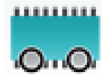
MASER ENGINEERING

Work supported by FP7-ICT-216436



ATHENIS Automotive tested high-voltage embedded non-volatile memory integrated SoC

Automotive Devices

Reliability test and Analysis facilities

Public Workshop at Fondazione Bruno Kessler
December 15th 2010 Povo-Trento

Patrick Grunder, Tijs Lammertink, Kees Revenberg
MASER Engineering, Enschede, The Netherlands

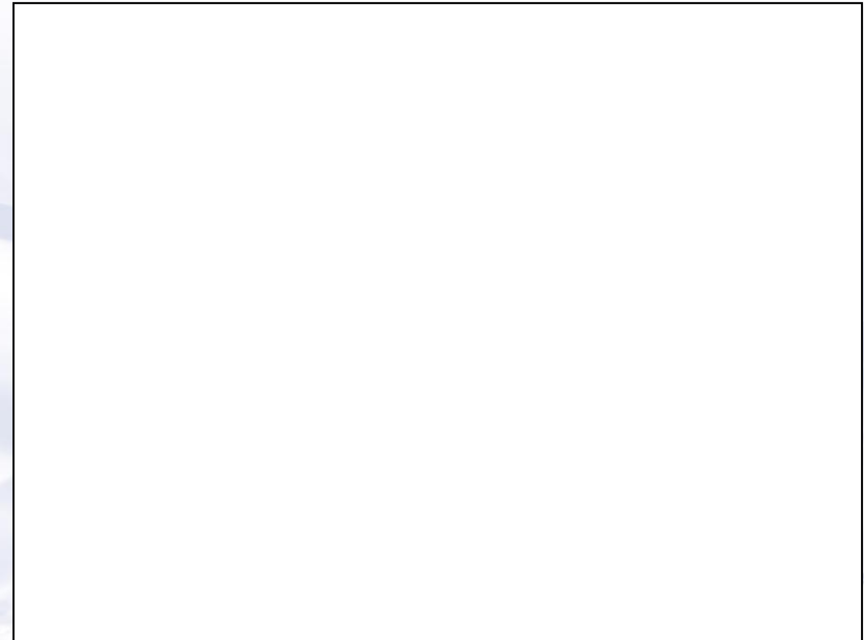
© **MASER Engineering B.V.** P.O. Box 1438 7500BK ENSCHEDE The Netherlands.
Phone +31 53 4 80 26 80 Fax +31 53 4 80 26 70 E-mail: info@maser.nl Internet: www.maser.nl

Contents

- **Introduction**
  - Automotive testing of electrical and electronic devices
- **Reliability testing**
  - Standards
  - Specific tests
  - Results and Trends
- **Failure analysis**
  - General (automotive device) flow
  - Sample preparation by SDB FIB/SEM
  - Results on Nanomech / MEMS devices
- **Summary**

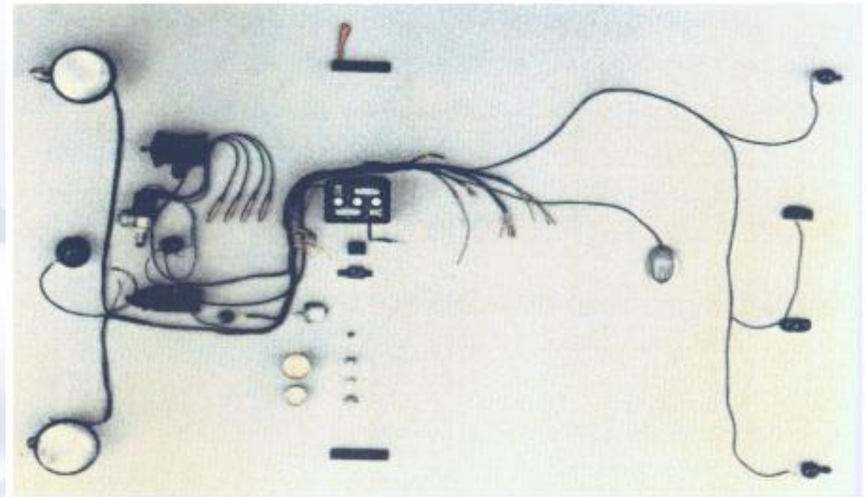
© MASER Engineering B.V.
P.O. Box 1438 7500BK ENSCHEDE The Netherlands.
Phone +31 53 4 80 26 80 Fax +31 53 4 80 26 70 E-mail: info@maser.nl Internet: www.maser.nl

