MEMS devices
application based testing

CEEES Seminar

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MASER ENGINEERING

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EUROPEAN CEEES SEMINAR

EUROPEAN RELIABILITY AND ENVIRONMENTAL TESTING CONNECTED

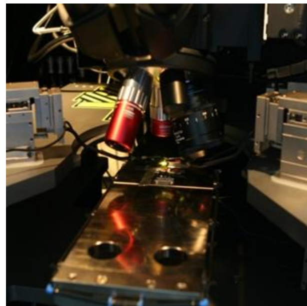
FHI PLATFORM OMGEVINGSTECHNOLOGIE

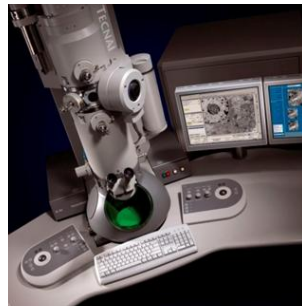
Outline

- **Introduction**
- **MEMS classification**
  - Sensing & Actuating
  - Manufacturing technology
- **MEMS applications**
- **Reliability Test procedures**
- **Examples**
  - Gyroscope
  - Microphone
  - RF switch
- **Summary**

Introduction

- **MASER Engineering**



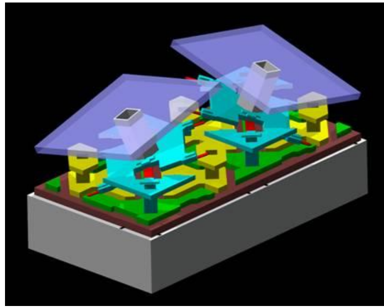


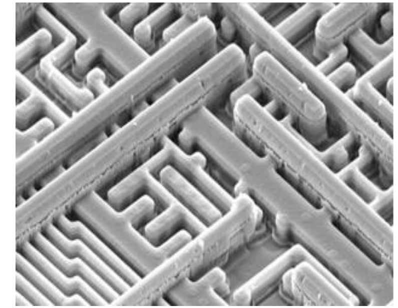
- **Independent Service Provider**
  - Failure Analysis and Electronic Materials Analysis
  - Deep submicron Circuit Edit
  - ESD/Latch Up testing and characterization
  - Reliability Test and Robustness assessment
  - ISO9001 certified and ISO17025 scope available
  - Since 1993, 40 engineers and technicians in Enschede

MEMS classification

- **Scale of Systems**
  - (sub)miniature [~1mm]
    - Precision Engineering, mainly in metals and glass
  - Micro-Electrical Mechanical Systems [10-100µm]
    - Sensors and other devices, mainly in silicon
  - Nano-Electrical Mechanical Systems [0,1-1µm]
    - Electronic devices, mainly in silicon
  - Nanotechnology [<100nm]
    - Mainly materials
- **Imaging system range**
  - Naked eye to STEM / AFM [1x to 40,000,000x]

MEMS classification





Electronics

MEMS

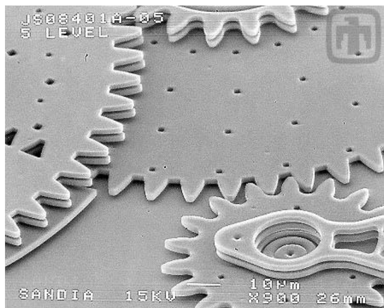
ElectroOptics

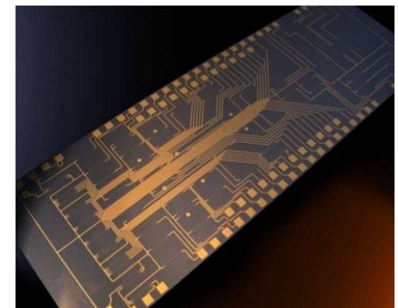
MOEMS

Mechanics

Optics

Optomechanics





MEMS classification

- **Sensing and Actuating**
  - Piezo-electric Inkjet Heads
  - Accelerometers & Gyroscopes
  - Flow & Pressure sensors
  - Optical beam movement and switching
  - Micro machines & micro motors
  - Linear – Comb – Resonator actuation
  - Liquid distribution channels
  - Energy harvesting

