Faszination Licht

Entwicklungstrends im LED Packaging

Dr. Rafael Jordan
Business Development Team

Technische Universität Berlin
Forschungsschwerpunkt
Technologien der Mikroperipherik

Fraunhofer
IZM

Agenda

- **Introduction**
- **Hermetic Packaging**
- **Large Panel Packaging**
- **Failure Analysis**

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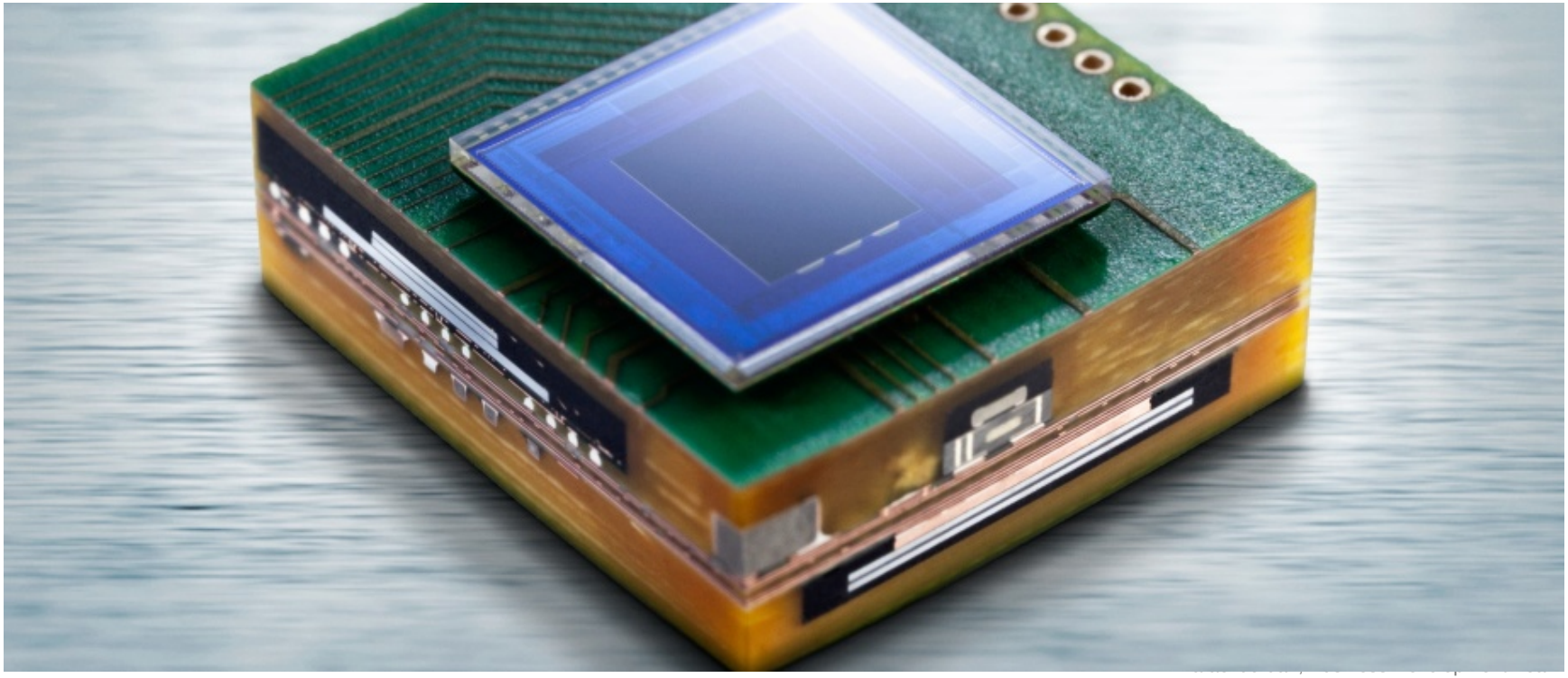
- Introduction
- Hermetic Packaging
- Large Panel Packaging
- Failure Analysis

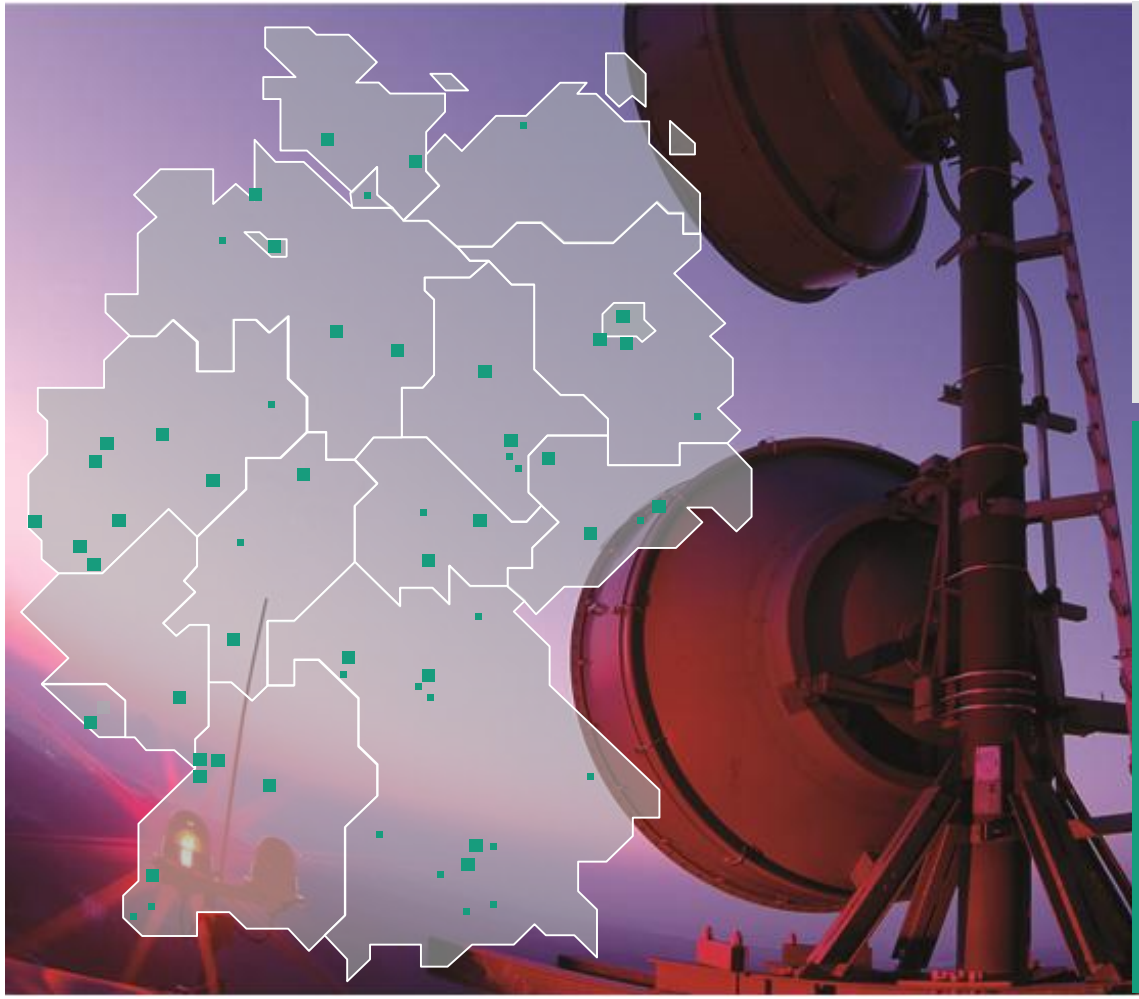
FRAUNHOFER IZM
RESEARCH FOR TOMORROW‘S PRODUCTS

Dr. Rafael Jordan

Business Unit Photonics



Overview Fraunhofer Gesellschaft



- 67 institutes
- 23,000 employees
- app. 2 billion € turnover
- app. 70% contract research

- Information Technology
- Light & Surfaces
- Life Sciences
- Micro Electronics
- Production
- Defense & Security
- Materials & Components

Technische Universität Berlin

Fraunhofer IZM

Fraunhofer IZM – Facts

Figures 2013

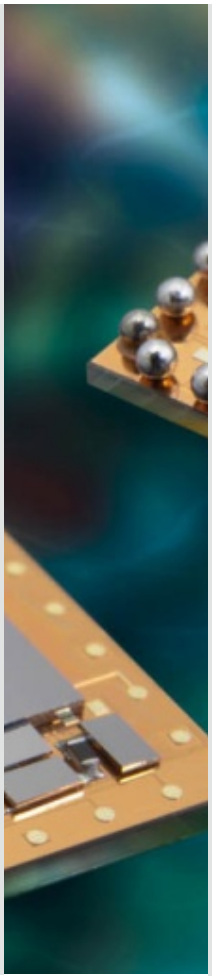
- 29.4 Mio. € turnover
- 77 % contract research
- 389 employees
  (230 full time, 159 PhD, trainee)

Locations

- Berlin
- Oberpfaffenhofen
- Dresden

Director

Prof. K.-D. Lang



University Cooperation

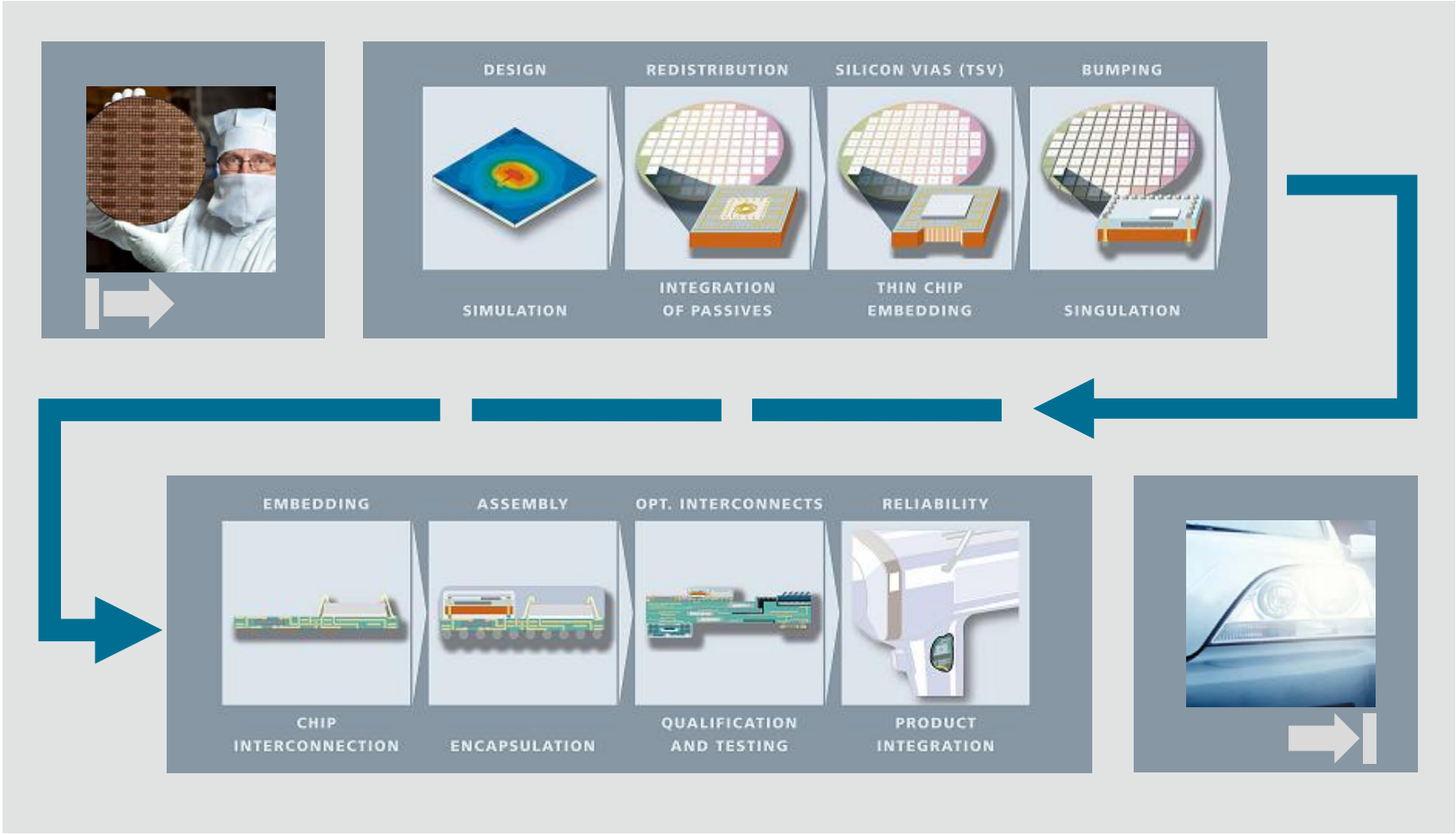
- Long term contract with Technical University of Berlin
- Research Center Microperipheric Technologies
- Approx. 90 additional staff
- Joint use of equipment, facilities and infrastructure

