E&M qualification and F/A of MEMS

MEMS seminar @ Salland Engineering – Zwolle, 5-6 June, 2019

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Introduction

- MASER Engineering is an Independent Service Provider
  - Founded in 1993 by Hans Kemper and Kees Revenberg, privately owned
- 25+ years experience in Reliability Test and Failure Analysis
- Main office and central laboratory in Enschede, The Netherlands
- 800m² office area and 2200m² ESD Protected Area for equipment
- 55 employees (>50% eng. Degree) and 5 EMEA sales representatives
- Supporting members of PLOT/FHI-NMI/Techworks/SEMI/GSA/JEDEC
- ESDA standardization committee member and co-chair
- Quality certificates for ISO-9001 and ISO-17025 accreditation
- Propriety ERP system with secure customer portal (CMIDS)

Introduction

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MEMS device classification

- MEMS bridge the real world to a digital world
- Direct sensing or actuating linked to signal processing
- Material processing or property conversion
- Scale of systems
  - (sub)miniature [~1mm]
    - Precision Engineering, mainly in metals and glass
  - Micro-Electrical Mechanical Systems [10-100um]
    - Sensors and other devices, mainly in silicon
  - Nano-Electrical Mechanical Systems [0,1-1um]
    - Electronic devices, mainly in silicon
  - Nanotechnology [<100nm]
    - Mainly materials

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MEMS device classification

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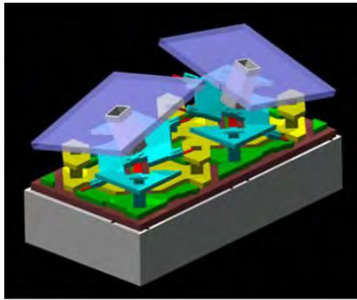
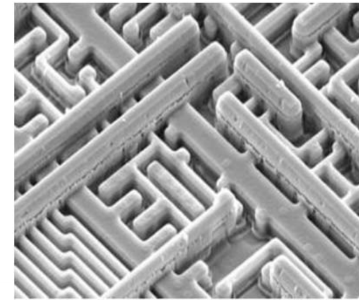
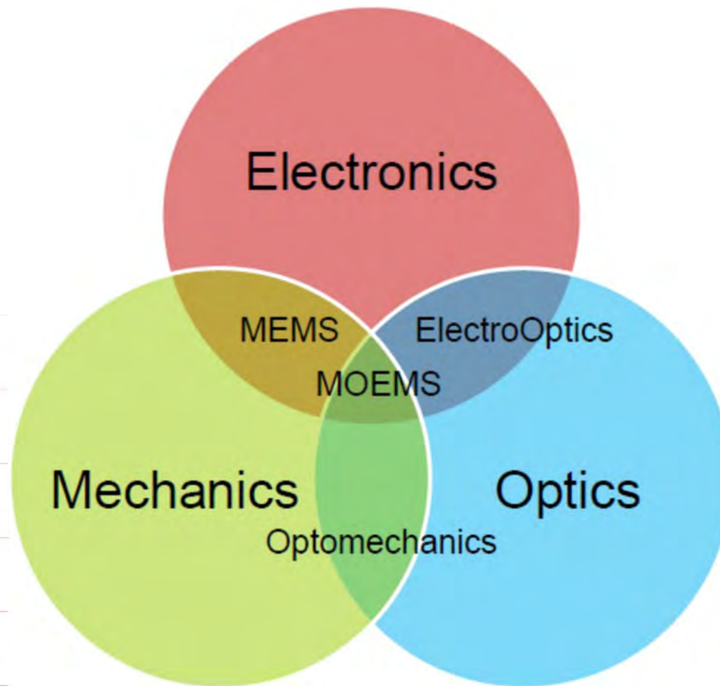
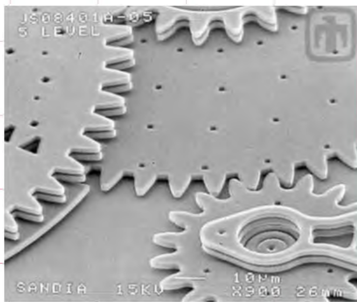
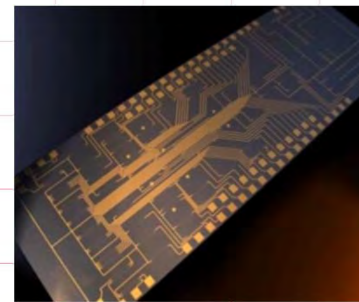








