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

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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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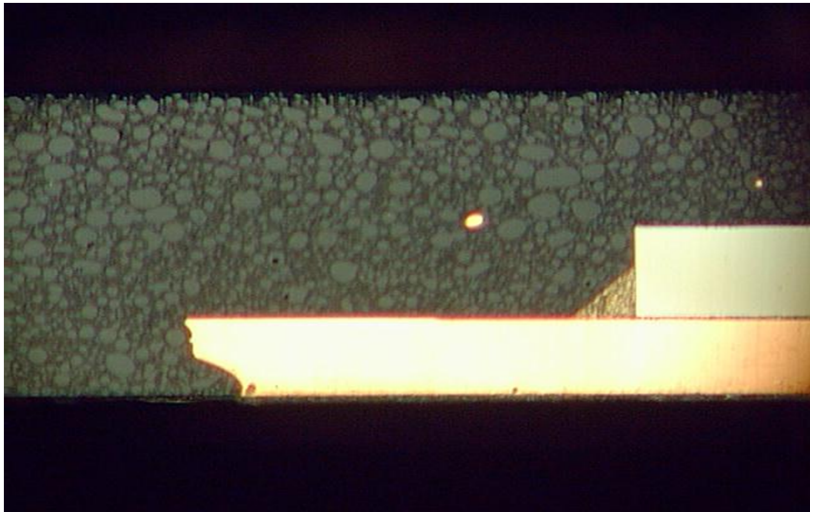
# Introduction of low-CTE (green) mould compounds

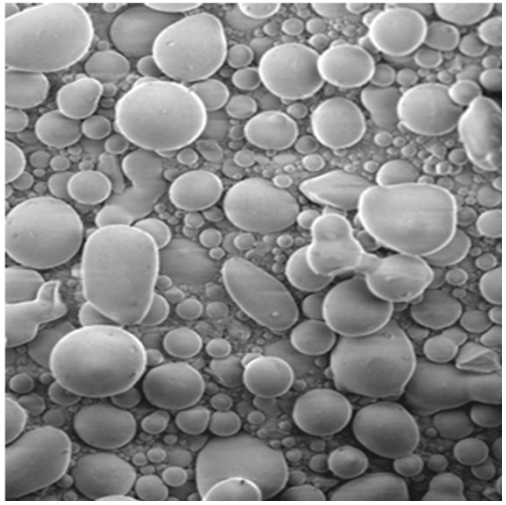
Driven by:

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

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

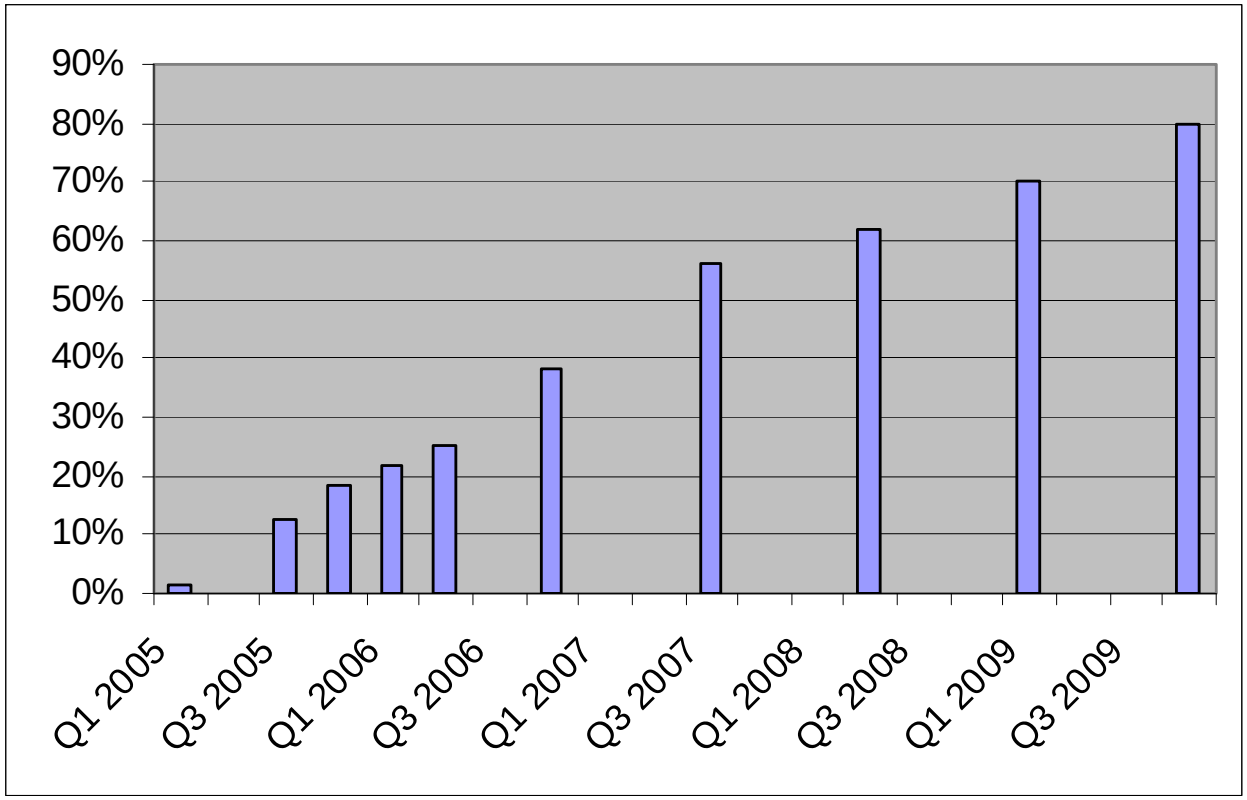
- high stiffness (25 GPa – 30 GPa)
- low CTE (7 – 9 ppm/°C).





# The change-over took place between 2005-2010

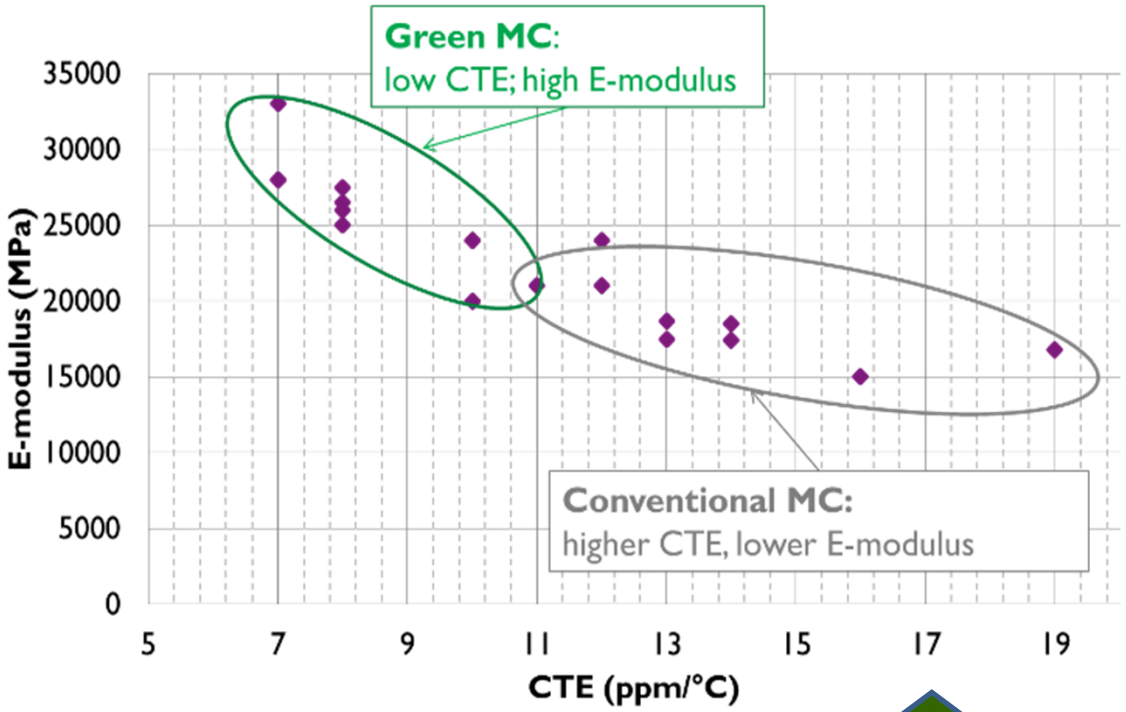
**Use of Green Mould Compounds for plastic packages**




(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

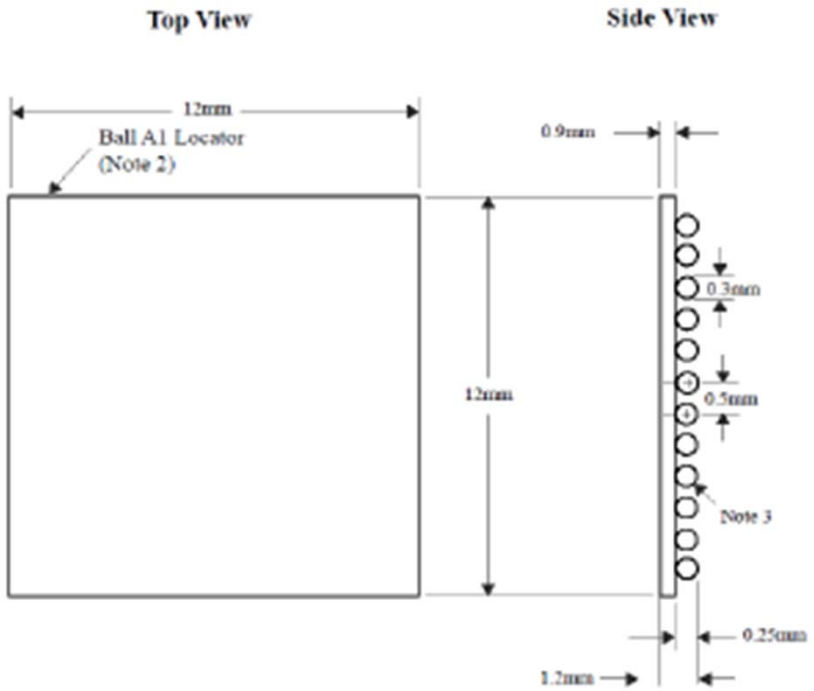


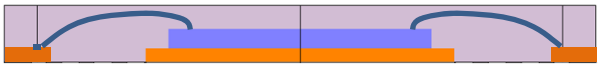

Figure 2 : BGA228 daisy chain component.