Electronics in cars



- **Daimler Motor coach, year of construction: 1886**
- **No electronic components**

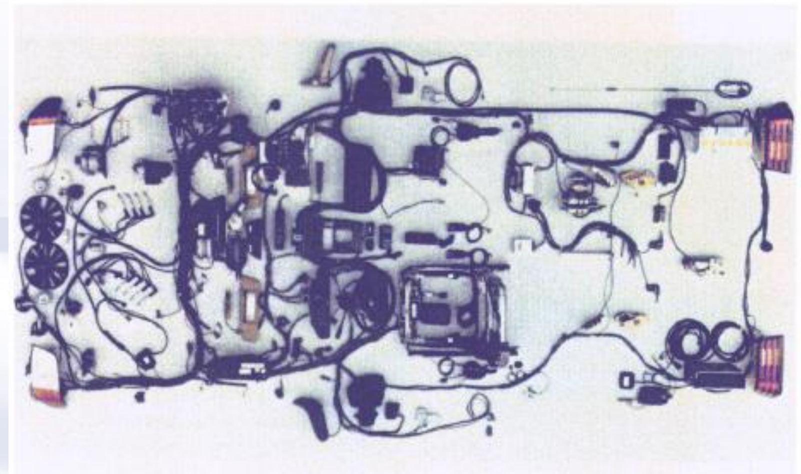
Electronics in cars



- **Mercedes-Benz SL300, year of construction: 1957**
- **Limited amount of electric components**

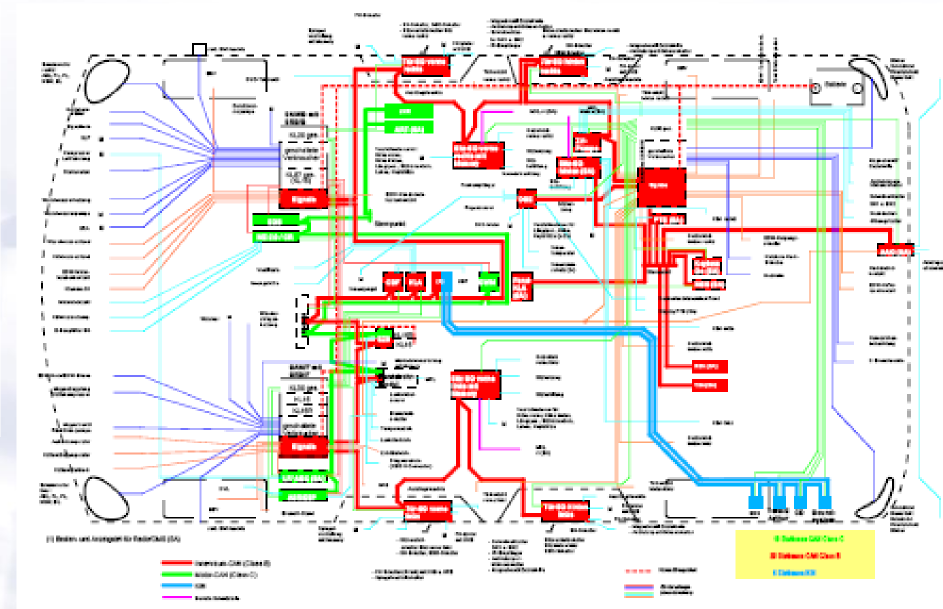
© MASER Engineering B.V.
P.O. Box 1438 7500BK ENSCHEDE The Netherlands.
Phone +31 53 4 80 26 80 Fax +31 53 4 80 26 70 E-mail: info@maser.nl Internet: www.maser.nl

Electronics in cars



- **Mercedes SL, year of construction: 1970**
- **Larger amount of electric and electronic components**

