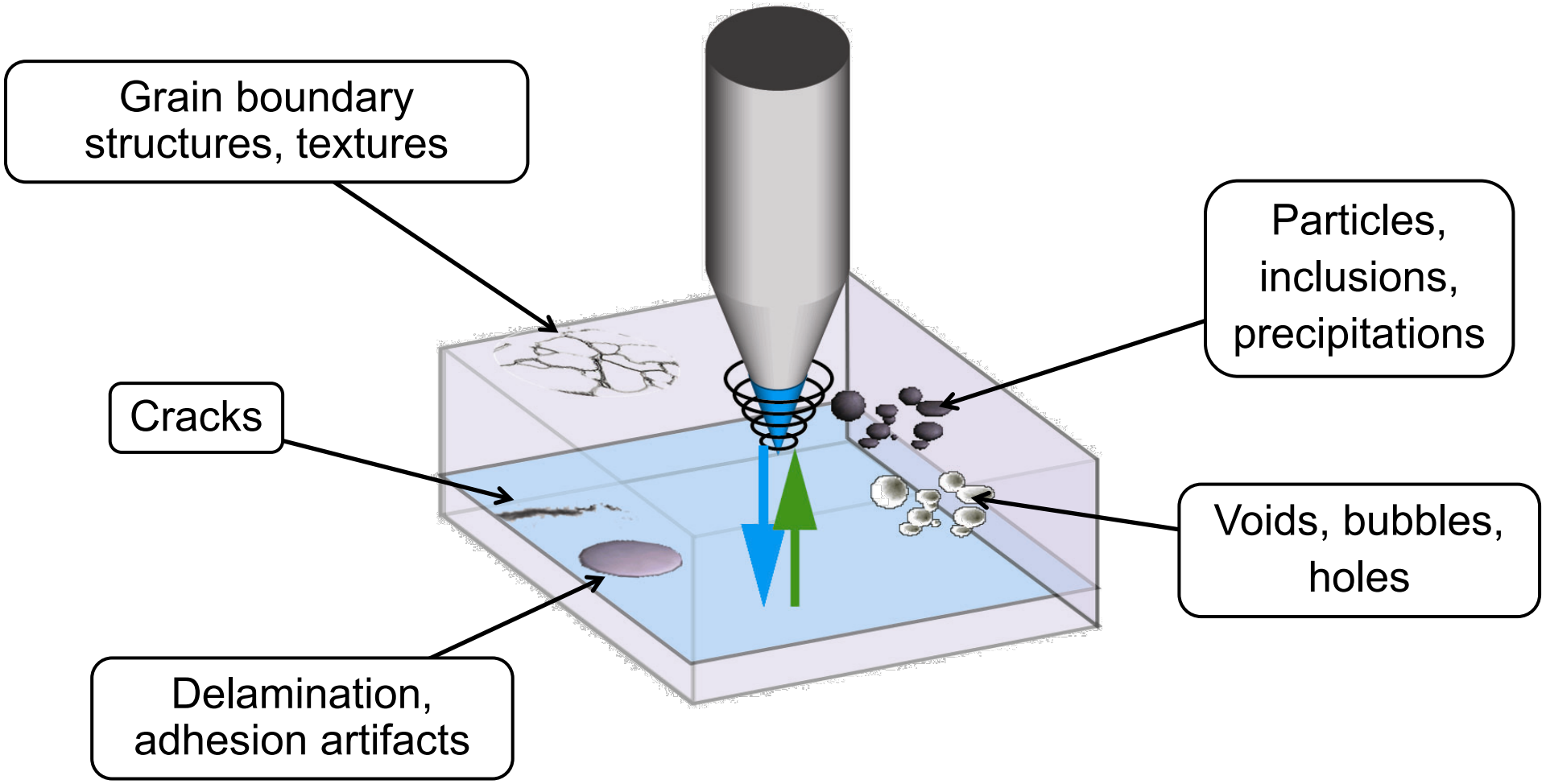
ρ … *density* , v … *sound velocity*



the higher the impedence mismatch at the interface, the higher the intensity of the reflected signal (= brightness in the image).

air: Z=0 -> total reflection & phase inversion

Detection and Sample Interaction



Sound reflection & properties of ultrasonic waves

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General principle:

Changes in acoustic impedance inside a material:

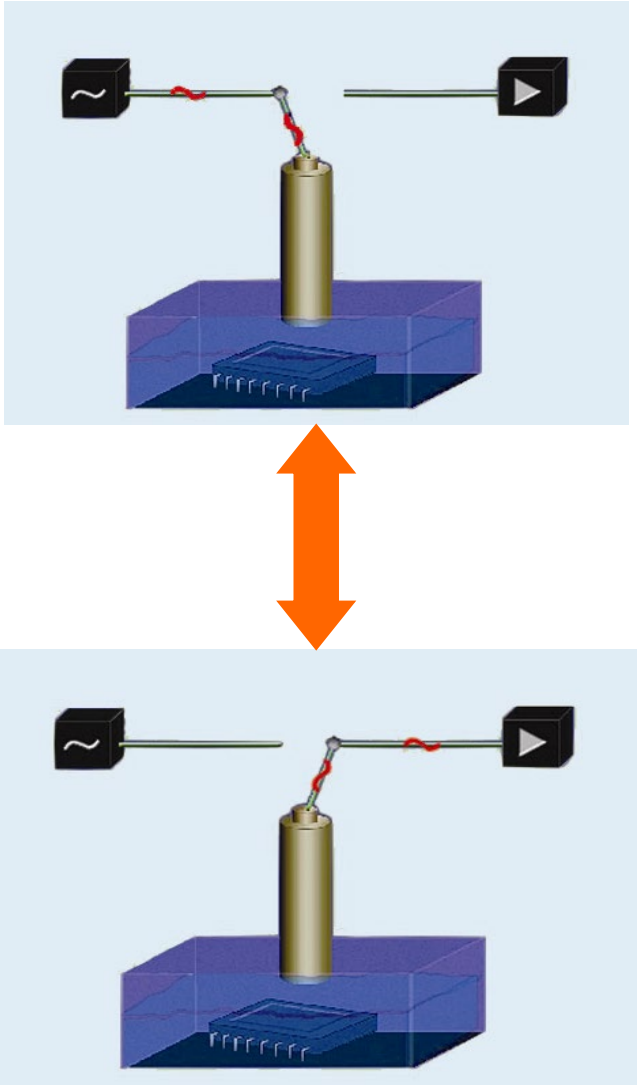
A portion of sound is reflected and the remainder propagates through the sample or boundary interface.

…at grain boundaries, inclusions, cracks, holes and voids.

Characteristics of ultrasonic waves:

- Freely propagate through liquids and solids
- Reflect at boundaries of internal flaws and change of material
- Capable of being focused, straight transmission
- Suitable for real-time processing
- Harmless to the human body
- Non-destructive to material

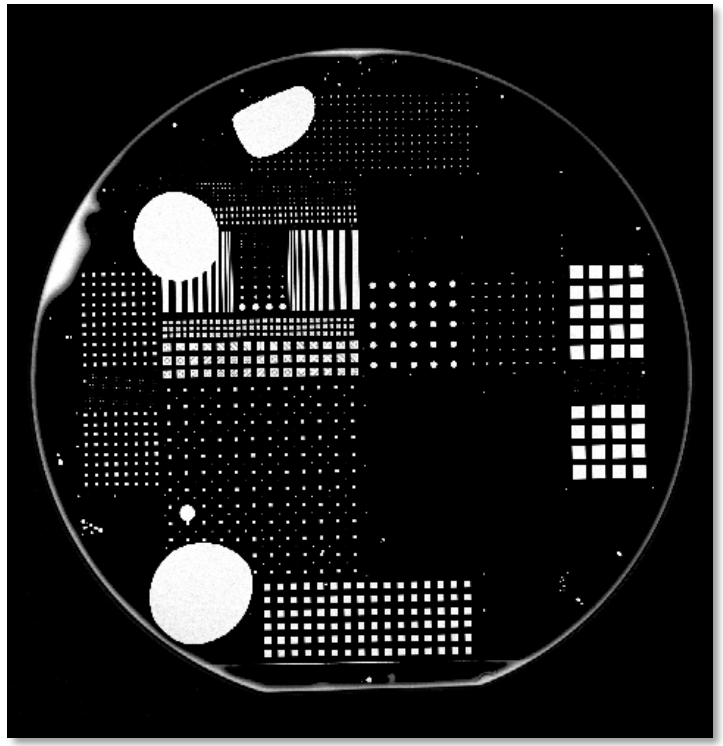
Graphical presentation of working method



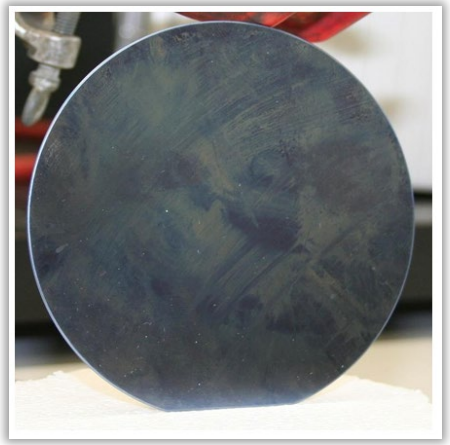
- The Scanning Acoustic Microscope operates with the pulse reflection method. A special acoustic lens produces, transmits and receives short sound pulses at high penetration rate.
- The acoustic lens converts high frequency electromagnetic vibrations which are propagated as a parallel plane wave field inside the lens. The cavity focuses the sound field on the sample through the coupling medium.
- The acoustic lens receives the sound pulses reflected from the sample.
- The transducer transforms the sound pulses into electromagnetic pulses which are displayed as pixels with defined gray values.
- To produce an image, the acoustic objective lens scans the sample line by line.
- A transducer with good focusing properties on axis can be used for both transmitting and receiving the signal.

Comparison of bonded wafer analysis

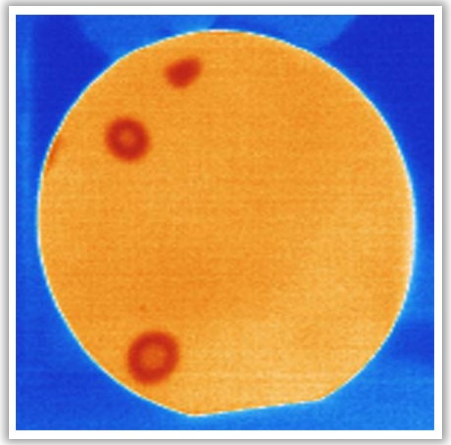
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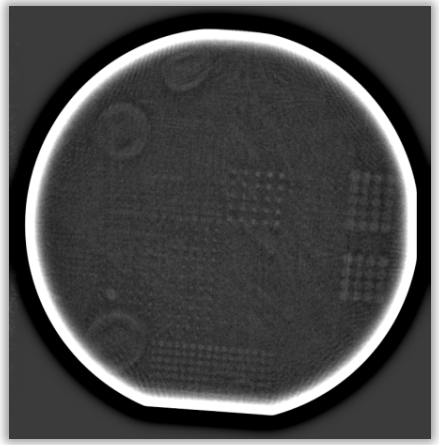
SAM



Optical



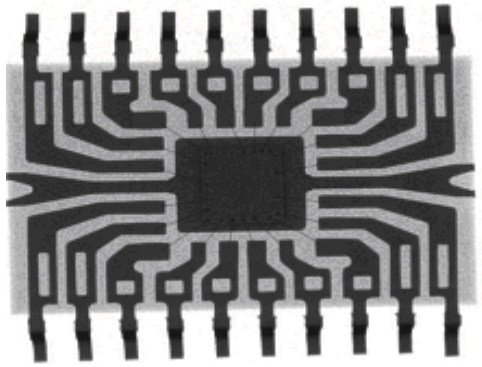
IR



XRAY CT

X-ray vs. SAM

X-ray



The interior of the sample is visualized with both techniques. The ultrasonic microscopy allows detection of delamination with two methods:

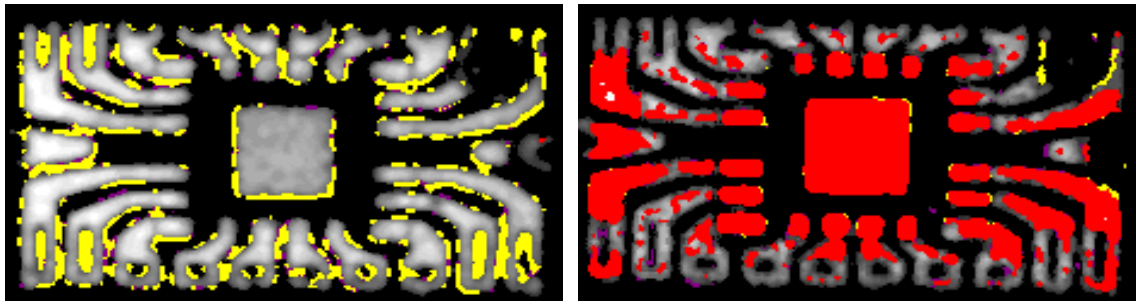
1. Total reflection of the ultrasonic wave
2. Phase detection

SAM (Phase detection)

Defect free | Delamination

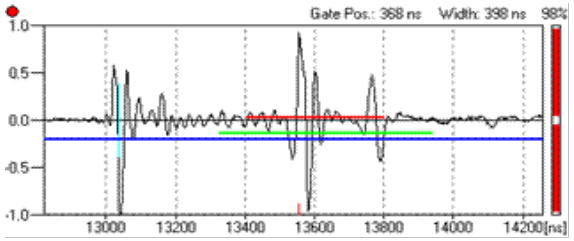


Phase detection

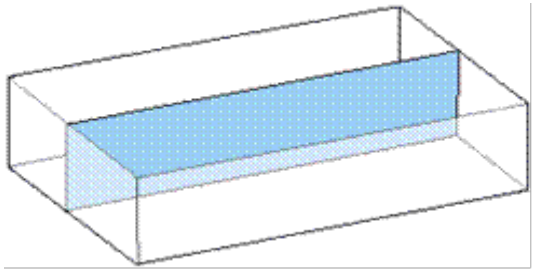


Delaminations appear as bright areas (upper image) or marked as red using the phase detection tool (lower image).

