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Failure Mechanisms and Risk on LEDs and LED Systems

SMT 5.5. – 07.05.2015



Zwolle



Noerdlingen



Stuttgart



Dresden



Bath

...certified by RoodMicrotec



Why is the life time limited?

The LED chip has a proven life time of more than
50.000 hours

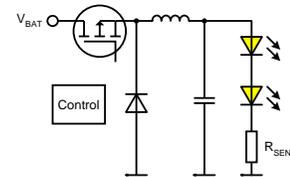
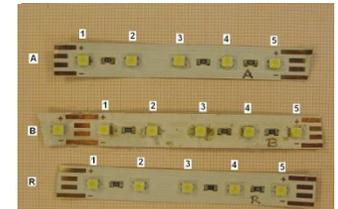
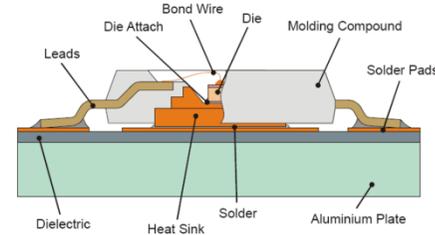
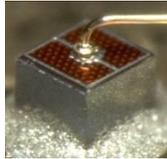
but:

- **Complexity of a LED Lamp / System**
- **Power supply**
- **System set-up**
- **Environmental stress**

can reduce the overall life time drastically

LED Lamps – Construction

- **Chip**
- **Interconnection / packaging**
- **Interconnection / printed board**
- **Overall thermal management**
- **Electrical driving circuit**
- **Lenses and protection to the environment**



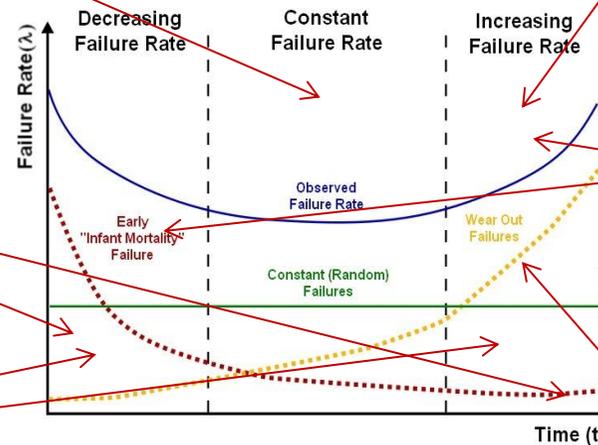
Impacts to the LED lamp / system life time

**Intrinsic capability of chip,
design and manufacturing process**

Interconnection LED and LED board

**Electronic driving
and control
circuits**

**Environmental
conditions**



ESD damage

Thermal management

Requirements for an „added value“ Failure Analysis

- **Expectation: root cause identification**
- **Needs: Details of the system life history**
 - **Know-how of LED manufacturing technologies**
 - **Systematical analysis approach**
 - **Knowledge about analysis tools and methods**
 - **Electrical system know-how**
 - **Ability to put all puzzle pieces together to draw a conclusion for improvement possibilities**

Methodology:how to find failures

- **Ask questions**
 - Detailed operation and storage conditions
 - Environmental conditions
- **Characterisation**
 - Functionality and I/V curves
 - Light intensity, spectral characteristics
 - Viewing angle
- **Non destructive analysis**
 - Xray / Ultra sonic
 - Optical microscopy
- **Destructive analysis**
 - Separation of the piece parts (identification of the defective system component)
 - Chemical decapping and/or metallographic grinding
- **Physical analysis**
 - FIB / SEM „**Focus Ion Beam**“/„**Scanning Emission Microscopy**“
 - OBIRCH / Emission microscopy „**Optical Beam Induced Resistivity Change**“
 - EBIC „**Electron Beam Induced Current** “
 - Cathodolumiscence

