

PROOF OF RELIABILITY USING INTERCONNECT **S**TRESS **T**EST



Reliability

Part 2

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AGENDA



- 1** Introduction: PCB - reliability
- 2** How to “measure” reliability
- 3** Display of reliability test results
- 4** Influencing factors
- 5** Portfolio of reliability related service features

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RELIABILITY OF PCBs

Introduction



- What is reliability?

“Reliability describes the ability of a system or component to function under stated conditions for a specified period of time.”

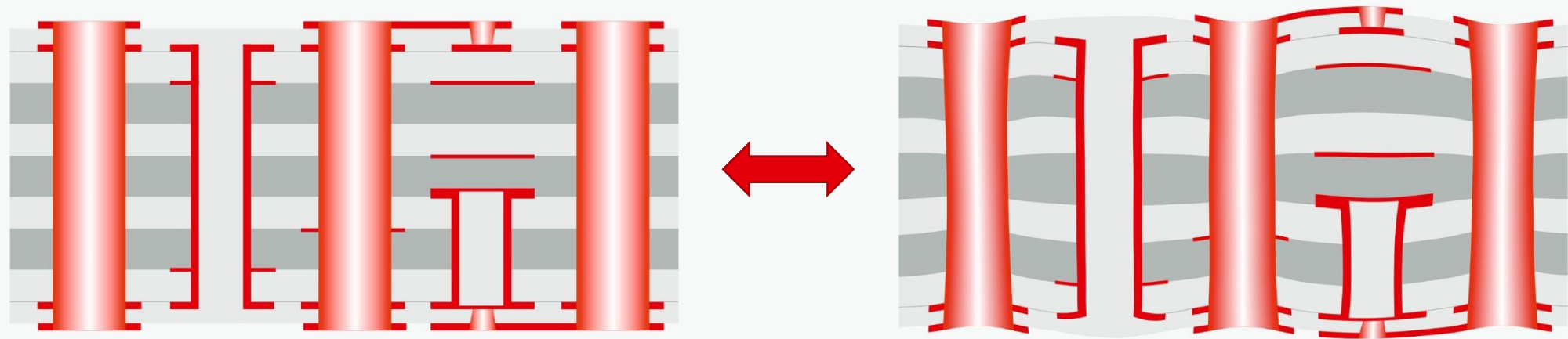
RELIABILITY OF PCBs

Introduction



■ Reliability of PCBs

- Providing of the desired electrical functions for the whole specified service life
- Even flawless PCBs will fail after some time if they are exposed to temperature fluctuations. The root cause for this are the different Coefficients of Thermal Expansion in z-direction (CTE_z) of Copper and base materials.



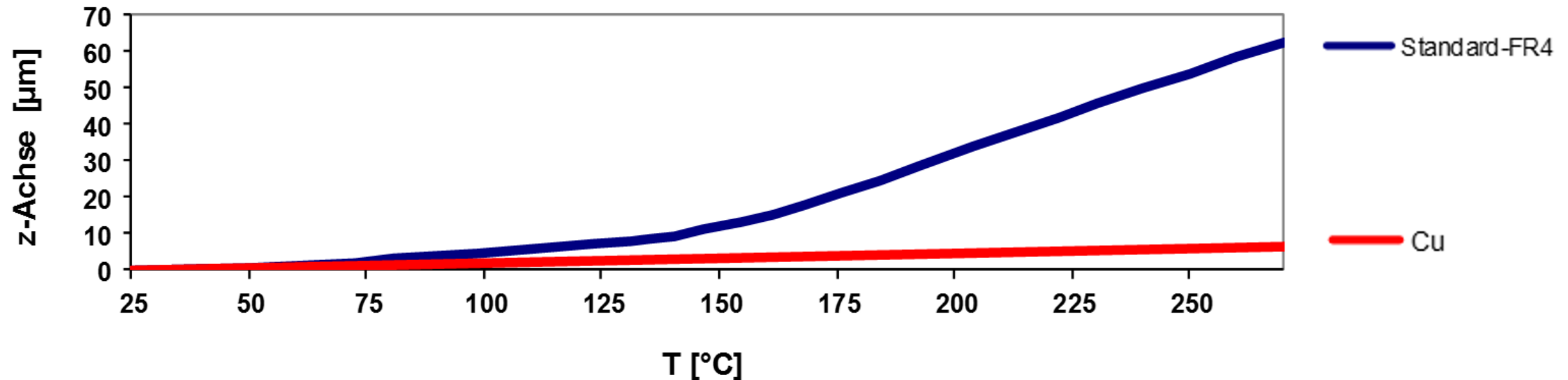
RELIABILITY OF PCBs

Introduction



Comparison of thermal expansion in z-direction of Copper (Cu) and base material (FR4)

- FR4: CTEz = 40ppm/C°
- PCB-thickness: 1,60mm

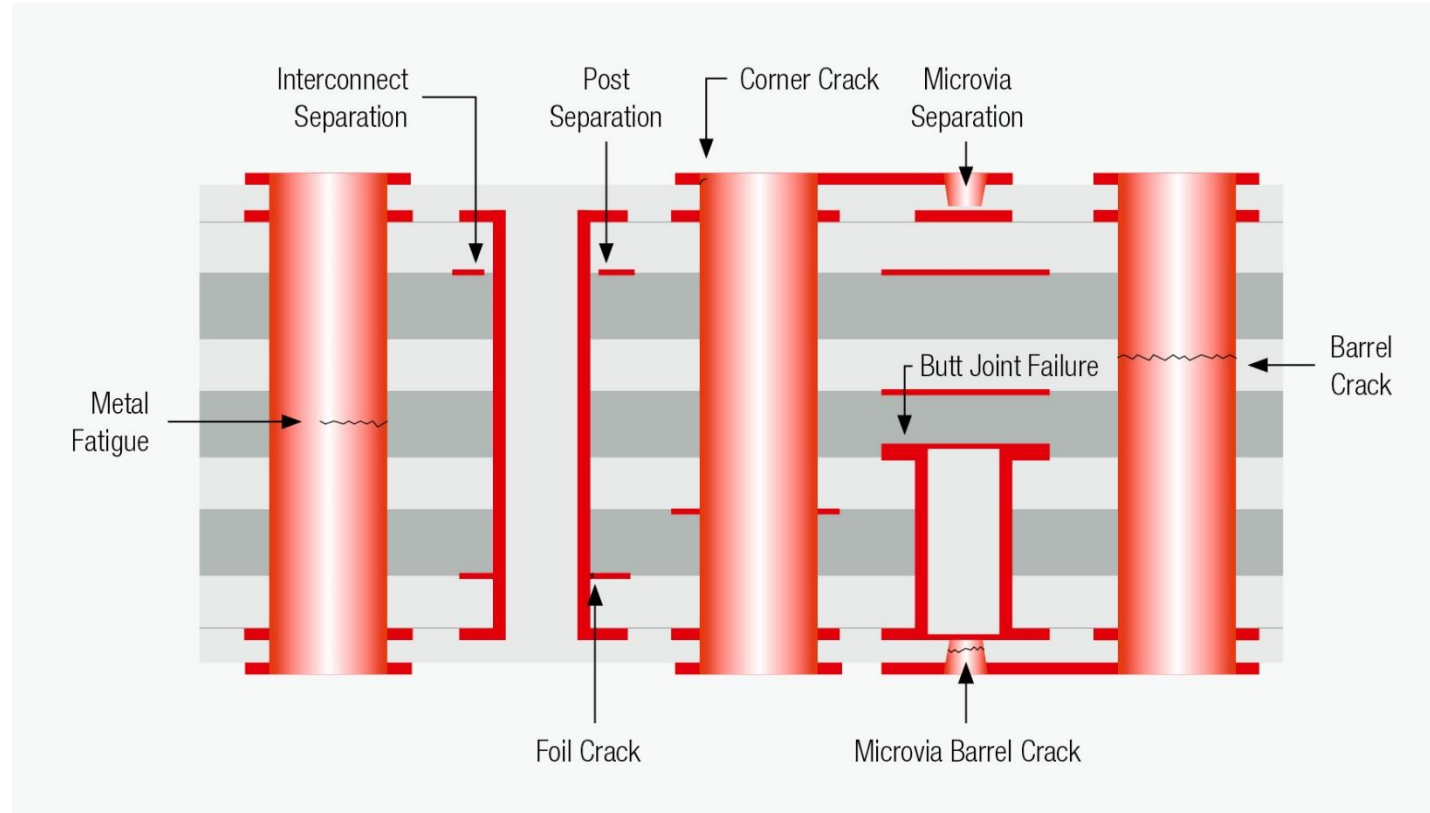


RELIABILITY OF PCBs

Introduction



Possible types of defects caused by mismatch of the CTEs:

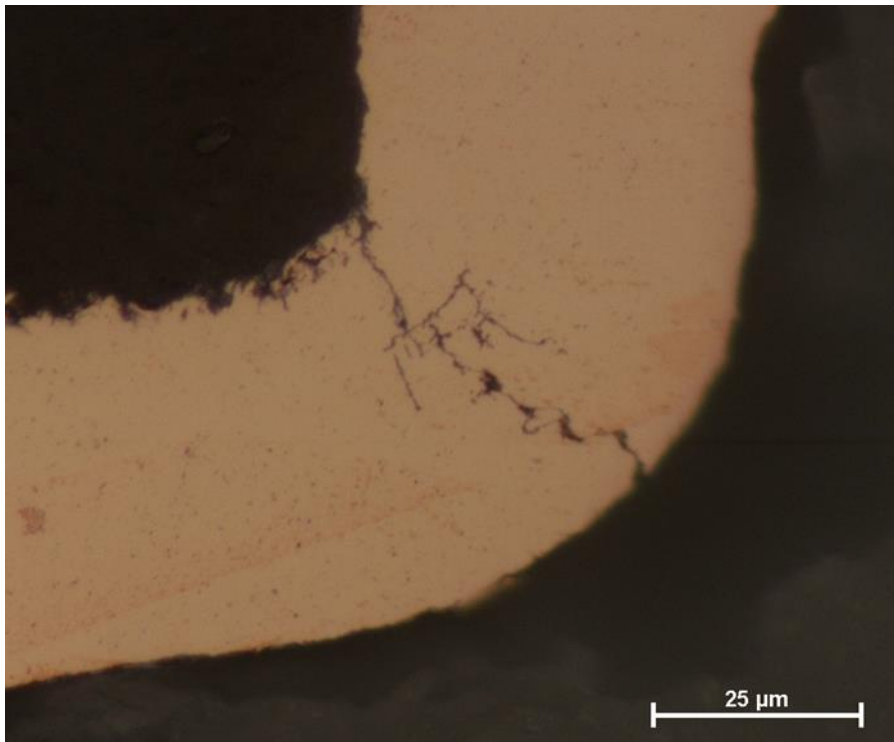


RELIABILITY OF PCBs

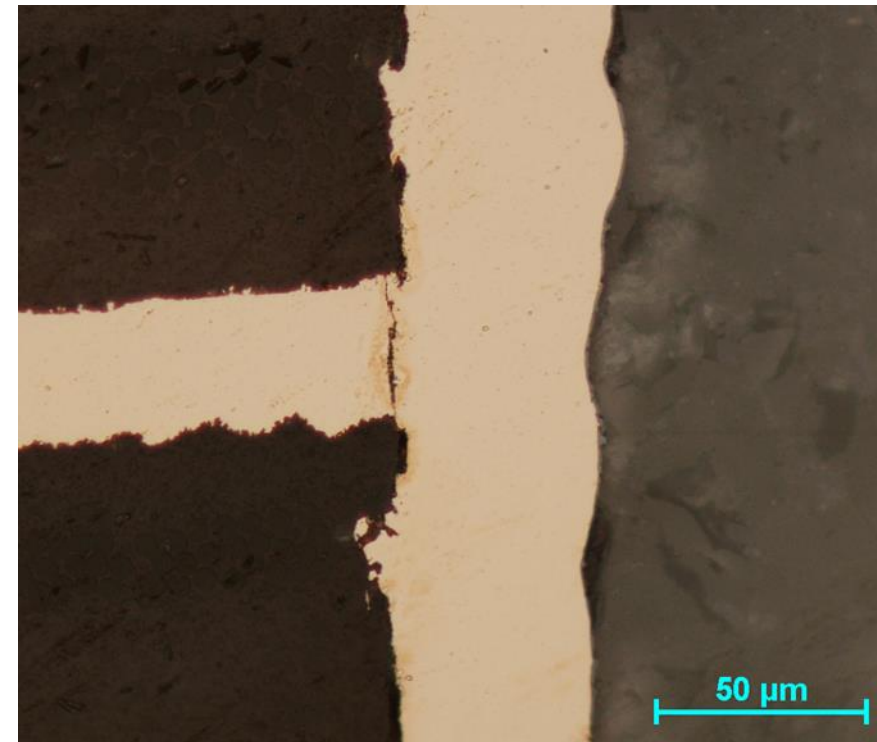
Introduction



Corner crack



Interconnect separation

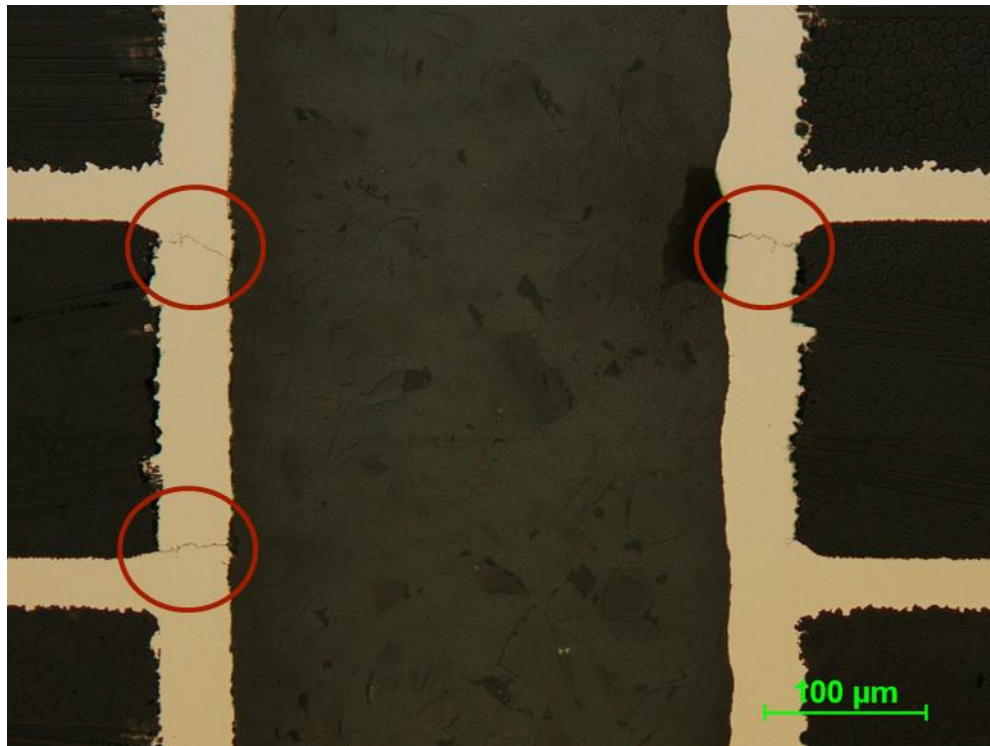


RELIABILITY OF PCBs

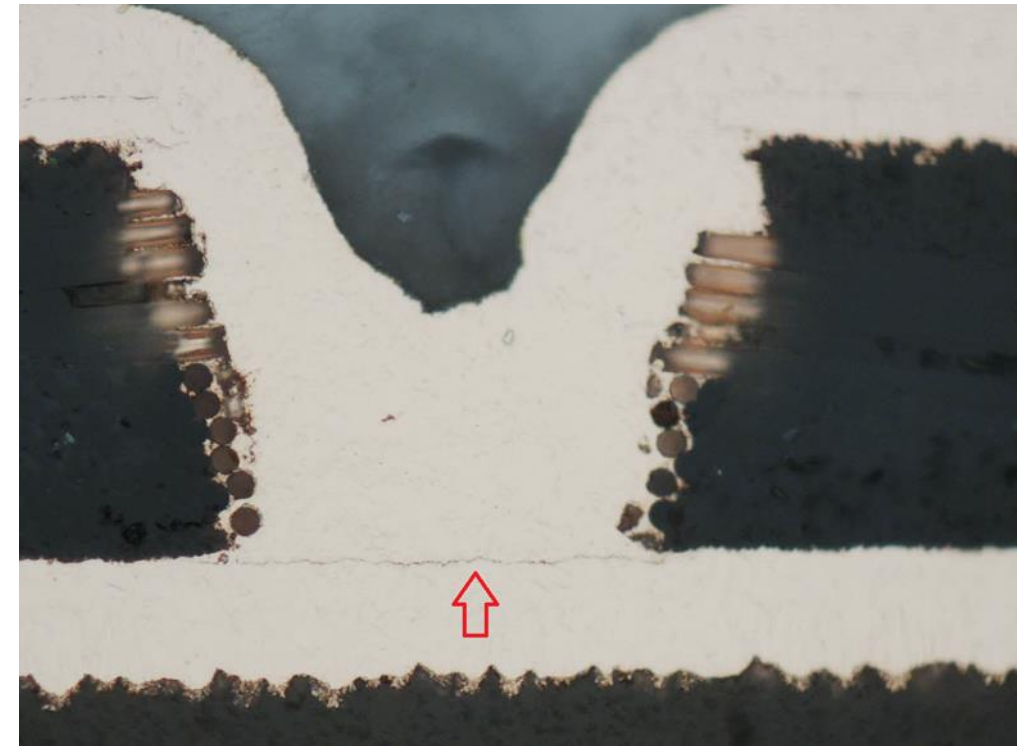
Introduction



Barrel crack



Separation between microvia and target pad





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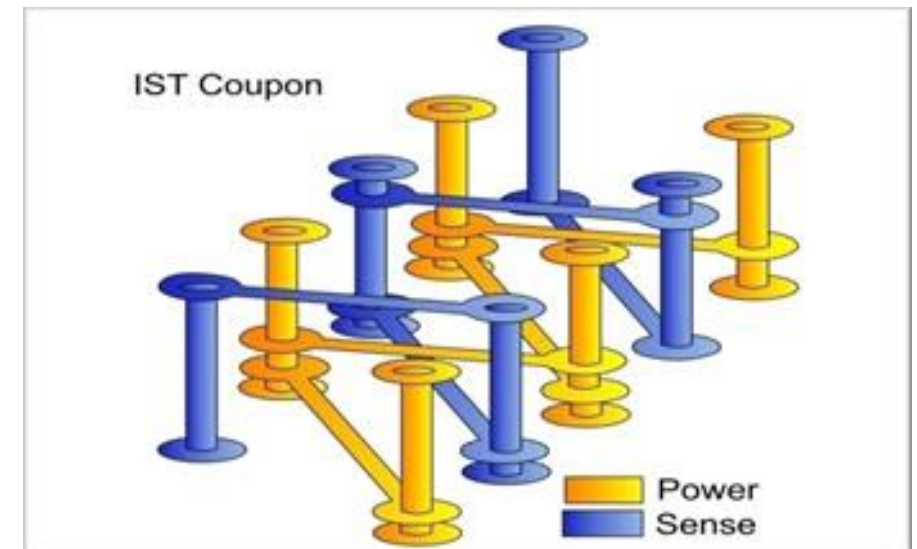
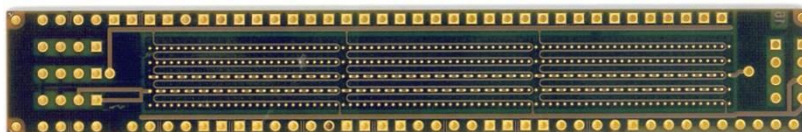
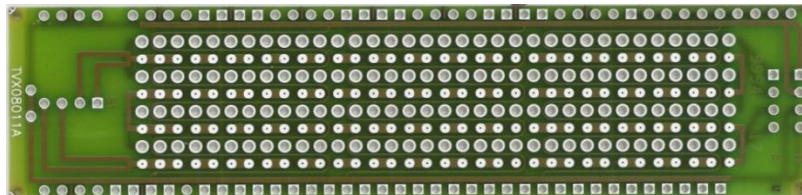


HOW TO "MEASURE" RELIABILITY

- Reliability is not a deterministic attribute and thus it's not possible to measure it directly.