- Material characterization
- Process evaluation
- Reliability testing
- Failure analysis
- Sample production
- Training courses

Technische Universität Berlin

Fraunhofer IZM

Mission Fraunhofer IZM
Bringing Microelectronics into Application



Technische Universität Berlin

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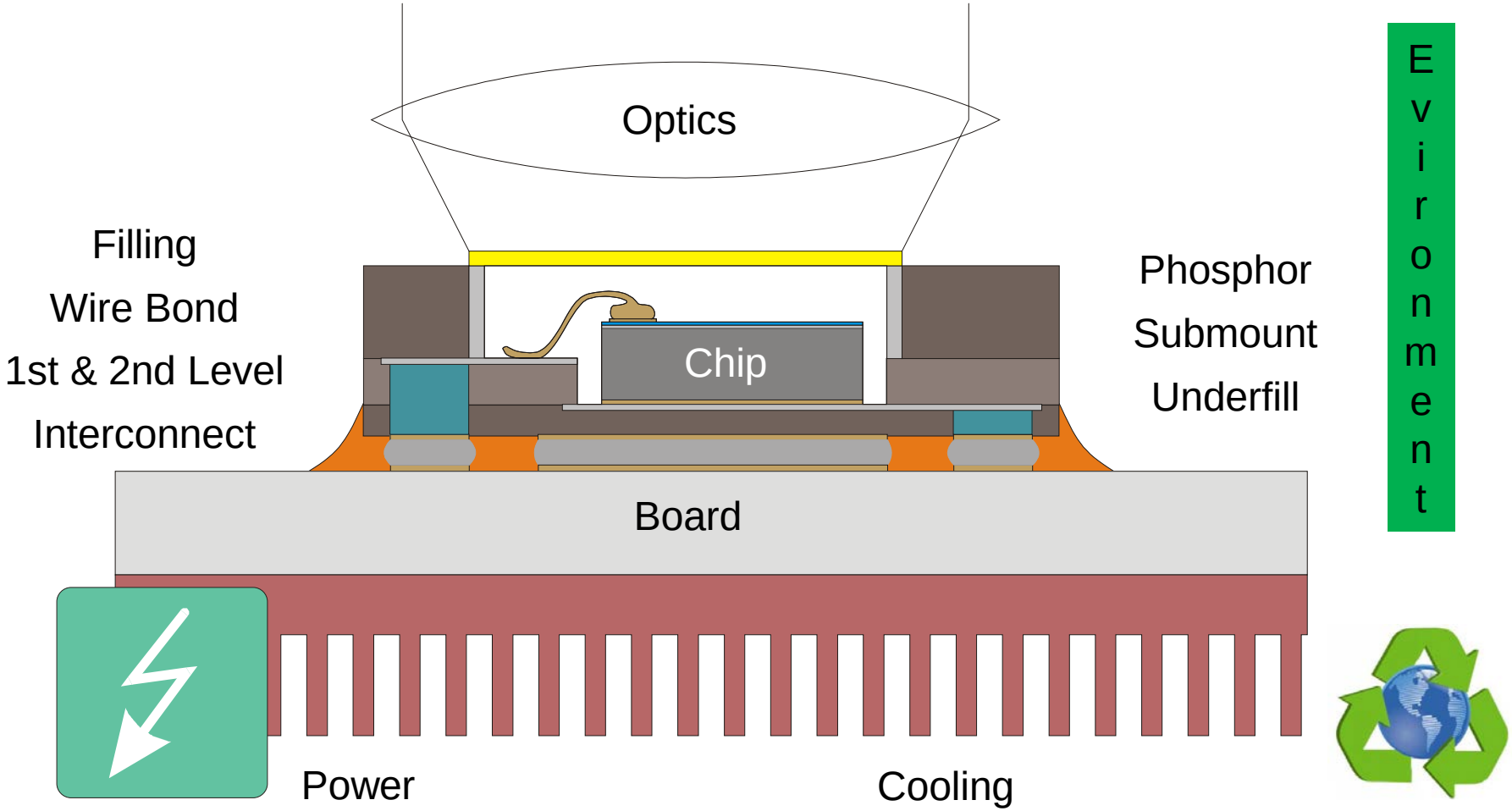
LED Packaging Tasks



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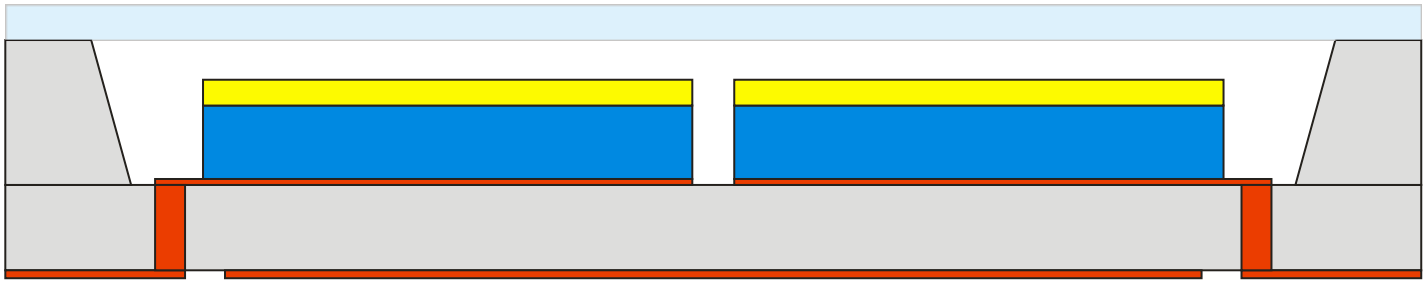
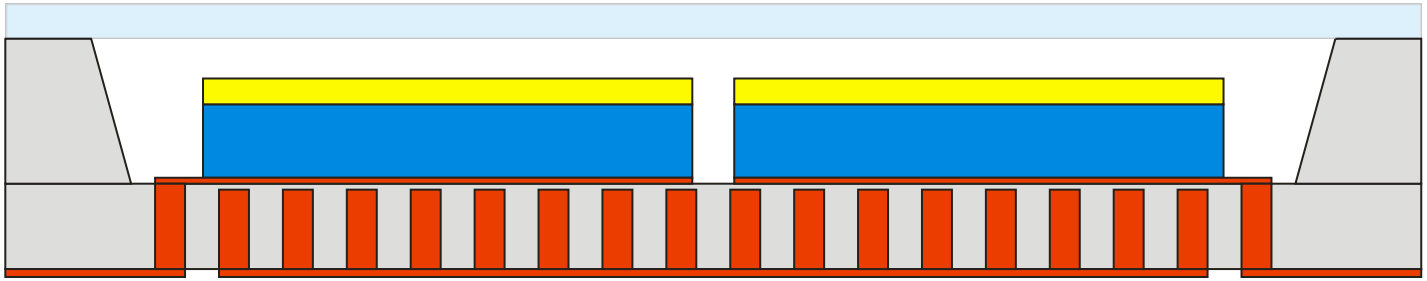
- **Failure Analysis**