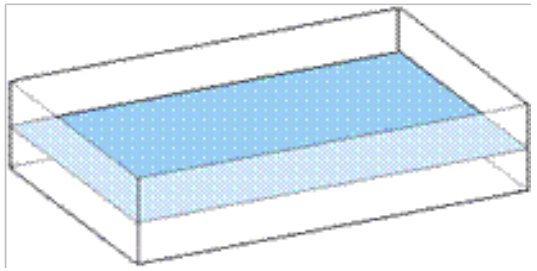
Different Scanning Modes



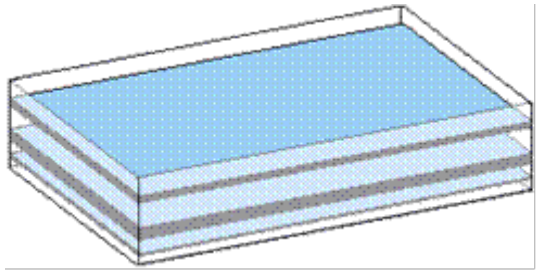
A-scan



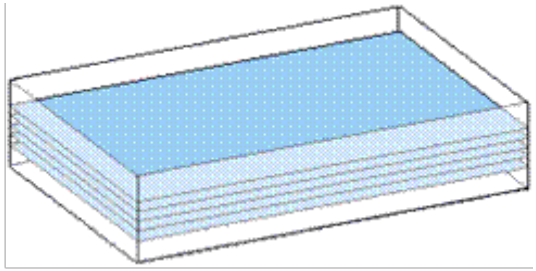
B-scan



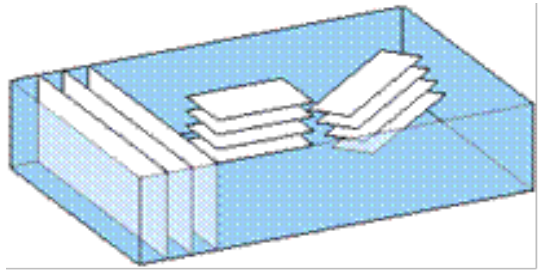
C-scan



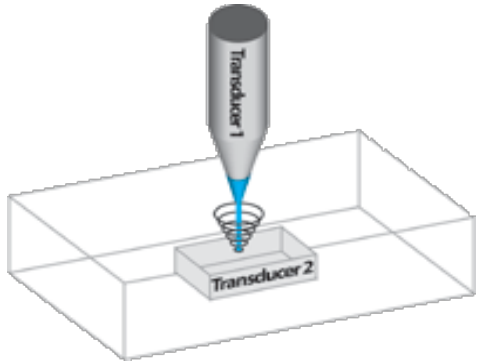
G-scan



X-scan



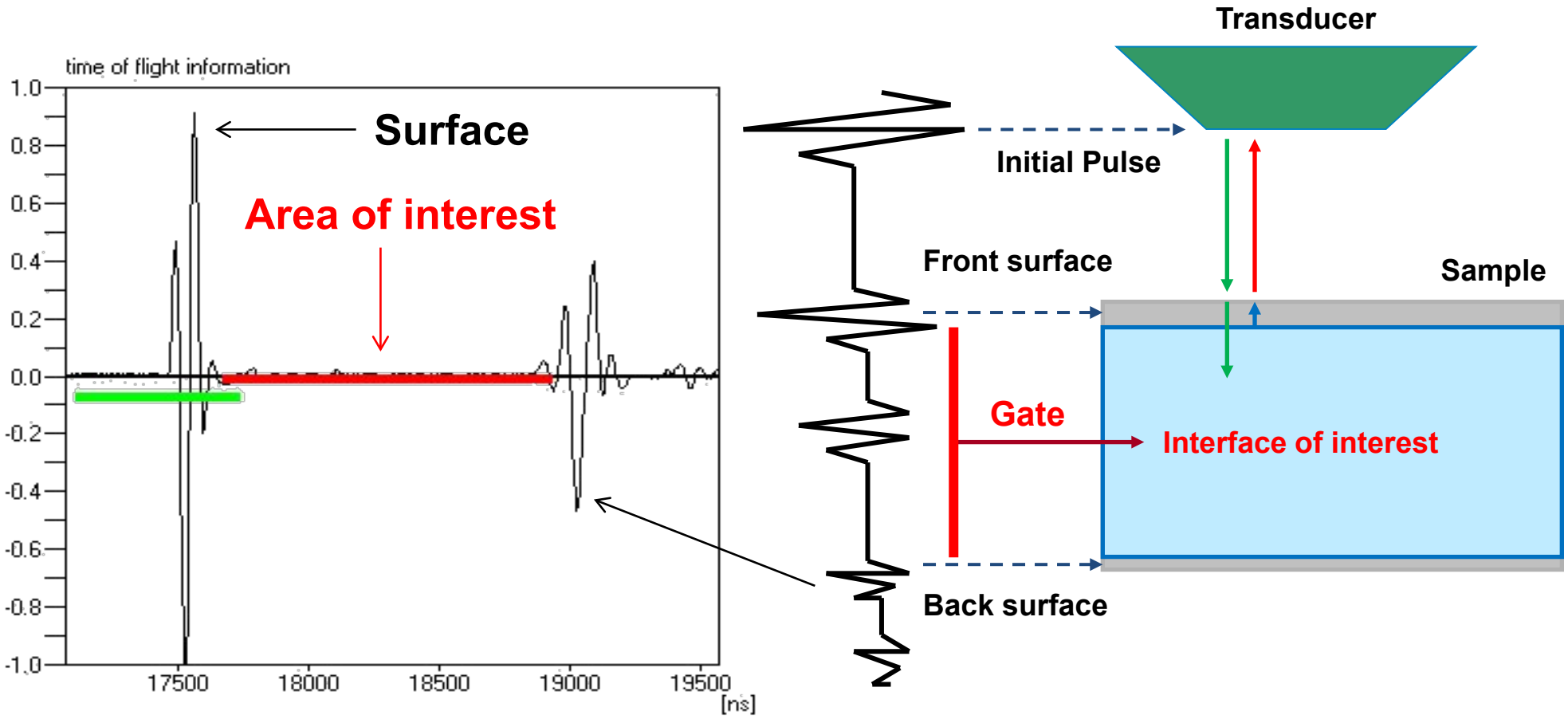
Z-scan



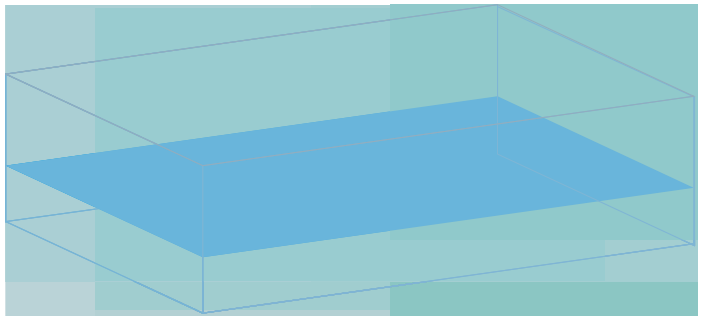
Through-scan

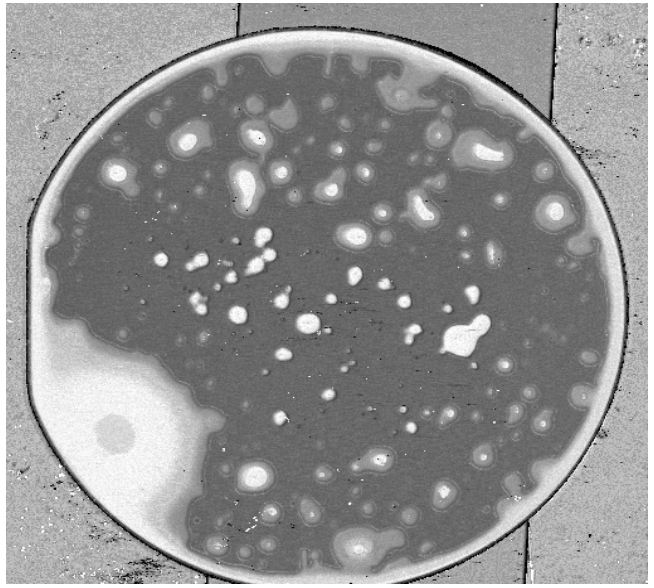
A-scan

Reflection of the ultrasonic beam at interfaces with impedance mismatch, back wall, defects, layer interfaces, ...



C-scan





One layer of the sample:

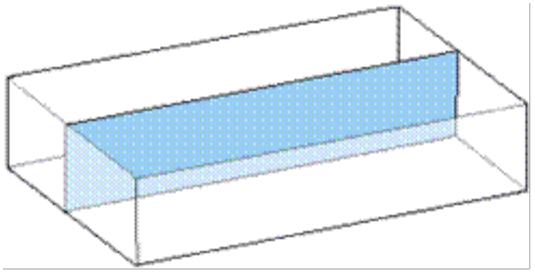
- layer thickness given by the gate width
- layer depth given by the gate position

The intensity of the echo is corresponding to the brightness in the image

Determination of:

- defect position
- defect shape
- defect size

B-scan

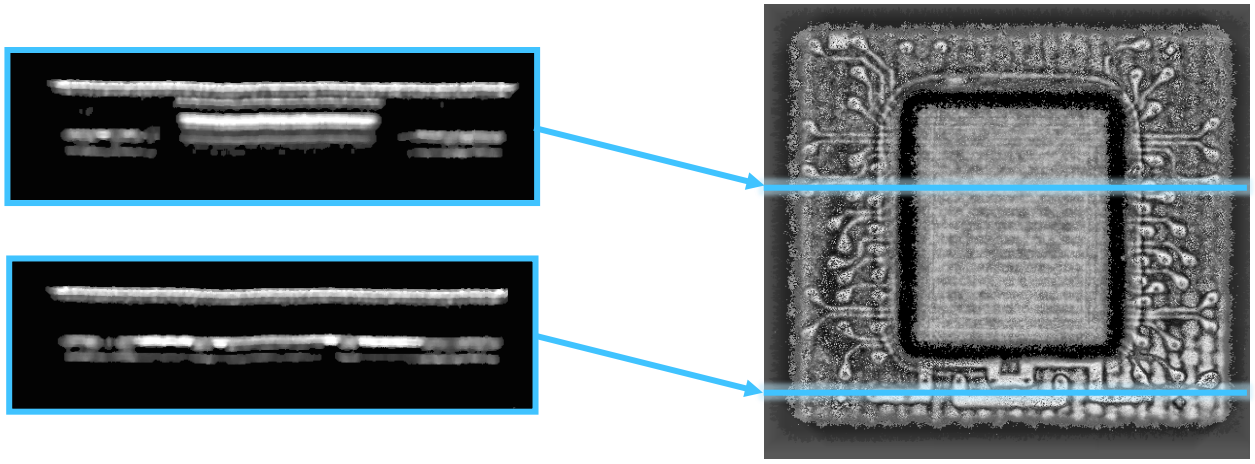


Cross section through the sample:

- examined thickness given by B-Scan width (thickness=vt)

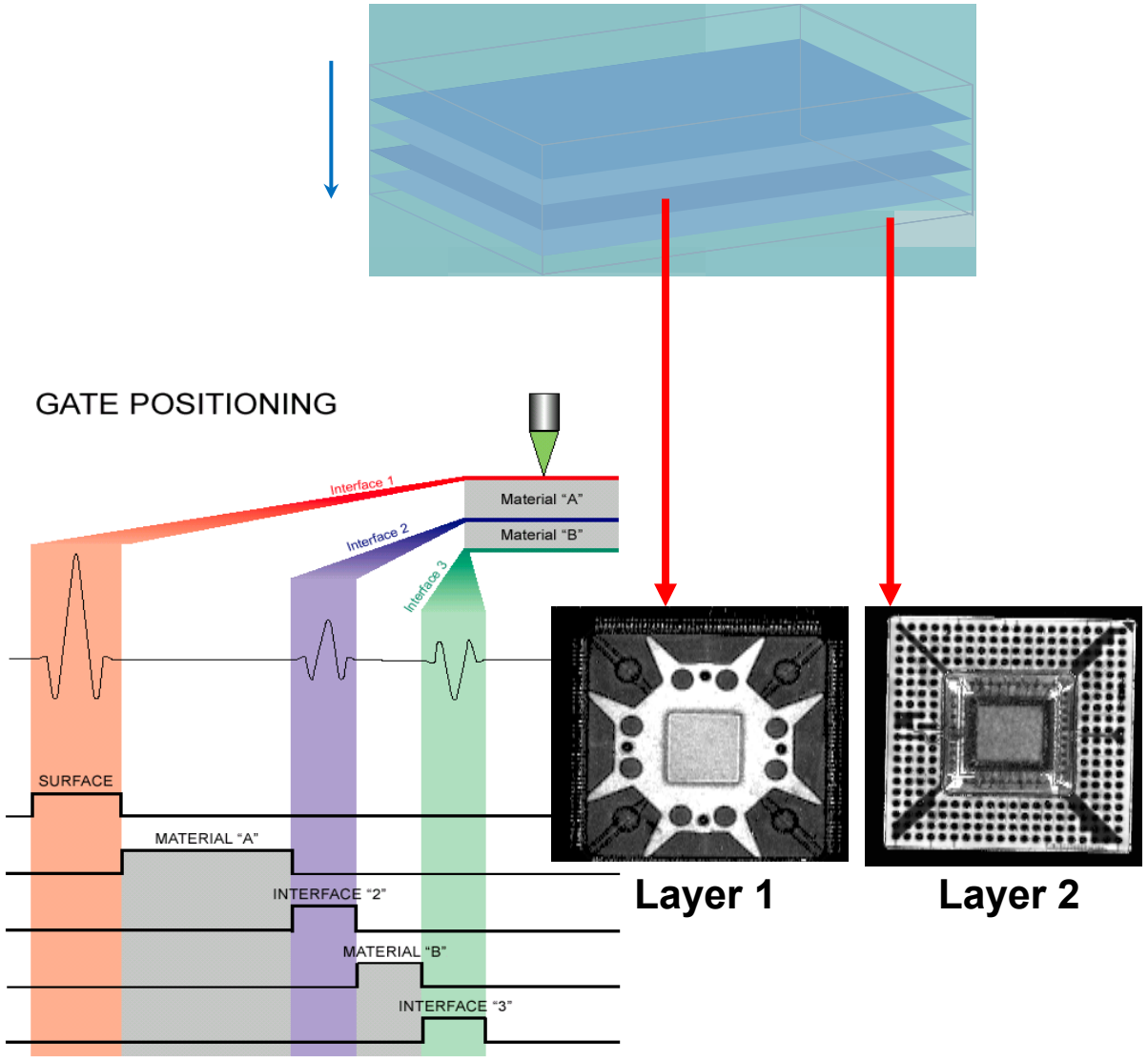
Determination of cross section profile:

- number of interfaces
- depth of interfaces
- defect depth



- To perform B-scan, right click at the C-scan image and select **Add B-scan Line**.
- Afterwards, select the region to be sectioned (multiple B-scan can be done).
- The depth of the virtual section depends on the data gate length at the A-scan

X-scan



Slices of volume sections in different depths:

- number of layers given by ratio of B-Scan width and gate width
- investigated thickness given by B-Scan width

Determination of (additional to C-scan):

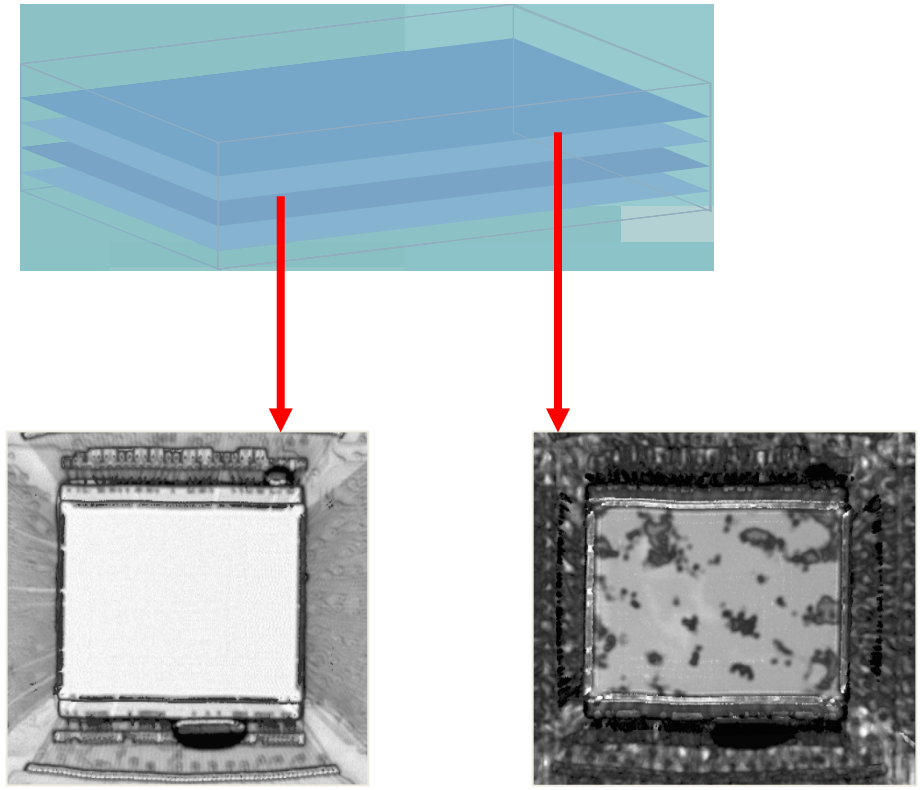
- quick overview of the sample interior
- defect position in the depth

→ **....n images....**

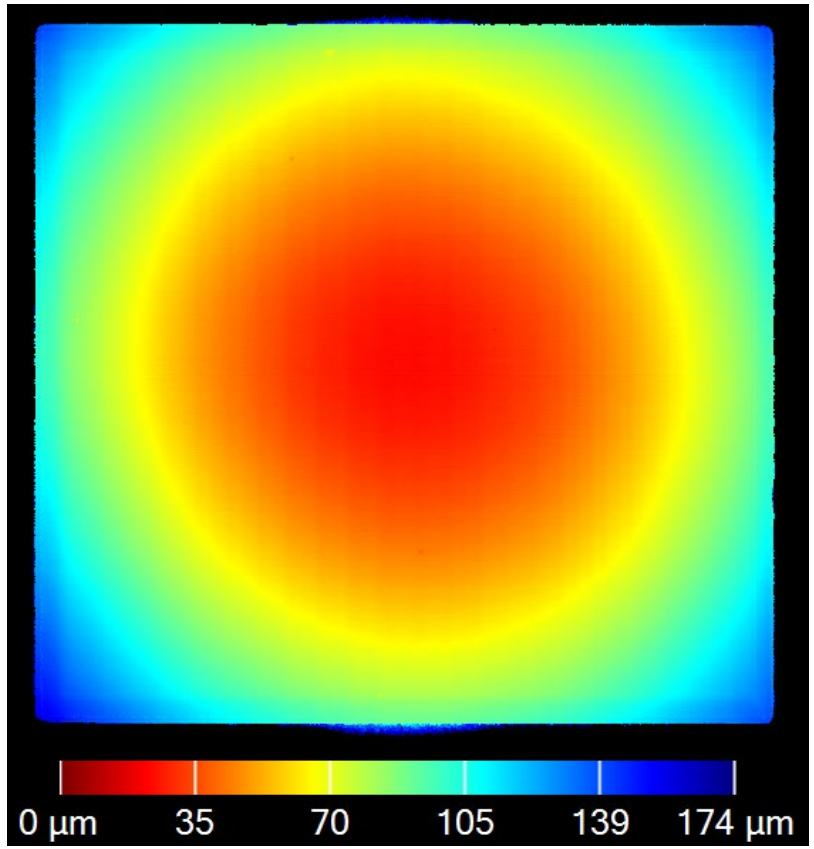
→ **....n layers....**

G-scan

- Similar to X-Scan
- but each gate can be chosen with different parameters, like amplification and filters.