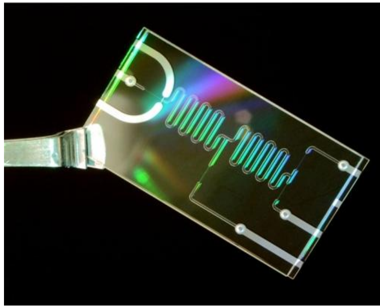
MEMS classification

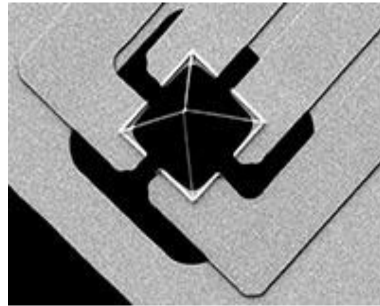
- **Manufacturing Technology**
  - Modified and Extended Silicon SEMI
    - Lithography for patterning
    - Deep Reactive Ion Etching (DRIE)
    - Wet & Dry chemical etching
    - Chemical Vapor Deposition - Sputtering
    - Chemical Mechanical Polishing (CMP)
    - Sacrificial & Structural layers
    - Stacking & Capping assembly
    - Plastic and Ceramic cavity packaging
  - MEMS first → Assembly based manufacturing
  - MEMS last → Add on to Si-wafer process

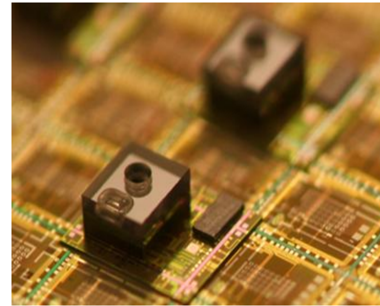
MEMS applications

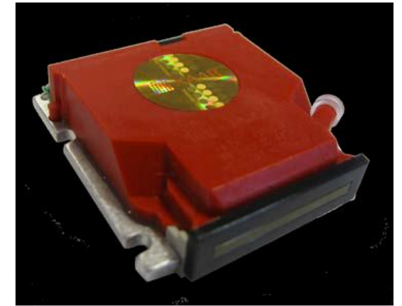
- **Automotive**
  - Airbag – ESP – Tire pressure – GPS navigation
- **Consumer**
  - GPS navigation – Phone microphone – Camera
- **Office & Industrial**
  - Beamer – Inkjet printers – P & T & rH sensing
- **Medical**
  - Nanopumps – Lab-on-a-Chip – micro-needles
- **(aero)Space & Military**
  - Gyroscopes and accelerometers for navigation

