PVA TePla

Scanning Acoustic Microscopy

Analytical Systems

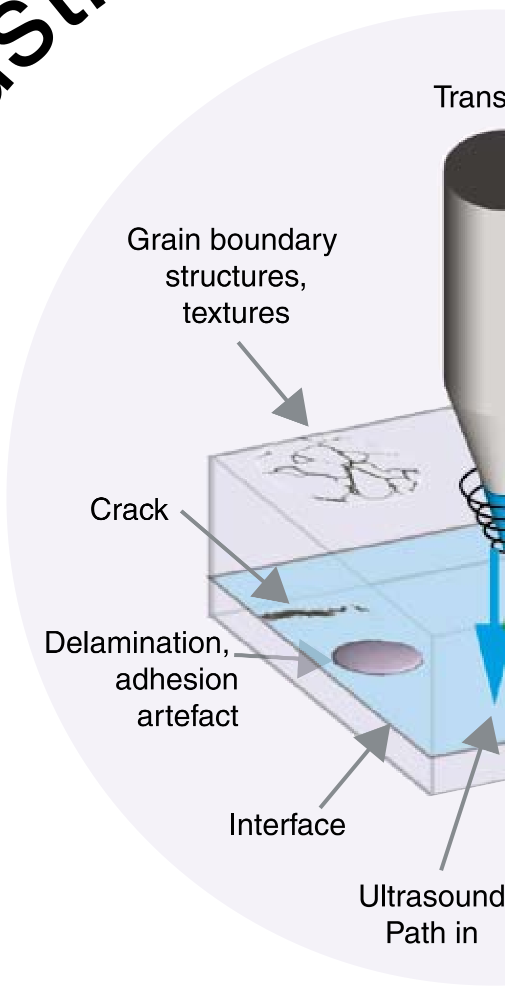
Discover the world of PVA TePla Analytical Systems Scanning Acoustic Microscopes

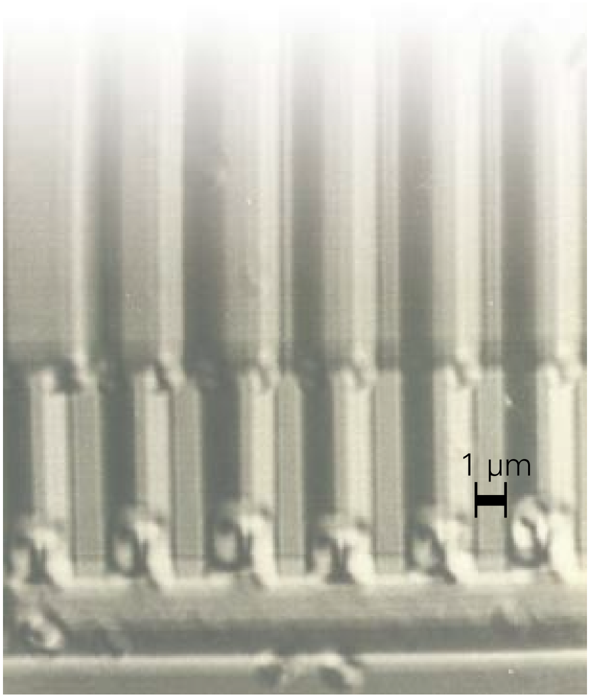
New ways of thinking and visionary ideas are behind our successful concepts of trend-setting scanning acoustic microscopy technologies.

In almost all fields of modern science and technology the demands for innovative, advanced solutions for non-destructive imaging with SAM have increased.

PVA TePla Analytical Systems introduces the SAM series based on the earlier generations of KSI scanning acoustic microscopes. The unique PVA TePla Analytical Systems transducers with frequencies up to 2000 MHz extend imaging and analytical resolution beyond previously achievable limits.

Acoustic Imagin



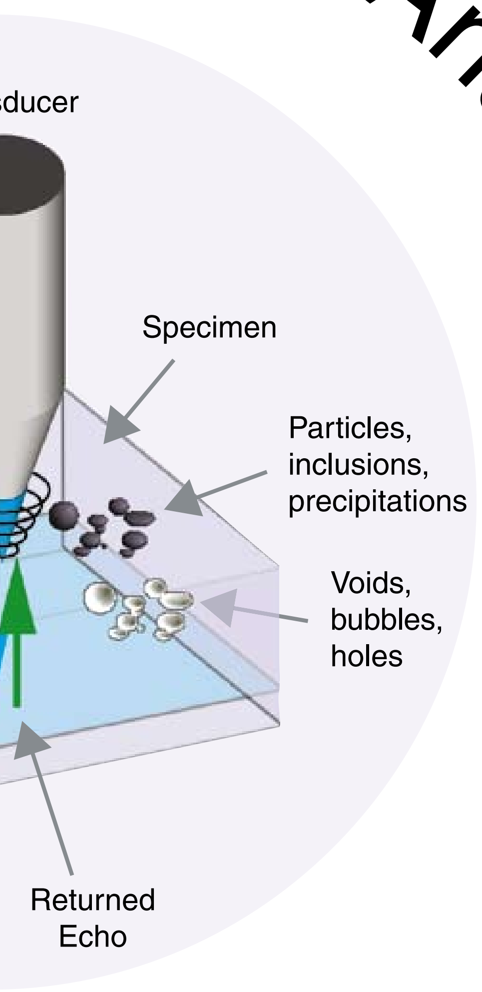


High resolution acoustic image of a Si - based semiconductor structure

Bonded Si wafer, X-ray observation of the bonding interface

Bonded Si wafer, IR c
bonding interface

ng and Analysis



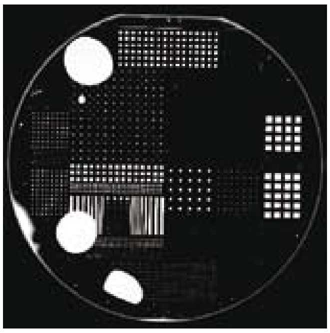
PVA TePla Analytical Systems presents a new generation of scanning acoustic microscopes incorporating the latest technologies with new and improved functionality:

- The highest resolution available with a worldwide unique frequency spectrum up to 2000 MHz.
- Simple operation with Windows graphical user interface and integrated process automation.
- Flexible application through different scan modes and a variety of different transducers.
- Modular concept and product platform strategy on all SAM products to increase uptime and reduce cost of ownership.

