Future Metrology Needs for Next Generation MEMS

Gilles Fresquet

September 2014
OVERVIEW

• Founded in 1983
• Headquarter: located in Nîmes, France: Management/R&D/Marketing
• 70 FTEs, 80% engineers & PhD,
• Strong IP portfolio (50+ patents families)
ORGANIZATION

Subsidiaries:

FOGALE Inc.
San Francisco, Ca.

FOGALE Asia
Tainan Taiwan

Manufacturing

Common Lab I.E.F

FOGALE

Demo center

George Charpack Institute

Future Metrology Needs for Next Generation MEMS
Future Metrology Needs for Next Generation MEMS

- 3D IC TSV
- MEMS
- Advanced Packaging
- Micro fluidic
- Advanced stacked substrates
- GaN/Sapphire, Thick SOI.....
- µlenses & WL optics
Future Metrology Needs for Next Generation MEMS

FOGALE MEMS solutions:
MEMS in motion & environmental chamber
WLP process control
Wafer & bonded wafer bow, TTV
Overlay Registration
Inspection
Surface profiling

PRODUCTS: FROM LAB TO FABS
Future Metrology Needs for Next Generation MEMS

Next-Generation Metrology Tools Will Evolve into Multi-Parameter Instruments

Why?

- Need for smaller, faster and less expensive devices
- Manufacturers will pack an ever-increasing number of sensors, IC and actuators into single packages. with increasing pin counts, smaller connections shrinking dimensions
- The cost per measurement must continually decrease
- MEMS Std. ≠ SEMI Std.
New challenges for metrology:
Increasing device performance, reducing cost and size, and advancing integrated solutions drive the requirements for advances in in line and out of the line metrology and testing solutions.

<table>
<thead>
<tr>
<th>WHERE?</th>
<th>CHALLENGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fab In line</td>
<td>New materials (ex: PZT, Ceramic)</td>
</tr>
<tr>
<td></td>
<td>$X,Y \rightarrow X,Y,Z$</td>
</tr>
<tr>
<td></td>
<td>Buried cavities and patterns inspection</td>
</tr>
<tr>
<td></td>
<td>Overlay/registration down to 0.1µm accuracy</td>
</tr>
<tr>
<td></td>
<td>Smaller CD’s, smaller and more TSVs: dimensions</td>
</tr>
<tr>
<td></td>
<td>Bonding quality (interface defects, adhesion strength)</td>
</tr>
<tr>
<td></td>
<td>Wafer level Packaging Process control</td>
</tr>
<tr>
<td></td>
<td>Strain, stress monitoring, Residual stress</td>
</tr>
<tr>
<td></td>
<td>Defect capture for New bonding and micromachining methods</td>
</tr>
<tr>
<td></td>
<td>.....</td>
</tr>
<tr>
<td>Assembly &amp; Packaging</td>
<td>Mechanical Stress</td>
</tr>
<tr>
<td></td>
<td>Hermeticity</td>
</tr>
<tr>
<td>Testing Out line</td>
<td>Reliability</td>
</tr>
<tr>
<td></td>
<td>MEMS in motion analysis through Cap on devices with smaller dimensions</td>
</tr>
<tr>
<td></td>
<td>Q factor analysis on final device</td>
</tr>
<tr>
<td></td>
<td>Prediction of device performance</td>
</tr>
<tr>
<td></td>
<td>.....</td>
</tr>
</tbody>
</table>
Future Metrology Needs for Next Generation MEMS

New challenges for in-line metrology: An example
Overlay Registration down to 0.1 μm

Within field of view Registration

Challenge:
High magnification microscope objectives but low depth of field

Others: Out of field of view Registration for MEMS application on large dies
Example: Front to back registration of back side trench versus front μfluidic device (3 cm)

Dual side microscopy with automatic alignment

High accuracy (0.1 μm) displacement stage
Repeatability (3 σ) < 0.5 μm
FRONT END: MODULAR AND FLEXIBLE SOLUTION

METROLOGY: TOPOGRAPHY AND TOMOGRAPHY are required

- Thickness measurement (large measurement range): from 10nm to several mm
- Surface Profiling: from nm to mm in z