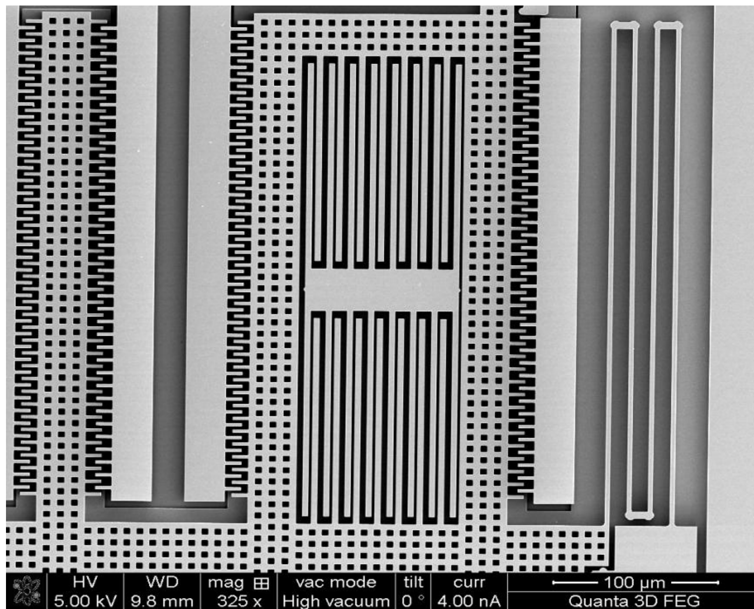
MEMS applications

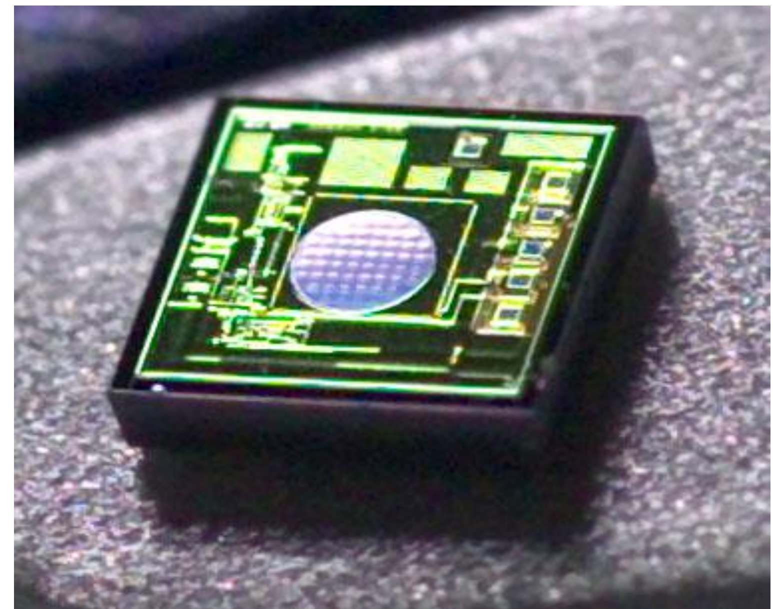












Reliability Test procedures

- **MEMS in its operational environment**
- **System In Package in a system**
  - Assembly related failure sources
- **Proper operation and function until**
  - Moment of Failure, stuck at or intermittent
  - Failure mechanism stops function
- **Prediction of that moment**

→**Goal of the Reliability Assessment**

Duration → quality level

Repeatability → robustness level

Reliability Test procedures

- **MEMS in its operational environment**
  - Exposed to the outside world
  - No or limited protection to harsh environments
  - Extended exposure compared to electronics
  - Safety critical applications
- **Stress test similarity with electronics**
  - Yes → same manufacturing techniques
  - No → other, weaker materials
  - No → more complex packaging
  - No → different environmental stress

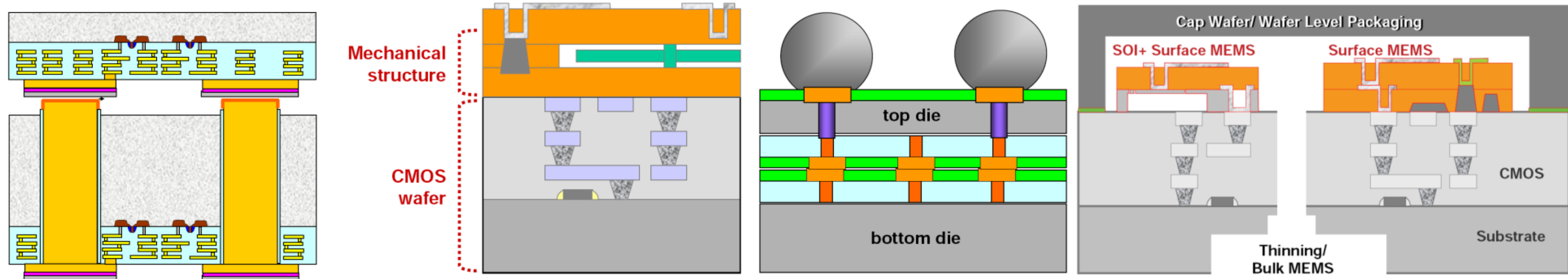
Reliability Test procedures

- **MEMS Qualification procedures**
  - Exposed to the outside world
  - Not or limited protection to harsh environment
  - Extended exposure compared to electronics
  - Safety critical applications
- **General Qualification procedures**
  - JEDEC 47 based
  - AEC-Q100 based
  - Customer requirements