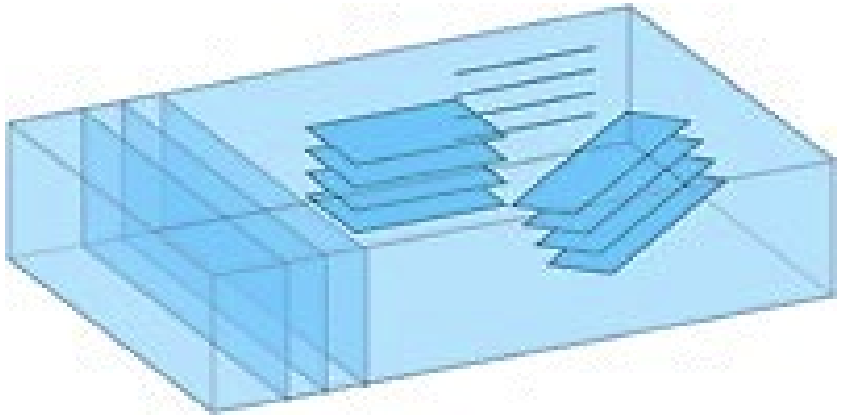


Time-of-flight (TOF)



- TOF imaging utilizes the amount of time needed for the reflected acoustic signal.
- Several information including surface profile and layer thickness can be evaluated.

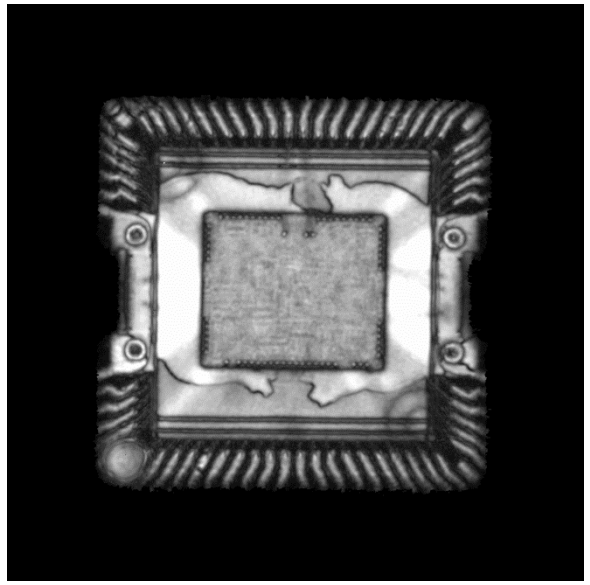
Z-scan

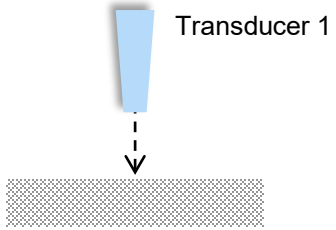


- Using the **Z-scan-mode**, all A-scan data will be stored in a file.
  - The file size might be up to 2 GByte.
- The scanning time is equal to a normal C-scan.
- This new mode allows all individual gate settings, like A-,C-,B-scan, slice and 3D scan (including amplitude and time of flight data) afterwards, thus the sample can be “cut” into individual layers.
- All data are stored for further investigations in one file.

Through scan

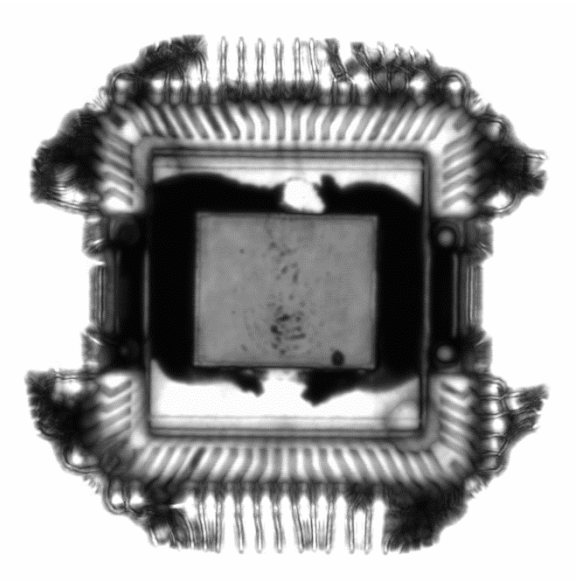
Reflection (echo)

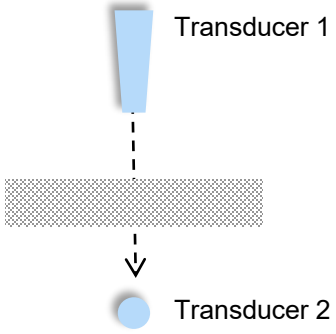




Delamination / Void displayed as bright

Transmission (through)





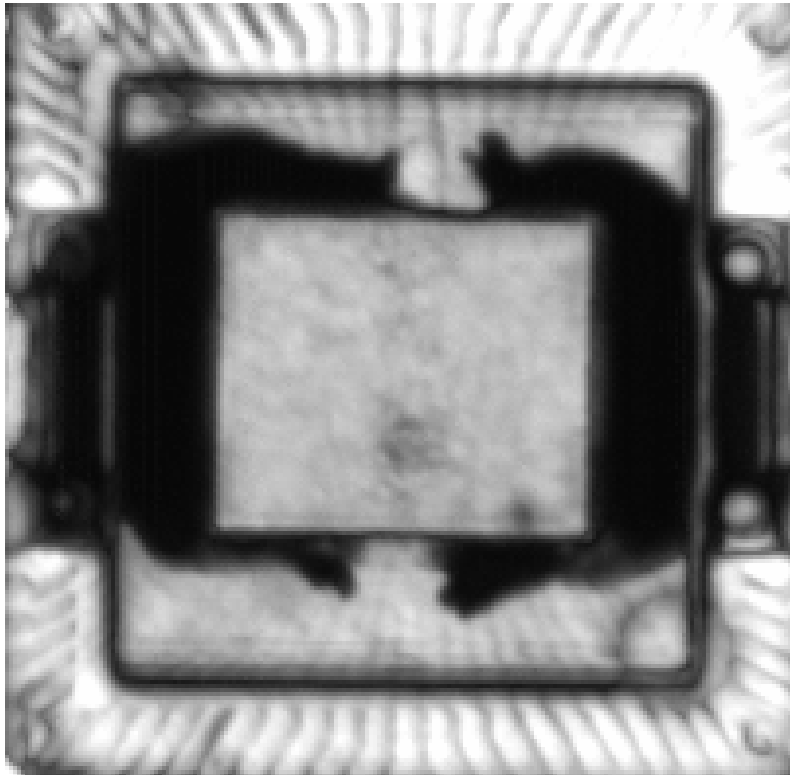
Delamination / Void displayed as dark

- **Conventional Through scan** imaging involves a fixed focus position of the receiving transducer.
- The new aproach uses **DTS (Dynamic Through Scan)** wherein the receiving element is a focusing transducer with movable focus position.

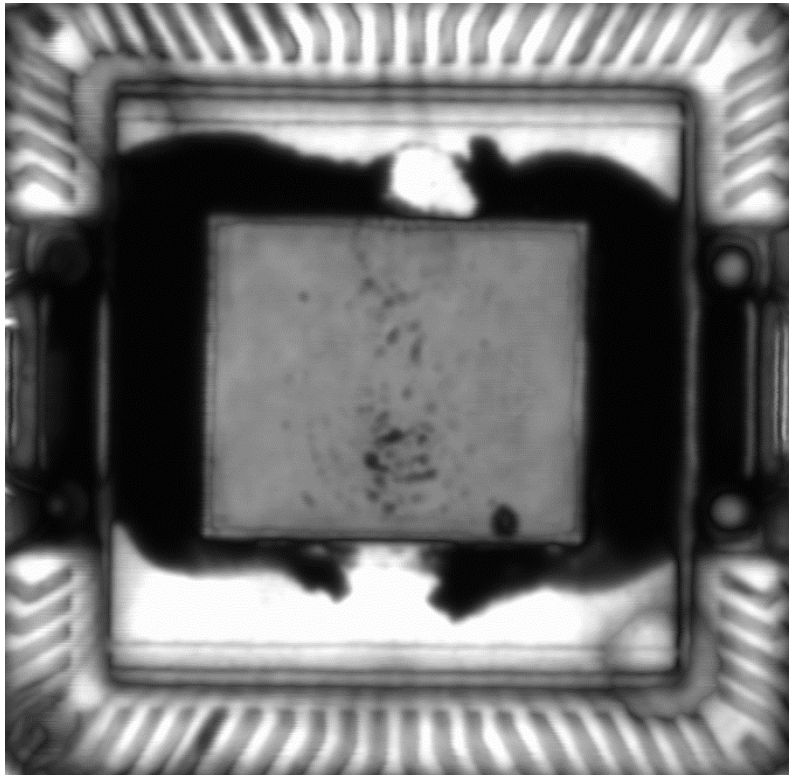
Through scan

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Conventional Through Scan

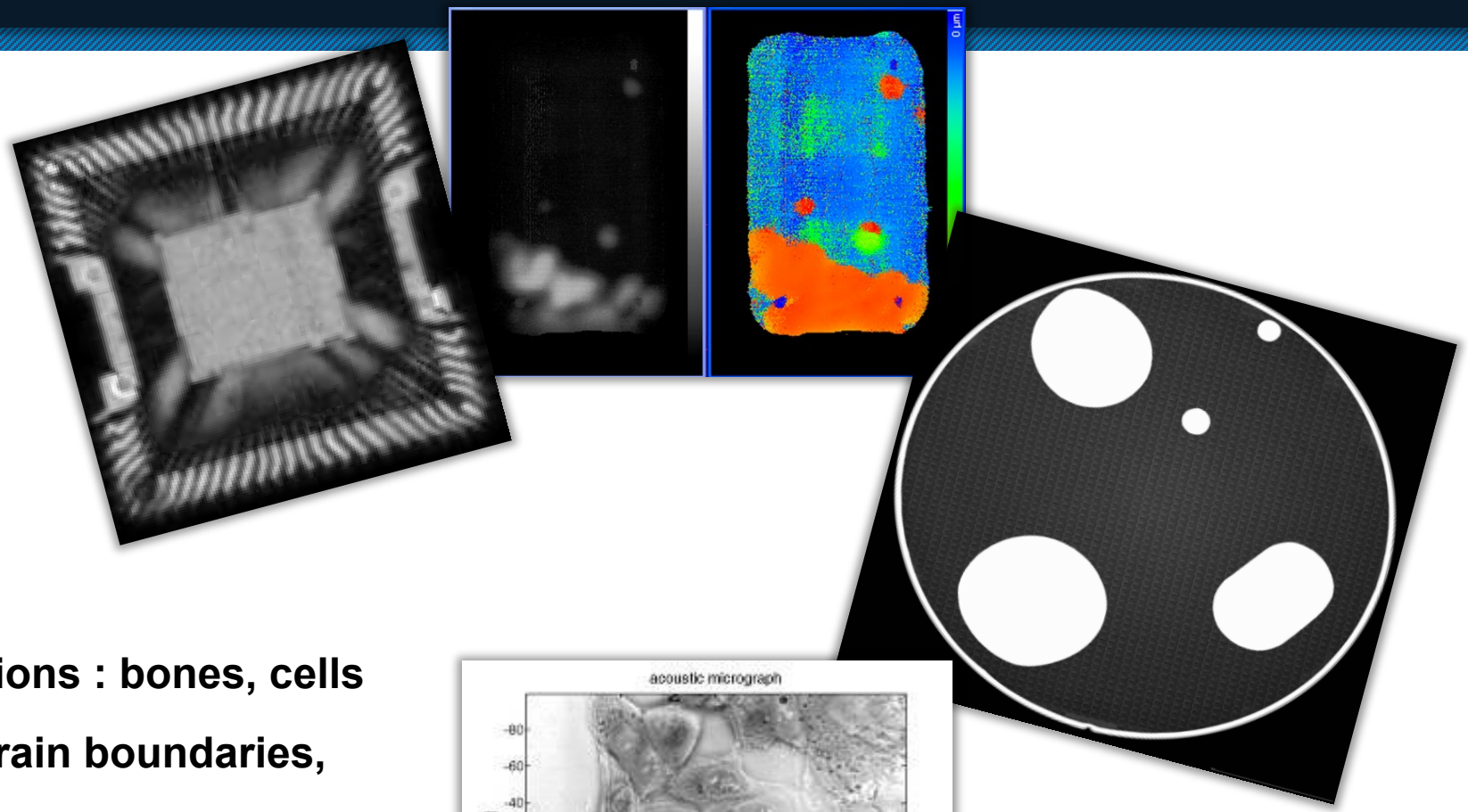


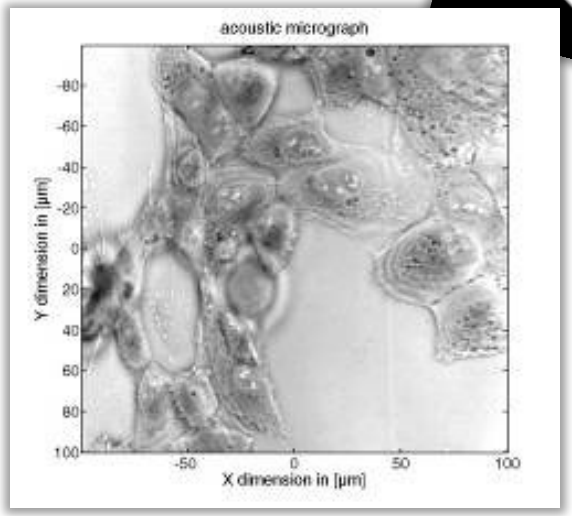
Dynamic Through Scan



Typical applications for SAM

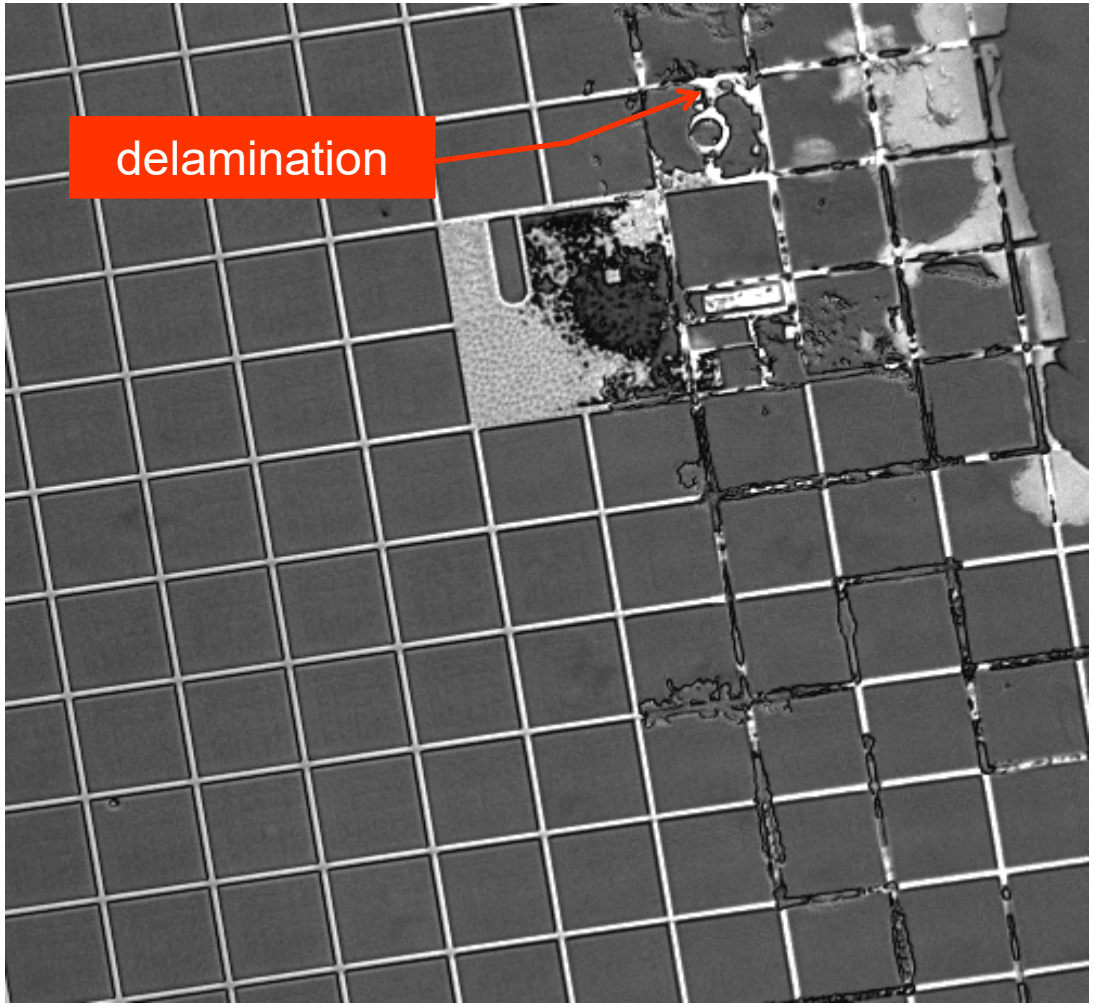
- molded devices
- Flip chips
- bonded wafer
- PCBs
- Capacitors and resistances
- Ceramics / metals / Plastic
- biological/ medical applications : bones, cells
- material characterization: grain boundaries, crystal orientation





LED wafer bonding (front-end process)