Steps for an „added value“ Failure Analysis

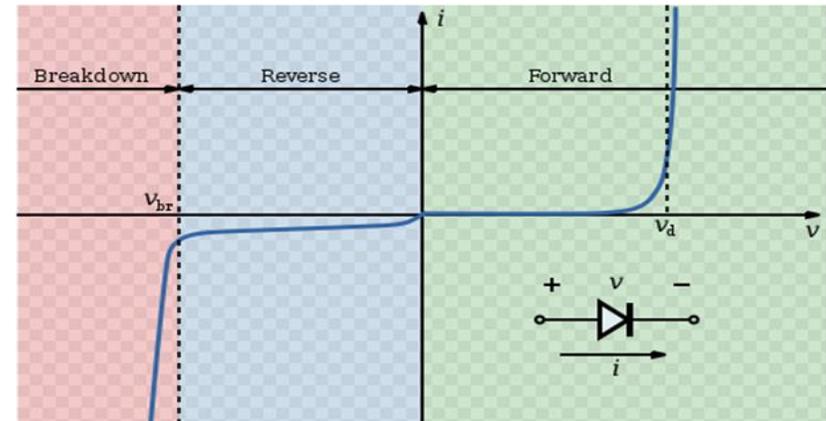
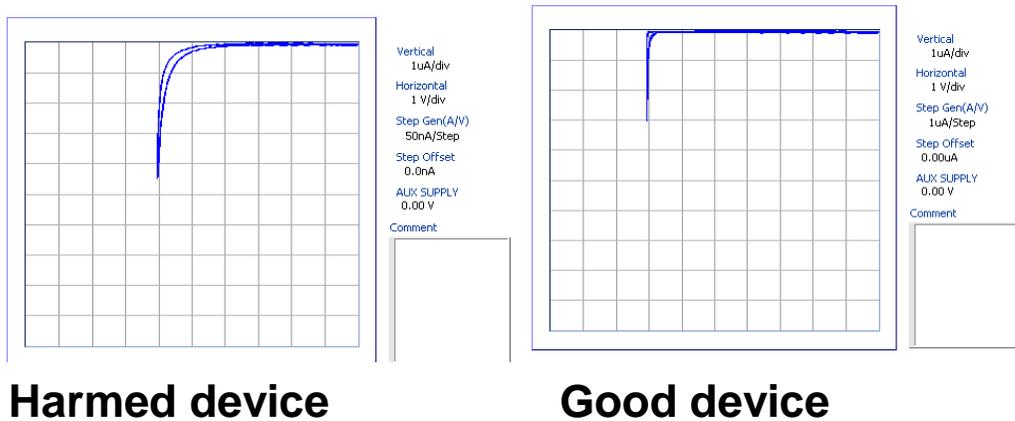
- Visual check compared to a reference sample
- Confirmation of electrical behavior
- Link the given information with the findings
 - **Do they match?**
 - Draw a failure tree
 - Exclude - if possible - branches
 - Prioritize
- Start analysis with system separation

Steps for an „added value“ Failure Analysis

- **Separation: is the LED defective?**
- **If yes -> the goal is to visualize the problem**
 - Is the result explainable (customer information!)
- **If no -> analyse the electronics**
 - Visual inspection of connections, solder joints, „burned“ spots or components
 - Check circuit drawing of build-in electronic and measure
- **Check power source**

LED defects / Chip degradation: reverse current

Increased reverse current, decreased break-down voltage
as a indication for impacts in the epitaxial layer system

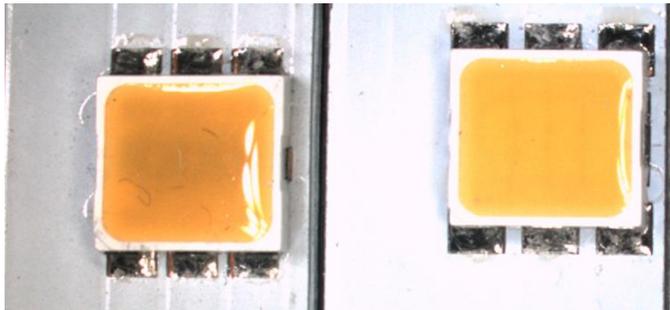


Increased reverse current as indication for early failures

LED defects

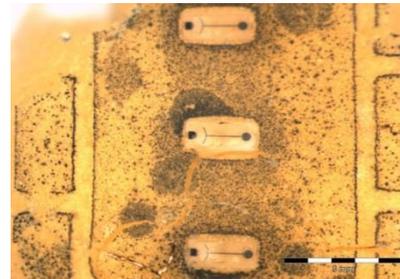
Packaging technology

Failure after Life test 4000h and field failure

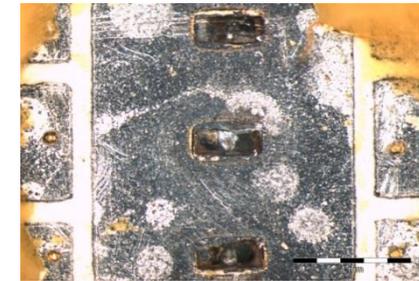


Field failure

Reference



Die left at soft housing



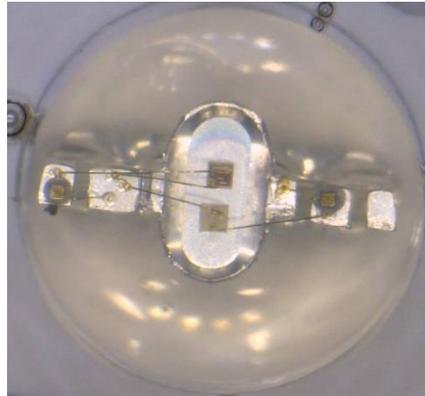
die imprints on submount

Removal of encapsulant, chip stick at the housing material, die attachment insufficient