PVA TePla Analytical Systems continuously identifies customer requirements and is outstandingly creative and innovative. PVA TePla Analytical Systems scanning acoustic microscopes are ideally suited to applications:

- Nondestructive and fast examination of volume and structural defects in different materials.
- Displaying of non-homogeneities, density differences, tensions, delaminations
- Layer-thickness measurement, reliability examination, judgment of material connections.
- The confocal properties can be exploited to give enhanced depth resolution to examine individual interfaces.

observation of the



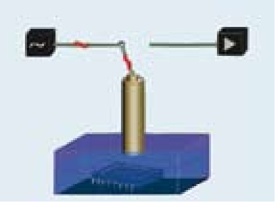
Bonded Si wafer, SAM observation of the bonding interface

High performance transducer made in PVA TePla Analytical Systems factory

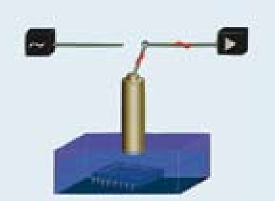
The Operation Principle

The Scanning Acoustic Microscope operates with the pulse reflection method. The special acoustic objective-centerpiece of the microscope produces, transmits and receives short sound pulses of high penetration rate. The acoustic lens converts high frequency electromagnetic vibrations which are propagated as a plane parallel wave field inside the lens. The cavity focuses the sound field on the sample through the coupling medium (water). 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 scans the sample line by line. A transducer with good focusing properties on axis can be used for both transmitting and receiving the signal. The image is formed by scanning the transducer mechanically over the sample.



Transmission of the sound pulses into the sample



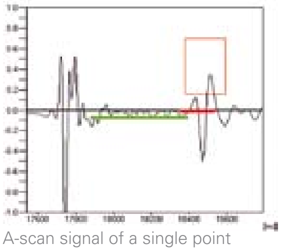
Reception of sound pulses

The time to build up a complete image depends on the scan rate and the selected image resolution. For a given deflection of the acoustic objective at 50 Hz and 512 pixels per line, it takes about 10 s to produce an image of 512 x 512 pixels.

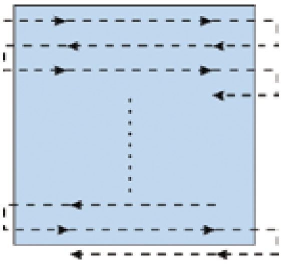
The unique characteristic of acoustic microscopy is in the ability to take an image of the interaction of acoustic waves with the elastic properties of a specimen with the resolution of optical light microscopy. In many applications of acoustic microscopy, the microscope is used to image the interior of an opaque material. In such cases some lower frequencies 5 to 50 MHz are used to achieve greater penetration. Use of this types often include examination of packaging materials to ensure integrity, especially in high value-added industries.

More rigid specimens, including most metals, semiconductors and ceramics, a dominant role in the contrast can be played by Rayleigh waves in the surface. If the specimen has a surface layer, then the propagation of the Rayleigh waves is sensitive to the disturbing action of the layer. If the specimen is anisotropic, then there will be dependence on the orientation of the surface and the direction of propagation in it. If there are surface cracks or boundaries, there will be a strong contrast when they scatter the Rayleigh waves. In this case, frequencies up to 800-2000 MHz are required.

Several transducers cover a wide range of frequencies and lens designs for different applications. The return echoes from each scan position are analyzed for amplitude, time of flight and polarity. For easy interpretation phase inversions are displayed in color. Numerous scan modes are developed and used for analysis.



A-scan signal of a single point position

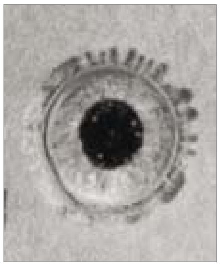
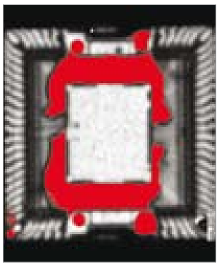
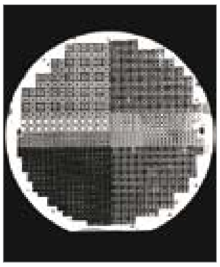


Schematic of a meander scan over the specimen area

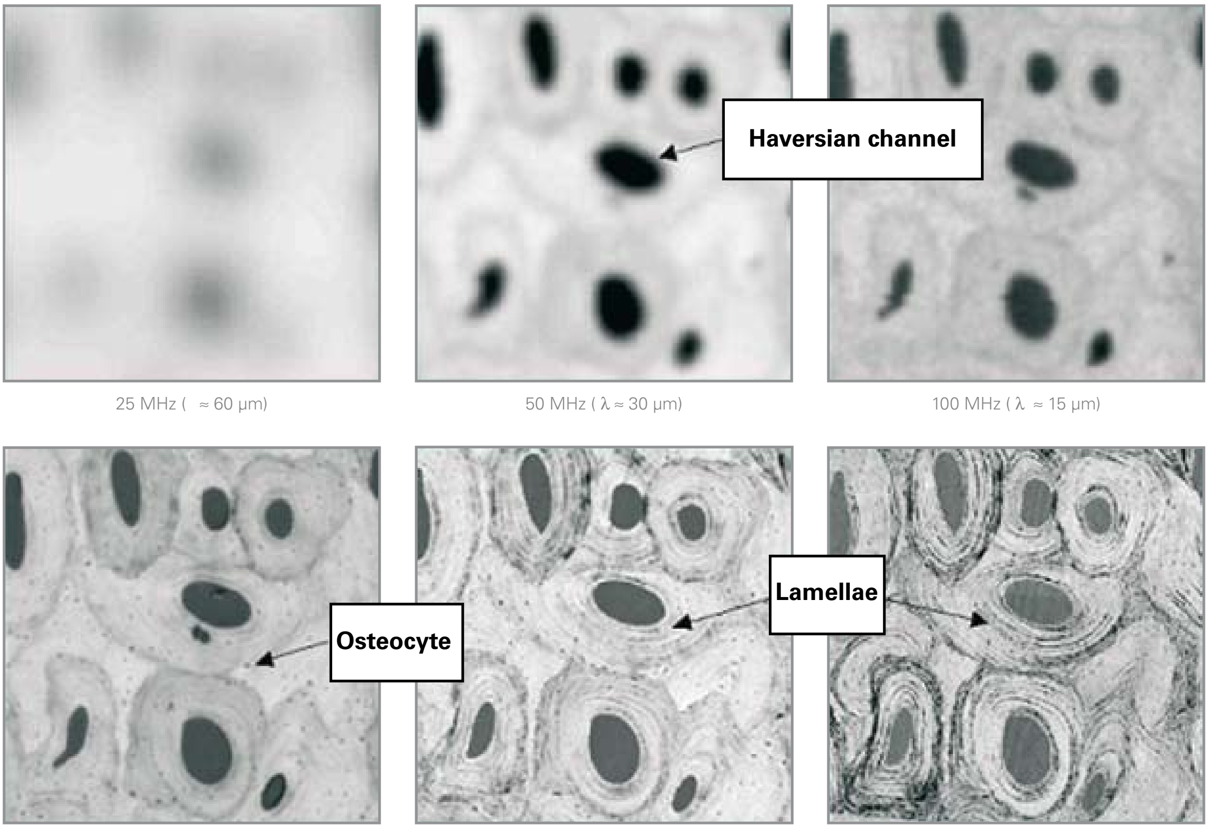
PVA TePla Analytical Systems acoustic microscopes provide the largest frequency range for non-destructive ultrasonic testing. For routine use 2000 MHz is the highest practical frequency, which offers a resolution of about 0,3 µm = λ/2, which is comparable to high resolution optical microscopy.