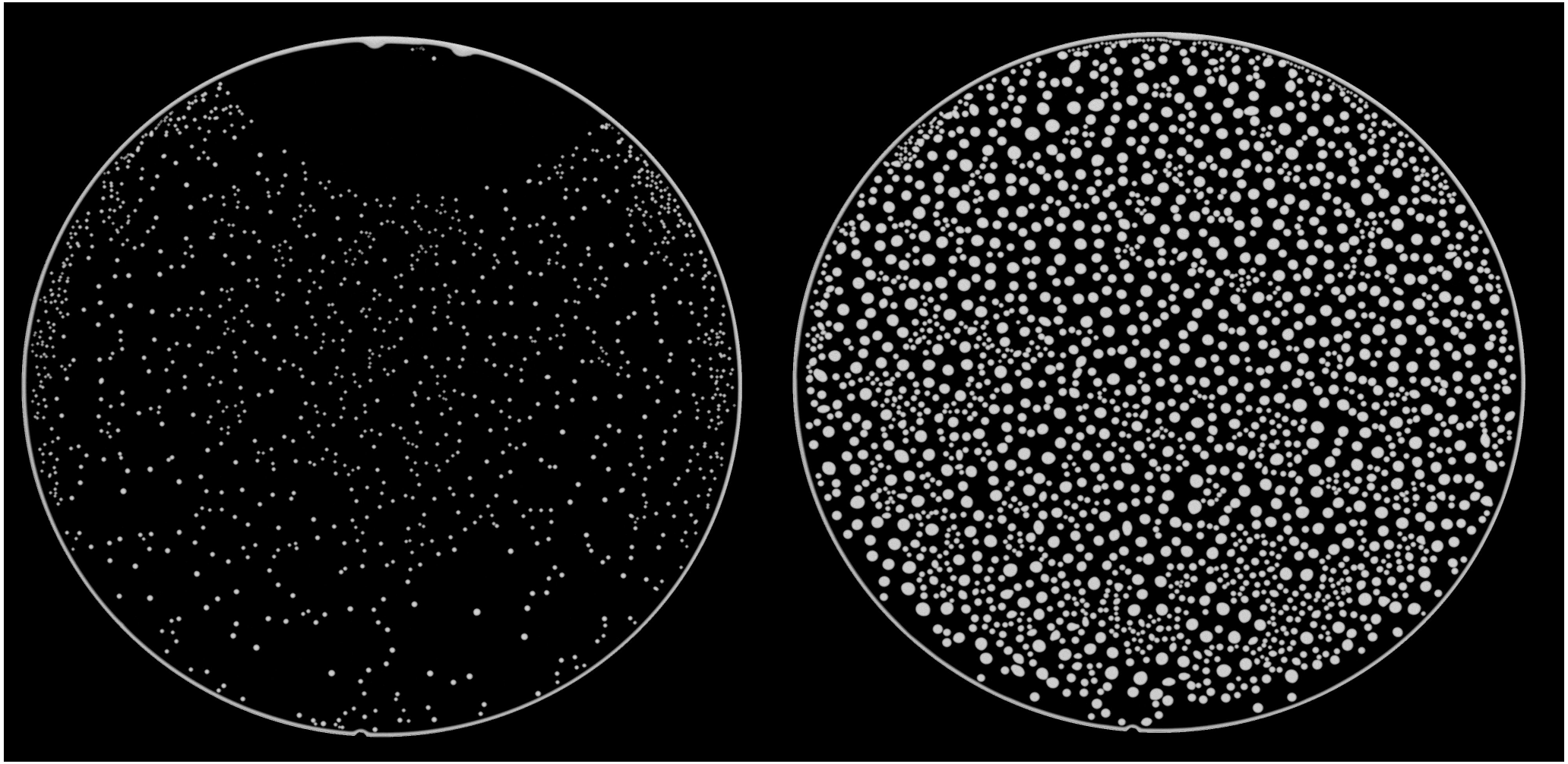
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SAM is used to non-destructively inspect wafers for bond delamination.

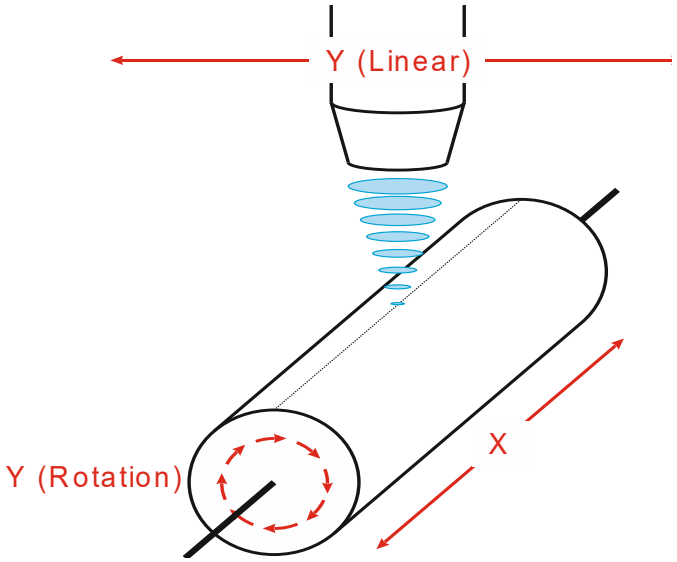
Bonding interface inspection: 12 inch wafer

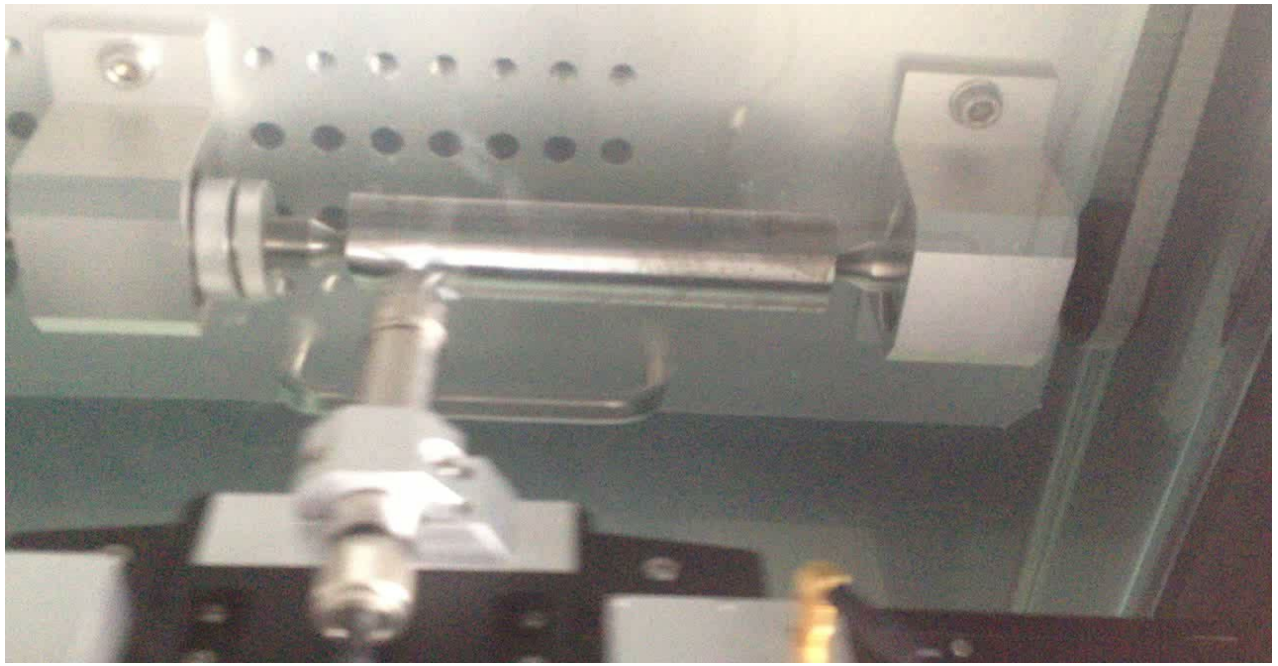
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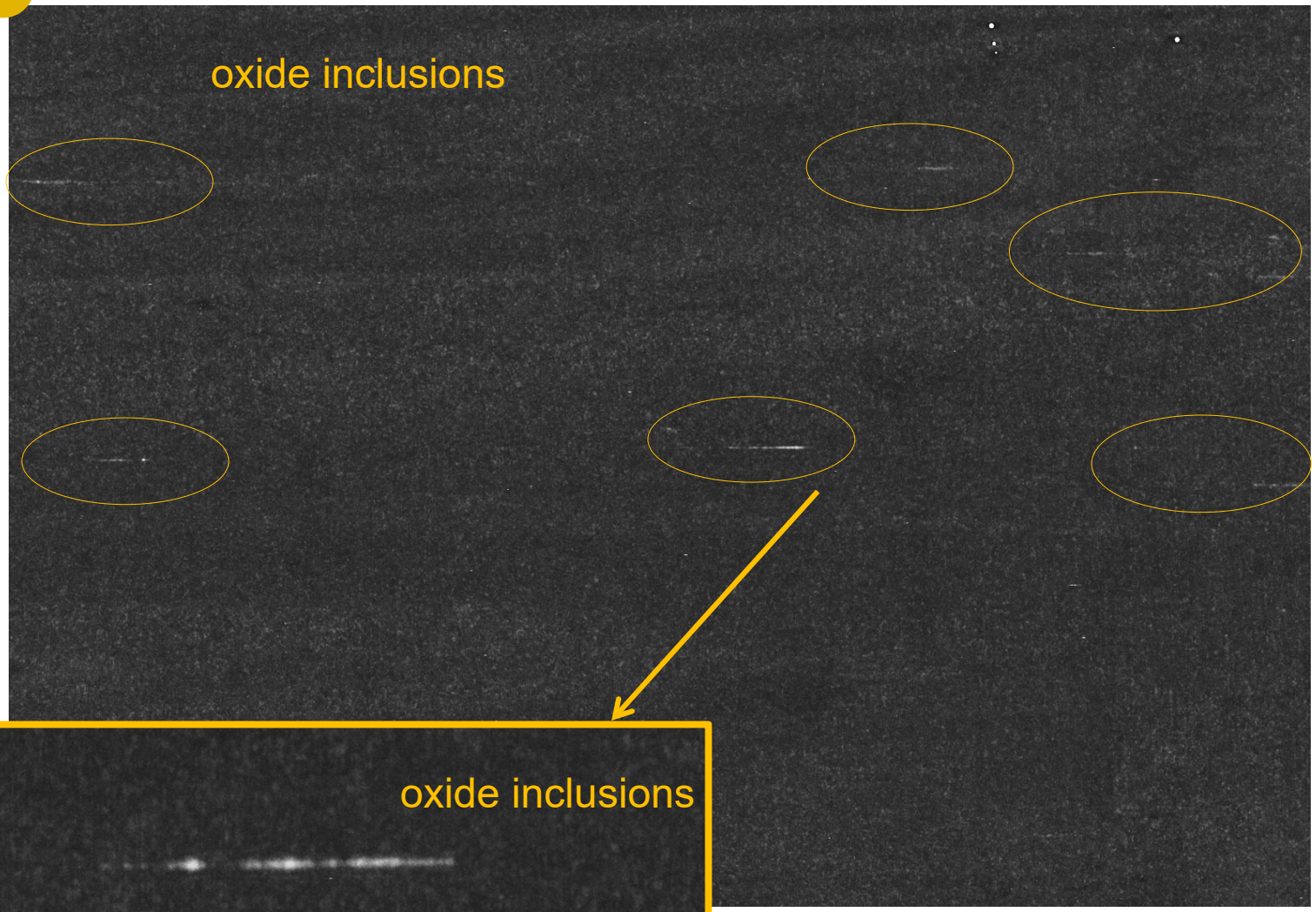
Rotational scanner

transducer: 15MHz 1.5 inch

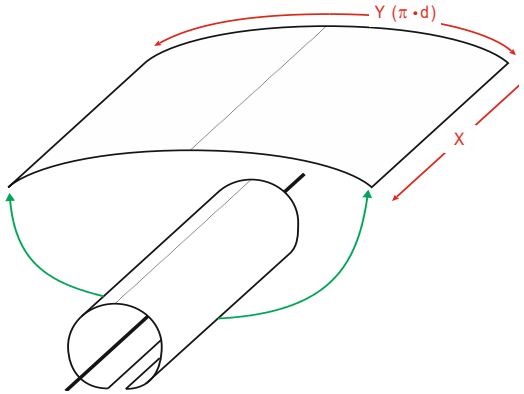




Metal cylinder – detection of oxide inclusions



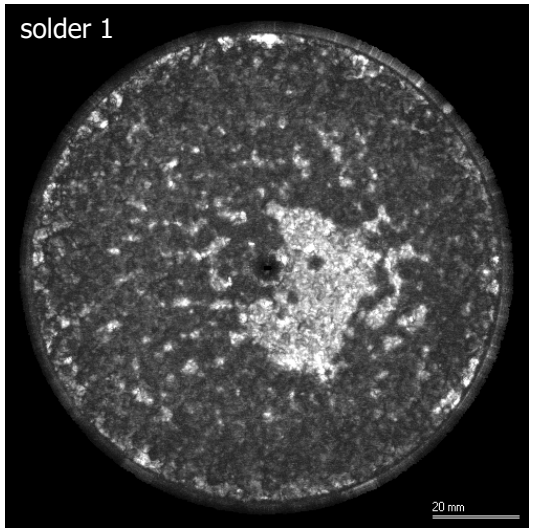
captured image
(boundary surface)

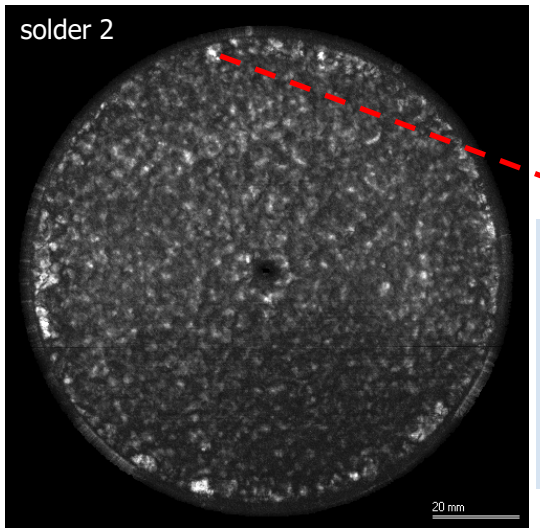


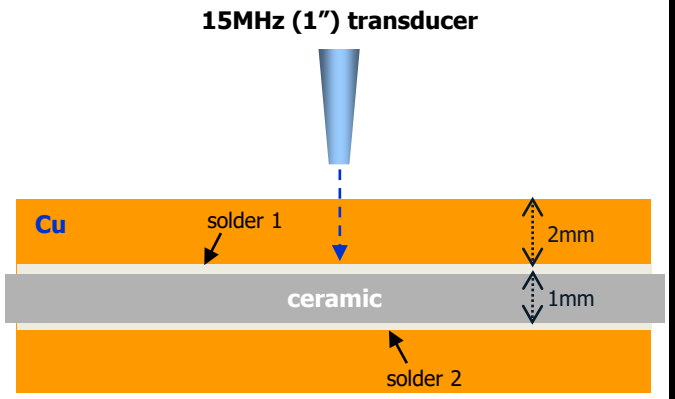
- **High reflectivity** indicates a large difference in the acoustic impedance (s. page 2) in the SAM image inclusions compard to the matrix
- Showing a large acoustic impedance difference compared to the matrix were detected (see white structures within the encircled areas)
- Enlarged images of areas 1, 2 and 3 are shown on the next slide