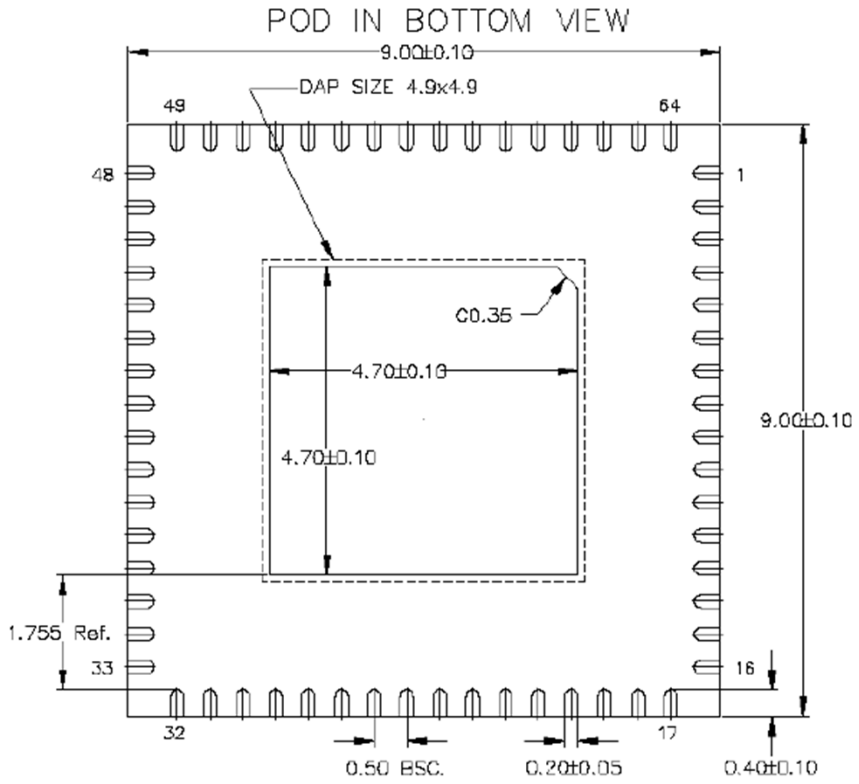
**Variations**

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






**Variations**

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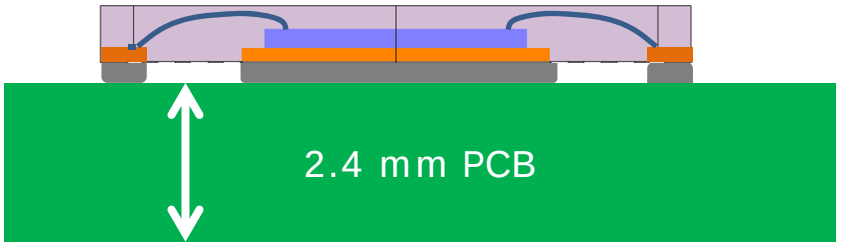
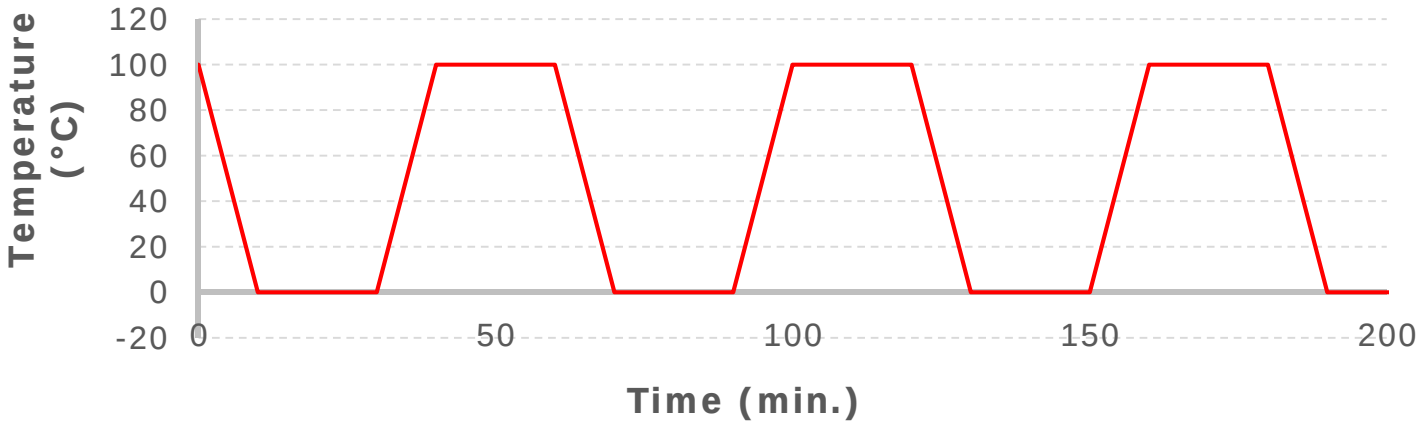
| Solder ball | + | paste |
|---|---|---|
| • SnPb | | SnPb |
| • SAC305 | | SAC305 |
| • SAC105 | | SAC305 |

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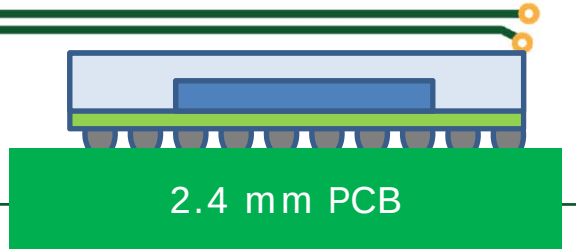
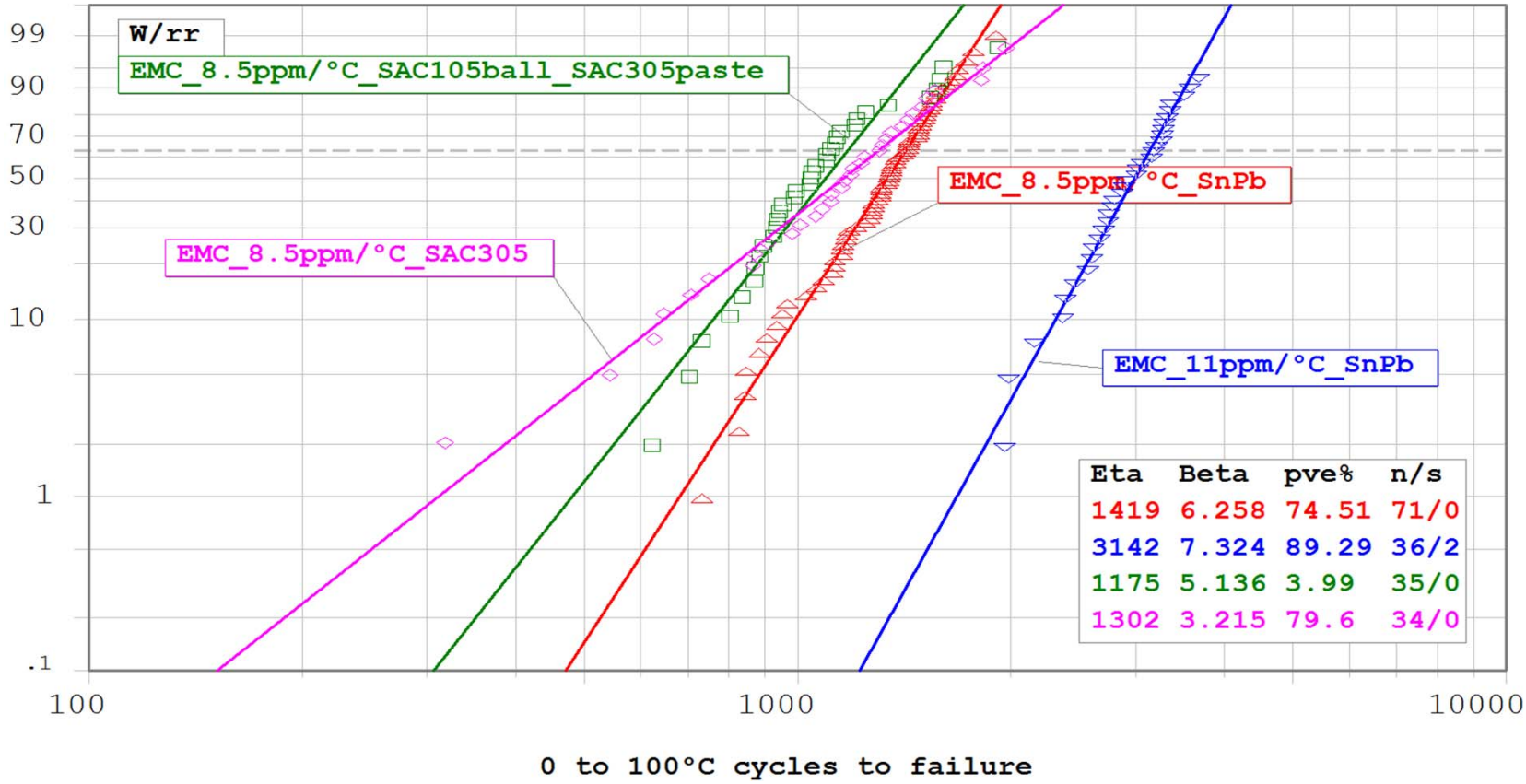
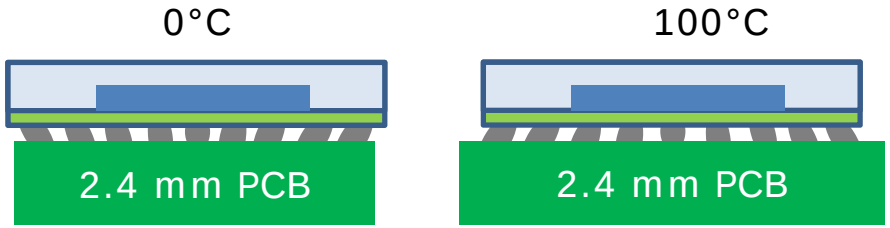
# Result 1: BGA225 12x12 mm (0.5 mm pitch)