PVA TePla Analytical Systems acoustic microscopes work on the principal of partial transmission and partial reflection of ultrasound whenever a change in acoustic impedance is encountered. Material boundaries or property changes can cause these changes in impedance. By measuring the amount of sound returned as a fraction of the amount of entering the boundary materials can be characterised.

Frequency ranges with the attainable imaging resolution and applications referred to the respective resolving power attainable within this frequency range.

10 MHz	30 MHz	100 MHz	1000 MHz	2000 MHz
0.15 mm	50 µm	15 µm	> 1 µm	0.2 µm
				
Welding Structure	Packages	Wafer	Grains	Fibers
Quality Control	Semiconductor	Semiconductor	Material Research	Material Analysis

Attainable imaging resolution depending of the working frequency of the transducer, shown on a biomedical bone sample. By courtesy of Dr. Raum, University of Halle, Germany



25 MHz (≈ 60 µm)

50 MHz (λ ≈ 30 µm)

100 MHz (λ ≈ 15 µm)

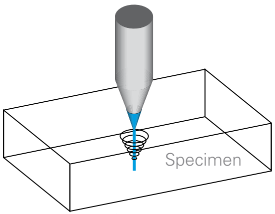
200 MHz (λ ≈ 7,5 µm)

400 MHz (λ ≈ 3,7 µm)

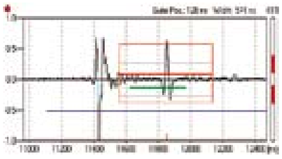
900 MHz (λ ≈ 1,6 µm)

Typical Scan Modes and their Application

With the Acoustic Microscope the integrated circuit represented above can be penetrated and observed without any destruction or damage in its whole volume. To get detailed insights, different scan modes are used whose application is explained at the following examples. All example pictures were won at the same integrated circuit which is shown above.

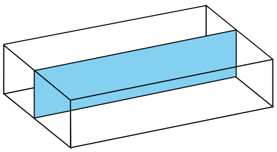


A-scan



A-scan signal with a selected gate (red box)

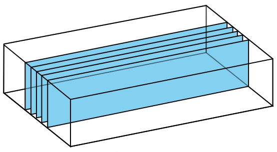
A-scan - the information is contained in the way that the acoustic wave is reflected from the specimen. This time of flight information is depending upon the depths of the sample feature. A digital waveform on the user interface screen displays the arriving echoes. This quantitative time distance measurement (echo- time) display is used to set electronic gates to select the depth range of view. If more than one gate is placed (G-scan) multiple images are displayed on the monitor screen.



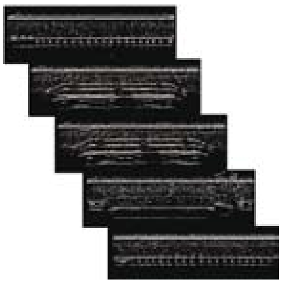
B-scan

Cross section images of a semiconductor device

B-scan - the scanner is moving in a desired direction to get either a cross section image in X or Y direction. The depth of different structures can be measured.

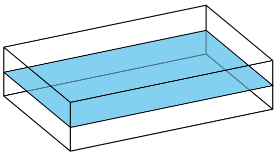


P-scan

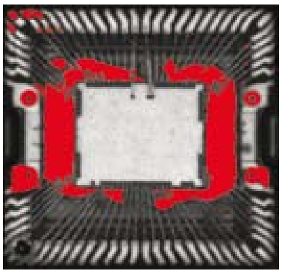


Cross section images of an IC

P-scan - cascade display of parallel arrays of cross section plans from top to the bottom, the slices are free selectable.

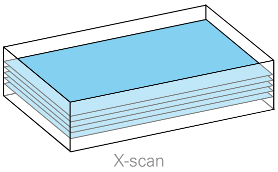


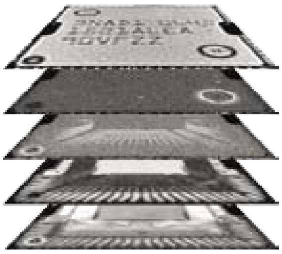
C-scan



C-scan of the IC above

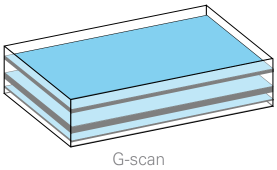
C-scan - moves the scanner in a meander pattern over the sample, depending on the setting of instrument parameters. The image is composed line by line. Delaminated areas are shown in red.

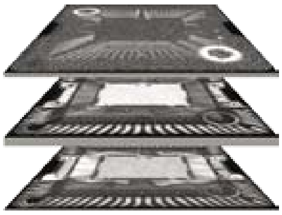




Different depth information of of the IC above

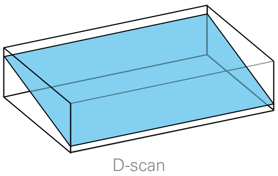
X-scan - more than 50 images could be displayed from different layers during one scan in realtime, areas and image depths free selectable by the operator.

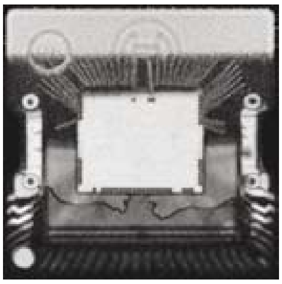




Images of 3 different layers of the IC above

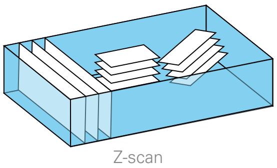
G-scan - produces multiple images depending on selected instrument parameter settings. Different settings can be stored for automatic evaluation.

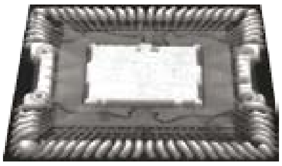




Diagonal-scan through of the IC above

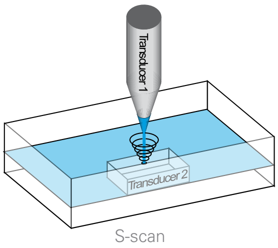
D-scan - a combination of the B-scan and C-scan functions. A meander scan is carried out and the position of the gate is altered at the same time. The resulting image represents a diagonal section through the sample.