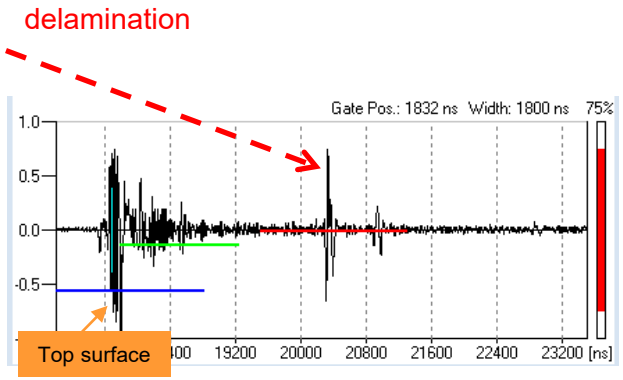
Cu disc – solder delamination

Sample 1

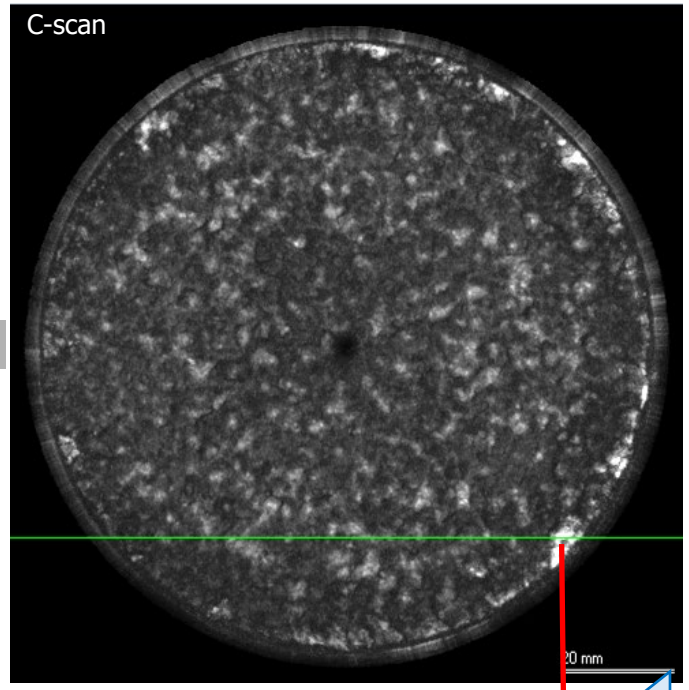


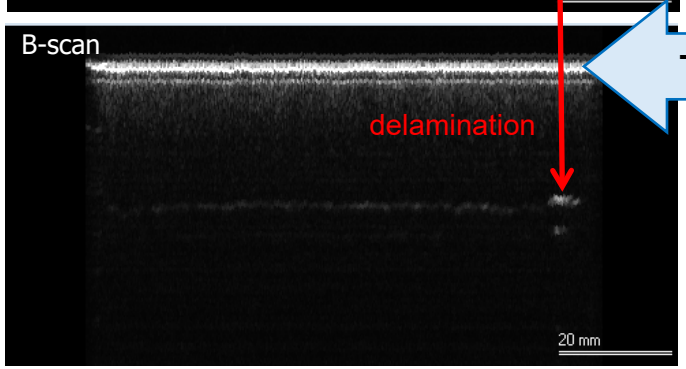






Sample 2

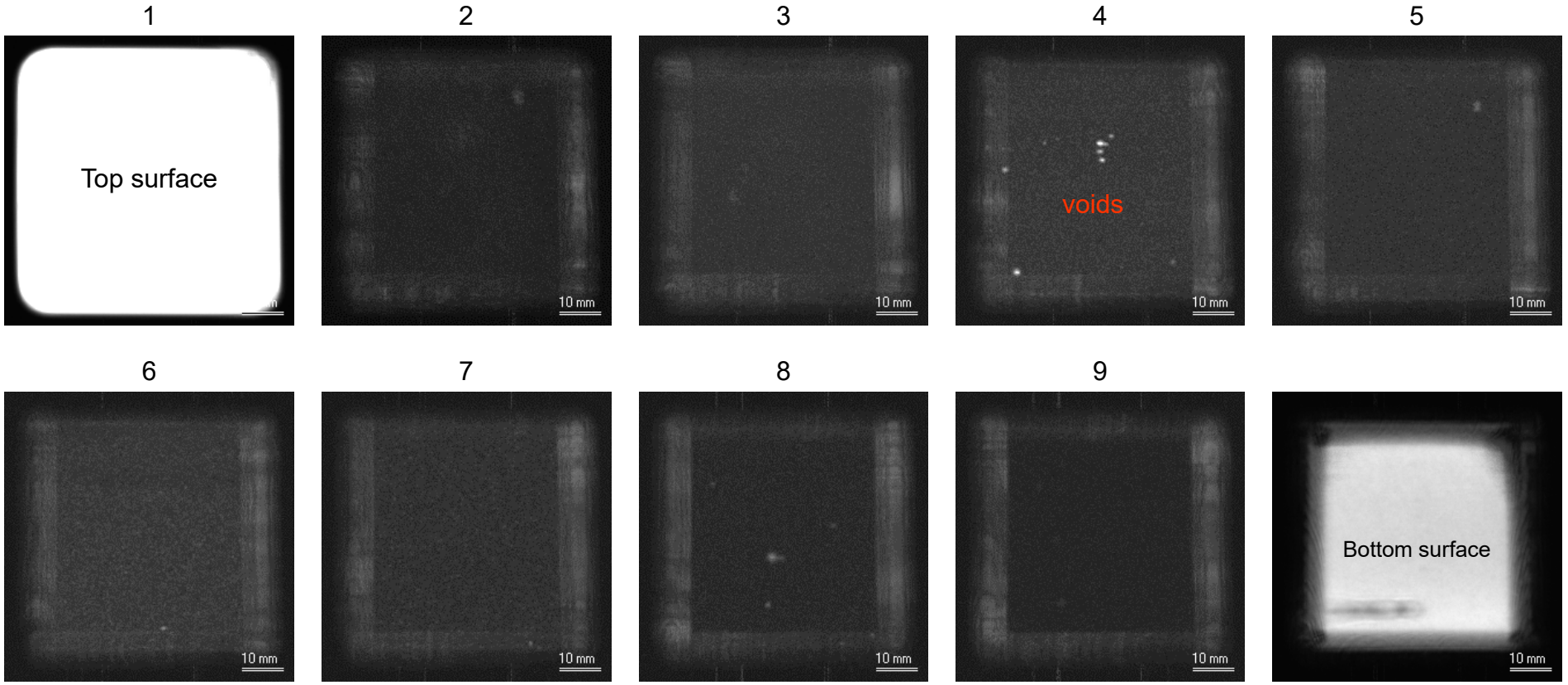


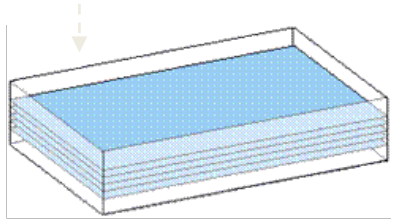


Top Surface

Equal slices along the volume of the metal block

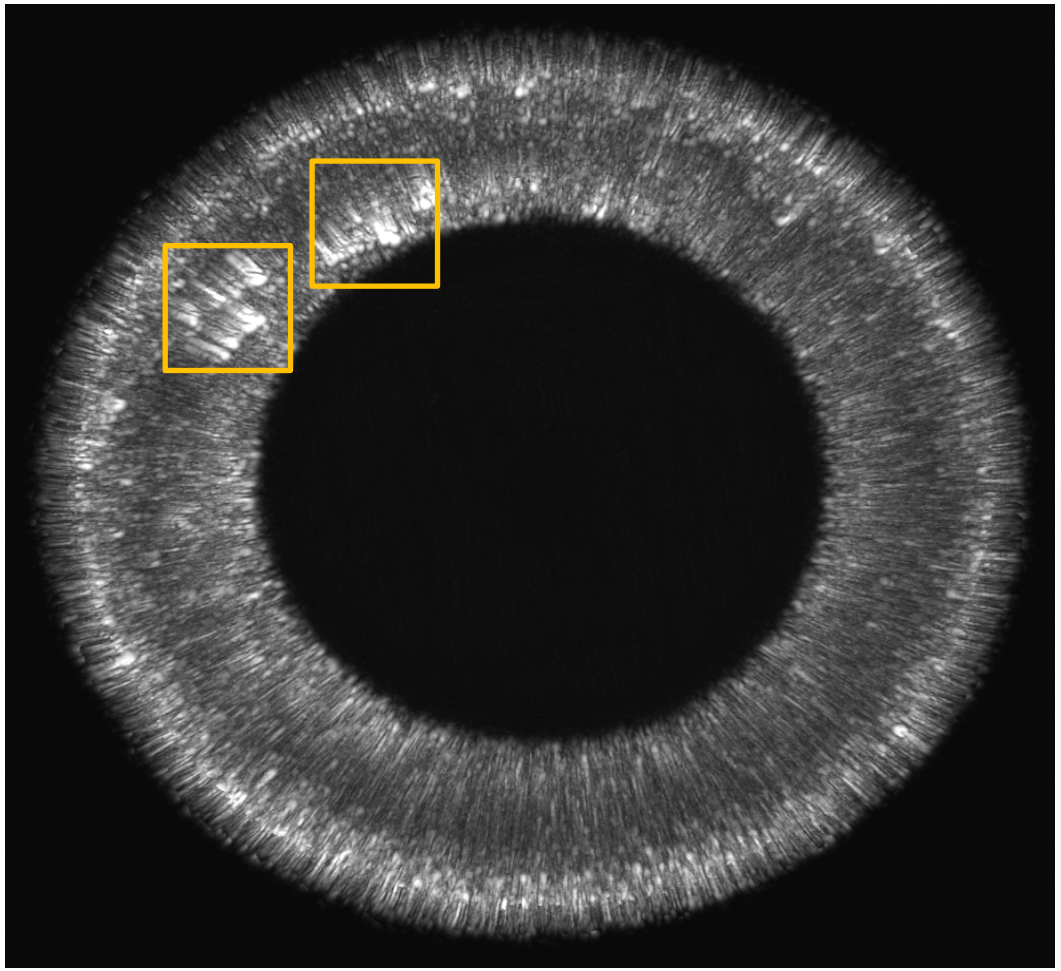
X-Scan

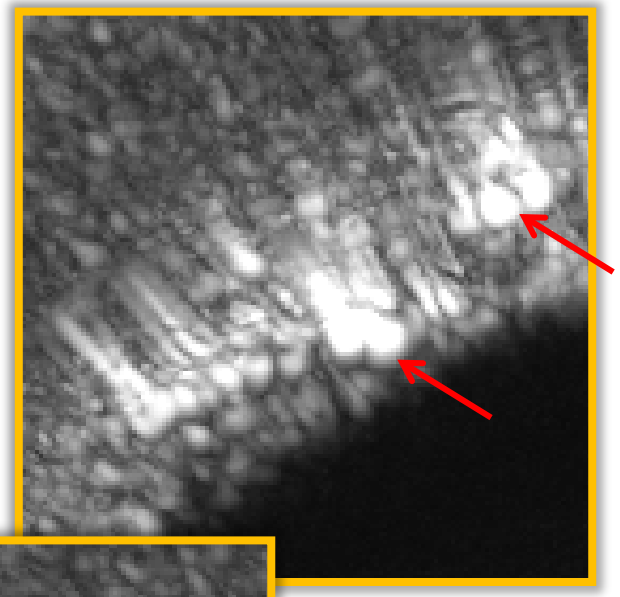


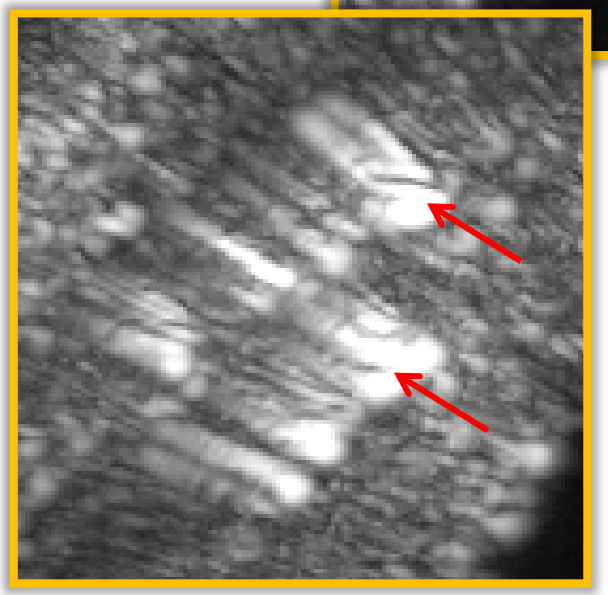


X-scan is a simultaneous scan showing series of equally spaced slices from the top to the bottom. Each slice is approximately 3mm.

Voids in a turbine

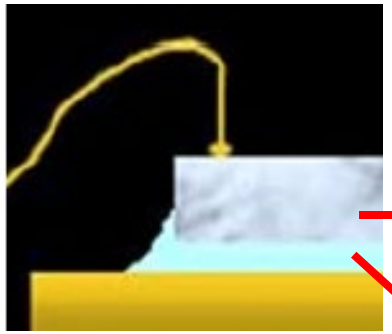




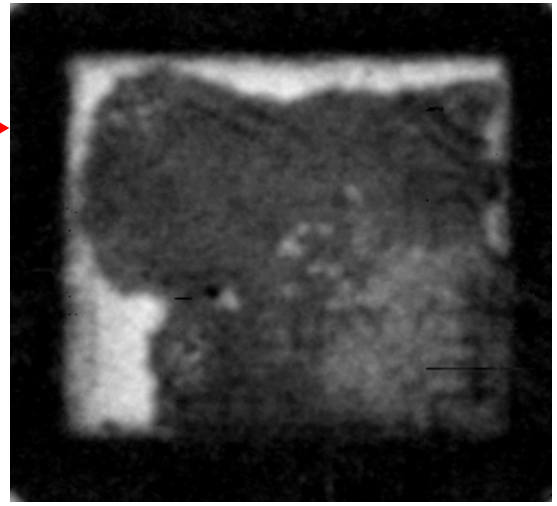


very bright spots (exemplary marked by red arrows) = **voids**

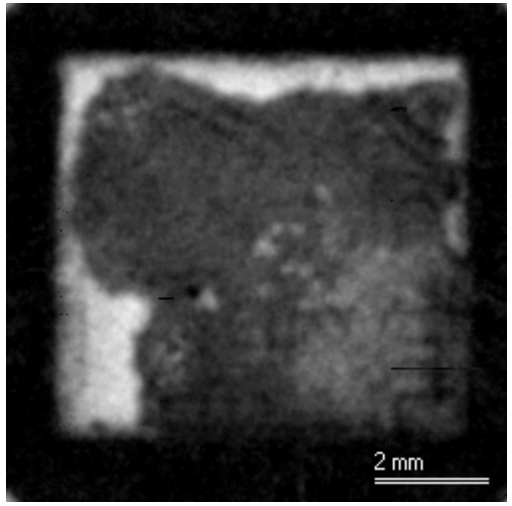
Die attach

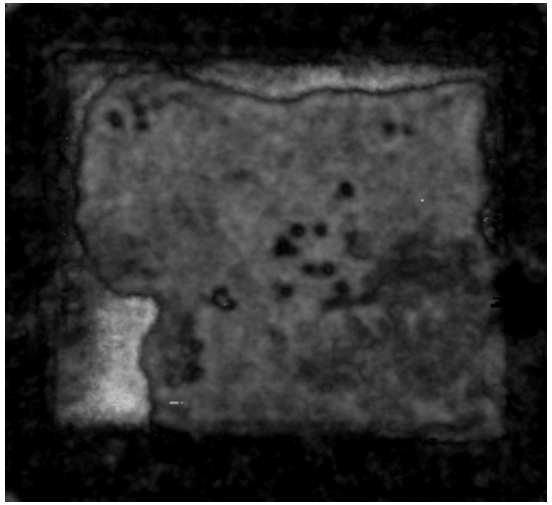


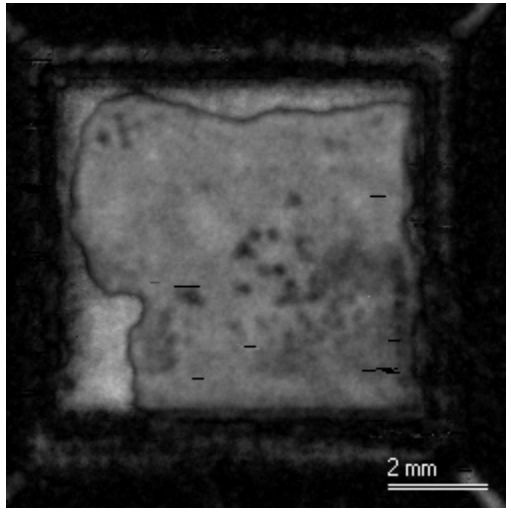
50MHz (10mm)



125MHz (9mm)