- Therefore the reliability is determined indirectly. Specimens are repeatedly exposed to strain until a predefined failure criteria is reached.
- One run with exposure to strain and relief of the strain is called a cycle.
- The number of cycles that the specimens accomplished without reaching the failure criteria represents the gauge for the evaluation of the reliability of a particular product.

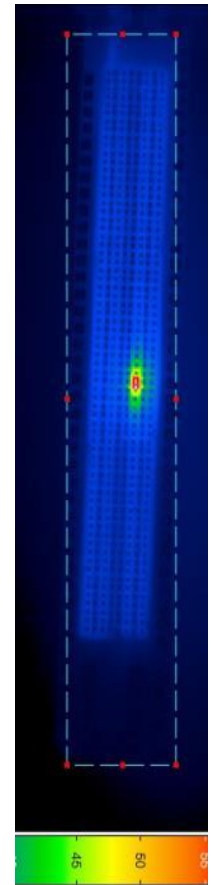
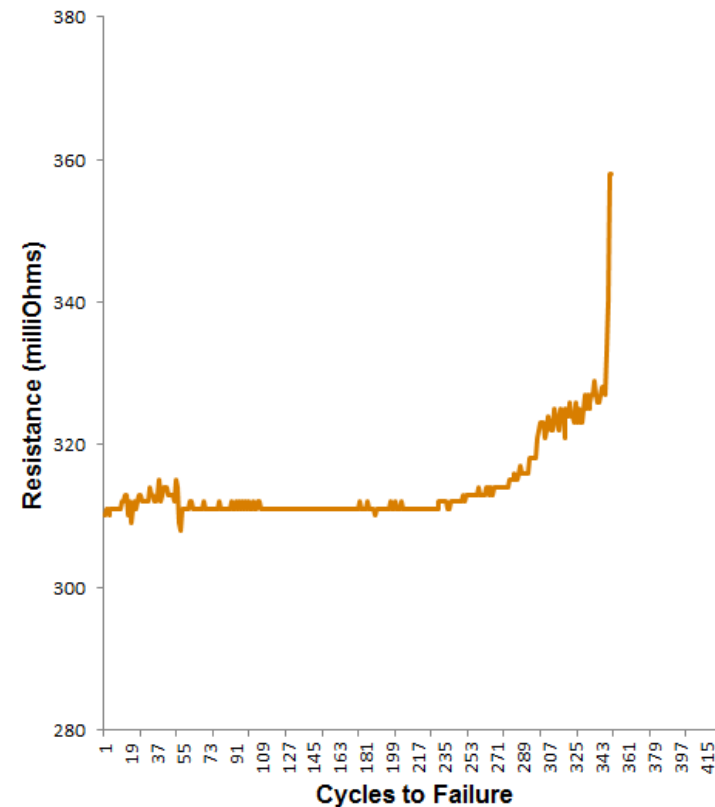
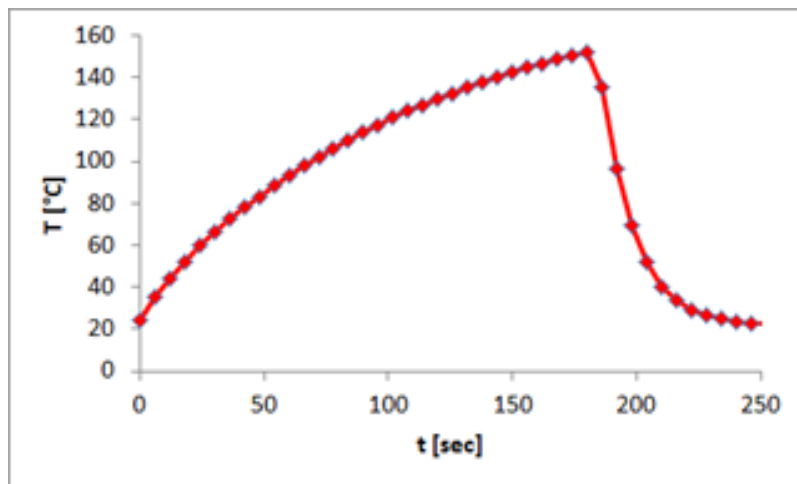
HOW TO "MEASURE" RELIABILITY

- **Interconnect-Stress-Test (IST) (IPC-TM-650 2.6.26 Method A)**
 - Specific test coupons, adapted to the PCB-Layout



