esa
5th electronic materials, processes and packaging for space workshop (EMPPS)
20 - 22 may 2014, esa-estec, the netherlands
European Space Agency

REDUCED 2ND LEVEL SOLDER JOINT LIFE TIME OF LOW-CTE MOLD COMPOUND PACKAGES

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imec

EDM
Electronics Design & Manufacturing

Outline

- Introduction of Low-CTE Mould compound for packages
- Experimental setup
- Experimental results:
  - PBGA228
  - QFN64
- Correlation with FEM simulations
- FEM based parameter study
- Impact of board stiffness and board fixation
- Other concerns related to low-CTE mould compound packages
- Conclusions

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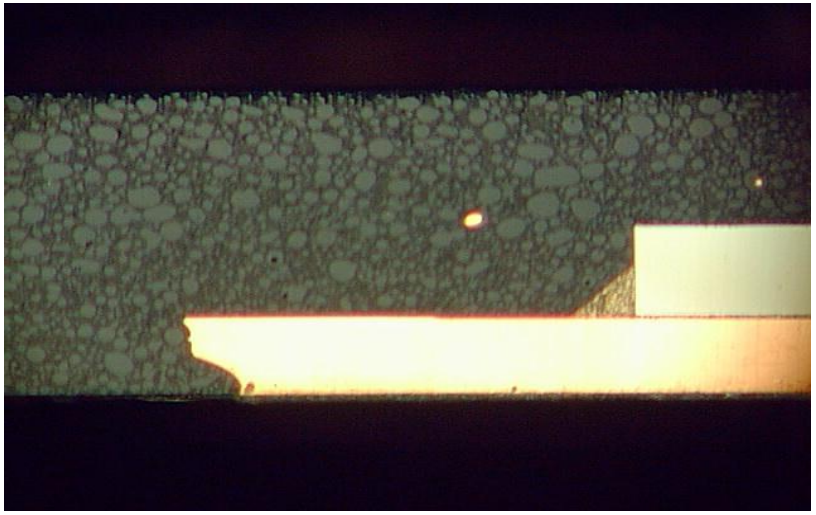
Introduction of low-CTE (green) mould compounds

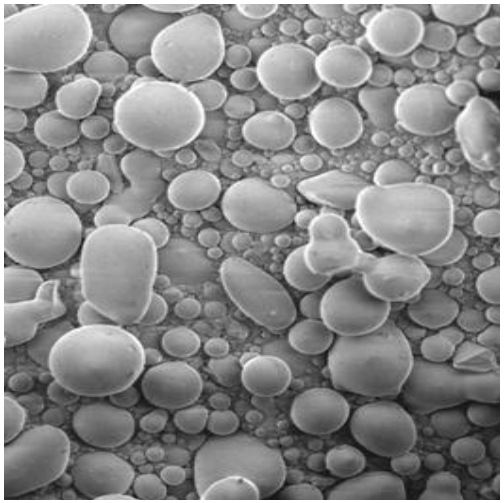
Driven by:

- "Going Green" trend: Halogen-free plastics
- Need for reduced moisture sensitivity (lead-free)
- Cost

High filling (>85%) of silica particles, resulting in

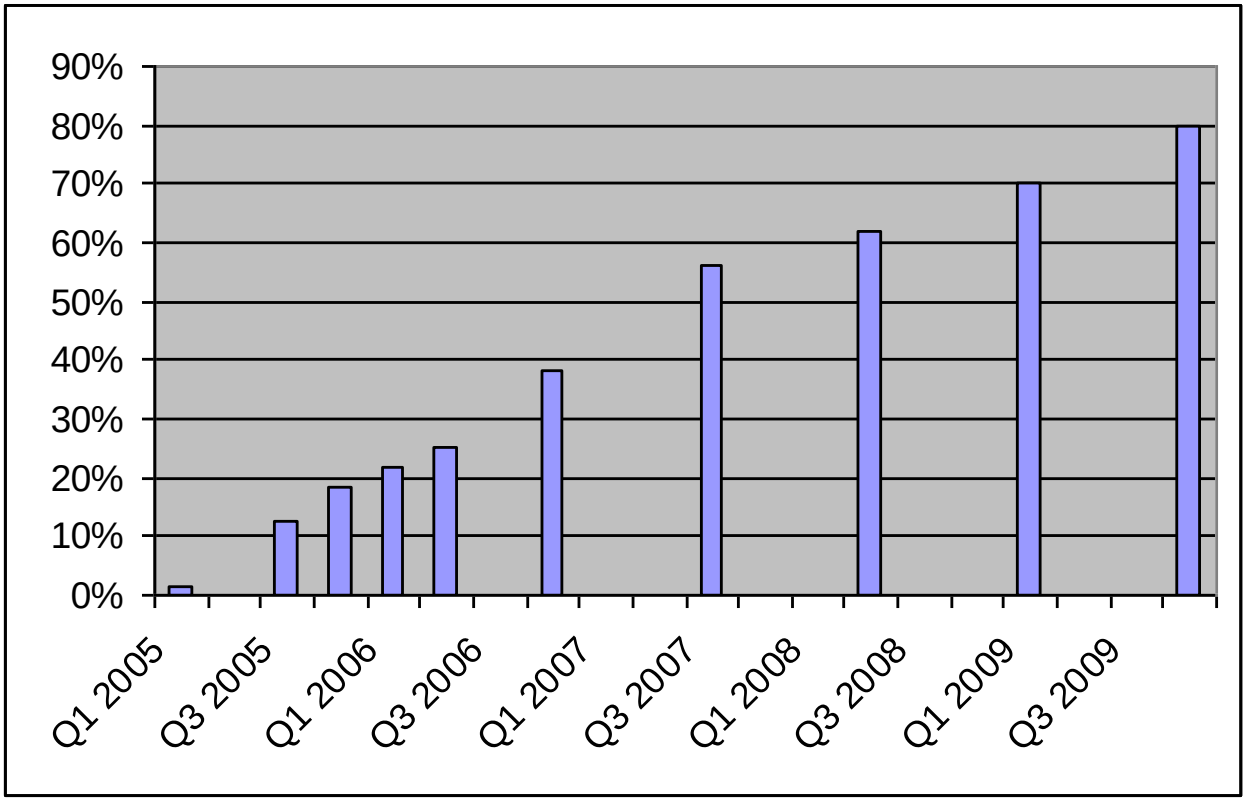
- high stiffness (25 GPa – 30 GPa)
- low CTE (7 – 9 ppm/°C).





The change-over took place between 2005-2010

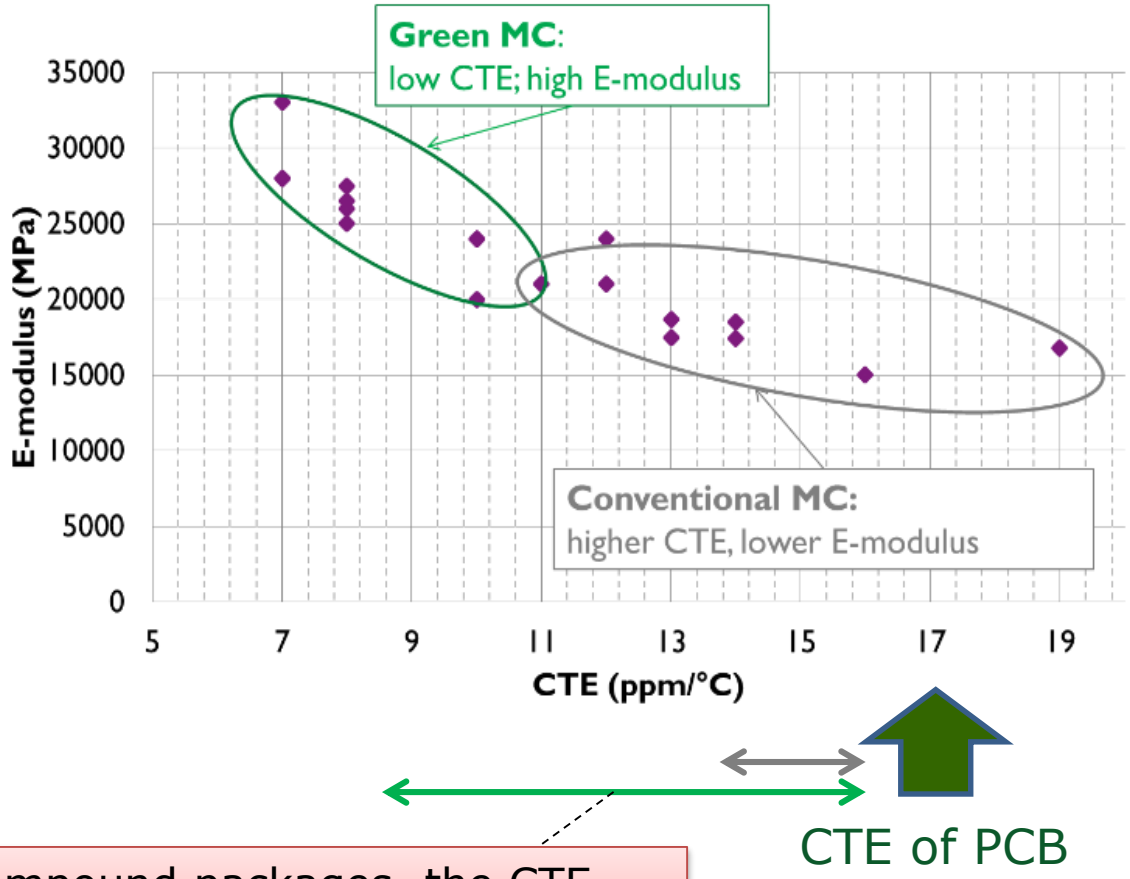
Use of Green Mould Compounds for plastic packages



(data from a leading semiconductor supplier)

Typical properties for green mold compounds

Low-CTE mold compounds are stiffer



With low-CTE mold compound packages, the CTE mismatch with the PCB increases by several factors

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Selected packages for TC study: **PBGA 228 I/O's – 0.5 mm pitch**

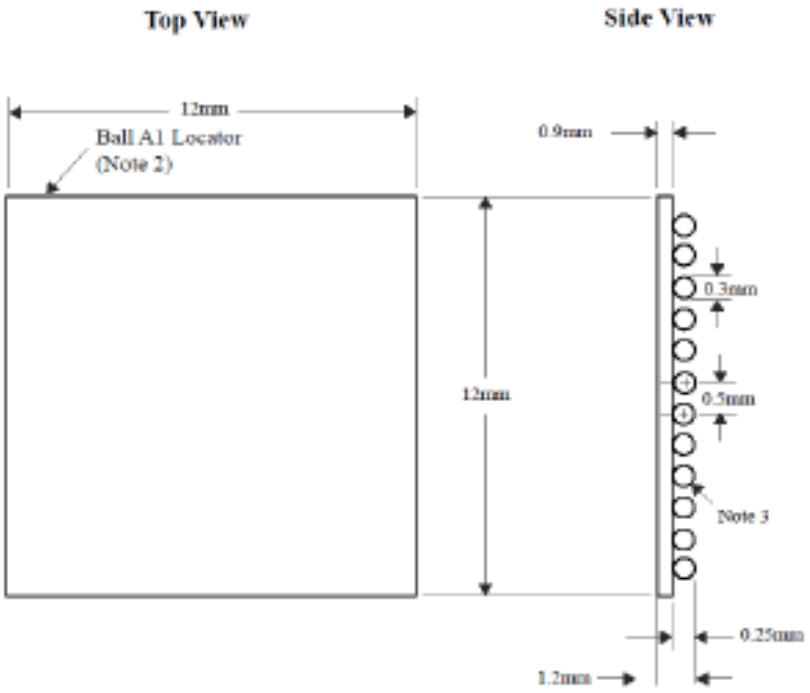


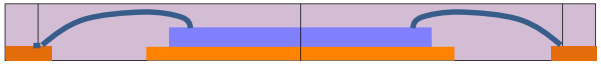
Figure 2 : BGA228 daisy chain component.