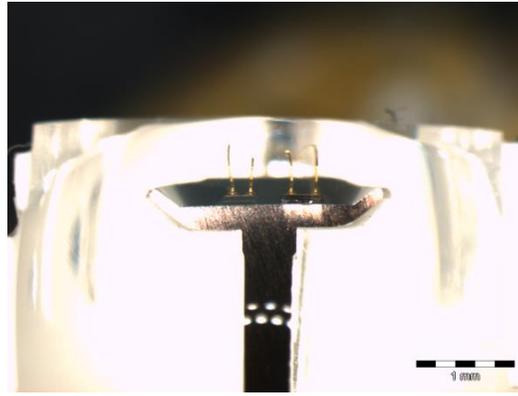
Package and interconnection material not sufficient

LED defects

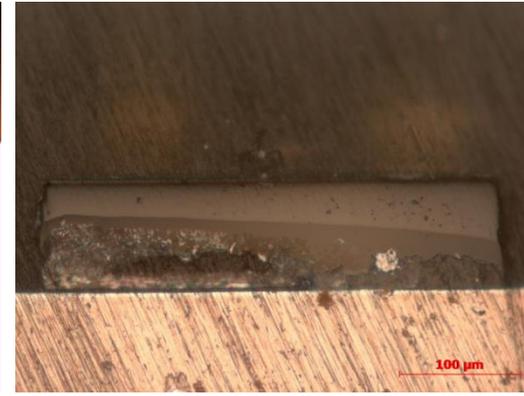
Packaging technology



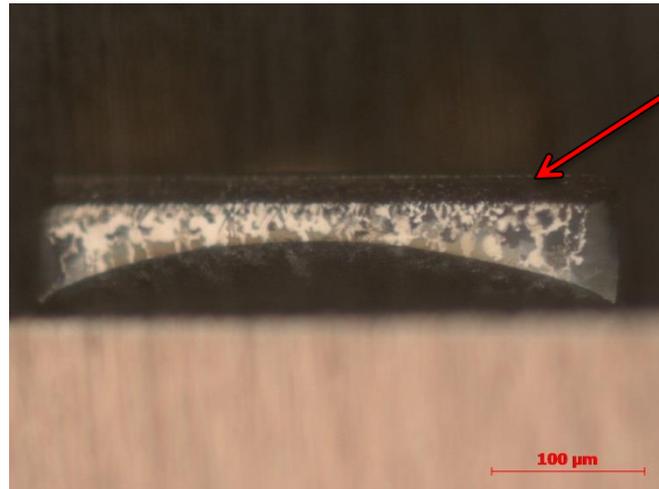
2 color LED



Grinding from the side



Electrical good die after grinding



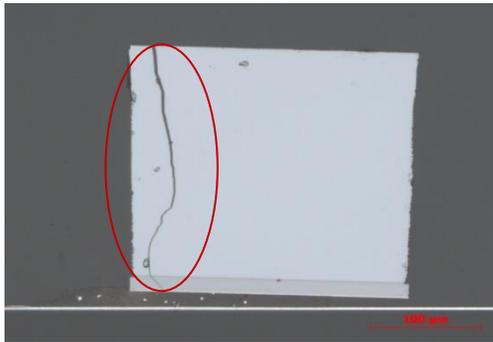
Silver-migration - short circuit / leakage only the green LED fails

Root cause: higher power consumption of the green LED results into an activation of a chemical reaction of glue thinner liquid with the Ag from the paddle

For the red LED the risk is also present – it will be a question of time until it fails.

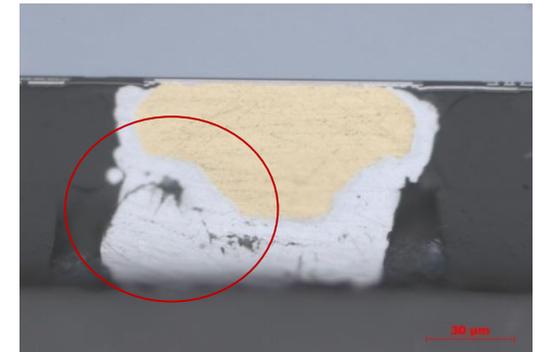
LED defects

Packaging technology



Crack in die due to insufficient die attach material and mechanical stress at placement

Solder material can not withstand the different thermal expansion of material used

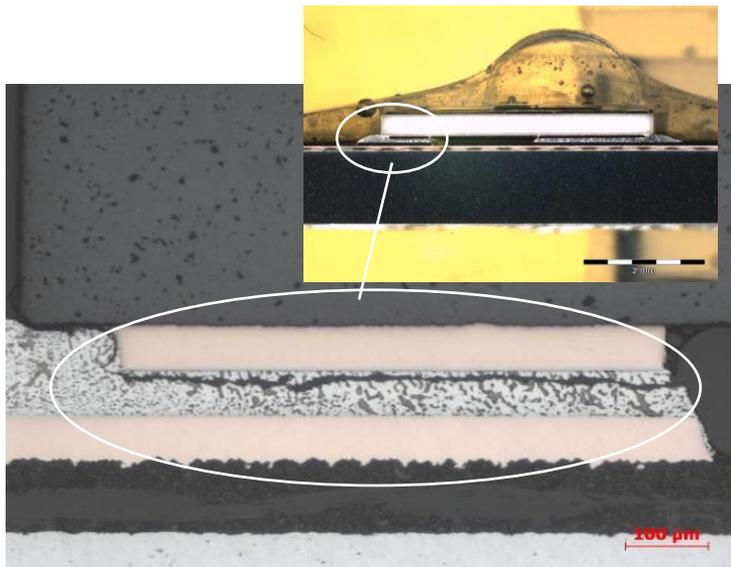


Mechanical stress by different thermal expansion coefficient and insufficient die attach