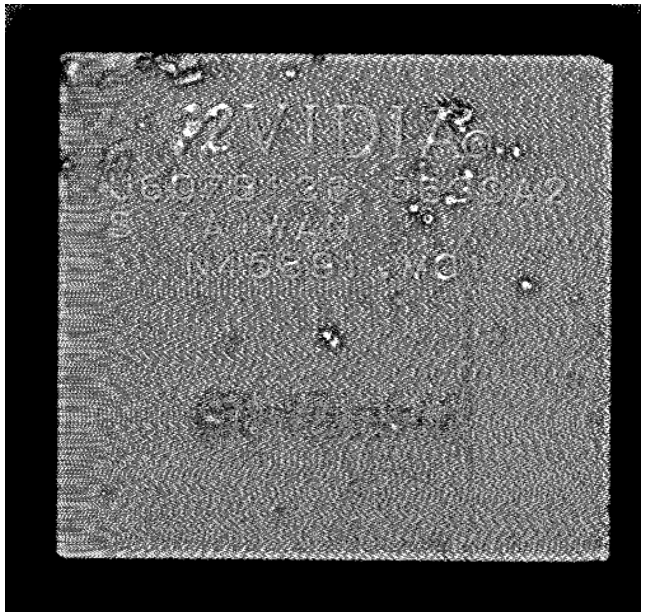




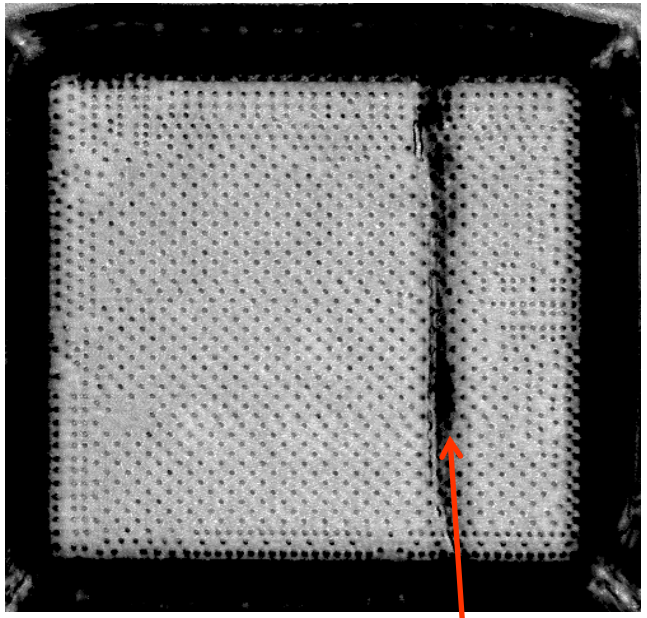
Microcracks on the die

G-Scan

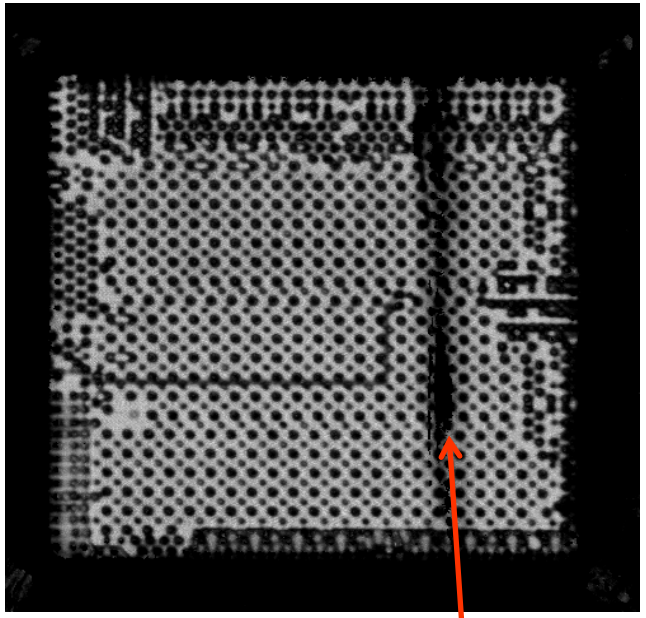
Surface



Die Bottom



Die Attach

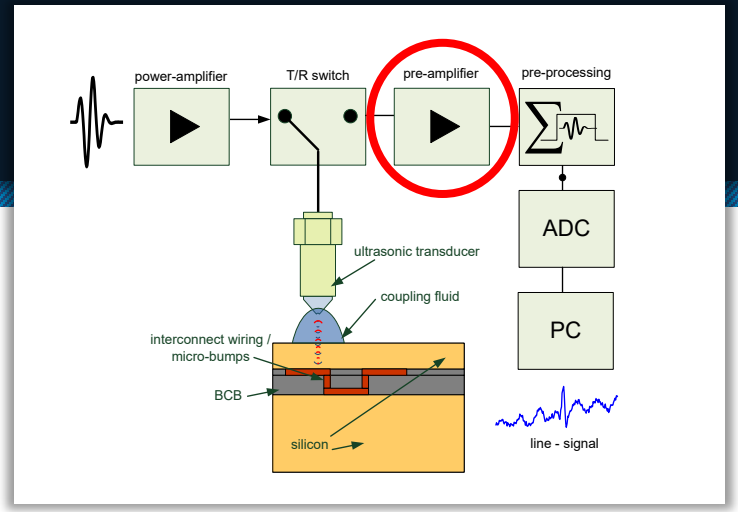


No manifestation of microcrack is visible on the die surface. However, at the die bottom, the microcrack is clearly visible as a wide dark line shown on the scanned image.

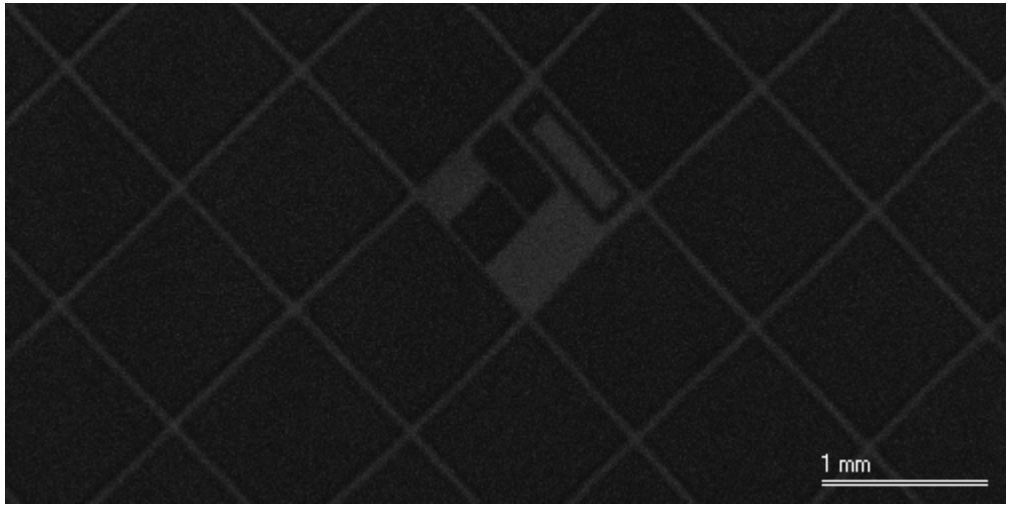
COVALENT METROLOGY

Advanced SAM technology and applications

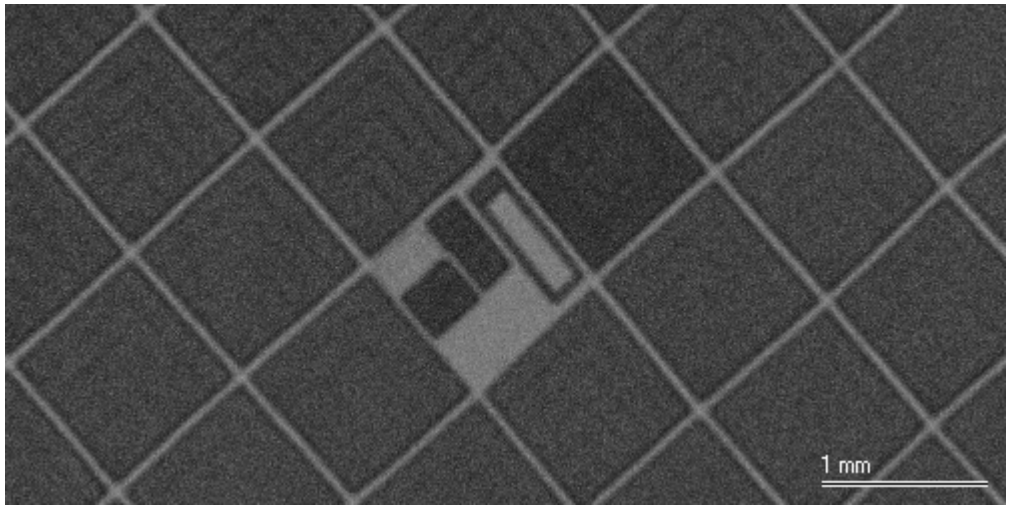
New high resolution pre amplifier



Improvement of image quality:
higher bandwidth due to new chip technology, bandwidth up to 160 MHz, reduction of image noise, up to 10 dB more gain



“Dead” transducer: 50 dB



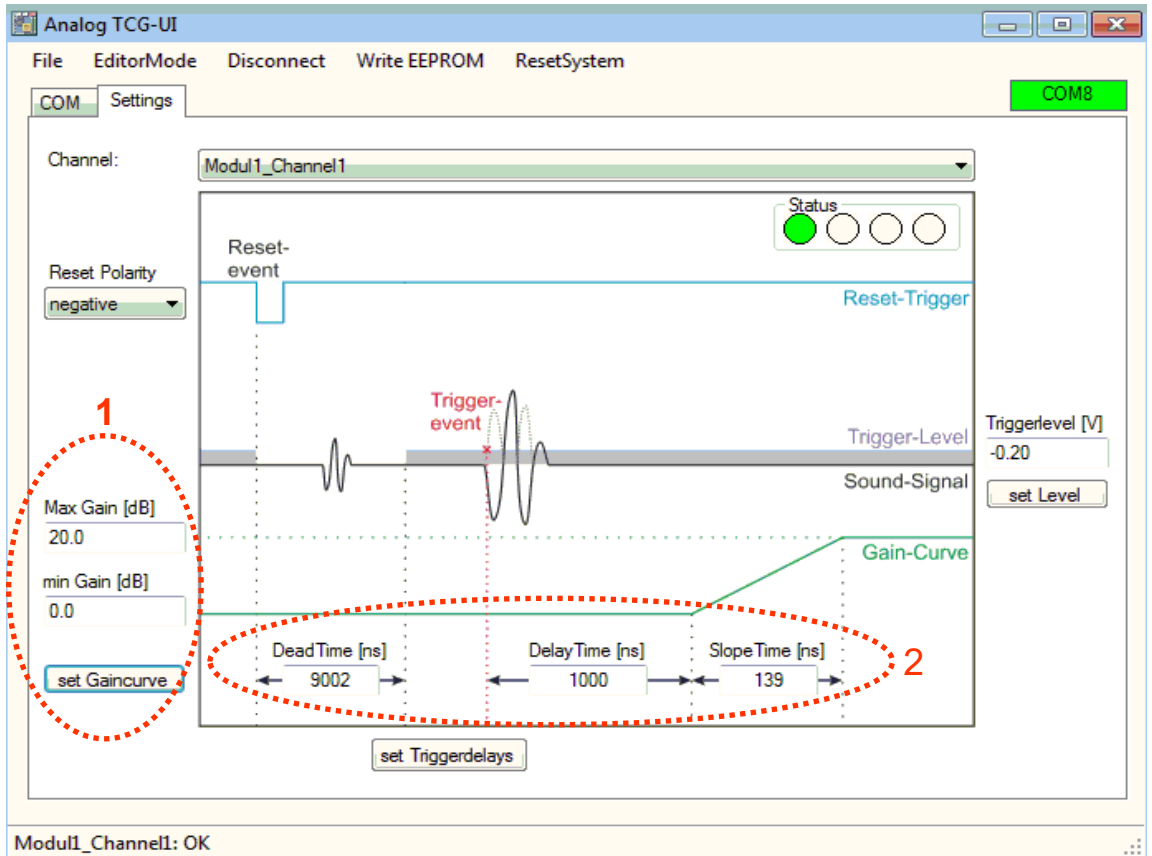
“Dead” transducer: 50 dB
new pre amplifier

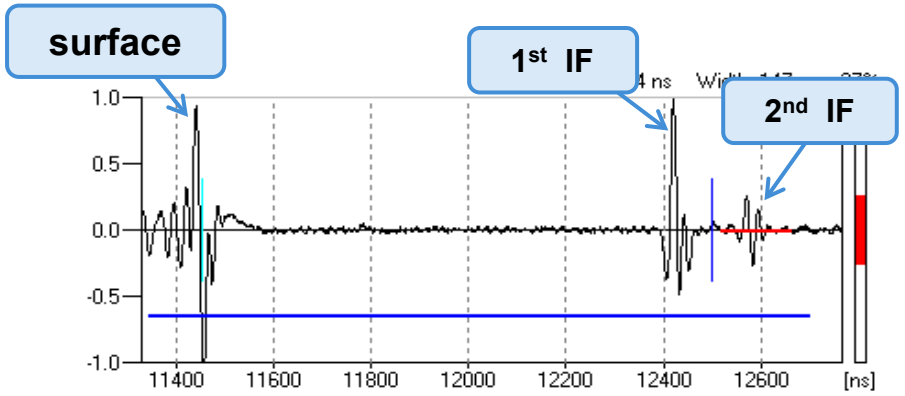
TIME CORRECTED GAIN (TCG): optimized amplification

COVALENT METROLOGY

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 only for the 2nd peak, avoiding the 1st IF to become oversaturated.





1. Gain adjustment
2. Trigger delay adjustment
   - enter the dead time: starting at this TOF first peak found at higher TOF is taken as reference (usually it should be the surface peak) for the trigger event
   - enter the delay time: how many ns from the reference peak the selected gain should be applied ?
   - Enter the slope of the applied gain

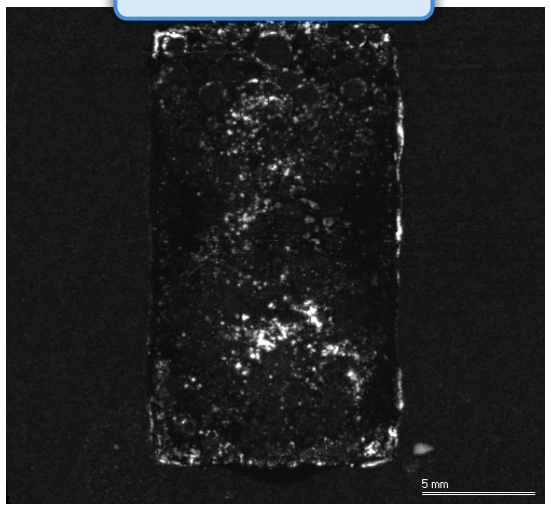
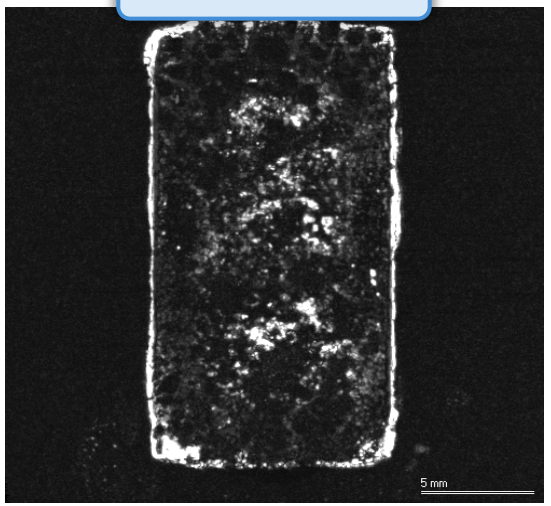
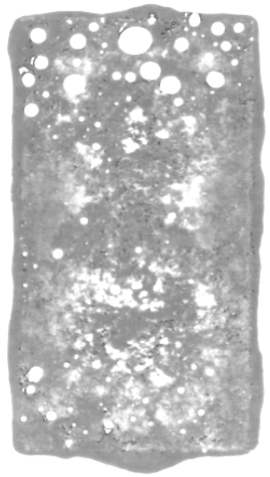
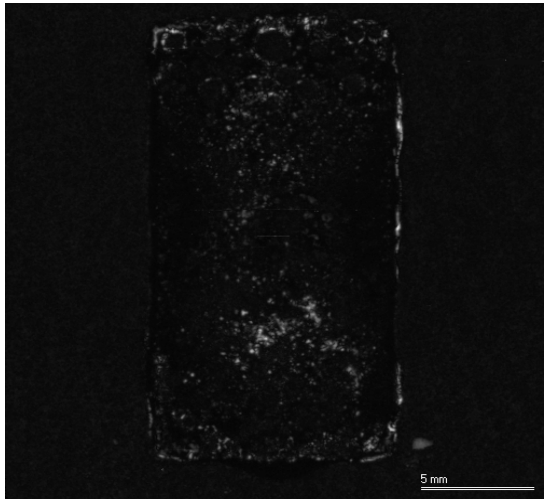
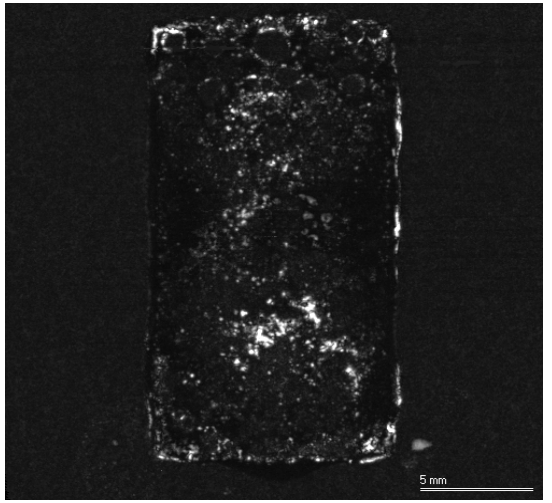
Simultaneous scan of different interfaces (G-scan) with and without Time Corrected Gain

COVALENT METROLOGY

with **TCG**

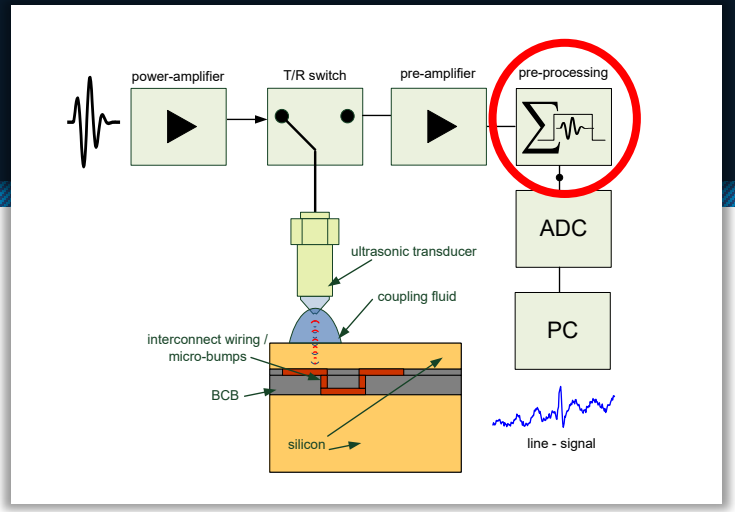
TCG enables a simultaneous scan of interfaces located in different depths

without **TCG**

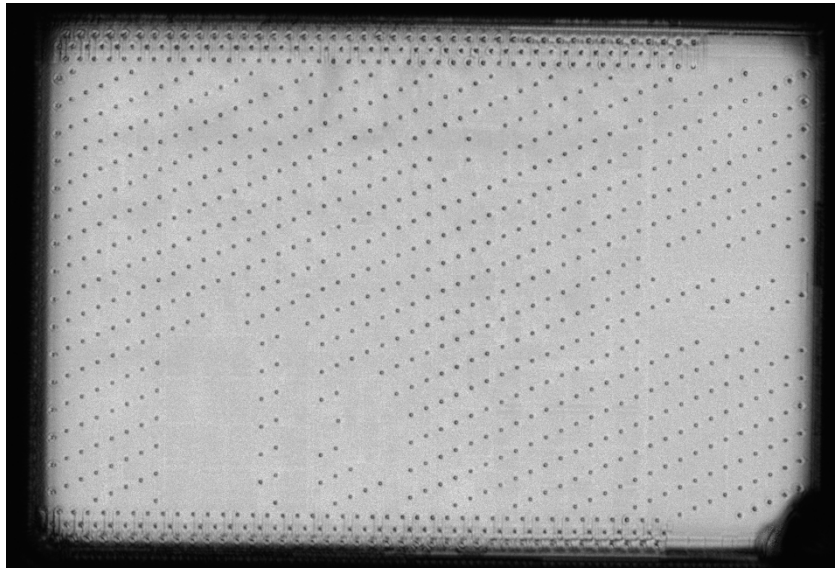
LID / STIM IF	Volume Scan	STIM / DIE IF
		
FILENAME: 40MHz_16mm_IF1_TCG.bmp	FILENAME: 40MHz_16mm_vol_TCG.bmp	FILENAME: 40MHz_16mm_IF2_TCG.bmp
		