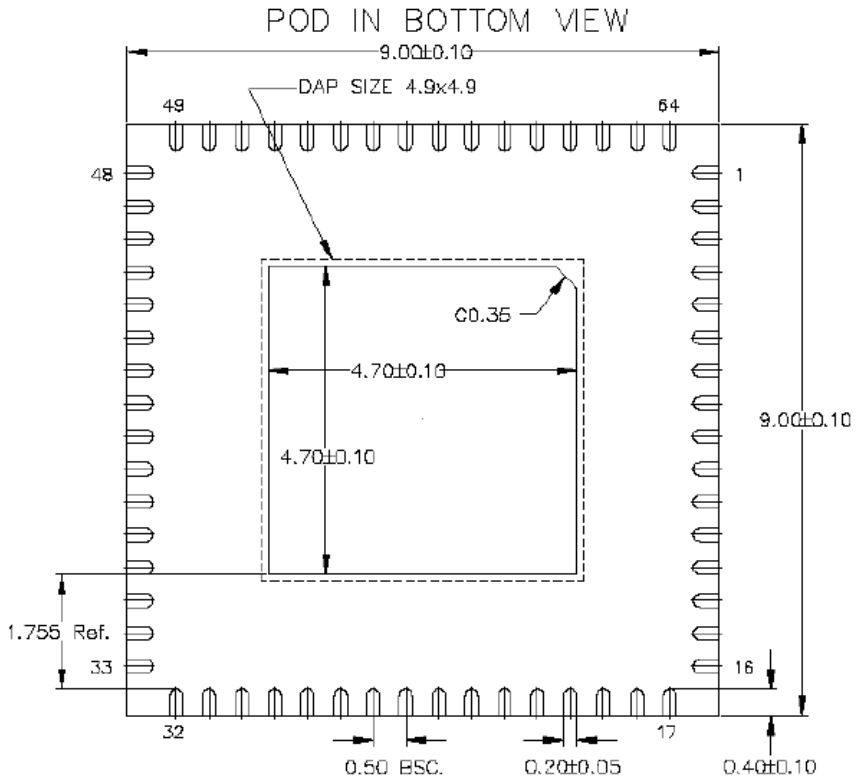
Variations

Mould compounds:
- GMC: 8.5 ppm/°C
- Conv MC: 11 ppm/°C

Solder ball	+	paste
• SnPb		SnPb
• SAC305		SAC305
• SAC105		SAC305

Selected packages for TC study: **QFN 64 I/O's – 0.5 mm pitch**





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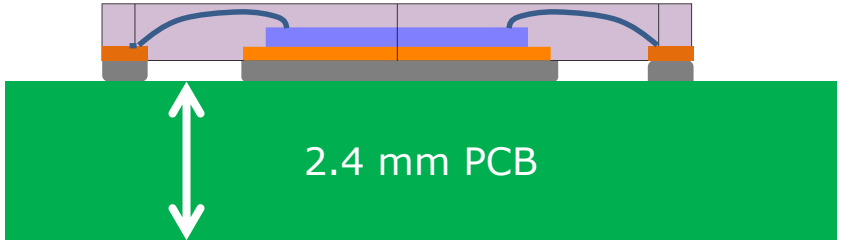
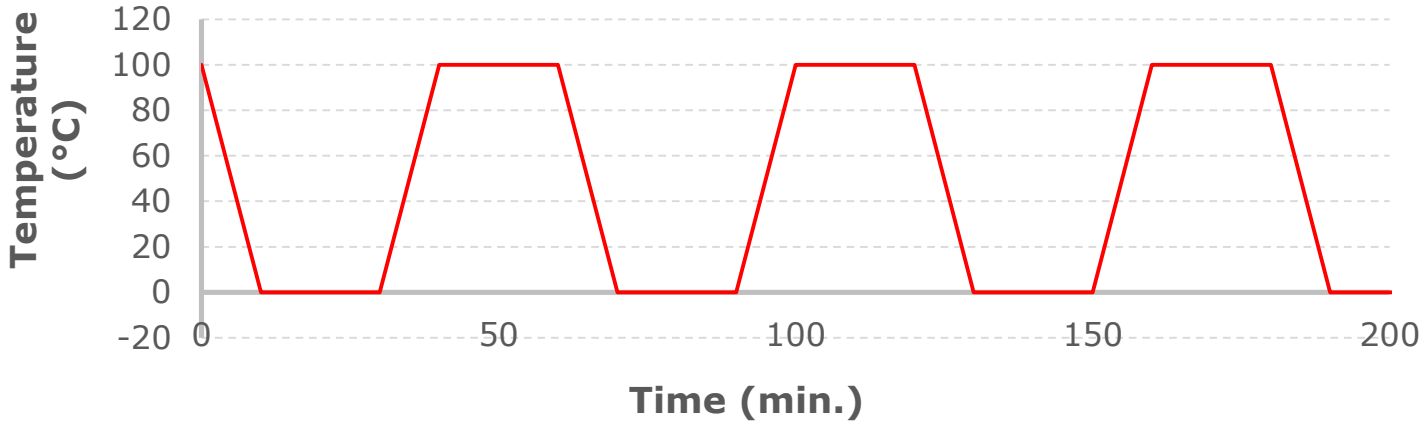
- Conv MC: 11 ppm/°C

Solder ball	+	paste
• SnPb		SnPb
• SAC305		SAC305
• SAC105		SAC305

Test conditions

- The **IPC-9701 TC1** accelerated test condition for solder joint evaluation was selected as the most appropriate test.
  - 0 to 100°C thermal cycling (air-to-air)
  - Total cycling time = 1 hour
    - ramp up time = 10 minutes
    - dwell-time = 20 minutes
  - In-situ measurement for opens





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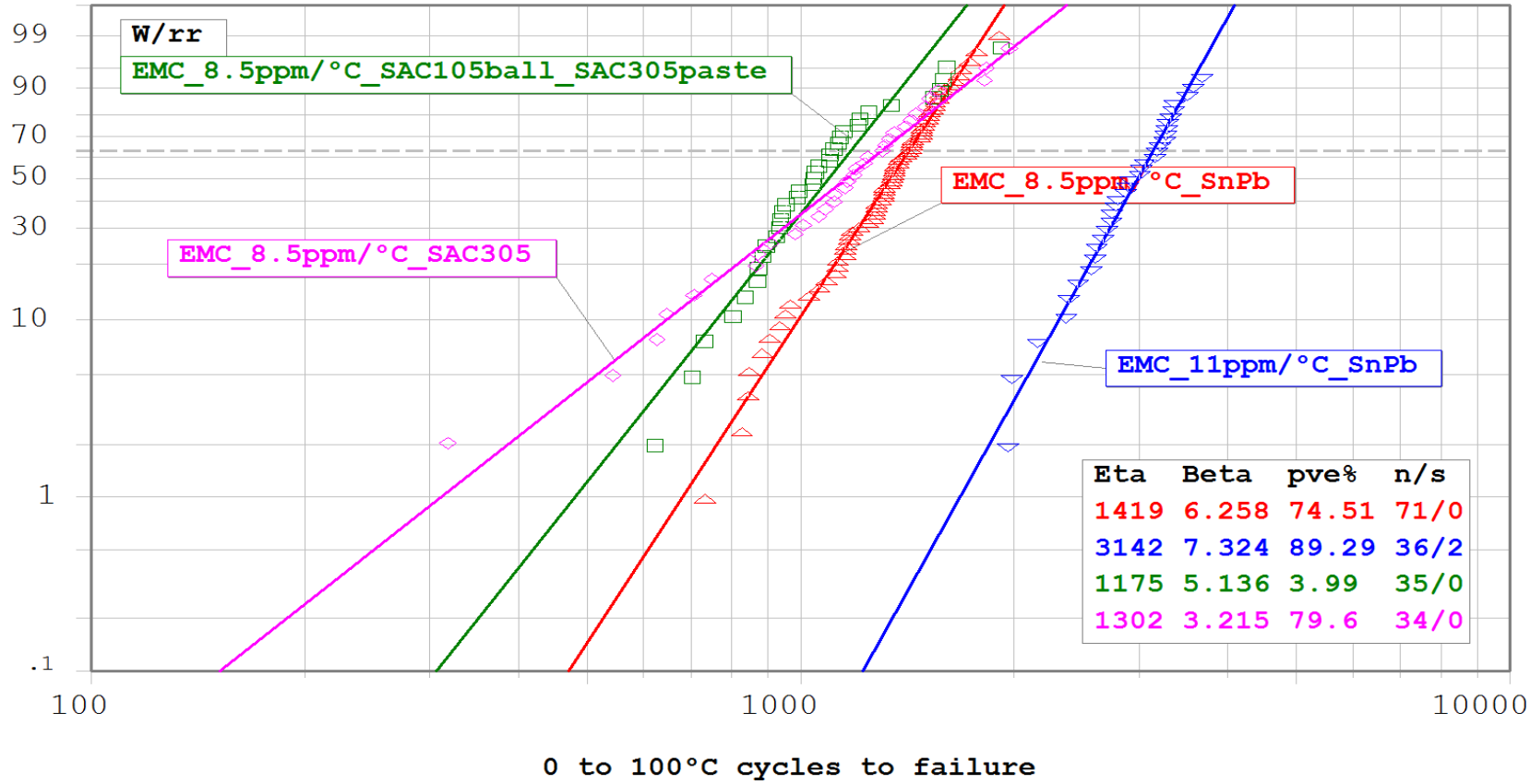
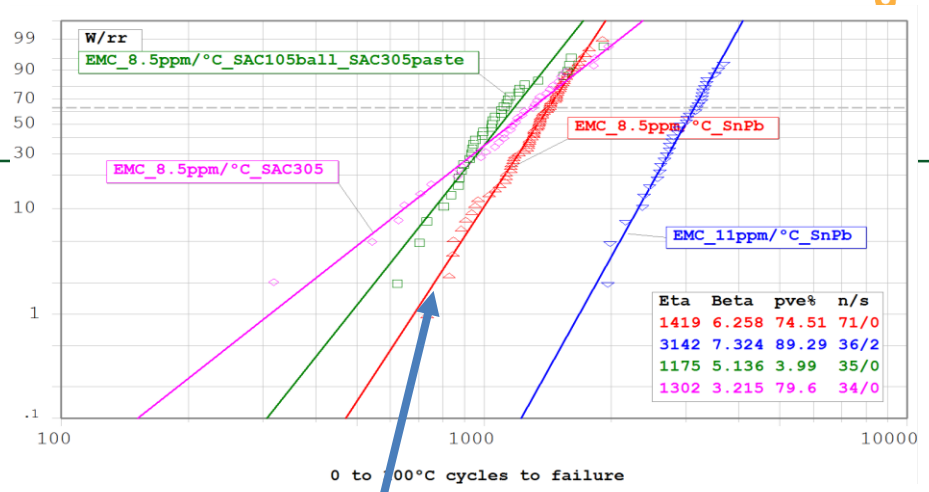
Result 1: BGA225 12x12 mm (0.5 mm pitch)