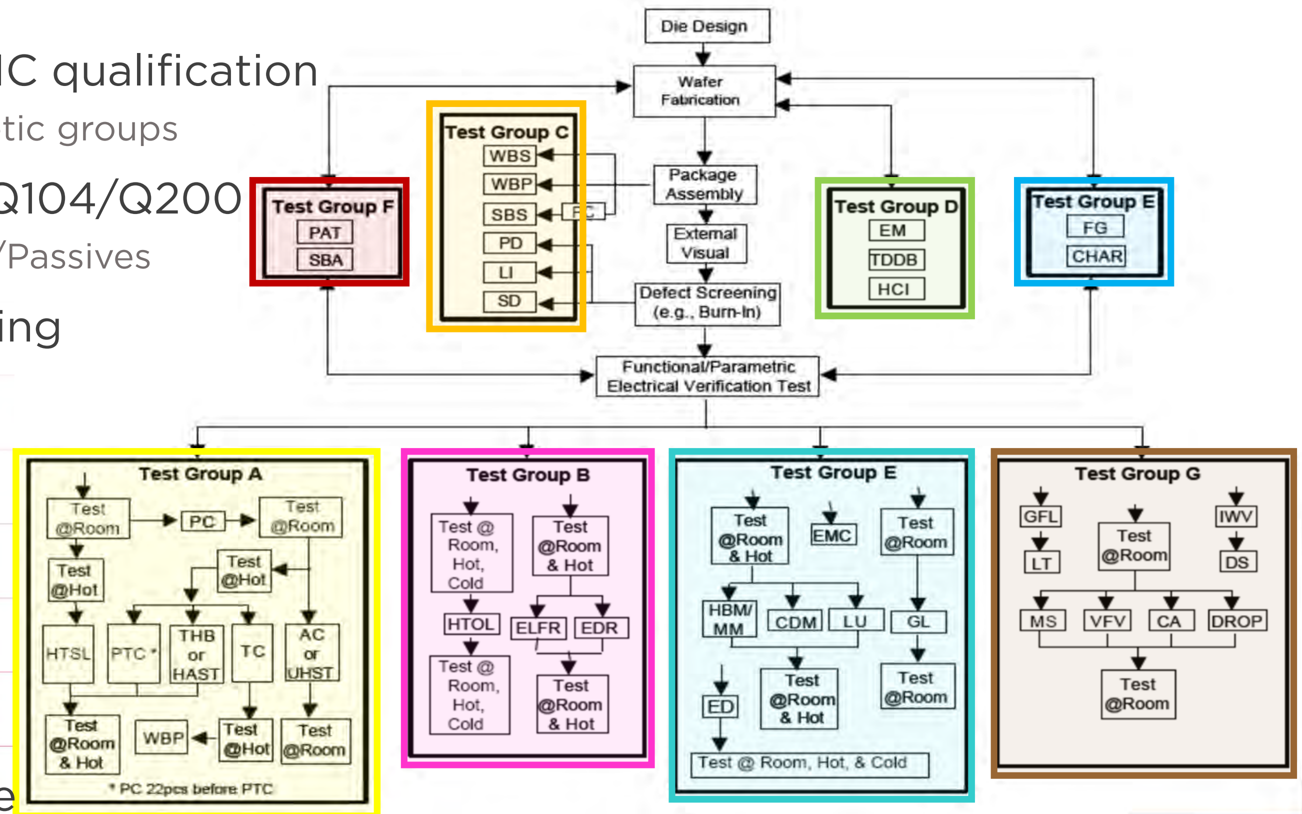


Qualification procedures and standards

- MEMS add challenging parameters to qualification procedures
- Range of standards and procedures for semiconductor devices
  - JEDEC – AEC – MIL – ESCC – IEC – ISO – JIS – IPC – UN and more
- Application driven
  - ICT – Automotive – Industrial – Medical – (Aero)Space – Military
- Well established for semiconductor devices
  - IC's – IC Packages – PCB – System level
- Missing link on additional non-electrical stressors
  - Mechanical impact during accelerated life test and readpoint test
  - Chemical impact during accelerated life test and readpoint test
- ESD test standards based on systems
  - Not suited for (small) components and MEMS
  - New standard on Human Metal Model will replace system IEC 61000-4-2 standard