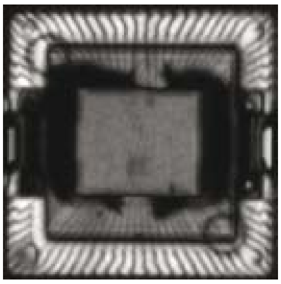




3-D reconstruction of a Z-scan of the IC above

Z-scan - automated volume acquisition. Enables offline reconstruction of A, B, C, D, P, X, 3-D scans and time of flight images with free selectable gate windows.





Transmission image of the IC above

S-scan - the simultaneous imaging or through scan mode. A transducer above the samples emits an ultrasonic signal which will be detected by a second transducer placed at the bottom. This image mode provides lower volume resolution information due to the second transducer at the bottom of the sample.

The SAM Product Line

AM 150 / 200 / 300

is a simple to use scanning acoustic microscope platform for advanced industry quality control and research. It is a cost-effective tool enabling non destructive acoustic investigations using new rf and transducer technologies of up to 400 MHz.

Built around a core platform that utilises the latest production and research technology, the AM 150 / 200 / 300 can accurately handle samples through a precision alignment subsystem. It has an ultrasound frequency range up to 500 MHz, with transducers from 3 MHz - 250 MHz. Water tank and scanner could be designed according to customer requirements.

SAM 300

is a dedicated high throughput,non destructive tool for quality and process control and research applications. It enables detailed acoustic investigations through new rf and transducer technologies of up to 400 MHz. A graphical user interface ensures that the powerful functionality of SAM 300 is easily applied.

Built to industry standards around a core platform that utilises the latest production and research technology, the SAM 300 can accurately handle samples up to 320 mm x 320 mm x 45 mm (w/l/h). It has an ultrasound frequency range up to 500 MHz with transducer from 3 MHz - 400 MHz. Different tank sizes and trays are available.

SAM 400

is a high-performance tool enabling non destructive acoustic investigations for dedicated high throughput analysis, quality control and research applications. It features a new high speed maintenance free stage and new rf and transducer technologies of up to 400 MHz, controlled through a user friendly graphical interface.

Built to semiconductor industry standards around a core platform that utilises the latest production and research technology, the SAM 400 can accurately handle wafers up to 300 mm and samples up to 420 mm x 420 mm x 45 mm (w/l/h). It has an ultrasound frequency range up to 500 MHz with transducer from 3 MHz - 400 MHz. Different tank sizes and trays are available.

USAM P I / PII

Instruments for highend research and industrial applications mounted on a vibration-free workbench. Combined scanning acoustic microscope and light microscope allow to immediately switch between the two working positions.

The acoustic and light microscope images are aligned in x-y direction with an accuracy of 5 µm, allowing the operator to compare exactly the same area of view on the specimen in both methods.

Selectable frequency range:

USAM PI	100 MHz - 800 MHz
USAM PII	100 MHz - 2000 MHz

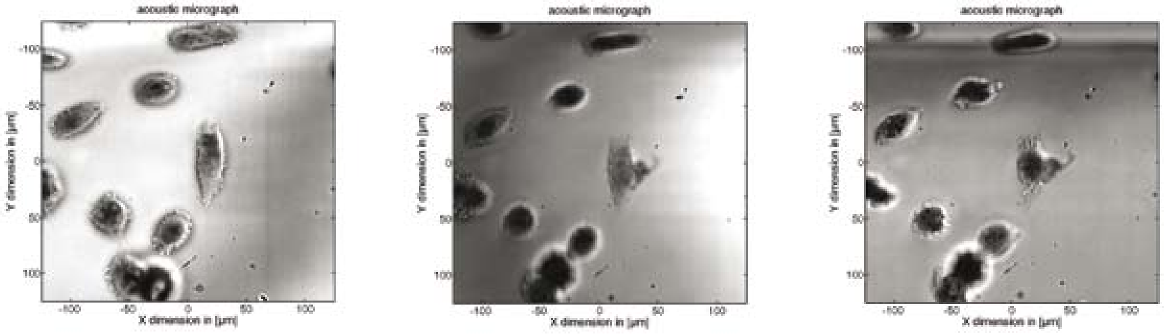
USAM P I / PII inverted

Instruments for highend research and industrial applications mounted on a vibration-free workbench. Combined high resolution scanning acoustic microscope with an inverted light microscope allow to immediately switch between the two working positions.

The acoustic and light microscope images are aligned in x-y direction with an accuracy of 5 µm, allowing the operator to compare exactly the same area of view on the specimen in both methods.

Selectable frequency range:

USAM PI inverted	100 MHz - 800 MHz
USAM PII inverted	100 MHz - 2000 MHz



Series of cell pics: Acoustic micrographs of HeLa cells during oncological treatment with CISPLATIN. The image at the left hand side was recorded at the initiation of the treatment while the center and right hand side data were recorded at 10h and 18h post treatment, respectively. By courtesy of Dr. Brand, University of Halle, Germany

SAM 300 / 400 TWIN and QUAD

SAM 300 / 400 TWIN and QUAD are high performance tools enabling non destructive acoustic investigations for high throughput analysis, quality control and research applications. They feature a new high speed linear motion scanner and new rf and transducer technologies of up to 400 MHz, controlled through a user friendly graphical interface.

A new master/slave concept enables arrays of two or four transducers to acquire simultanous acoustic images.

Built to semiconductor industry standards around a core platform that utilises the latest production and research technology, the SAM TWIN SCAN and QUAD SCAN can accurately handle wafers up to 300 / 400 mm. Ultrasound frequency range up to 500 MHz with transducer from 3 MHz - 400 MHz.

Sample handling range (w/l/h):

SAM 300 TWIN and QUAD	320mm x 320mm x 45mm
SAM 400 TWIN and QUAD	420mm x 420mm x 45mm

SAM 300 W

SAM 300 W is a product line especially developed for "inline" production control. It is corresponding to the clean room class10.

It is designed for inspection of wafers or bonded wafers (MEMS) for voids, inclusions or delaminations in bonded interfaces.