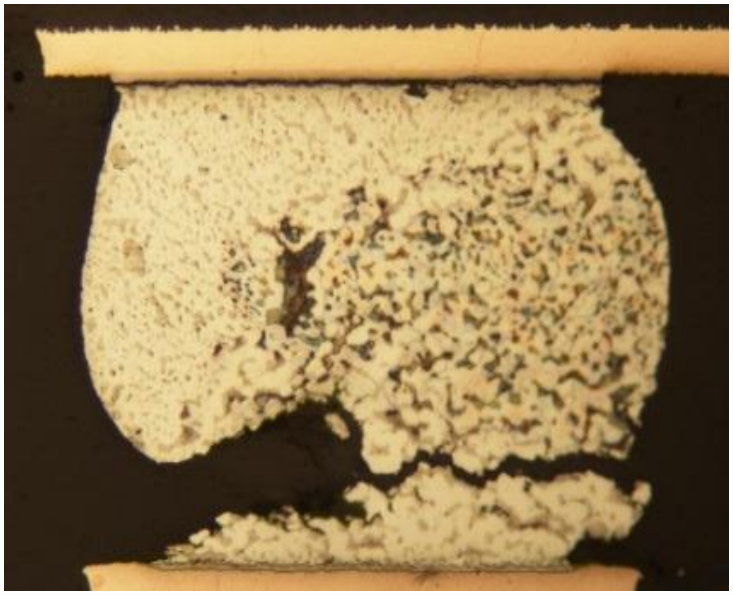
2.4 mm PCB

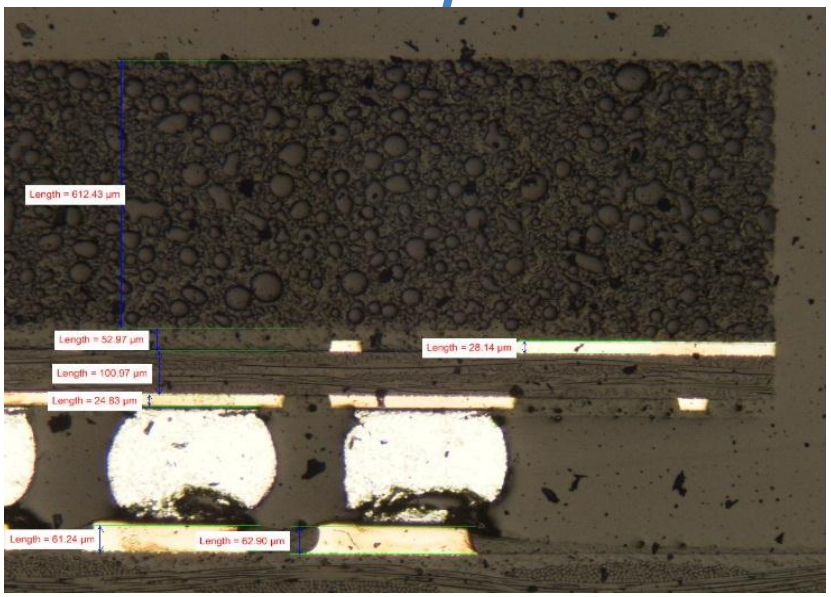


Impact of mold CTE: Life time (11ppm BGA) ~ **2.2** * Life time (8.5ppm BGA)
Impact of mold CTE is far greater than the chosen solder composition

Failure analysis

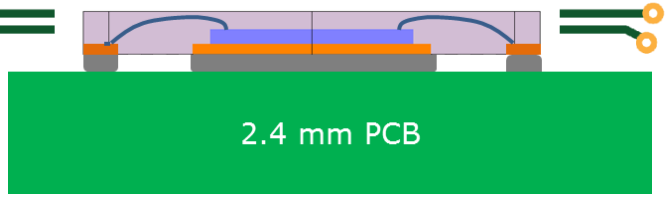


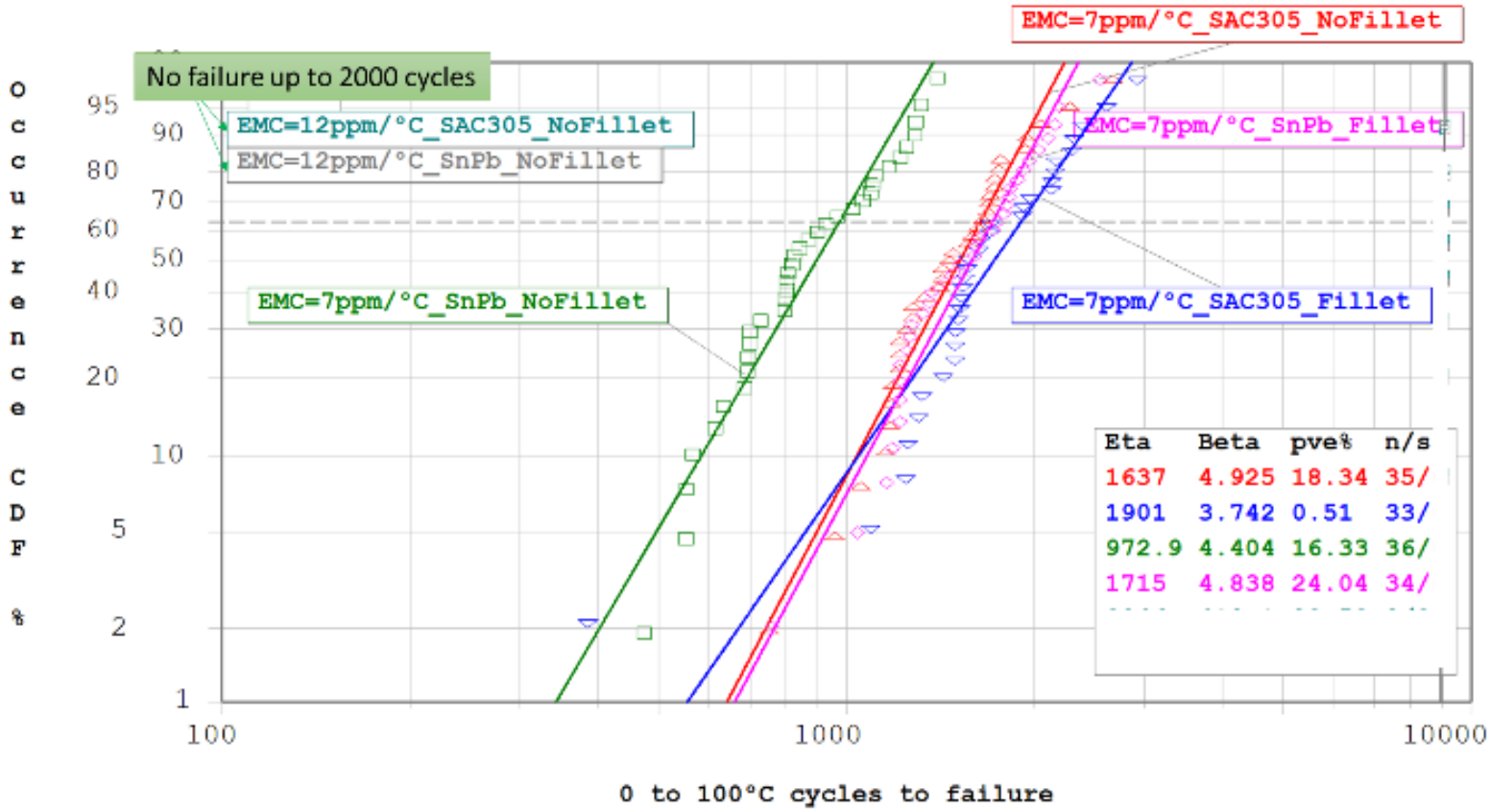




Heavily damaged solder joint especially at the corner/edge area indicative for a large mismatch

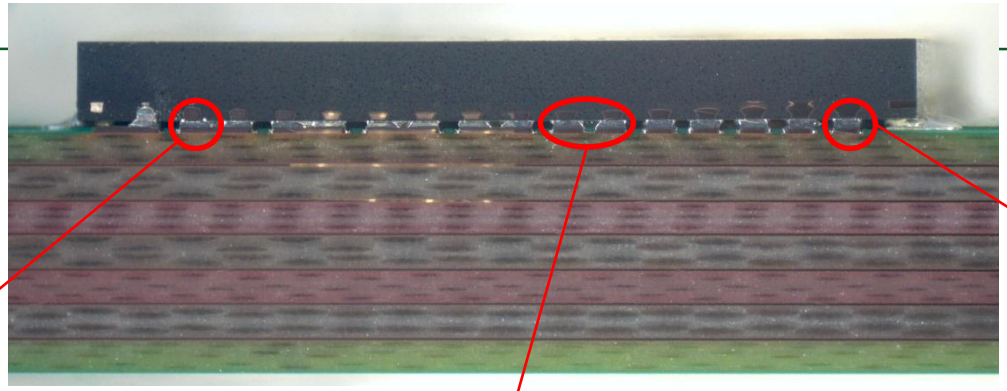
Result 2: QFN64 9x9 mm (0.5 mm pitch)

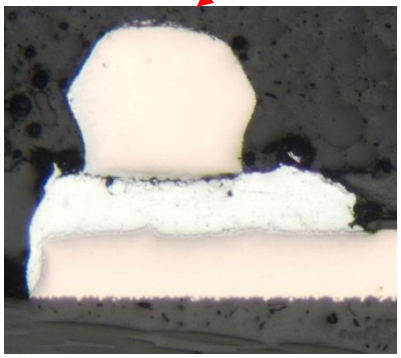


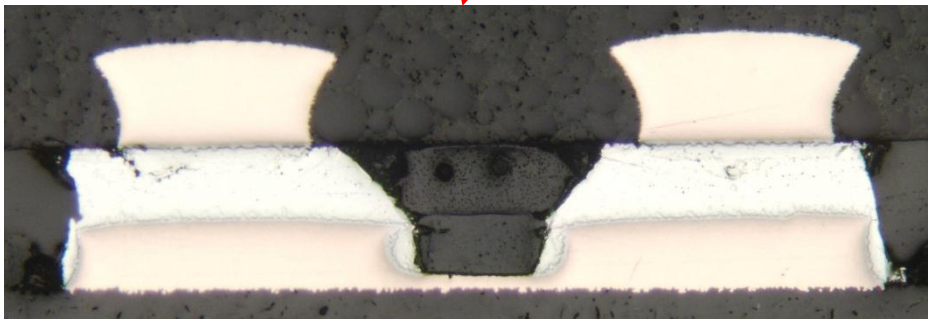


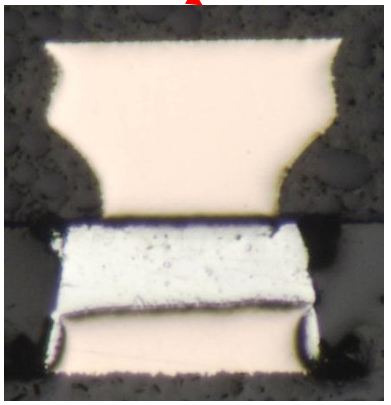
QFN's with 7ppm/°C: (almost) **all failed** after 2000 cycles
QFN's with 12 ppm/°C: **no failures** after 2000 cycles

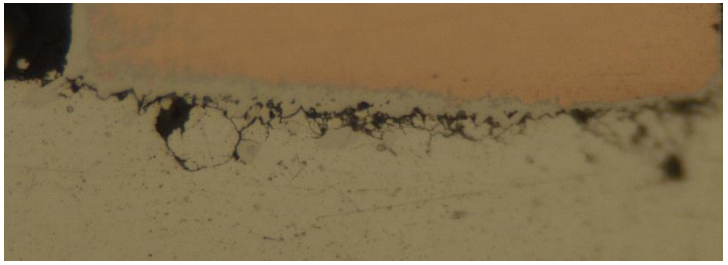
QFN64: 7ppm/°C EMC – SAC305 solder – No wettable flank