FILENAME: 40MHz_16mm_IF1_no TCG.bmp	FILENAME: 40MHz_16mm_vol_no TCG.bmp	FILENAME: 40MHz_16mm_IF2.bmp

transducer: 40MHz 16 mm

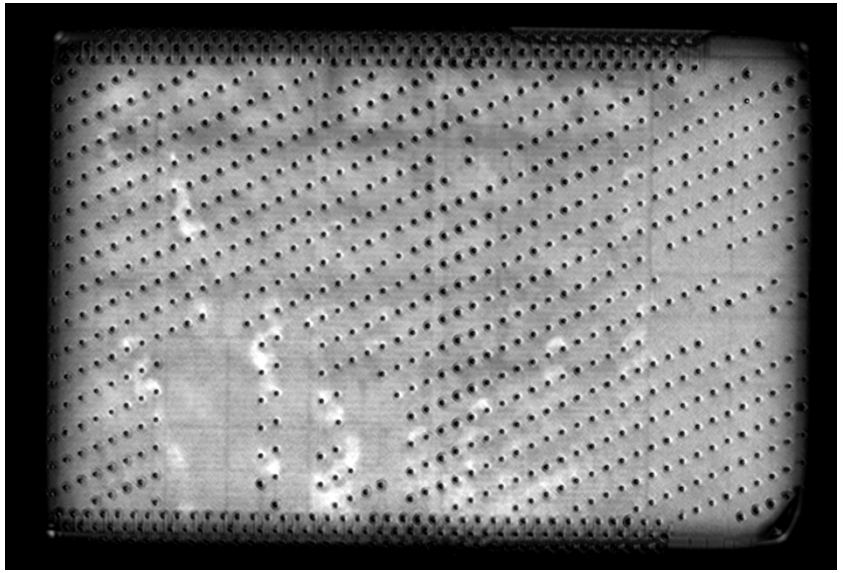
Technical Advances in SAM – analog pre-processing –



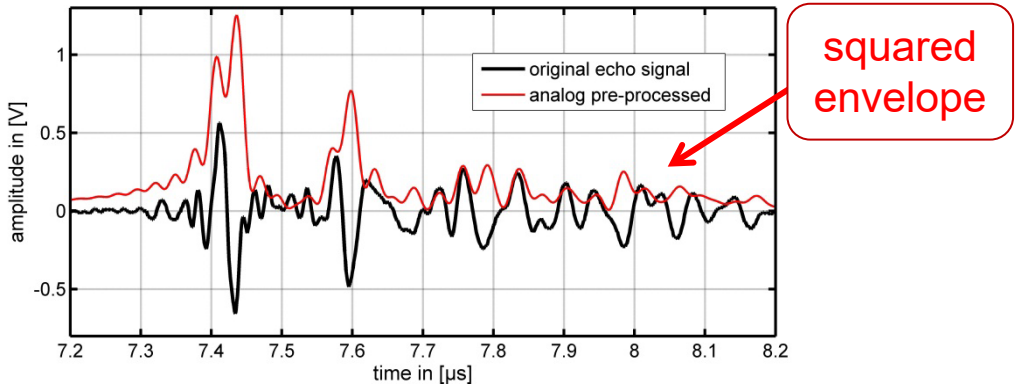
Die bump IF without pre-processing



Die bump interface with pre-processing

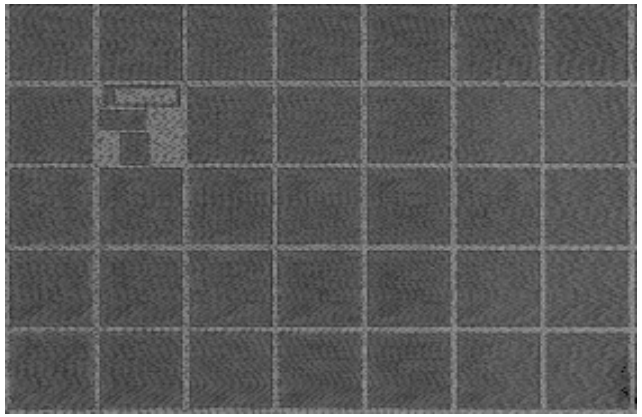


- pre-processing rf-data during scan
- analog -> extremely fast (real-time)
- HILBERT integration of signal
- low-noise components / increased SNR

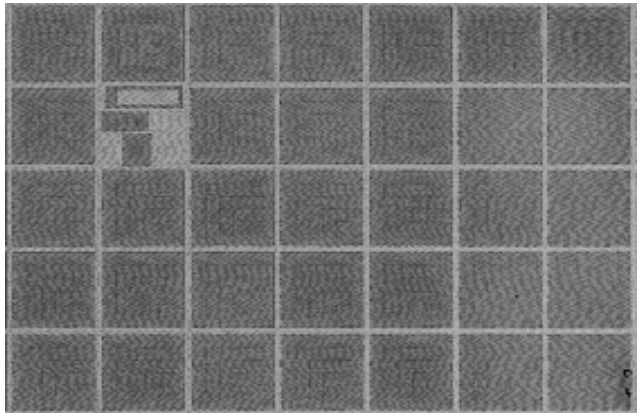


Optimized high frequency electronics: Signal filter

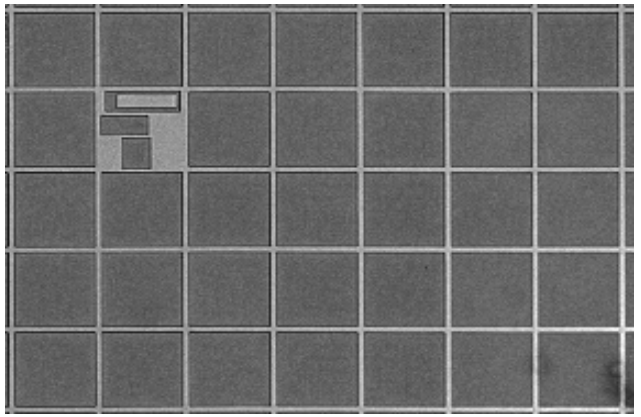
Standard Components



New PVA Pre Amp

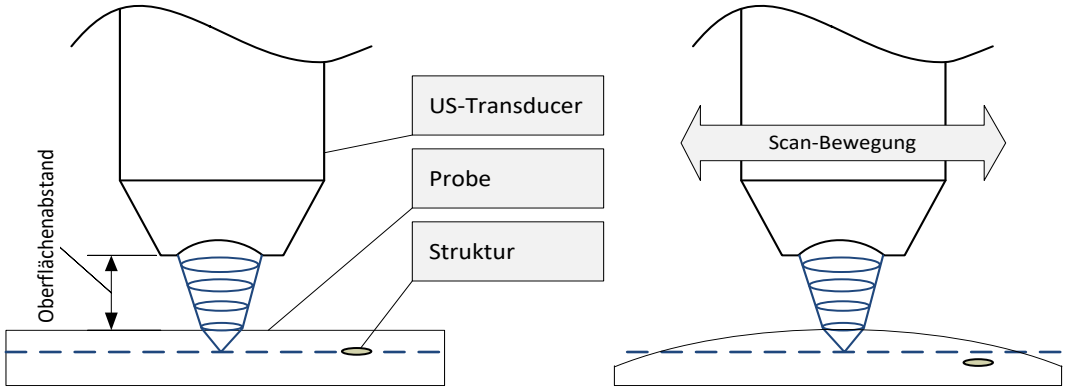


Filter (HILBERT)



High Speed Axis – task

Current Technology



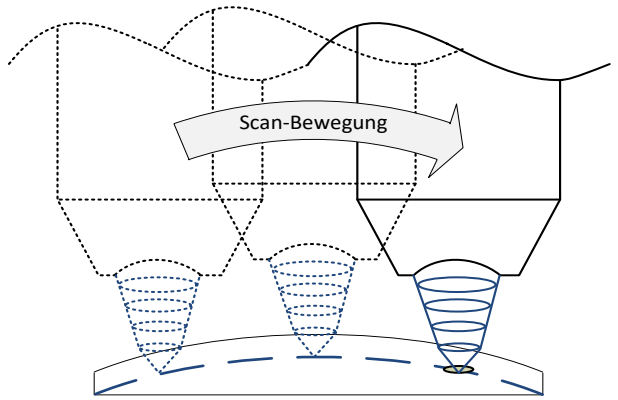
Linear Scanning:

Limited focus due to bending,

surface trigger limited to ~600µm bow

⇒ **Certain areas out of focus**

Active Z Movement During Scan

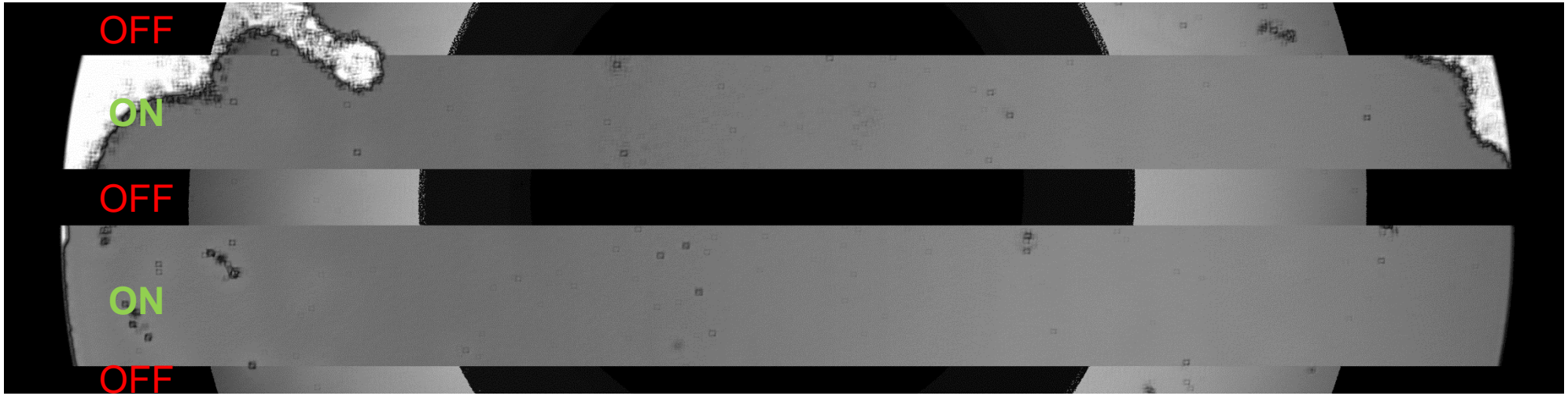


HiSA-System controls active the focus distance

=> Sample always in focus

Bow: 2 mm

Wafer scan of strongly bowed wafer with and without HiSA

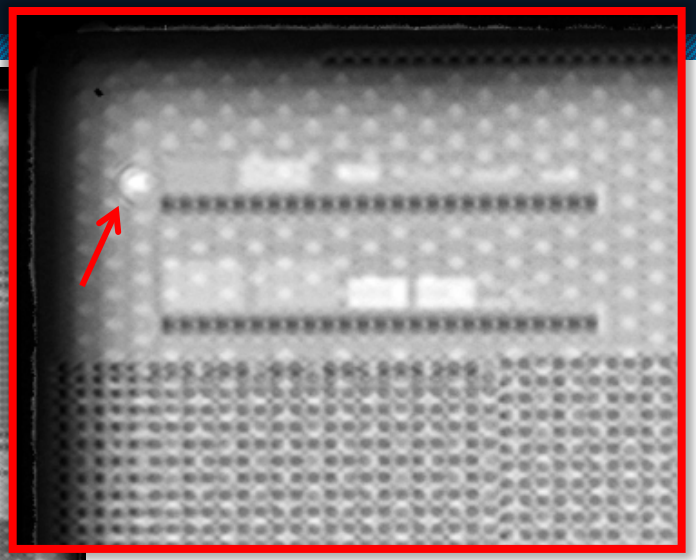


HiSA compensates surface topography irregularities (bow /warpage)

FC/PBGA active z-axis (HiSA)

COVALENT METROLOGY





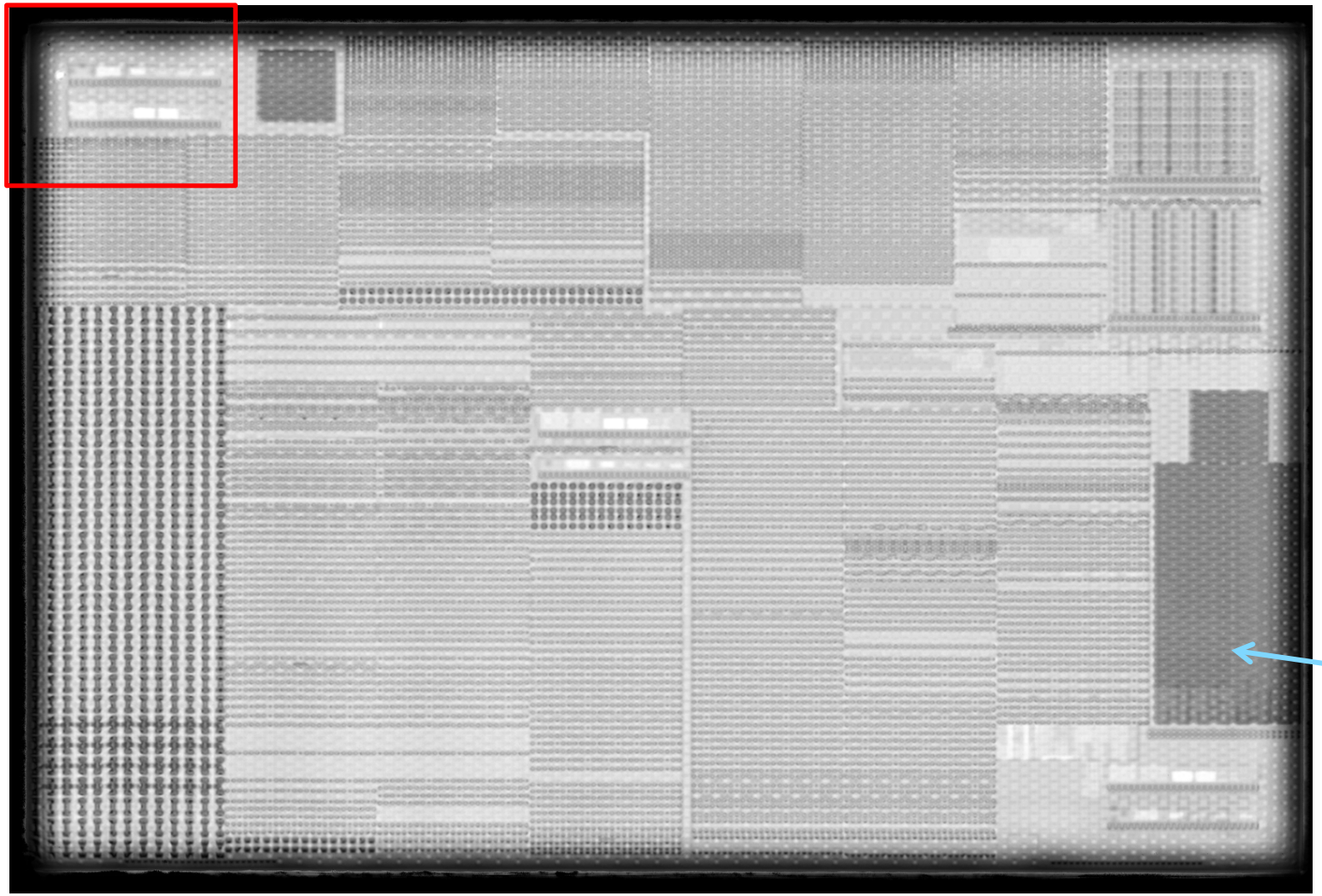
ILD delamination

Fringes due to the unevenness of the sample

FILENAME: pan190 Hilbert off G Early gates-14.tif

transducer: 190 MHz / 8 mm

FC/PBGA active z-axis (HiSA)