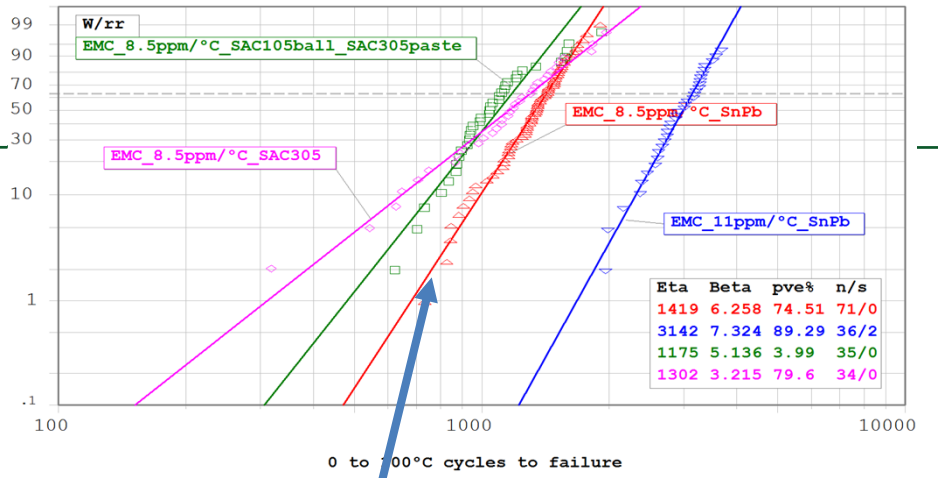


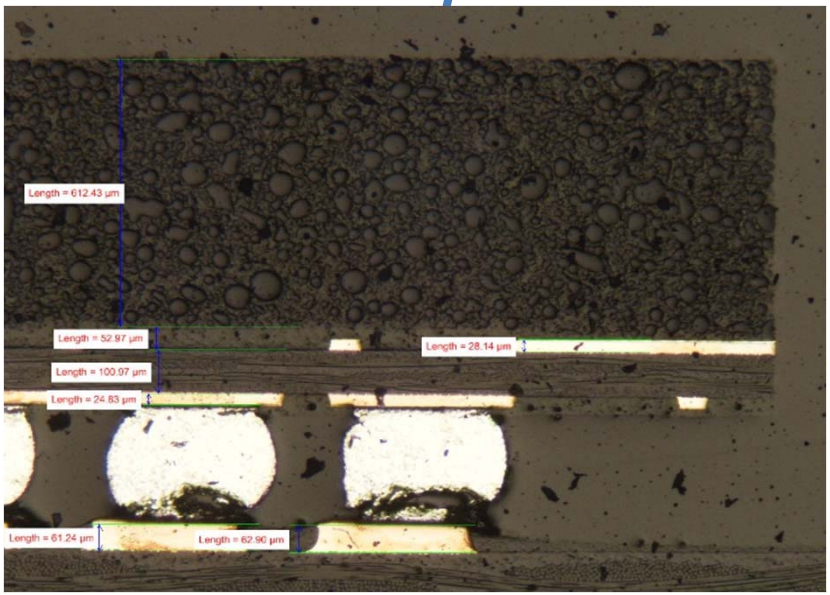




Impact of mold CTE: Life time (11ppm BGA) ~ **2.2** * Life time (8.5ppm BGA)
Impact of mold CTE is far greater than the chosen solder composition

# Failure analysis

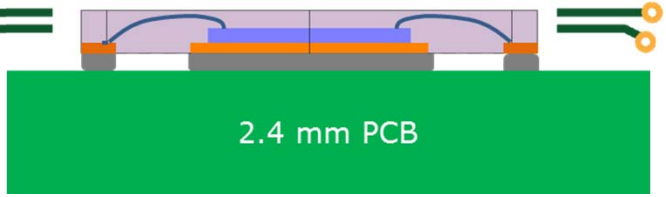


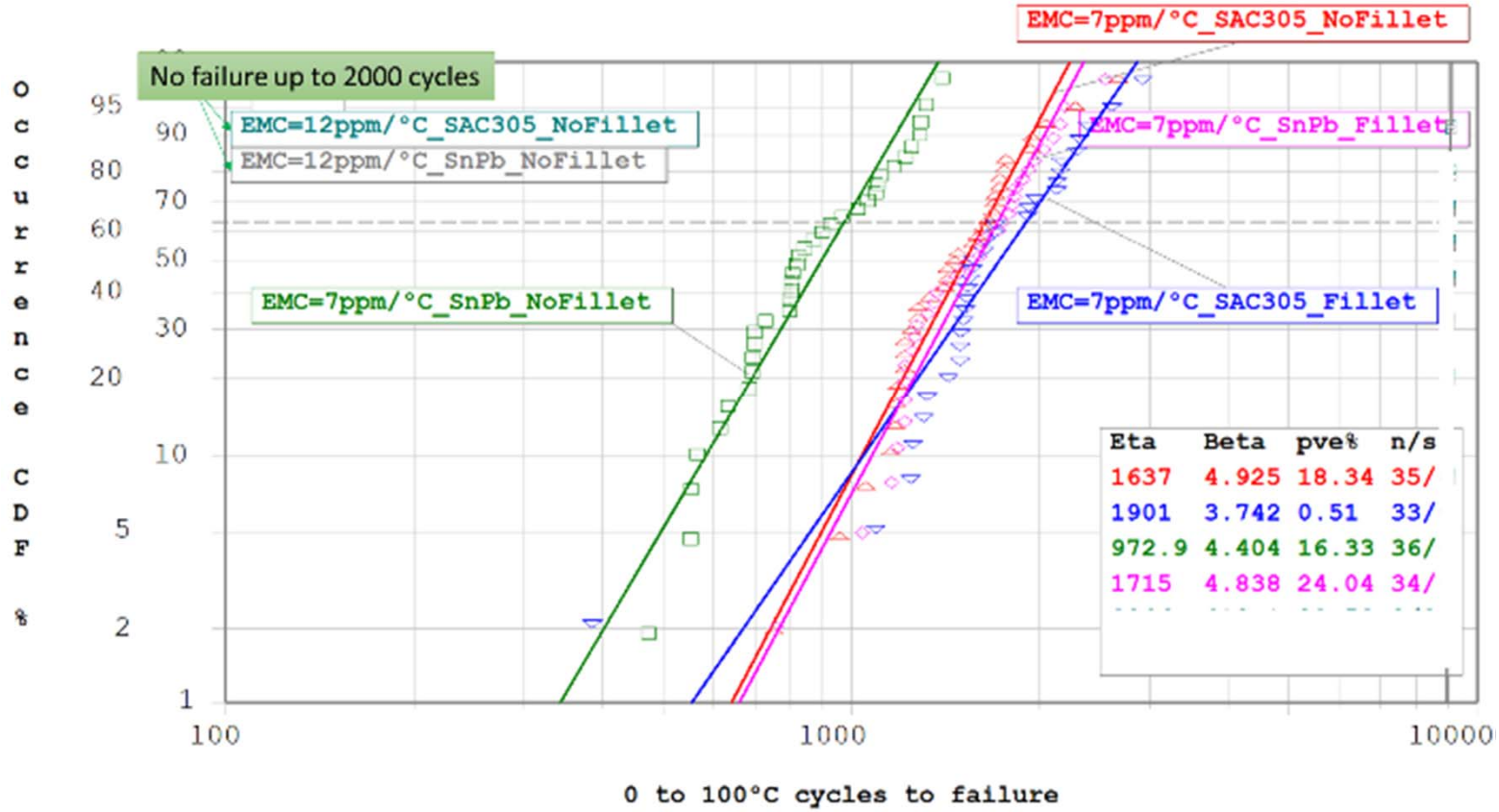




**Heavily damaged** solder joint especially at the corner/edge area indicative for a large mismatch

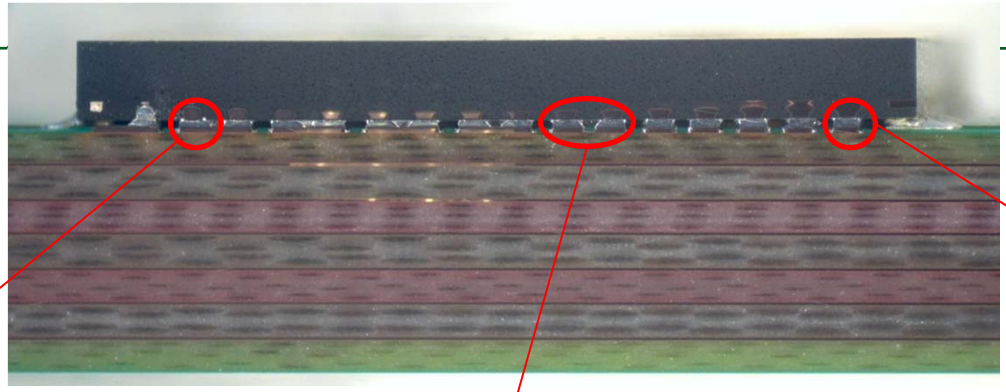
# Result 2: QFN64 9x9 mm (0.5 mm pitch)

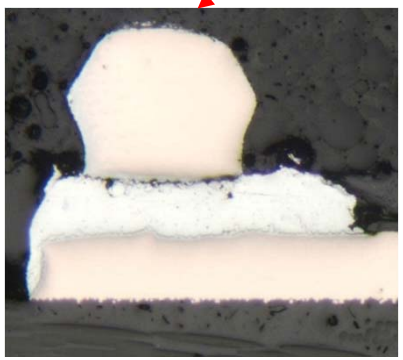


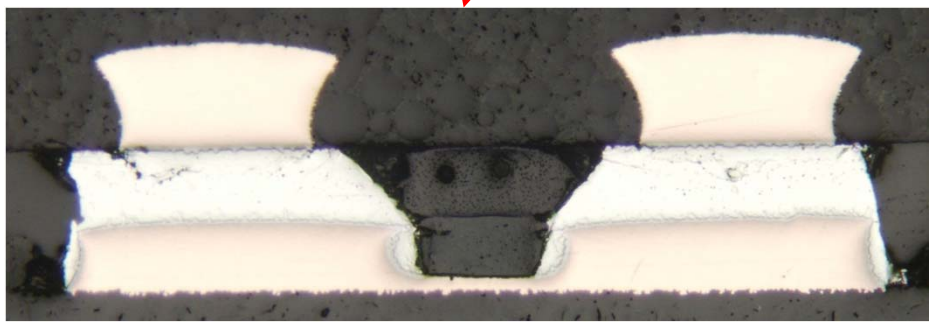



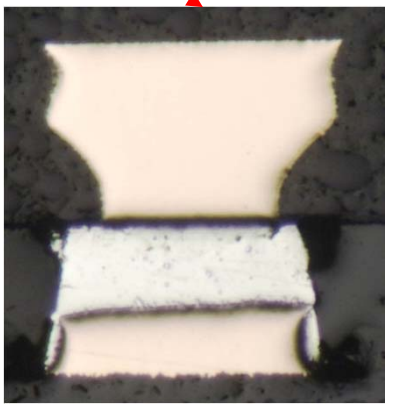

QFN's with 7ppm/°C: (almost) **all failed** after 2000 cycles
QFN's with 12 ppm/°C: **no failures** after 2000 cycles

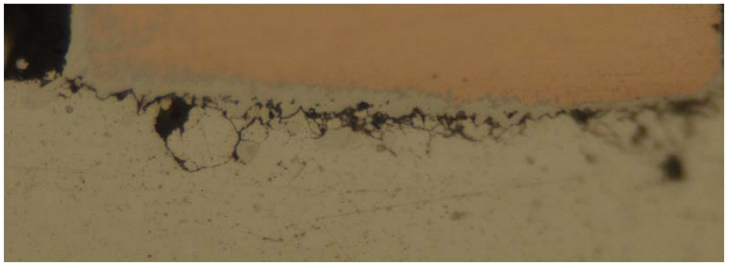
# QFN64: 7ppm/°C EMC – SAC305 solder – No wettable flank