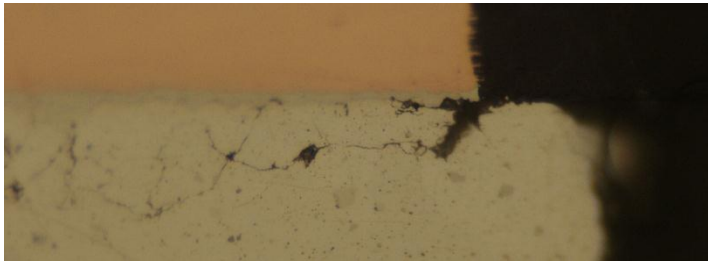




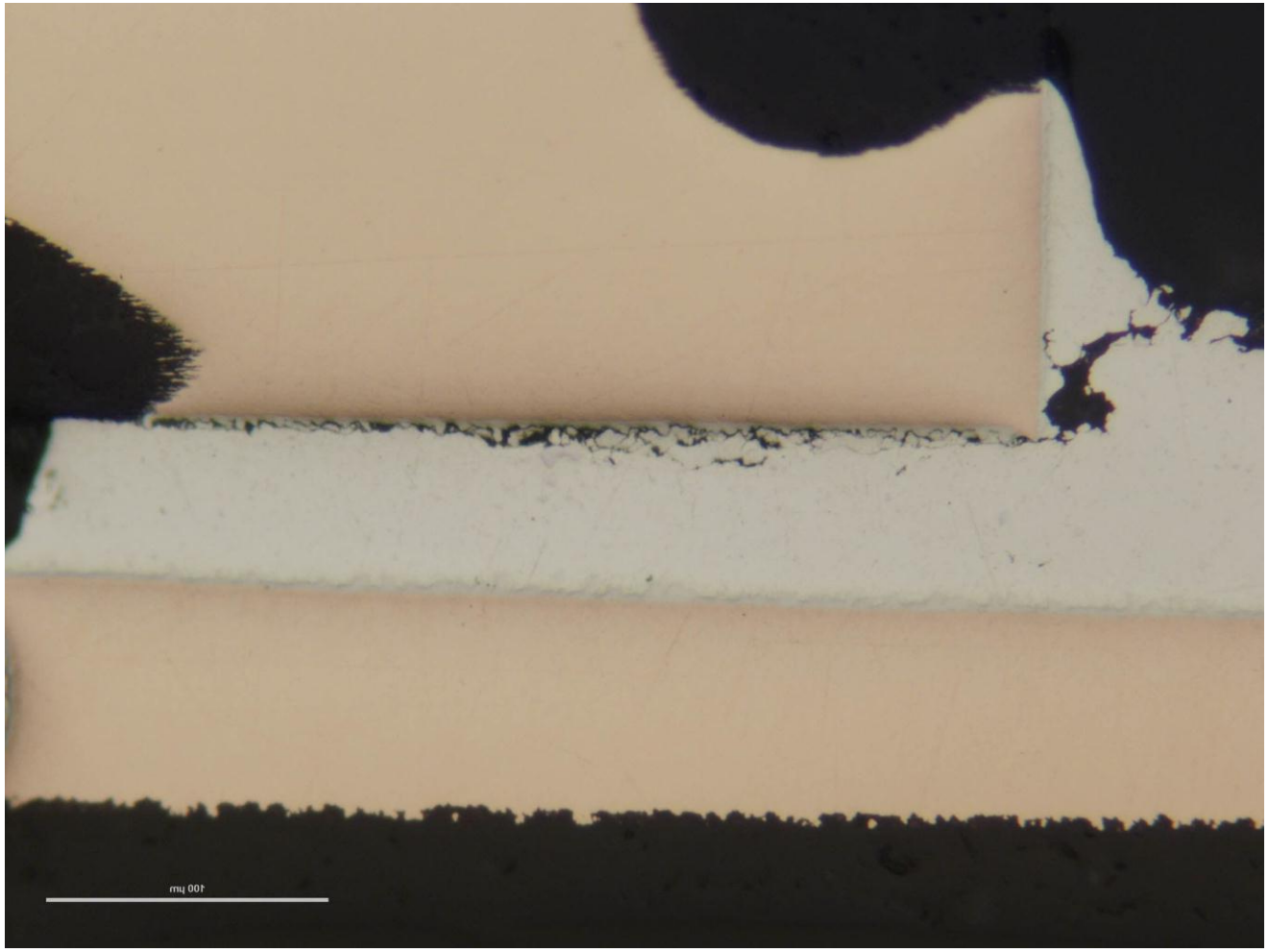








QFN64: 7ppm/°C EMC – SAC305 solder – No wettable flank



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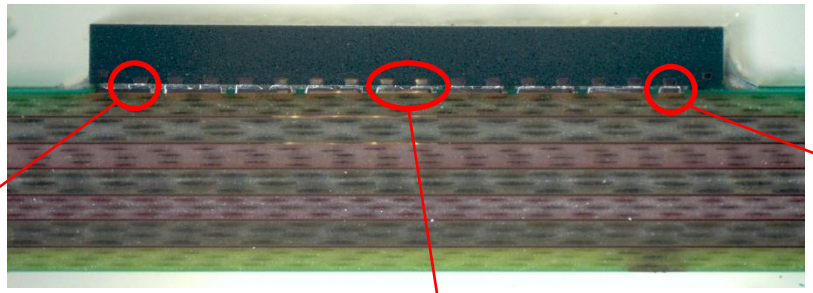
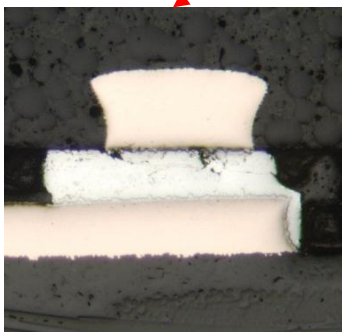
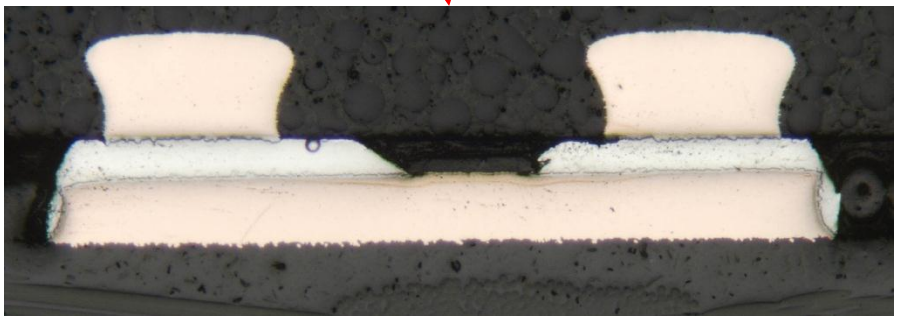
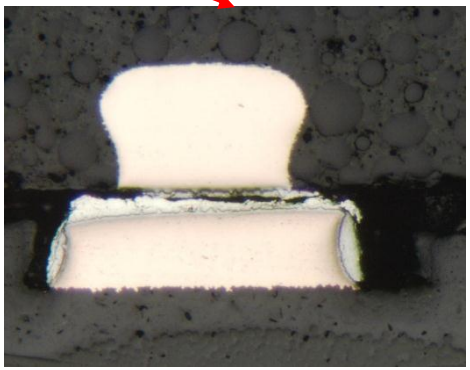
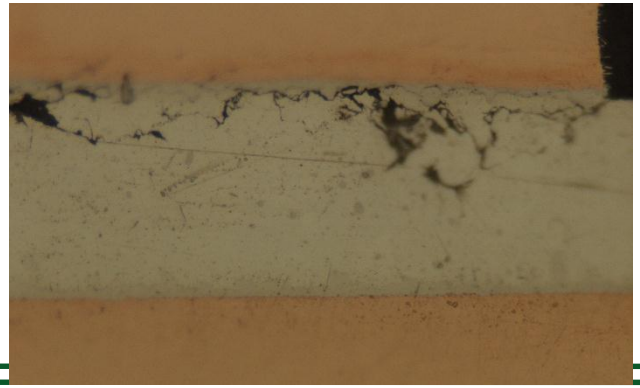
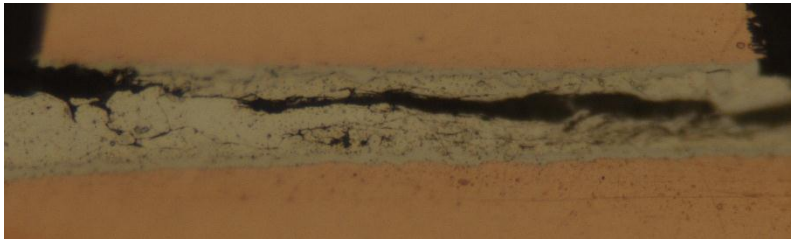




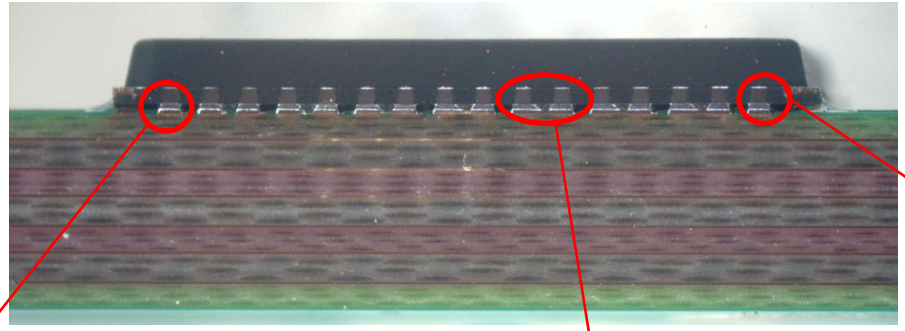


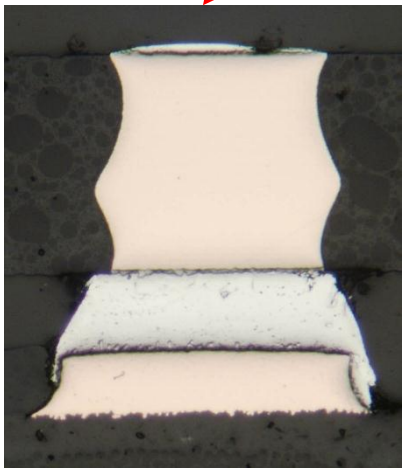


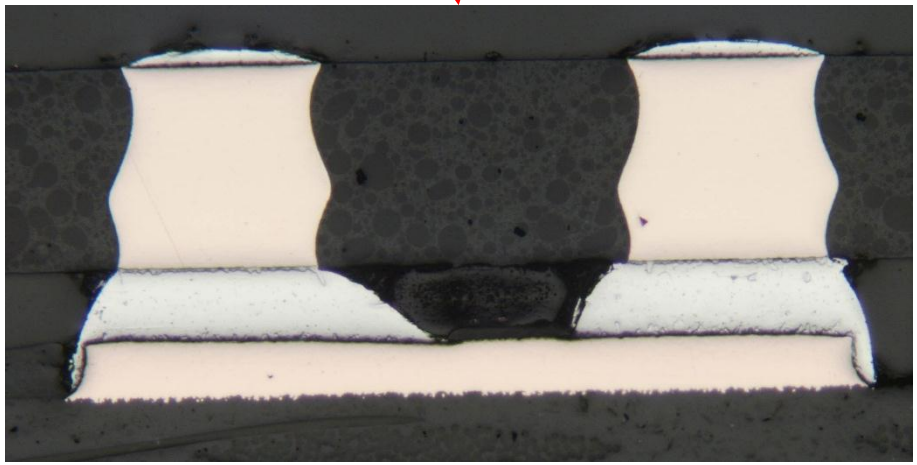


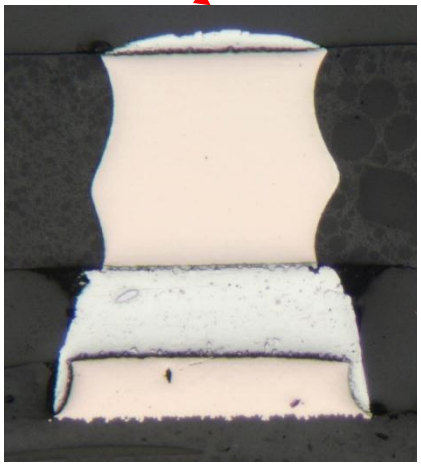


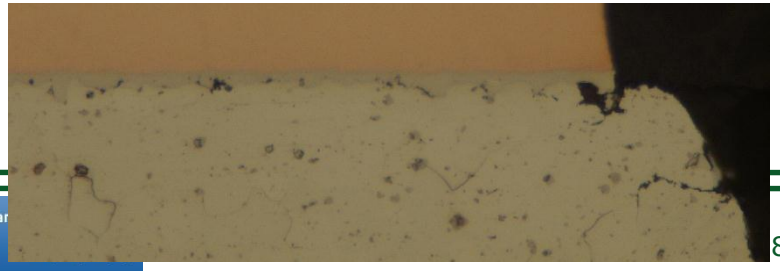
QFN64: 12 ppm/°C EMC – SAC305 solder – No wettable flank