  → **Failure mode effect driven**

Reliability Test procedures

- **Impact of package complexity**
  - Multiple interconnections in metal and polymer
  - MEMS last requires extended back-end of line
  - Wafer based assembly to meet high volume
- **Package design and integration**
  - Essential for successful MEMS devices



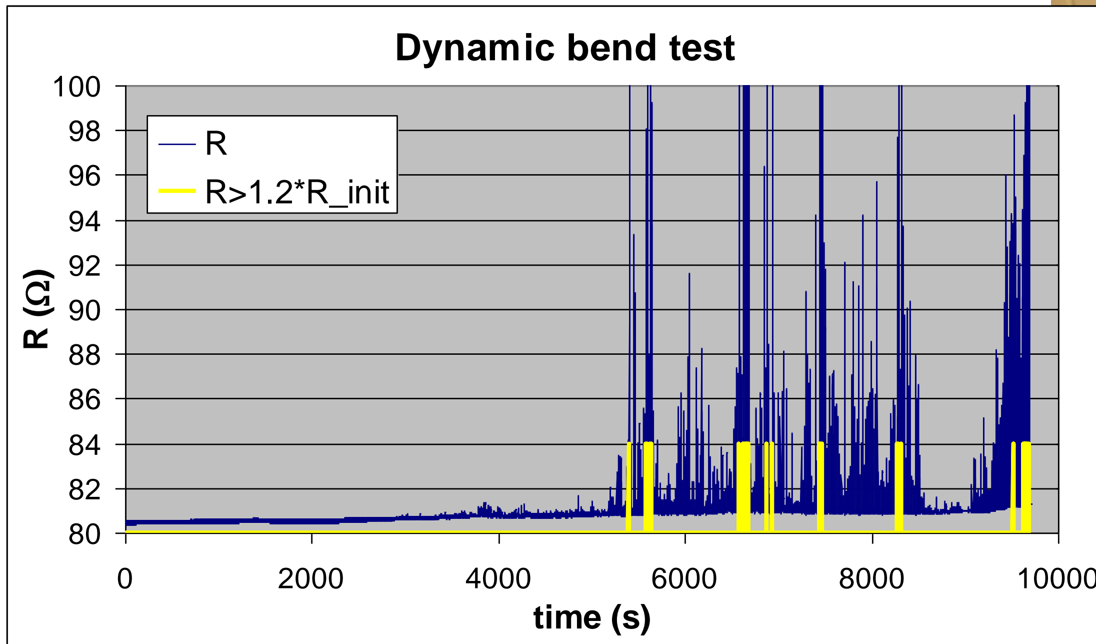
Reliability Test procedures

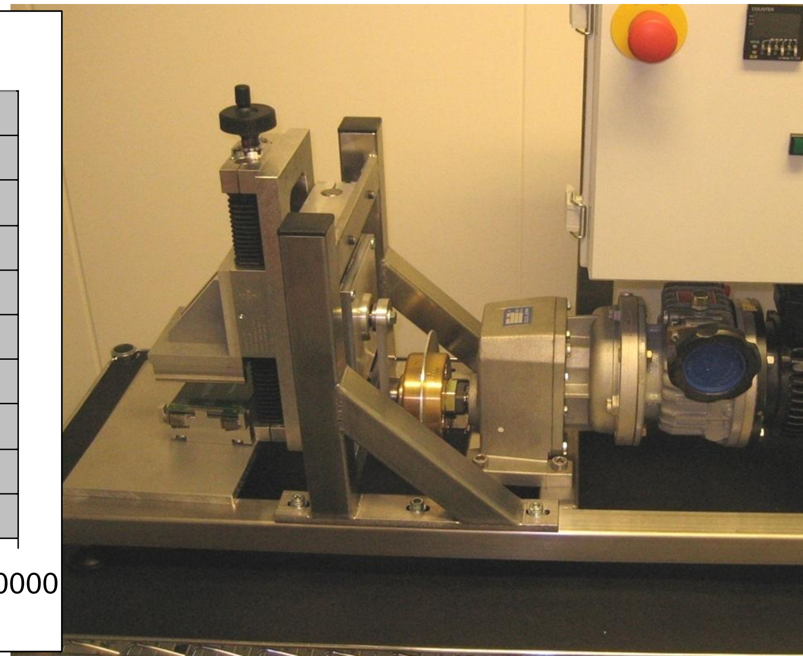
- **New failure mechanisms**
  - Misfit of materials
  - Stiction of moving elements
  - Corrosion
  - Delamination
  - Shock & Vibration induced material fatigue
  - Shorts and opens
  - Arcing in small cavities
  - ESD behavior