Hermetic Concept

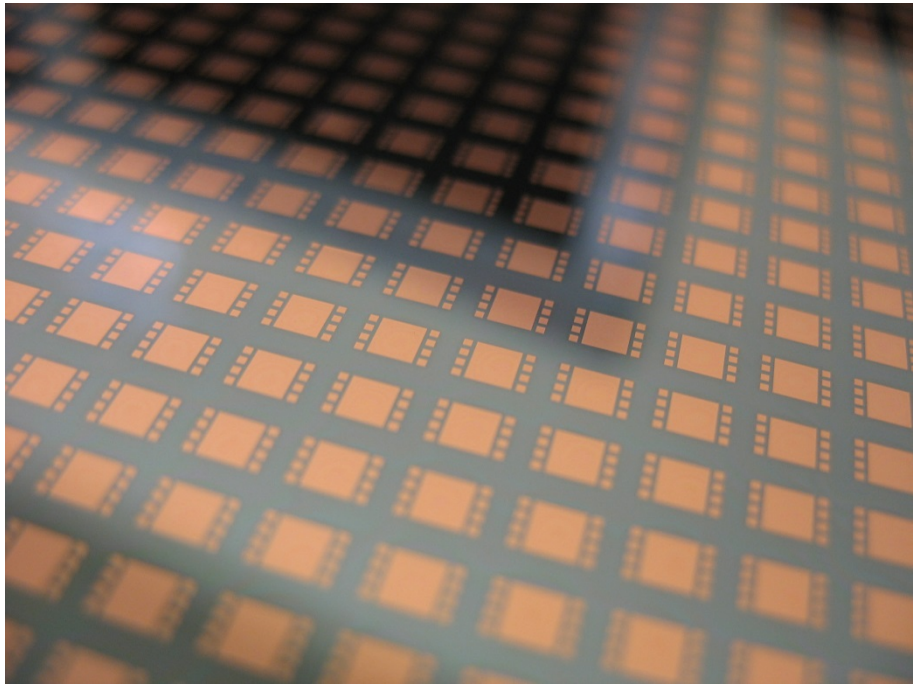


electrical vias

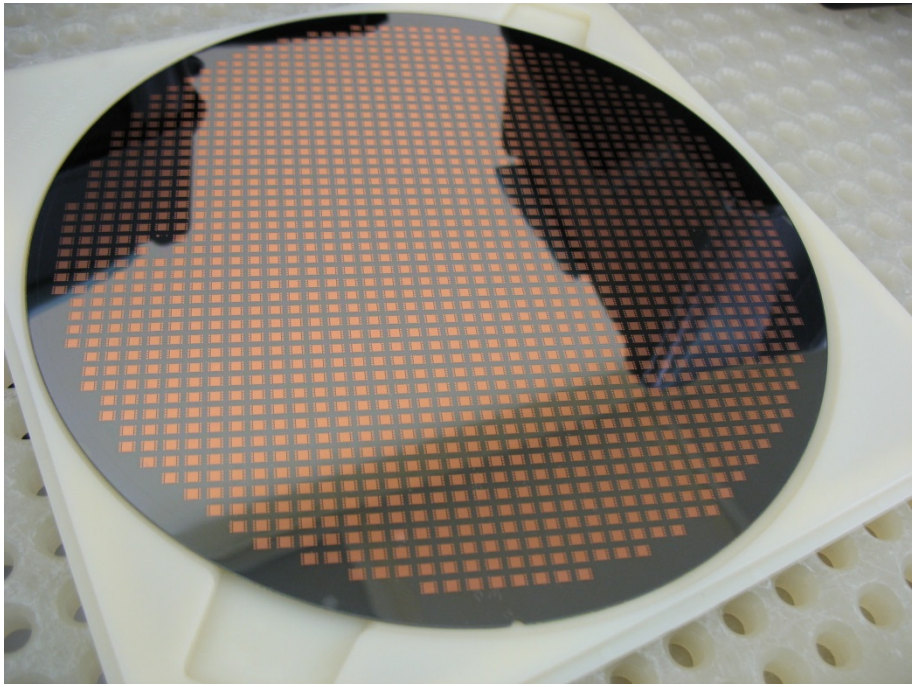


electrical and thermal vias

Silicon Substrate Wafer with TSVs

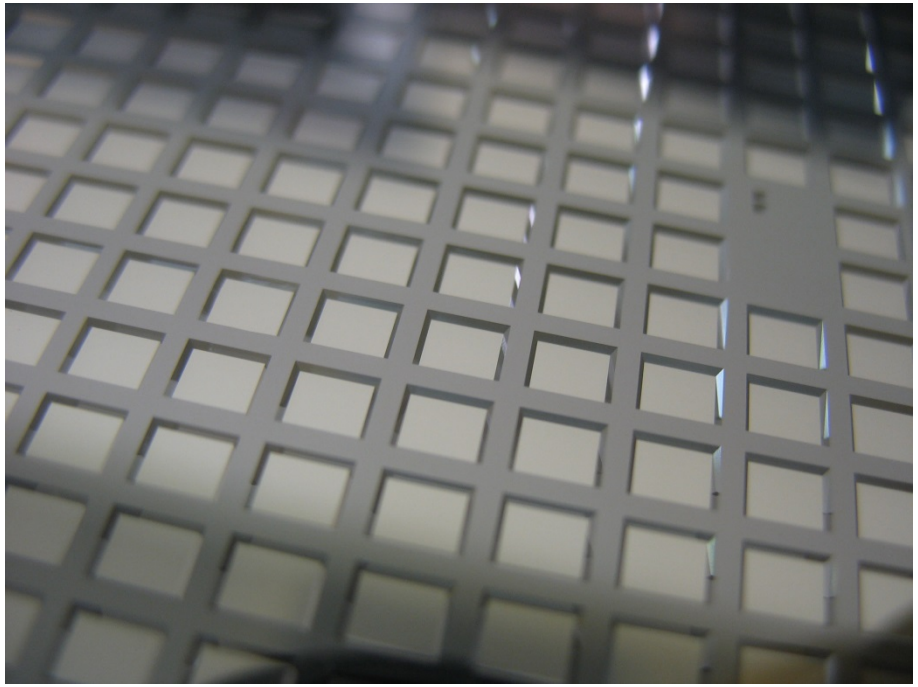


Silicon Substrate Wafer
backside view on soldering pads

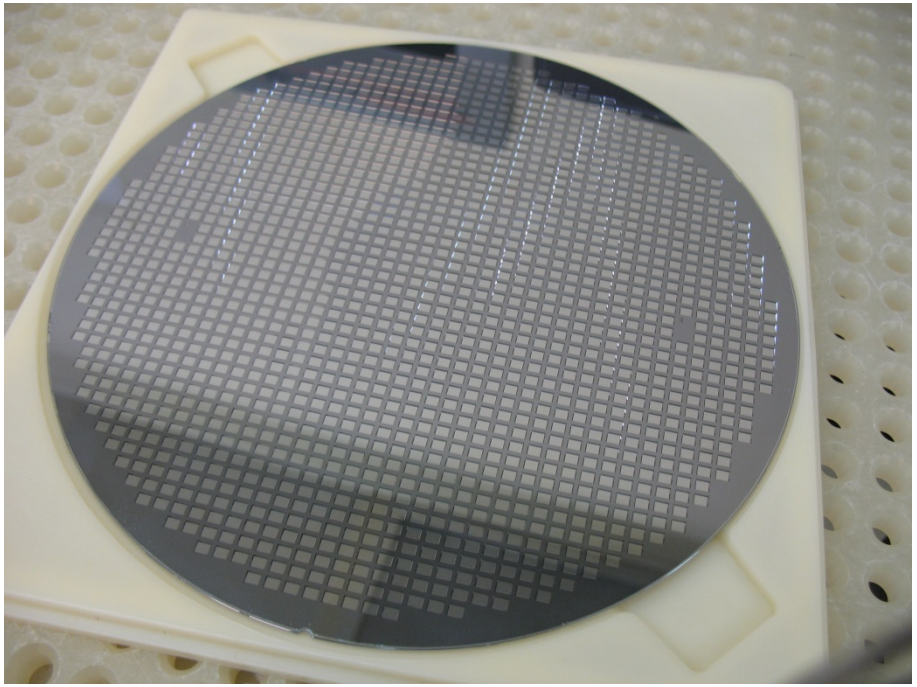


Silicon Substrate Wafer
overview

Silicon Glass Cap Wafer

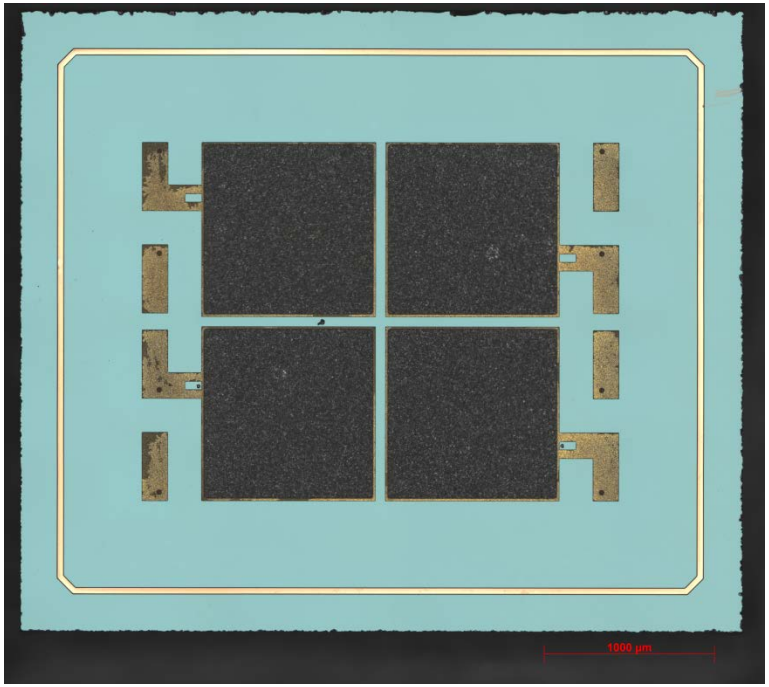


Si/glass cap wafer
with tapered reflector edges

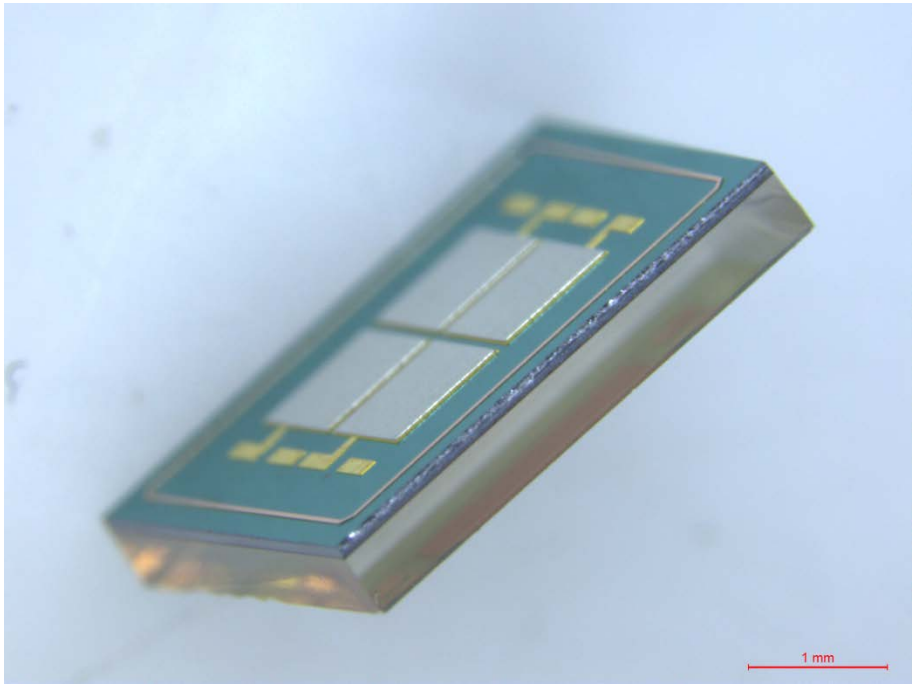