Electronics in cars



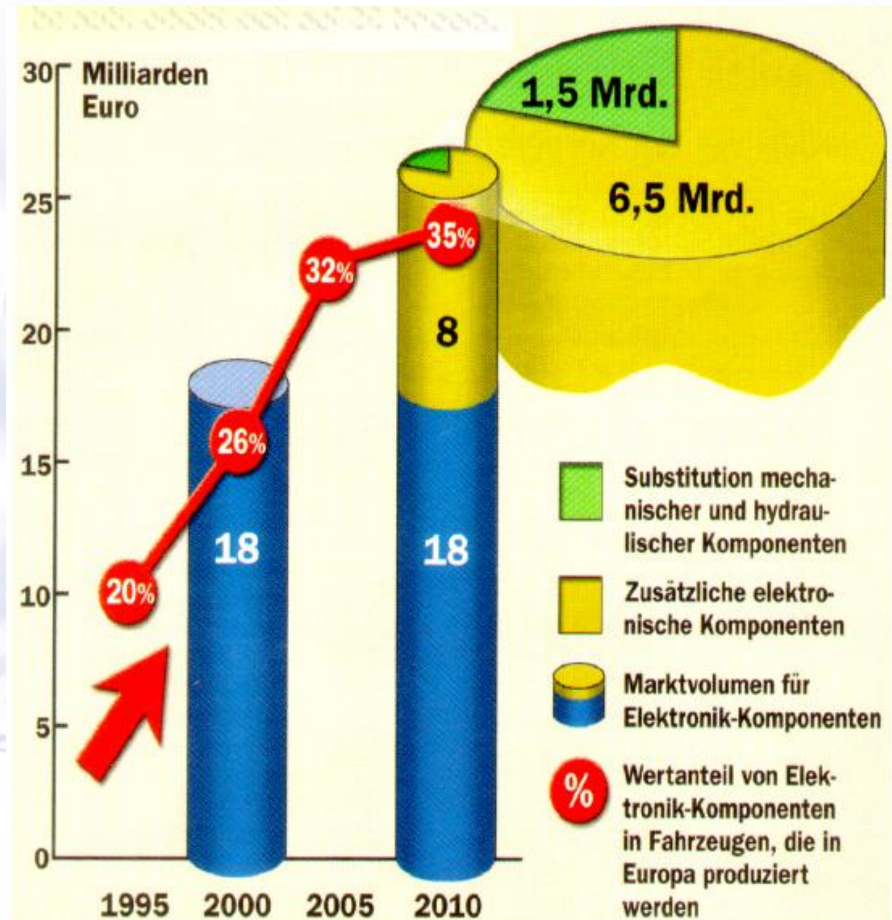
- Mercedes-Benz S-klasse, year of construction: 2000
- Extensive electrical and electronic circuits and modules

© MASER Engineering B.V. P.O. Box 1438 7500BK ENSCHEDE The Netherlands.
Phone +31 53 4 80 26 80 Fax +31 53 4 80 26 70 E-mail: info@maser.nl Internet: www.maser.nl

Electronics in cars

Car innovations

- BMW: 90% by electronics
  - More components
  - Increasing reliability
  - Reduced costs per module
- Safety systems
  - Airbag
- Improved mechanics
  - ABS / ESP / ASR
- Replaced mechanics
  - Motormanagement
  - Handbrake



Reliability Testing of IC's

- **J1879**
  - Handbook for Robustness Validation of Semiconductor Devices in Automotive Applications
  - Joint SAE-ZVEI-JSAE-AEC plan
- **AEC-Q100**
  - Automotive Industry driven
  - 1995 version A issued
  - 2010 version G1 active
  - Free on www.aeccouncil.com
- **JEDEC**
  - General procedures
  - Guidelines and Test standards
  - Free on www.jedec.org