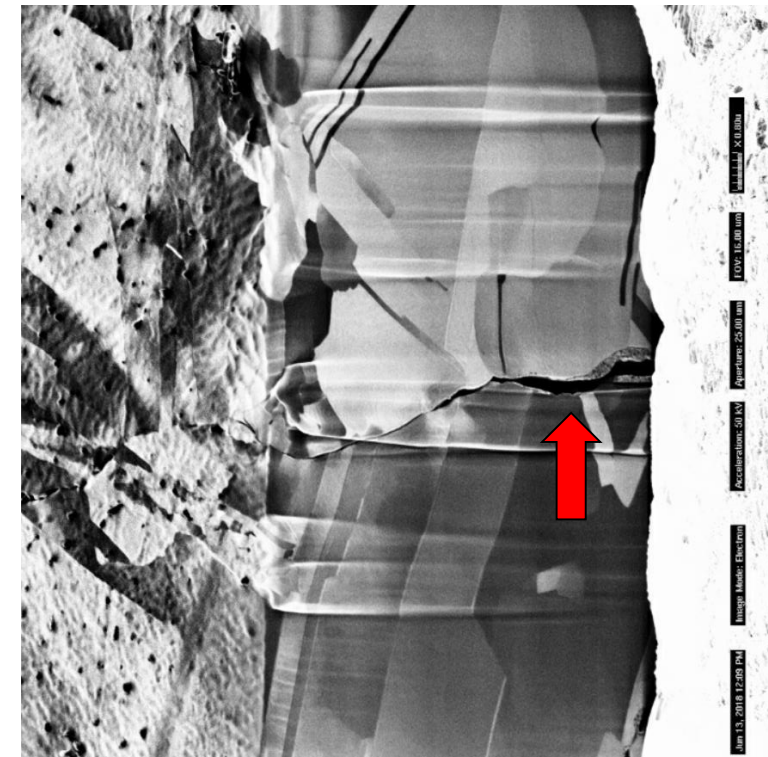
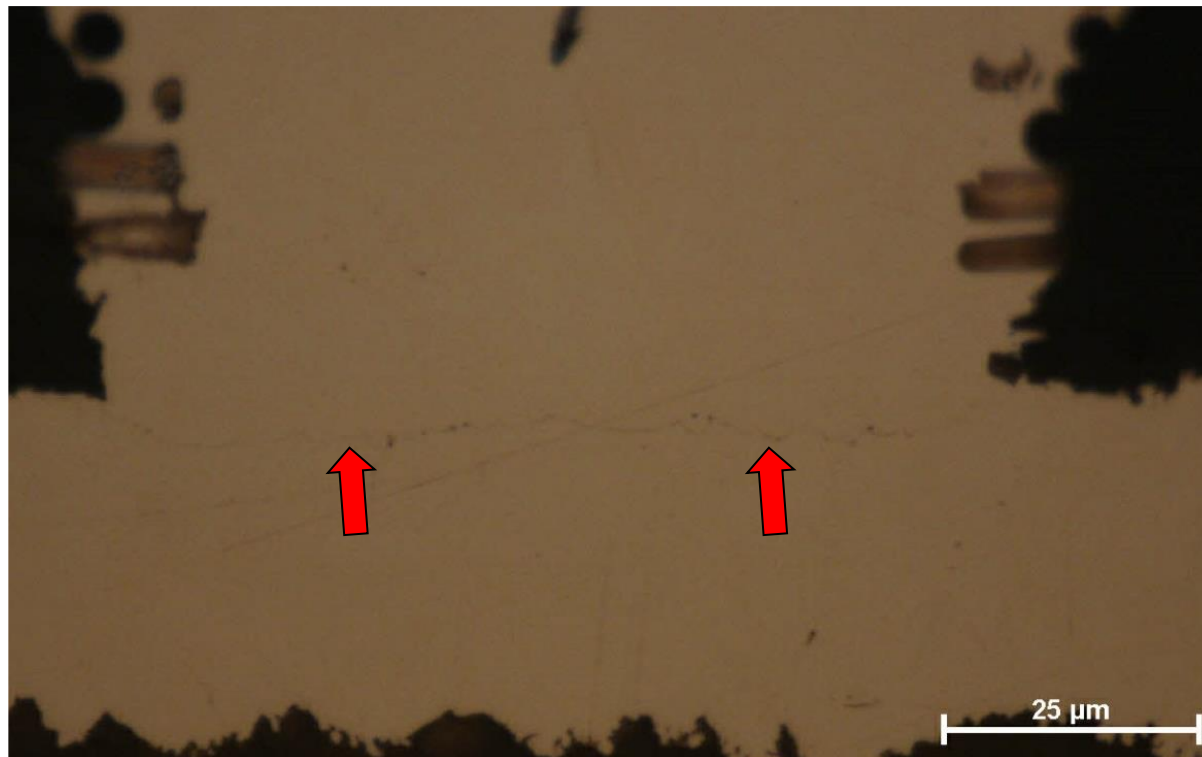
HOW TO "MEASURE" RELIABILITY

- Short cycle times (1000 cycles ~ 4d)
- Simulation of soldering cycles („precon“)
- Constant online monitoring of the resistance
- Stop when failure criteria is reached



HOW TO "MEASURE" RELIABILITY

- Very good ability of detecting failures
- Example: Bad connection between target pad and microvia:





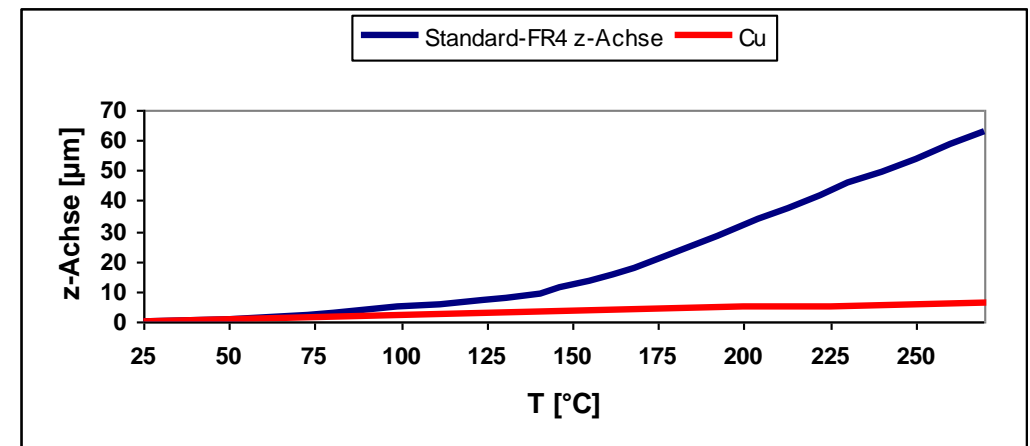
HOW TO "MEASURE" RELIABILITY

- Because of the good ability of detecting failures and the comparatively short runtime that is needed, the IST is used by WE for monitoring the quality of several production processes (plating, desmear, laser drilling)
- Test plan:

	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Prepreg Process	A	B	A	B	A	-	-
Facility 3 + Facility 2	X	X	X	X	-	-	-
2x Facility 2	-	-	-	-	X	-	-
Facility 3 + Cu-Filling 1	-	X	X	-	-	-	-
Facility 2 + Cu-Filling 2	-	X	X	-	-	-	-

HOW TO "MEASURE" RELIABILITY

- **Advantages of the IST:**
 - Comparatively short cycle time (~5min)
 - Constant online-measurement of the resistance
 - Automated stopping of test when failure criteria is reached
 - Simulation of soldering cycles (precon)
 - Effective error detection, also for microvias
- **Disadvantages of the IST:**
 - Specific test coupons are needed, PCBs can not be tested
 - (no test temperatures below room temperature possible)





AGENDA

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- 4 Influencing factors
- 5 Portfolio of reliability related service features



DISPLAY OF RELIABILITY TEST RESULTS

- The results of temperature cycling tests consist of a number of specimen $X_1 \dots X_n$ and each a related number of cycles Y_1 bis Y_n that were passed before the failure criteria was reached.

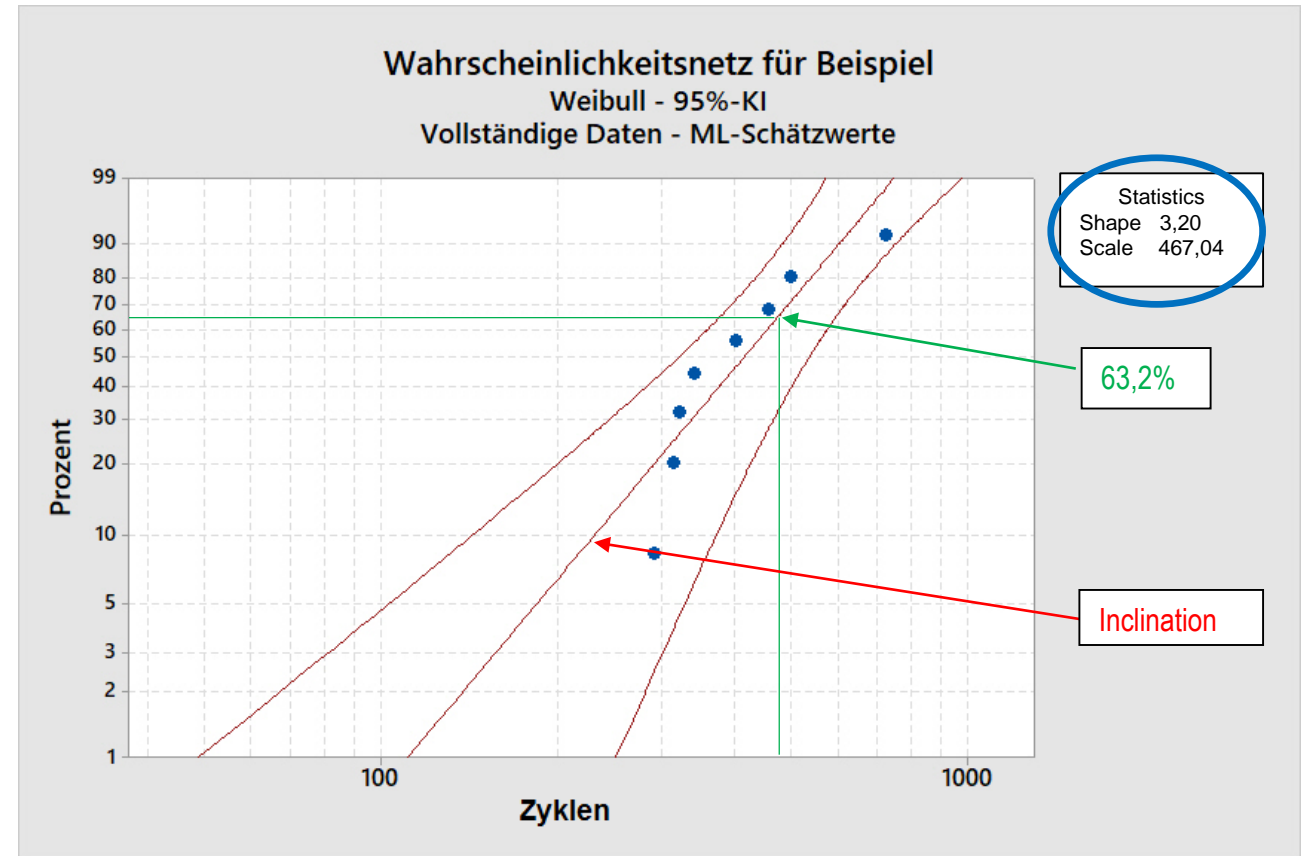
Coupon ID	Pwr Cycles	Pwr %	SenseA Cycles	SnsA %	SenseB Cycles	SnsB %	Results
S3-TC-1	314	0.4	314	10	314	7.1	Sense A
S3-TC-2	322	-0.8	322	10	322	0.4	Sense A
S3-TC-3	458	-0.2	458	10	458	1.8	Sense A
S3-TC-4	342	-0.2	342	10	342	6.4	Sense A
S3-TC-5	292	-0.2	292	10	292	2.6	Sense A
S3-TC-6	498	-0.7	498	10	498	7.0	Sense A
S3-TC-7	403	-1.3	403	10	403	3.8	Sense A
S3-TC-8	722	-0.5	722	10	722	2.6	Sense A