Si/glass cap wafer
overview

Silicon Substrate

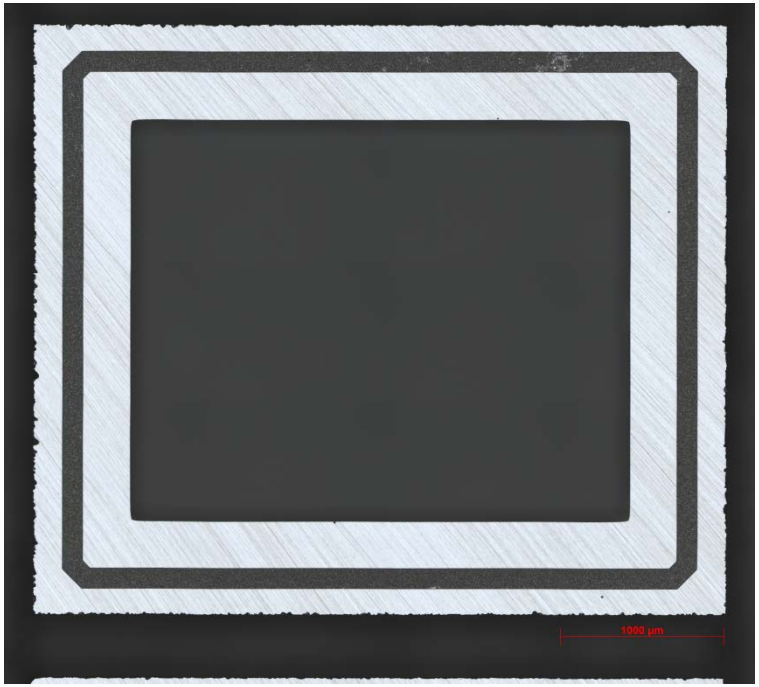


Silicon Substrate with 4 Component Positions with AuSn

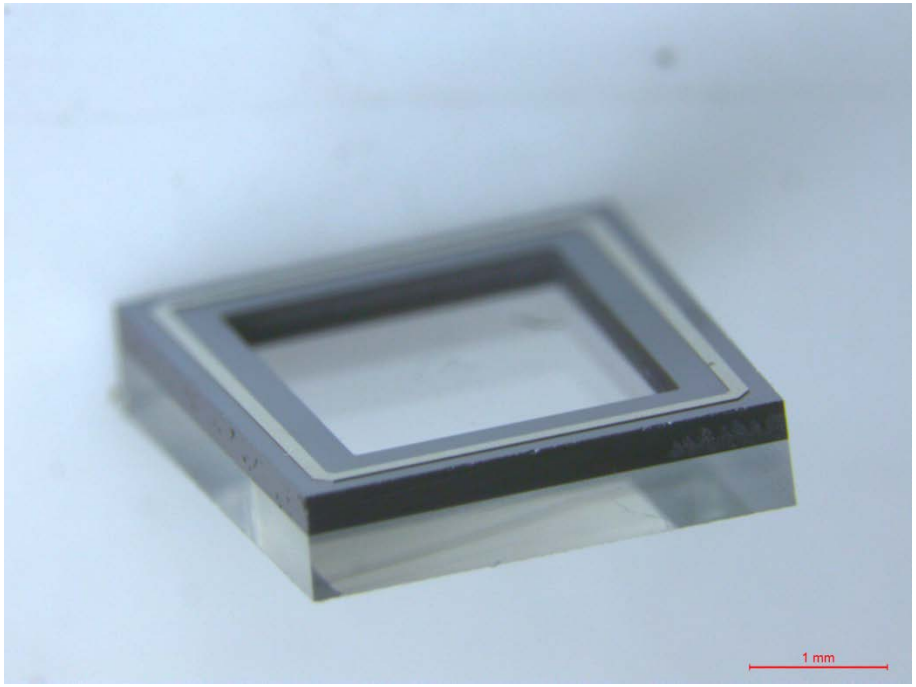


Silicon Substrate with Intermediate Glass Carrier

Glas Cap

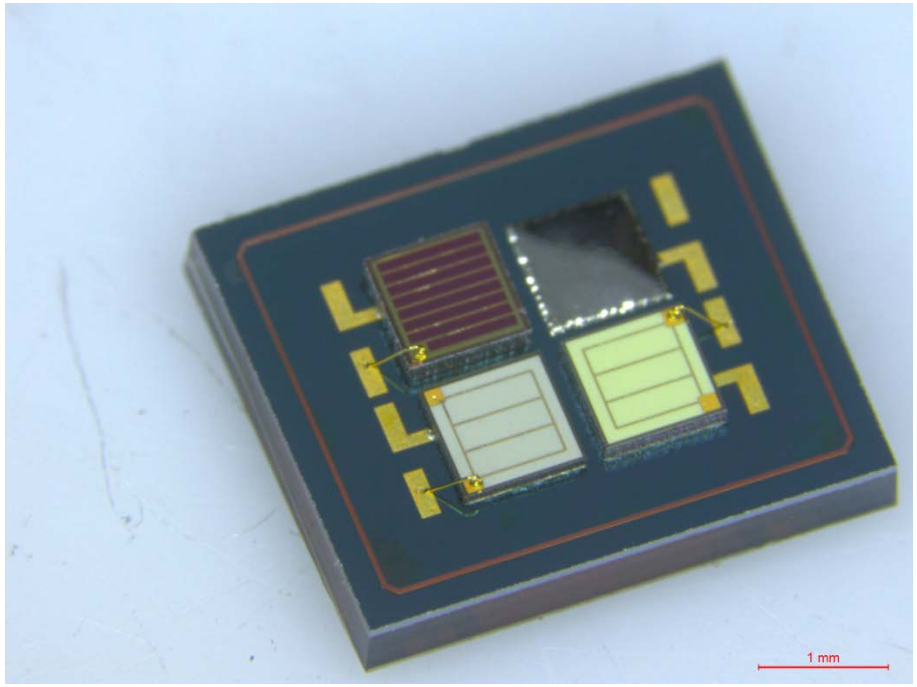


Top View von Glass Cap

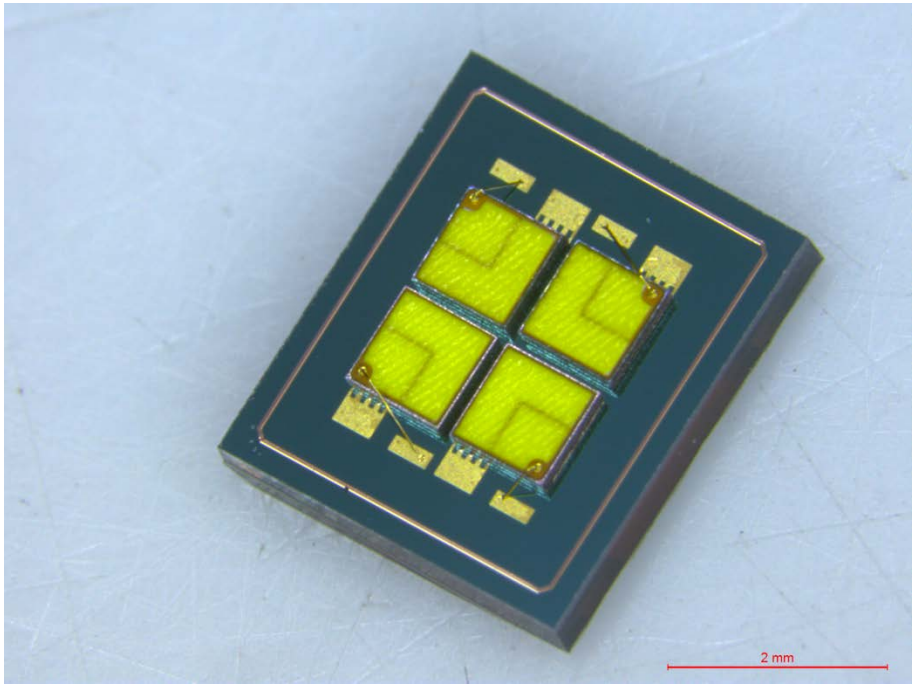


Side View on Glas Cap

Die and Wire Bonded LEDs

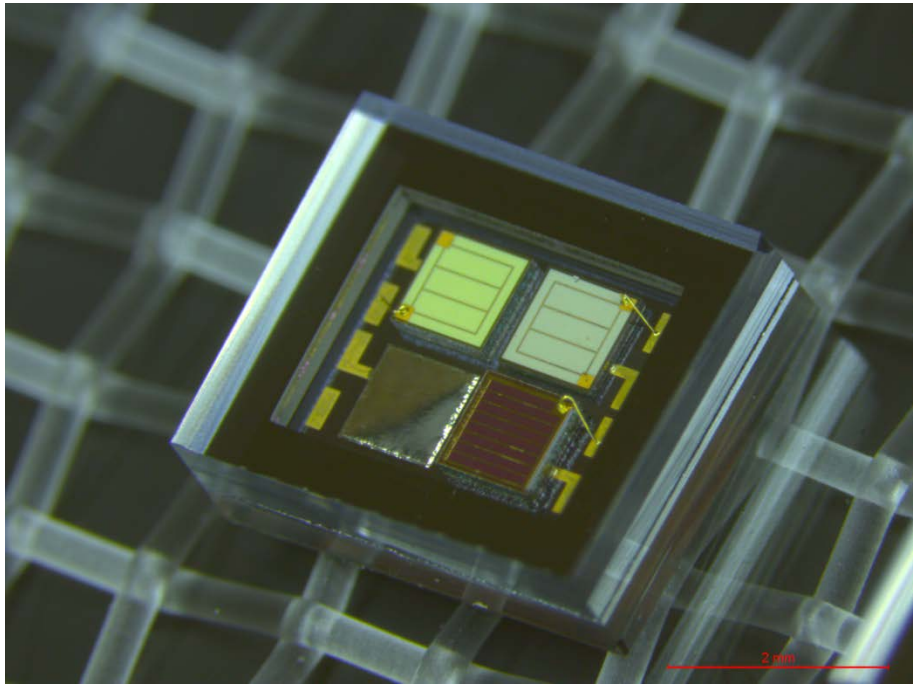


Top View Wire Bonded RGB LEDs
(one position free, e.g. for photodiode)

