H-C3 INTEGRATED GRADUATE PROGRAM

RELIABILITY ASSURANCE USING LIFE TIME INDICATORS FOR ENVIRONMENTAL LOADS

Tilman Eckert

Research Area C: Situation Aware Flexible Communication
Focus 1: Low-Power Wireless Sensor Nodes / Systems

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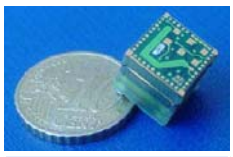
Reliability Assurance for Wireless Sensor Network Nodes

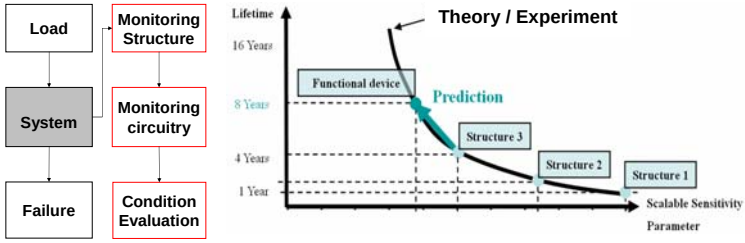


eGrain

- Sensors / Actors
- Wireless Communication Interface
- µController / Memory
- Energy Supply

- Technical Requirements:
  - Miniaturized
  - Mobile, stand-alone
  - Intelligent, networked
  - Reliable, energy-efficient

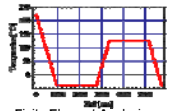
Autonomous Energy Supply
Energy Harvesting
Environmental Loads
(Temperature Cycles, Vibration)
Load
Limitation of Life Time



Condition Monitoring using Life Time Indicators

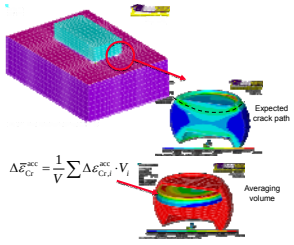
Design of a Life Time Indicator for Vibration and Thermal Load

- Flip Chip Life Time Indicator on FR4
- Thermal Cycling Profile



- Finite Element Analysis: Calculation of the accumulated equivalent creep strain $\Delta\varepsilon_{Cr}^{acc}$ per cycle using the temperature-, time-, and stress-dependent material law for SnAg3.5 solder:

$$\dot{\varepsilon}_{Cr} = c_1[\sinh(c_2\sigma)]^{c_3}\exp\left(-\frac{C_4}{kT}\right)$$

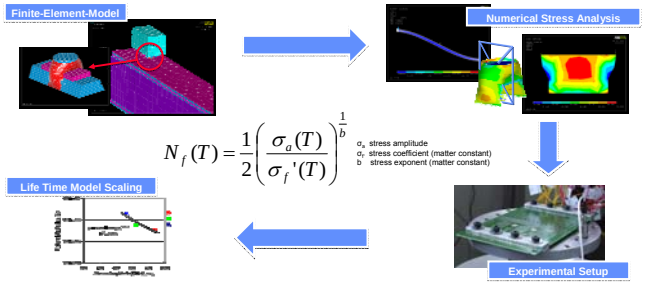


$$\Delta\bar{\varepsilon}_{Cr}^{acc} = \frac{1}{V}\sum\Delta\varepsilon_{Cr,i}^{acc}\cdot V_i$$

- Life Time Calculation using the Coffin-Manson-Relationship (SnAg3.5)

$$N_f = \Theta(\Delta\varepsilon_{Cr}^{acc})^c = 7.03(\Delta\varepsilon_{Cr}^{acc})^{-1,429}$$

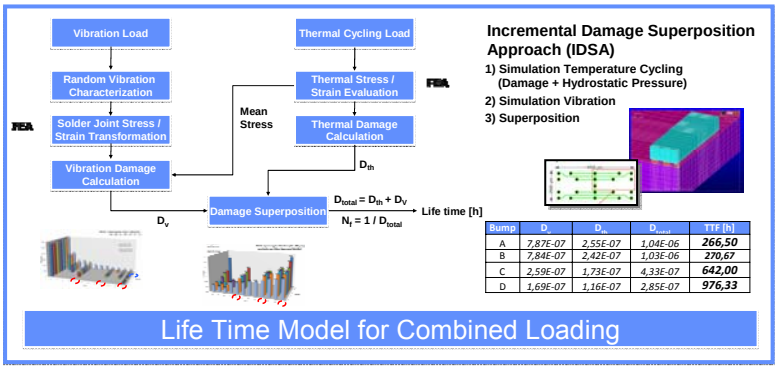
Life Time Model for Thermal Cycling



$$N_f(T) = \frac{1}{2}\left(\frac{\sigma_a(T)}{\sigma_f'(T)}\right)^{\frac{1}{b}}$$

σ_a stress amplitude
σ_f stress coefficient (matter constant)
b stress exponent (matter constant)

Life Time Model for Vibration



Bump	D_{th}	D_v	$D_{v,...}$	TTF [h]
A	7,87E-07	2,55E-07	1,04E-06	**266,50**
B	7,84E-07	2,42E-07	1,03E-06	**270,67**
C	2,59E-07	1,73E-07	4,33E-07	**642,00**
D	1,69E-07	1,16E-07	2,85E-07	**976,33**

Life Time Model for Combined Loading

Optimized Life Time Indicator