Advanced Testing

Physics-of-Failure

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Contents

- Reasons for “advanced” testing
- Physics-of-Failure
- Fatigue
- Stretchable electronics
- Summary

Why testing?

- Qualification & release tests
  - Verification
  - Validation
- Accelerated & aggravated tests
- Specific tests
- Physics of failure

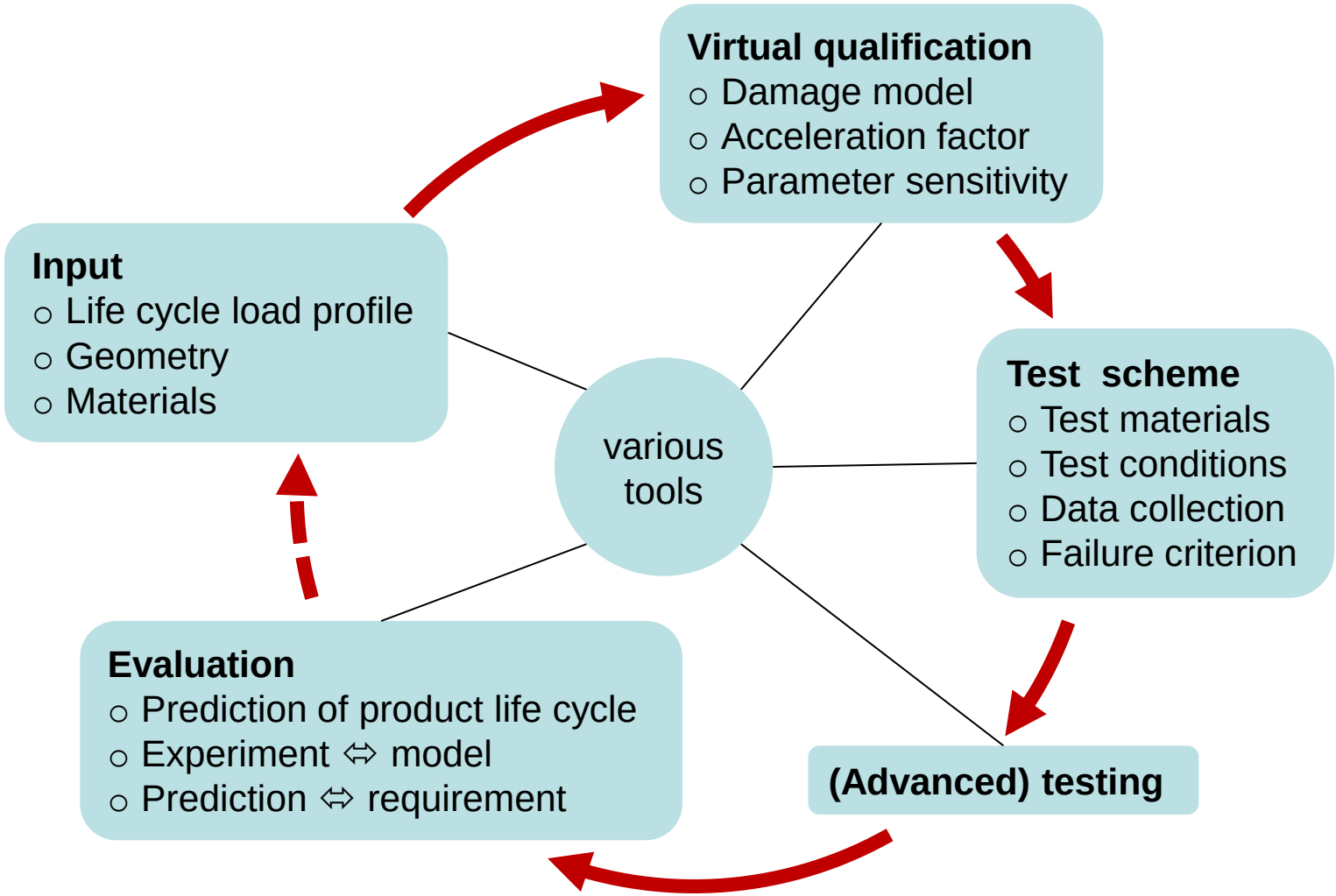
➔ Standard tests (e.g. IEC60068-)
  - "did I make the thing right?"
  - "did I make the right thing?"