E & M qualification tests on MEMS

- JESD47K Stress driven IC qualification
  - IC qual with (non-)hermetic groups
- AEC-Q100/Q101/Q102/Q104/Q200
  - ICs/Discrete/Opto/MCM/Passives
- MEMS extensions covering
  - Cavities, open or closed
  - Ceramic / Metal stacks
  - Bio sensitivity
  - Chemical sensitivity
  - Mechanical parameters
  - Optical parameters
- E-test read point issue
- Aging model – AF figure



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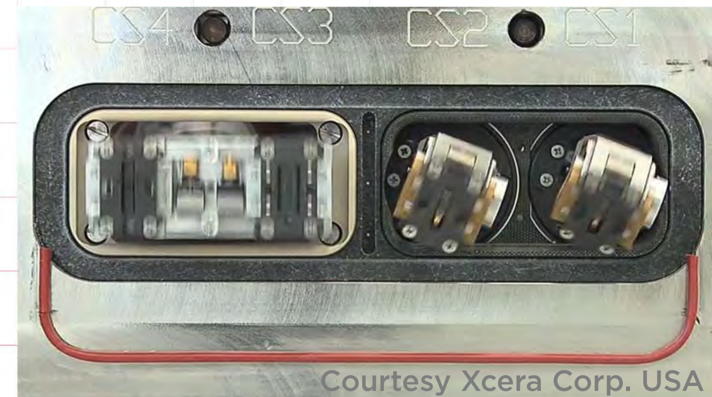
E & M qualification tools for MEMS

- Non-electrical parameters difficult to add for production
- Standard Semi device tools for HTOL/TCY/HAST/PTC
- Chemical/Optical parameters during characterization
- Example: complex handling system for gyroscope MEMS
- TPMS test at 230km/h, 60 units, 24 hours, 6-axis



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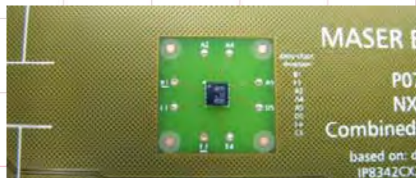
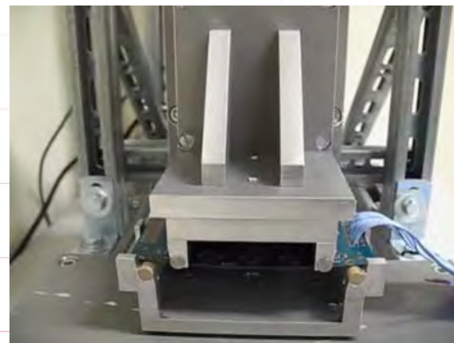
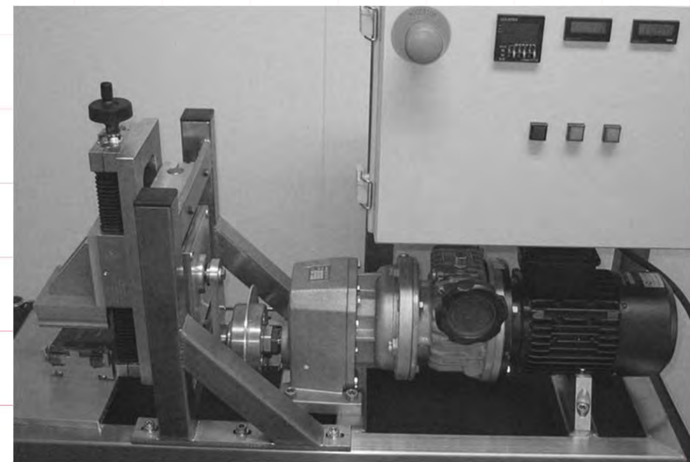
E & M qualification tools for MEMS