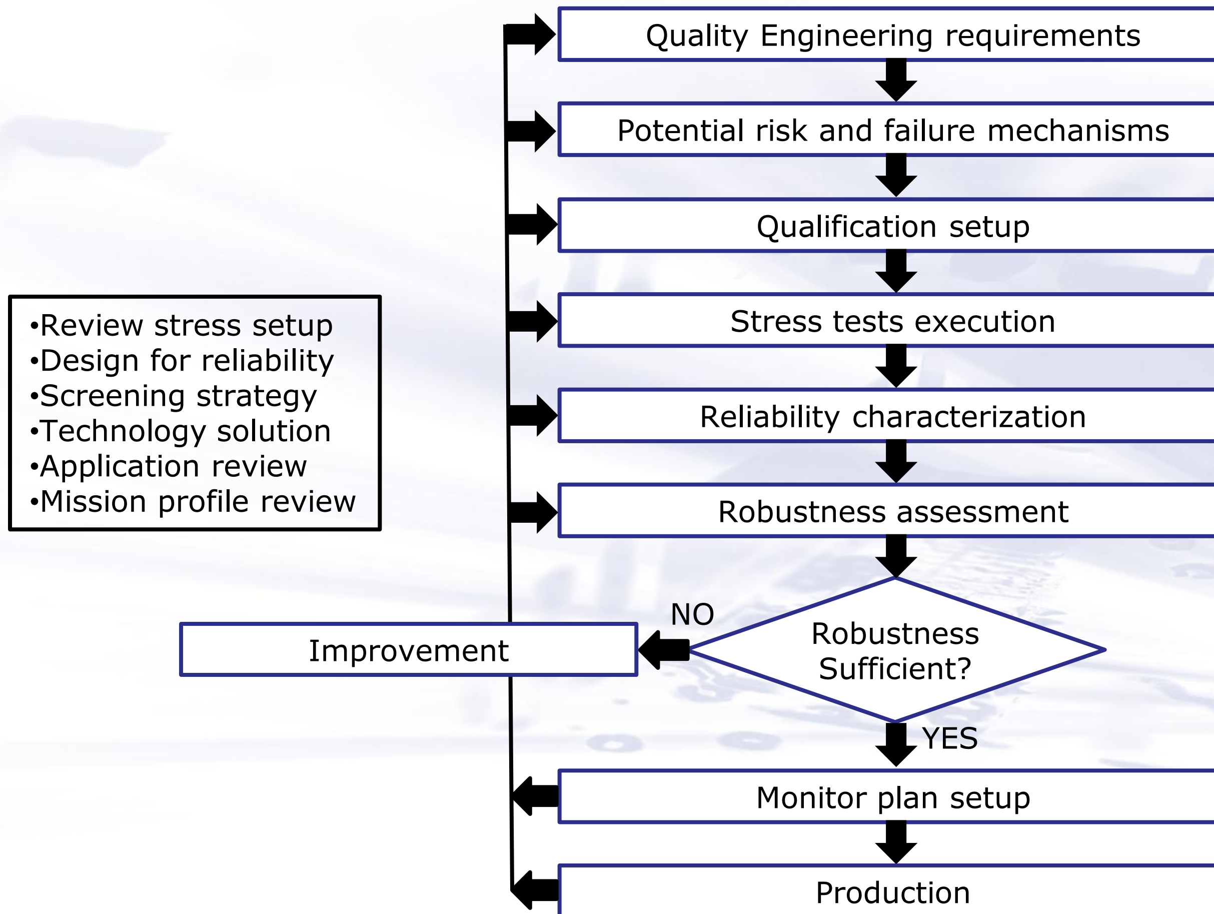
AEC-Q100 founders, left to right:
Earl Fisher (FORD) – Gerald Servais (Delco/GM)
Jerry Jennings (Chrysler) – Robert Knoell (FORD)

J1879 Robustness Validation

- **Key components**
  - Knowledge of application / user environment → mission profile
  - Knowledge of failure mechanisms and modes → knowledge database
  - Acceleration models → definition and assessing accelerated tests
  - Testing until failure or end of life determination
- **Inputs**
  - Knowledge matrix of failure mechanisms
  - Mission profile defines test boundaries
  - Robustness Assessment of failure mechanisms
- **Goal**
  - Improvement of robustness
  - From prediction to Risk reduction
  - Smarter, more efficient, effective and reliable test procedures

© MASER Engineering B.V. P.O. Box 1438 7500BK ENSCHEDE The Netherlands.
Phone +31 53 4 80 26 80 Fax +31 53 4 80 26 70 E-mail: info@maser.nl Internet: www.maser.nl

