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Failure Analysis Going Towards Anamnesis

a Holistic Approach for Successful Root Cause Detection

May 2015

Zwolle

Noerdlingen

Stuttgart

Dresden

Bath

Outline:

- Failure analysis going towards anamnesis (system and life considerations)
- Failure analysis on integrated circuit
- Failure analysis on other electronic components
- Methods and approaches
- Examples of failure analysis jobs
- Identity check / counterfeit components

Failure Analysis, a Complex Course ...

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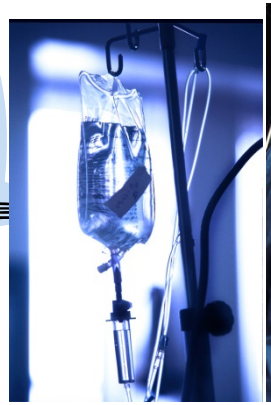
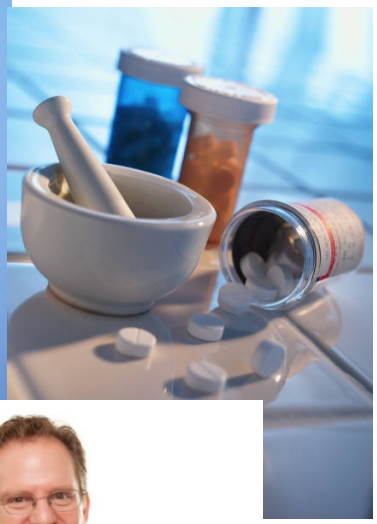


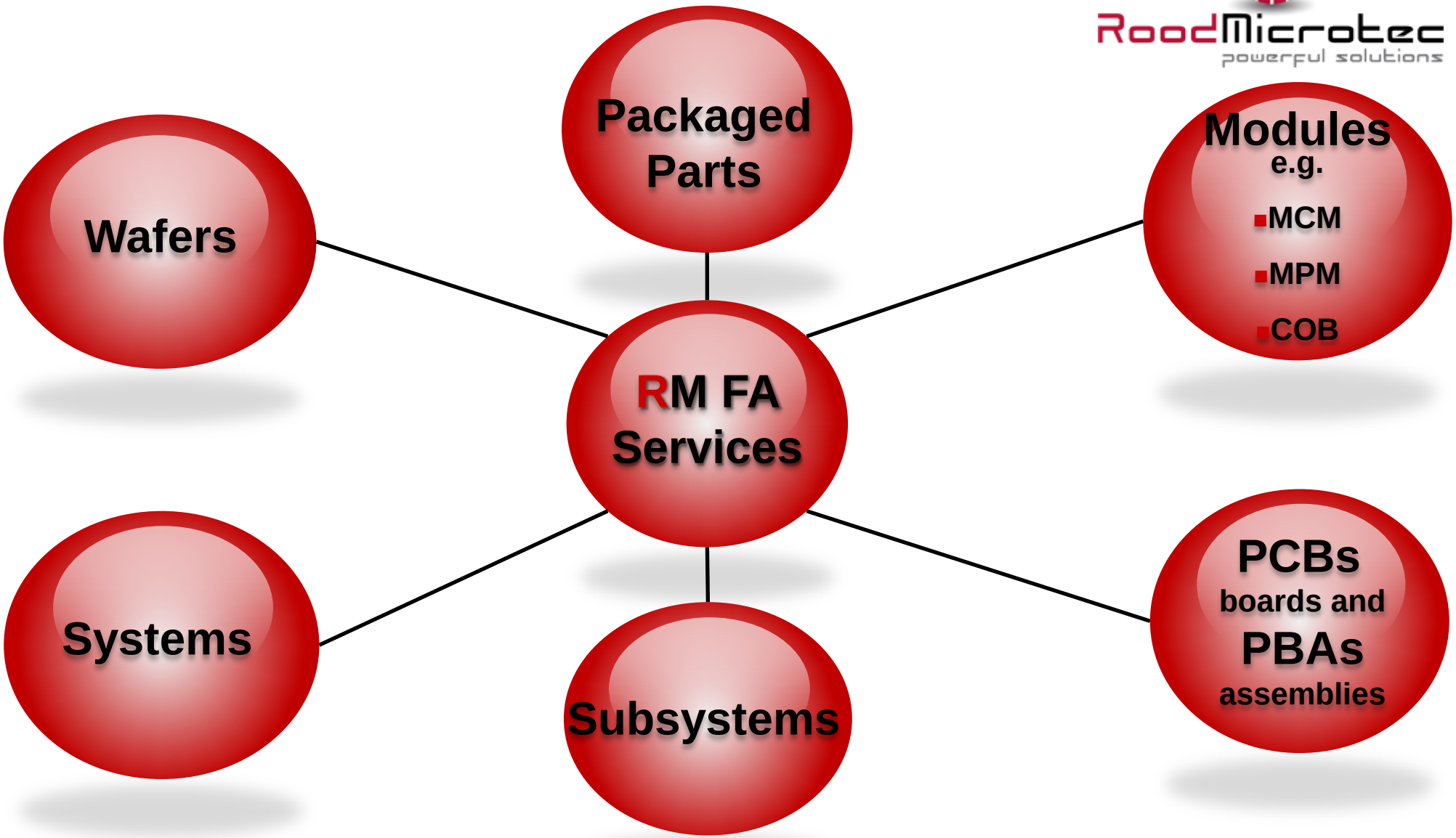


… or do you trust in a doctor, making a prompt surgery of your abdominal pain, without asking what you had for dinner last night ?

RoodMicrotec – the leading independent European company for testing, quality services, failure/technology analysis, and ASIC/ASSP supply services.

RoodMicrotec Failure Analysis Services Overview

Services From Wafer- To System Level



FA Services For All Component Types

Active Components

like:

- ICs
- Transistors
- Diodes
- Sensors

Passive Components

like:

- Resistors
- Capacitors
- Inductors
- LRC circuit
- MISC

Optoelectronic Components

like :

- LEDs and displays
- Image sensors
- Optical transmission systems

Electronic subsystems and entire systems

Other devices

like:

- Relays
- Motors
- PCBs

RoodMicrotec Key FA Services

Failure Analysis

Our Capabilities

- Verification of system functionality
- Circuit analysis
- Failure simulation, localization & reproduction
- Electrical failure analysis
- Diagnostics
- Compliance Test

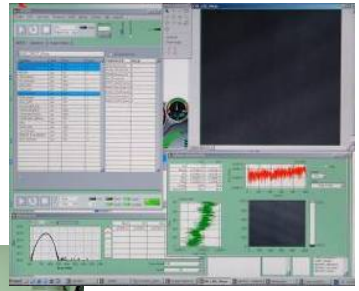
Our Assets

- Long time experience in interpreting various failure mechanisms
- Accredited by DAkkS (German Accreditation Body)
- Examinations according to
  - ISO/IEC 17025
  - ISO 9001

Non Destructive - Destructive Physical Failure Analysis

- Optical microscopy (OM)
- 2D X-Ray microscopy
- 3D X-Ray tomography
- Scanning acoustic microscopy (SAM)
- Scanning electron microscopy (SEM)
- Focused ion beam (FIB)
- Transmission electron microscopy (TEM)
- Emission microscopy (EMMI)
- Optical beam induced resistivity change (OBIRCH)
- Lock-in thermography
- Liquid crystal thermography (LCT)

- In-circuit probing & curve tracing
- EDX material analysis
- Hot spot analysis with infrared cameras
- Thermal analysis, Ionograph
- PIND Tests



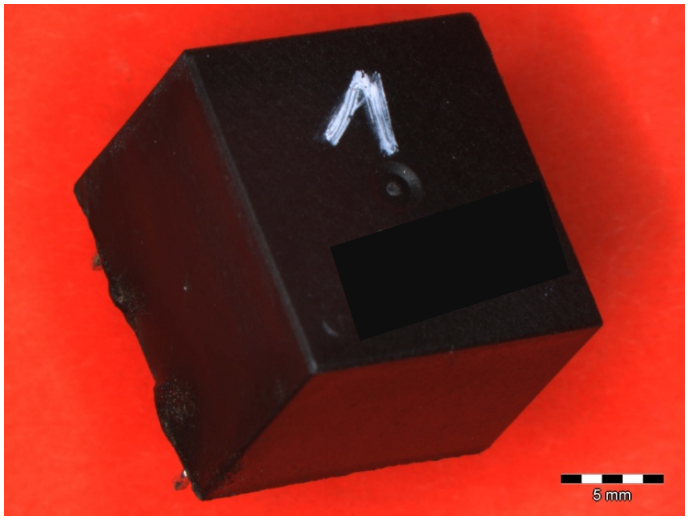
Failure Analysis Reporting Levels

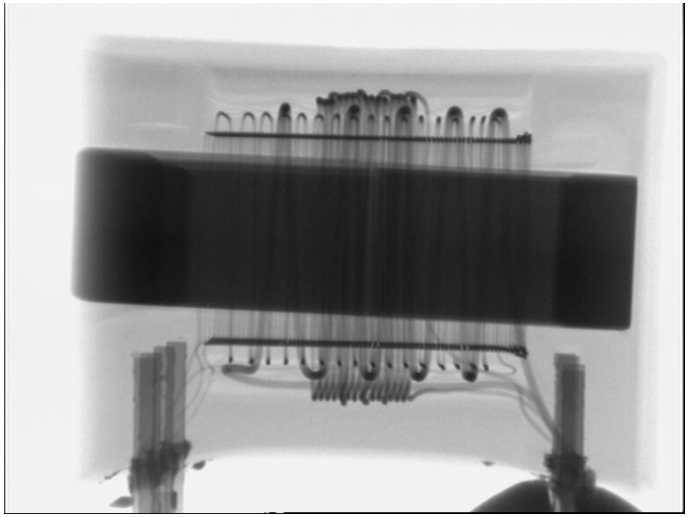
- **Summary / Report about failure location & analytical description**

- **Root cause analysis: making use of our experts' decades of experience**

  - **Assessment of manufacturing quality**
  - **Assessment of application conditions (anamnesis)**
  - **Recommendations for corrective actions**

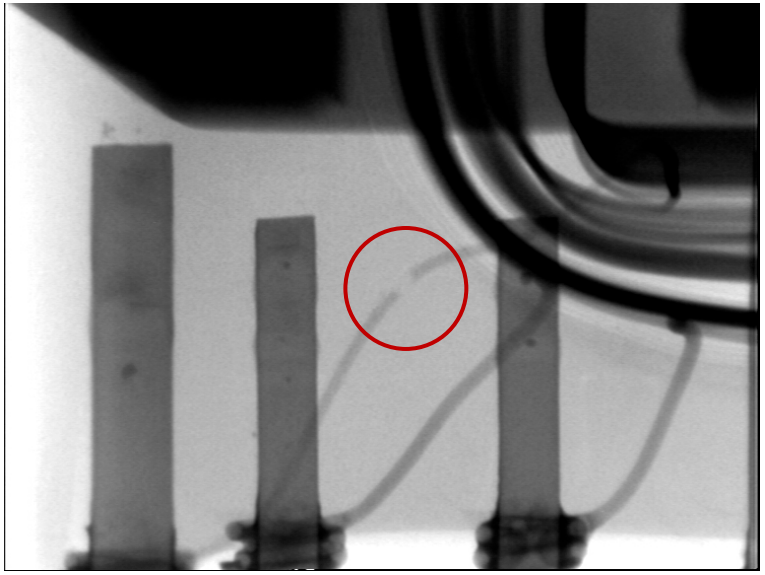
FA on Switching Power Supply



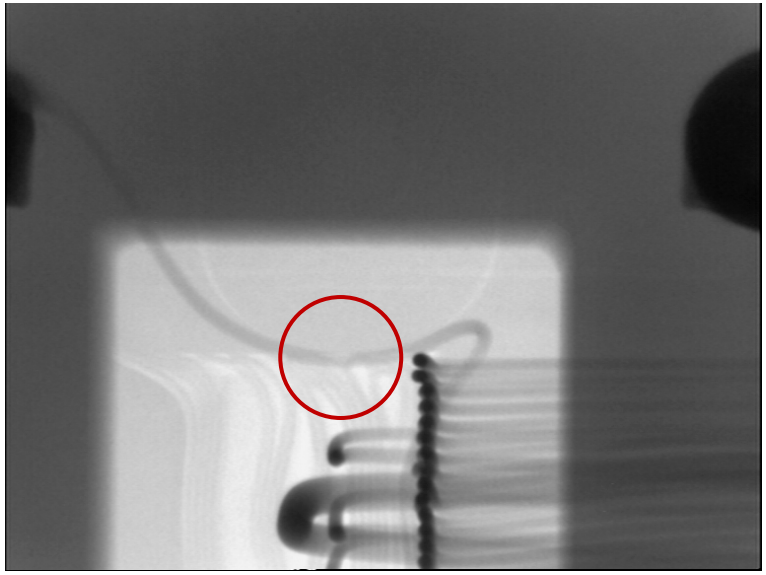


- **Open circuit at positive terminal**
- **Manufacturer's analysis stated electrical overstress**
- **Application in bottling plant of brewery**