- Bending tool for lateral stress on metal interconnects
- Pure sine wave movement in Z-axis mounting
- Resistance scanner per interconnect in daisy chain mode
- >500.000 bendings for EOL testing







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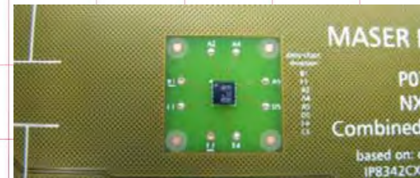
E & M qualification tools for MEMS

- Shock test tool for high impact drop
- Half sine, 1500g/0,1 ms
- Glitch detector on every daisy chain
- >50.000 drops for EOL testing
- Monitoring boards and devices
- Applications:
  - impact sensors, microphones, loudspeakers
  - SMT interconnect on board, System in Package MEMS



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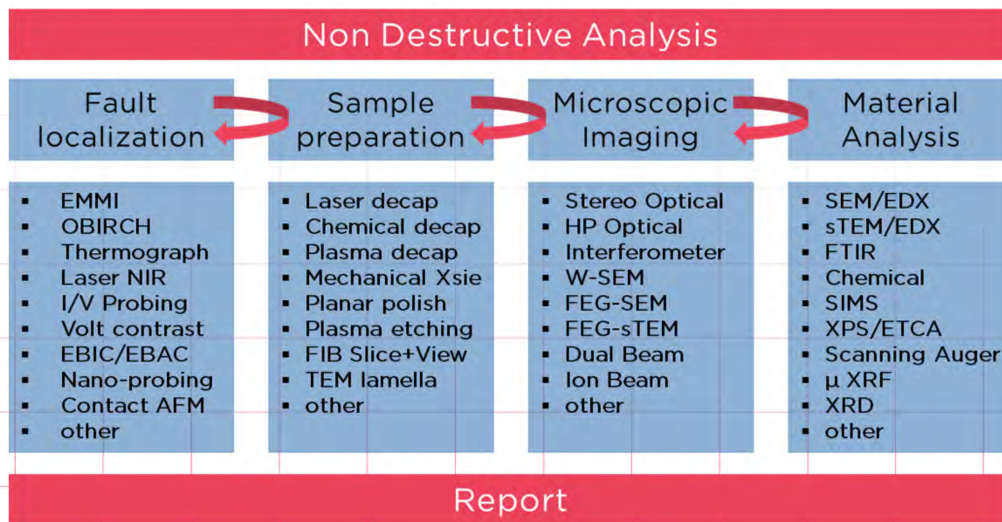
Failure Analysis on MEMS

- Based on Semi F/A tools and procedures
  - Non Destructive Analysis techniques
    - E-test – VIS – XRAY – SAM – EOTPR – LIT – SEM
  - Iterative procedure, fault driven



- MEMS challenges
  - Complex 3D packaging structure
  - Not all NDA techniques are suitable
  - Cavity devices
  - Wider range of packaging materials
  - Free moving/standing parts during demounting → lost parts
  - Lack of physical phenomena at fail locations or weak spots
  - New failure mechanisms