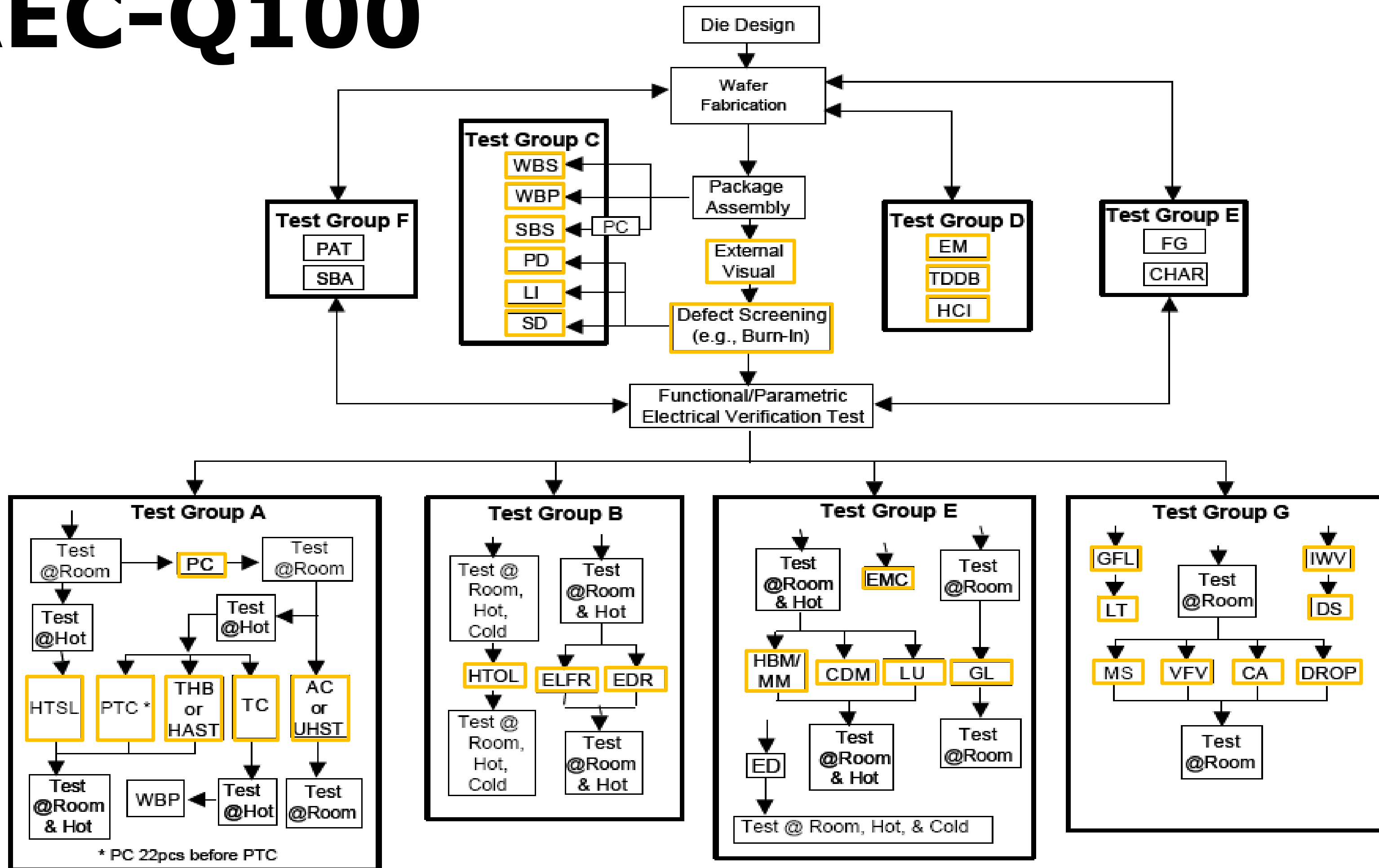
SAE-J1879 Qualification Flow



AEC-Q100

- **Scope**
  - Failure mechanism based stress test qualification for IC’s
- **Goal**
  - Precipitate failures in an accelerated manner
  - Scan for any potential new and unique failure mechanisms
  - Scan for introduction of failures that do not correlate with normal use
  - Scan for any extreme user condition that impacts acceleration factors
- **Definition of Grades**
  - Grade 0: -40°C to +150°C
  - Grade 1: -40°C to +125°C
  - Grade 2: -40°C to +105°C
  - Grade 3: -40°C to +85°C
  - Grade 4: 0°C to +70°C

AEC-Q100



Automotive (MEMS) Reliability

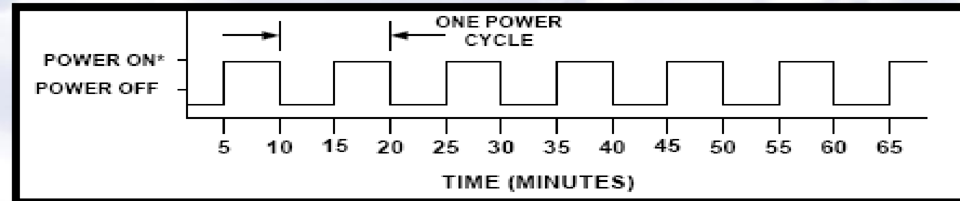
- **AEC-Q100 based tests on nanomech devices**
  - Test standard references acc. JESD22 or MIL-STD883
  - Electrical readpoint on Riffle system in cooperation with UniFe partner