➔ Not necessarily standard
  - Use degradation models

➔ Not standard
  - Develop degradation models
  - Quest for (new) failure modes
  - New technologies
  - New applications

➔ Structured approach

PoF – Approach for Reliability Assessment



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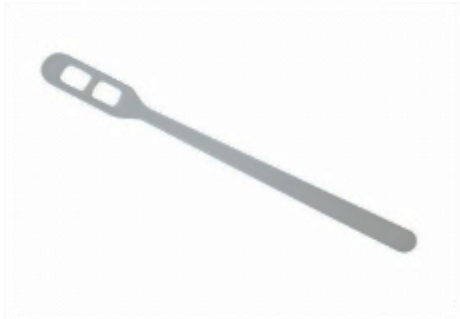
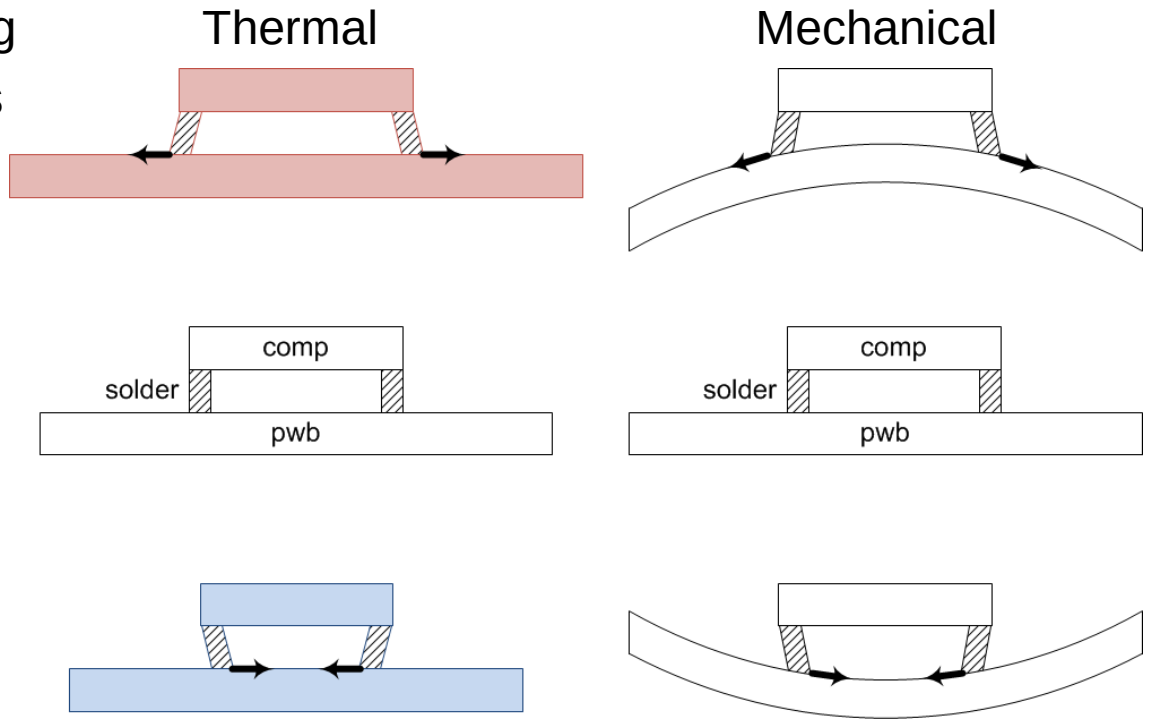
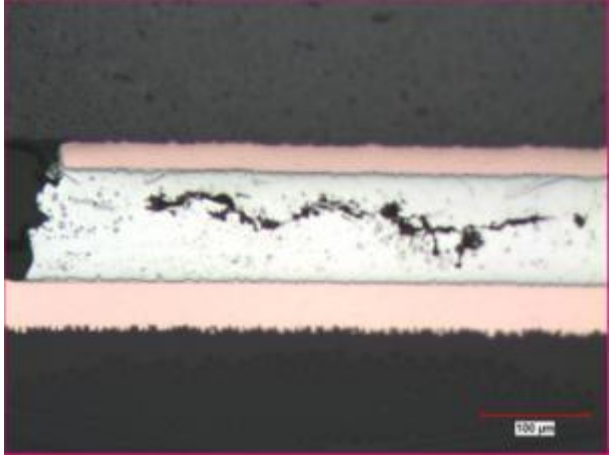
Fatigue