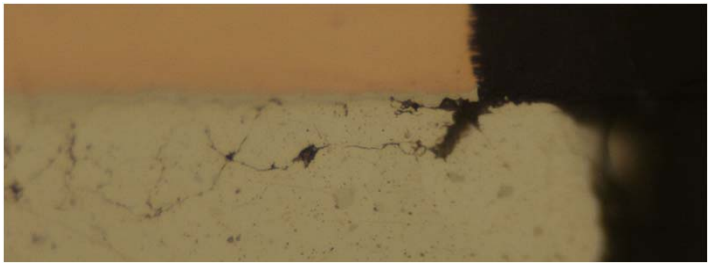




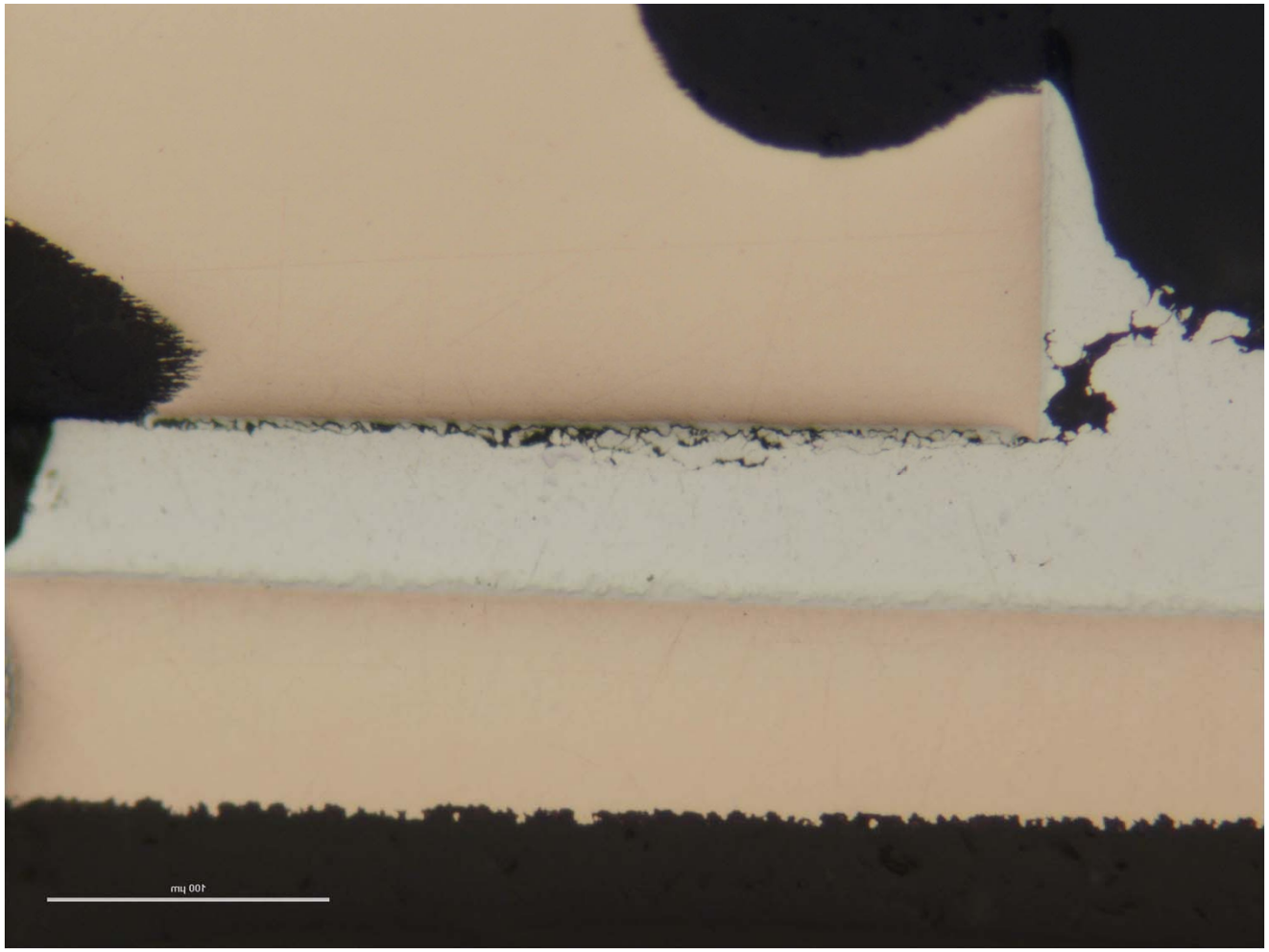




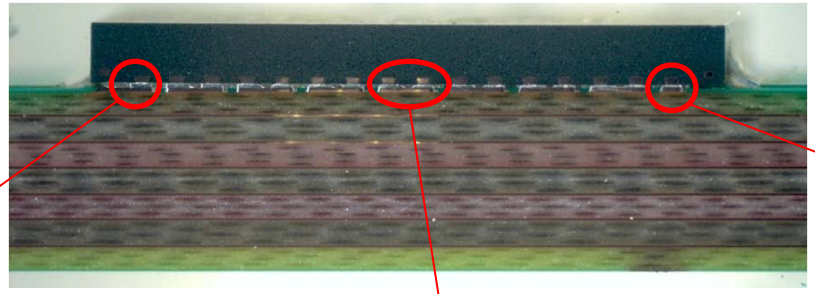


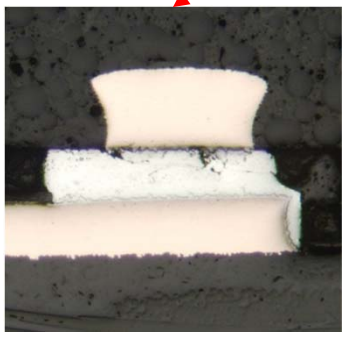


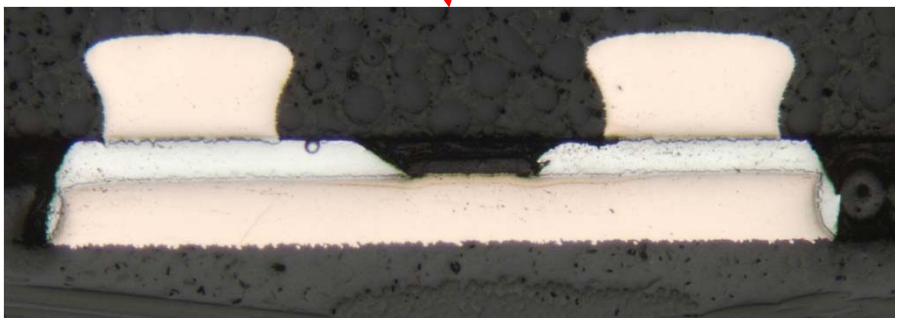
# QFN64: 7ppm/°C EMC – SAC305 solder – No wettable flank

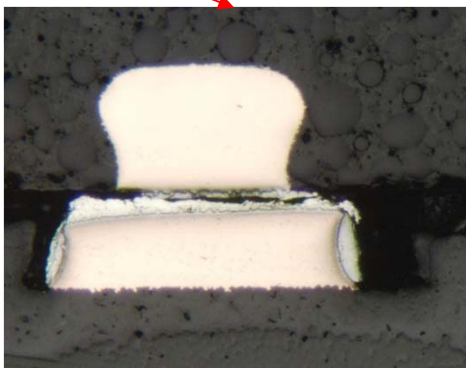


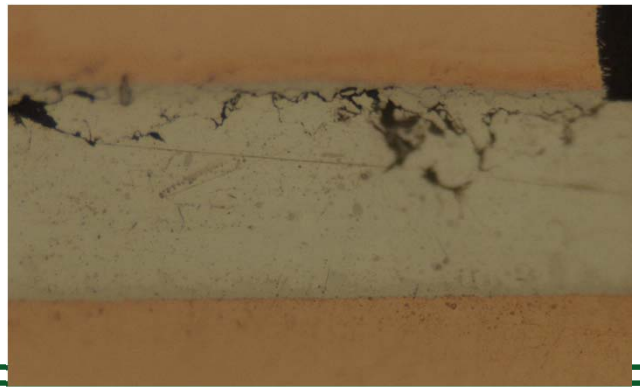
# QFN64: 7ppm/°C EMC – SAC305 solder – Wettable flank