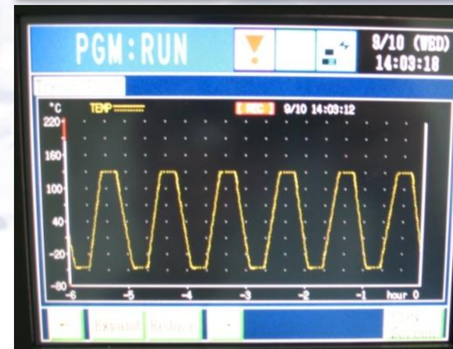
TEST	JEDEC	TYPE	CONDITION	RESULT
HTOL		High temp. operating life	10K cycles @ 150°C	More stable
HTSL	JESD22-A103-C	High temp. storage life	6 weeks @ 200°C	Minor drift
LIQ-LIQ	JESD22-A106	Fast temperature changes	100 cy -55°C to +150°C	Minor drift
TC	JESD22-A104	Thermal cycling	500 cy -65°C to +150°C, 2	Minor drift
HAST	JESD22-A118-C	Humidity test	130°C 85% humidity, 2 atm for 96 hours	Minor drift
CA	MIL-STD883	Constant acceleration	20,000g / 1min / Y1 axis	No drift
MS	JESD22-B104	Mechanical shock	10 half sine shocks 1500g @ 0.5ms	No drift
VFV	JESD22-B103	Variable frequency vibration	10 sweeps of 20-20,000Hz @ 50g	No drift

© MASER Engineering B.V. P.O. Box 1438 7500BK ENSCHEDE The Netherlands.
Phone +31 53 4 80 26 80 Fax +31 53 4 80 26 70 E-mail: info@maser.nl Internet: www.maser.nl

Automotive (MEMS) Reliability

- **Power Temperature Cycling**
  - JEDEC JESD22-A105C
  - 1000 cycles -40°C to +85°C, 6.25K/min, operational, power on/off
  - 1000 cycles -40°C to +125°C, 5.5K/min, operational, power on/off
  - Single chamber, fast cycling system, easy cabling feedthrough

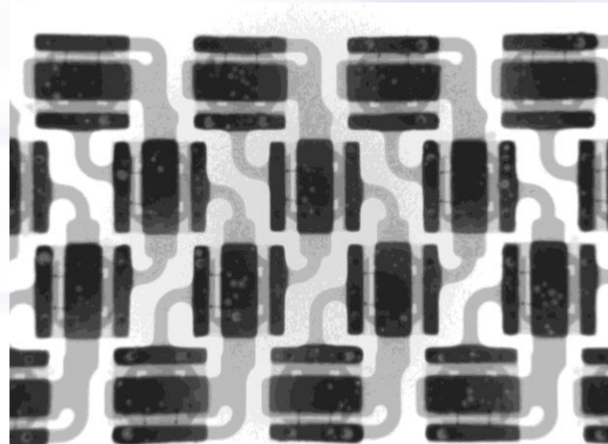


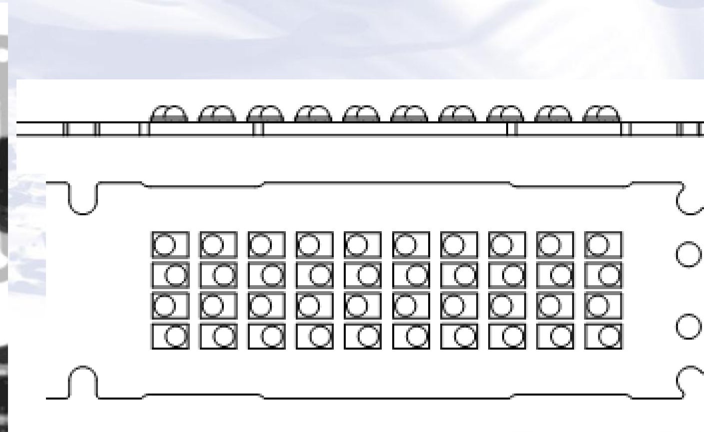


© MASER Engineering B.V.

Automotive (MEMS) Reliability

- **Liquid to Liquid shock**
  - Inert liquid in hot/cold bath
  - Very fast heat/cold transfer (>100K/min.)
- **Automotive applications**
  - Stacked wafers for MEMS structures → adhesion
  - Additional Back End Of Line process metal adhesion → nanomech
  - Solder attachment quality of power LED mounting → car lighting





© MASER Engineering B.V. P.O. Box 1438 7500BK ENSCHEDE The Netherlands.
Phone +31 53 4 80 26 80 Fax +31 53 4 80 26 70 E-mail: info@maser.nl Internet: www.maser.nl

