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 \mu m/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

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

⇒ Certain areas out of focus

HiSA-System controls active the focus distance

⇒ Sample always in focus
Bow: 2 mm
Hardware development GHz SAM: 100 MHz-2000 MHz

- Pulser Unit
- Motion Controller
- Receiver Unit
- Gate
- Control Center
- Scanner
- motion Controller
- rs 232/gpiB/usB
- Pulse
- x-stAGe
- y-stAGe
- z-stAGe
- receive Signal
- trigger
- rF-signal
- video signal
- sample
GHz imaging of real small µ-Bumps

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

GHz-SAM

Scanning head with 1GHz 100° lens
3. SAM analysis examples:

Stack dies

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

TSV`s
4 x 3 dies stack: A Scan plot: smallest data gate size: 140 ps-7 GSPS ADC board

A-Scan

- 1st die
- 2nd die
- 3rd die

mold compound

350 ns
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)
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 repetition 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)
- SAM C-scan, f= 1GHz
- Position for FIB cut
- FESEM, 5 kV
Real small µ-bumps

- BCB “indentation” used for image alignment

• acoustic micrograph @ 1GHz
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

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 throughput 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
V(z)-curves: Unique finger print

Defocus 10 µm
V(z)-curves: Unique finger print

Defocus 25 µm

- particularly
- different
- intensity distribution
V(z)-curves: Unique finger print

Defocus 37 µm
Further correlations GHz SAM-FIB based on V(z) analysis
Orientation by LM-images

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- 3D 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
END

Thank you!