→ **Minimize effects by design**

Reliability Test procedures

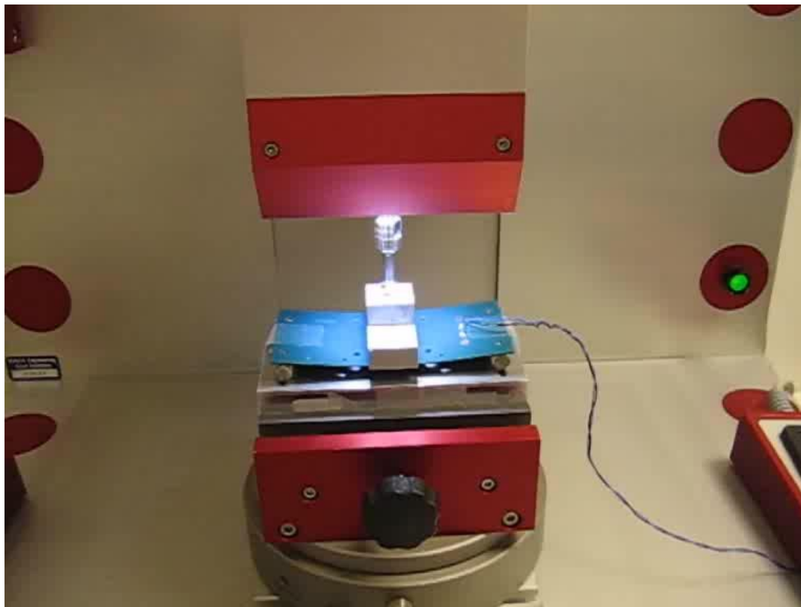
- **Impact on test techniques**
  - Stress impact after soldering
  - Continuous monitoring of impact