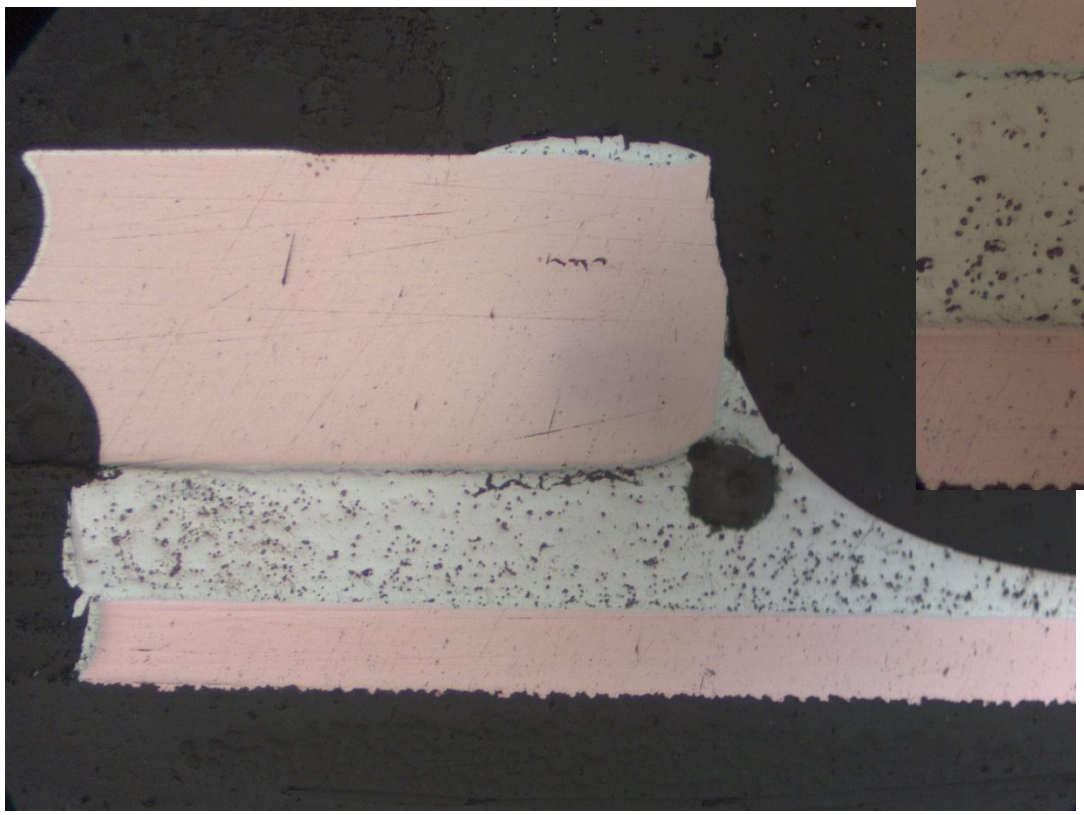


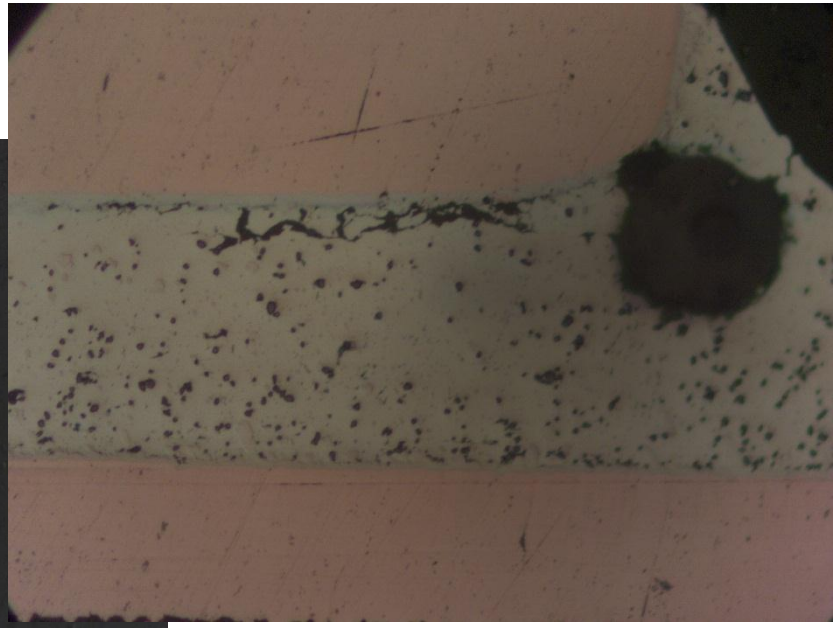






Failure analysis





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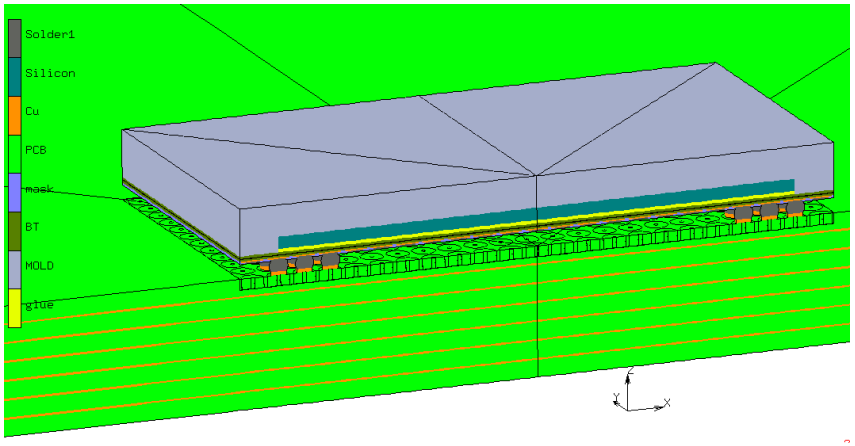
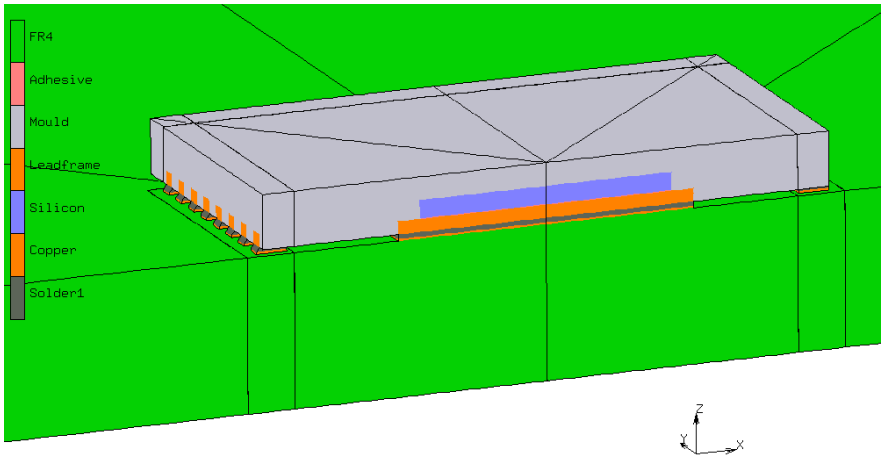
Thermo-mechanical analysis of package assemblies using FEM