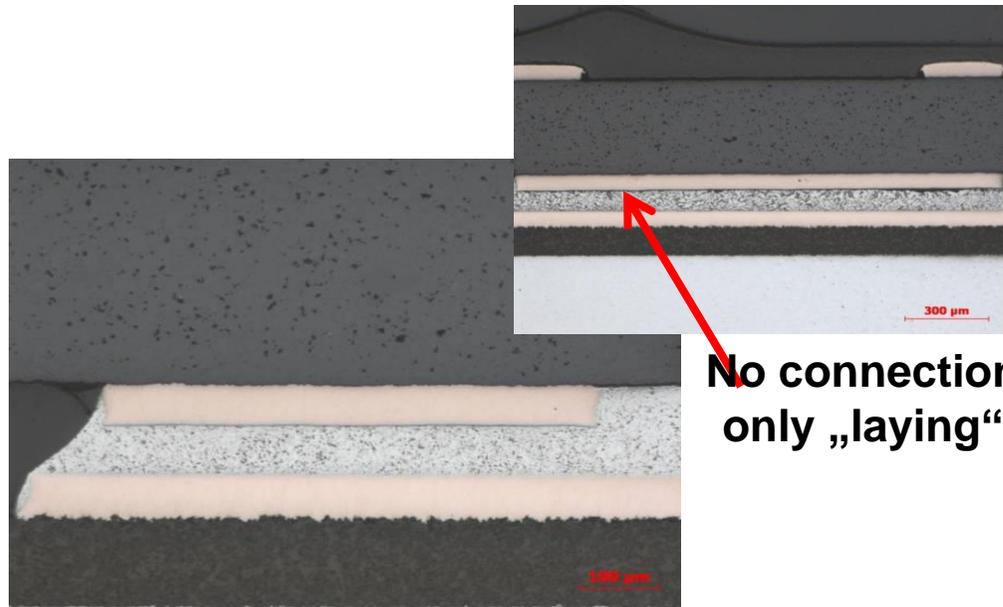
LED defects / System defects

Interconnection LED printed board

Solder joint between LED package and printed board open after 1000 temperature cycles



Cracks in solder joint



No connection
only „laying“

0 h sample

Thermal expansion of the different material not well matched

LED defects

Manufacturing process

Damage by too high temperature during soldering process

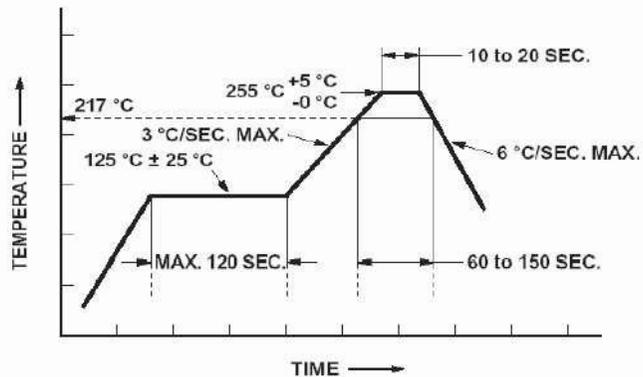
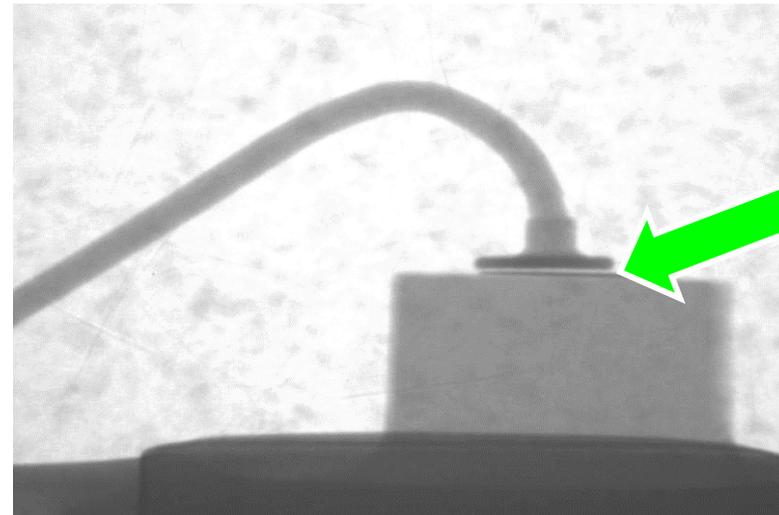
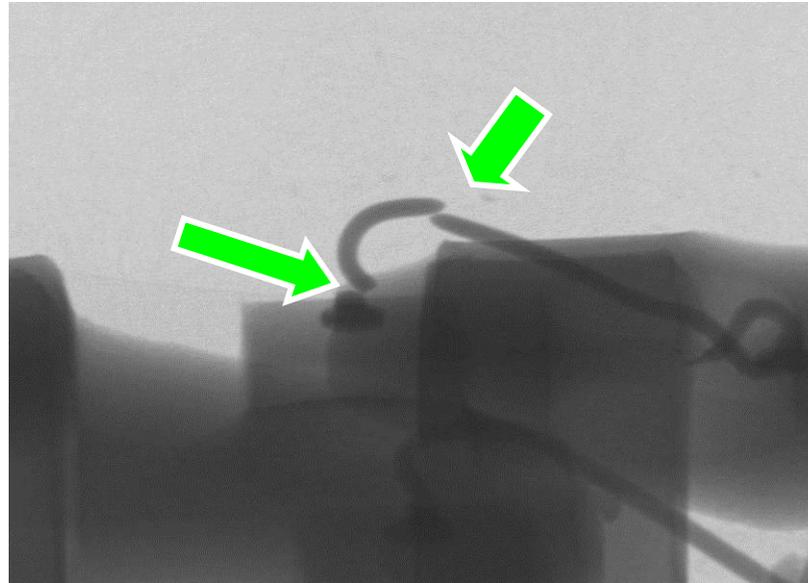