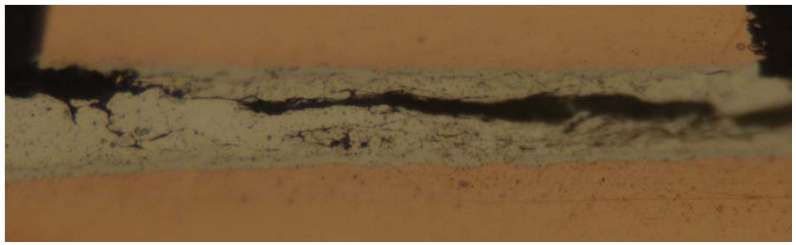




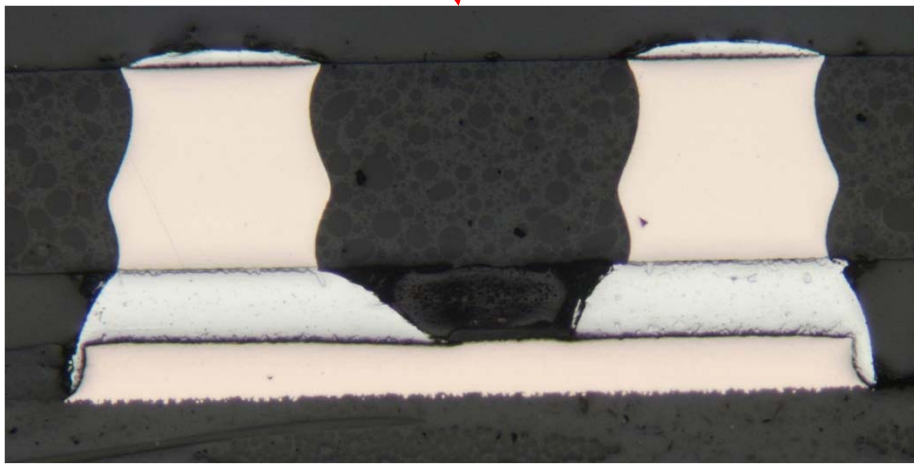


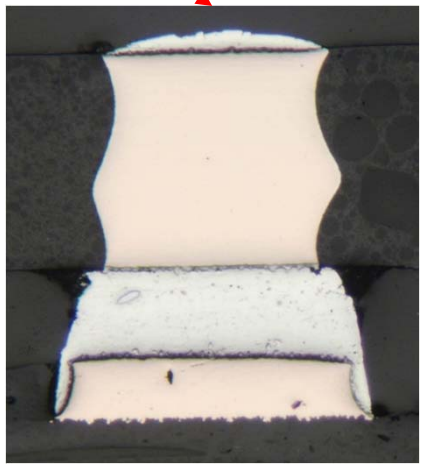


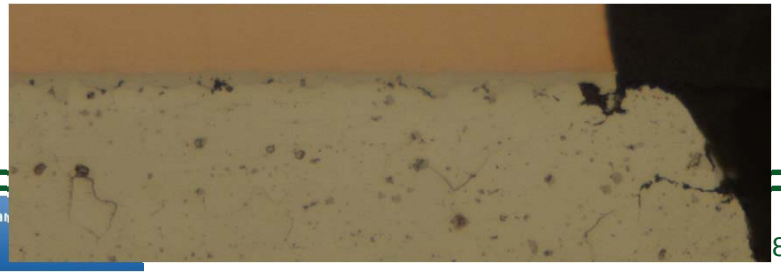




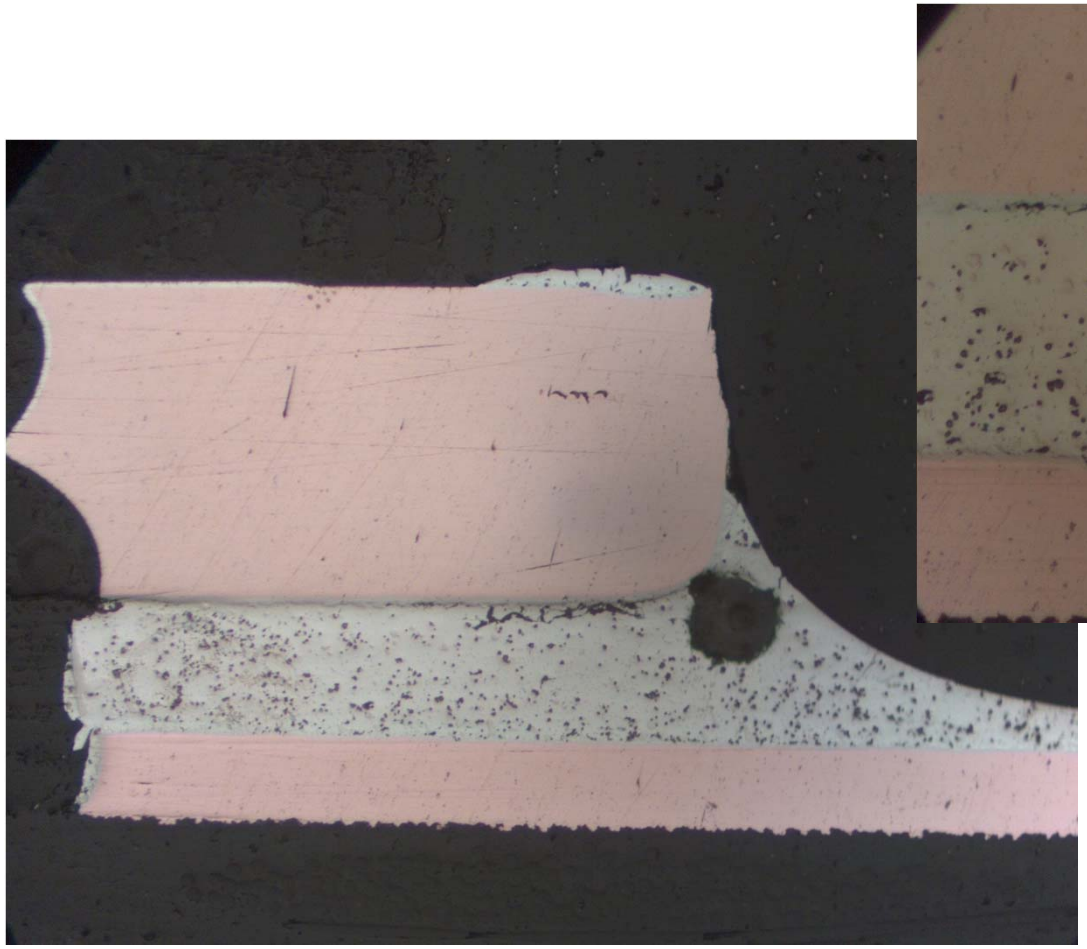
# QFN64: 12 ppm/°C EMC – SAC305 solder – No wettable flank

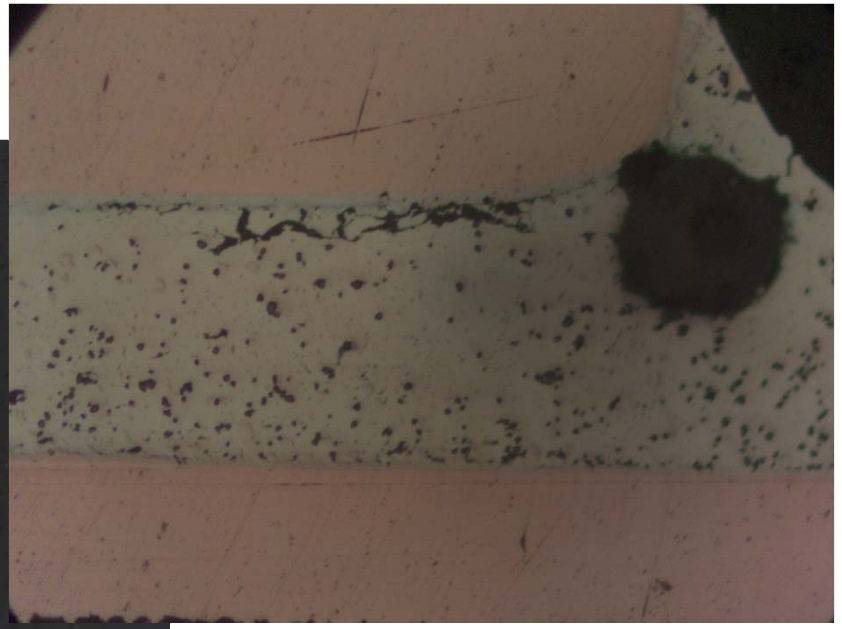






# Failure analysis





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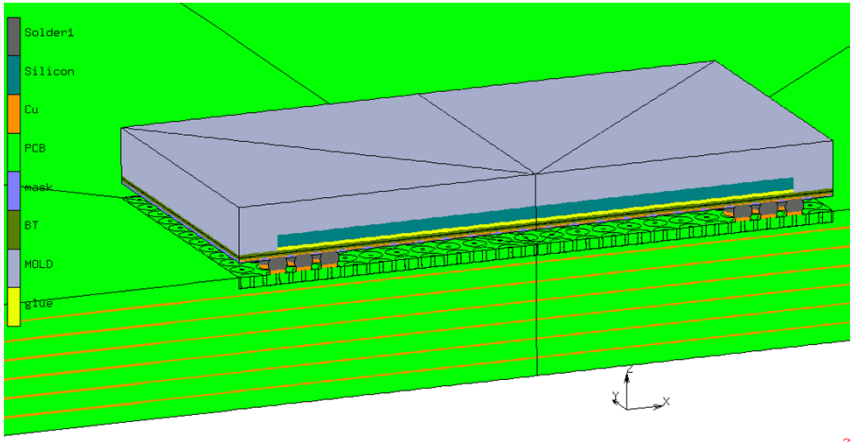
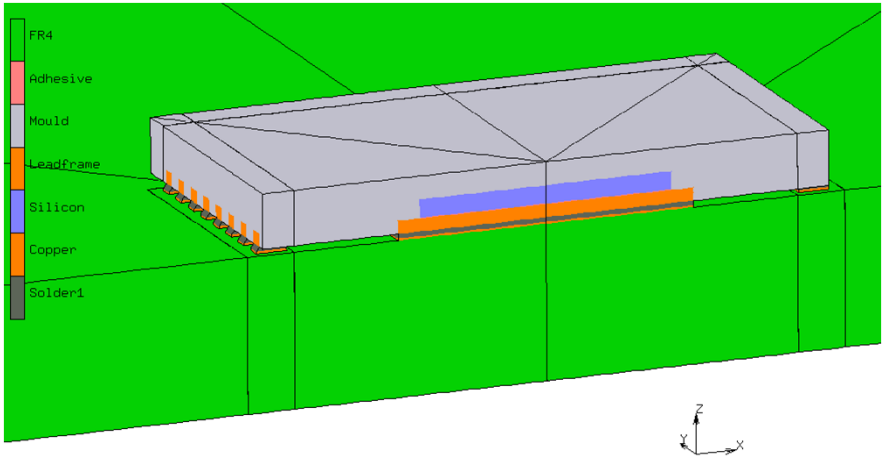
# Thermo-mechanical analysis of package assemblies using FEM