FA on Switching Power Supply

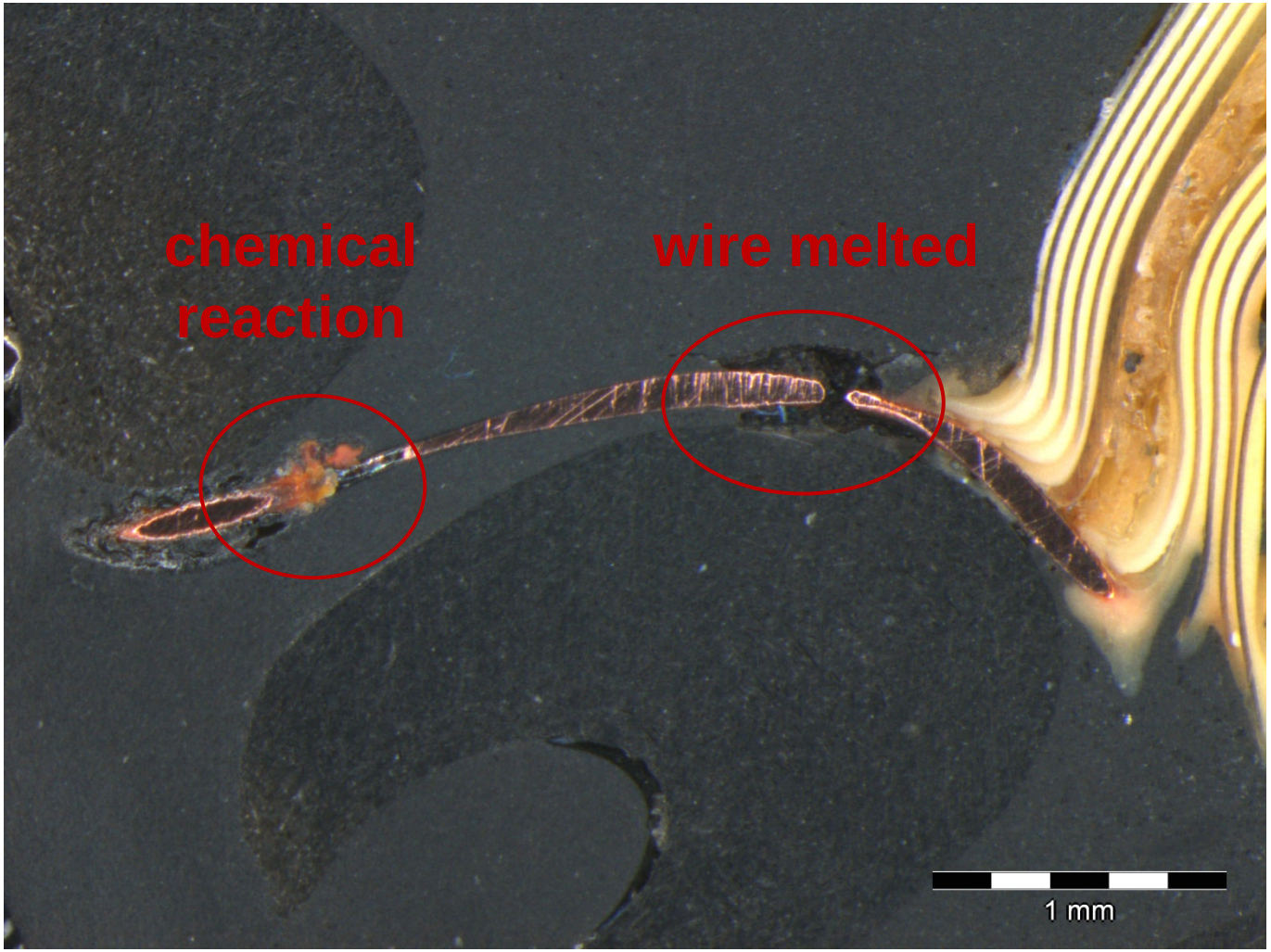


open wire



structural change in wire

FA on Switching Power Supply



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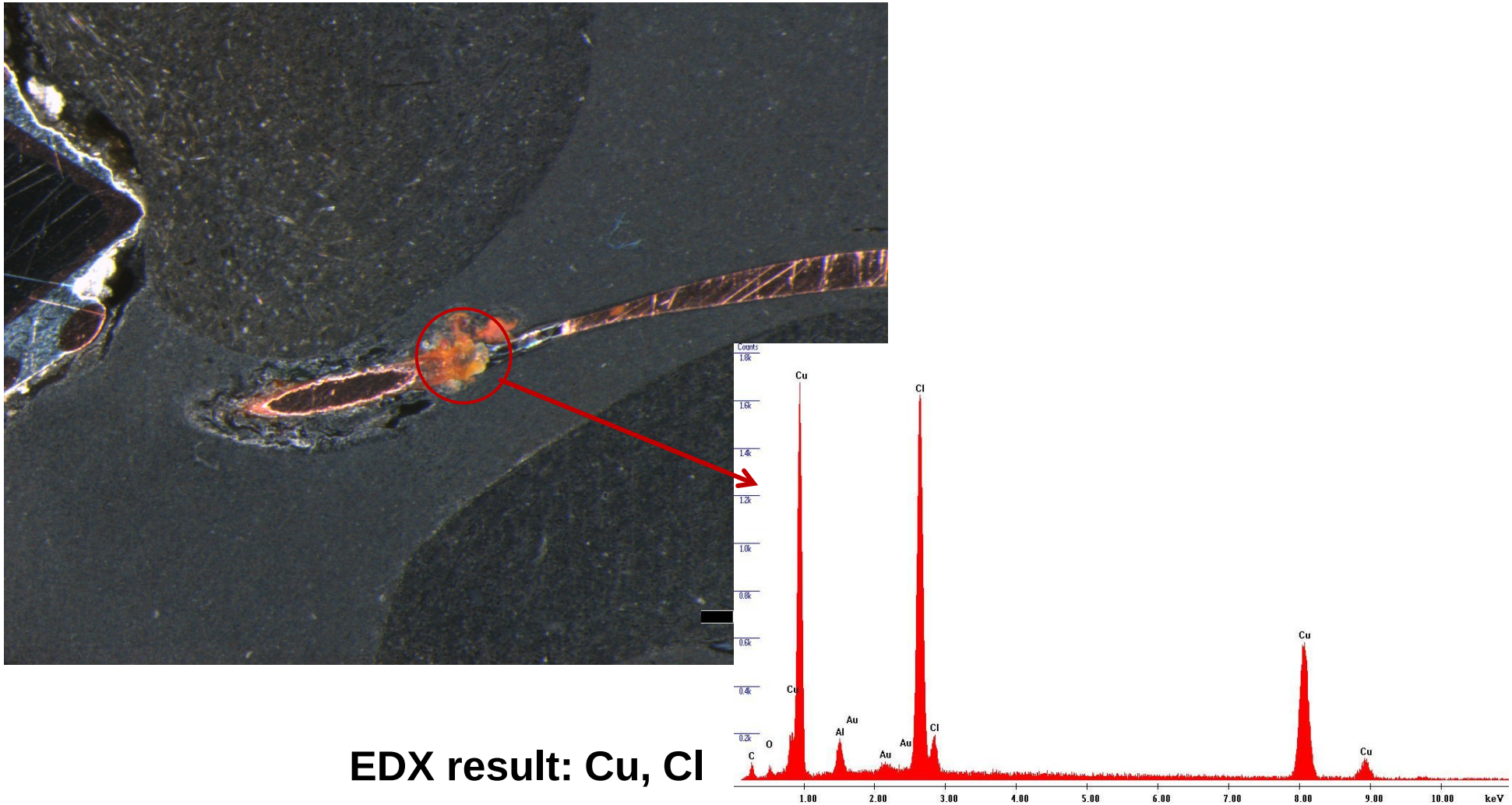


EDX result: Cu, Cl

FA on Switching Power Supply

- **Chlorine content in mold compound 300 ppm**
- **Diffusion of Cl- ions to positive terminal**
- **Cracks in varnish**
- **CuCl formation**
- **Reduction of cross section / increasing current density**
- **Melting of wire**

→ **Root cause: wrong mold compound material**

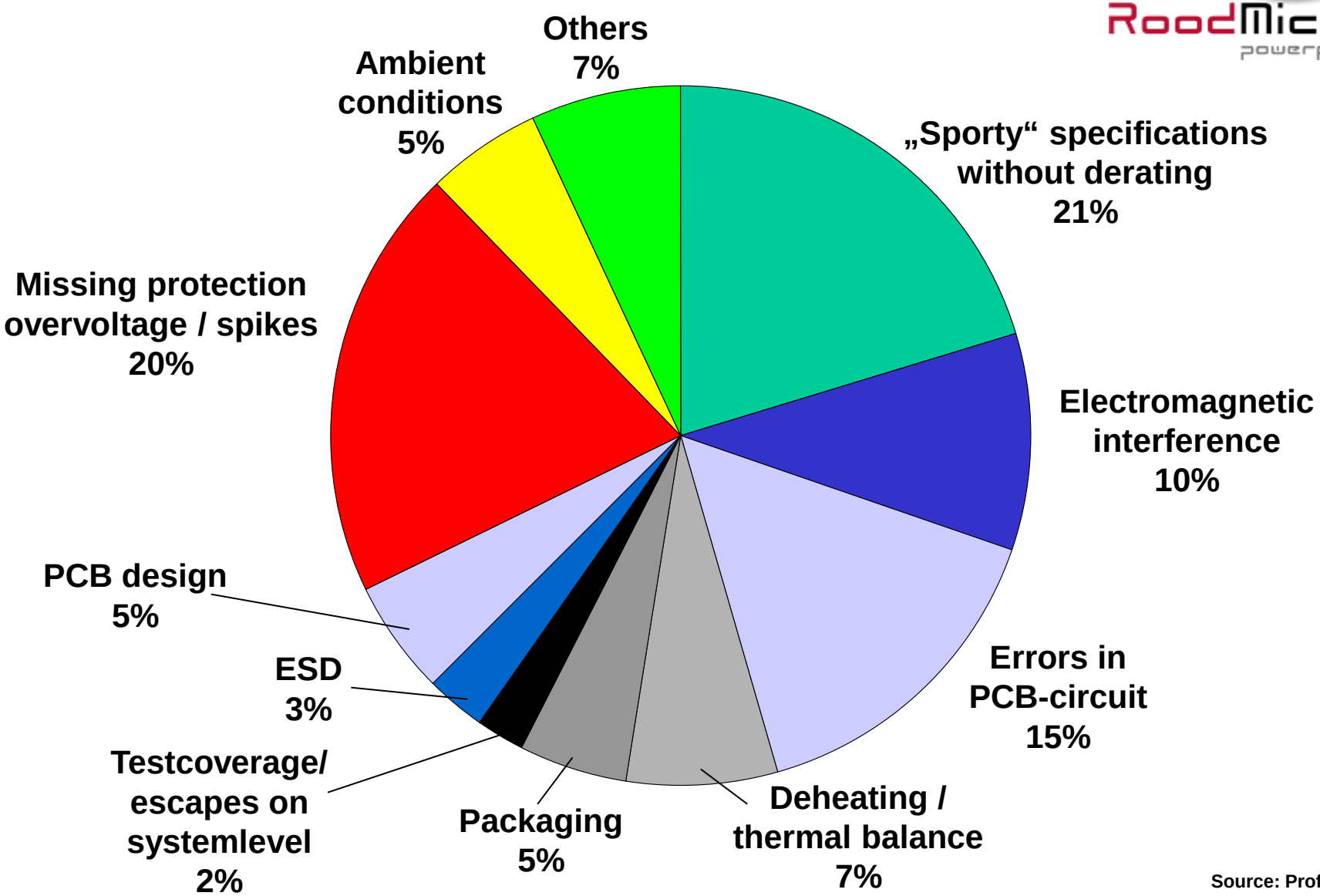
Anamnesis

Key questions

- **Failure: production or application oriented**
- **Changes in production flow**
- **Critical application**
- **Single or systematic failure**