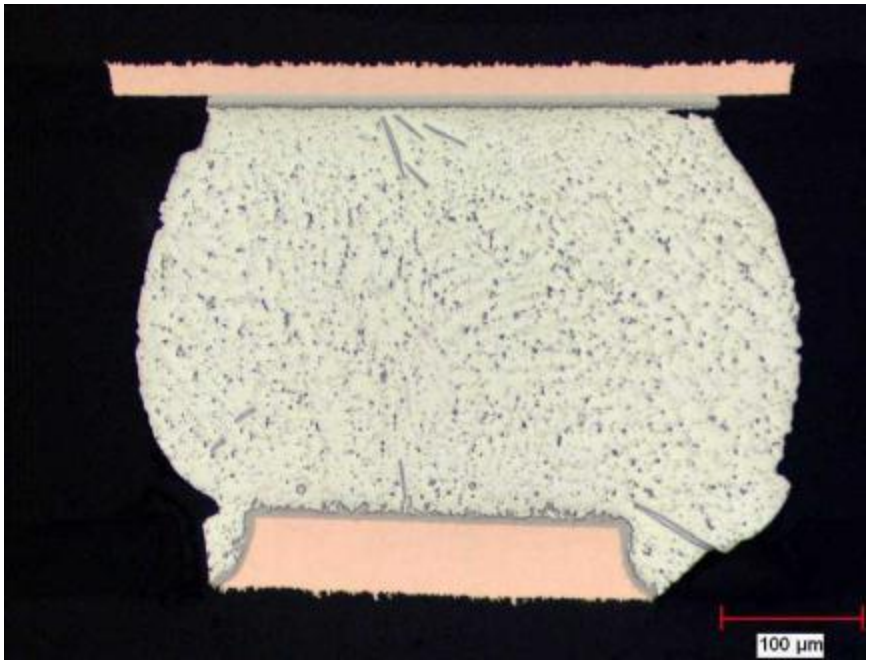
- Cyclic loading – unloading
- Deformation accumulates
- Finally fracture occurs

