Bruker Stylus and 3D Microscope Systems
Solutions for Semiconductor Applications

Atomic Force Microscopy
3D Optical Microscopy
Tribology
Automated AFM
Stylus Profilometry
Mechanical Testing, Nano Indentation

Innovation with Integrity
Outline

• Brief Intro - Bruker, BNS, SOM General Overview

• Bruker Dektak Stylus Products – Semi Applications

• Bruker Contour Products - Semi Applications

• Bruker ContourSP – MCM/HDI Metrology

• Summary and Questions
Matt Novak, Ph.D.

Bruker Corporation

Nano Surfaces – Stylus and Optical Metrology

- Applications Development Engineering Manager at Bruker SOM (2.5 years)
- Industry experience (17 years) optical engineering, fabrication and metrology
- Earned Ph.D. – during work with private metrology equipment manufacturer
Bruker Company Profile

**Bruker**: Leading provider of high-performance analytical instrument solutions for life science, diagnostic and applied markets

**KEY FIGURES**

- Founded in 1960
- $1.79B revenue
- ~6,700 employees
- ~82% of revenues outside of the US
- ~Direct sales organizations in 33 countries
- ~1,000 R&D professionals with strong track record of innovation
Bruker Nano Surfaces Division
Surface Metrology and Science BMAT

- Scanning Probe Microscopy
- 3D Optical Microscopy
- Stylus Profilometry
- Tribology and Mechanical Testing
Bruker Stylus and Optical Metrology
SOM - World Leading Surface Metrology

- History of QA/QC solutions for industry
  - Semiconductor
    100+ Installed base multi-chip module inspection at board level
  - Data Storage
    500+ Installed base disk drive slider metrology
  - Electronics and Industrial
    1000+ Installed base
  - Worldwide
    10,000+ Installed base

- Manufacturing Excellence
  - Lean, six sigma-based process
  - 100+ systems/quarter capacity
  - Rapid production ramp capability

New Facility - Tucson, Arizona, USA
Opened December 2011
Bruker Stylus and Optical Metrology

Our Products Broad Overview

ContourGT-X
NPFLEx
ContourGT-IM
ContourGT Auto-Ready
DektakXT
ContourGT-K
Dektak XTL
ContourSP

9/25/2013
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Bruker DektakXT Stylus Profilers
Industrial Standard for Films and Steps

- **Dektak Reputation:** Field proven performance, ease of use and reliability
- **Dektak Experience:** 44+ year history in stylus profiler technology with over 10,000 installed systems world wide
- **Dektak Service & Support:** Regional call centers world wide for prompt, local support network

Dektak Stylus Profilers
- Over Four Decades of Innovation

9/25/2013
DektakXT and DektakXTL
Semiconductor Related Applications

- **Wafer Applications**
  - Step Height for deposited thin films (Metal, Organic)
  - Step Height for Resists (Soft film materials)
  - Etching Rate Determinations
  - CMP (Chemical Mechanical Polishing)
    - Erosion, Dishing and Bow

- **Glass Substrate Applications**
  - Step Height measurement for LCD R&D
  - Step Height Measurement for OLED R&D
  - Touch Panel coating film thickness measurement
  - Thin film measurements for solar coating

- **Large Substrate Applications**
  - Printed circuit boards
    - Bumps, step height
  - Window coatings
  - Wafer masks
  - Wafer chuck coatings
  - Polishing pads
Dektak XTL Stylus Profiler
0.5 nm Repeatability Step Metrology Serves Range of Applications
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- **Bruker 3D Microscope Products - Semi Applications**
- Bruker ContourSP – MCM/HDI Metrology
- Summary and Questions
3D Optical Microscopes
What is a 3D microscope, anyway??

- Microscope with special objectives, scanned perpendicular to sample – reflected signal processed to produce accurate height map

Coherent light interference builds height map
3D Optical Microscopes
Accurate, Fast, Gage Capable

WLI technique creates coherence images continuously as special microscope objective is moving vertically.

Software analyzes coherence images through focus to determine the height of the surface at each pixel.
ContourGT-X 3D Optical Microscope
Stable, Accurate, Automation Ready

- Optical Metrology Module (OMM) with self-calibration
- Programmable 8” or 12” Stage
- Automated Tip-Tilt in the head (+/- 6 degrees)
- Automated Z-Axis Focus
- Single Objective Adapter up to 5 -Position Automated Turret

- Dell Multi-Core PC Running Windows 7, 64 Bit Platform
- Vision64 Operation Software
- Single 23” Monitor with 1920x1080 resolution
- Small Footprint Option with Automation Ready Package
- Integrated Isolation Table
3D Microscope Surface Metrology
General Benefits of Core Technology

- Fast, accurate, GR&R capable metrology
- Non-contact, non-destructive
- 1000+ analysis parameters
- Stable and operator independent data
Apply Benefits to Industry Problems
Semiconductor Applications

- Broad range of applications including:
  - Vias, Trench depths, CDs
  - Laser probe mark depth
  - Sensor dimensions and frequency performance (MEMS, DMEMS)
  - Cu wire bonding (bond force optimization, near line inspection)
  - Multichip Module HDI production inspection
  - Wafer Roughness
  - Others
Range of Semiconductor Applications

Bruker Confidential

Stylus and Optical Metrology Unit
Wafer Roughness
3D Areal Measurement – Large Area, FAST!