  Broadband DUV and WL optical techniques are required

- X,Y CD: resolution down to 0.2 µm in X & Y
- Tomography: multiple stack layers, measurement of individual layers

INSPECTION: DEFECT REVIEW

- down to 0.2µm resolution
- Defect review: buried µcracks, edge defects and unrevealed patterns detection
- Bonding: Die shear evaluation

Multiple measurement/inspection planes of focus are required
MEMS: Silicon cooking

Specific measurement dedicated to MEMS will always be required

- Tilted mirrors: Angle/roughness → High NA required/sub nm level surface profiling
- Micromachining: smaller devices, thinner sacrificial layers → detect stiction
- MEMS wafers processed on both sides: Registration/overlay with higher accuracy
- Small buried cavities: dimension measurement through Si (ex: Ink jet MEMS)

Others:

- Same needs than 3D IC TSV
- Via/trench dimensions, voids in metal filled TSV at Via filling, seed and diffusion barrier conformity at the TSV sidewall ….
MEMS: Assembly and Packaging

Packaging accounts for 80% of the cost of a MEMS device
Packaging process could be a root cause of device failure

→ Wafer Level Packaging is preferred

Multi Die

MEMS WLP
MEMS: Assembly and Packaging

Such wafer level approach will ideally require new control methods:

- Electrical connection performance
- Adhesion and assembly defect review
- Inter die gap and constraints after stacking
- Die Alignment accuracy
- Device in Package MEMS in motion analysis
- Hermeticity
Future Metrology Needs for Next Generation MEMS

MEMS: Hermeticity

Device

- Resonators (pressure, inertials, fluidic, ...)
- Time freq. (Quartz, Si, μwatch atomic, ...)
- Thermal sensor (matricial bolometers, ...)
- Absolute P sensor
- Switch RF
- Filters? (BAW, FBAR, SAW, Si Bar, ...)

Lifetime required: 10 to 20 years!!

Internal Pressure

- <10^{-3} \text{ à } 10^{-2} \text{ mbar}
- <10^{-3} \text{ mbar}
- <10^{-3} \text{ à } 10^{-2} \text{ mbar}
- <1 \text{ mbar to mbars}
- mbars
- mbars

![Graph showing leakage rates and time to pressure changes]
MEMS Packaging: Hermeticity & reliability

- 10 years storage
- Leak rate < 10atm-cc/sec

- Need for In line and out of the line leak control
- Need for In MEMS embedded leak detector? Si Getter.....
MEMS In motion

Thermally actuated silicone membrane (courtesy Barcelone University)

In Plane/Out of the plane measurement

Today:
WLI phase shift or z-scan
Doppler laser
Environmental chamber (Vac. P)

How to perform such metrology after Packaging?

Electrostatic actuation study

Phase shifting stroboscopic interferometry
Test device with out of plane actuation

Test device with in plane electrostatic actuation
MEMS In motion new requirements:

Develop IR interferometric methods

Develop full field optical methods to perform measurement through Cap while keeping in mind that device are becoming smaller and smaller

Out of the plane:
- Interferometric objectives able to compensate cap thickness (up to 500µm?)

In plane:
- Lateral resolution <<1µm
μfluidic devices: a specific case?

Today: Only Ink jet in H.V.M.

Others: “Spider Assembly”

Tomorrow: PCB like assembly

3 Materials: Glass/polymer/silicon

Standardization needed

Requirements:

- In line Process control solutions on standardized process flow
- Out of the line, μfluidic device characterization
NEWS: FOGALE RECEIVED THE AWARD OF THE BEST 3D METROLOGY INSPECTION TOOL (SEMICON WEST)
Thanks for your attention!!

Gilles FRESQUET  
Semiconductor Business Dept Director  
FOGALE nanotech Vice President  
125 Rue de l'Hostellerie  
Ville Active  
BâtA-Parc Acti +  
30900 NÎMES-FRANCE  
Email: g.fresquet@fogale.fr  
Tel: +33(0)466620555  
Mobile: +33(0)684133831  
Fax: +33(0)466627160  
http://www.fogale-semicon.com/