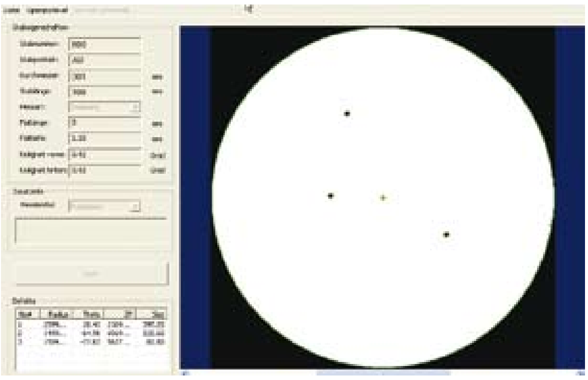
It has the following features:

- Fully automated, integrated image analysis software for defect recognition and mapping
- High performance acoustic scanning system with linear motion scanner, motorized z drive and acoustic autofocus
- 20 mm high speed robot for wafer handling up to 300 mm.
- Fully automated wafer chuck for wafer handling in water
- Up to 3 cassette load stations, drying unit, flipping station
- Bar code reader and pre-aligner
- SECS interface for wafer fab communication

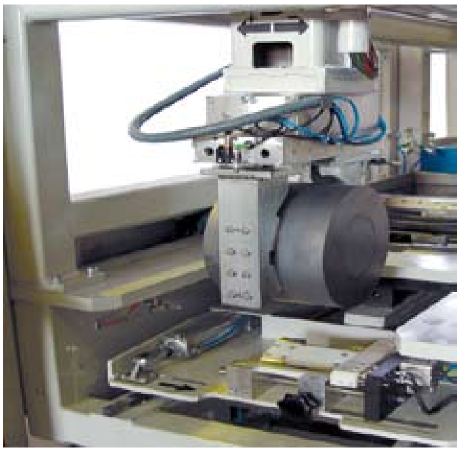
Auto Ingot for Quality Control of Ingots

The Auto Ingot is an instrument for volume inspection of single crystal ingots (Si, Ge, GaAs e.g.), analysis of voids, inclusions, estimation of the depth and size. It enables inspection of 5-12 inch Si ingots up to 400 mm thickness and a weight of 75 kg. The defect resolution is ≥100 µm voids in Silicon. Investigations of large and heavy parts must be customised according to geometry (load port and scanner).

- Loading port for 5-12 inch Si ingots
- Special adjustment feature for ingot alignment as compensation of wedge effects if the ingot front surface is not perpendicular to the ingot centre line
- Pre aligner and notch finder (or flat)
- High precision gripping device for ingots up to 75 kg
- Fast multiple transducer scanning system (4 heads)
- Drying station during and after inspection
- Analysis software and hardware for defect depth detection
- Automated exchange of couple fluid (water)
- 5 high performance RAID 1 workstations for acquiring of data's
- SEM/SESC`s interface for fab host communication
- Defect review software: the system will estimate the 3-dimensional location of a defect inside the crystal volume (x;y;z) including compensation of wedge effects
- High acquisition throughput due to 4 channel system
- High resolution transducer array (detection of 100 µm voids possible)
- Patent protected concept



Result sheet of an ingot inspection



Ingot load station with gripping device

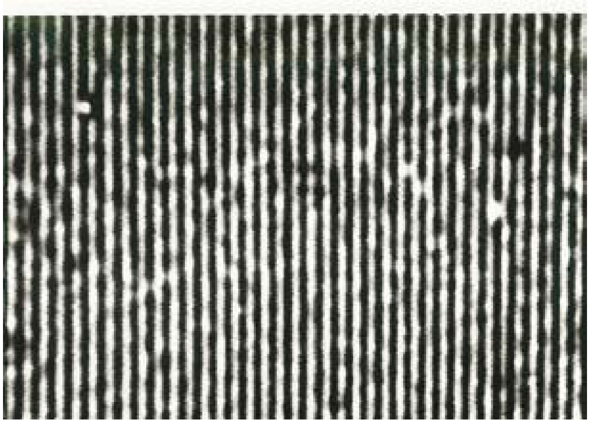
worldwide unique frequency range

3 MHz
50 MHz
100 MHz
200 MHz
400 MHz
800 MHz
1000 MHz
2000 MHz

High resolution transducer up to 2000 MHz

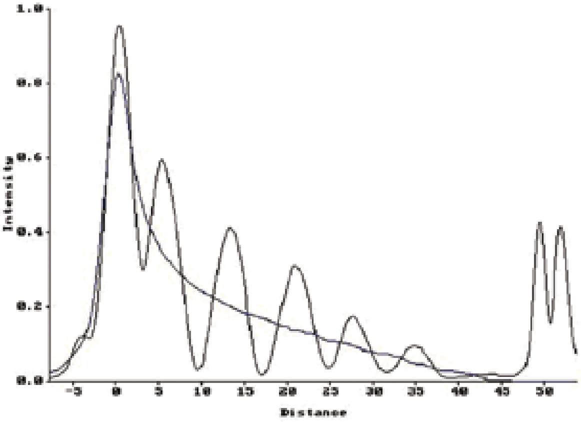
The frequency of 2000 MHz is the worldwide highest practical frequency supplied by PVA TePla Analytical Systems for acoustic imaging and analysis, which offers resolution values down to 0,3 µm. PVA TePla Analytical Systems provides transducers from 800 - 2000 MHz for different high resolution applications.

There are many situations where, for thin coating layers, the measurement of the elastic properties of the layer structure could be important to understand the properties of coating processes. Even more desirable in some applications is the knowledge of stresses in the layer. It is now possible to make measurements by quantitative acoustic microscopy that will yield this kind of information. Accurate elastic measurements by acoustic microscopy were pioneered using cylindrical lenses which brought the acoustic beam to a focus along a line. This means that Rayleigh waves were excited in the surface of the material in one azimuthal direction in the surface only, so that even if the sample was anisotropic only one Rayleigh velocity would be involved. Line-focus-beam lenses give particularly well defined oscillations in the variation of signal with defocus - the so-called V(z) curve - and by suitable Fourier analysis surface wave velocities can be determined from the period of the oscillations with an accuracy which can exceed 0.1 %. The attenuation of surface waves can also be measured.



High resolution image of an optical grid taken at 2000 MHz.
Distance between the lines: 0,3 µm

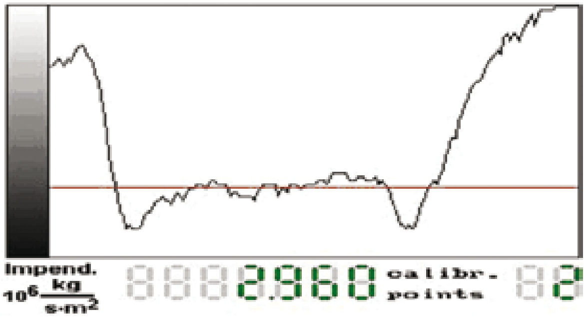
For the calculation of the velocity of acoustic surface waves a direct measurement of oscillation periods of V(z) curves can be made. The velocity of leaky surface waves is determined by comparing the recorded V(z) curve with a stored standard curve.