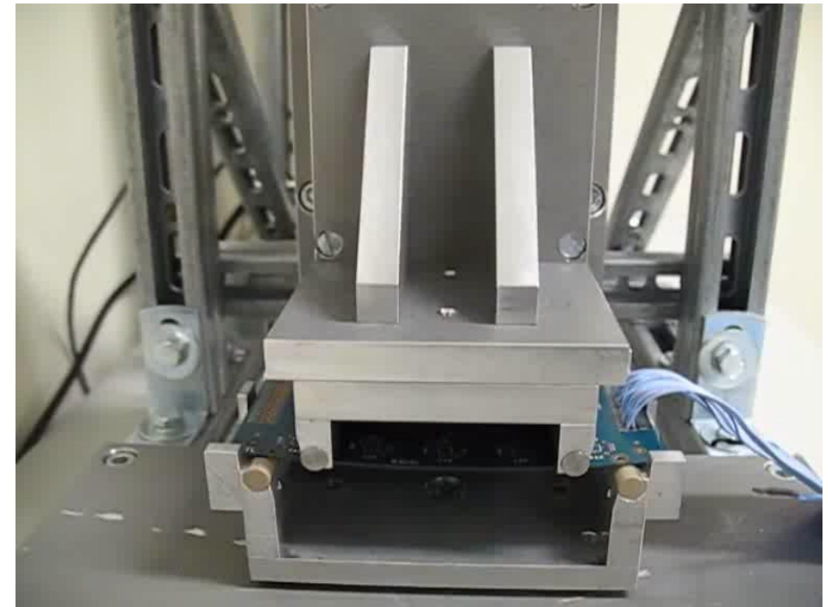




Reliability Test procedures

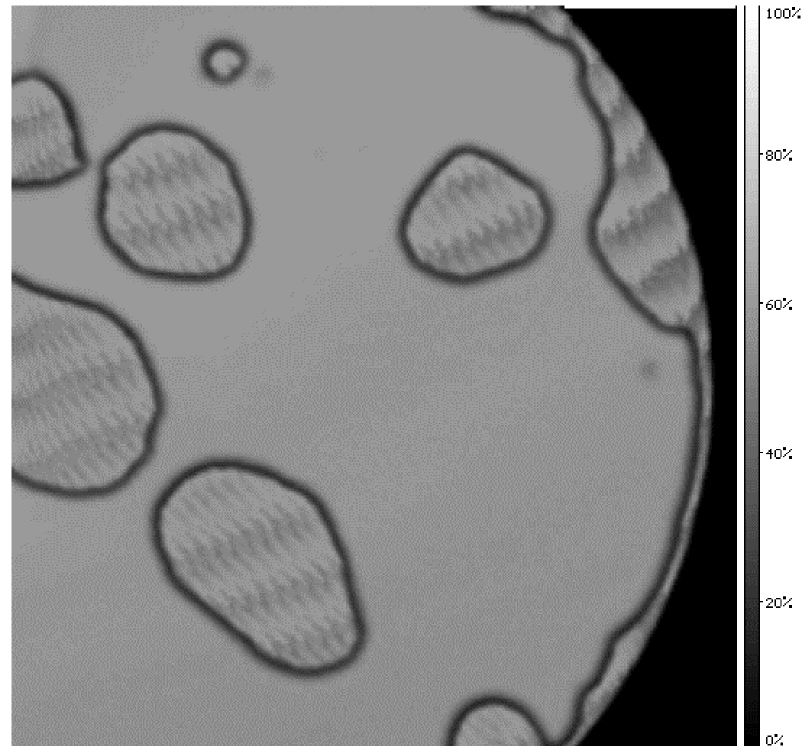
- **Impact on test techniques**
  - Insert movement parameter in active MEMS





