FOGALE METROLOGY SOLUTIONS FOR ALL 3D MEASUREMENTS

BOW  WARP  RST  TSV  EXCENTRICITY  CD  STRESS  ROUGHNESS  BUMPS  THICKNESS

FOGALE nanotech
Semiconductor Metrology Solutions

SEMICON RUSSIA 2013

Guénael RIBETTE
WHO IS FOGALE COMPANY ???
Since 1983, world leader for conception and manufacturing of non-contact dimensional metrology systems

- Capacitive and Optical technologies
- Engineering, studies, conception and manufacturing
- Spin-off of between CEA LETI & ONERA

- 4 patents/year
- Installed base for optics, MEMS and semiconductor > 400 units

Turnover: 11.6 M$ (2012)
Staff: 55 (Headquarter)
FOGALE METROLOGY SOLUTIONS FOR ALL 3D MEASUREMENTS

BOW  WA

ORGANIZATION

Subsidiaries:

FOGALE Inc.
Boston USA

FOGALE Asia
Tainan Taiwan

Applications/technologies

Common lab in IEF/FOGALE Research

Manufacturing Toulouse

FOGALE Headquarter NIMES

Application Lab Ax en Provence

INSPECTION  TRENCHES  PROFILO  COPLANARITY  COPPER NAILS  EDGE TRIM  MEMS
Semicon market for FOGALE with the TMAP MACHINES

- 3D integration: Stacking of multiple chips on top of each other within a single semiconductor package

- MEMS: Micro Electro Mechanical System

- Substrate dimensional control
  - TTV, bow, warp and surface topography
  - SiC, Sapphire, Heavily doped SOI, GaN
What Are you doing in FOGALE?
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As defined by semi-Standart, 4 points are necessary to measure the Bow.

In this case, the bow has a negative value. This is usually the case when wafers are subject to gravity.
A minimum of 9 points are necessary to measure the warp of the wafer but more give better results.

Warp is always positive.

Note: to remove the effect of gravity, for Bow and Warp, you can measure the upper surface of wafer, then flip it and measure the lower surface. The software automatically flip the lower surface measurement and does the calculation for each point: (upper surface – lower surface)/2. This result does not take the gravity into account.
Spot positioning by IR microscopy

Bacside of the wafer is up

Backside lighting

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Seed Ti/Cu and Fill Cu

TSV: 30um diameter

2um SiO2

Si substrate, t: ~ 750 um

Via Depth: ~135 um

(1)

(2)

(3)
Spot positioning by using IR microscopy
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Experiment: measure 5 vias in the XSEM structures in different locations.

Verify by XSEM:
- Average after correction with toplayer: 34.35 μm.
• Measure every die (37) over the west-east axis

“M” shape of depth across 300 wafer diameter

Courtesy of IMEC
- Excentricity with A1 to A4
- Thickness with B, C, D
- Distance between two points
Diameter measurements on TSV
Diameter measurements on TSV with color flags for Go-NoGo.
Hole critical dimension measurement
Stress measurement
### ROUGHNESS

**Roughness 5 points**

<table>
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<tr>
<th>Point</th>
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<th>$R_a$ (nm)</th>
<th>$peakpeak$ (nm)</th>
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Sub-Nanometer resolution
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ROUGHNESS

Sub-Nanometer resolution

Roughness measurement: 250 x 200 μm² field of view
Phase shifting method
Camera view
Surface topography
Roughness measurement on germanium

Sub-Nanometer resolution
Roughness measurement on ZnSe

Sub-Nanometer resolution
All measurements on Bumps: height, coplanarity, size XY, etc...
Objective used: 20 X
Lateral resolution: 0.8µm
T, TTV, Bow, Warp

By adding a reference surface inside the interferometer, an absolute distance measurement can be performed to measure flatness of the wafer.