BGA228

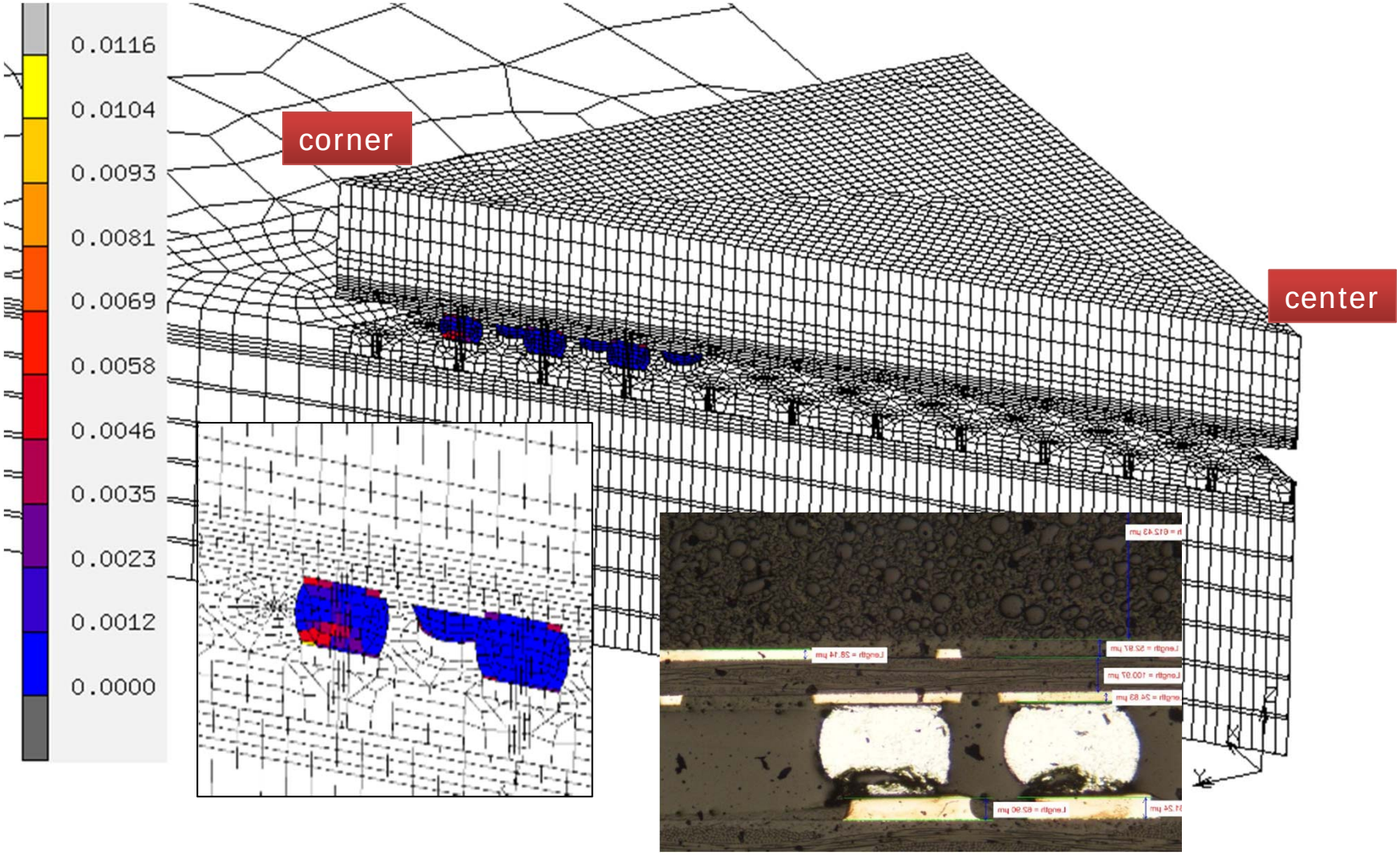



QFN64

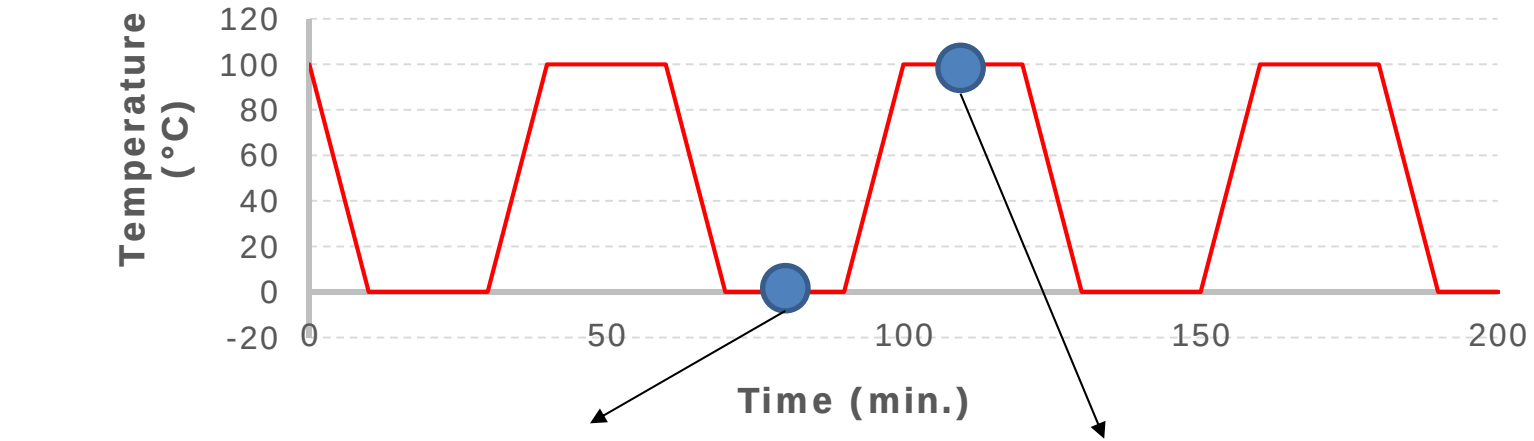


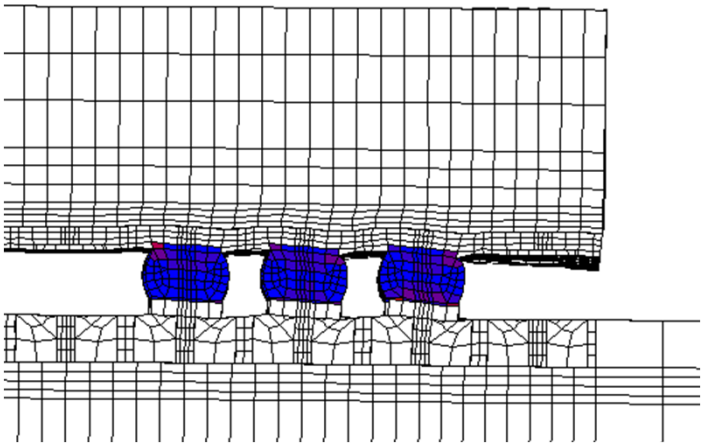

- ANAND creep model for simulation of creep deformation in the solder joint
- Creep strain per cycle can be translated into expected average life time to failure

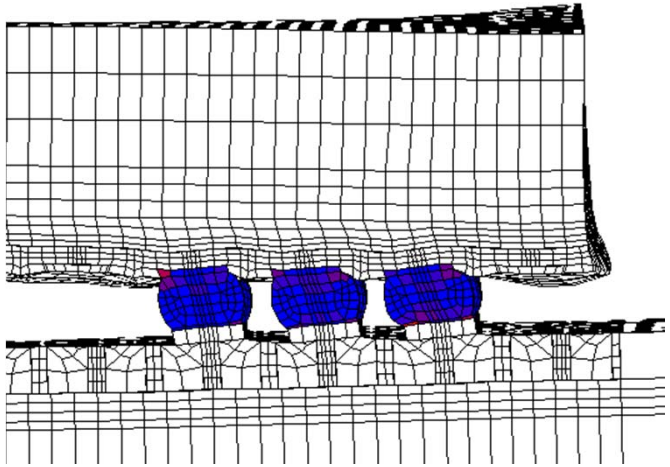
# Validation of critical joint/zone for BGA228



# Thermal cycling effect on solder joints

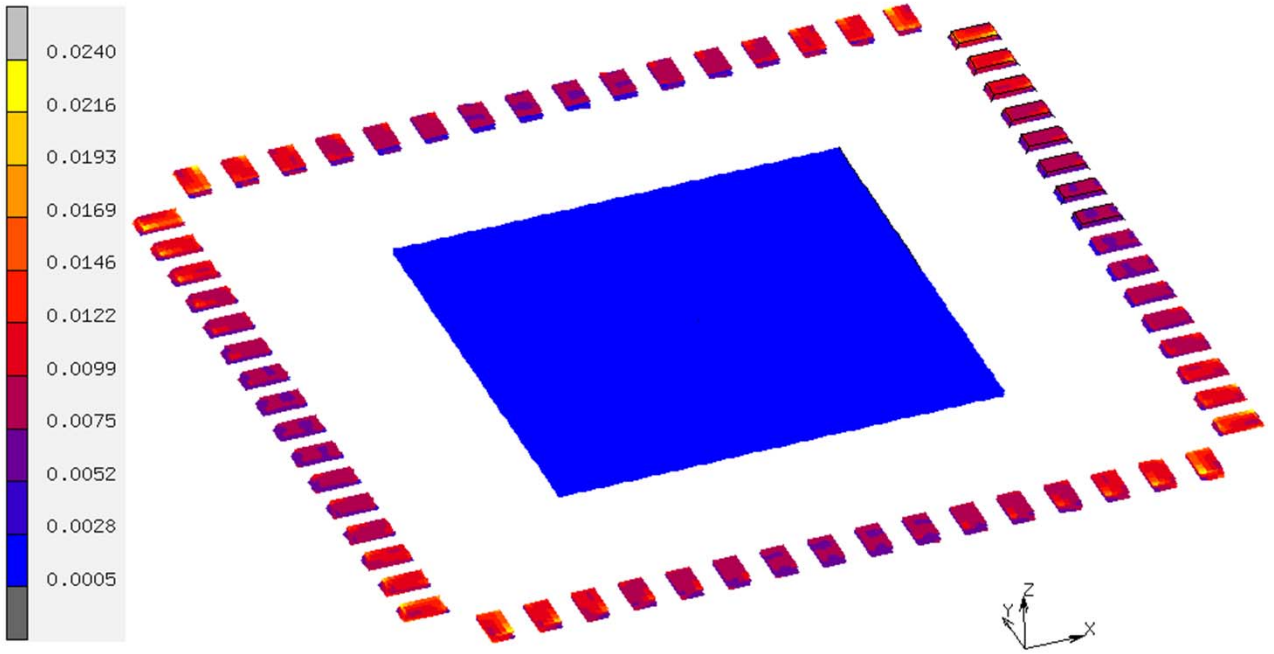


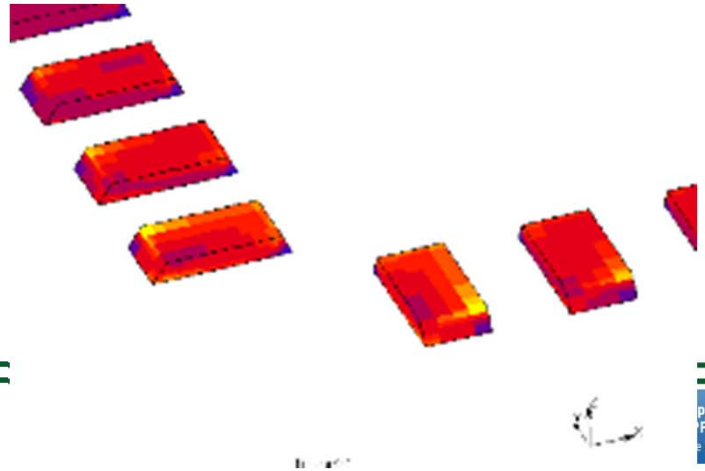



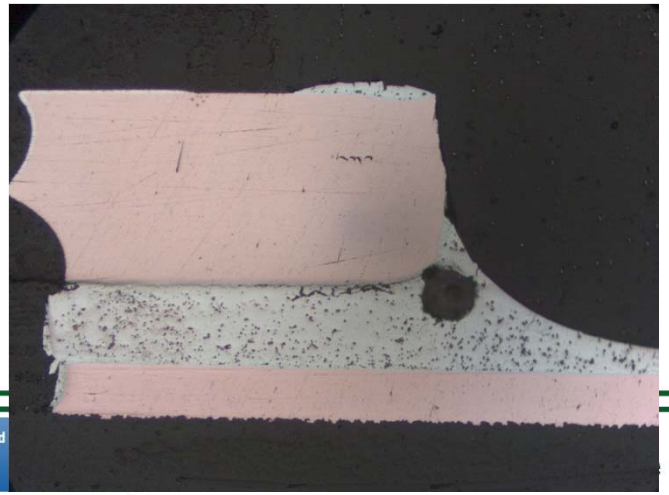


# Validation of critical joint/zone for QFN64

Creep strain (-)