Failure Analysis flow

1. **Device reconditioning**
   - Package or Die extraction – Reballing – Lead straightening
2. **E-test**
   - ATE datalog fault confirmation – Schmoo plots – DFT vector analysis
3. **Non destructive inspection**
   - X-ray microscopy – Scanning Acoustic Microscopy
4. **Sample preparation**
   - Decapsulation – X sectioning – Planar mechanical polishing – Plasma
5. **Fault localisation**
   - VIS+NIR Photon Emission – MWIR emission – LASER stimulated
6. **Optical and Electron Microscopy**
   - LP/HP optical – SEM/EDX – FIB/SEM – sTEM/EDX
7. **Advanced Physical and Material Analysis**
   - External visual – Reballing – Lead straightening

Step 4 – 7 can have multiple iterations

Automotive F/A flow

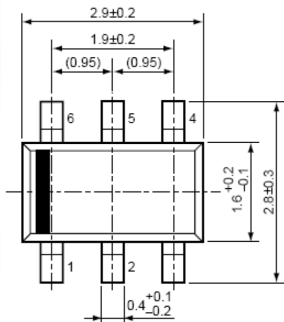
1. **First report**
   - Fault confirmation in 4 days after receipt of part
2. **Containment report**
   - Intermediate report in 7 days
3. **Final report**
   - Final 8D report including preventive actions in 21 days

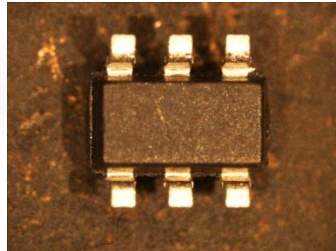
Industrial the same exept delays in working days (5/week)

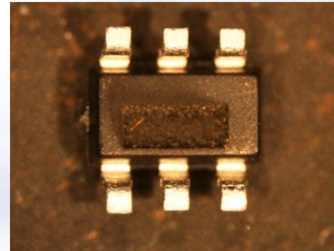
Both have difficulties to meet for complex timing faults or new failure modes
No compensation for device complexity, ie. Resistor vs. 65nm ASIC

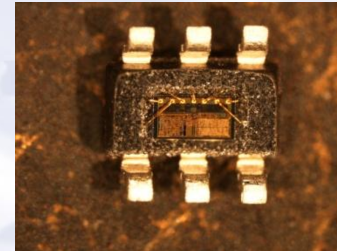
Automotive (MEMS) Analysis

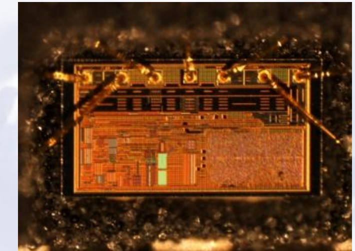
- **Sample preparation**
  - LASER ablation assisted decapsulation (example 2.9x1.6mm body)



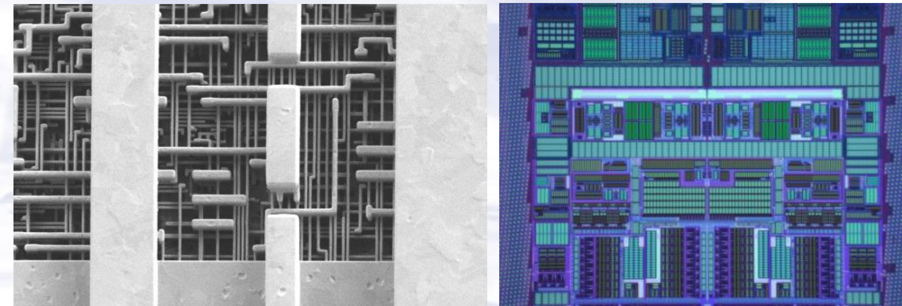








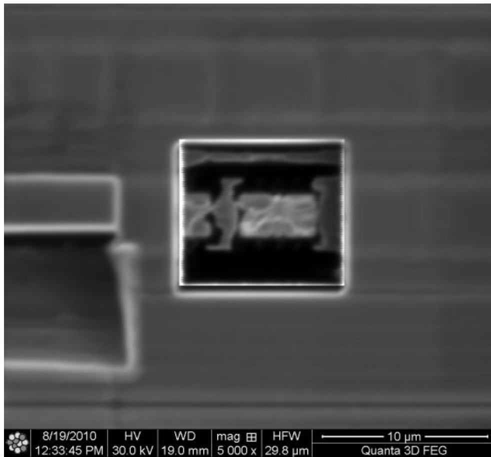
  - Mechanical polishing
  - Reactive Ion Etching
  - Small Dual Beam FIB/SEM
  - sTEM sample preparation