Limited lucidity, not suitable for the comparison of several test series!

- Preferred option: Weibull-Distribution

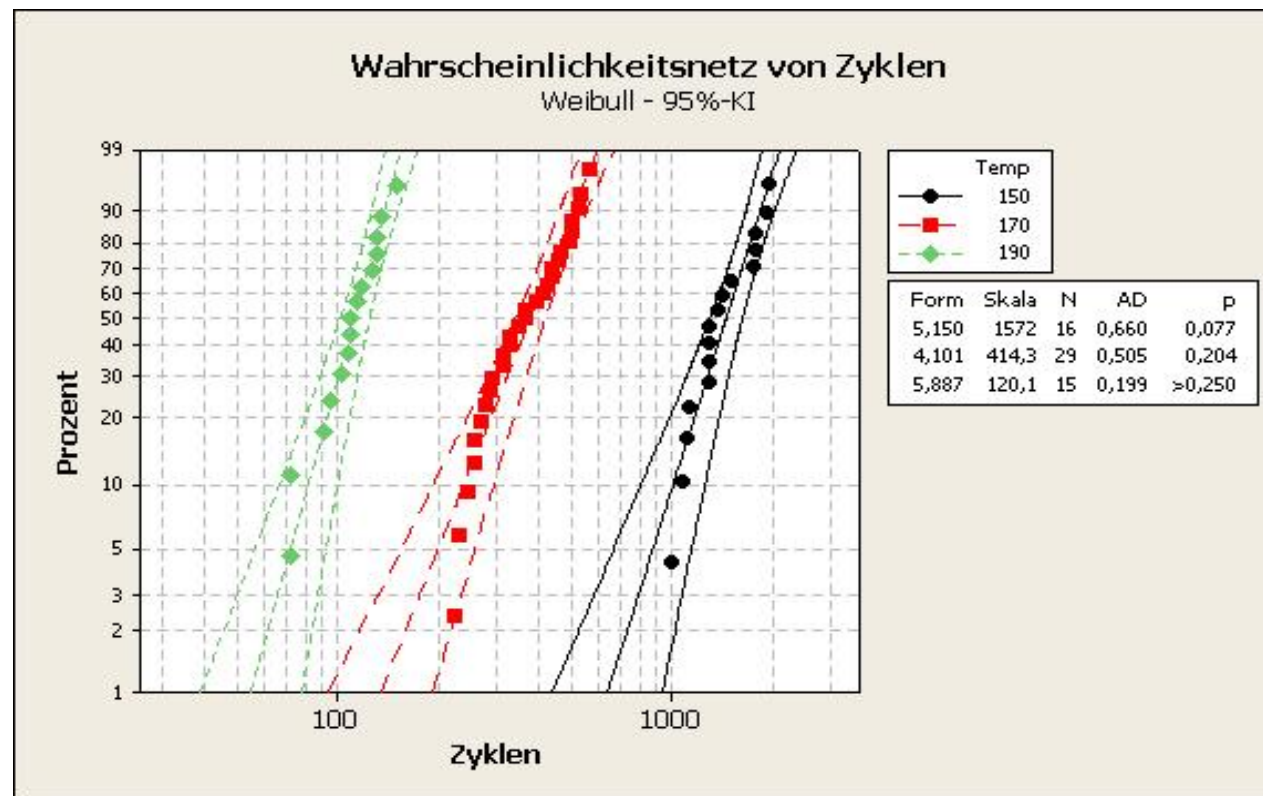
DISPLAY OF RELIABILITY TEST RESULTS

- **Shape:** This parameter refers to the type of the distribution. In the diagram it defines the inclination of the linear slope.
- **Scale:** This parameter indicates the number of cycles where 63,2% of the specimen failed. It is a good parameter for the fast comparison of different test series.



DISPLAY OF RELIABILITY TEST RESULTS

- Fast and clear comparison of different test series
- Example: A test series with identical test coupons and different test temperatures:



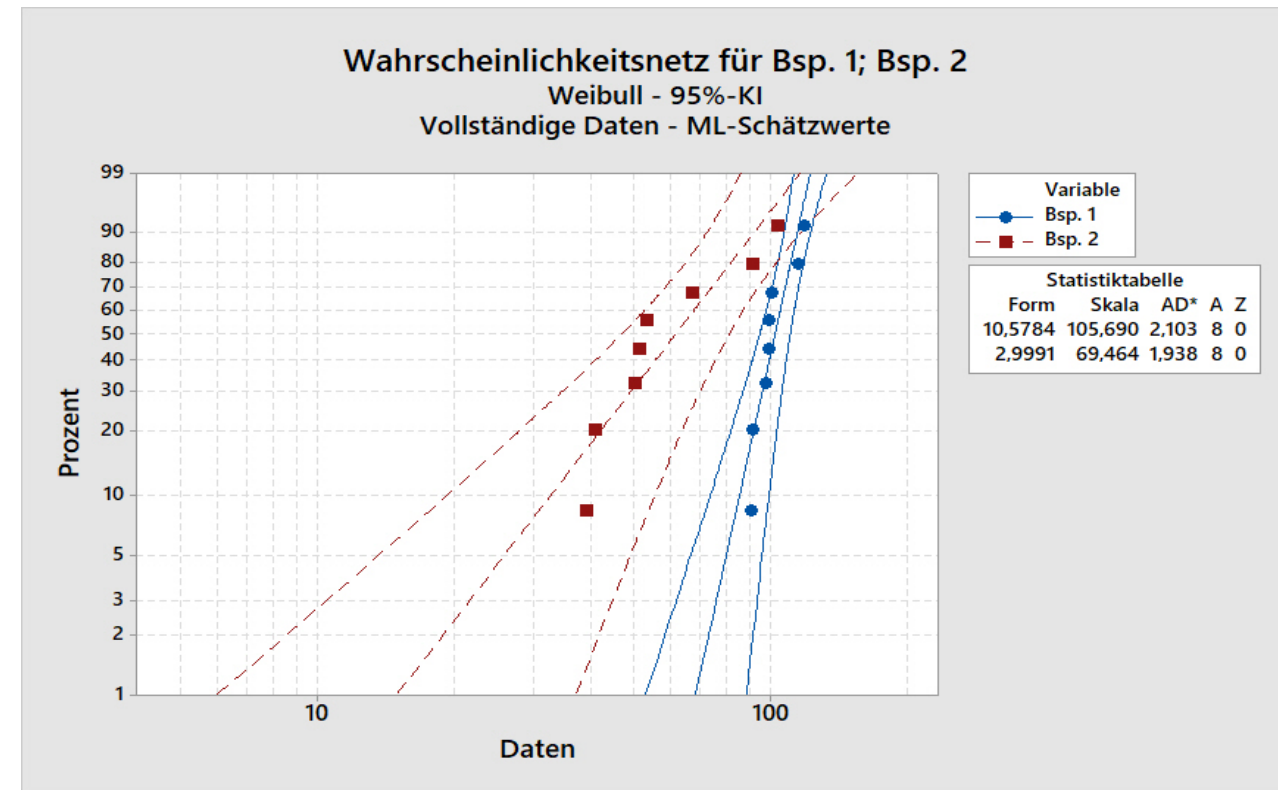
DISPLAY OF RELIABILITY TEST RESULTS

Divergent shape parameters:

- The test series are not comparable. Either the test parameters or the buildup of the test coupons need to be adjusted.
Example: Test temperature is too high

OR

- The test proves, that the examined test specimens do not only have different reliabilities, but also differ in the root cause of failure.