**Sa:** 3.258 nm

*nm level roughness over mm scale!*
High Aspect Ratio Measurements

Challenging for Metrology Systems

- Traditional optics can measure vias of 4:1 aspect ratio, trenches up to 10:1
- Beyond this, shadowing and diffraction limit capability
Specialized Objective and Algorithms
Significantly Improve Performance

- Highly Collimated Illumination
- Intelligent Separation of Substrate and Via Signal
- Precise System Alignment
- Trench Capability - 25:1
- Via Capability – 10:1

![Graph showing Measured TSVs]

- Measured TSVs

- Width in microns

- Depth in microns

Legend:
- Long trenches
- Round or square vias
TTM Specialized Objectives
Through Transmissive Media

- 2X, 10X, 20X objectives enable system magnifications from 1X – 40X
- Measure samples through glass and other materials up to 3mm thick
- Universal housing supports multiple magnifications and compensation materials
- For static & dynamic 3D measurements
Custom Objectives

Separate Illuminator for Deep Features

Advantages of illumination from below of the objective
- Collimated illuminating beam better penetrates the via
- High numerical aperture of objective captures most light
Deep Trench Measurements
Multiple Trenches Measured in Each Scan

- Integrated image processing automatically identifies and reports individual trench data
- Average Depth: 14.3 microns (across all the lines)
- Width from 1 to 10 microns
- Average 1 Sigma Standard Deviation of depth: 70nm
Probe Mark Solution
Auto Detect Deepest Point

Auto filter removes higher level from the reference area
Probe Mark Solution
Auto Detect Highest Peak

Auto filter removes lower level from the reference
Deposition, Etch, Probe Marks

Fast, accurate dimensions – non-contact!
Lead Frame Surfaces
Roughness and 3D Areal Parameters

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<tr>
<td>Sz</td>
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Roughness and Sdr Uniformity

Lead vs. Die Area – Roughness alone not enough to tell the story

Die B – Sdr demonstrates difference even though Sa behaves like Die A
Die Attach
*Height and Tilt Referenced to Lead Frame*

**X Profile (0.859 mm)**
- Delta: X(mm) = -0.667
- Z(µm) = 286.111

**Y Profile (1.145 mm)**
- Delta: Y(mm) = 0.415
- Z(µm) = 286.586

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**Table:**

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Laser Mark and Bump Heights
Auto detect troughs and peaks

Software auto detects features of interest – fast and accurate
Cu Wire Bonding Near Line Monitor
Cavity Depth and Ball Height Metrology
Wire Bond Near Line Monitor

3D Optical Microscope >5x Faster than industry standard methodology

- Sample Preparation (minutes): 10
- Measurement / Analysis (minutes): 0.25
- Total Time: 40 minutes

- Sample Preparation (minutes): 15
- Measurement / Analysis (minutes): 40
- Total Time: 55 minutes
**Al Pad Metal Splash**  
*Auto Detection and Analysis*

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**Splash Analysis**

The area of interest is identified by software.

**Highest peak and volume of Splash**

**Table:**

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<th>Rp μm</th>
<th>Volume um³</th>
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**Summary Statistics:**

- Avg: 2677.00
- Std: 244.00
- Skewness: 0.00
- Range: 486.00
**Al Pad Cavity Depth**

*Auto Detection and Analysis*

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Max Depth Analysis

![Image of analysis with a red arrow pointing to a region labeled 'Max depth below pad surface']

<table>
<thead>
<tr>
<th>No</th>
<th>Region</th>
<th>Area (mm²)</th>
<th>Full X Diameter (µm)</th>
<th>Full Y Diameter (µm)</th>
<th>Rv % (µm)</th>
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<td>0.000</td>
<td>-0.830</td>
<td>0.000</td>
</tr>
</tbody>
</table>
Vision64 Production Software Module
Operator interface enables simplified use
Solder Ball Grid Array Measurements
Areal Measurement of Single Die
3D Interactive Analysis Plot

Note Defective Area
Single Measurement of Defective Area
Single Measurement of Defective Area
Database can Flag Defects by Diameter
Programmable Stage Automation
Fast and simple operator setup

- XY Scatter and XY Grid functionality
- Wafer overlays clarify die positions and setup
- Grids are numbered and sub-grid (measure) locations are easily marked
- Variety of traversal patterns offered to customize motion
Programmable Staging
Wafer Grid and Within-Die Variable Points
Cassette Loading Wafer Automation
*ContourGT-X Automation Ready Solution*

