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Board level reliability

simulation becomes inevitable

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‘In reliability assessment experiments and simulations should go hand in hand.’

No experiments without support of models

No model-simulations without experimental verification (falsification)

Contents

- Introduction
- Examples
  - Translation factors, board stiffness, cyclic bending
- Discussion
- Conclusions

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Trends & consequences

- Lead free **è** SACXYZ
- Miniaturization **è** Increased thermal loads
- Portable applications **è** Mechanical loads
- Shorter development cycle **è** Advanced testing
- System-in-package, MEMS, etc. **è** µ/M-System Level Reliability

è Simulation techniques to assist experiments **ç**

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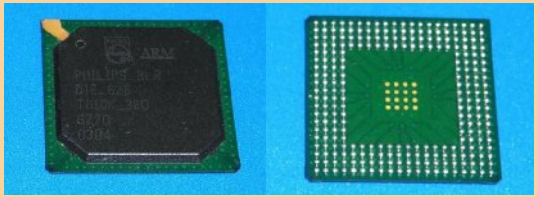
Translation factors

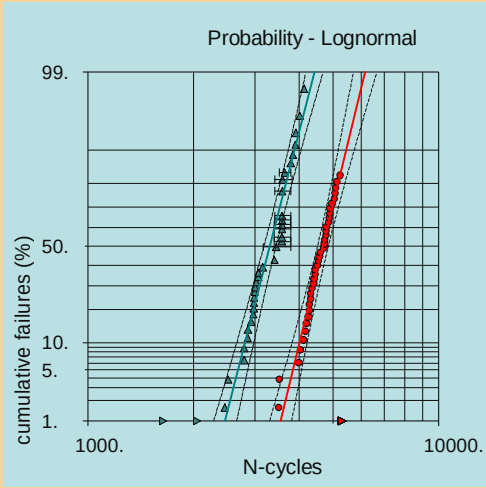
Experiment on BGA256

- Use of acceleration factors from test to operational conditions
  - Physical model
  - Coffin-Manson (fatigue)

$$\frac{\Delta e}{2} = \frac{s'_f}{E}(2N_f)^b + e'_f(2N_f)^c$$



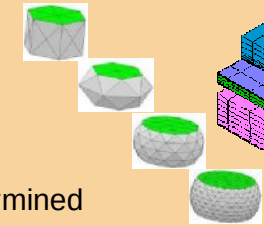
TST -55ºC/+125ºC/40’

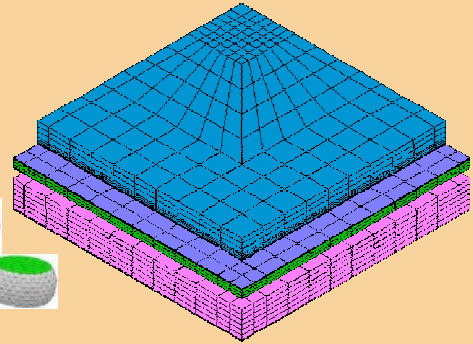


TCT -40ºC/+125ºC/60’

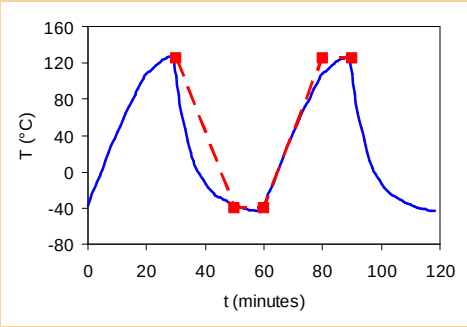
Translation factors

FEM





- Quarter BGA modeled
  - Solder ball geometry determined with surface evolver
  - Only critical solder ball fully modeled
- Material properties
  - Solder has creep and plasticity
- Loading
  - TCT -40°C/125°C/60’
  - TST -55°C/125°C/40’