→ Thickness, TTV, Bow and Warp are obtained in one pass
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If one buried layer is not transparent to IR light (Heavily doped, Metal…) or if one layer refractive index is unknown → DUAL MODE required

**Single Mode:**
Multiple layer Thickness measurement capability

Up to Max. Total Thickness
Max. Thickness= \( \sum n_i \cdot T_i = \text{Measurement Range} \)

Measurement range depends on sensor used
T, TTV, Bow, Warp: How to control wafer on temporary carrier?
If the glue layer is unknown → Refractive index calculation by using DUAL sensor

[Diagram showing layers: Layer 1: Si, Glue, Layer 2: Si or Glass]

Single IR mode can be performed by each sensor if the material is transparent to NIR wavelength:
Sensor 1 → Layer 1 thickness \( T_1 \)
Sensor 1 → Optical Path through Polymer Layer = \( n_{\text{polymer}} \cdot T_{\text{polymer}} \)
Sensor 1 or Sensor 2 → Layer 3 Thickness \( T_3 \)

Dual Mode → Total thickness (after calibration as defined by SEMI standards)
\( T_{\text{polymer}} = \text{Total thickness} - (T_1 + T_3) \)

Refractive index \( n_{\text{polymer}} = \frac{\text{Optical Path through Polymer layer}}{T_{\text{polymer}}} \)
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Bow and Warp measurement

Thickness/TTV for Si/Glue/Si

Top Si

Carrier Si

Glue

THICKNESS
INSPECTION AFTER BONDING: NOTCH INSPECTION
Wafer on temporary carrier: interface inspection by IR microscopy (defect detection)

- Cracks
- Delaminating
- Voids
- Notch misalignment
- Edge defects

Unique!! Only FOGALE
Wafer on temporary carrier: interface inspection by IR microscopy (defect detection)

Cracks on wafer edge
TSV Reveal and μBump inspection by using WL microscopy

C4 Bumps

Defects after TSV reveal

Unique!! Only FOGALE
FOGALE METROLOGY SOLUTIONS FOR ALL 3D MEASUREMENTS

- Bow Warp
- RST
- Stress Excentricity
- CD
- TSV
- Roughness
- Bumps
- Thickness
- Inspection
- trenches
- Profile
- Co-planarity
- Copper
- Nails
- Edge
- Trim
- MEMS

Diagram: Shortest ball from substrate, Seating Plane, Co-planarity value.
Bumps coplanarity
Measurement within a die

Height

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Mean: 3.38988889
Max: 3.46
Min: 3.26
Std dev: 0.04675699

Co-planarity

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<td>-0.006</td>
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Std dev: 0.01369373

Note: Co-planarity within a field of view <<100nm
Edge trimming dimensional control with confocal chromatic

Applications: L & z dimensions
FOGALE METROLOGY SOLUTIONS FOR ALL 3D MEASUREMENTS

EDGE TRIM
• Membrane shape (bow) measurement after bonding:

The shape of the membrane is measured by IR metrology scanning & curved membranes detected by IR microscopy.

IR visual inspection through Si Cap

Bow measurement by IR interferometry

- Flat membrane
- Curved membrane
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ALL THESE APPLICATIONS CAN BE DONE ON THE SAME MACHINE !!!!!!!

WHICH TECHNOLOGY FOGALE IS USING ?
LISE SENSOR IN TEMPORAL MODE
Confocal Chromatic technology

Single point method: no z-scan required due to multi confocal points → x,y scan only
3D Surface Profiling: Full Field White Light Interferometer

Measurement done all over the field of view of the microscope: Z-scan only
UPPER & LOWER HEAD OF TMAP

Cameras & sensors in the same optical path. Multi wavelength illumination: IR + WL. Multi sensor capability: confocal/WLI/IR

Thickness and Overlay registration (in plane and out of the plane)

Bonding wafer: void detection

Etc….
IS IT POSSIBLE TO SEE THE TMAP MACHINES?
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R&D

PRODUCTION UP TO 10 LOAD PORTS
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if you wish to have more information, please come to BLMS booth.

Thank you for your attention