Figure 7b. Recommended Pb-free Reflow Soldering Profile.



Lift of the bond due to thermal stress during the

LED defects / Handling - manufacturing process

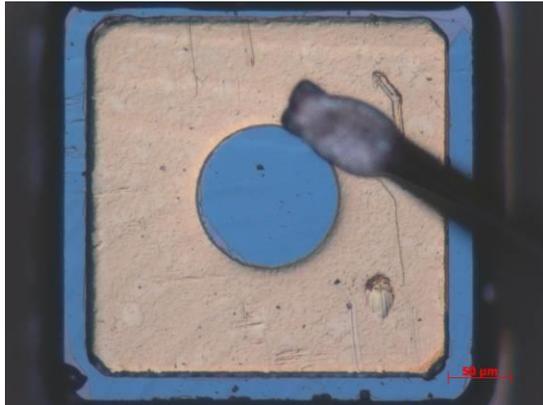


**Wire bond lift could be caused during
„pick and place“ process by a „sharp“ nozzle**

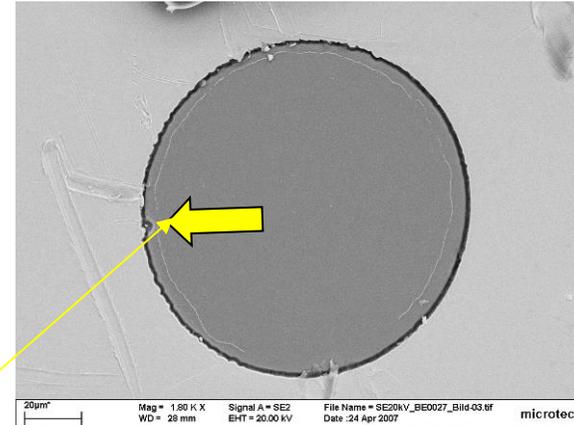
Mechanical deformation of the bond wires