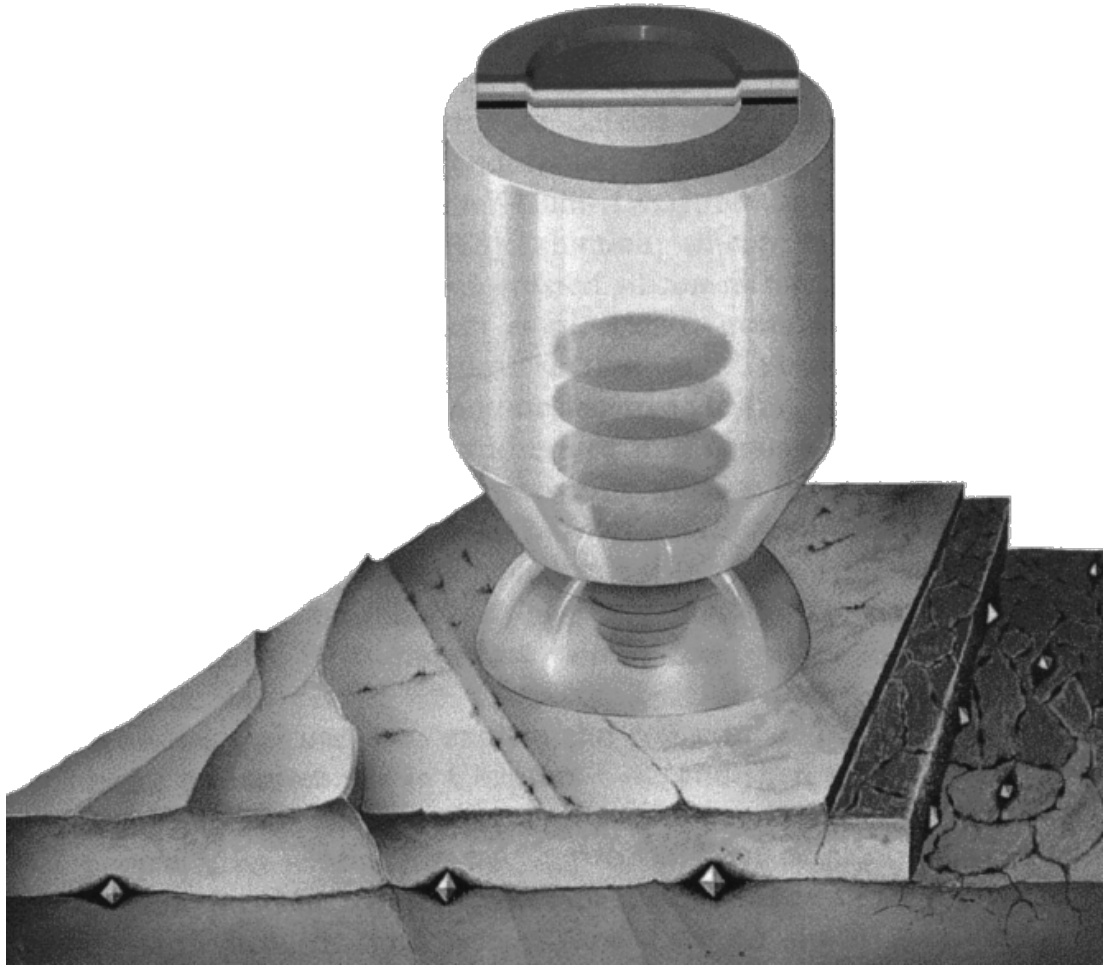
FILENAME: pan190 Hilbert off G-13.tif

transducer: 190 MHz / 8 mm

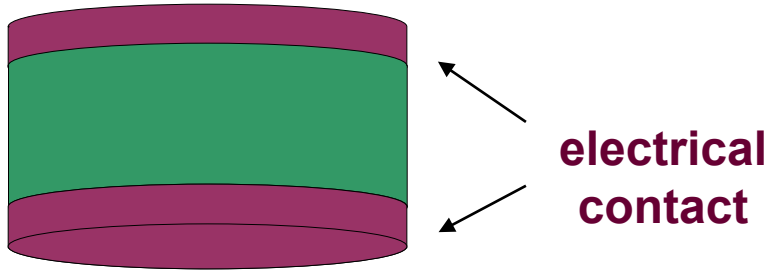
HiSA system: actively moves the z-axis to follow the warpage of the sample

using the HiSA system no fringes due to the unevenness of the sample are observed

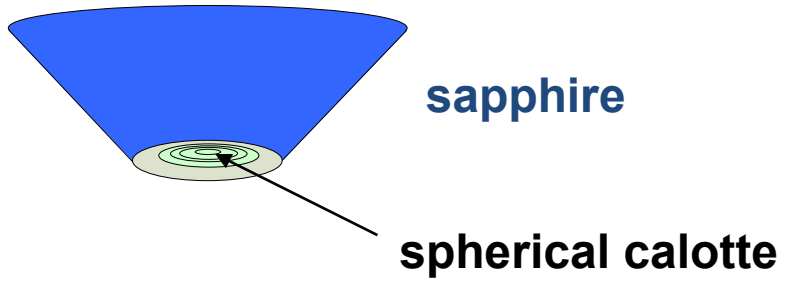
Transducer: The heart of scanning acoustic microscopy



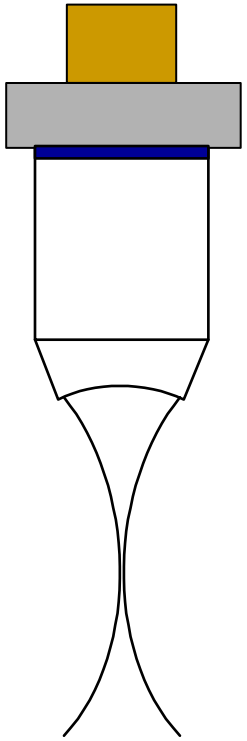
transducer element :



acoustic lens :



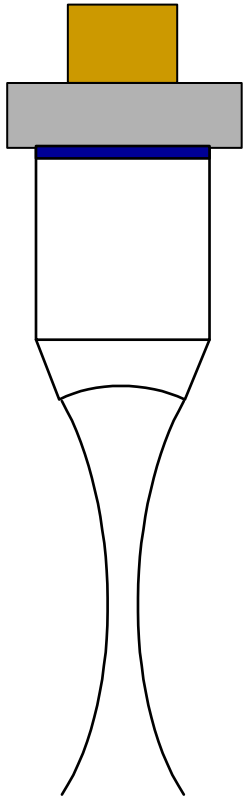
Acoustic Transducer Properties



Ultra high/ high f:



1. Higher resolution
2. Shorter focal lengths
3. Less penetration (Thinner packages)



Mid range/ low f:



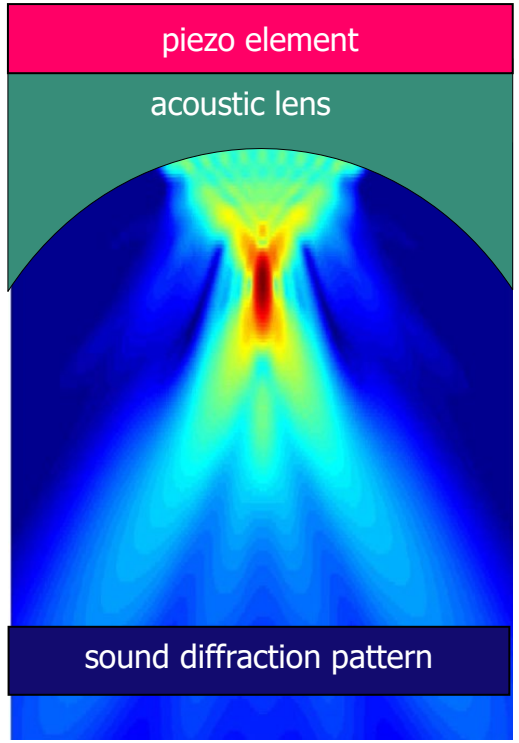
1. Lower resolution
2. Longer focal lengths
3. Greater penetration (Thicker packages)

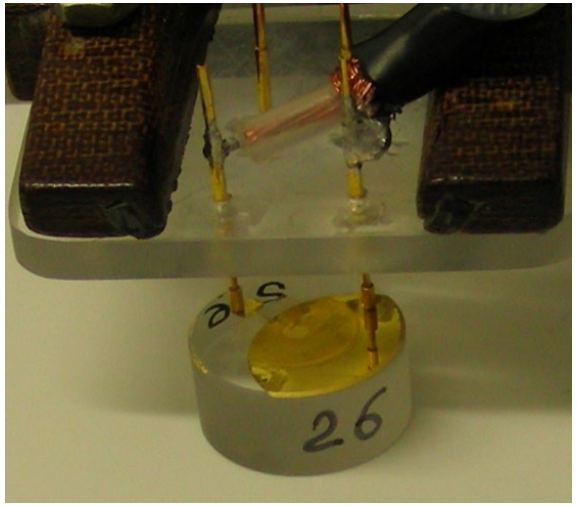
General Rules:

- Ultra high frequency (0,4-2 GHz) for ceramics, alloys, nano-voids, cells: defects, boundaries
- High frequency (100-230 MHz) for thin plastic packages and flip chips: delaminations, defects, cracks
- Mid range frequency (50-75 MHz) for BGAs, die attach, die top: delaminations, defects, cracks
- Low frequency (10-30 MHz) for anodic bonding, welding structures, packages

Technical Advances in SAM – transducer design –

- Optimized transducer design and performance
- Piezo elements sputtered on lens substrate (saphire or quartz)
- Application specific lens design
- Numerical simulation of sound propagation / pressure distribution
- Focusing and frequency adjusted during design: acoustic impedeance net work

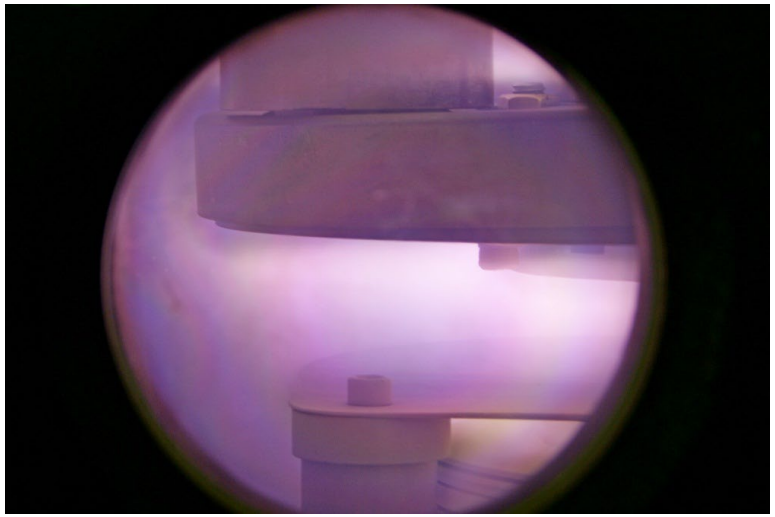


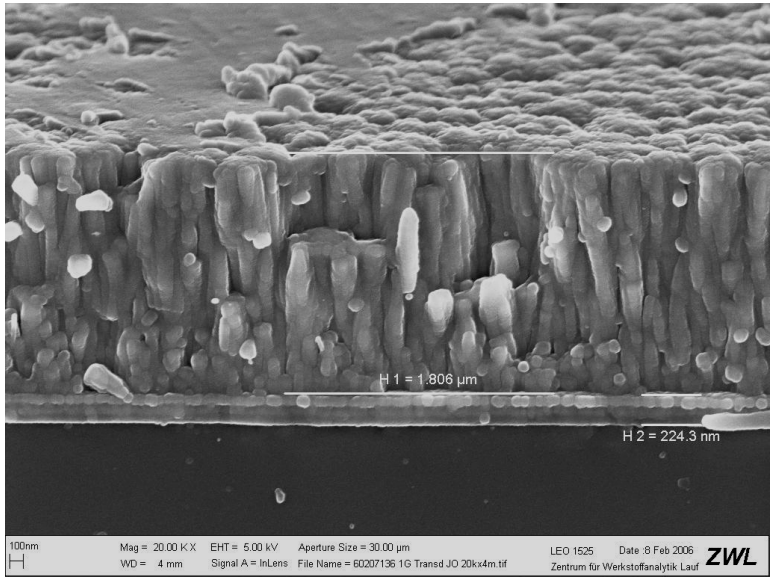




Technical Advances in SAM – transducer design –







- thin film technology
- Piezo layers from 100 µm-1µm
- **f=100 MHz-2000 MHz**
- **WD=10mm-40µm**

Acoustic Transducers

- Transducer parameters:
  - **Focal length**
  - **Frequency**
  - **Bandwidth**



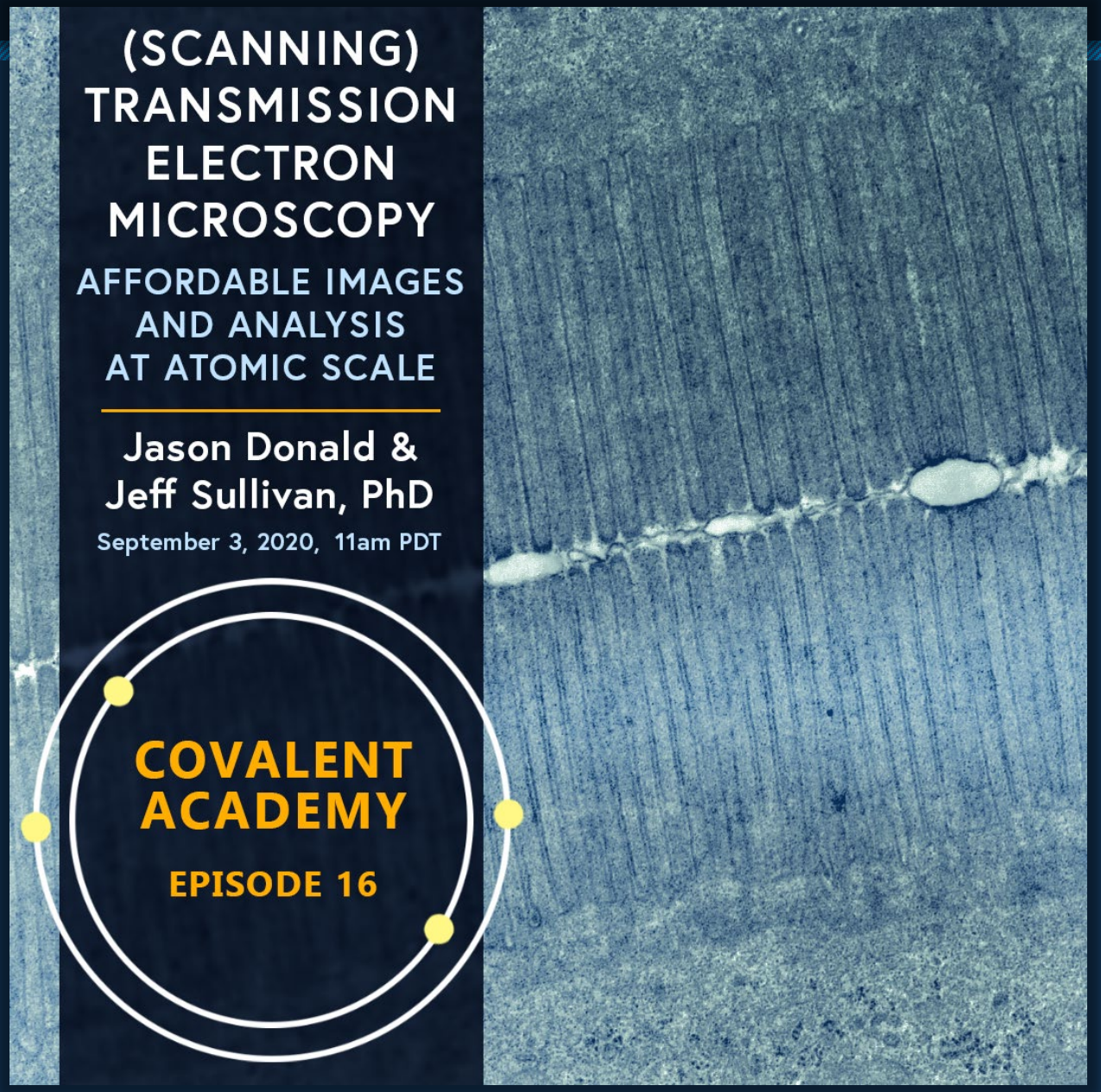
COVALENT METROLOGY

- E N D -



Up next on Covalent Academy…

COVALENT METROLOGY



Covalent Community

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HOME TECHNIQUES PRICING ABOUT US LOGIN



Important Message to our Valued Customers:
(Essential Businesses and Urgent Samples)

We are updating information on this website and some destinations maybe under construction. We appreciate your understanding and patience as we complete these improvements. Thank you.

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- Flexible Services

Covalent Metrology is a modern materials characterization company staffed by world-class scientists and engineers

$ TRANSPARENT PRICING

Covalent Community

COVALENT METROLOGY

Data Portal

Customer Access to Data & Community Content

The DATA PORTAL is used by Customers and Lab Partners for uploading and downloading data. It requires two-factor authentication and advanced password protection. Data Portal users have complete access through their home page on the portal to all Community content, and do not require a separate Community account.

Covalent Community

All Other Users

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Q & A Session

COVALENT METROLOGY

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