- Metrology solution for auto loading up to 300 mm wafers
- 200mm, 300mm handler system provides front end operator interface
- SECS standard communication
- Factory MES or SPC system seamlessly interacts with handler interface
- Cleanroom compatibility with optional enclosures available
Bruker 3D Optical Microscopes
Quality Characteristics

FAST
ACCURATE
REPEATABLE
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• **Bruker ContourSP – MCM/HDI Metrology**

• Summary and Questions
Push to Smaller, Higher Density
Increased Demands on Metrology Tools

Convergence / Integration
- Mobile Ubiquity
- Higher Quality Display, U/I
- Cost / yielded Product

Higher I/O Density
- Thermal Management
- Z-axis constraints
- Cost / yielded Product

Smaller/Higher Density Features
- Greater complexity (more layers, fiber reinforcement, etc)
- Increasingly thin
- Cost / yielded bumped, singulated board

Metrology Capability
- Smaller/denser features
- Thinner boards
- Expanding range of measurements, GR&R

Cost / Measured Panel
- Higher Throughput
- Max. Up-time MTBF
- Minimum recipe/ deployment time
- Maximize operator efficiency
Trend Towards Finer Features

*Increased Value/Chip*

Semi Growth forecast: CAGR of 4.1 per cent from 2011-2016, reaching $368 billion in 2016 (IDC Jan 13).

Trend to larger wafers, finer features

Value/chip increases due to finer scale

Cost of scrap increases – pushes demand for metrology
ContourSP HDI PCB Panel Metrology

Metrology and Analysis at Varied Steps in Build-Up PCB Production

ContourSP Provides Comprehensive Metrology At Each Stage to Minimize End of Line Scrap and Maximize Total Process Yield
ContourSP HDI PCB Panel Metrology
Comprehensive Metrology up to 600 mm x 600 mm Panels

Defects and CD Variations of Layers may Decrease Performance, Lower Yield, and Increase Scrap + Product Cost
ContourSP HDI PCB Panel Metrology
Comprehensive High Volume HDI/MCM PCB Production Analysis

Ra Surface Roughness
• Accurate & repeatable 3D Ra
• Inner-Core, build-up, Dielectric and other important process layers

Trace Analysis
• Width, height, and spacing of traces on a flat substrate
• Needle density calculations (similar to anchor calculations)

Unmatched Analysis Capability
ContourSP HDI PCB Panel Metrology
Comprehensive High Volume HDI/MCM PCB Production Analysis

Overlay Analysis

- Measure relative concentricity to detect shifts in layer alignment
- 3D analysis used to avoid focus variation problems

Surface Anchor Analysis

- Number of anchor regions
- Area of each region
- Anchor region depth
- Anchor volume

Unmatched Analysis Capability
Advanced VIA Analysis

- Depth, top and bottom diameter
- Roughness of anchor & via regions
- **Dynamic Signal Segmentation** for accuracy in Presence of Fiber Layers

Circle Connect Analysis

- Finds and measure center and diameter of circular features
- Measure lines extending from or connecting circles

**Unmatched Analysis Capability**
ContourSP HDI PCB Panel Metrology
Comprehensive High Volume HDI/MCM PCB Production Analysis

**Dynamic Signal Segmentation**

- Patent-pending method uses enhanced signal from interferometry
- Separates out Signals from
  - Substrate
  - Fiber Layer
  - Bottom Beneath the Fibers
- Calculates
  - Shelf Depth
  - Shelf Width
  - Bottom Diameter
  - Length of Residual Fiber

*Provides Most Accurate Bottom VIA Diameter and Residual Fiber Length Analysis For Re-enforced PCB’s*
Pad Clearance Analysis

- Calculates the gap (clearance) between the edge pads and the closest panel feature

Auto Alignment & Critical Dimension Analysis

- Easy set-up of a large variety of fiducials for automated alignment
- Optional s/w ensures fast, accurate location of desired features

Unmatched Analysis Capability
Panel Recess (Dimple) Analysis

- Measurement of “dimples” on the central features
- Depth of recess of the dimple
- Thickness of the pad on which the dimple is located

Solder Mask & Opening Analysis

- Dimensions and heights of mask, pads and substrate within the mask
- Displays the relative heights of all features the x and y dimensions or diameter of the mask and pad features

Unmatched Analysis Capability
ContourSP HDI PCB Panel Metrology
High Efficiency, Streamlined Next Generation Metrology

- Streamlined, Easy to Use Software Interface
- 64 bit multi-core processing
- Enhanced *Ease of Use and Stage Automation Creation*
- **Recipe Copy Exact on EVERY Tool**
- Fastest set up of Panel Automation
- Overall enhanced system for most efficient operation
Bruker BNS – SOM BU
Worldwide Presence - World Class Support
SUMMARY

- Introduced Bruker, BNS and SOM
- Showed range of capabilities for stylus and optical metrology tools for related semiconductor and electronics manufacture
- Bruker is excited to learn how we can partner with industry producers to solve production monitoring needs
THANK YOU!!!
QUESTIONS?

www.bruker.com

Bruker Nano Surfaces
Stylus and Optical Metrology

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