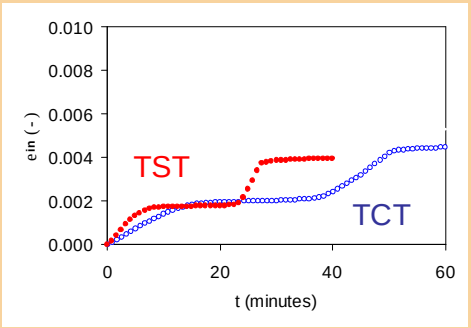


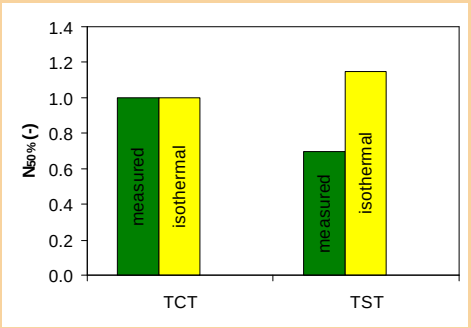
(FEM-work by Marjolein Jansen, Philips Applied Technologies)

Translation factors

FEM

- Calculation of inelastic strain
  - Assumed isothermal situation
- Comparison with experiment
  - Trend incorrect

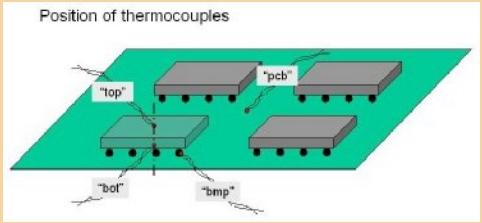


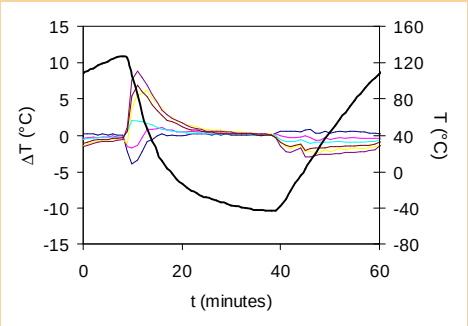


Translation factors

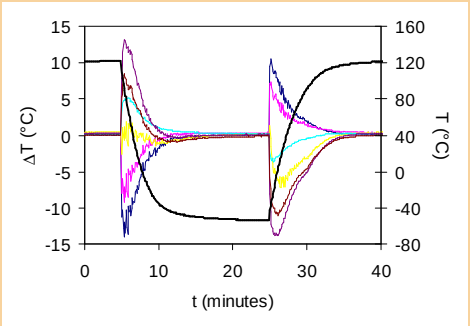
Experiment-2

- Temperature gradients
  - ΔT: package - board





TCT -40ºC/+125ºC/60’

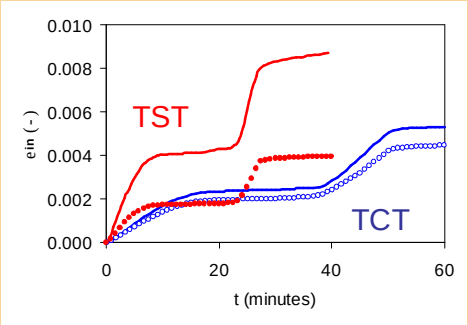


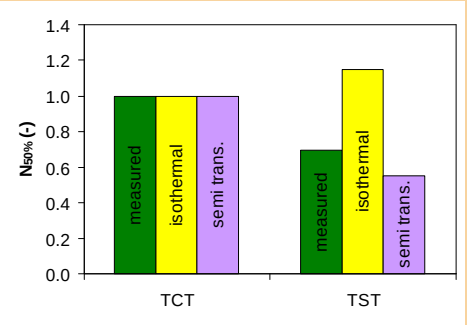
TST -55ºC/+125ºC/40’

Translation factors

FEM-2

- Inelastic strain
  - Semi-transient model
  - Larger strain in TST
- Comparison with experiment
  - Trend correct





(Microelectronics Reliability 47 (2007) 444–449)