- **Failure analysis starts with the component**
- **Anamnesis on system and application level**

Significant Failure Causes

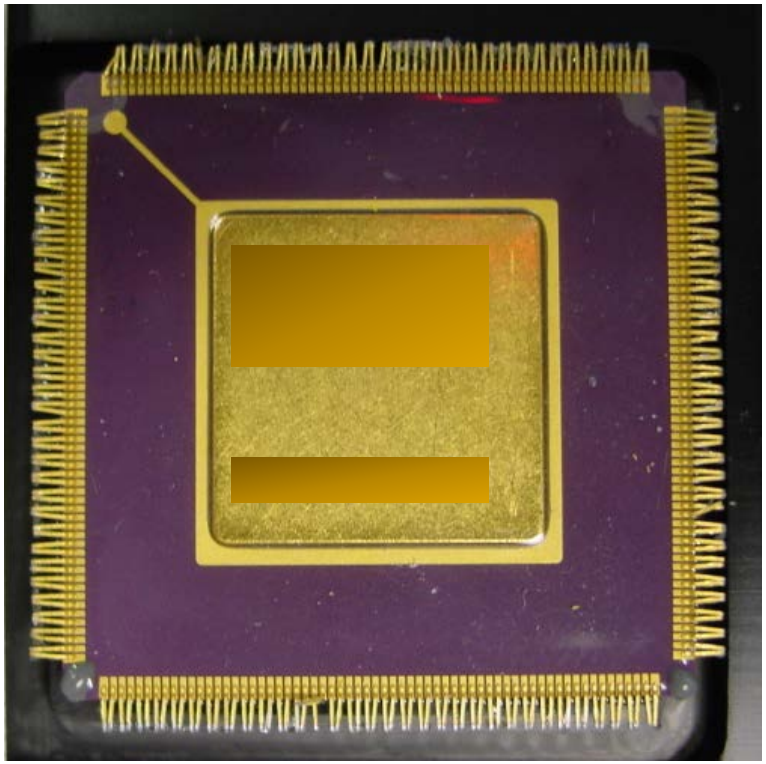


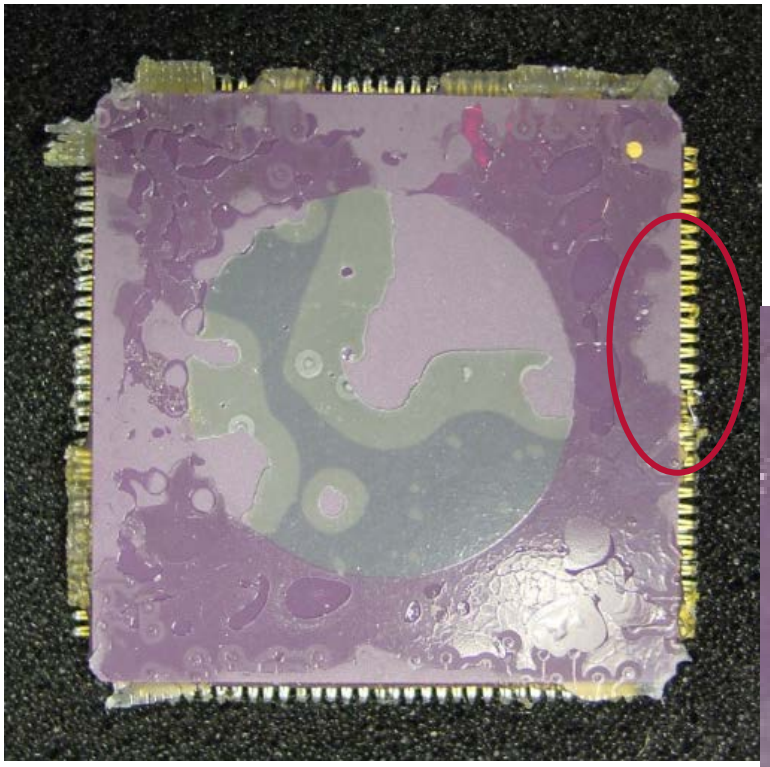
Source: Prof. Jakob, EMPA

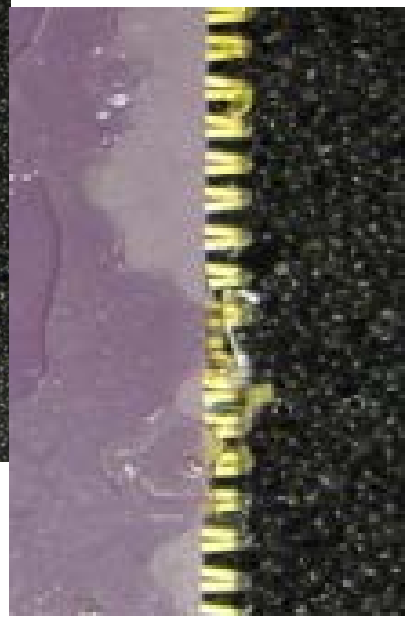
Structure of Anamnesis

Failure history	**When occured, comparable failures, statistics, production chain**
Application / circuitry	**Ambient conditions, power cycles, electrical protection, stability, clocking, on/off-conditions, EMI**
Subsystem	**Interconnection technology, PCB layout, PCB bending, vibration, overvoltage protection**
Component packaging	**Test before packaging, ESD/ESDFOS, influence of ultrasonic treatment, counterfeit devices**
Assembly (PCB)	**Solder profiles, PCB layout, ESD**
PBA Manufacturing	**Statistical records, shmootests, tool statistic, contamination, physical or parametric failure**

IC Failure Analysis



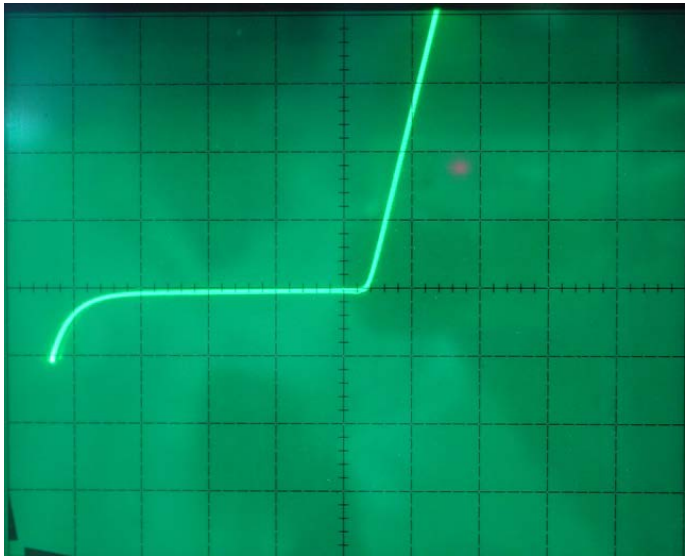




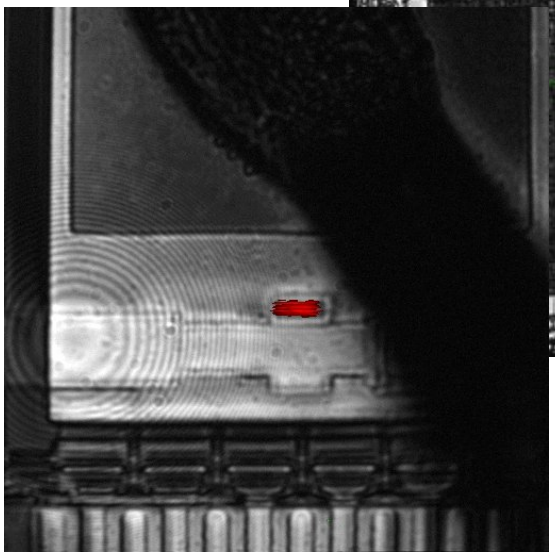
History

- Field failure (1.5 years in application)
- Reference available
- Single failure (at date of analysis)

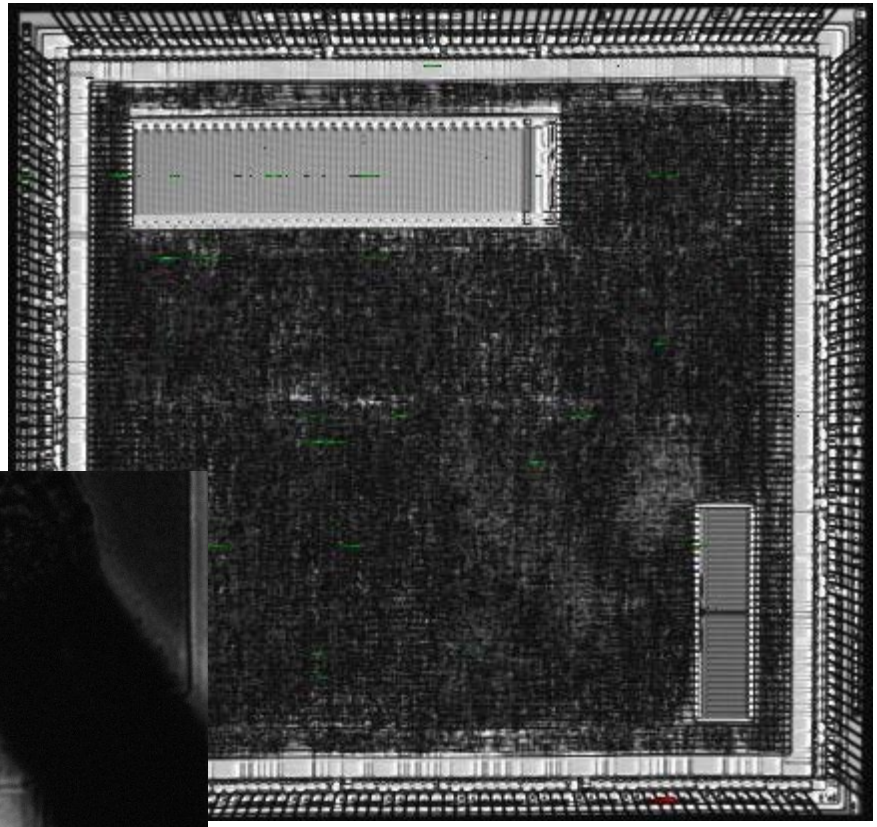
IC Failure Analysis



Curve tracer, ohmic part

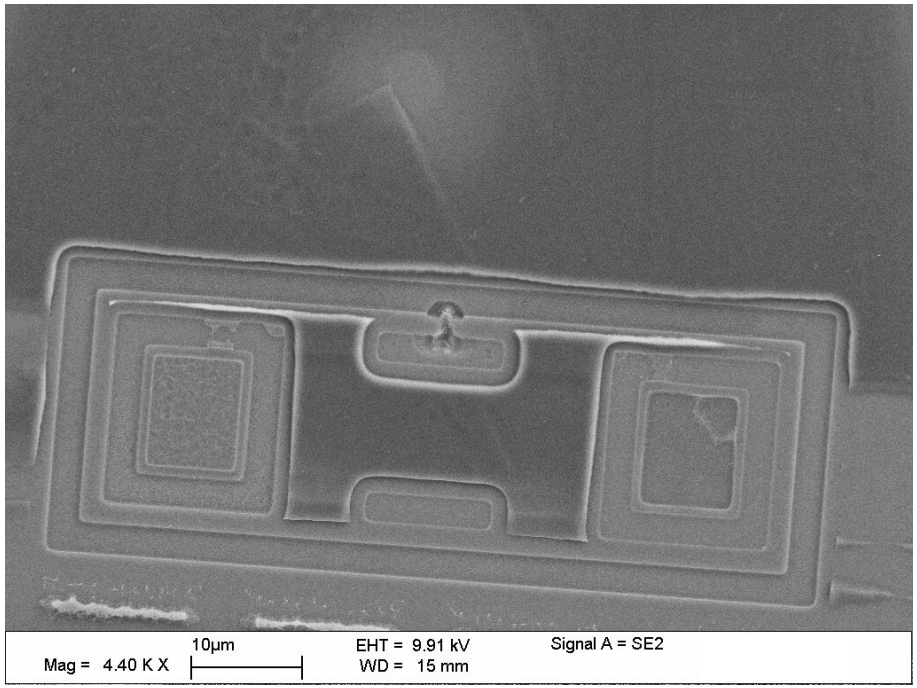


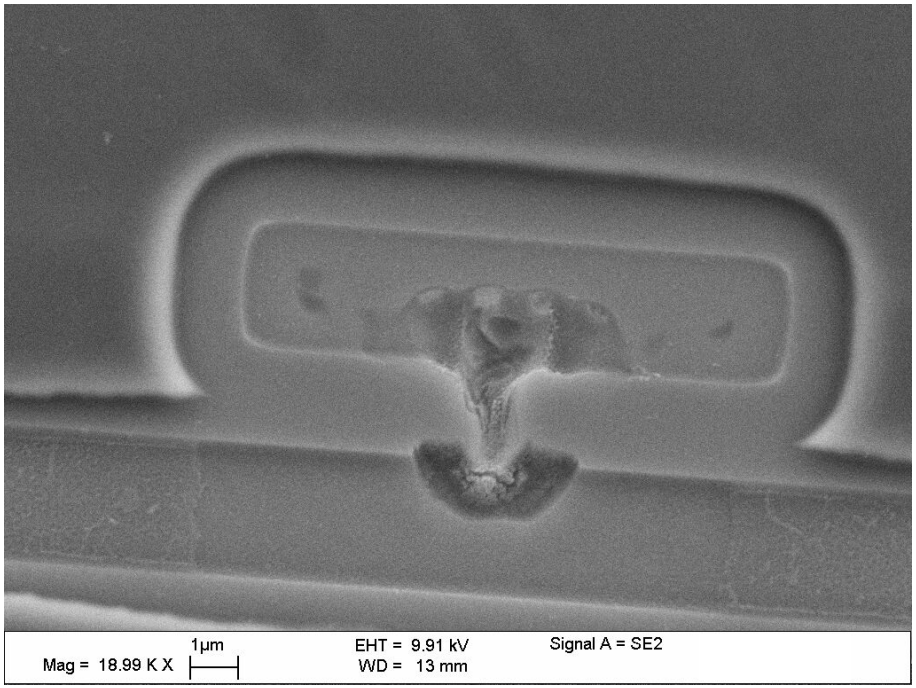
Localisation using OBIRCH Signal at EDS protection area of an input