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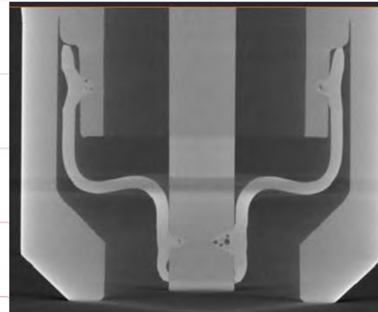
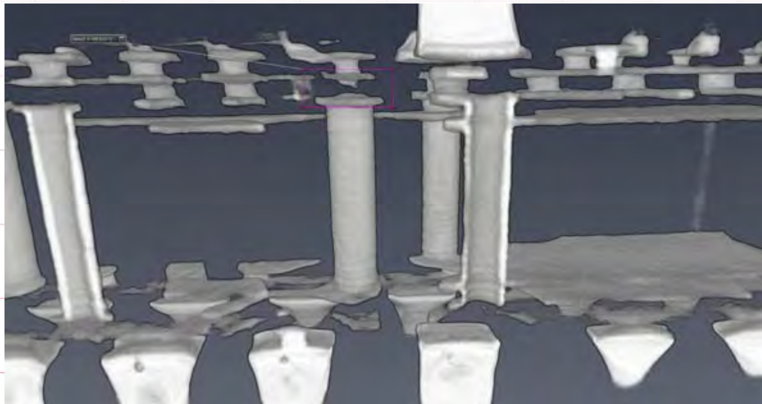
3D XRAY Inspection

- 3D XRAY microscopy
  - XRAY Computer Tomography is a 360° image recording and volume reconstruction
  - Advantage for MEMS is the improved internal construction versus the flat view in 2D-XRAY
  - Good progress with nano-focus tubes and high resolution digital detectors
  - Voxel resolution of real tomograph ~500nm and combined 2D/3D ~5µm
- 2D versus 3D visibility enhancement of metal cap pressure sensor
  - Focus on laser micro-welding which became invisible to inspect, even after cross sectioning



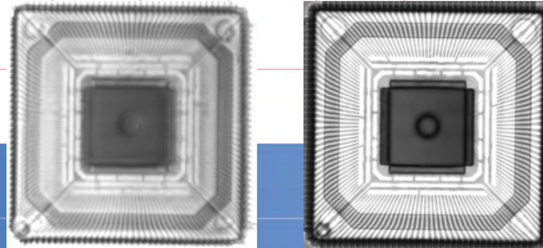
3D XRAY Inspection

- High resolution 3D XRAY tomography
  - Lambda sensor terminals
  - Dual metal wafer with TSV
    - TSV metallization
    - Stack bonding
    - Vertical allignment



Ultrasound Microscopy

- High Definition Ultrasound microscopy (Scanning Acoustic Microscopy)
- Combined improvement on all main modules of a SAM system
  - Acoustic lenses and objectives at ultra high frequencies 100MHz – 800MHz
  - High speed reflected pulse acquisition with 4GHz DAQ and new digital filter modules
  - Very stable dual gantry scanner with precision front- and back side Z-axis motor
  - 40MHz throughscan detector with separate Z-axis focus motor
  - HiSa curved sample tracking
- Limited destructive analysis
  - Determine that fault location is in the remaining part
  - Remove bulk Silicon from backside
  - Backside scan with deep submicron resolving power
  - US up to 1 GHz



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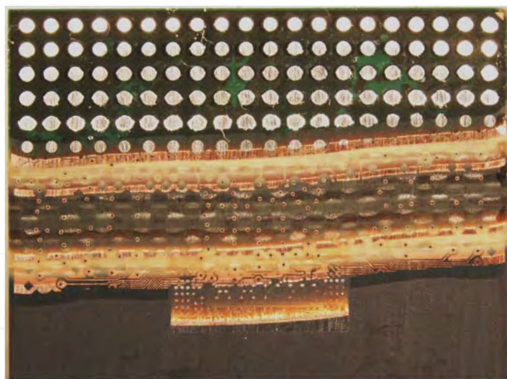
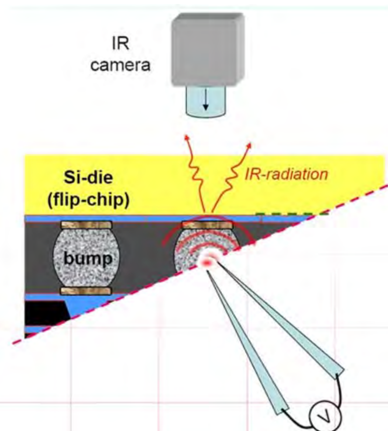
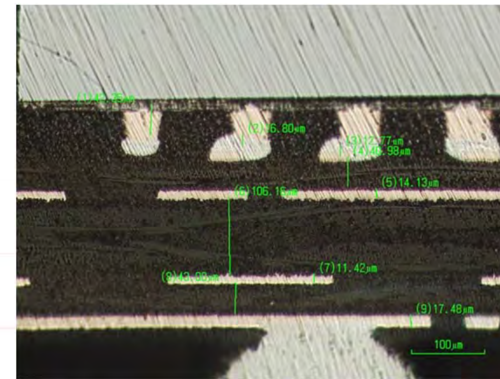
3D Lock-In Thermography