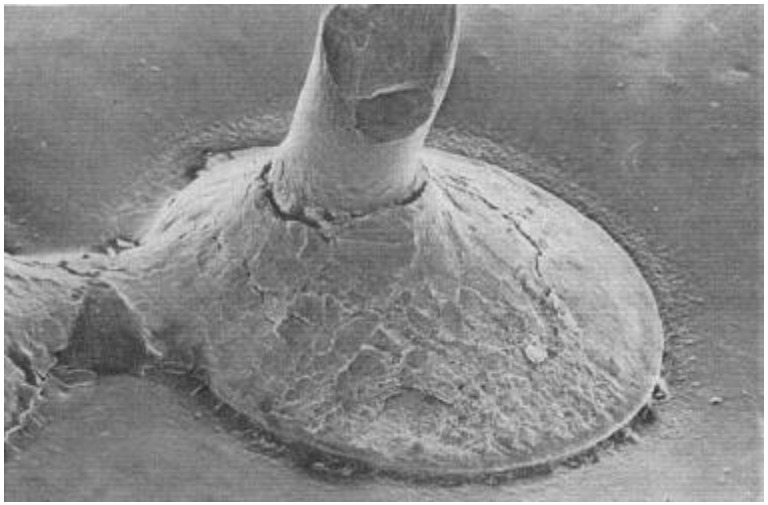




Fatigue micrographs soldered interconnections



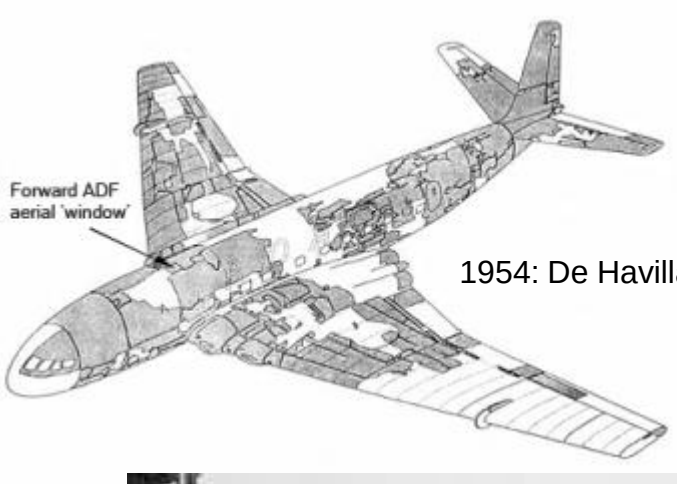




1980: Alexander Kielland

Cyclic loading – (In)famous examples

1842: Meudon



1954: De Havilland Comet

1998: ICE Eschede

1943: SS Schenectady

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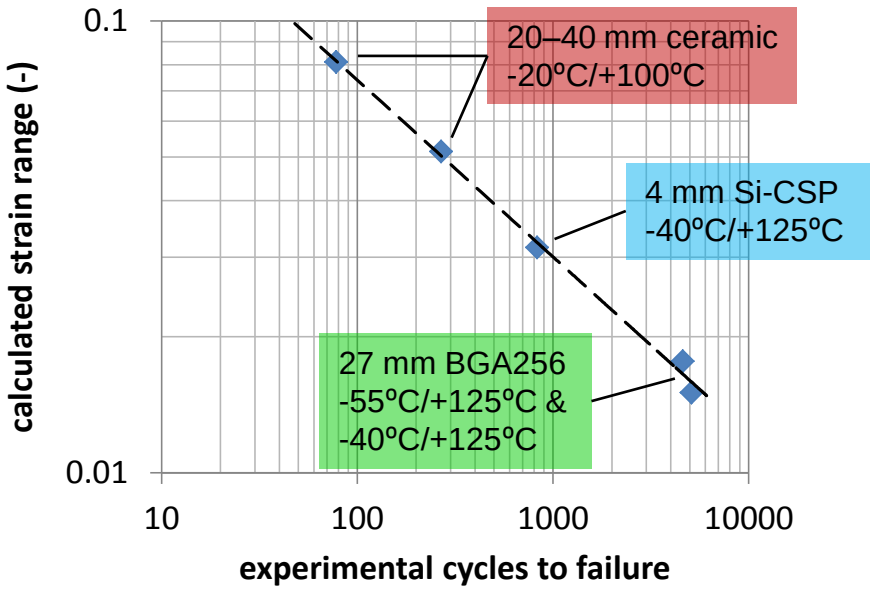
Fatigue models
“strain vs cycles”

- Coffin-Manson relation
  - Low cycle fatigue
  - Mostly plastic strain

$$\frac{\Delta\varepsilon_p}{2} = \varepsilon_f' \frac{1}{(2N_f)^C} \propto \frac{1}{N_f^{0.4}}$$