Overview

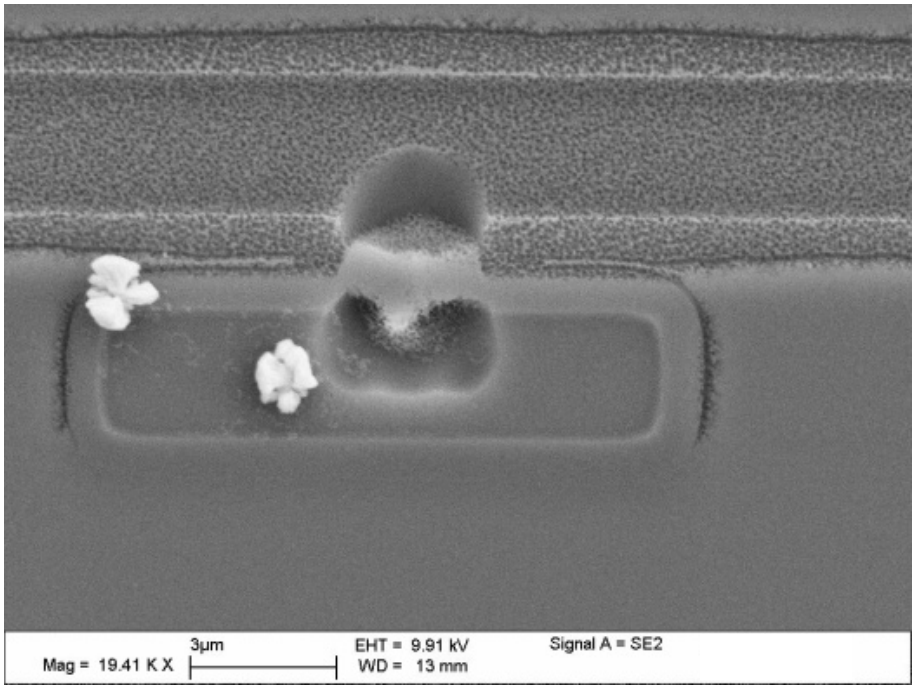
IC Failure Analysis

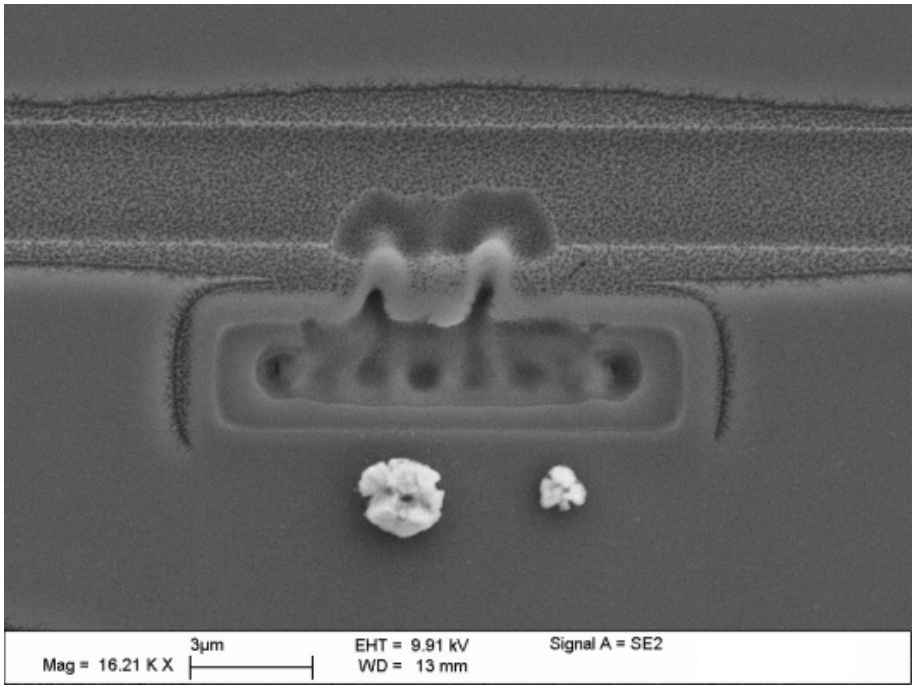




- **After deprocessing -> mechanical damage**
- **ESD, EOS or an ESD caused EOS**
- **Volume several µm³ -> ESD energy not high enough**

IC Failure Analysis





- **Other inputs also showing damages**
- **No electrical degradation**
- **On board measurements showing voltage spikes**

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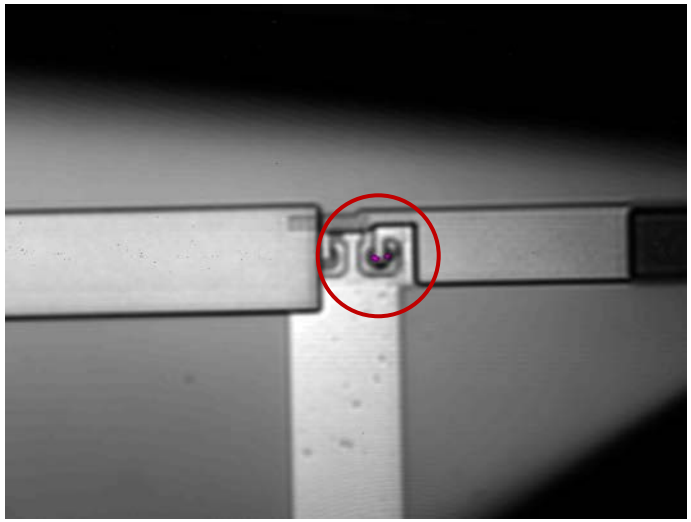
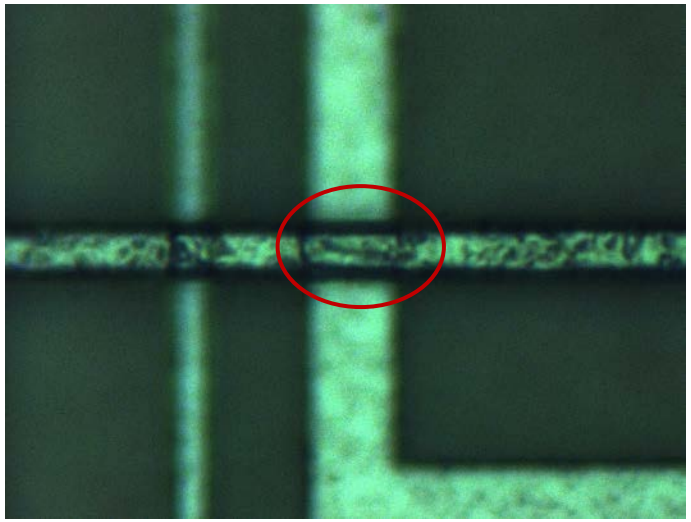
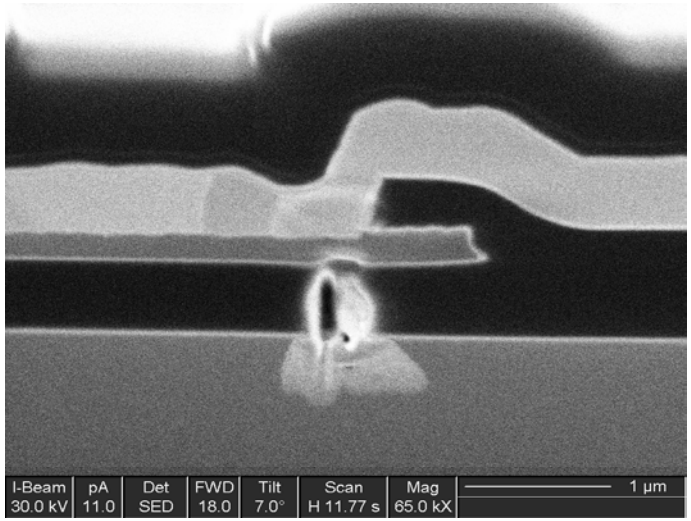
Result

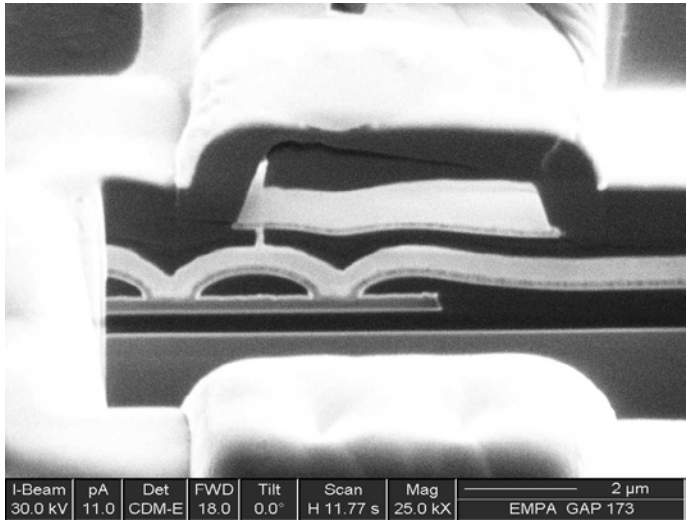
- Error pattern EOS
- Root Cause: Insufficient circuit schematic
- Further fails have to be expected

ESD Failures









ESD **ESDFOS ***

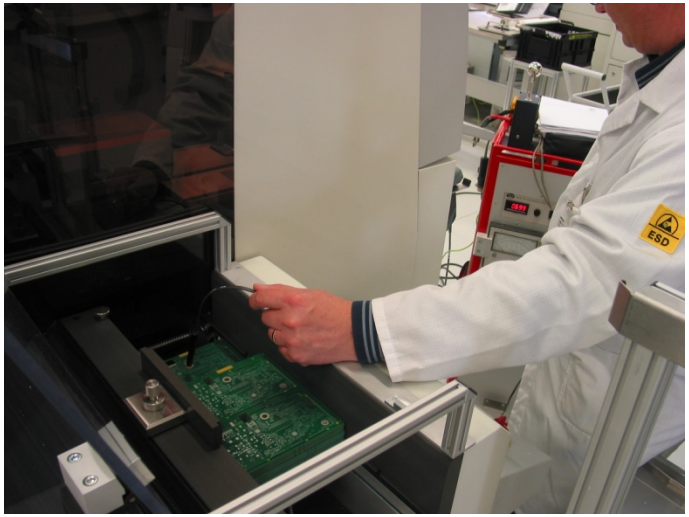
*** ESDFOS: ESD from outside to surface**

ESD Failures

- **95% are caused in production (ESDFOS & CBE*)**
- **Only 5% are EDS failures from field**
- **In many cases transmuted to an EOS**
- **Difficult or impossible to detect pre-damages**
- **Important to take precautions**
- **ESD evaluation of process equipment**

* CBE: charge board event

ESD Failures



ESD evaluation on running production line

FIB Chip Modification (incl. Cu cuts)