BGA228

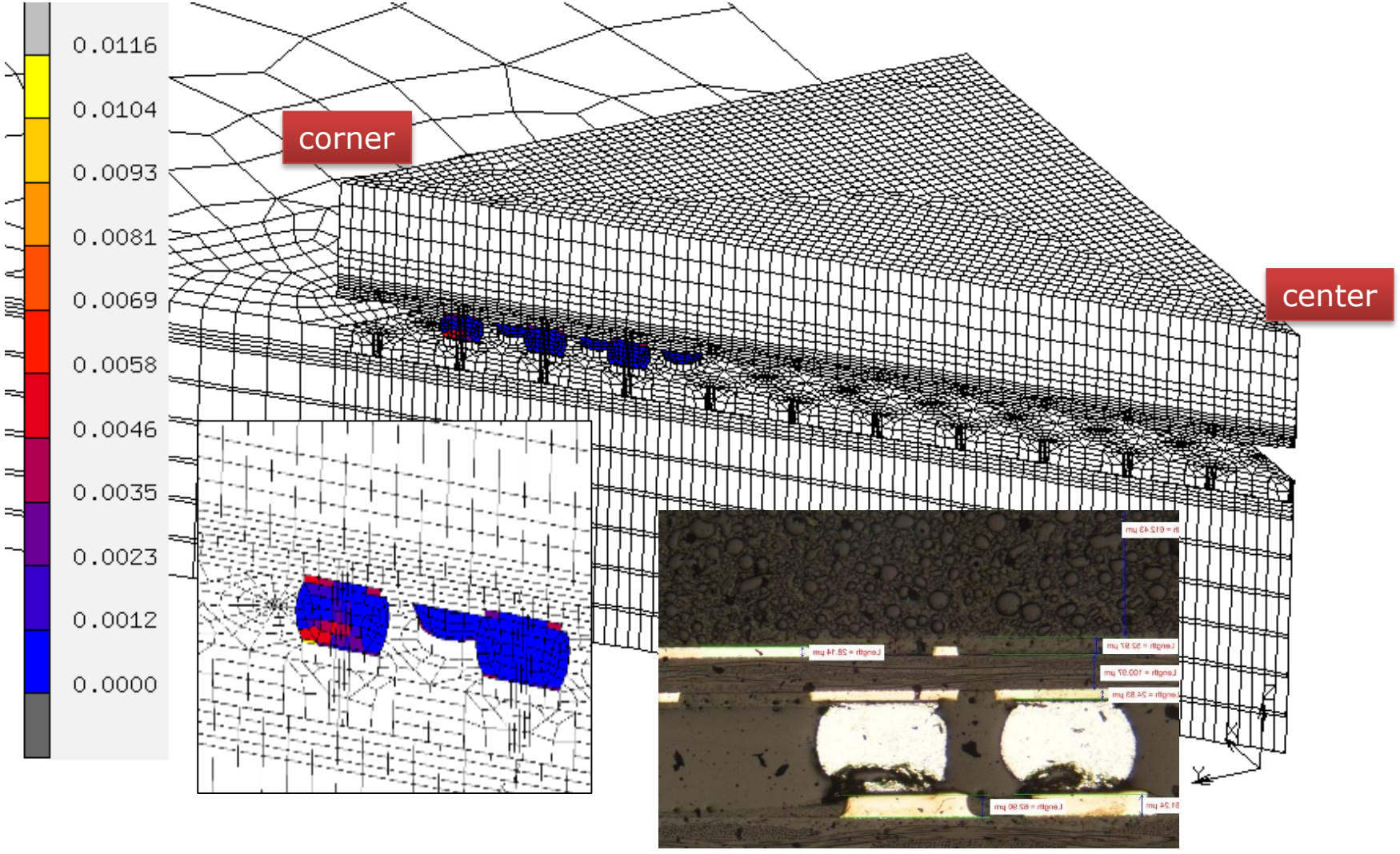


QFN64

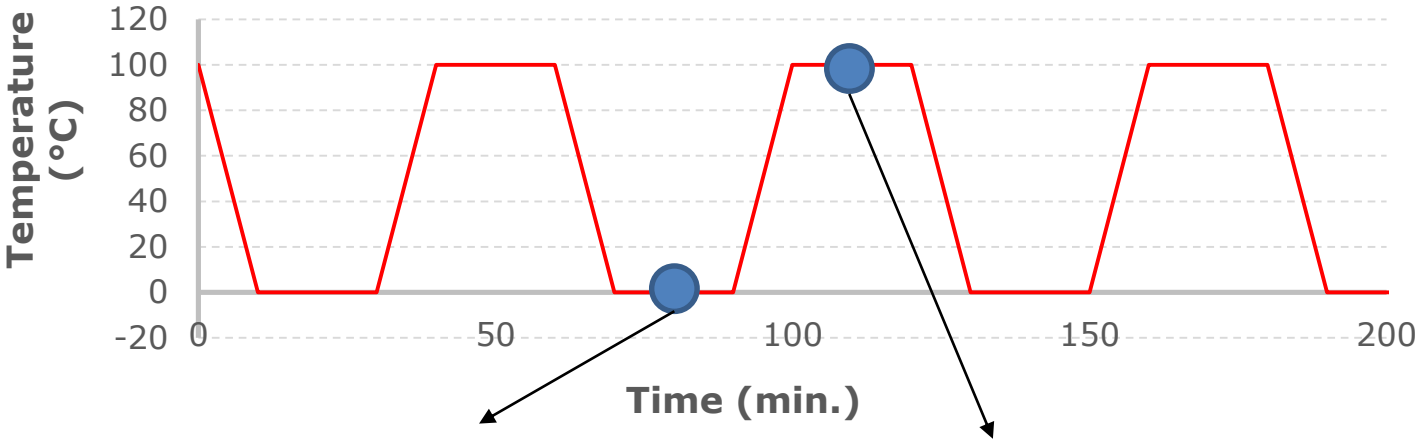


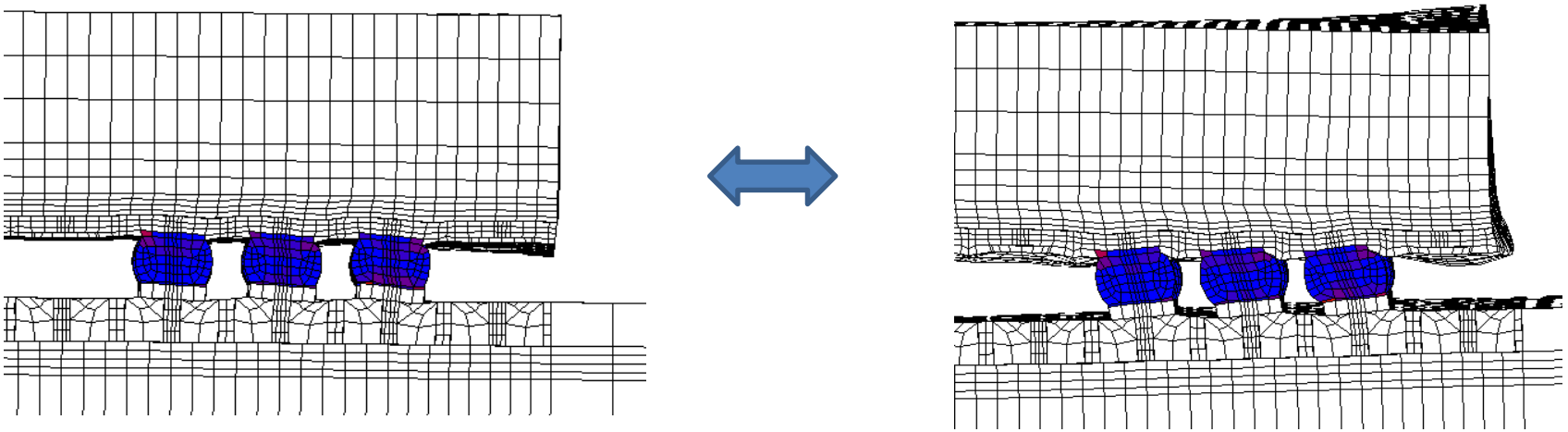
- ANAND creep model for simulation of creep deformation in the solder joint
- Creep strain per cycle can be translated into expected average life time to failure

Validation of critical joint/zone for BGA228



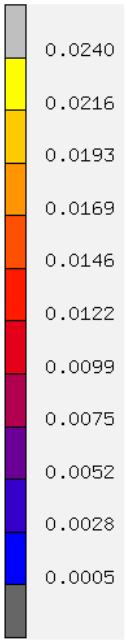
Thermal cycling effect on solder joints

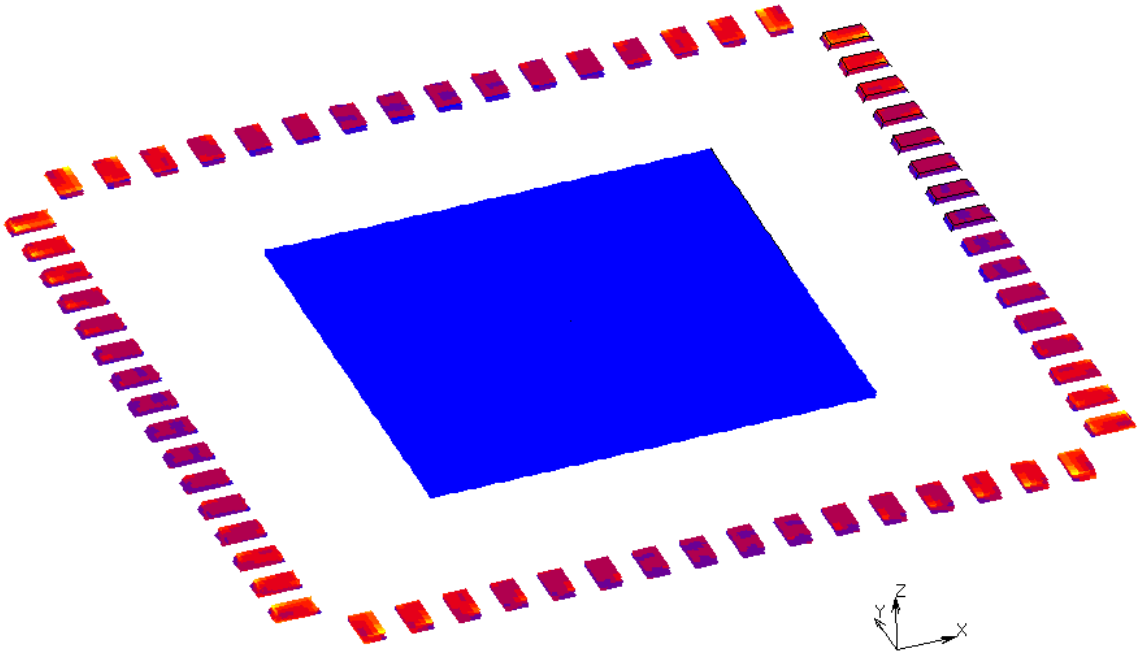


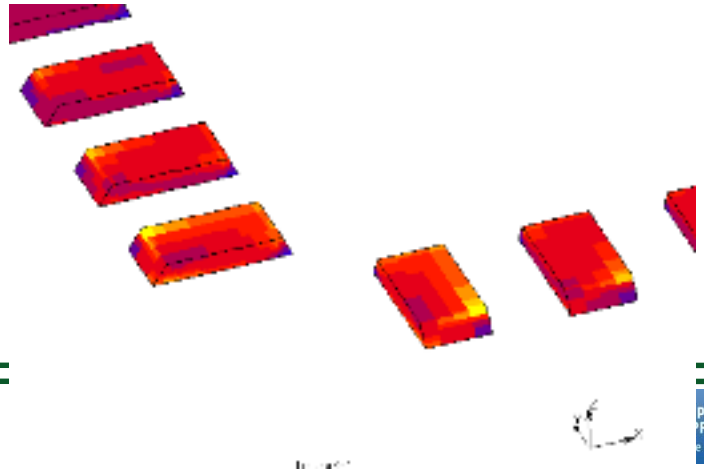


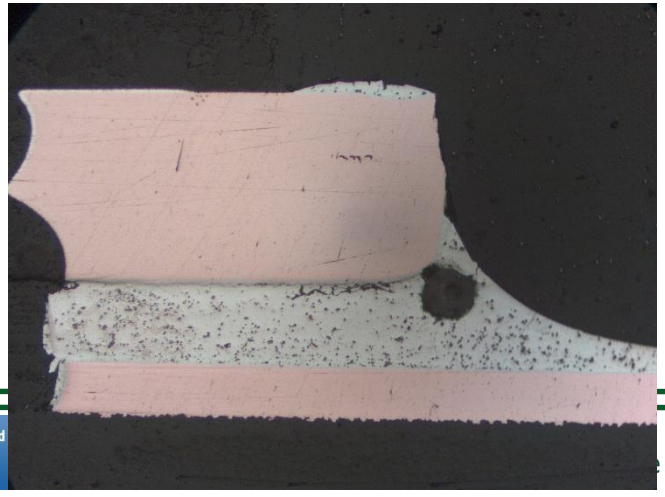
Validation of critical joint/zone for QFN64

Creep strain (-)









