

RELIABILITY ASSURANCE USING LIFE TIME INDICATORS FOR ENVIRONMENTAL LOADS

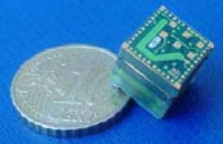
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Research Area C: Situation Aware Flexible Communication
Focus 1: Low-Power Wireless Sensor Nodes / Systems

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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

Load

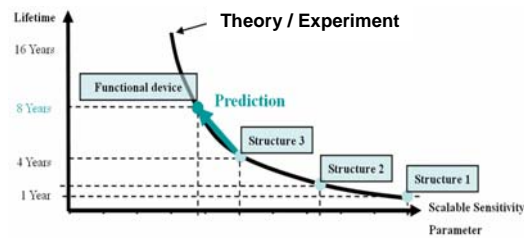
System

Failure

Monitoring Structure

Monitoring circuitry

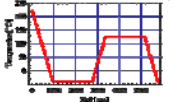
Condition Evaluation

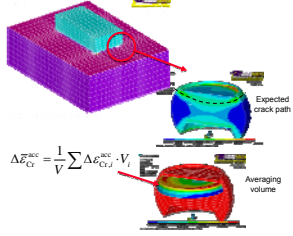


Condition Monitoring using Life Time Indicators

Design of a Life Time Indicator for Vibration and Thermal Load

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





Expected crack path

Averaging volume

$$\Delta \epsilon_{Cr}^{acc} = \frac{1}{V} \sum \Delta \epsilon_{Cr}^{acc} \cdot V_i$$

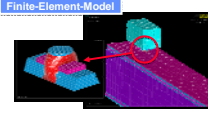
- Finite Element Analysis: Calculation of the accumulated equivalent creep strain $\Delta \epsilon_{Cr}^{acc}$ per cycle using the temperature-, time-, and stress-dependent material law for SnAg3.5 solder:

$$\dot{\epsilon}_c = c_1 [\sinh(c_2 \sigma)]^n \exp\left(-\frac{C_3}{KT}\right)$$
- Life Time Calculation using the Coffin-Manson-Relationship (SnAg3.5)

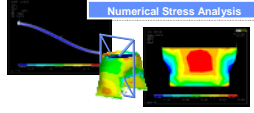
$$N_f = \Theta (\Delta \epsilon_{Cr}^{acc})^c = 7.03 (\Delta \epsilon_{Cr}^{acc})^{-1.429}$$

Life Time Model for Thermal Cycling

Finite-Element-Model



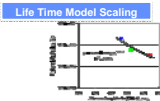
Numerical Stress Analysis




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

σ_a : stress amplitude
 σ_j' : stress coefficient (matter constant)
 b : stress exponent (matter constant)

Life Time Model Scaling



Experimental Setup



Life Time Model for Vibration

Vibration Load

Random Vibration Characterization

Solder Joint Stress / Strain Transformation

Vibration Damage Calculation

D_v

Thermal Cycling Load

Thermal Stress / Strain Evaluation

Thermal Damage Calculation

D_{th}

Mean Stress

Damage Superposition

$D_{total} = D_{th} + D_v$

$N_f = 1 / D_{total}$ Life time [h]

Life Time Model for Combined Loading

Incremental Damage Superposition Approach (IDSA)

- Simulation Temperature Cycling (Damage + Hydrostatic Pressure)
- Simulation Vibration
- Superposition

Bump	D_v	D_{th}	D_{total}	YTF [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

Optimized Life Time Indicator