- Preparation of reference part in identical package as defect part



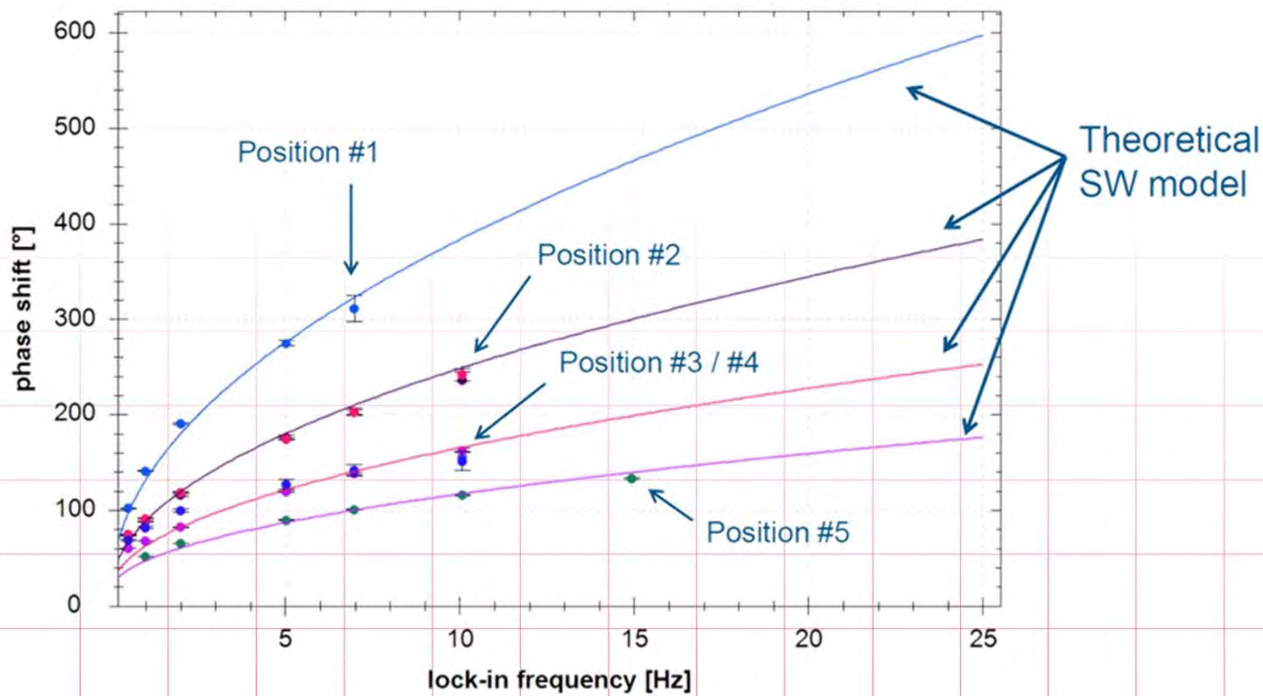


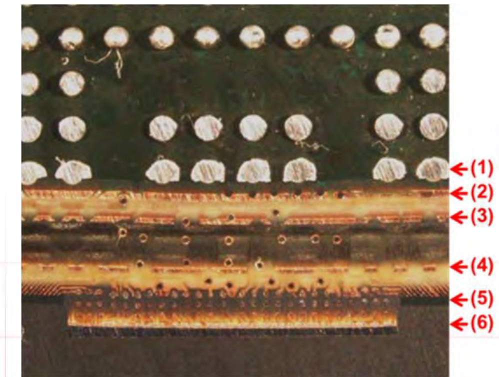


- ~5° angle polishing
- Hot spot introduction on multiple interfaces (=Z-axis)