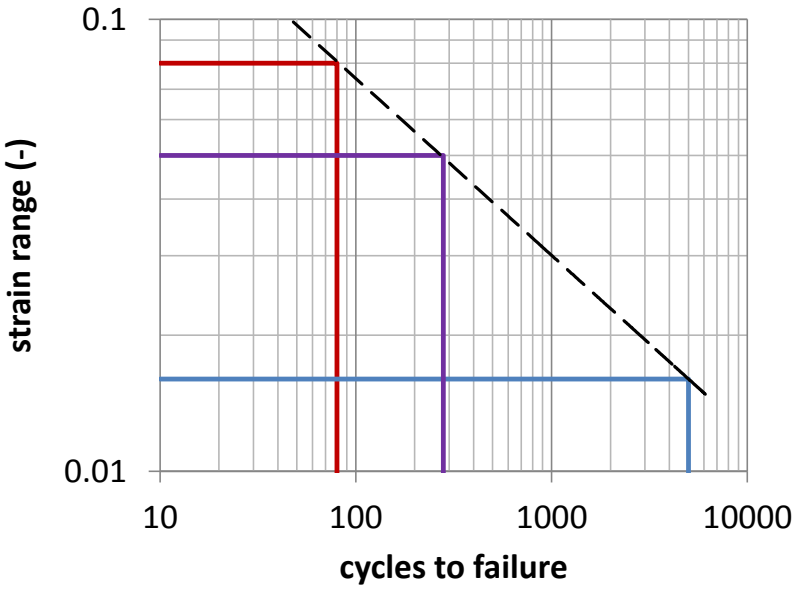
- Interplay of
  - Test load
  - Material combination

Lead-free solder (SAC)



- Use
  - Translate between test conditions
  - Estimate operational life

- Tests to calibrate the model
- Determine strain in operational conditions
- Estimate operational lifetime



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Stretchable electronics

STretchable **EL**ectronics for **L**arge **A**rea Applications

- Monitoring of human body functions
  - Recovery from illness
  - Activity related

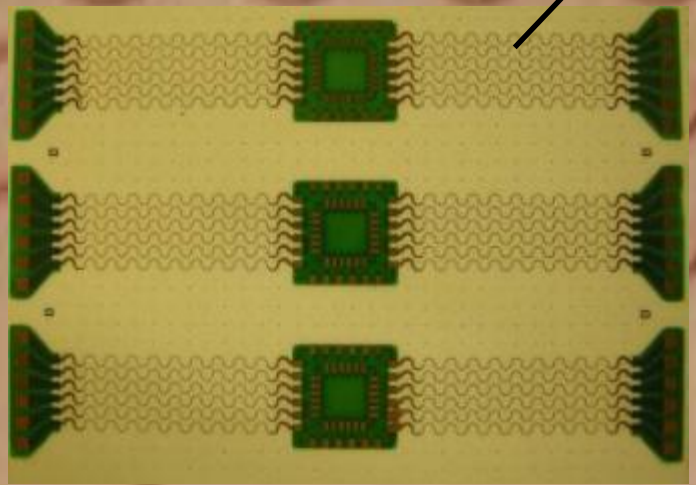
- Requirements
  - Full measurement capabilities ➔ direct skin contact
  - Wearing comfort ➔ flexible, stretchable, soft-touch

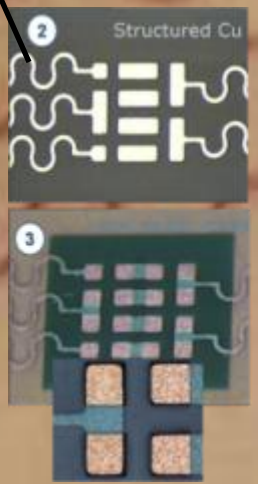
- Relation between technology capability & application mission profiles

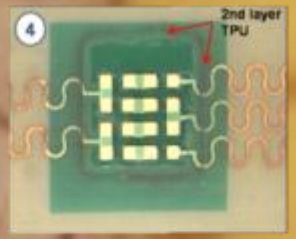
- IST-028026, 2006 – 2009

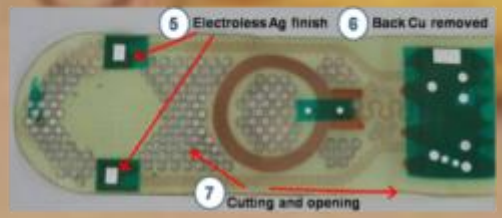
Technologies
“SCB, SMI, SPB”