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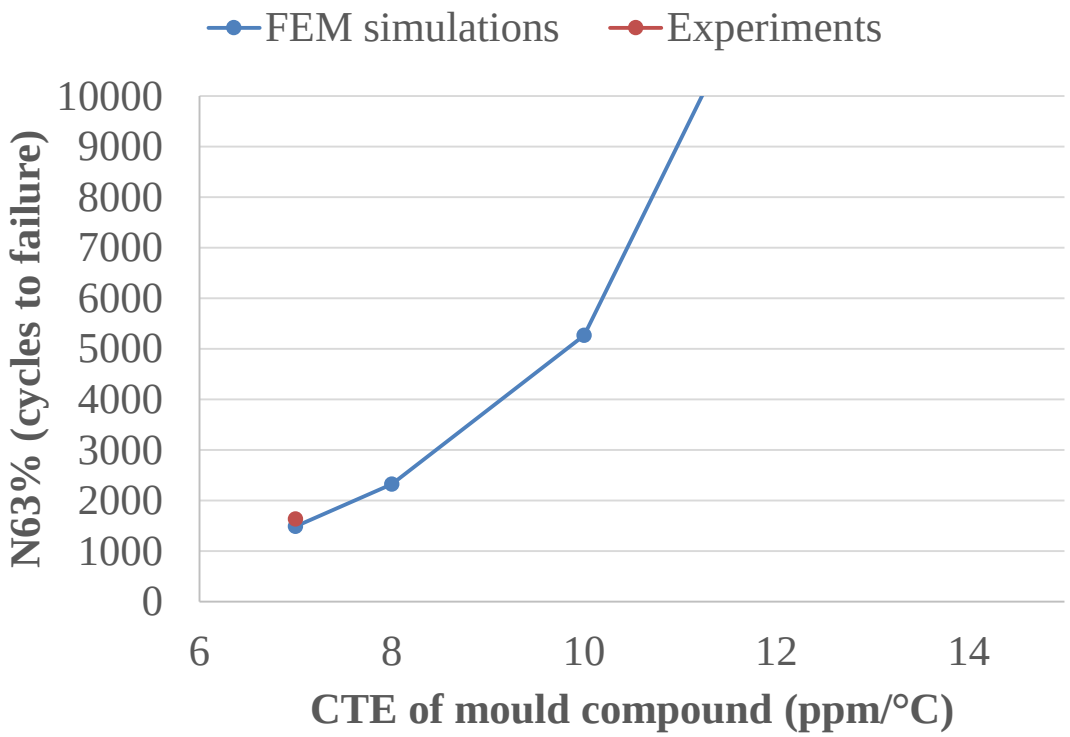
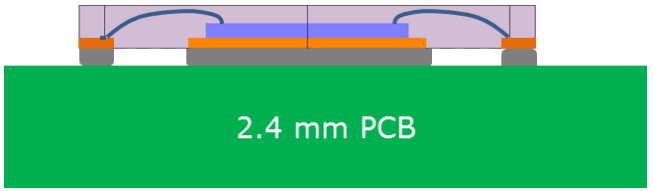
Relation between life time and mould CTE (for QFN 64)





0 to 100°C TC
Board thickness = 2.4 mm

Life time **exponentially** drops with reduced CTE of the mould compound

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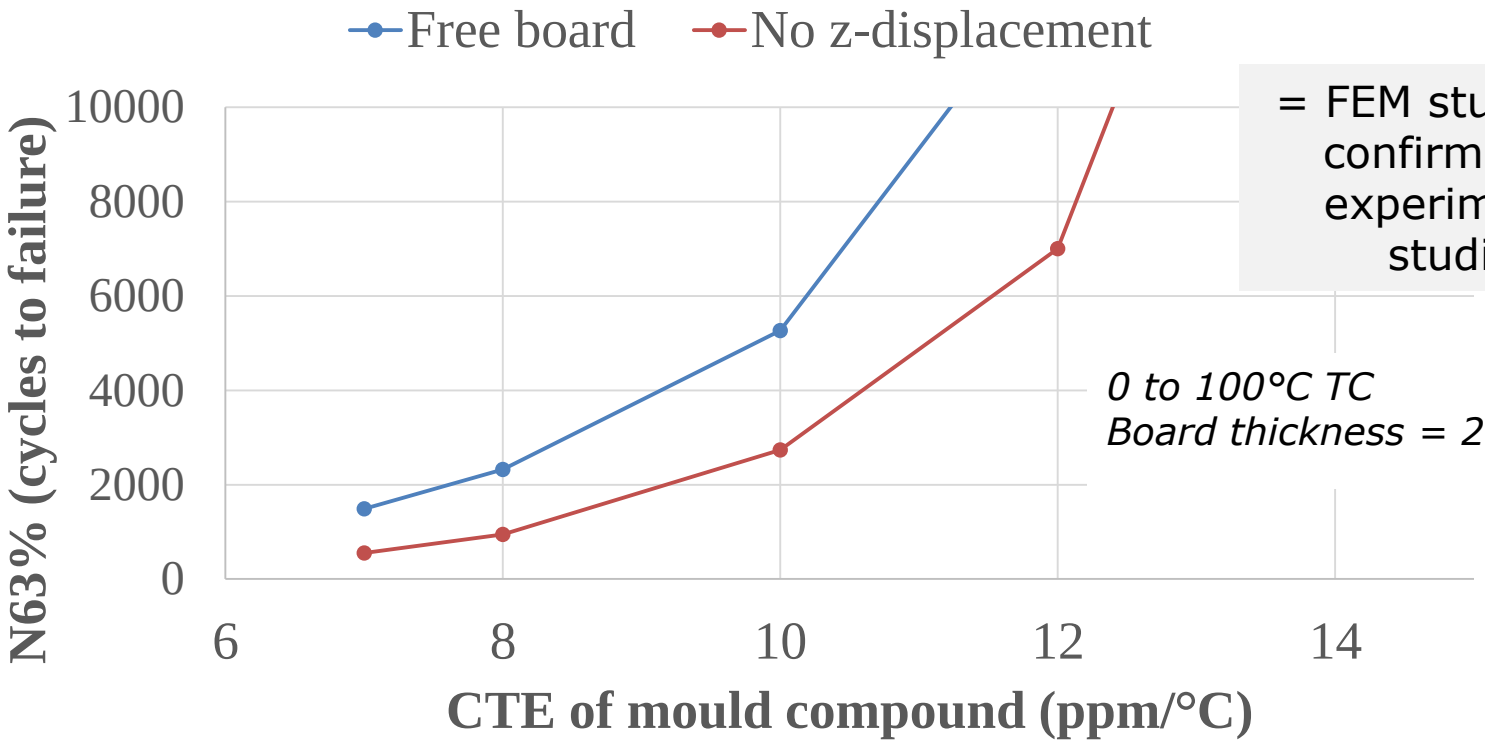
QFN64 9x9mm: impact of board (non-)flexibility



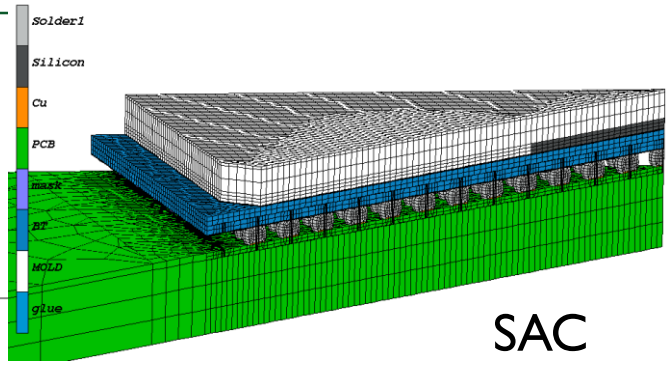
= FEM study, and confirmed by experimental studies

0 to 100°C TC
Board thickness = 2.4 mm

When board is not allowed to bend anymore (= no z-displacement):
QFN's with **12 ppm/°C**: life time drops from >10000 to 7000 cycles
QFN's with **7ppm/°C**: life time drops from ~1500 to ~500 cycles

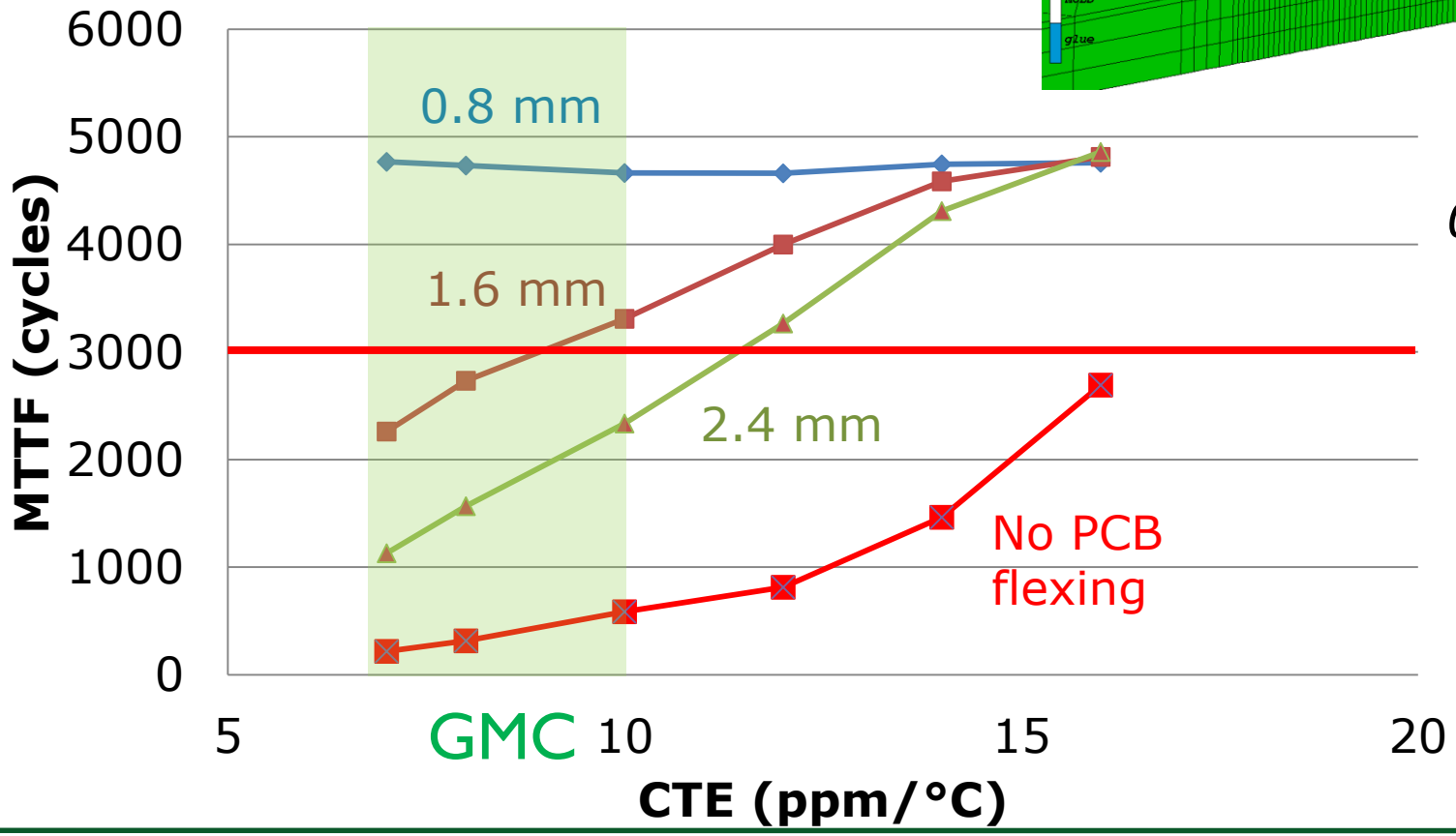
Former results showing the impact of board flexibility