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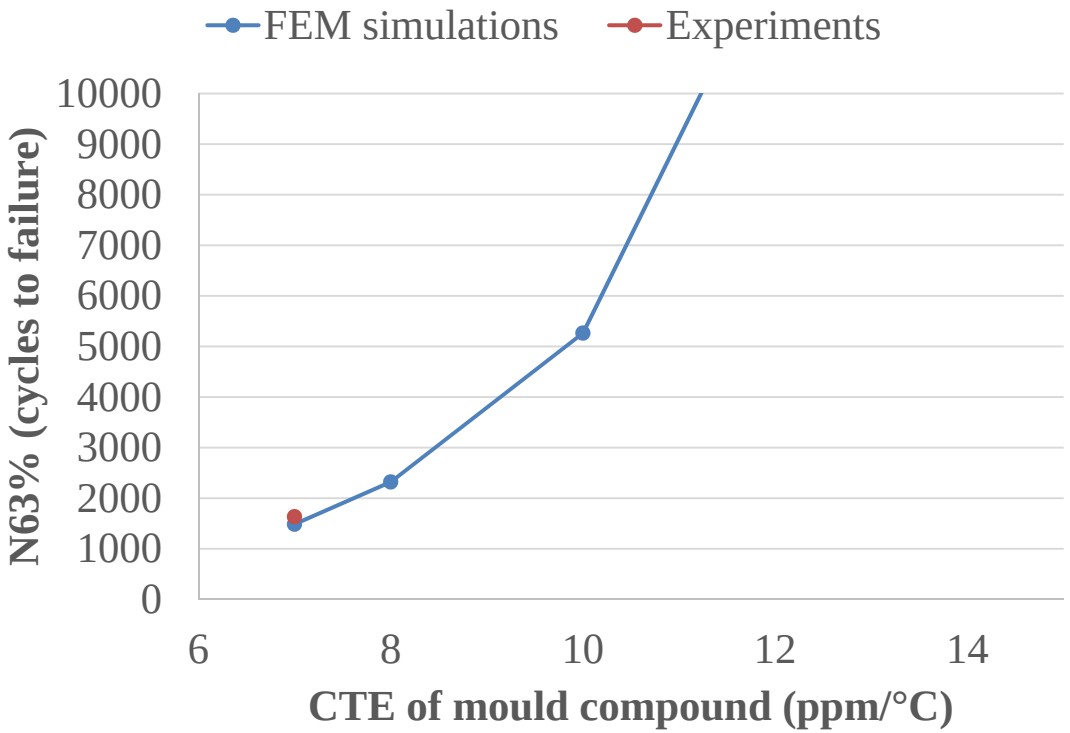
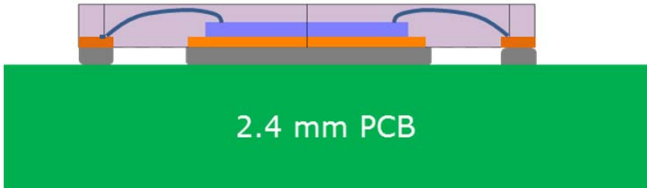
# Relation between life time and mould CTE (for QFN 64)




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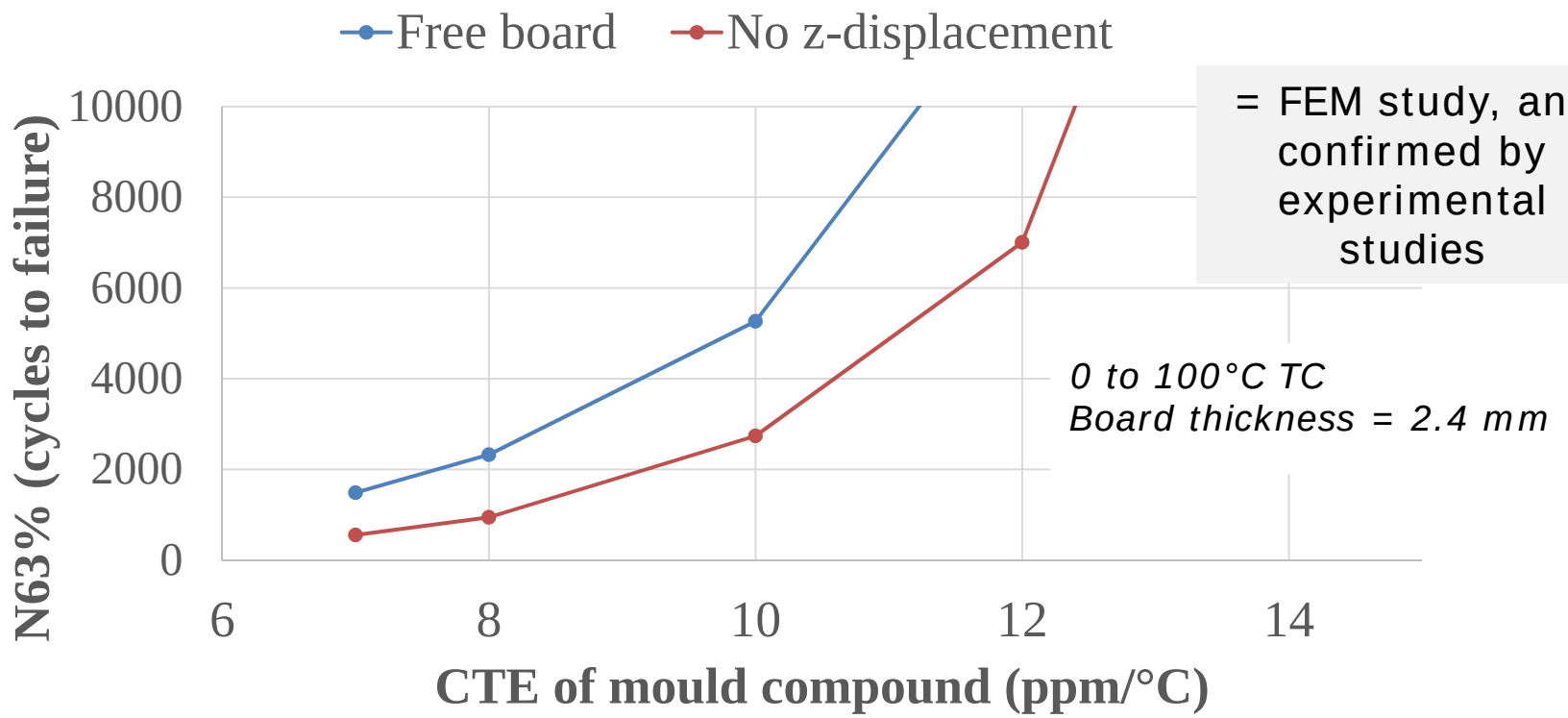
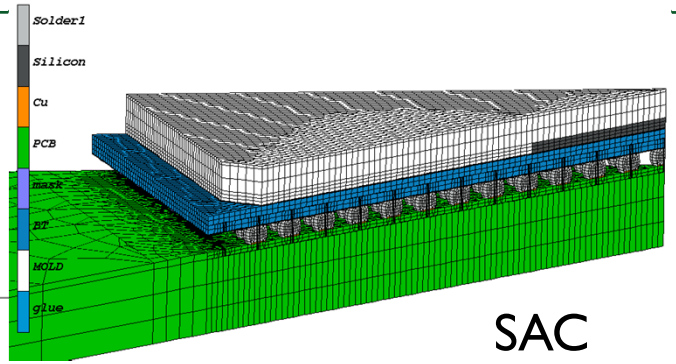
# QFN64 9x9mm: impact of board (non-)flexibility




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

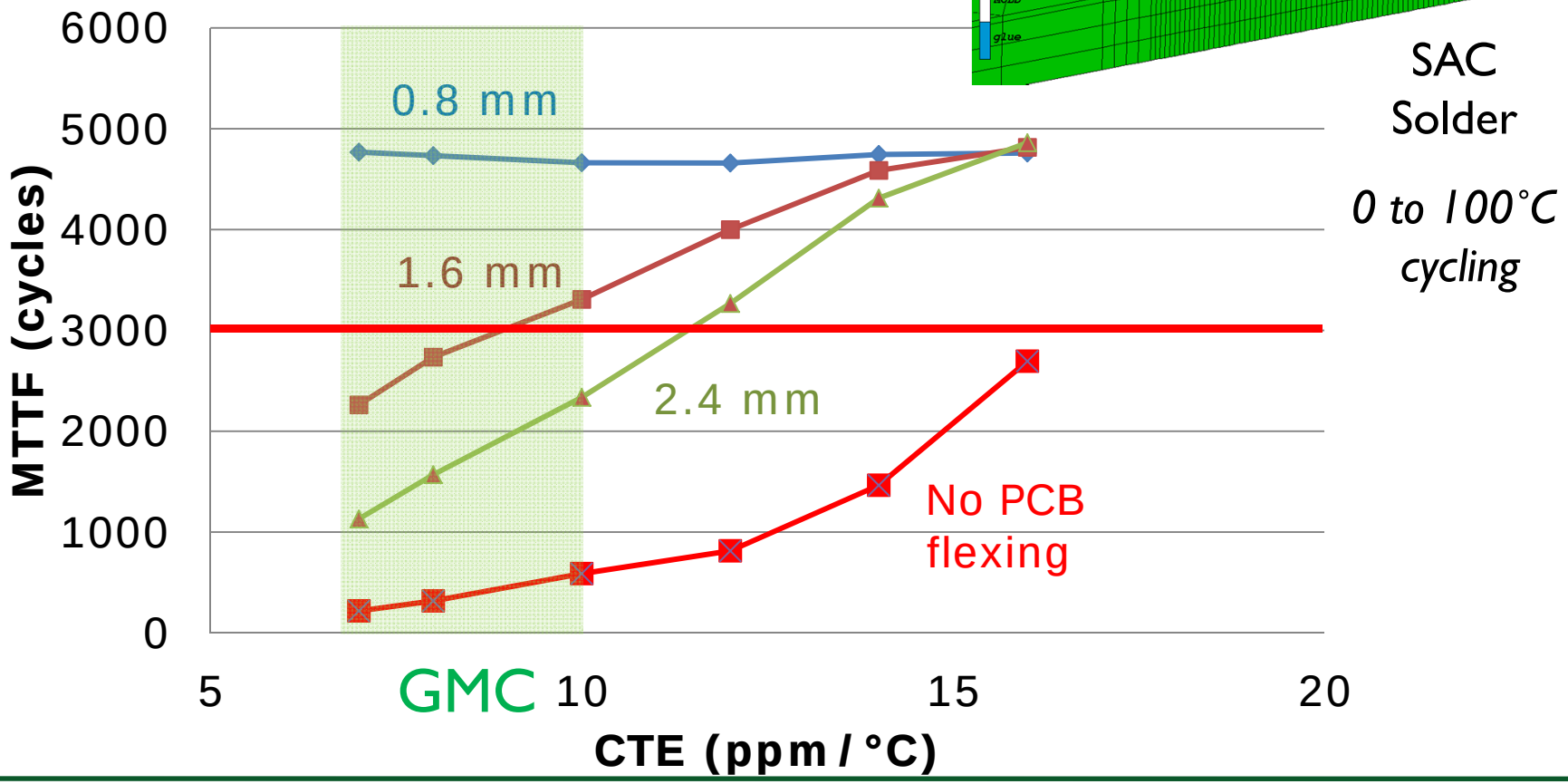
# Former results showing the impact of board flexibility