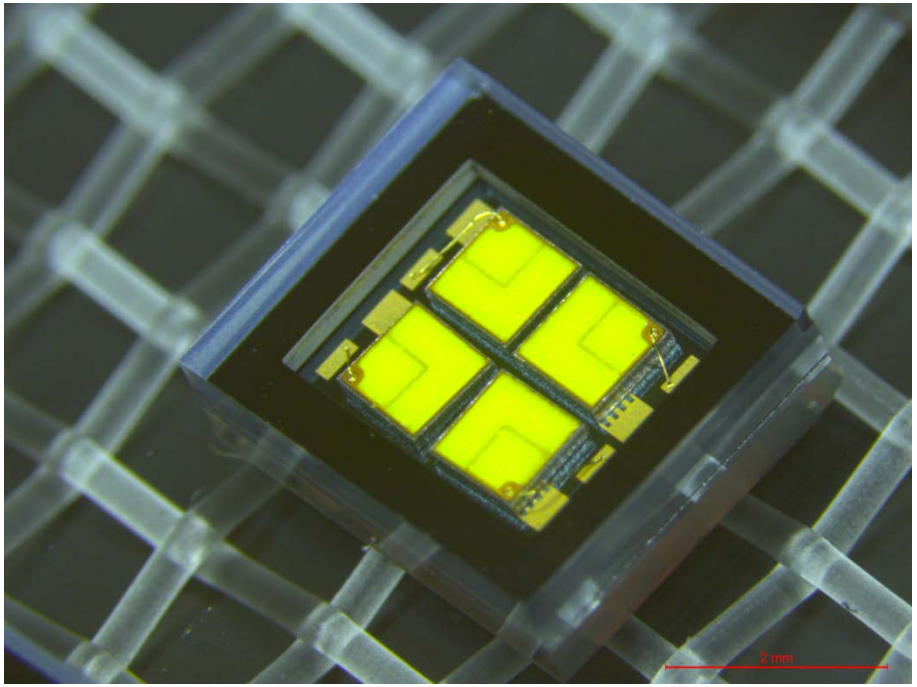


Side View Wire Bonded White LEDs

Full Assembled Packages

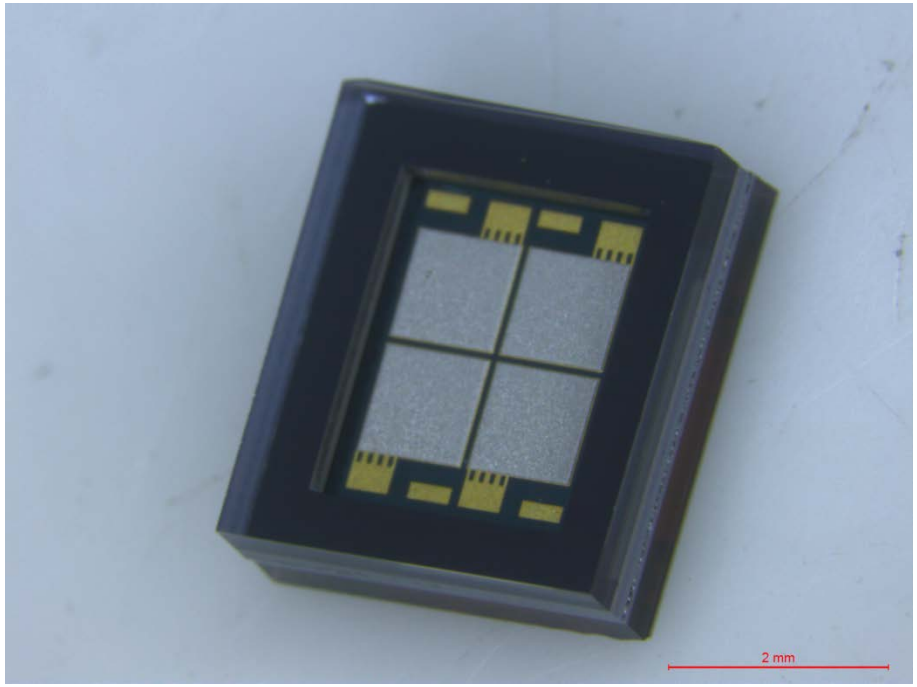


RGB LED Package

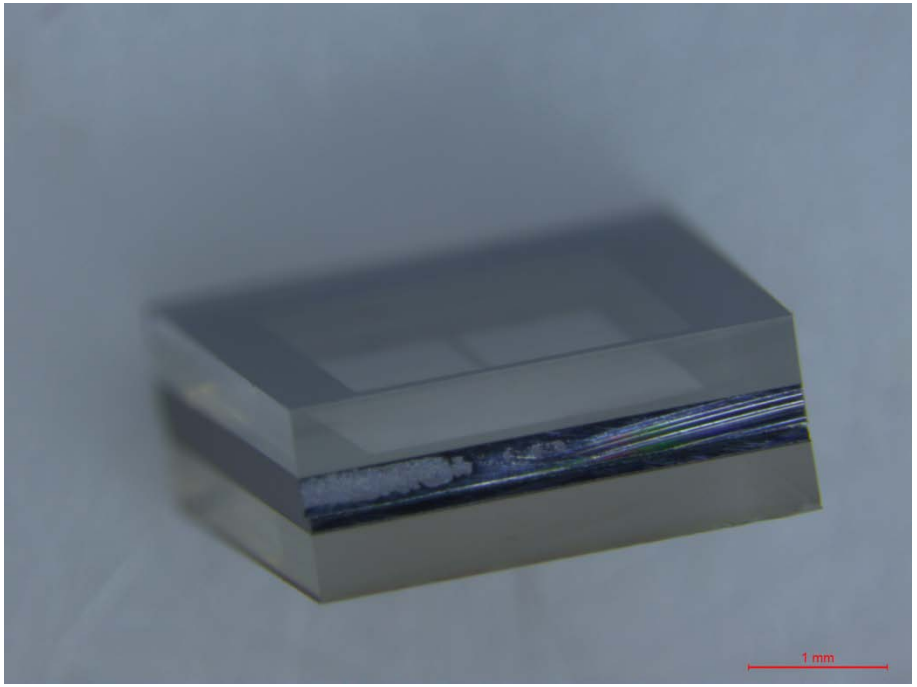


White LED Package

Solder Interconnection Analysis

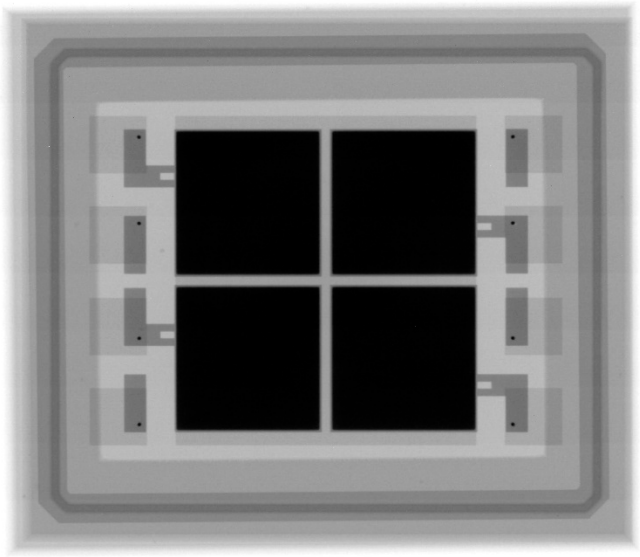


Glas Cap on Silicon Substrate

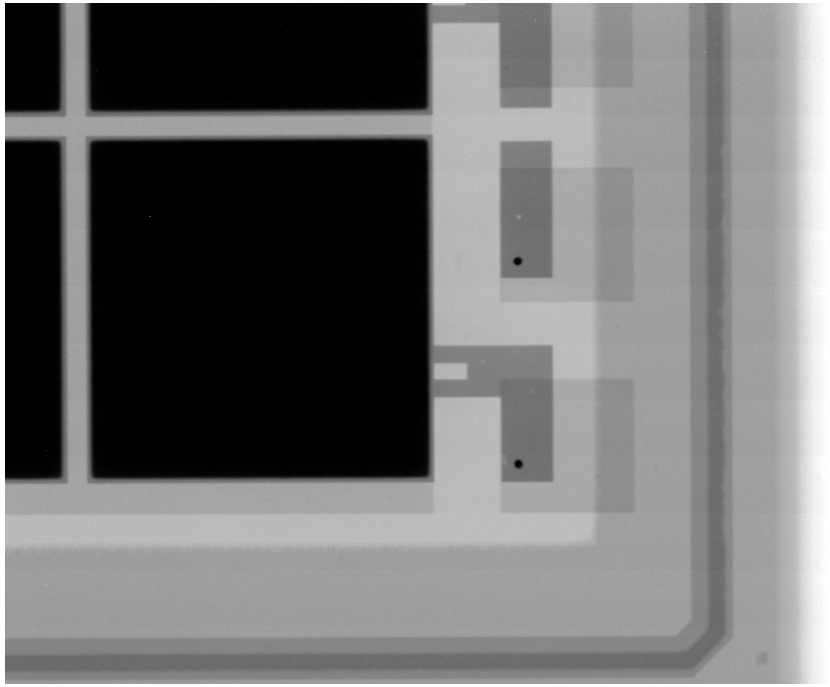


Side View Glas Cap on Silicon Substrate with Intermediate Glass Carrier

Solder Interconnection Analysis



x-ray Overview



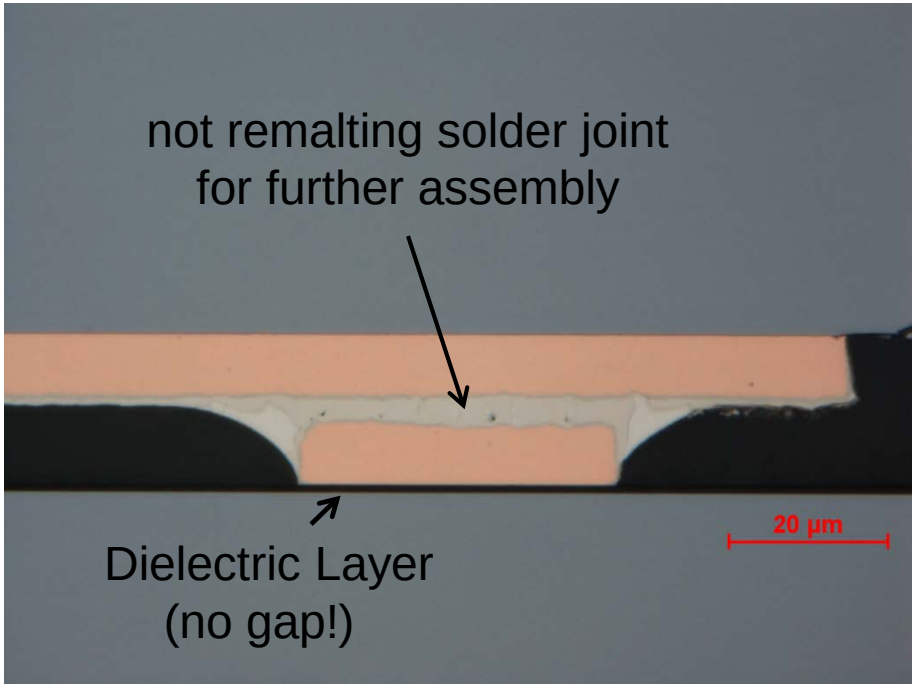
x-ray Focus

Complete void free process!

Dr. Rafael Jordan, Business Development Team

Solder Interconnection Analysis

Glas Cap on Silicon Substrate



Side View Glas Cap on Silicon Substrate

Acknowledgements

ENLIGHT
Energy efficient & intelligent lighting systems

EnLight stands for “Energy efficient & intelligent lighting systems” and was an EU funded and Philips Lighting coordinated project which ran from 2011 to 2014. The consortium consisted of 27 leading European companies and academic institutions from across the entire lighting value chain.

eniac
JOINT UNDERTAKING

Dr. Rafael Jordan, Business Development Team

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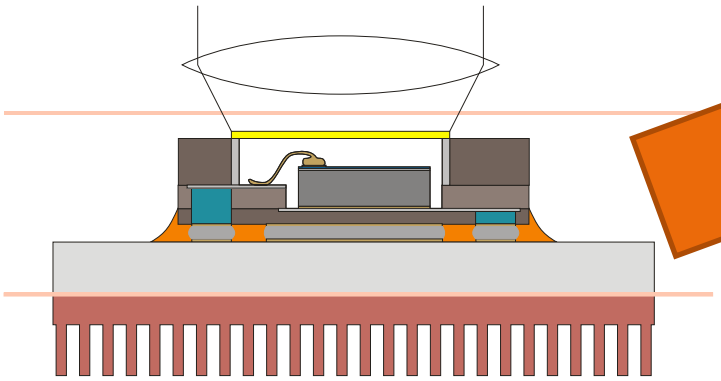
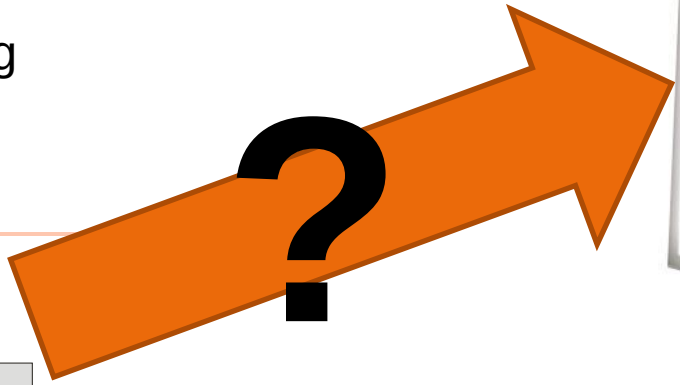
- **Large Panel Packaging**
- **Failure Analysis**

New LED Packaging Approach for Panel Level Packaging

conventional LED packaging





Lighting Panel

New Packaging approach required

- Large area manufacturing
- Low cost

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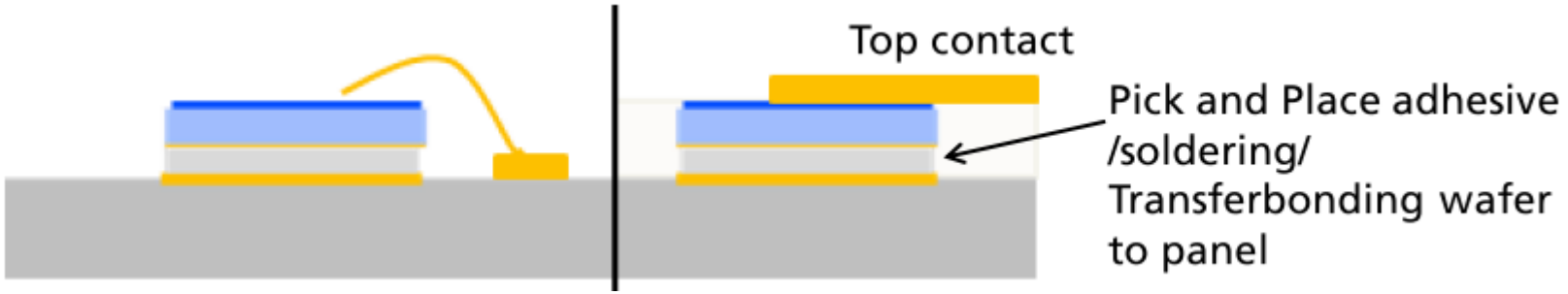
IZM

Two Panel Level Packaging Concepts

- Collective Transferbonding
  - Wafer to Panel
  - Transferbonding using temporary carrier
  - Top side contact through (wire bonding) or lamination

- Pick & Place and Lamination
  - Chip on Panel adhesive bonding
  - Top side contact through lamination