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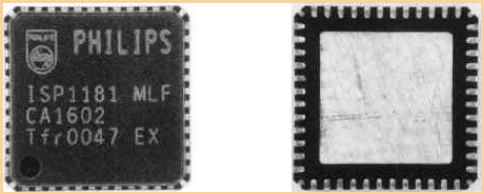
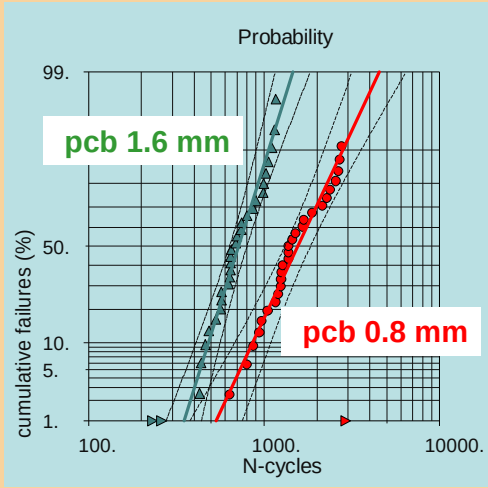
Assembly stiffness

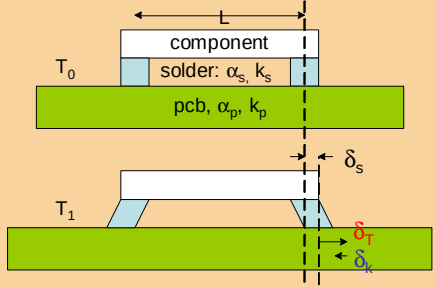
- Use of models to extrapolate in assembly variations
  - HVQFN48
  - -40ºC/+125ºC/60'-cycle
  - Pcb-thickness 1.6 & 0.8 mm





Assembly stiffness

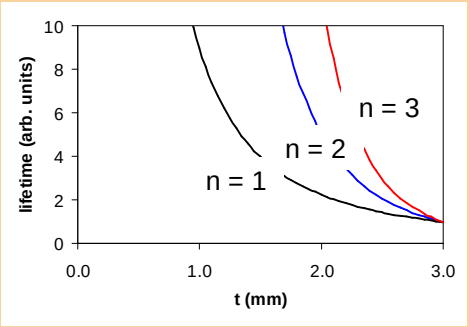
Analytical model



- Spring system
  - Thermal mismatch: d_T
  - Pcb counteracts by stiffness: d_k
  - Net displacement: d_s
  - Energy in solder: $U_k = \frac{1}{2} k_s d_s^2$
  - Lifetime: $t \sim 1/U_k$
  - Stiffness board: $k_p \sim t_p^n$

$$t = 2k_s \left(\frac{1 + b\, t_p^n / k_s}{d_T b\, t_p^n} \right)^2$$

- Unknowns: n, k_s



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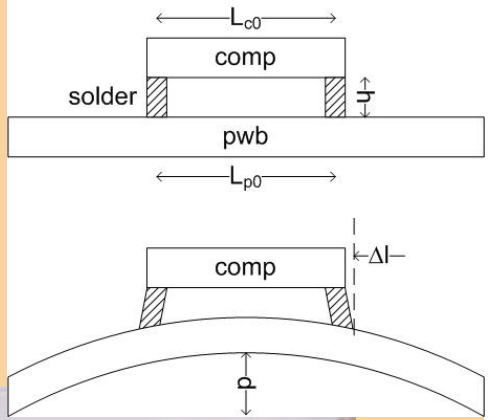
Mechanical bending

(co-operation with Calce)



