FOLP at the verge of volume production

Over the years, the industry became accustomed to Apple being forward-looking and deep analysis carried out by planning teams at Samsung,

Chip Industry Maps Heterogeneous Integration

Nicky Lu talks about ‘ubiquitous intelligence’

Advanced packaging to generate nearly US$3 billion in revenues in 2019, says TSMC chairman

Julian Ho, Taipei; Willis Ke, DIGITIMES  
Tuesday 26 March 2019

Pure-play foundry TSMC remains aggressive in expanding its advanced packaging business, which will generate nearly US$3 billion in revenues this year, according to company chairman Mark Liu.
Buried Costs!
Buried Costs are not Directly Controllable

**Buried costs do not include:**
- The bill of materials
- Direct labor
- Other directly controllable costs

**Buried package costs include:**
- Process development costs incurred during the bring-up of a product
- The cost of line scrap and field failures when products do not meet performance requirements
- The cost of lost sales when products are not able to ship on-time
There Might be a Few Gaps in Packaging Technology...

MIND THE GAP
Evolution of Semiconductor Inspection and Metrology
Evolution of Semiconductor Inspection and Metrology
Evolution of Semiconductor Inspection and Metrology

1970’s~1980’s

1980’s~1990’s

1990’s~2000’s

2000’s~2010’s
Evolution of Semiconductor Inspection and Metrology
Quality Systems Comparison

Wafer Fabrication

1. Fabrication Steps
   - Process Telemetry
   - In-Line Inspection or Metrology
     - Process Feedback
     - Physical Kill
     - Electrical Kill
2. All Layers Completed?
   - N
     - Next Layer
   - Y
     - Wafer Probe Test
3. Assembly Steps
   - In-Line Inspection or Metrology
4. All Asy Steps Completed?
   - N
     - Next Process
   - Y
     - Package Final Test
ZEISS 3D X-ray Solutions for Packaging

**Context**
- microCT (upgradeable to Versa)
- Next Generation Versa XRM
- Ultimate Nanoscale XRM

**Resolution:**
- 950 nm
- 500 nm
- 150 nm, 50 nm

**600-series Versa**
- Versatile submicron 3D resolution on a variety of intact samples

**800 Ultra**
- Nanoscale resolution for imaging ultra-fine pitch interconnects

Large field of view for all samples, high resolution for small samples
Versa X-ray Microscope vs. microCT

Working distance must increase as package body size increases.

Resolution decreases with increasing working distance.

Resolution is consistent (Resolution at a Distance)
Versa X-ray Microscope vs. microCT

Working distance must increase as package body size increases.

**Versa XRM**

**microCT**

Resolution is consistent (Resolution at a Distance)

$$\text{GeoMag} = (D_{ss} + D_{ds})$$

Working Distance (mm) vs. Resolution (μm)

<table>
<thead>
<tr>
<th>Working Distance (mm)</th>
<th>microCT</th>
<th>Versa XRM</th>
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<tbody>
<tr>
<td>0</td>
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Versa XRM 3D Dataset and Virtual Cross Section

3D Dataset

Interactive Virtual Cross Section
Failure Analysis and Package Characterization

Failure Analysis
- Root-cause analysis
- Usually 1~2 samples per job
- Each scan is unique
- Objective is defect visualization

Package Characterization
- Construction and process analysis
- Multiple samples per job (DOE’s, etc.)
- Scans are often repeated
- Objective is measurement of critical parameters
The Most Versatile 3D X-ray System in the Industry!

- μBump Short
- Trace Crack
- Head on Pillow
- Bump Void
- Bump Crack
- Solder Creep
- Incomplete Via
- Via Crack
- Underfill Void
- Electromigration
- TSV Void
- Si Crack
Lord Kelvin (William Thomson)

...when you can measure what you are speaking about, and express it in numbers, you know something about it...

Lecture on “Electrical Units of Measurement”, May 2, 1883
3D X-ray for Inspection and Measurement of Buried Features

- High-resolution tomography images with automated, repetitive scanning for same package design and location
- Measurement software and ZEISS support enable semi-automated 3D linear and volumetric measurements
- 3D enables many types of metrologies: solder volume, shape, extrusion analysis…
Versa XRM Measurement Workflow

Load Parts in Robotic System | Automatic Acquisition and Reconstruction | Mass Data Storage | Repetitive Measurement

3D Data

Customer Host

3D Measure
Case Study #1: μBump TCB Bond Line Thickness

Bond line thickness (BLT) is defined by die-to-die distance

Die tilt?
Case Study #2: μBump Solder Fillet Geometry

Virtual Cross Section

Value at Each μBump

Solder Fillet Area

Pad Area

Solder Fillet Area

Pad Area
Case Study #3: TSV Array Alignment Analysis

Top-down Microbump Pad Stack Alignment

Virtual Cross Section

Stack A

Stack B

X-axis

Y-axis

X-drift

Y-drift
Use of Versa 3D X-ray for Package Measurement

Results in faster, more accurate package development for on-time, on-target product launches by enabling:

- Larger inspection and measurement sample quantities for more robust process optimization
- More accurate, more comprehensive metrology compared to manual cross-section
- Statistically-valid DOEs, process splits and other statistical techniques
- Ability to analyze the same samples both before and after stress testing
- And lower buried costs!
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