Meandering Cu-tracks
to enable elongation







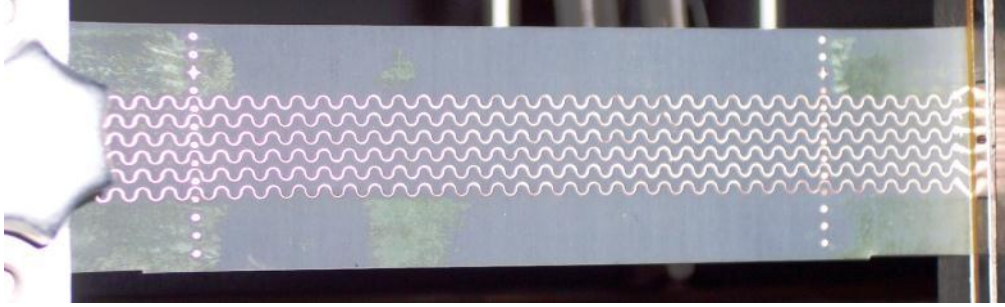


Applications & mission profiles

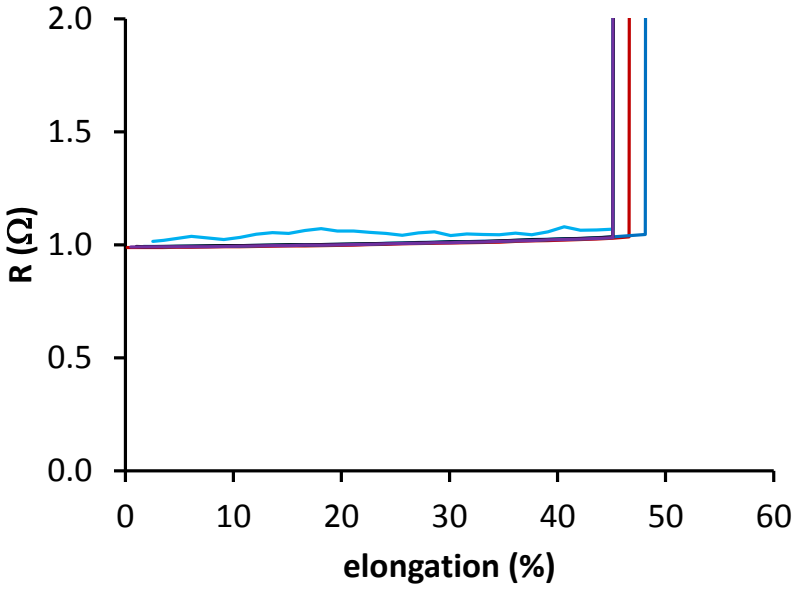
application	apply		use	
	strain (%)	cycles	strain (%)	cycles
Fitness	5	14,400	3	1,500,000
Respiratory	5	750	3	5,000,000
Band aid	15	100	3	10,000,000
Shoe insole	15	2	2	900,000