LED defects

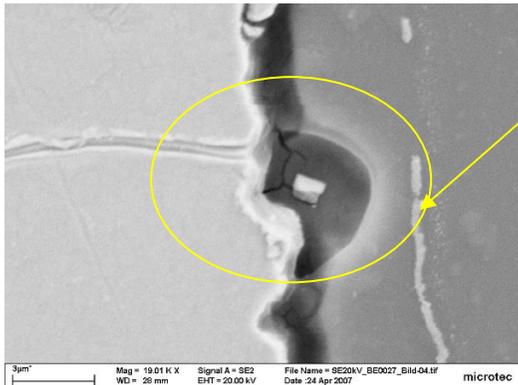
Handling: ESD damage



Chip overview



**Overview of lighting area:
Typical sign of a ESD damage**

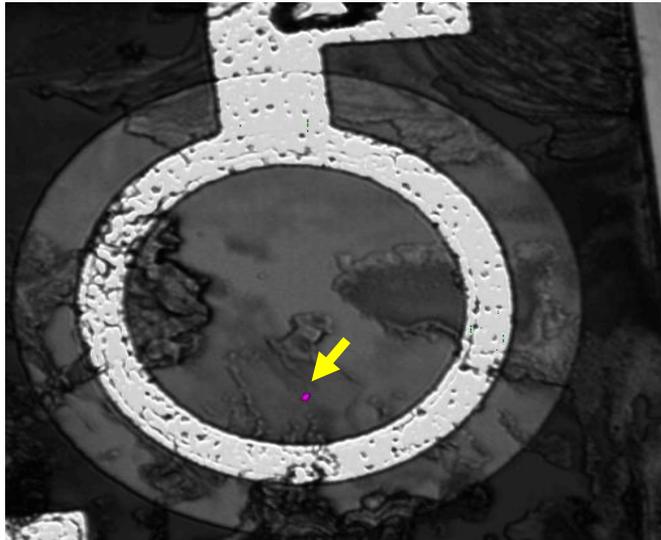


SEM analysis detail view of the damage

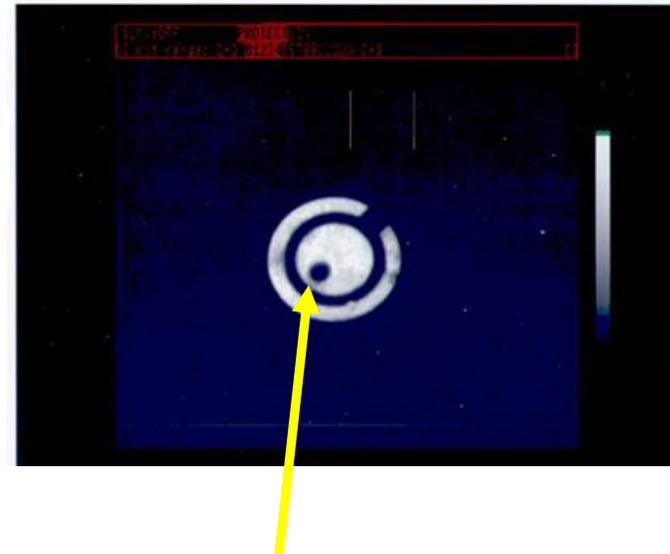
**Complete shortage of the LED induced
by ESD damage**

LED defects

Handling: ESD damage of LED



Reverse-leakage-current
detection by OBIRCH

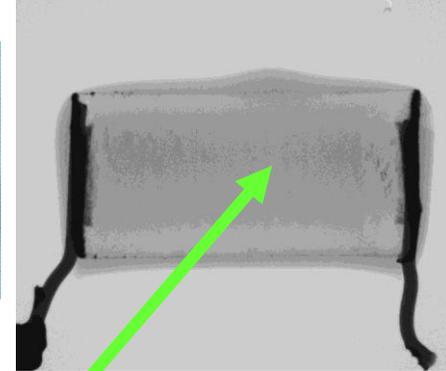
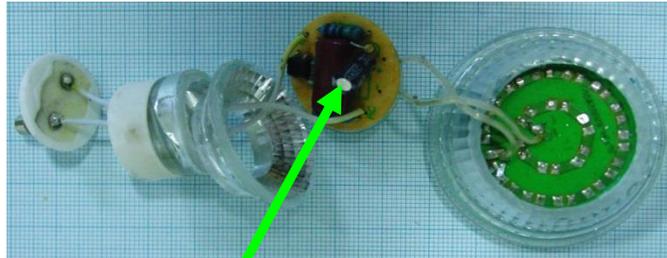


A large dark spot is already seen in
the driving mode. A starting point for
further degradation.