V(z) curve superimposed with standard curve

A further method for determining material properties is the evaluation of the amplitude (grey values) from the echo signal. An impedance value is assigned to every grey value. A reflection coefficient is calculated from the assigned impedance value and the impedance value of the coupled medium.

The corresponding acoustic impedance can be calculated using the C-scan information.



Acoustic impedance curve

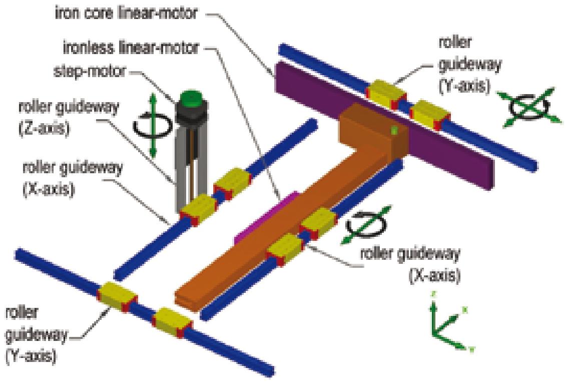
Scanning systems designed for a broad application range:

- High-resolution linear motion scanner up to 430 mm x-y travel range, scanning speed up to 1m/sec, acceleration up to 10 m/s^2
- High-speed magnetic driven scanner dedicated for high frequency investigations (>800 MHz):
  Scan ranges from 60 µm up to 1 mm
  Magnification 625x – 2000x :
  Scan speed: 2,5-10 sec/image
  (depending on image resolution)
- Air support direct drive linear motion system, wear resistant and maintenance free by combination of air bearings and linear motor technology.
  Scanning range: Up to 400 mm in x-y
  Scanning speed: Up to 1 m/sec
  Acceleration: 10 m/s^2

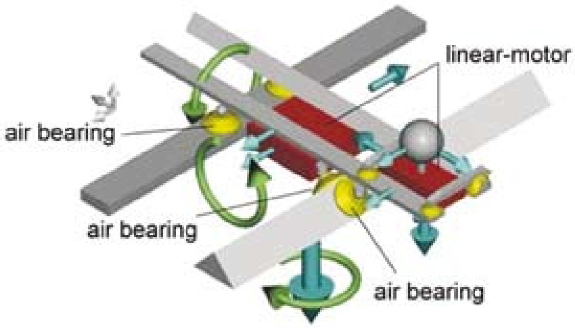
AutomatedTray Scanner for analysis of IC's in JEDEC Trays

High resolution linear motion scanner with a x-y range of 320 mm x 300 mm

Air support linear motion scanner for high throughput acoustic analysis, maintenance free



Schematic principle of the high resolution linear motion scanner



Schematic principle of the new air support linear motion scanner

PVA TePla Analytical Systems modular Platform Strategy

Positive impact of PVA TePla Analytical Systems rigorous product platform strategy:

Our major success factor is our unique technology base of shared components, which we use as platform to generate innovative products. This has the following advantages for our customers:

- Fast development of application specific solutions due to flexibility in modular platform concept
- High performance/ price ratio of all SAM products
- Improved serviceability resulting in affordable lifetime cost of ownership
- Powerful instruments with easy to use operation

Shared components

+

Specific components

SAM Series

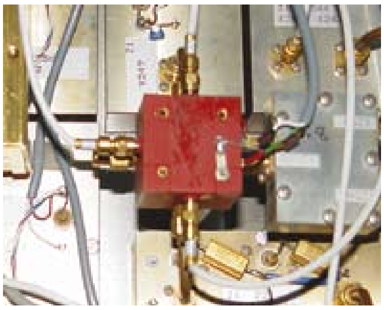
Transducers

Shared components

- rf devices
- scan modules

Specific components

- 3-300 MHz transducer
- 100-400 MHz acoustic objectives
- 800-2000 MHz ultra high frequency acoustic objectives



Electronics

Shared components

- electronic boards power supply units
- rf-units

Specific components

- customized design
- PC configuration
- RAID workstation

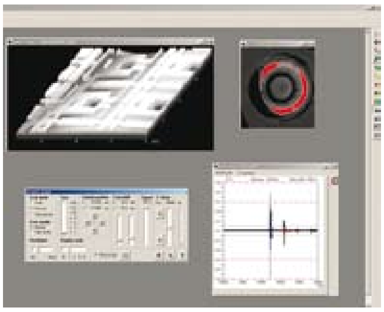
Scanning systems

Shared components

- stepper motor controlled motion systems
- linear motion scanner
- air support linear motion stage technology

Specific components

- variable scan fields
- application specific water tanks
- customized solutions



Software

Shared components

- control software
- operator GUI
- standard user licences

Specific components

- image analysis software
- control software for specific hardware components
- Software options
- customized solutions

Software functions for non-destructive defect and failure analysis

Visualisation

- Dedicated non destructive imaging and analysis of structures inside any bulk specimen
- 3-D reconstruction
- Display of mechanical properties of samples (hardness, density, stress, etc.)
- Time of flight measurement (A-scan)
- Cross-section images (B-scan)
- XY images: C-scan, D-scan, autoscan, multiscan

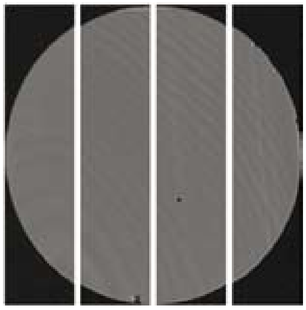
Quantification

- Fault statistics
- Histogram analysis
- Integrated measurement functions
- Film thickness measurement
- Multifunctional image processing
- Time of flight measurements
- Non-destructive depth measurement
- Digital signal analysis
- Phase measurements
- Defect maps including result files

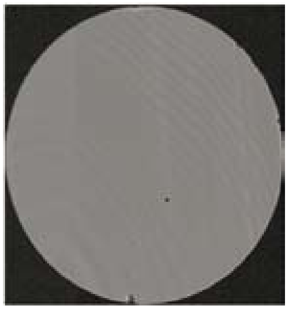
Automation

- Automatic X-Y-Z-scan and storage of all instrument parameters
- Automatic fault recognition
- Autofocus-system
- Remote control
- Fast auto sample detection
- Auto gate and gain control
- Auto signal analysis
- Auto loader system integration
- SECS interface
- Integration of bar code readers
- Auto alignment
- High speed robot for wafer up to 12 inch including cassette load stations

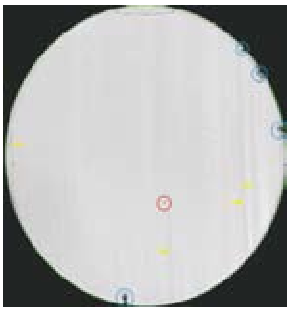
Workflow of getting images and results from scans with multiple transdusers