AGENDA

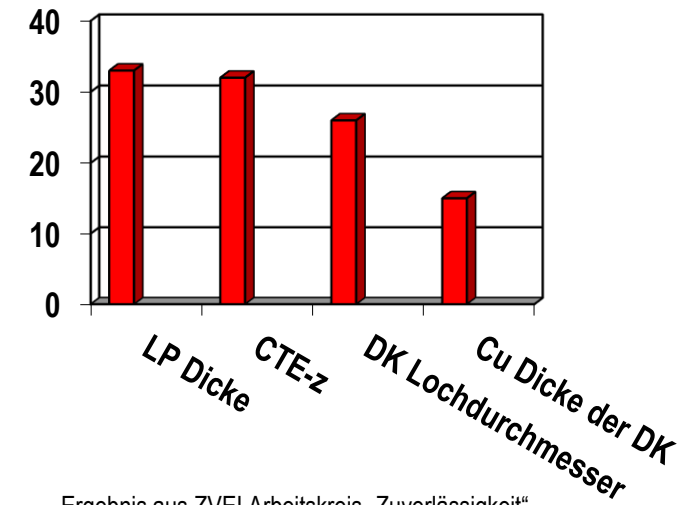
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INFLUENCING FACTORS

■ The most important factors regarding the reliability of plated holes are:

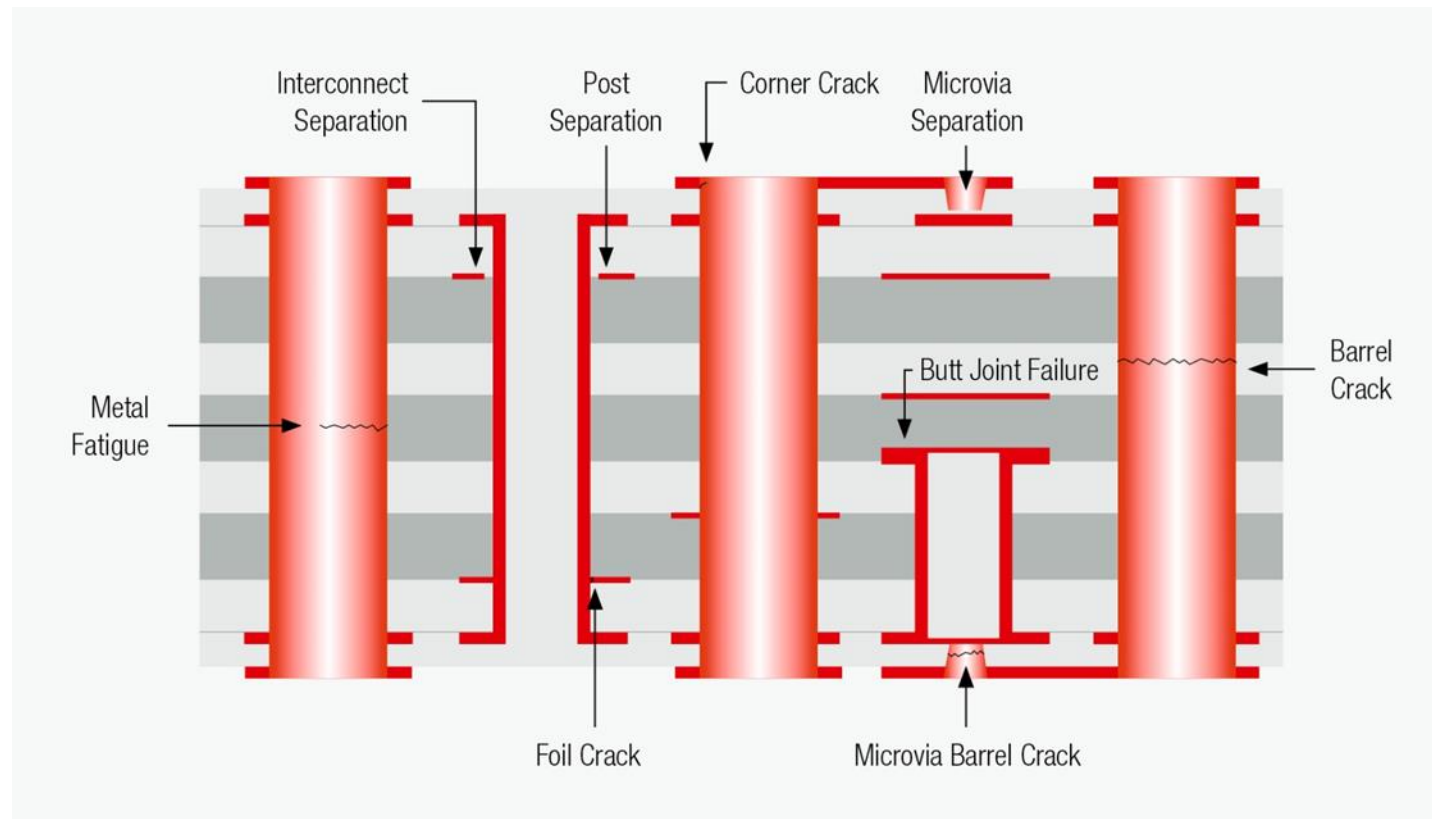
- Thermal expansion properties of the materials
 - Different coefficients of thermal expansion (CTE_z) of Cu and FR4
 - PCB-thickness!
- Sectional area of copper that is affected by the strain
 - Diameter of the PTHs
 - Copper thickness in the PTHs

Attention: A higher copper thickness in the PTH does not necessarily lead to a higher reliability!
- Operating conditions (!!!)



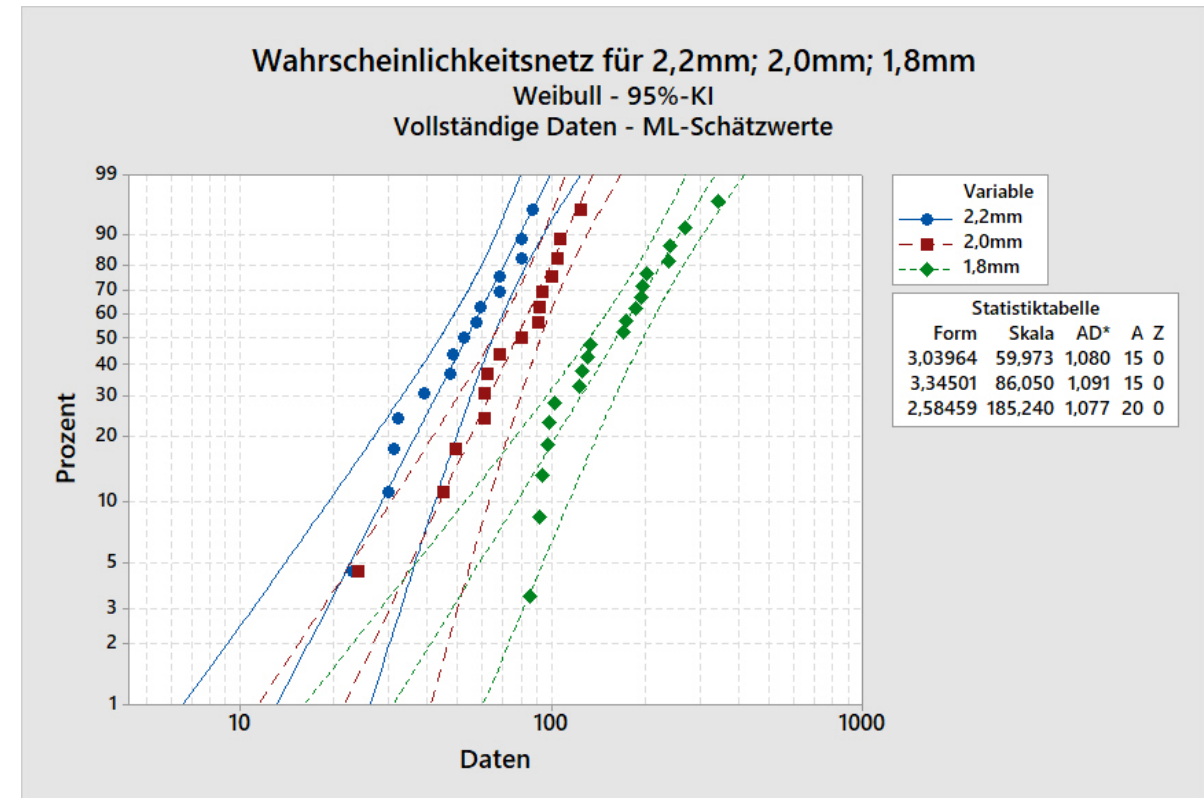
Ergebnis aus ZVEI Arbeitskreis „Zuverlässigkeit“