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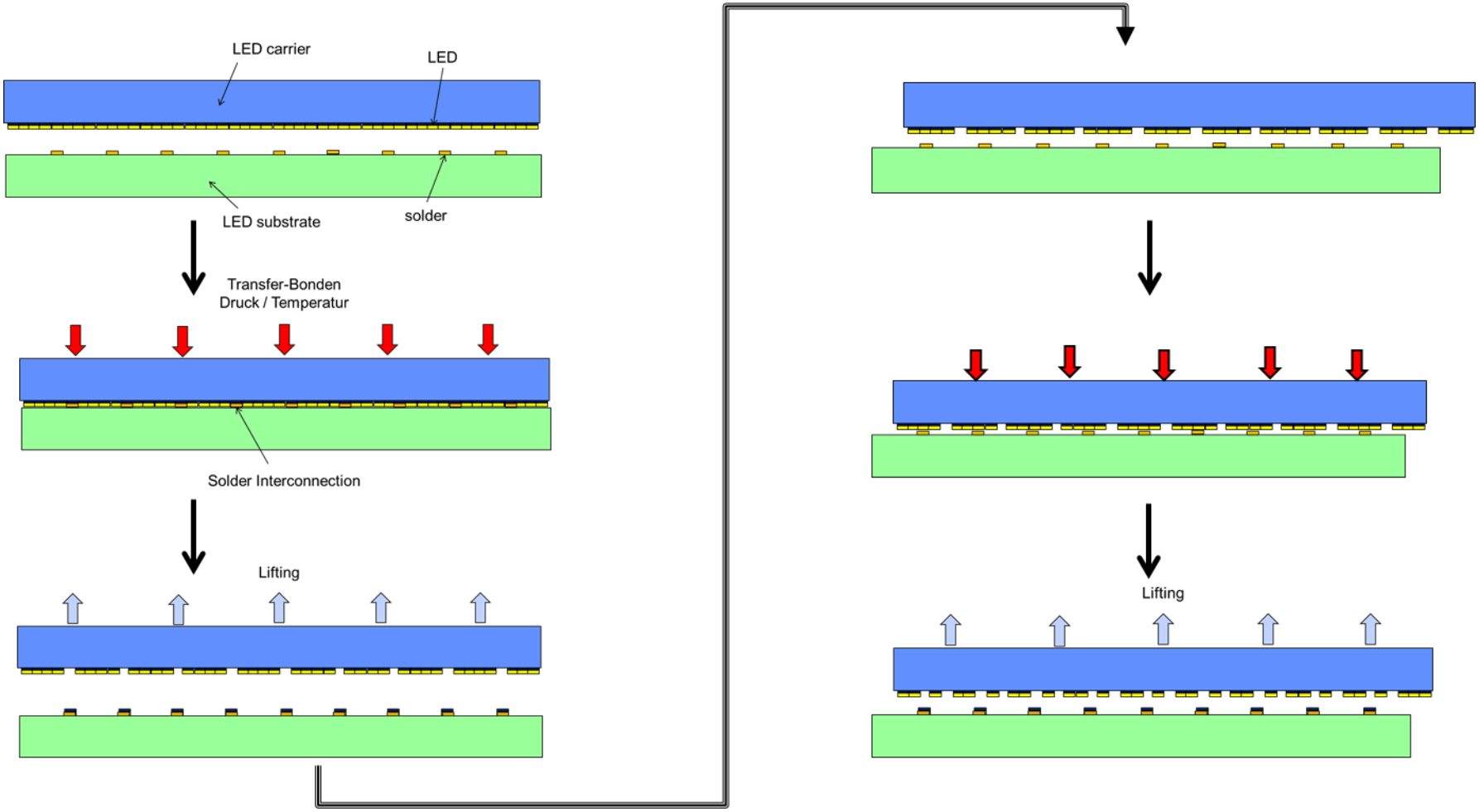
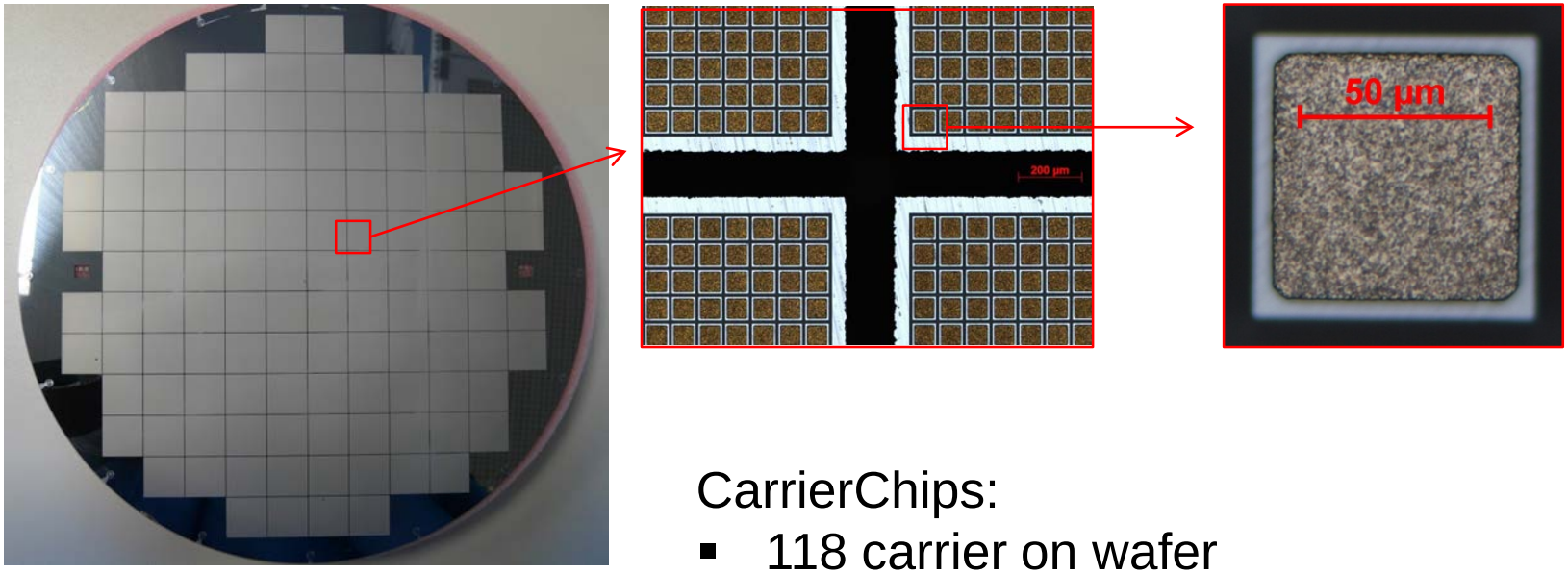
Collective Transferbonding - Process Flow



Collective Transferbonding

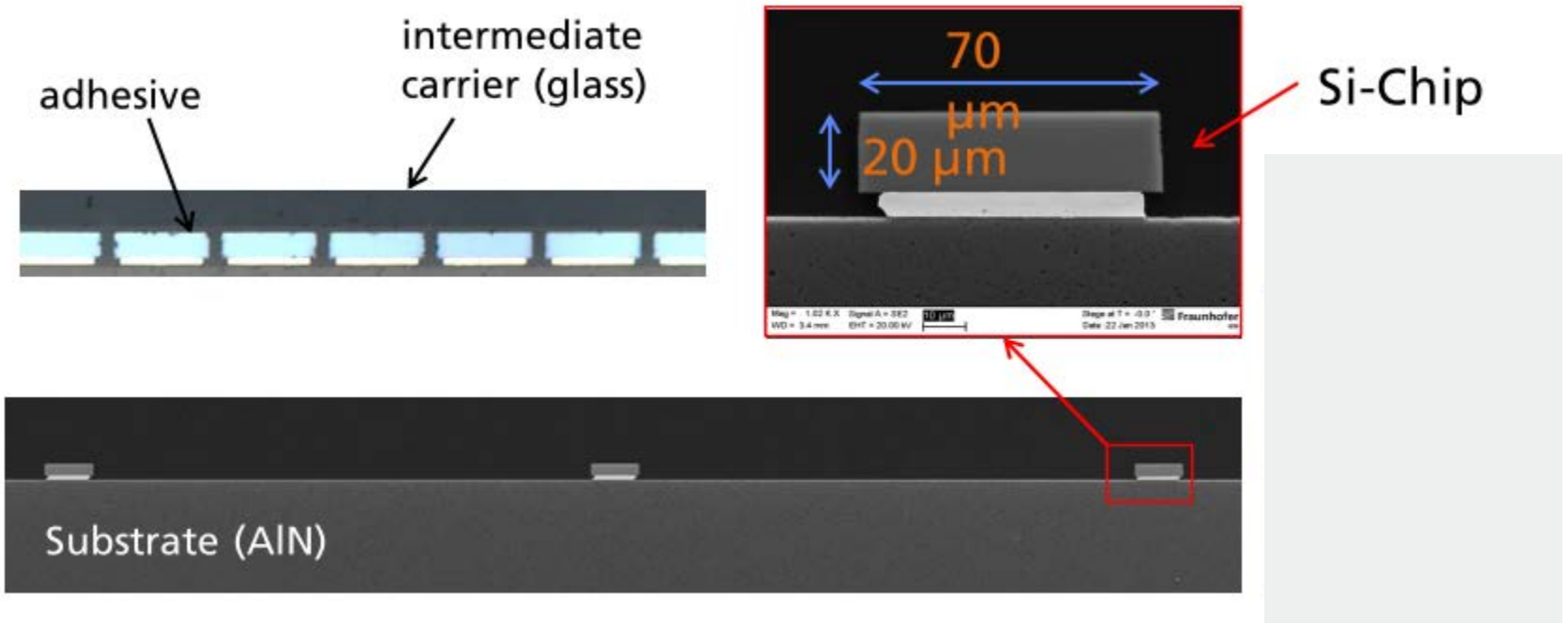


CarrierChips:

- 118 carrier on wafer
- 165 x 165 (27225 Chips on carrier)
- > 3 Mio. Chips on wafer
- Chipsize 75 µm
- Chips are sticked with PI auf Carrier

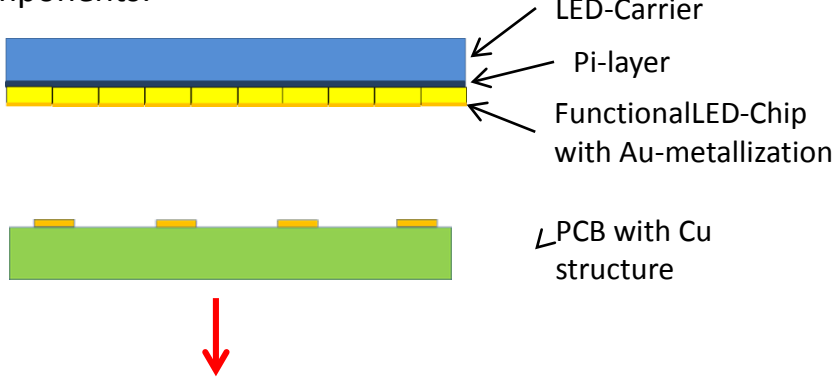
Assembly concept for small LED-Chips

- Temporarily Bonding of LEDs on Intermediate Carrier
- Handling of small Chips (70 µm edge length)
- Collective Soldering →high-precision and plane-parallel Assembly