1. aquire raw sample data



2. assemble image



3. process image

The image processing tool

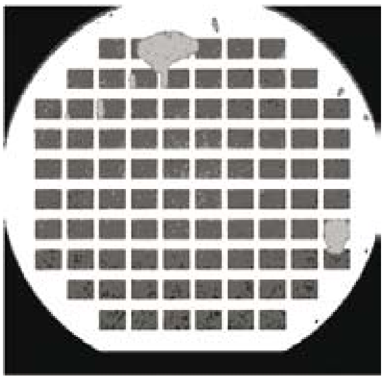
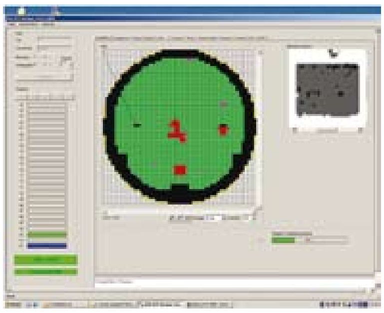


Image alignment and referencing

Die by die inspection
and defect classification



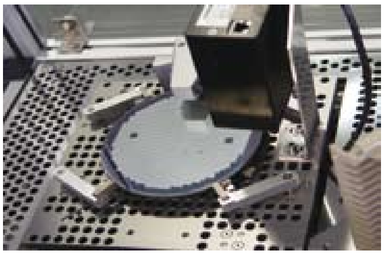
Wafermap and result generation

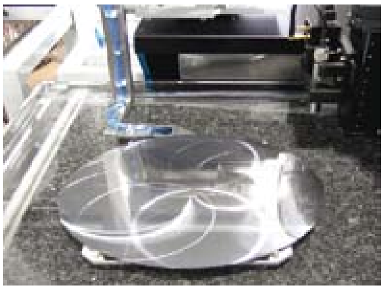
Special customized solutions for inline process diagnostic and control

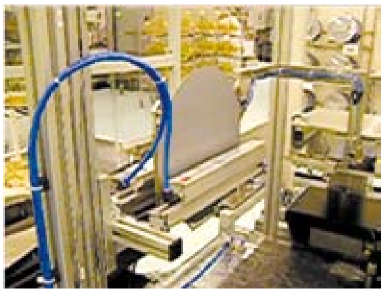
Automation Solutions

- Inline inspection from 2 - 12 inch
- Clean room compatibility down to class 10
- Integrated data analysis and automation software, fab communication by SECS interface
- Twin and Quad Scanner for highest throughput
- Arrays of 2 or more transducers for simultaneous image acquisition
- Fast data acquisition by master/slave computer configuration, enabling of transducer arrays for maximum throughput


High speed robot for wafer handling


Pre-aligner and bar code reader


Vacuum wafer chuck


Drying unit

Unique Solutions

High frequency imaging solutions for better resolution and for improved detection capabilities without influence on scanning time, due to hardware control of the signal processing process.

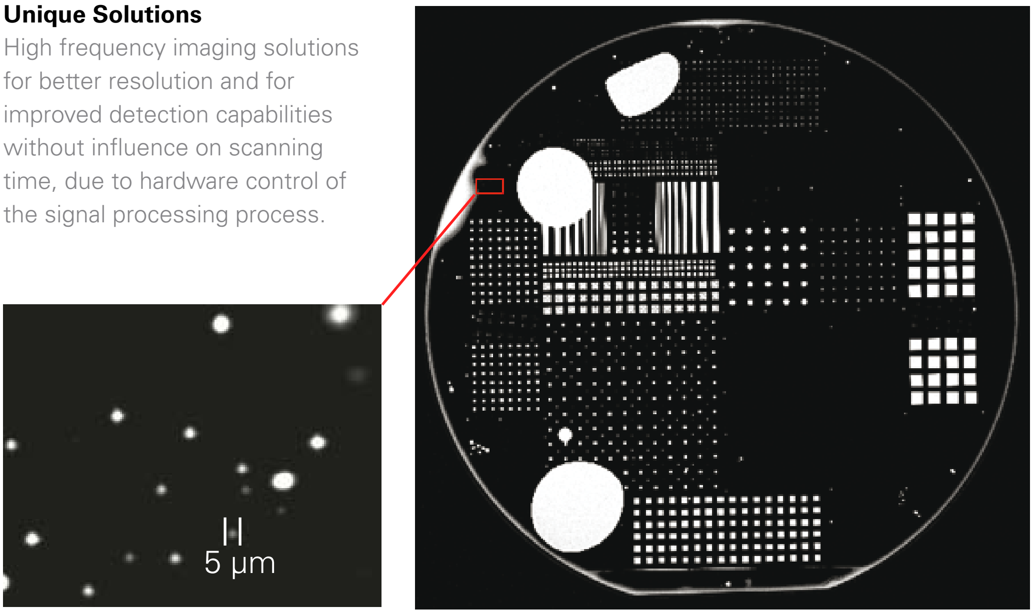
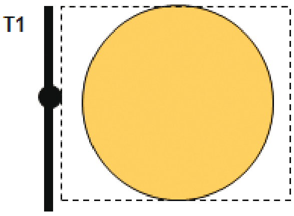
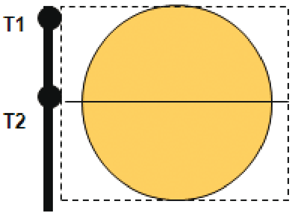


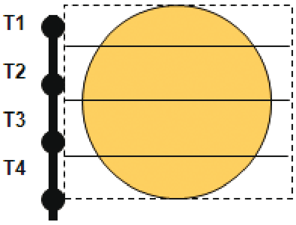
Image of a bonding interface taken at 110 MHz

Special customized solutions to increase throughput with 1 to 4 channel systems

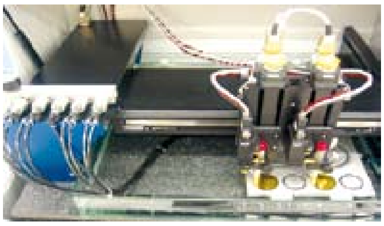
Scanning of 1-2 wafers simultaneously in 1-4 segments. Resolution for each segment: Pixel in x and y: up to 40000.