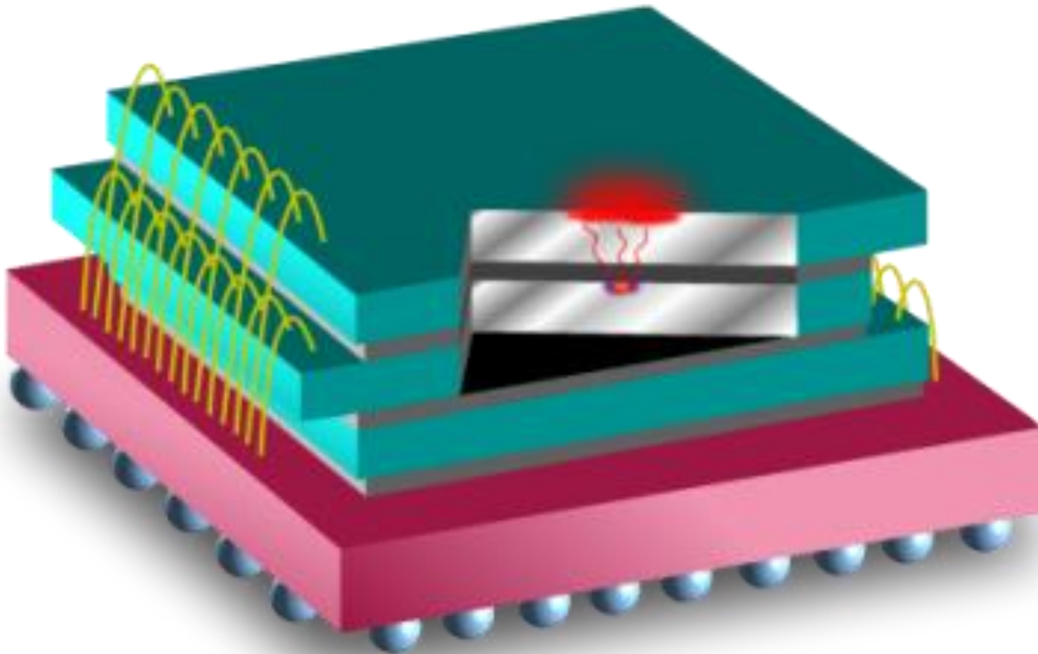
Reliability Test procedures

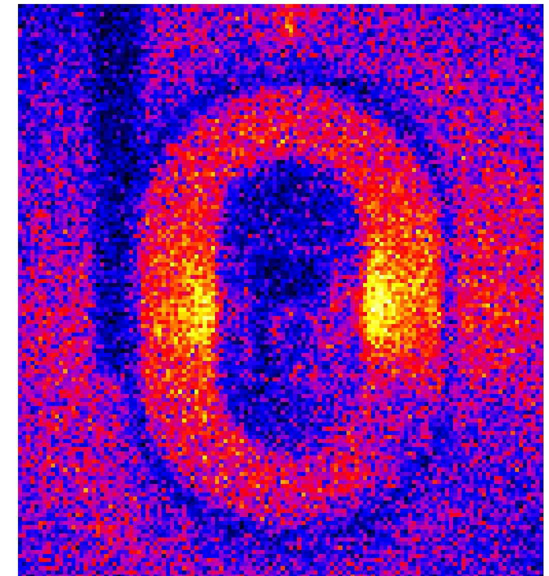
- **Impact on F/A techniques**
  - Full capping wafer delamination scan



Reliability Test procedures

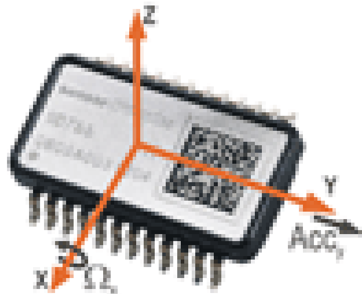
- **Impact on F/A techniques**
  - Thermal analysis of 3D structures

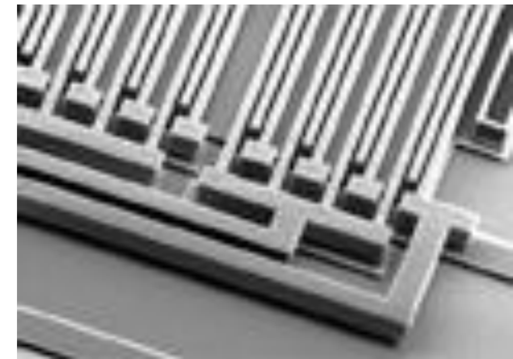




Examples

- **Gyroscope**
  - Automotive application (ESP) → safety critical
- **Approach**
  - AEC-Q100 flow
  - Die shear and Wire pull
  - Dedicated HTOL with active gyro and readout



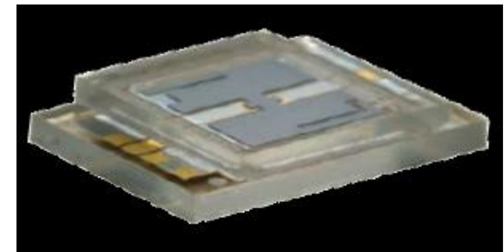


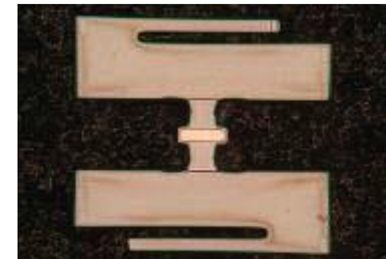
Examples

- **Microphone**
  - Mobile phone – Tablet computing
- **Approach**
  - JEDEC flow
  - Shear tests
  - Seal tests
  - Multiple axis shock
  - test with glitch detection

Examples

- **RF switch**
  - Antenna tuning – Automotive/Industrial Radar
- **Approach**
  - JEDEC flow
  - Active switching of RF power
  - DC resistance monitoring
  - Extended thermal shock
  - Seal tests





Summary

- MEMS bring additional challenges to Reliability Test.
- Integrated Packaging approach is essential for a reliable supply chain.
- New failure modes may require new test technology too.
- New techniques and tools have to be developed to address this new task.

Final Slide

Questions on this topic?

Thank your for your attention!

Courtesy: Tijs Lammertink – MASER Engineering
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