Purpose

- Construct S-N-curve for cyclic bending
- For thermal cycling well-known

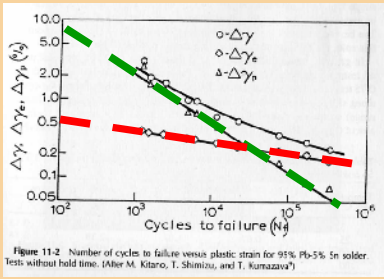
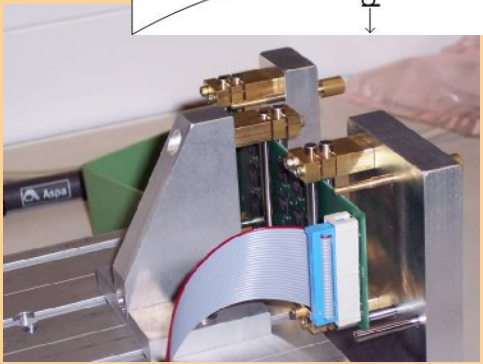


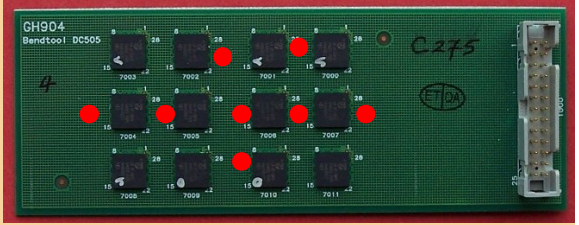
Figure 11-2 Number of cycles to failure versus plastic strain for 95% Pb-5% Sn solder. Tests without hold time. (After M. Kitano, T. Shimizu, and T. Kumazawa[9])

Thermal cycling, S. Vaynman, M. Fine, ch. 11 in: Solder joint reliability, ed. J. Lau

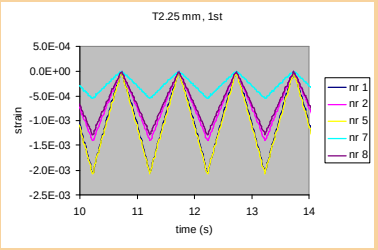


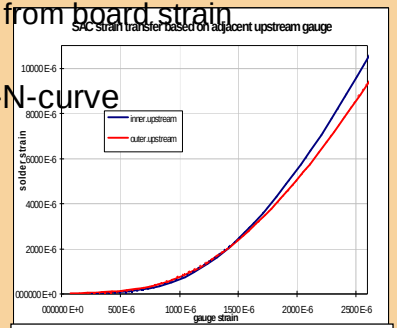
Mechanical bending

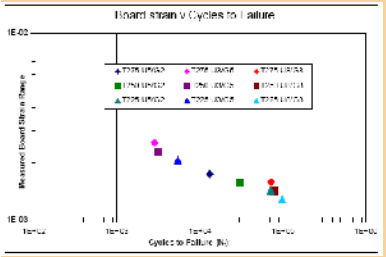
Approach

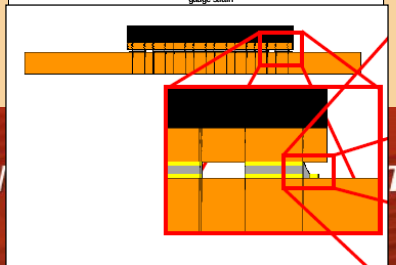


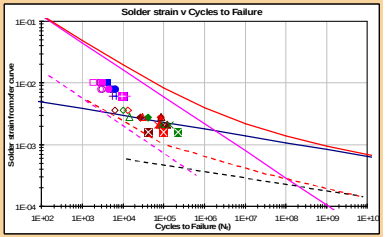
- Determine board strain S-N-curve
- FE-model of assembly
  - Transfer function from board strain to solder strain
- Construct solder S-N-curve
  - In progress











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Modeling

In the presented cases analytical and/or numerical models are necessary

Analytical:

- Fairly easy to understand
- Simple approach
- Almost everyone can use it

- One- or two-dimensional
- ‘Mono-physics’
- Many assumptions

Numerical:

- Multi-physics
- Three-dimensional
- More realistic

- Black box
- Complex (only ‘expert’ use)

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Conclusions

- Analytical/numerical simulations and experiments indeed go hand in hand
- Main goals are
  - Gain knowledge about product behavior under stress conditions
  - Design and carry out properly designed tests
- Many pitfalls …