3D Lock-In Thermography

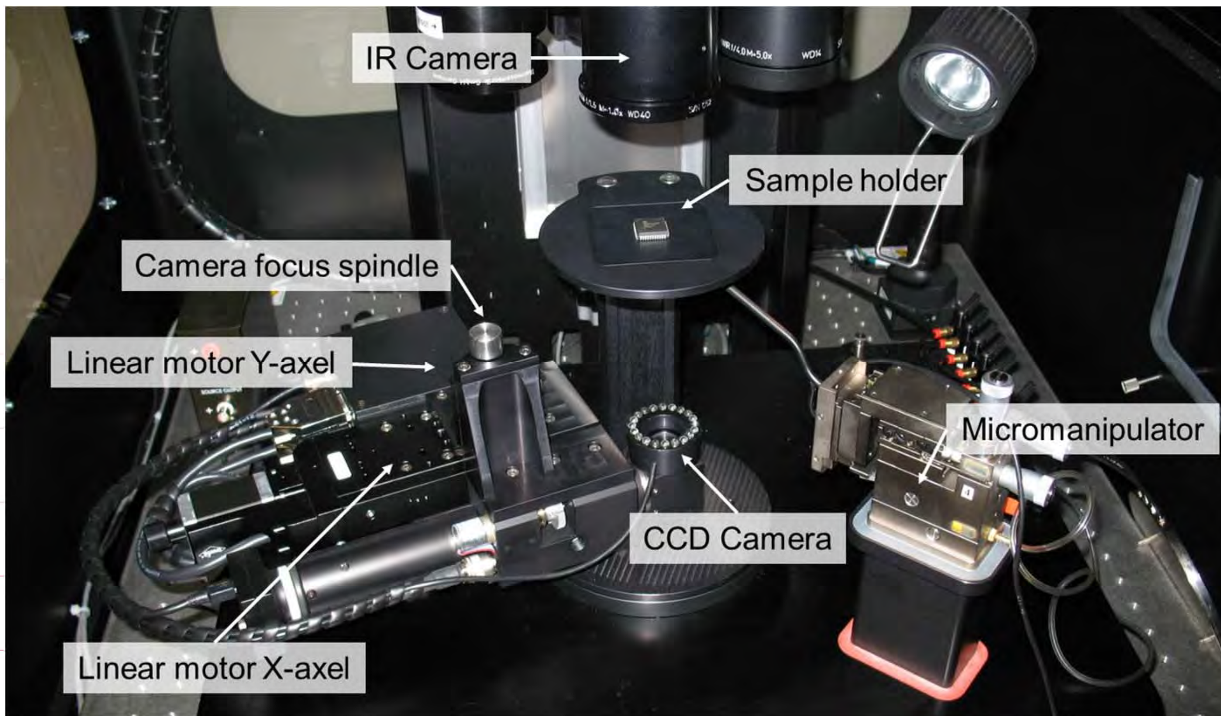
- Phase delay recording at various interfaces and lock-in frequencies

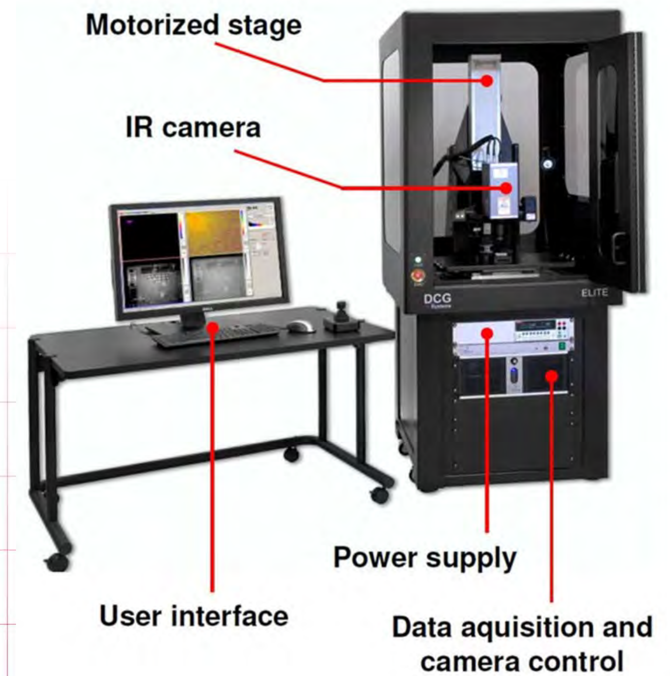




3D Lock-In Thermography

- 3D LIT analysis setup (extension by MASER Engineering)