PBGA 27x27 area array
1.27mm pitch



SAC Solder

0 to 100°C cycling



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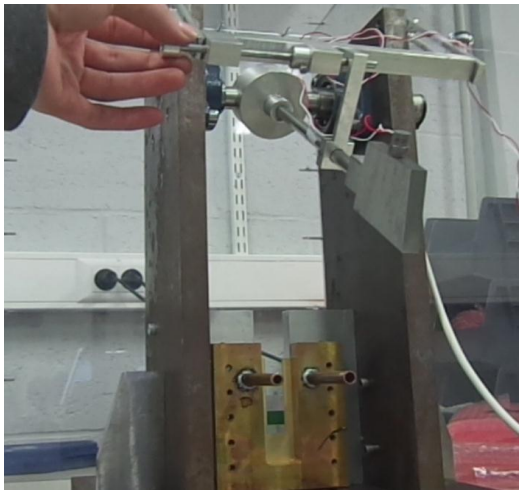
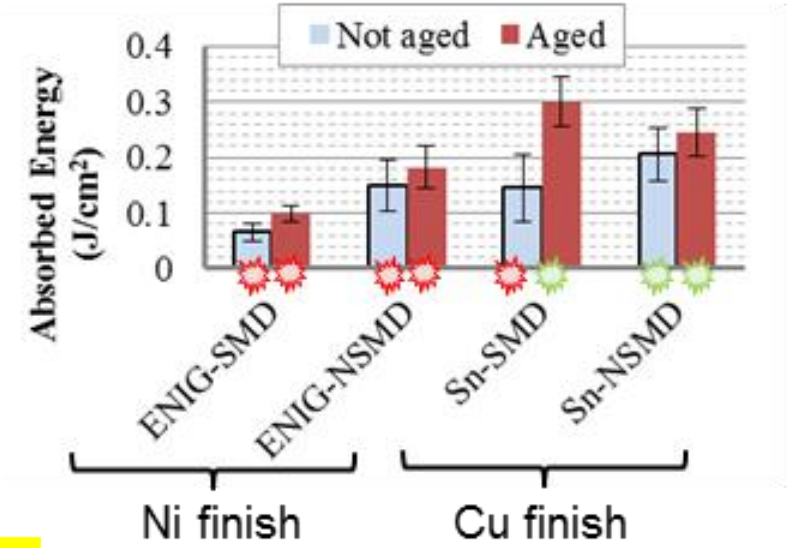
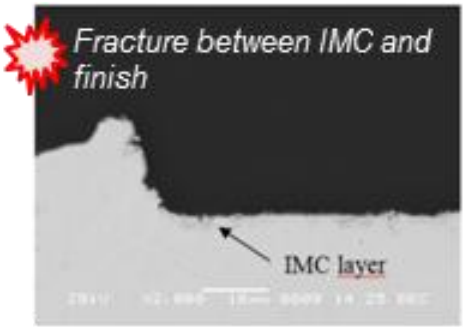
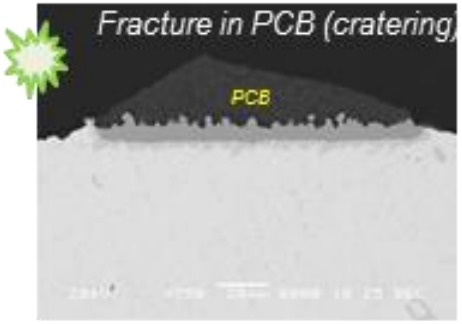
Stiffer packages in combination with **NiAu** finish: more prone to IMC fractures under **shock** loads



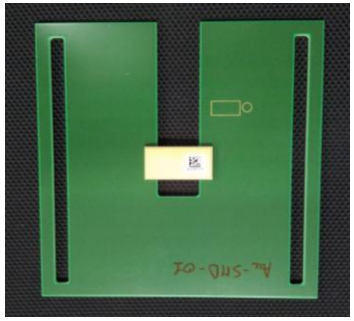


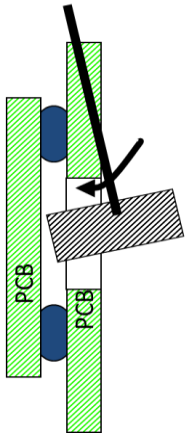
Ageing conditions: 1000 hours @150°C





PULL mode

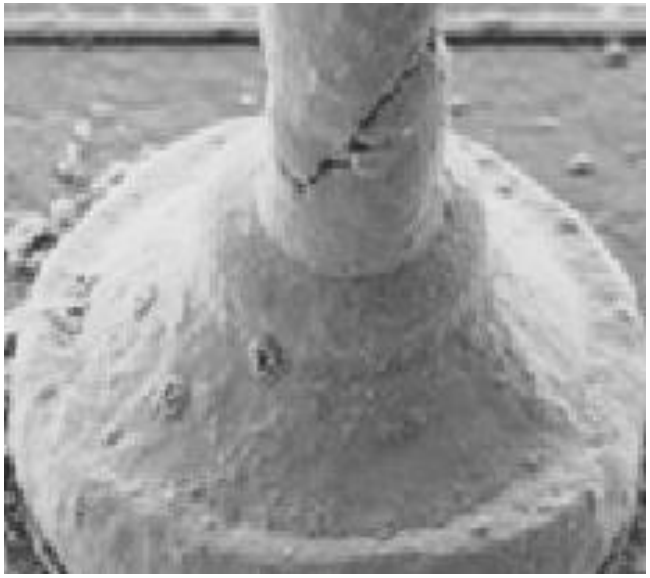


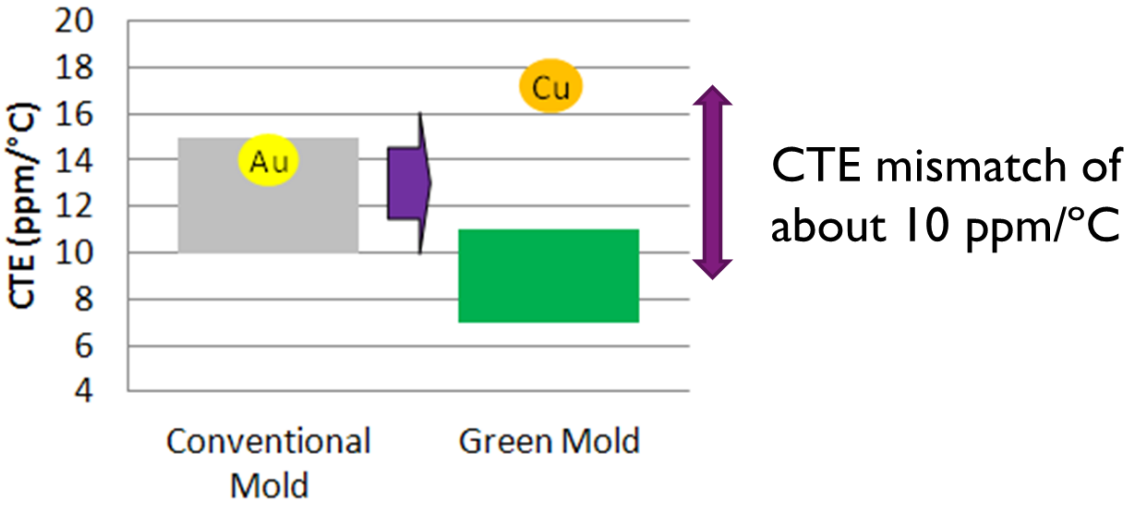


Solder joints on **Ni** have up to **50% lower** resistance to mechanical shock compared to joints on **Cu** based finishes

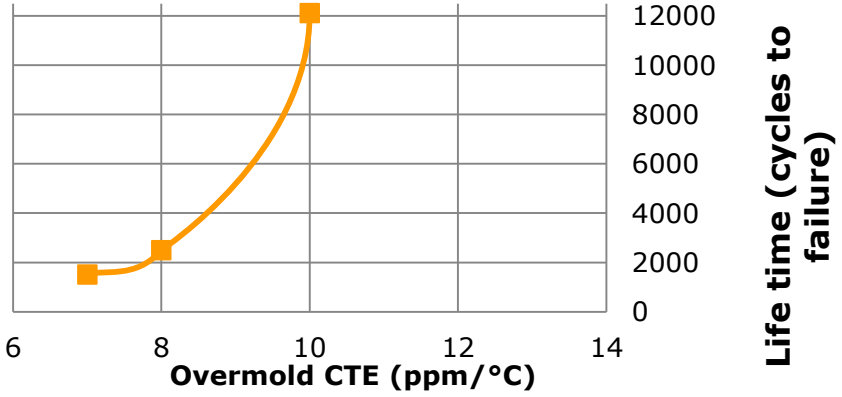
Low-CTE mould compounds in combination with **Cu wire** bonds: more risk for wire fatigue

Wire fatigue fracture after temperature cycling, induced by CTE mismatch between Cu wire and mould compound





Requirement of minimum mould CTE to avoid wire fatigue or use coated wire with increased resistance to fatigue fractures



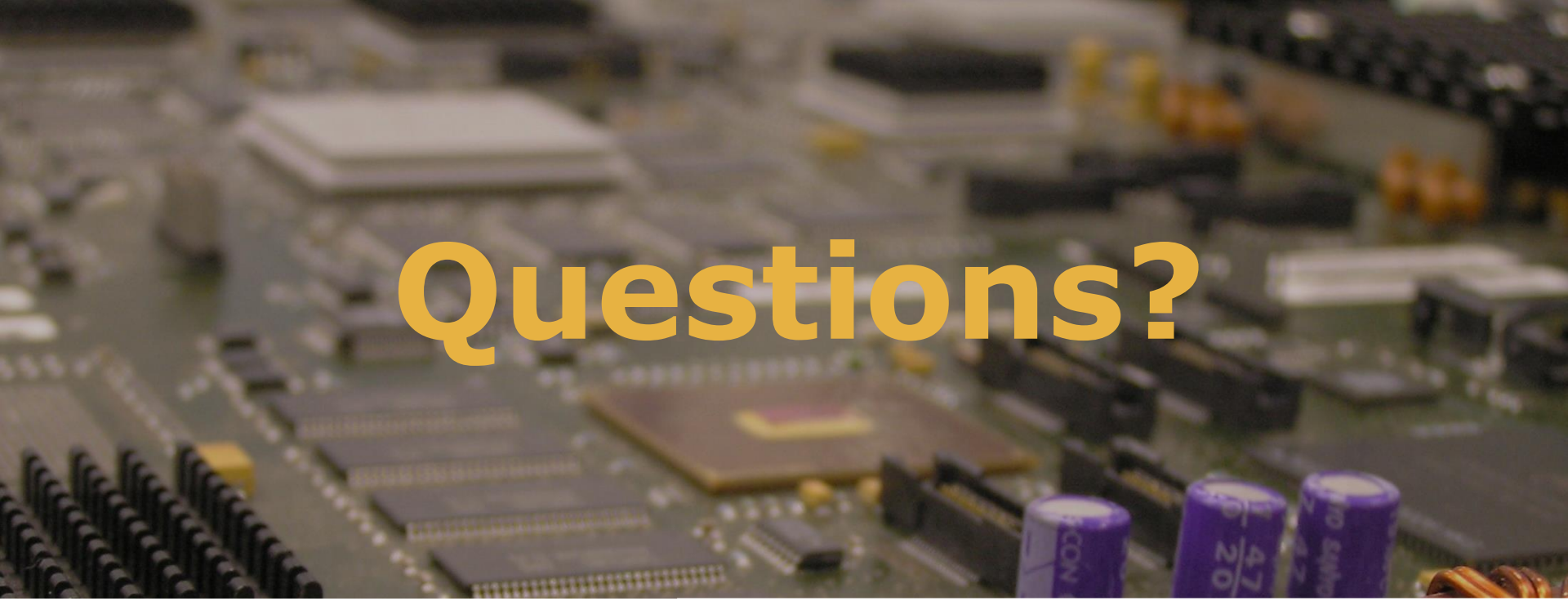
Outline

- Introduction of Low-CTE Mould compound for packages
- Experimental setup
- Experimental results:
  - PBGA228
  - QFN64
- Correlation with FEM simulations
- FEM based parameter study
- Impact of board stiffness and board fixation
- Other concerns related to low-CTE mould compound packages
- Conclusions

Conclusions

- Negative impact of low CTE “green” mould compounds on the solder joint second level reliability of QFN and BGA packages. Life time reduction up to 60% are measured
- The impact highly depends on the stiffness and support of the printed circuit board. The less the board can bend, the higher the impact of the low-CTE will be. Qualification of packages on rather flexible (<1.6 mm) boards can be a substantial overestimation of the life time for your real product
- For high reliability applications and electronics operating under severe conditions, this mould compound change creates a major reliability concern and requires thorough evaluation. The impact on electronics reliability is considerably greater than that of a change in solder alloy but as yet did not get a similar level of attention

Questions?



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