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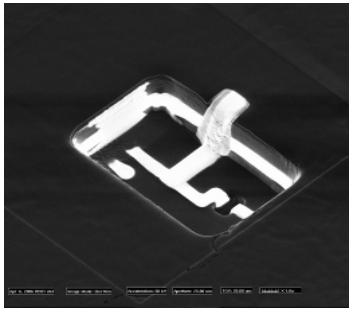
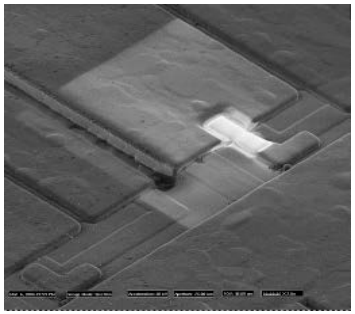
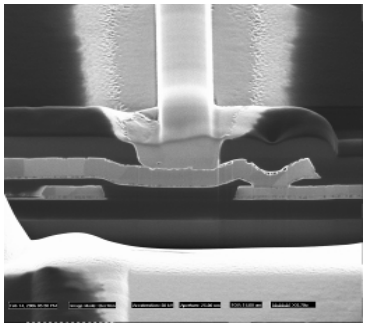
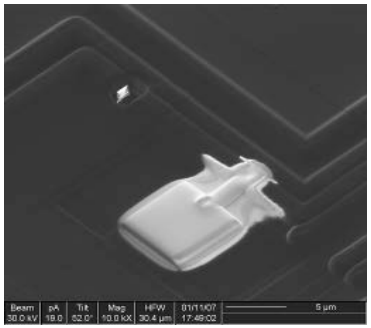
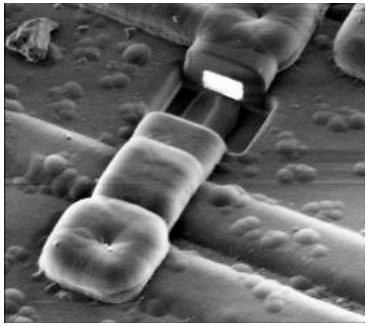
Silicon de-bug & chip repair modification on wafer level

Quick fix of e.g. design related bugs

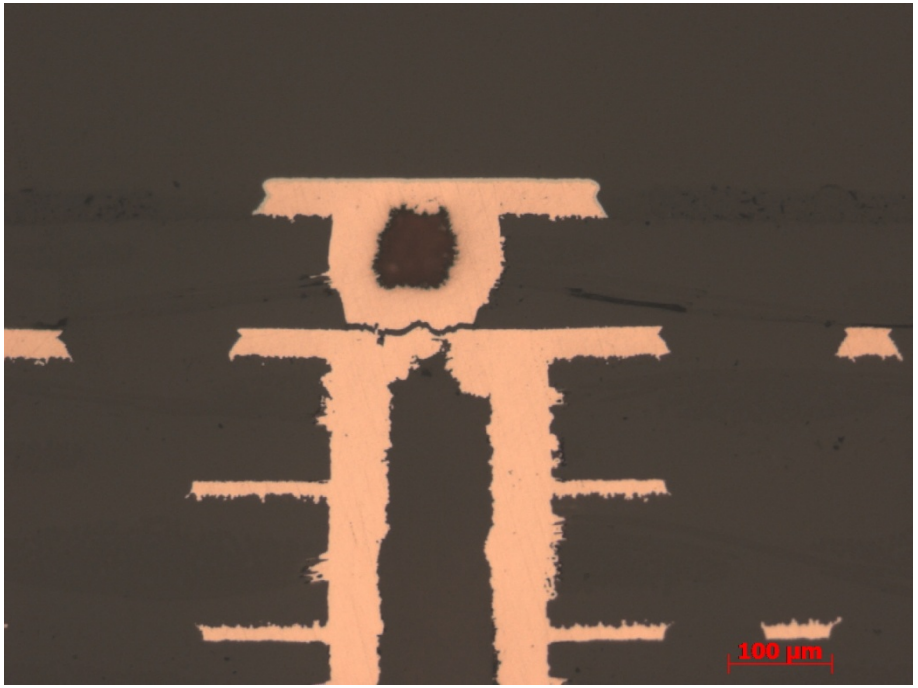
Risk reduction for mask set revision

Saving of valuable time-to-market in critical phase

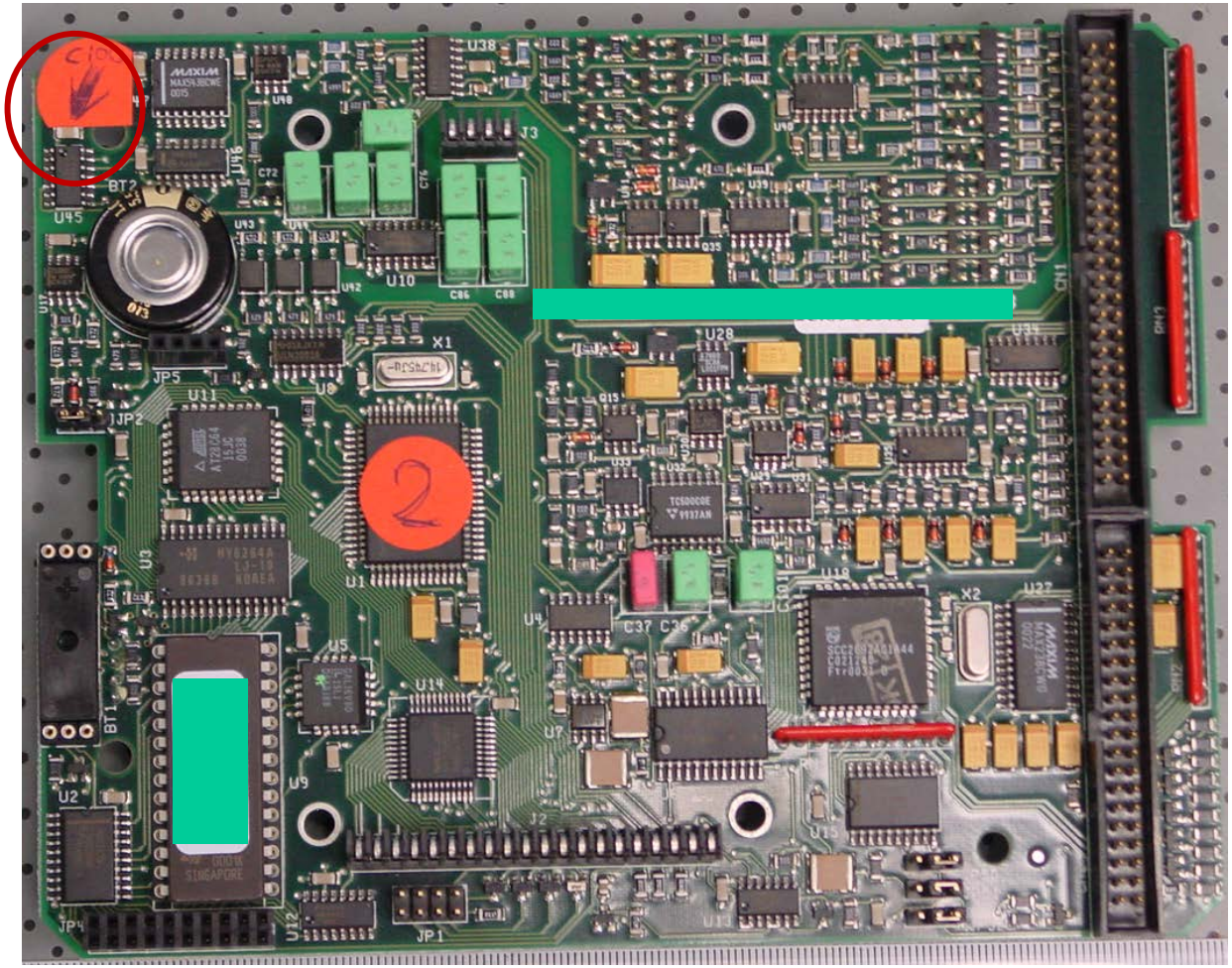






FA on Other Electronic Components

- **Larger feature size compared to integrated circuits**
- **Metallographic cross sectioning**

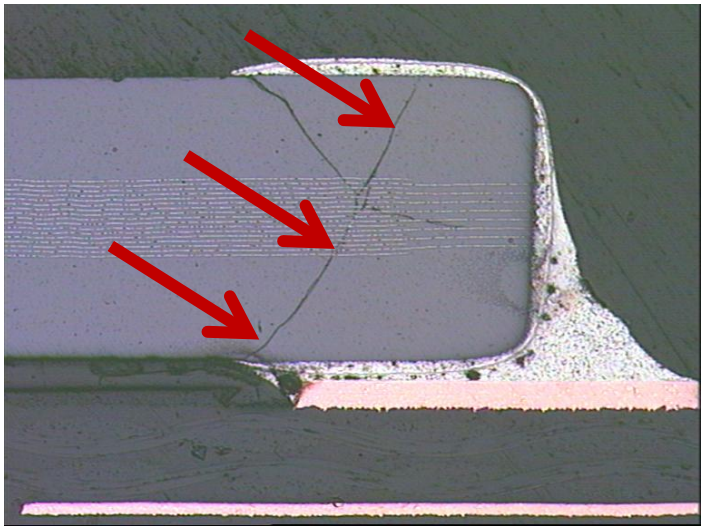


FA on Ceramic Capacitor

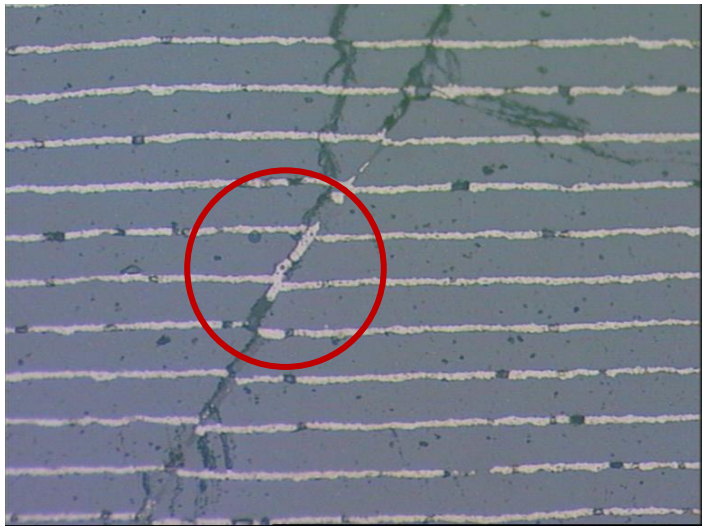


- Failed ceramic capacitor
- Field return
- 2 years in system
- Sensitivity to mechanical forces
- Improper assembly position

FA on Ceramic Capacitor



mechanically induced crack



short circuit

- Function: blocking capacitor
- Only 1 % of crack could be detected electrically
- Migration of silver metallization
- Electrical short circuit -> malfunction
- Local overheating created additional cracks