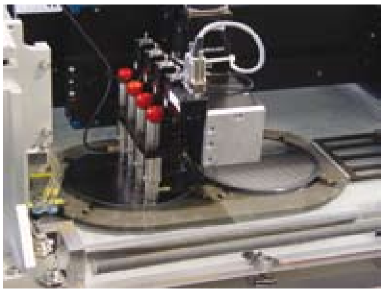


Scanner with one transducer (T1)

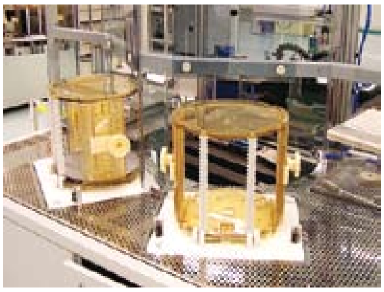


Scanner with two transducers for fast SAM investigations (T1, 2)

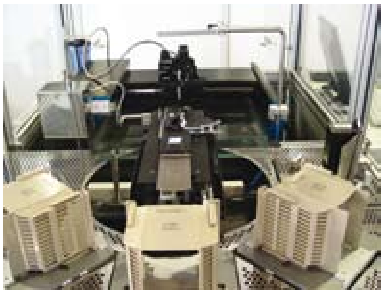
Scanner with four transducers for highest throughput of SAM investigations (T1, 2, 3, 4)



Scanning system with 4 z drives. Autofocus for each transducer



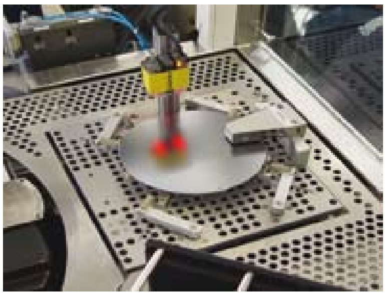
Two cassette loading station



Three cassette loading station

Vacuum wafer chuck for 2 wafers

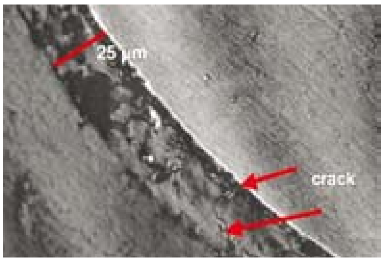
Vacuum wafer chuck



Pre-aligner and 2D bar code reader

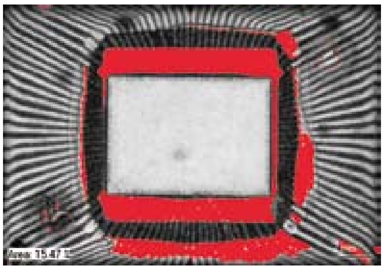
Industrial Application

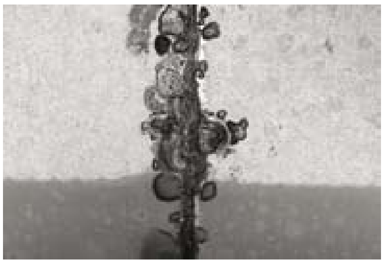
Semiconductor Application



Micro cracks in the buffer layer of a ball bearing. Even micro cracks (invisible with optical microscopy) were detected using specialy designed surface acoustic transducers.

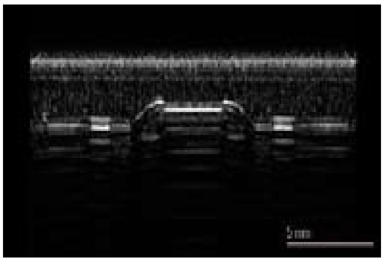
The image was taken at 1000 MHz.





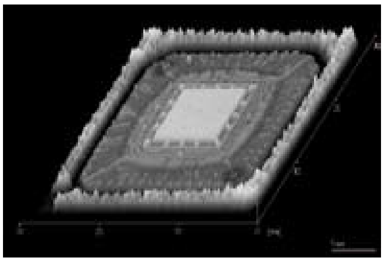
Corrosion analysis.
Primer- and varnish-sealed steel substrate. Corrosion spreads from the scratch introduced on the finishing layers as visible as a vertical line in the image.

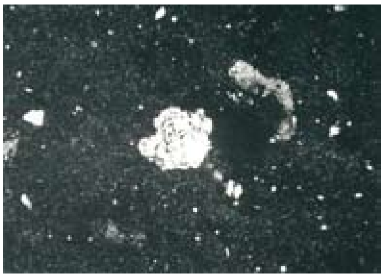
The image was taken at 100 MHz.



Poly-crystalline structure of solar cells. Crack propagation can be investigated by c-scan images.

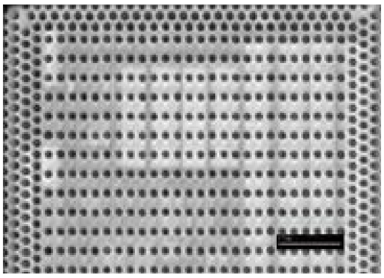
The image was taken at 100 MHz.





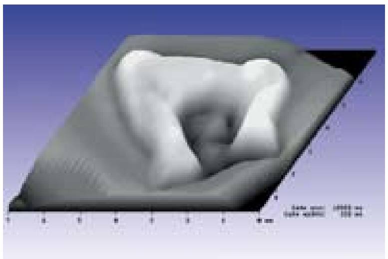
Voids and inclusions in a rubber with both soot and metal oxide inclusions (bright areas). Size and distribution of the voids are determined in a histogram using the integrated image analysis function.

The image was taken at 1300 MHz.



< Delamination inside the die-structure of an integrated circuit. Using the phase detection function, delaminated areas were marked in red automatically.

The image was taken at 80 MHz.



3-D plot of an acoustic C-scan image of a human tooth (cross section). It shows clearly the distinction between the outer enamel (hard) and the inner dentine (softer).

The image was taken at 80 MHz.

< B-scan: Acoustic cross-section image of an interated circuit structure. The depth of the different layers can be determined.

The image was taken at 100 MHz.

C-scan of earbone implant. Investigated was the healing process of the metallic implant between incus and stapes.

The image was taken at 100 MHz.

By courtesy of Dr. Sebastian Brand, University of Halle, Germany

< 3-D plot of a chip structure. The die top area was marked automatically using several options of the integrated image analysis functions.

The image was taken at 100 MHz.

Acoustic image of a cortical bone structure. Distinction can be made between the Harvensian channel the osteocyte and the lamelae.

The image was taken at 800 MHz.

By courtesy of Dr. Raum, University of Halle, Germany.

< Acoustic micrograph of a flip-chip-device. Layer adhesion and the bonding conditions of a flip chip connectors were evaluated.

The image was taken at 230 MHz.

Acoustic micrograph of viable HeLa cells under incubation conditions. These data give access to quantitative estimates of sound velocity and acoustic attenuation inside the cells with a resolution of up to 1 µm.

Image was recorded at 1000 MHz.

By courtesy of Dr. Sebastian Brand, University of Halle, Germany

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