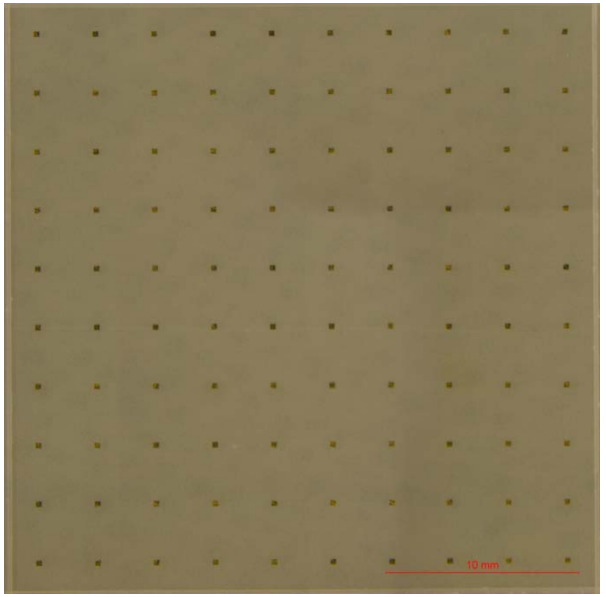


Collective Transferbonding with functional LEDs

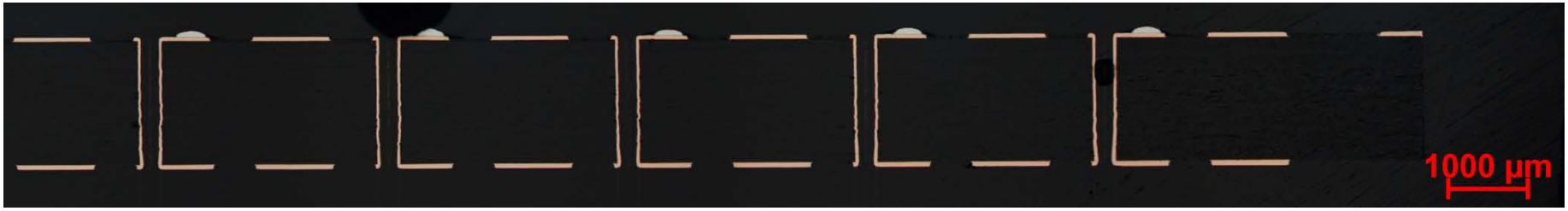
Components:



1.Step: stencil printing of solderpaste (SAC)



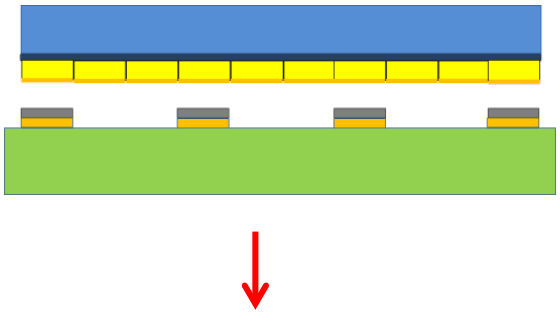
Topview on LED Carrier



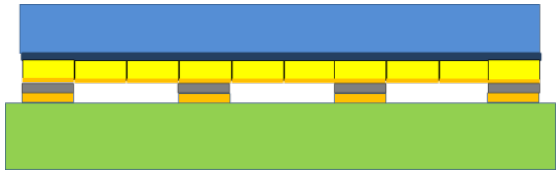
Crosssection of PCB with solder depot

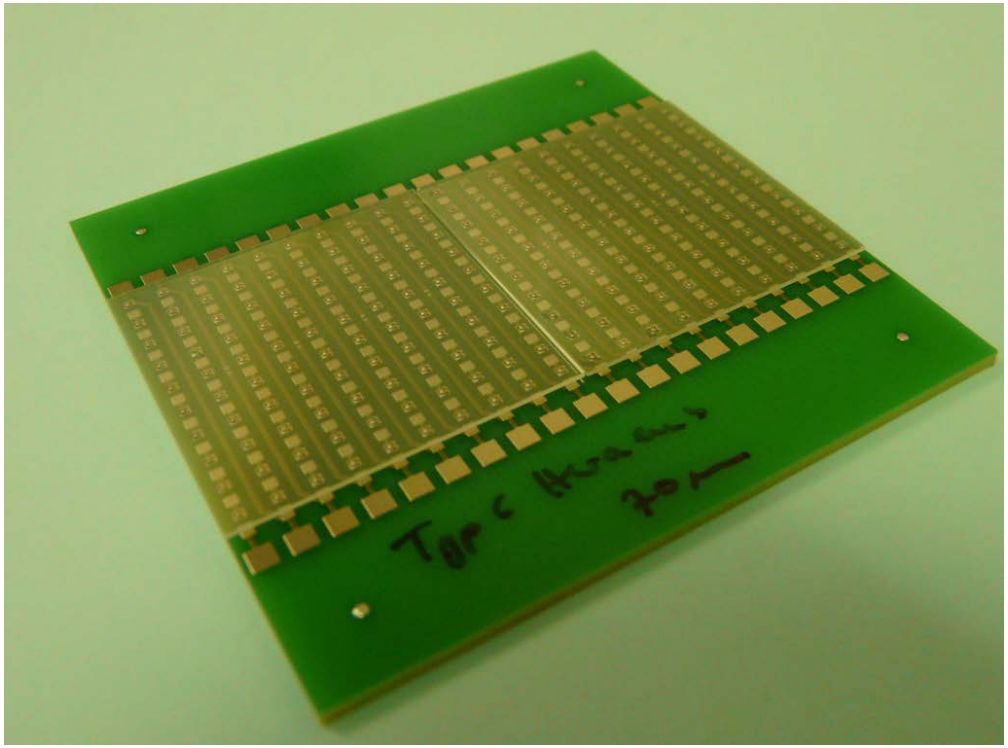
Collective Transferbonding with functional LEDs

2.Step: Alignment between PCB and LED Carrier



3.Step: Collective Transferbonding

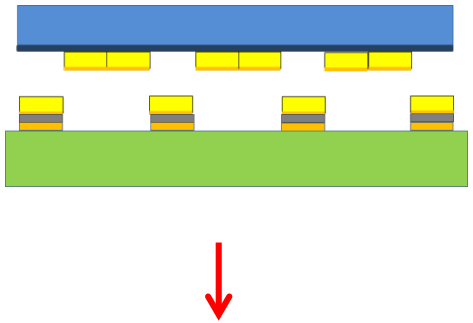




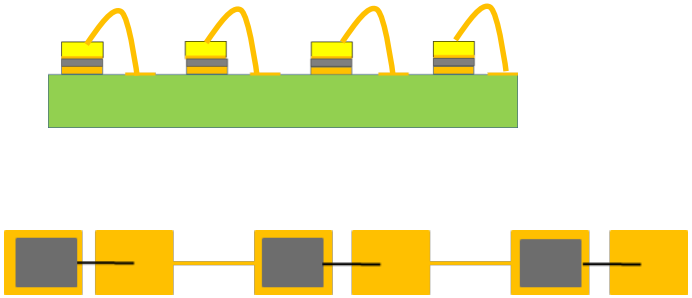
PCB with aligned LED Carrier

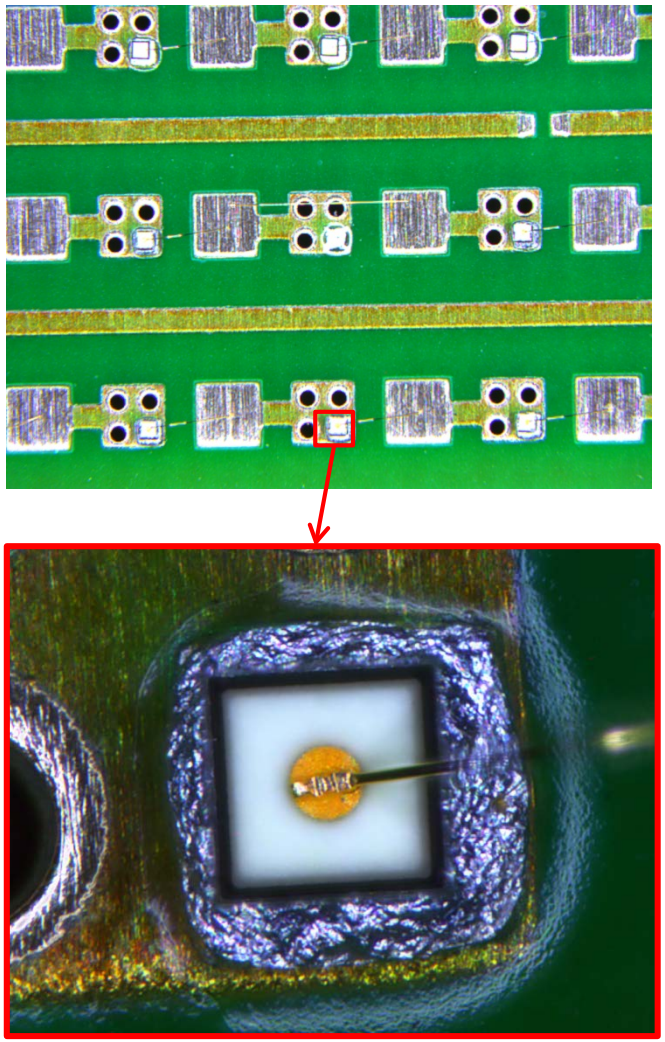
Collective Transferbonding with functional LEDs