Root cause: wrong position

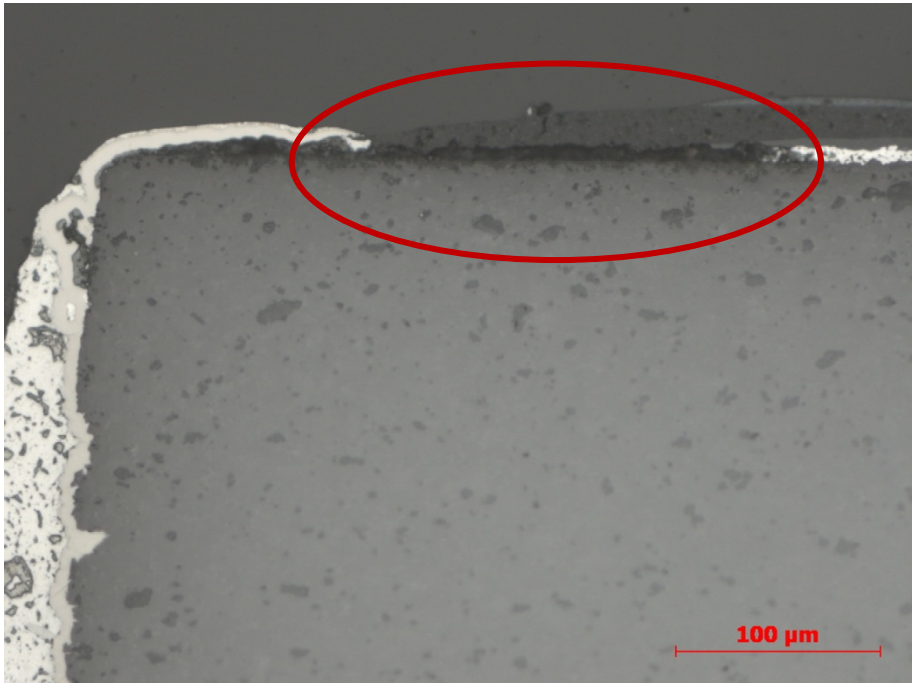
Failure Analysis on Resistor

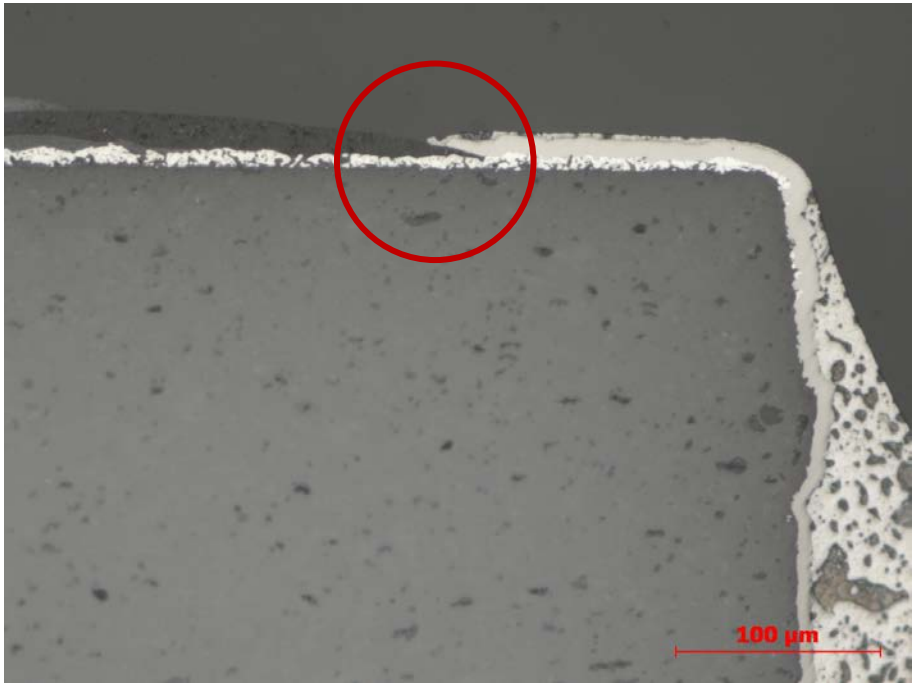
Application: control unit traffic light

Silver corrosion (Ag_2S)

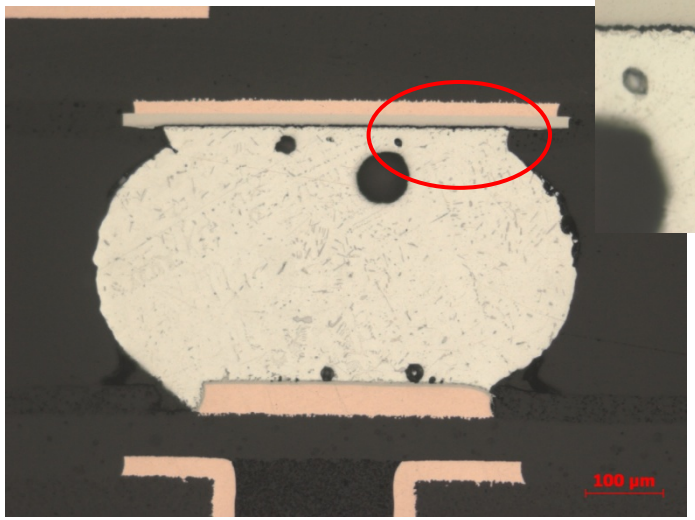
Only failed in China – reason ?

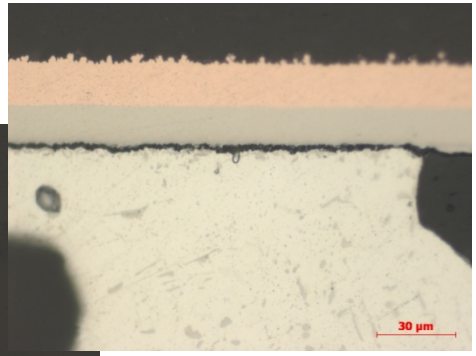
Higher sulphur content in petrol!



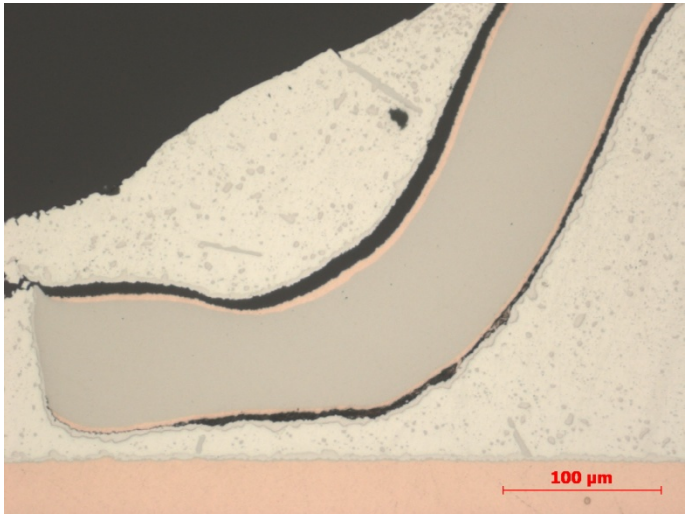


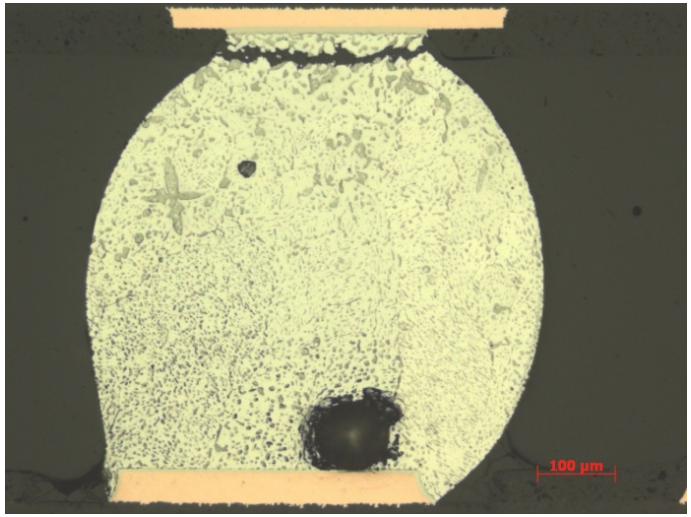
Solder Joints





metallurgical problem
intermetallic phase



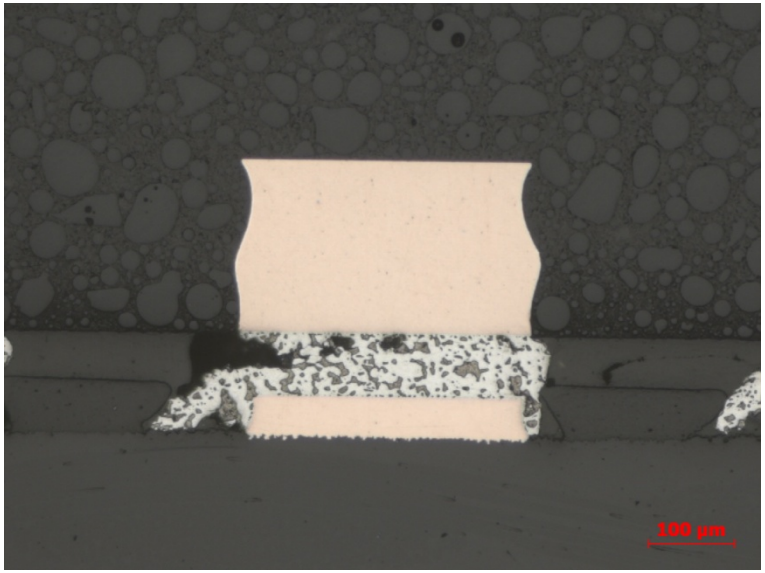


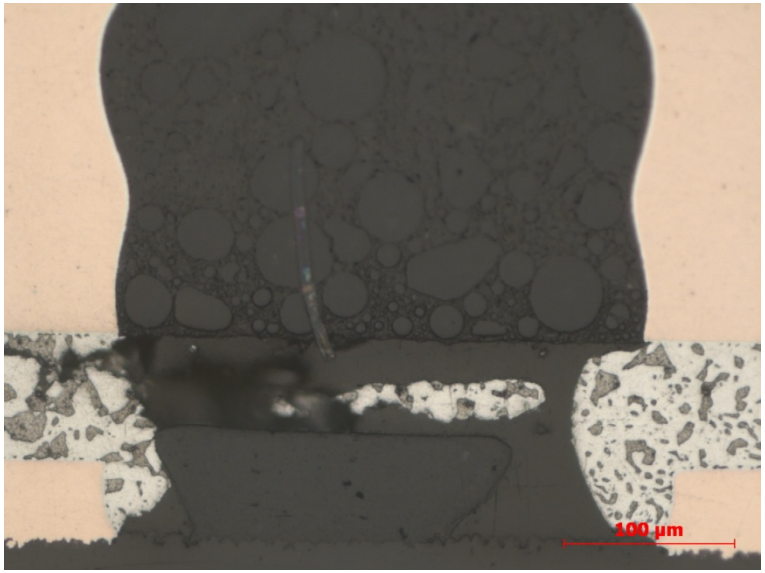
mechanical overstress
material fatigue

QFN Solder Joints

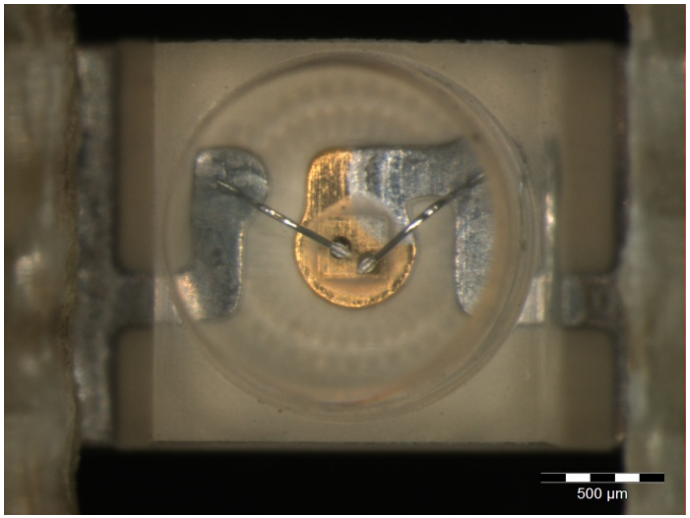
Metallographic Cross Sectioning QFN

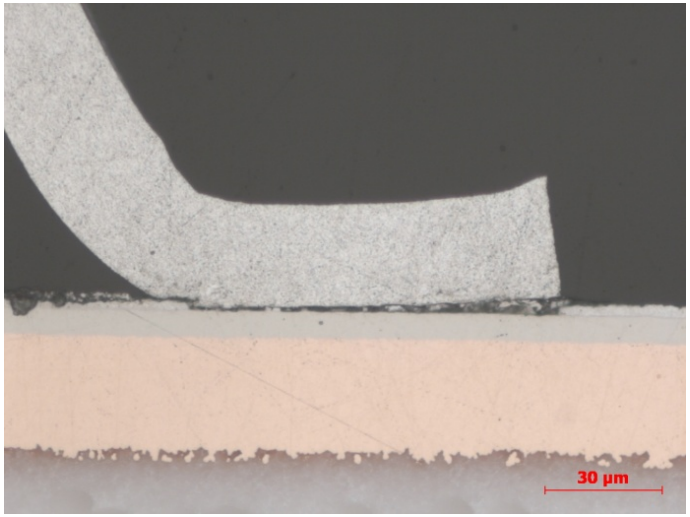
QFN in the centre of a pcb, combination of vibration and temperature for less than 2 years in the field – destroyed solder joints – material migrates and shortened 2 connections