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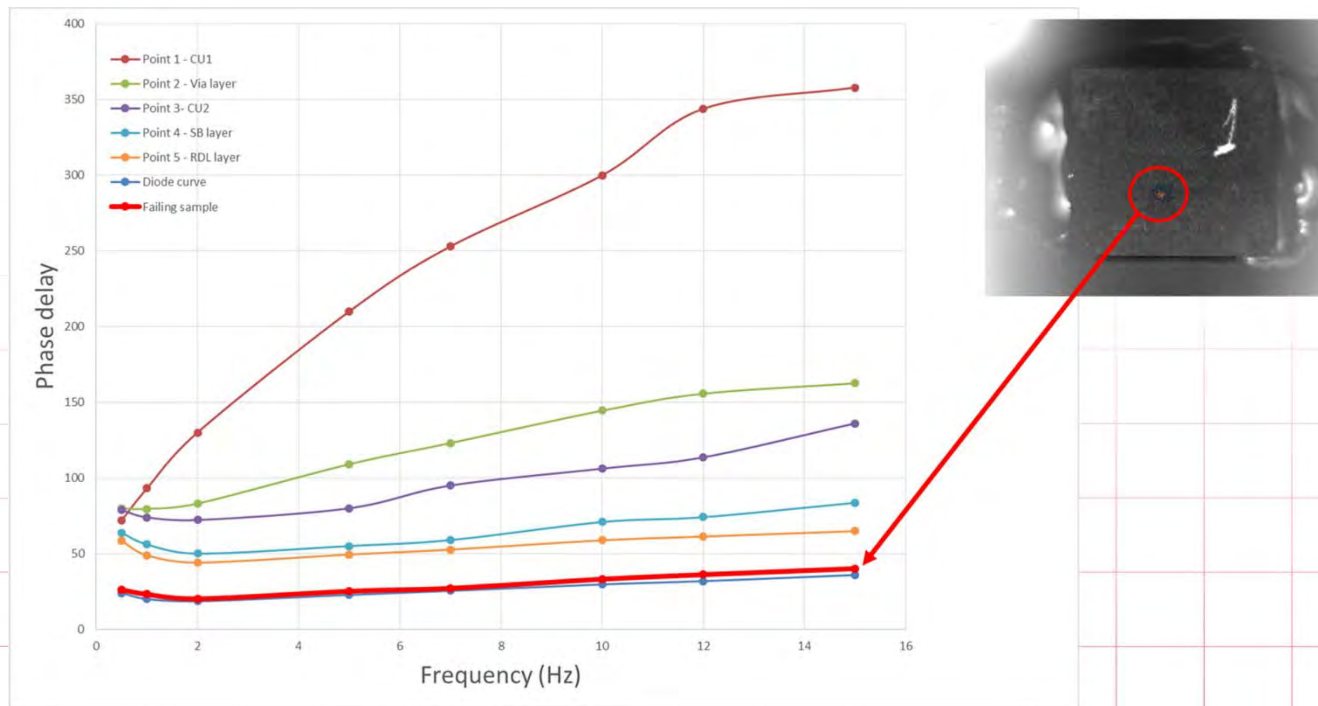
3D Lock-In Thermography

- 3D LIT defect part curve placement and 3D localization



Summary

- Application behaviour into model for E-test for read point testing
- MEMS behaviour correlation with E & M tests to E-test is essential
- MEMS device preparation is still challenging the development of new tools
- 3D IC packaging F/A tool developments are helpful for MEMS devices

Thank you for your attention!

Any questions?

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