INFLUENCING FACTORS



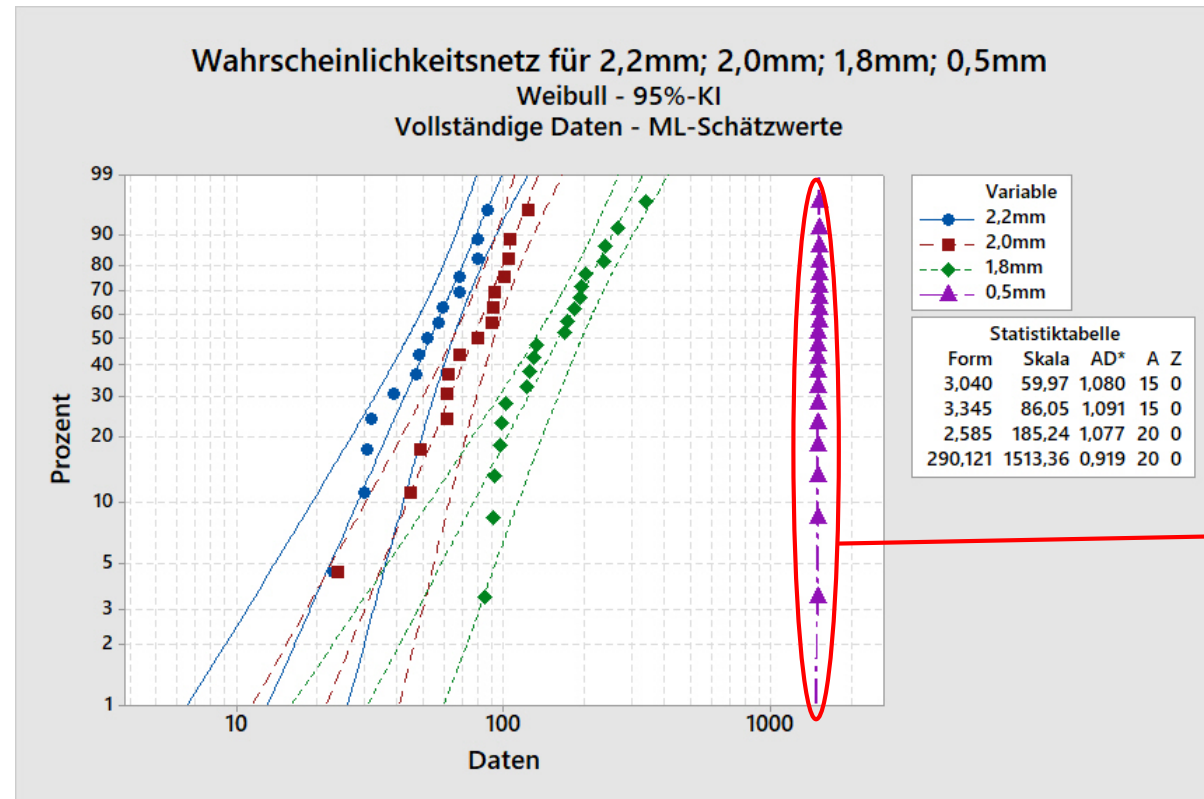
INFLUENCING FACTORS

- The influence of the PCB-thickness is significant:
 - About 20% of change of the PCB-thickness can lead to a difference in reliability at a ratio of 3!



INFLUENCING FACTORS

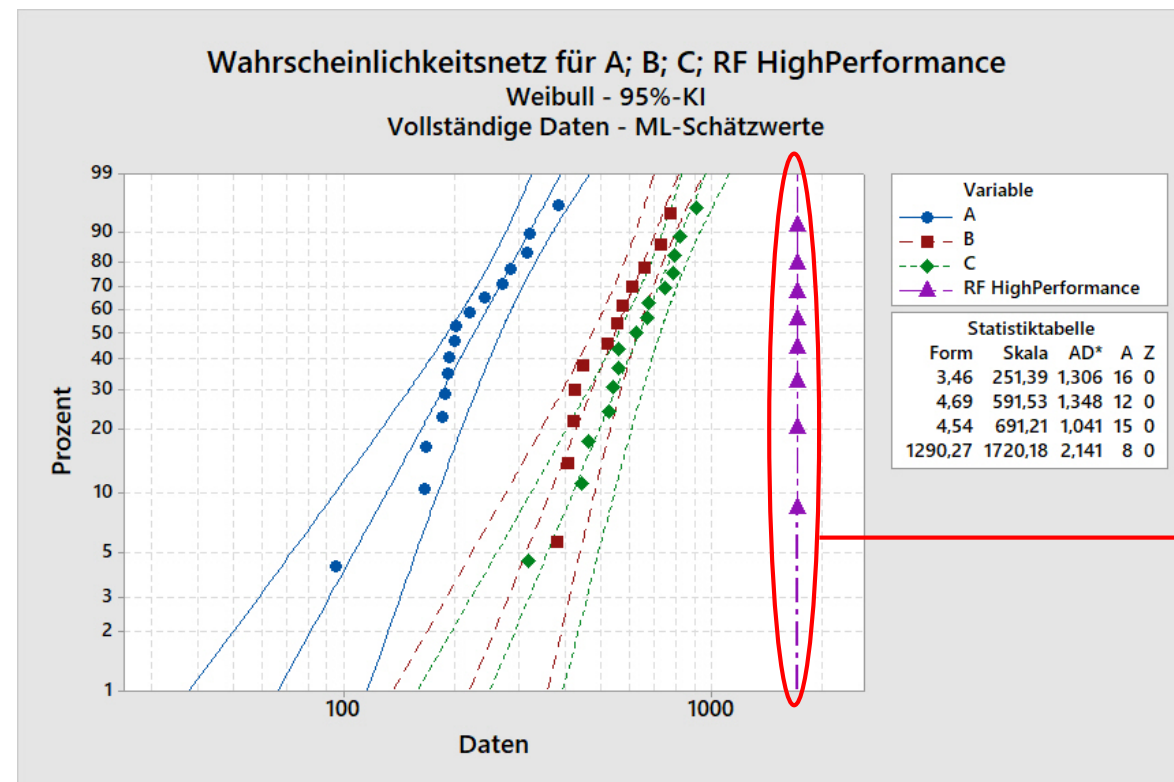
- The influence of the PCB-thickness is significant:



Specimens did not fail,
test was stopped

INFLUENCING FACTORS

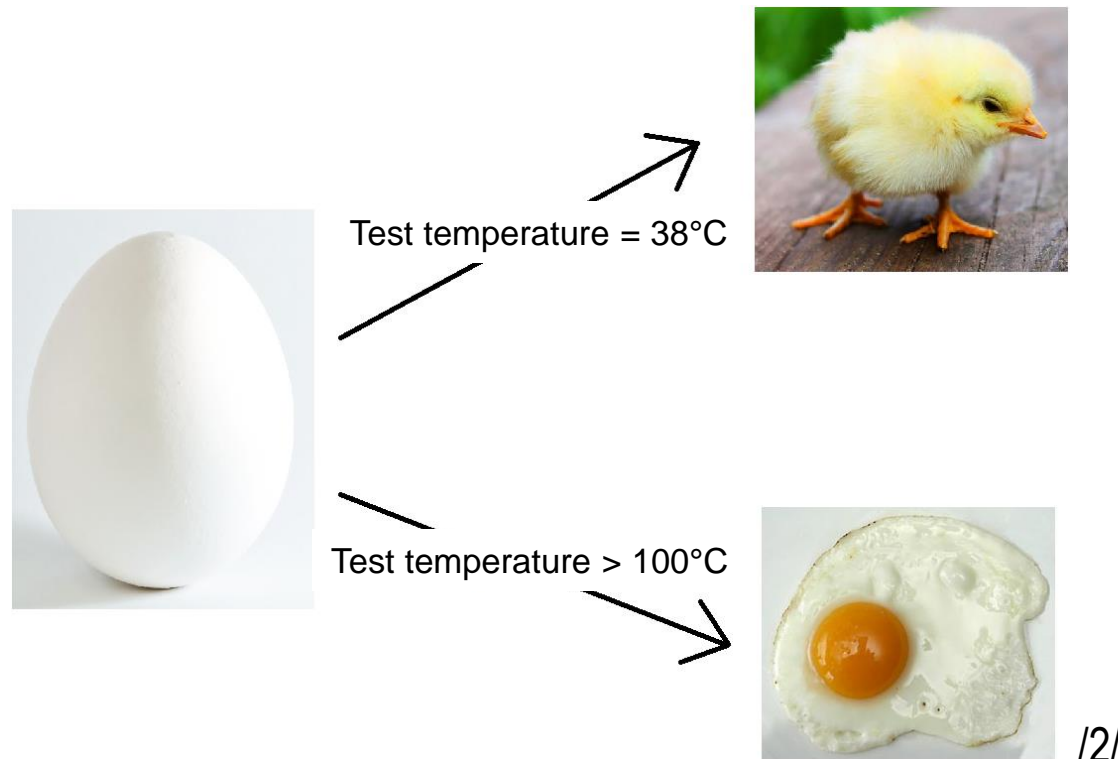
- The thermal properties of the base materials also have a significant impact on the reliability:



Specimens did not fail,
test was stopped

INFLUENCING FACTORS

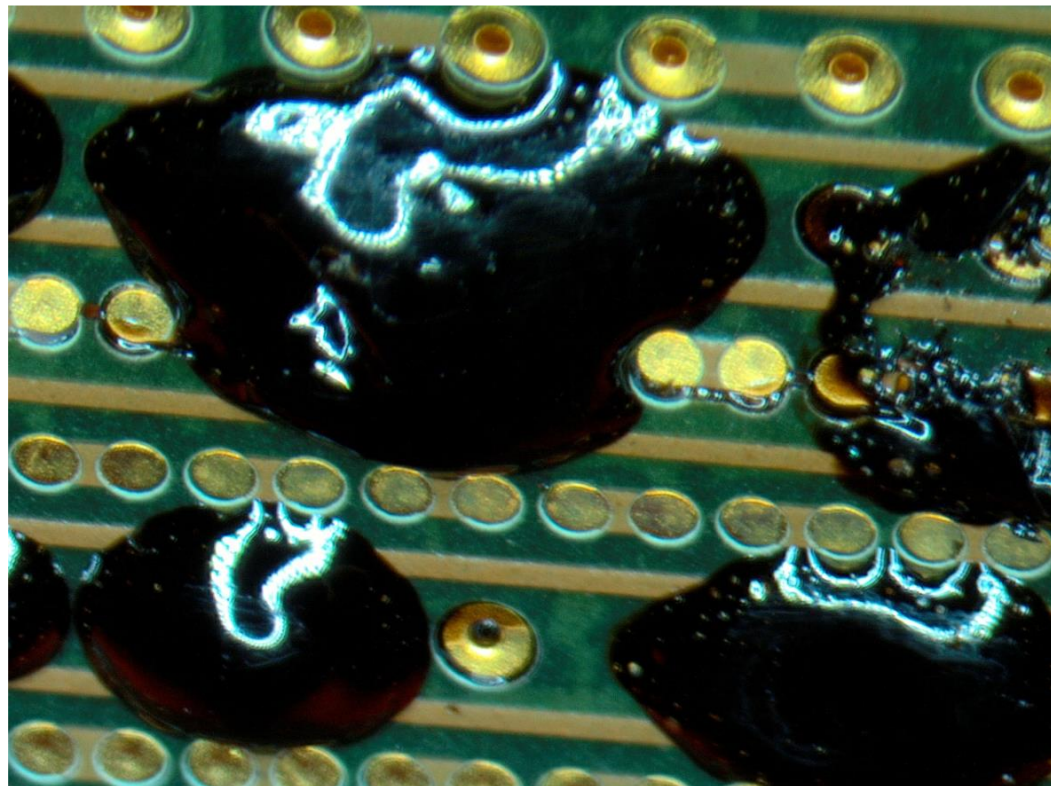
- The test parameters need to mesh with the operating conditions of the PCB!



- If the test parameters are too fierce, the mechanism of failure changes.
- The results of such tests are useless! (see also shape parameter)

INFLUENCING FACTORS

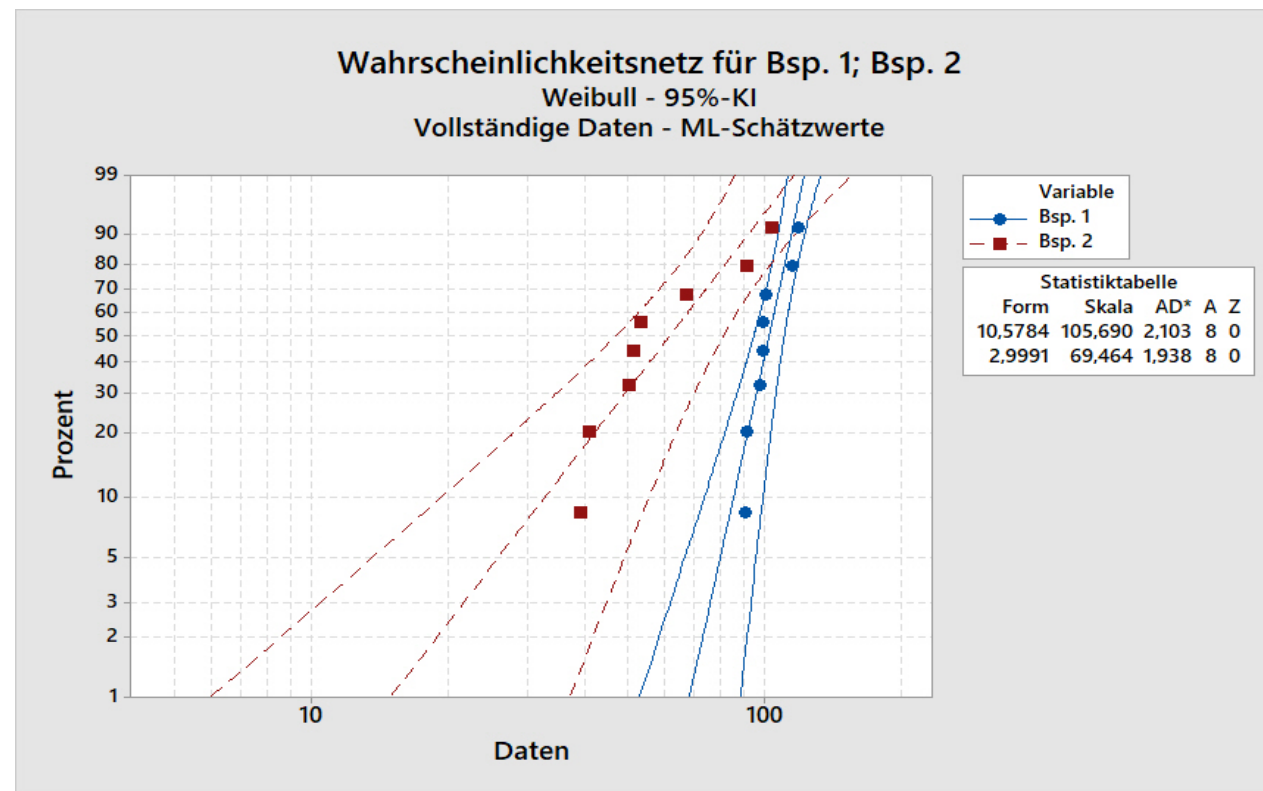
- Example: IST-test of a Tg135-material with a precon-temperature of 260°C



Destruction of the specimen due to spill of resin

INFLUENCING FACTORS

- Indicator: shape parameter of the Weibull-distribution





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RELIABILITY RELATED SERVICE FEATURES

Portfolio



■ Available tests at WE Circuit Board Technology

- TCT
- IST
- Climatic storage
- Soldering tests (Reflow)
- Peel tests
- TMA
- DSC
- CAF
- SIR
- FTIR

RELIABILITY RELATED SERVICE FEATURES

Portfolio



▪ Service features IST

- Verification of optimization changes, i.e.:
 - Material
 - Layer stack up
 - Via diameter
 - Copper thickness
 - Nonfunctional Pads
 - ...
- Tests with special/custom-built materials
- Validation of the reliability
 - Initial for a particular type of PCB
 - For every lot
 - For every panel ($\hat{=}$ every PCB)

Attention: Potentially very expensive!

RELIABILITY RELATED SERVICE FEATURES

Expertise in test engineering and PCB technology



Fast, time-saving simulation of manufacturing and operating conditions

- Recommendation of suitable test parameters
- Customized design of test coupons
- Multiple reflow simulation, accelerated life testing



Intensive monitoring for the precise detection of weak points

- Permanent recording of the "state of health" of the test coupons
- Time of occurrence of failure precisely identifiable, 100% documented
- Exact localisation of the fault position, precise microsection preparation



Statistical analysis

- Lifetime data
- Failure types



Identification of impact variables and definition of design recommendations

- Discussion of the test results
- Adjustments of the test conditions

THANK YOU FOR YOUR ATTENTION



**What kind of
application
do you have?**

**HOW can WE
support you?**



REFERENCES

- /1/: Design and Construction Affects on PWB Reliability, Paul Reid, PWB Interconnect Solutions
- /2/: Konsequenzen der fortlaufenden Miniaturisierung in der Elektronik, Zuverlässigkeit von Lötverbindungen miniaturisierter Bauteile, EMPA 13.06.2019, Heinz Wohlrabe