FA on LED

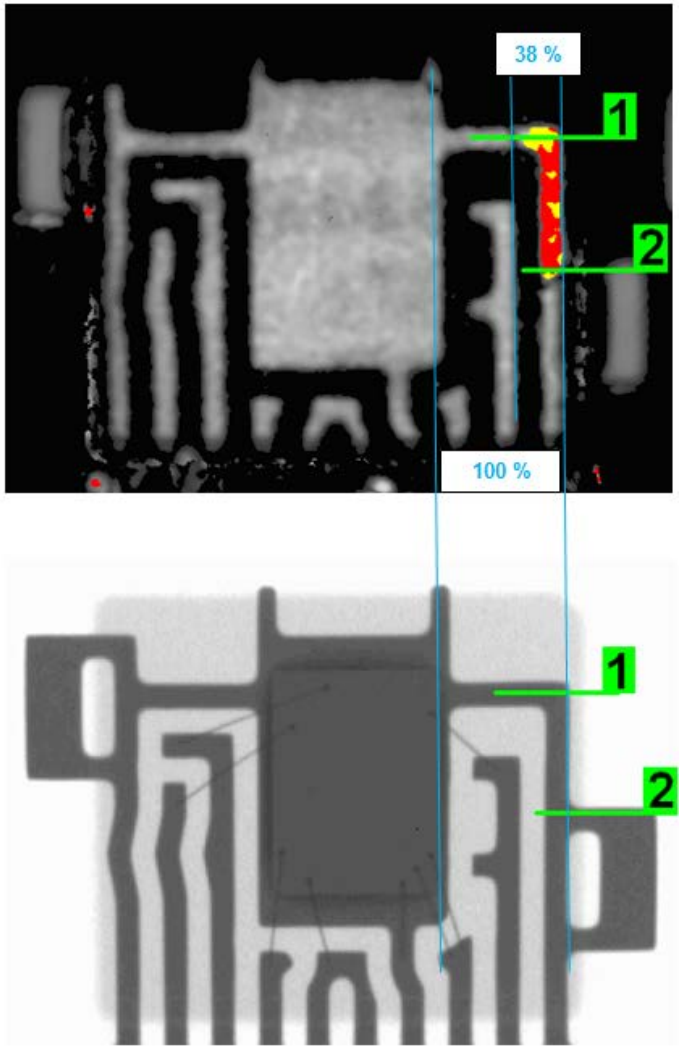


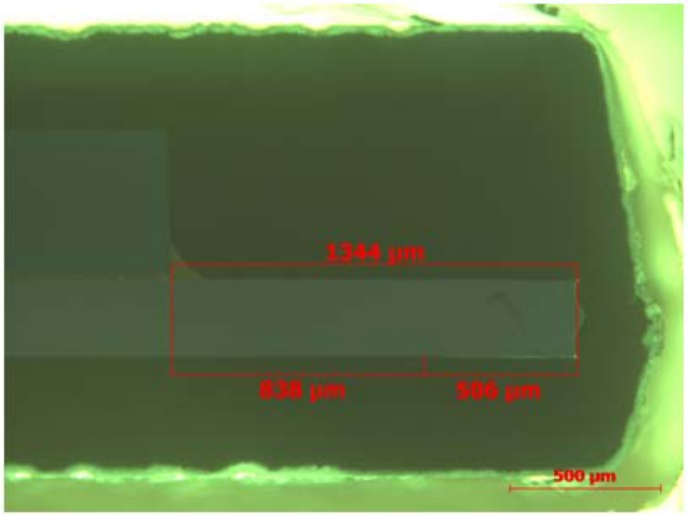


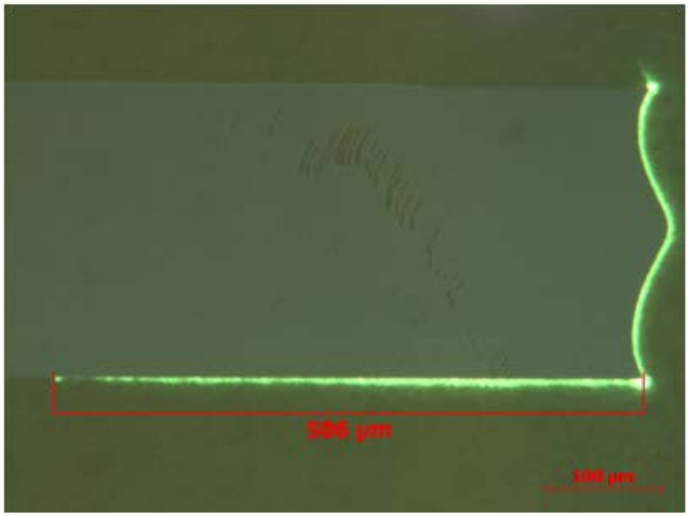
- LED showing intermittent open
- Field return
- Several weeks in application
- Masking problem on lead frame
- Wire bonding on tin layer

Reliability of LEDs is a huge issue. In 2013, RoodMicrotec performed more LED FAs than IC FAs

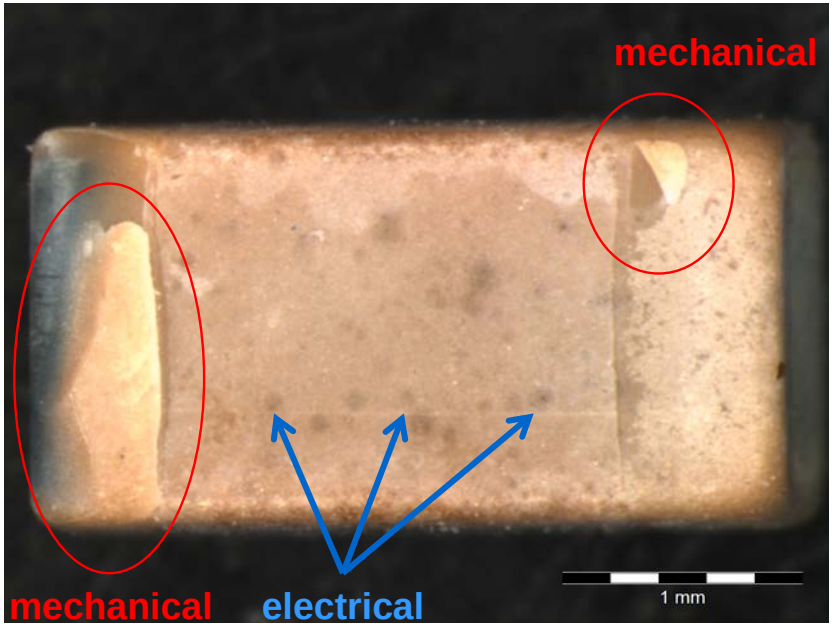
Dye Penetration / Fluorescence Microscopy