PBGA 27x27 area array
1.27mm pitch




SAC Solder

*0 to 100°C cycling*



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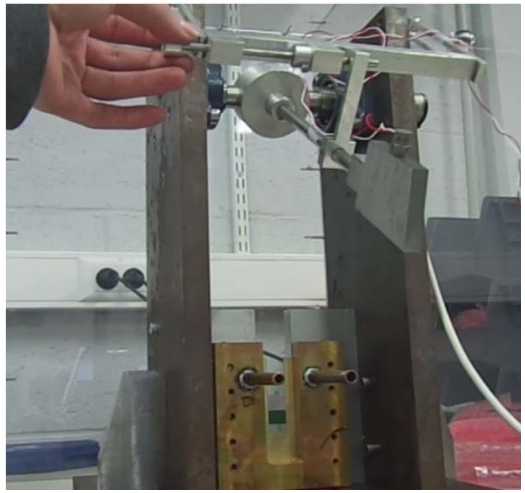
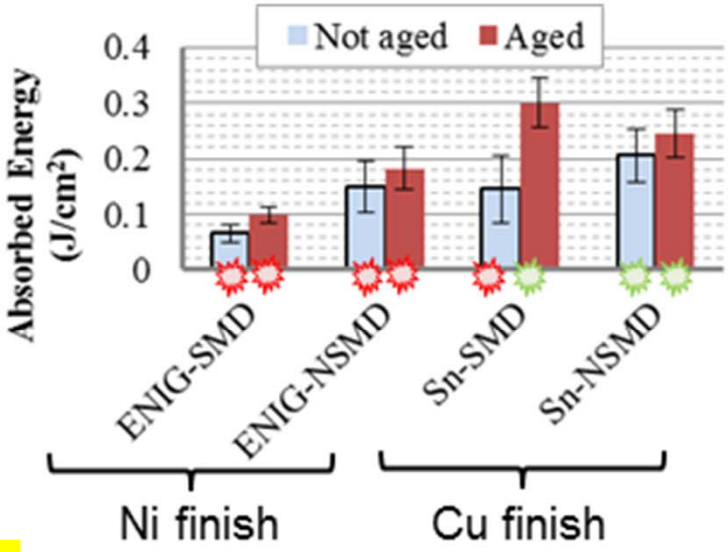
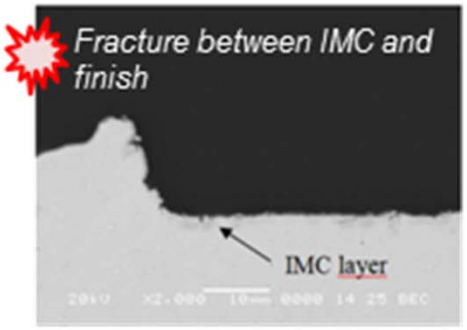
- Conclusions

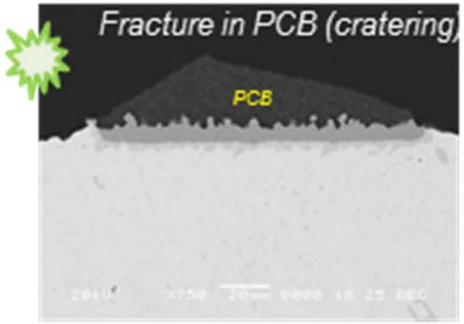
# **Stiffer** packages in combination with **NiAu** finish: more prone to IMC fractures under **shock** loads



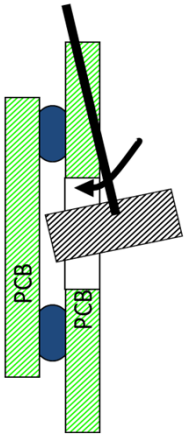



Ageing conditions: 1000 hours @150°C



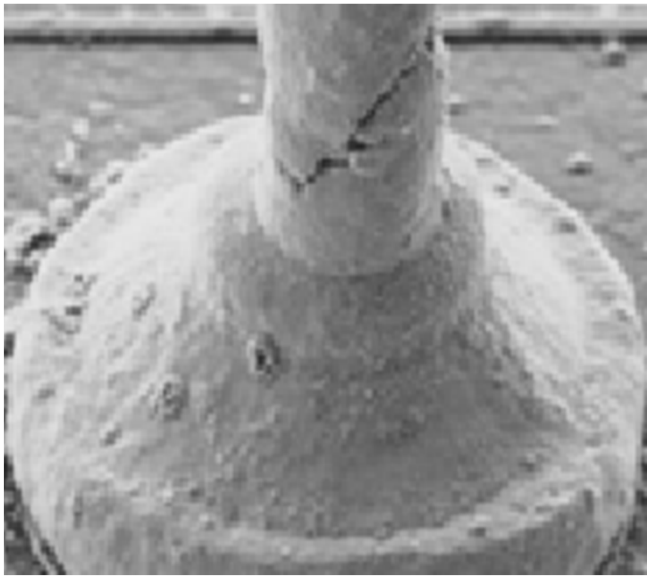

PULL mode

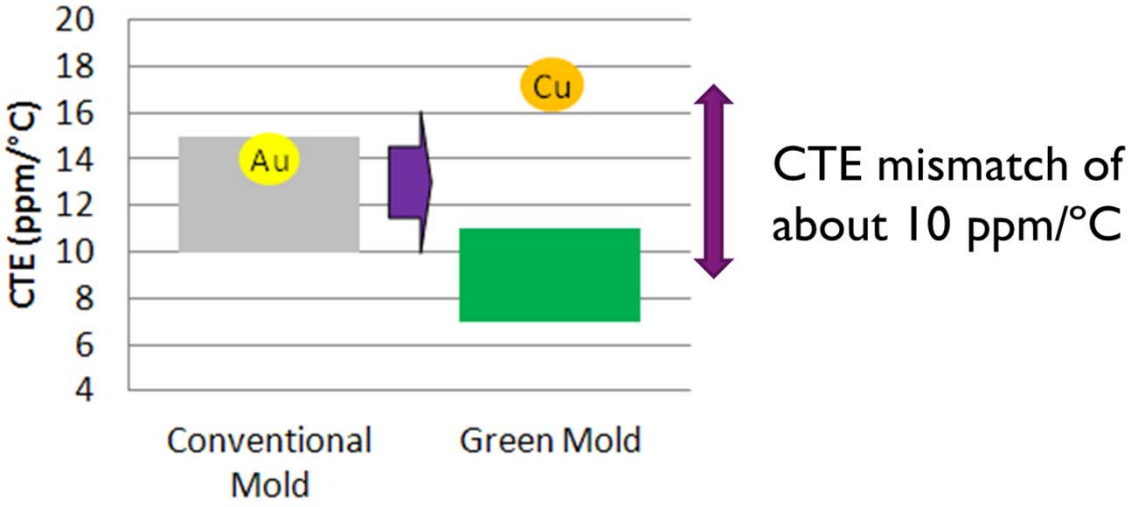



Solder joints on **Ni** have up to **50% lower** resistance to mechanical shock compared to joints on **Cu** based finishes

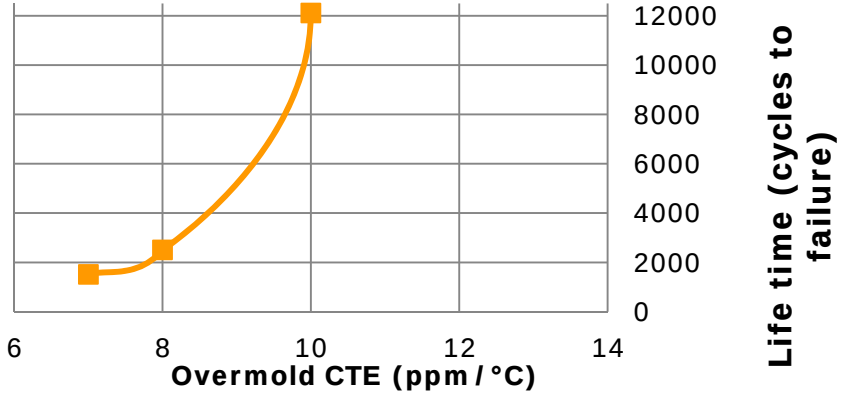
# Low-CTE mould compounds in combination with **Cu wire** bonds: more risk for wire fatigue

**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

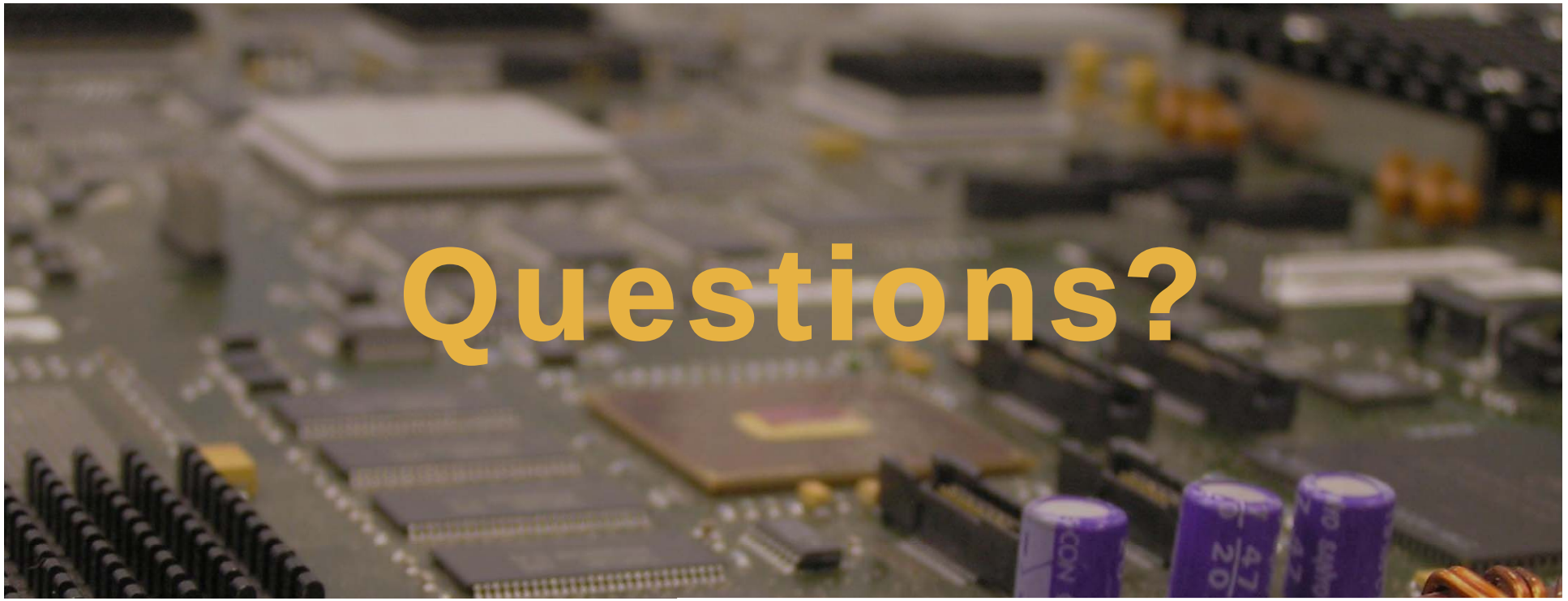


# Outline

- 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

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