Test must cover entire field of strain amplitude and stretching cycles

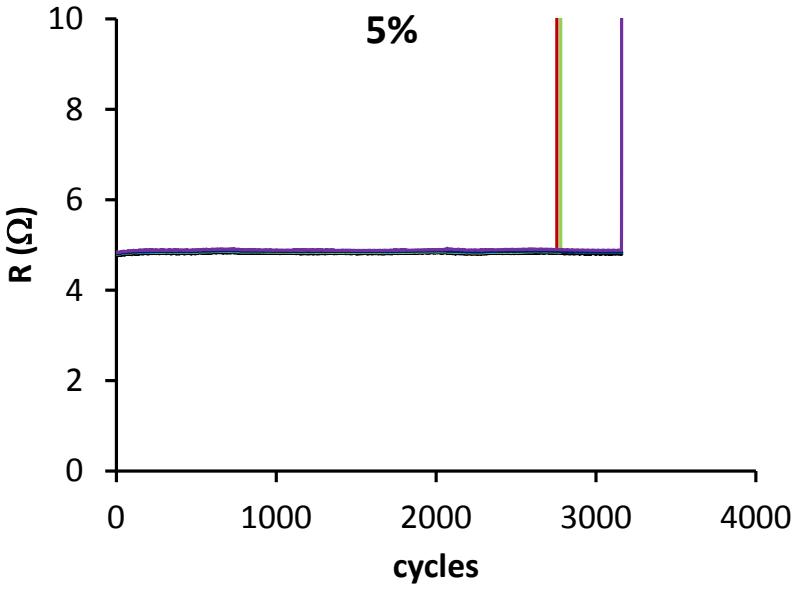
Test procedure



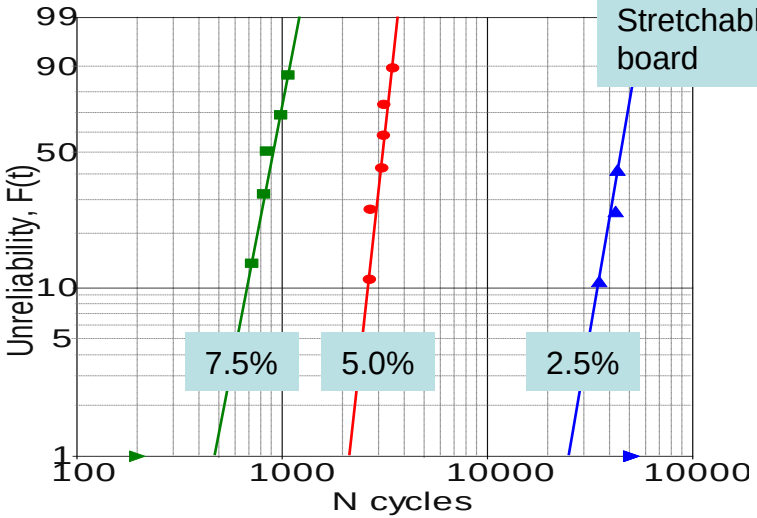
Maximum elongation: ε_{max}

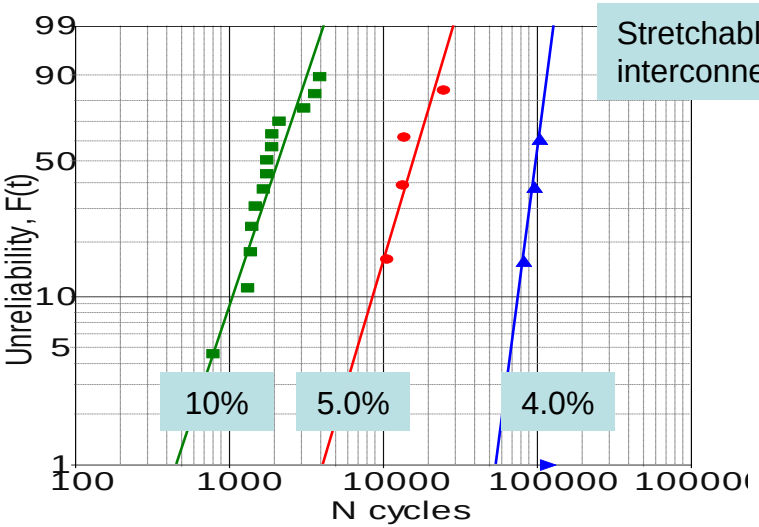


Cycle to failure at fraction of ε_{max}



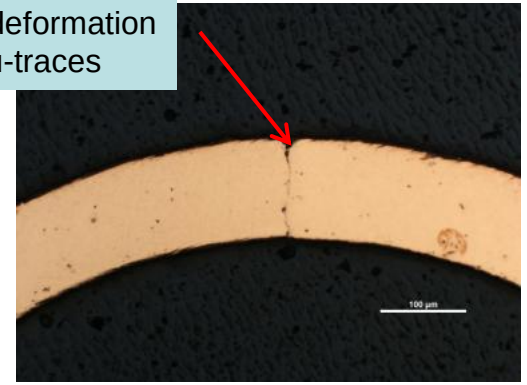
Statistical evaluation

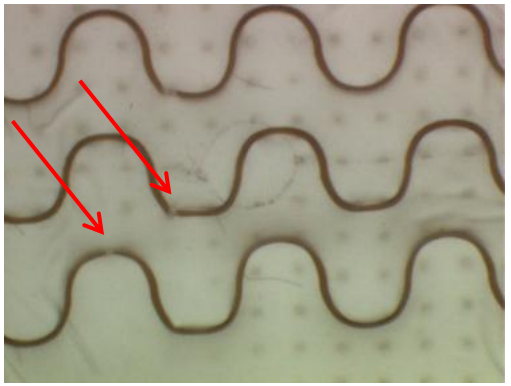




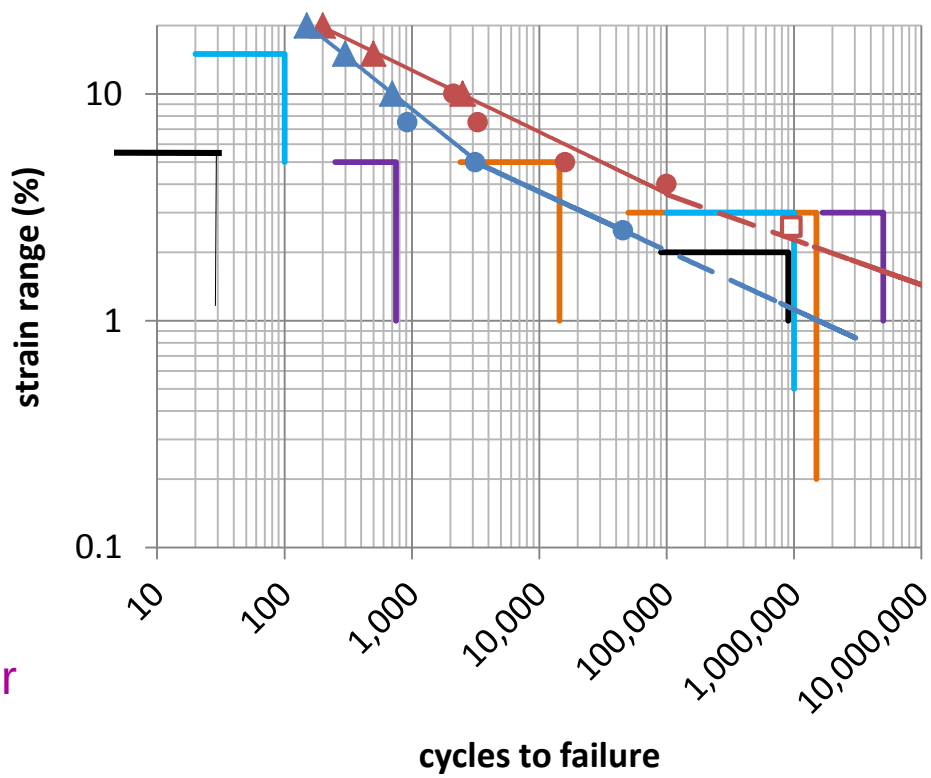
Failure analysis

Fatigue deformation of Cu-traces





Technology capability



$$\frac{\Delta\varepsilon_p}{2} = \varepsilon_f' \frac{1}{(2N_f)^C}$$

Cu-fatigue
C = 0.27–0.36

Fitness monitor
Respiratory monitor
Band aid
Shoe insole

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- Advanced testing
  - Application to new technologies
  - Identification of failure modes & mechanisms
  - Design of accelerated/aggravated tests
- Physics of Failure: structured methodology
- “Old” mechanisms ⇔ new applications