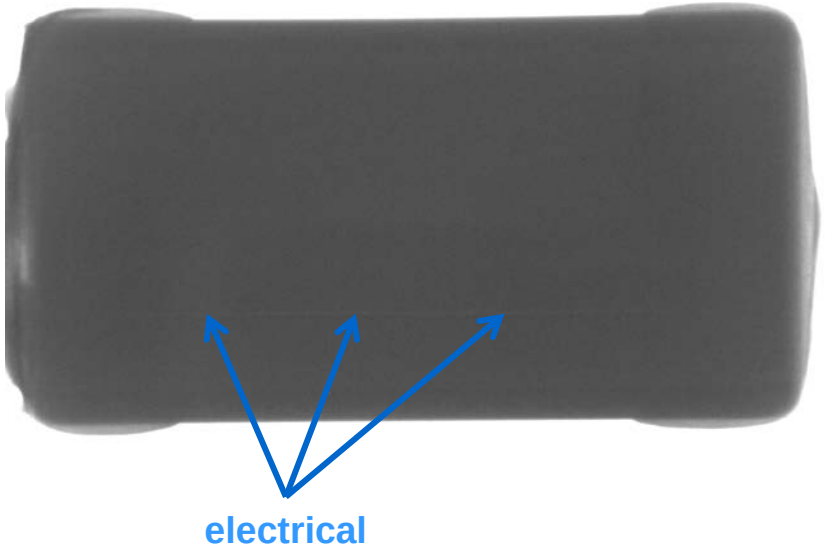


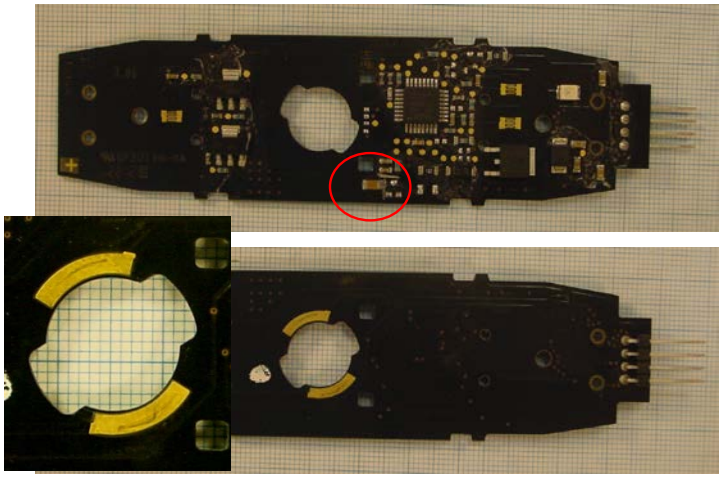


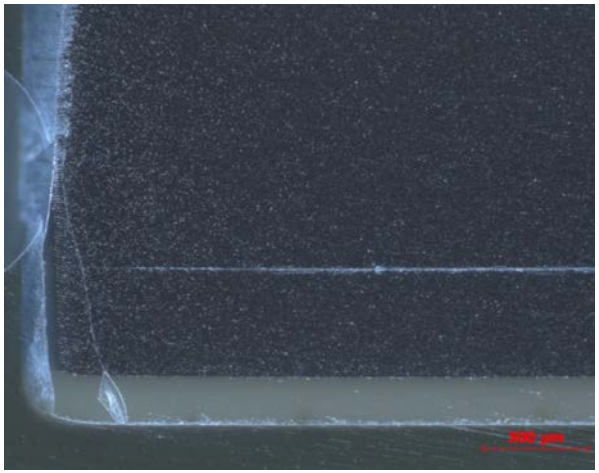


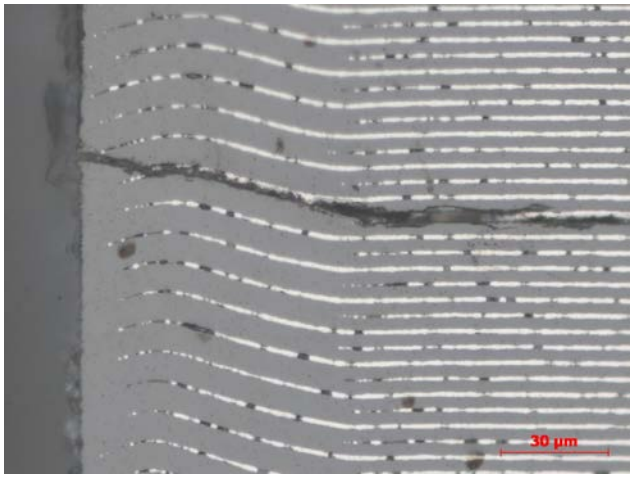
Failure Analysis on Ceramic Capacitors





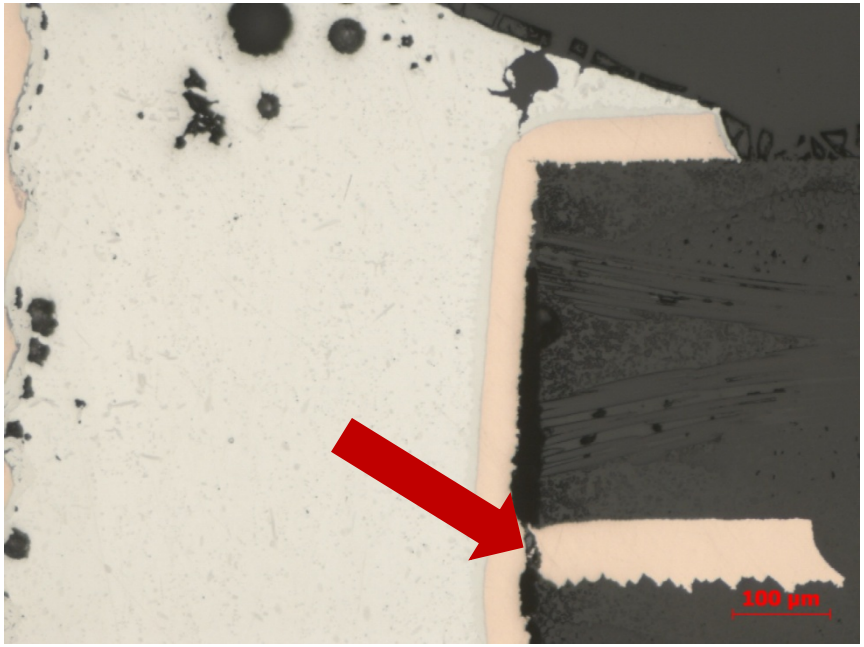


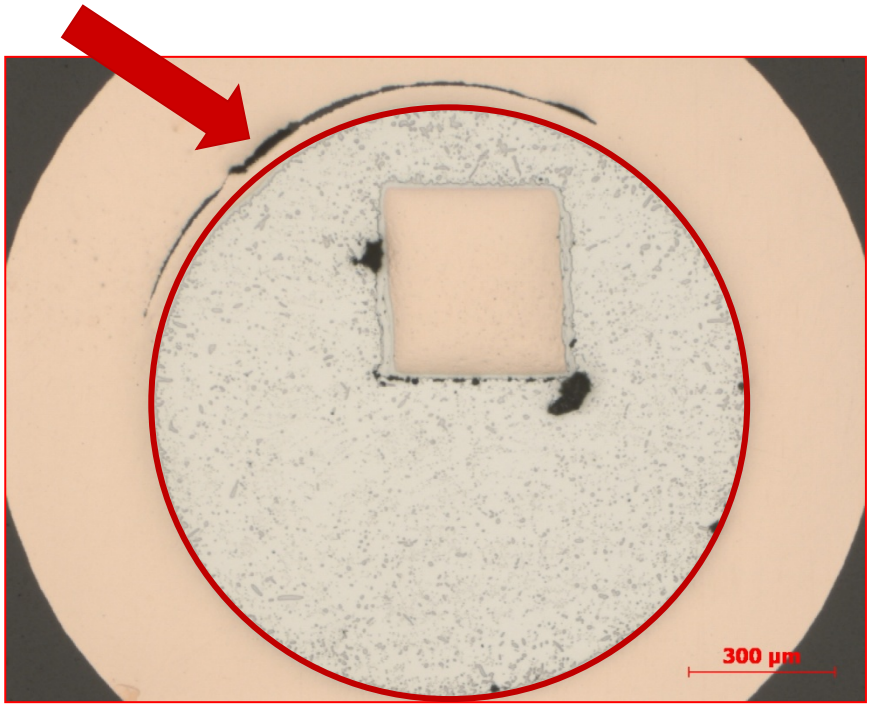




Failure Analysis on Printed Circuit Boards

Disconnectivity of inner layer to via

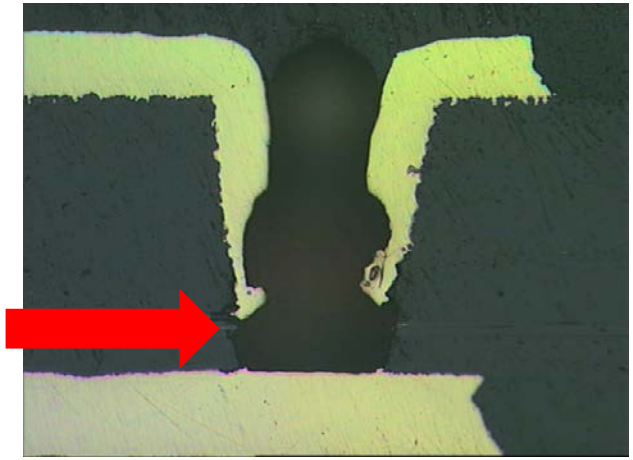


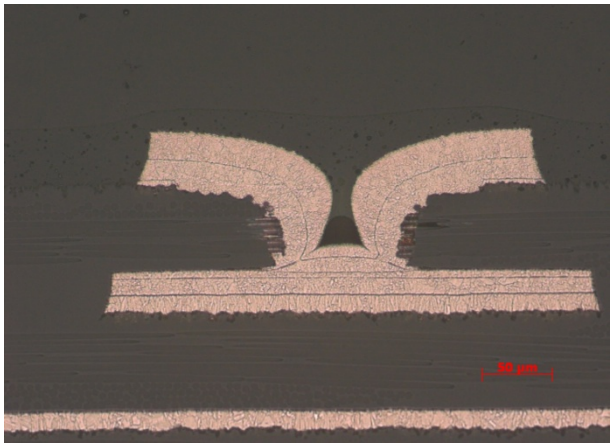


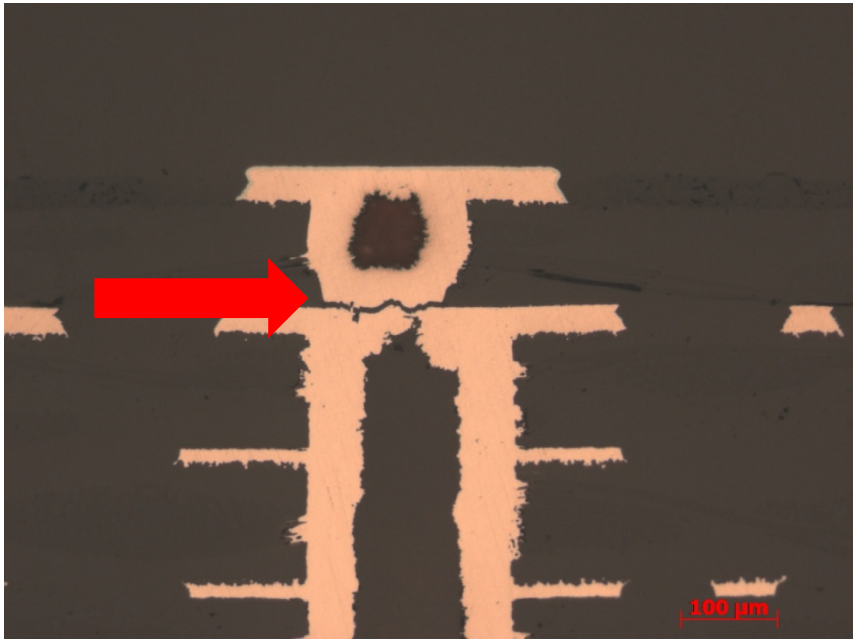
- Pin to small
- Tensile stress on via metallization after solidifying of solder material
- Stress proportional to solder filled gap
- Mechanical damage

Failure Analysis on Printed Circuit Boards

- **Microvias, blind vias und buried holes**

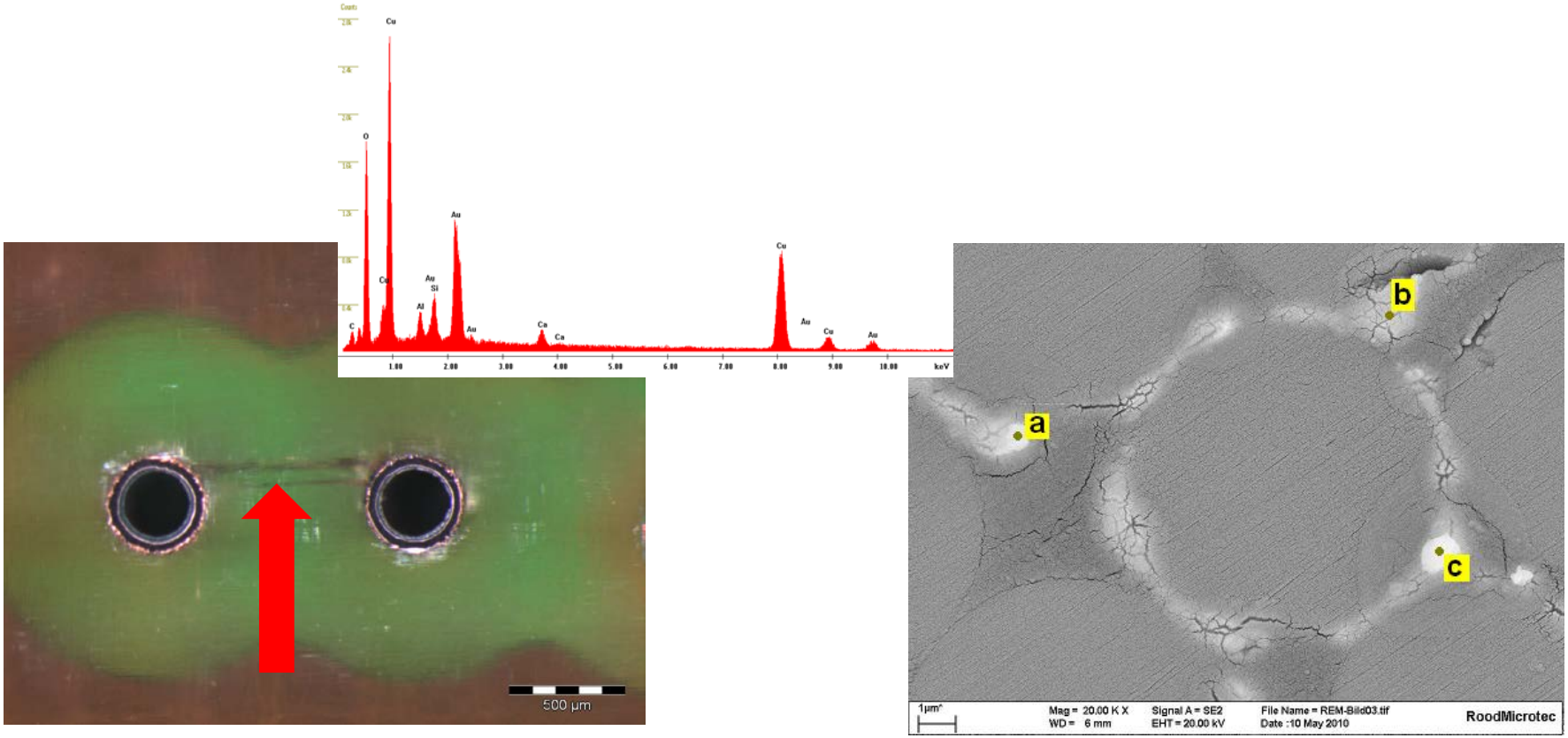




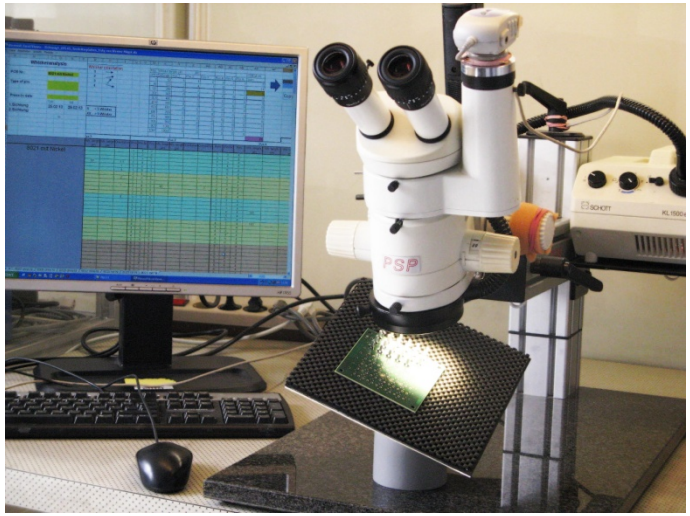


Failure Analysis on Printed Circuit Boards

- **CAF (Conductive Anodic Filament)**



Whisker Inspection



Whisker check

incl. data evaluation

Storage:

Ambient
Temperature / humidity
Temperature cycles

Identity Check / Counterfeit Check

1) **Fast identity check with original reference**
   - Chip in package
   - Chip bondage & dimension identical with original

2) **Fast identity check without original reference**
   - Chip in package
   - Original supplier chip

3) **Ageing test additional to identity check**
   - (1)&(2) plus:
   - Device outdated?
   - Solderability test

1) **Passive identification**
   - Fake device or wrong type
   - Simple ESD-Test

2) **Active identification**
   - (1) plus:
   - Simple electrical functional verification

3) **Parametric test**
   - (1) plus:
   - Detailed electrical functional verification

4) **Parametric and functional test**
   - (1) plus:
   - Complete electrical functional verification

Failure Analysis Expert Teams

RoodMicrotec
powerful solutions

15 team members

Expert teams

- General FA & ESD Evaluation
- Failure-& Material-Analysis
- PCB Analysis & Grindings
- Focused Ion Beam (FIB)
- Electrical Failure Analysis
- Optical Failure Analysis

- **Physicists**
- **Electronic Engineers**
- **Material Engineers**
- **Physical technical assistants**
- **Chemical technical assistants**
- **Metallographs**

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NanoPhysics good analysis needs strategy
NanoScope Services Ltd.

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Photonics BW
Silicon Saxony
LED Light for you powered by OSRAM
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