**Lumen degradation induced by ESD damage: „Dark-spot“
Beginning of degradation**

Electronic responsible for LED defects

LED lamp failure driving circuit

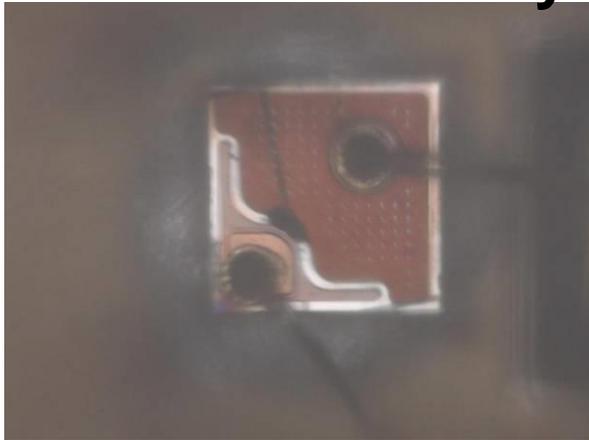


Defective tantal capacitor

Driving electronic failed due to Tantal capacitor
LED operates properly

Electronic responsible for LED defects

LED failure by driving circuit



Overview



Massive damage in the bond area

Shortage induced by EOS

System/Application Conditions

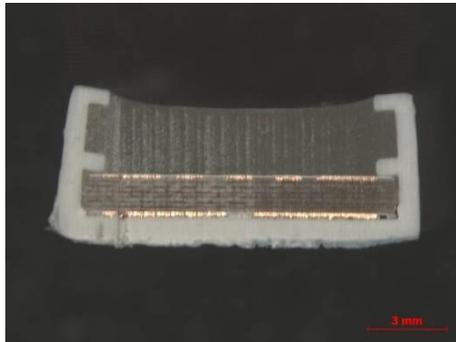
Light stripe: thermal management

$T_{\text{case}} \approx 100^{\circ}\text{C}$
life time only few hours



$T_{\text{case}} \approx 42^{\circ}\text{C}$
life time ≈ 9.000 hours

Comparism between good
and degraded sample



Plastic housing /FR4 printed board

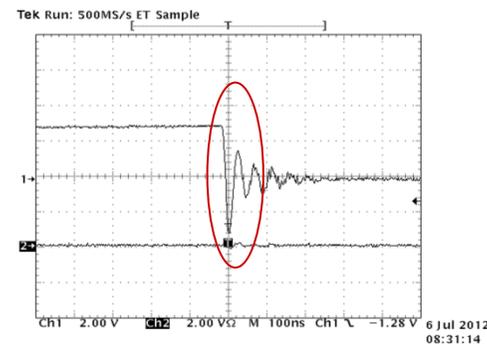
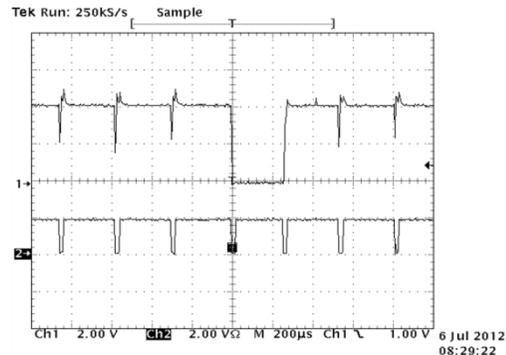


Aluminium housing / aluminium board

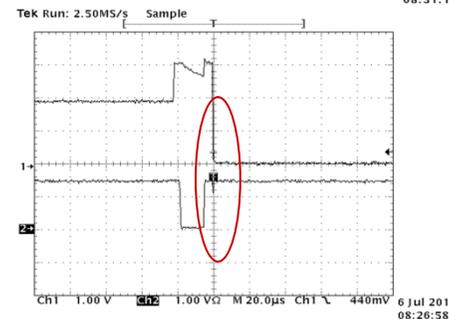
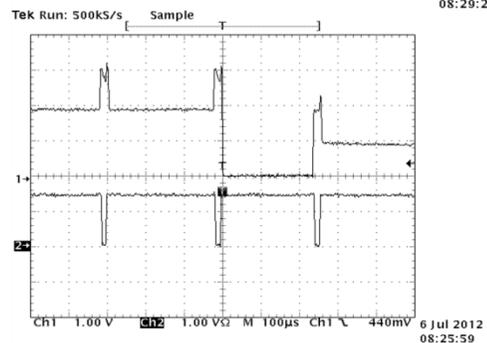
LED light stripe: massive degradation due to insufficient thermal management

System/Application Conditions

LED failure by driving circuit



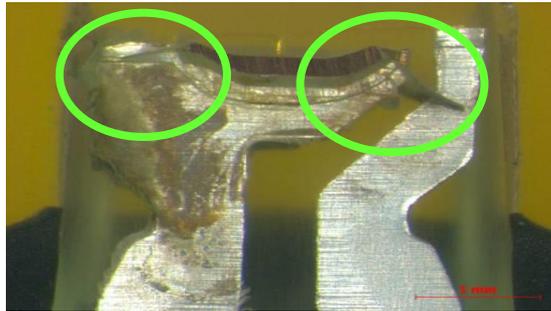
Previous circuit



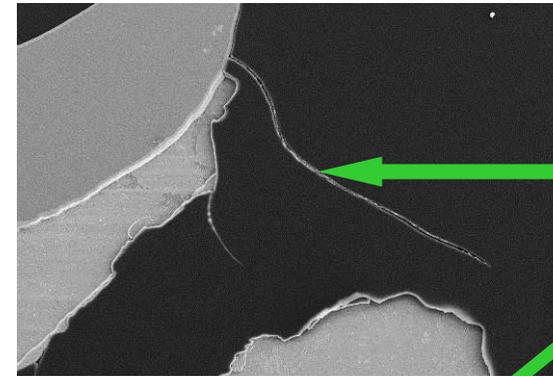
Improved circuit

“ spikes“ in the driving circuit reduce the lifetime of the LED drastically
Solution: serial diodes in both directions reduce the spikes drastically and increase the lifetime of the LEDs

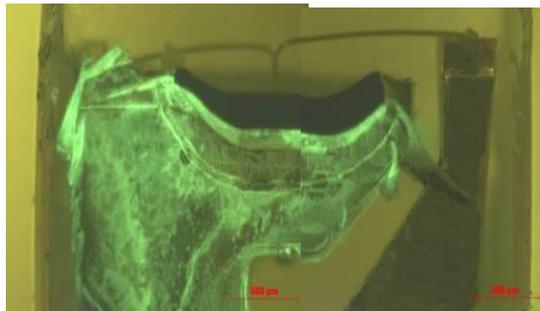
Environmental conditions:



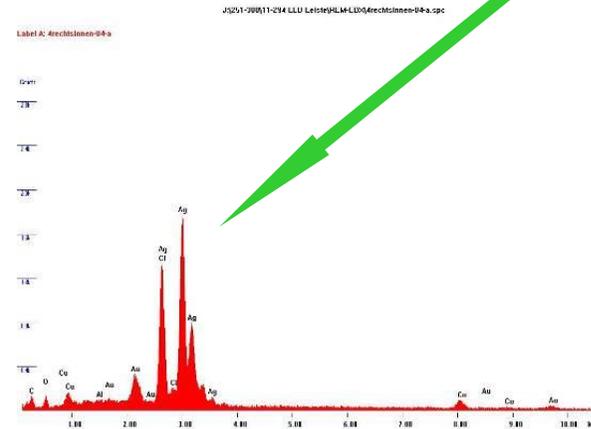
Silver migration and cracks



**Silver-migration
in the crack**



delamination detected by UV-light

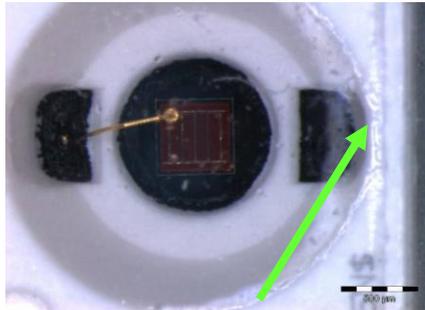


**Cracks and silver migration induced by the atmosphere
UV radiation, salty and humid atmosphere**

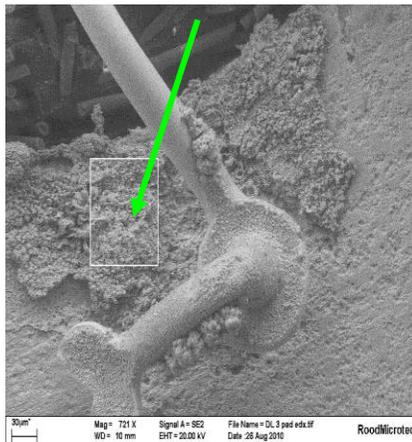
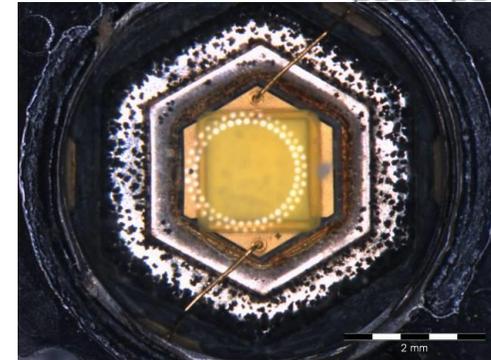
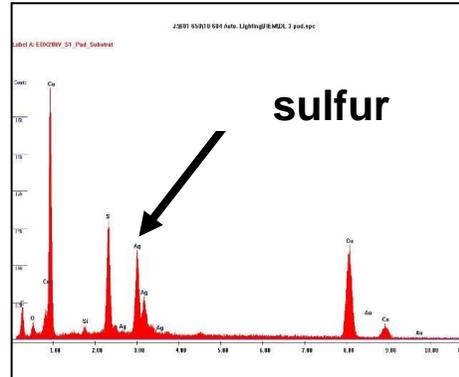
Environmental conditions:



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Silver sulfid



Silver-corrosion

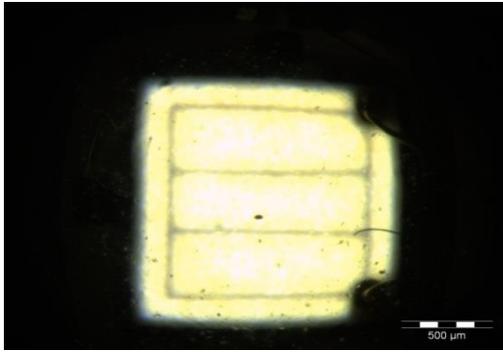


**Bond lifted from the
bondpad Silver corrosion
found under the pad.**

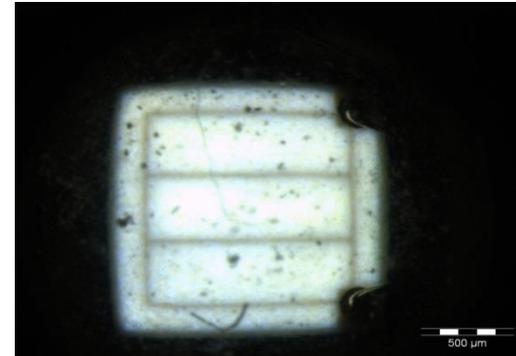
- open circuit induced by aggressive atmosphere in the neighbourhood
- increasing of series resistance

Environmental conditions:

Delamination of Encapsulant Material: chip itself remains stable



Yellowing



Reference

Parameter	Average Change [%]
Popt	-8,4
Colour Coordinate x	10,8
Colour Coordinate y	20,1

Insufficient protection against aggressive atmosphere



Summary

- **Failure analysis shifts from component level analysis to system level analysis**
 - **Without detailed information the analysis is a defect confirmation only without added value**
 - **Valid data sheets and circuit drawings are needed**
- **For corrective actions a root cause analysis is needed**
 - **For a root cause analysis know-how is a „must“**

Thank You for Your attention

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