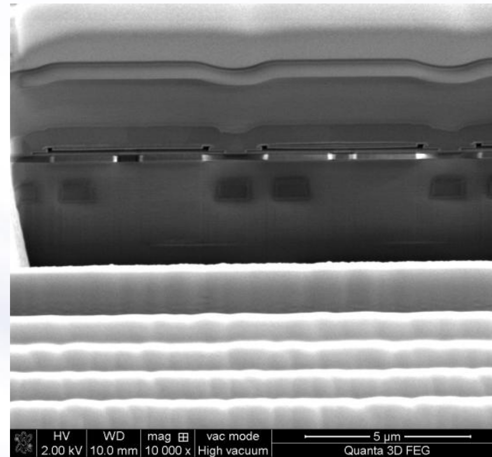
© MASER Engineering B.V. P.O. Box 1438 7500BK ENSCHEDE The Netherlands.
Phone +31 53 4 80 26 80 Fax +31 53 4 80 26 70 E-mail: info@maser.nl Internet: www.maser.nl

Work supported by FP7-ICT-216436

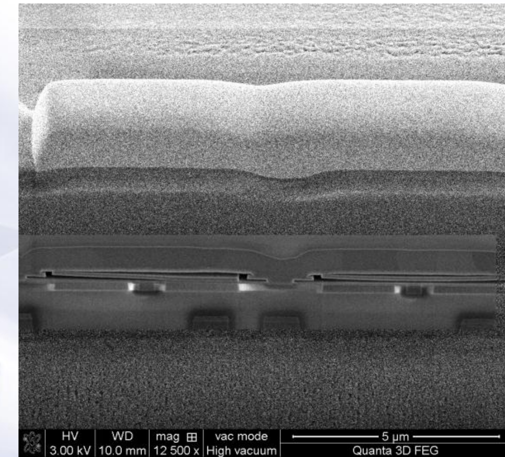
Automotive (MEMS) Analysis



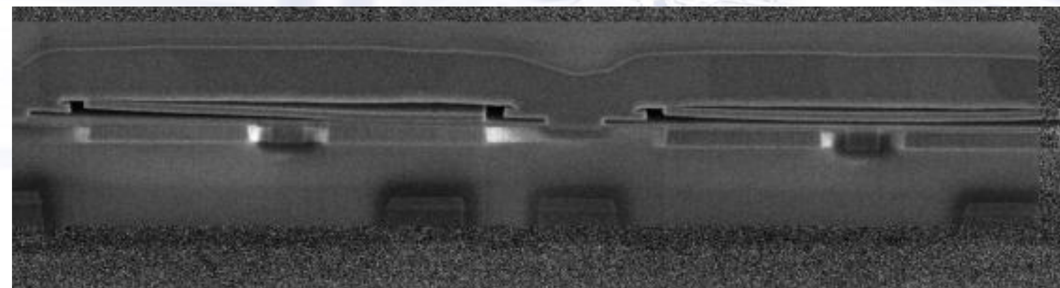
SDB cell opening



SDB Xsie



Cantilever distortion



MEMS move due to electrostatic charge induced by SEM

© MASER Engineering B.V. P.O. Box 1438 7500BK ENSCHEDE The Netherlands.
Phone +31 53 4 80 26 80 Fax +31 53 4 80 26 70 E-mail: info@maser.nl Internet: www.maser.nl

Summary

- **Athenis project achievements**
  - **Reliability Test**
    - New constructions generate new accelerated reliability test
    - Semiconductors step into high temperature applications
  - **Robustness**
    - Trend of component to module shift focus to robustness
    - Reliability is good, Robustness is better
  - **Failure Analysis**
    - SDB essential for detailed cavity opening
    - Planar polishing combined with selective chemical etching
    - SEM charging impact on MEMS devices not solved
    - Less impact imaging techniques to be studied: He-ion/SPM

© MASER Engineering B.V. P.O. Box 1438 7500BK ENSCHEDE The Netherlands.
Phone +31 53 4 80 26 80 Fax +31 53 4 80 26 70 E-mail: info@maser.nl Internet: www.maser.nl

Thank you for your attention

and

cooperation in the Athenis project

© MASER Engineering B.V.
P.O. Box 1438 7500BK ENSCHEDE The Netherlands.
Phone +31 53 4 80 26 80 Fax +31 53 4 80 26 70 E-mail: info@maser.nl Internet: www.maser.nl