4.Step: vertical removing of LED-Carrier



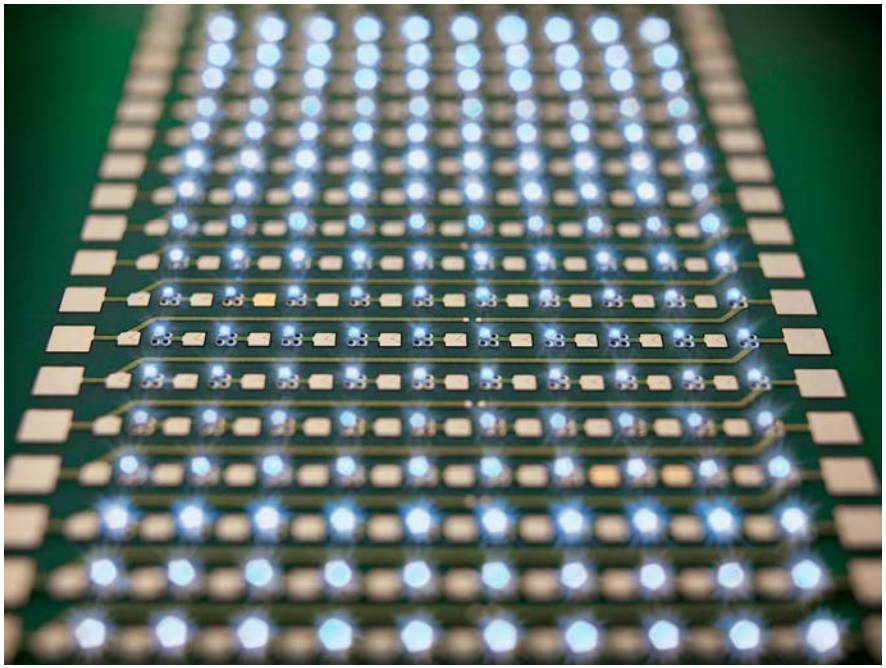
5.Step: Wire bonding

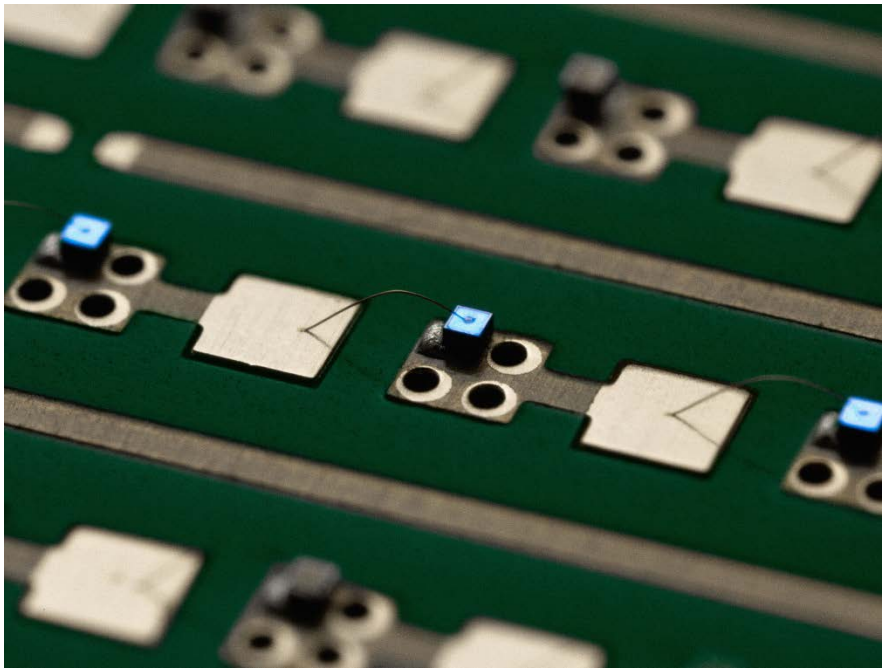




Assembled and wire bonded LEDs on a PCB

Demonstrators with functional LEDs





Serial connections of 10 blue LEDs at about 25V

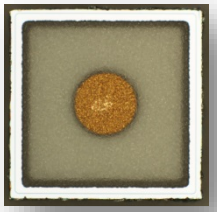
Two Panel Level Packaging Concepts

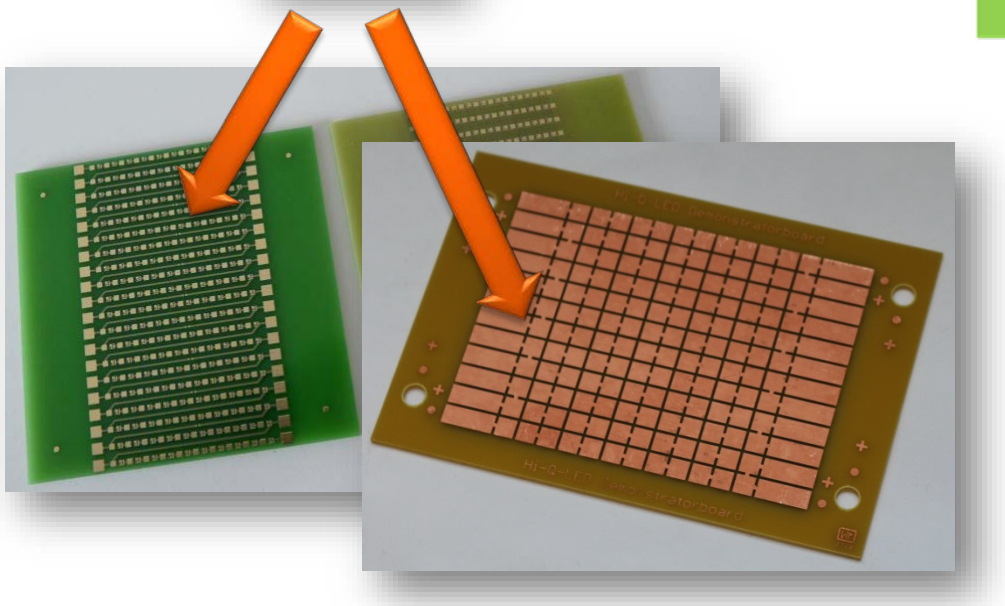
- Collective Transferbonding
  - Wafer to Panel
  - Transferbonding using temporary carrier
  - Top side contact through (wire bonding) or lamination

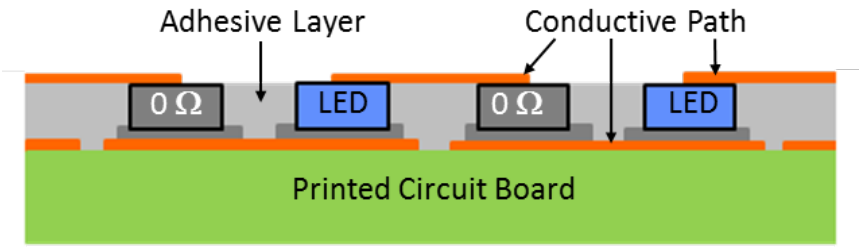
- Pick & Place and Lamination
  - Chip on Panel adhesive bonding
  - Top side contact through lamination

Panel Level Packaging Concept

LED with top and bottom contact







- pairwise connection of LEDs and z-feedthrougs (0 Ω-contact dies) at PCB by conductive adhesive (ICA) and on top by copper paths
- the whole sandwich is hold together by a polymeric adhesive layer

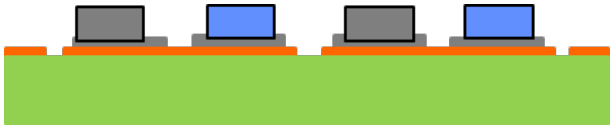
Assembling on PCBs of different sizes

Process Flow

Assembling of LEDs

screen printing of ICA
on structured PCB

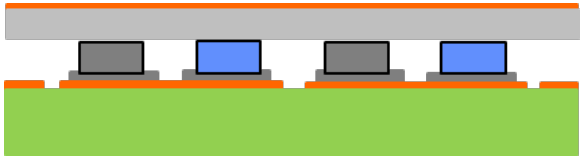
placing of LEDs
and z-contacts



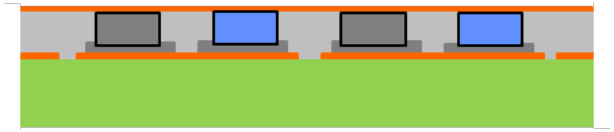
curing of ICA

Electrical Contacting

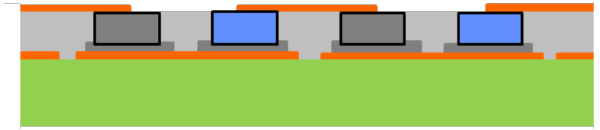
placing of adhesive layer and
copper foil on top



lamination under pressure at
elevated temperatures

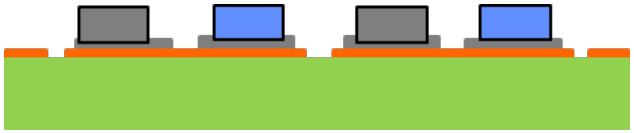


structuring of copper to connect
top contacts of LEDs



Placement of LEDs

LEDs > 200 µm²

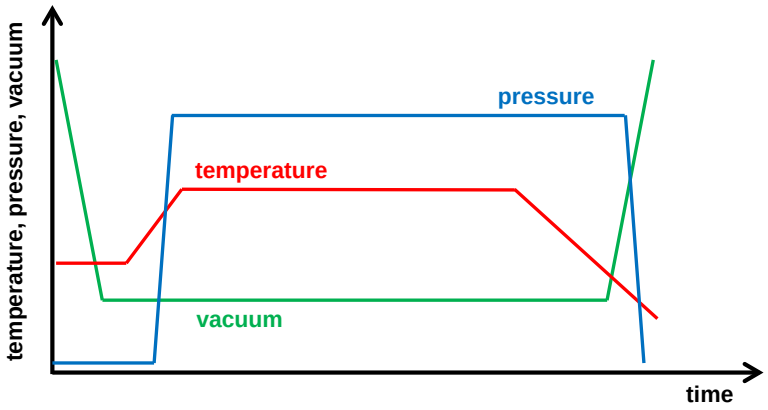


Pick-and-Place process with high yield

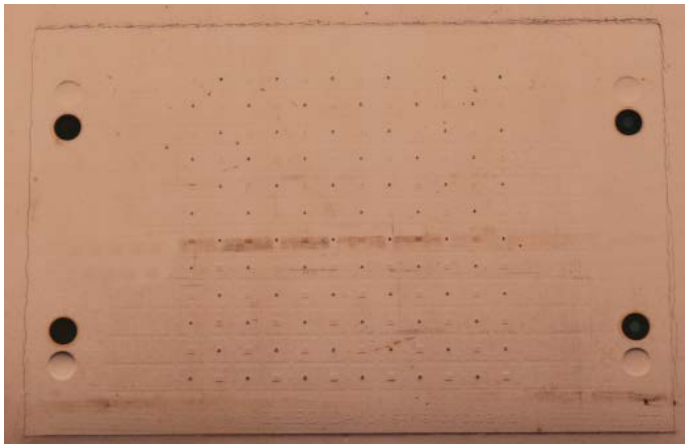
- High precision placement (± 15 µm)
- on large area up to 24“ x 18“ / 610 x 457 mm²
- High Speed (> 5000 c.p.h.)

Lamination

lamination of adhesive layer
together with structured or
unstructured copper foil



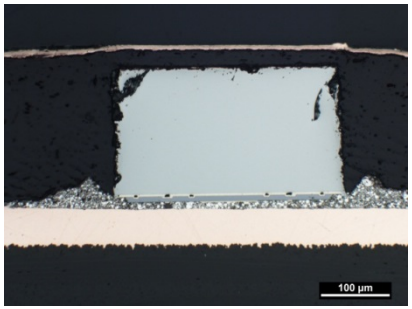
lamination cycle



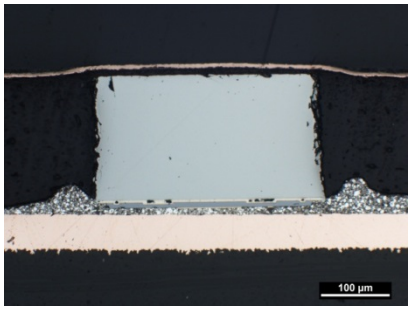
laminated unstructured board

Lamination

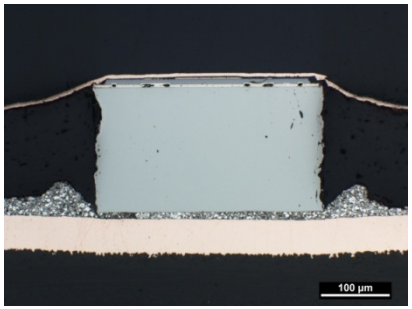
lamination of adhesive layer
together with structured or
unstructured copper foil



low pressure



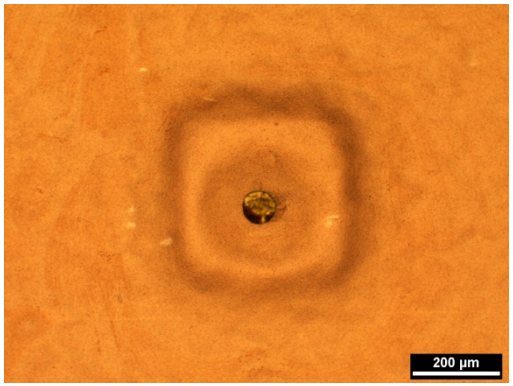
middle - optimum pressure



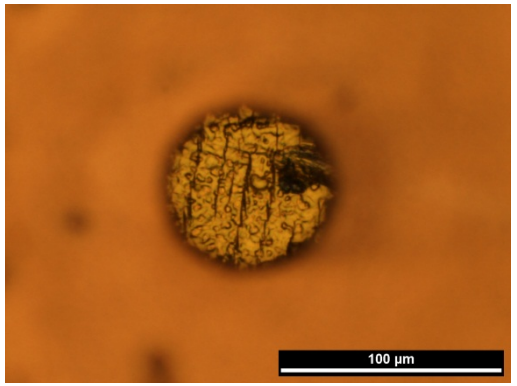
high pressure

Electrical Connection

Cu-structuring using
PCB-processes

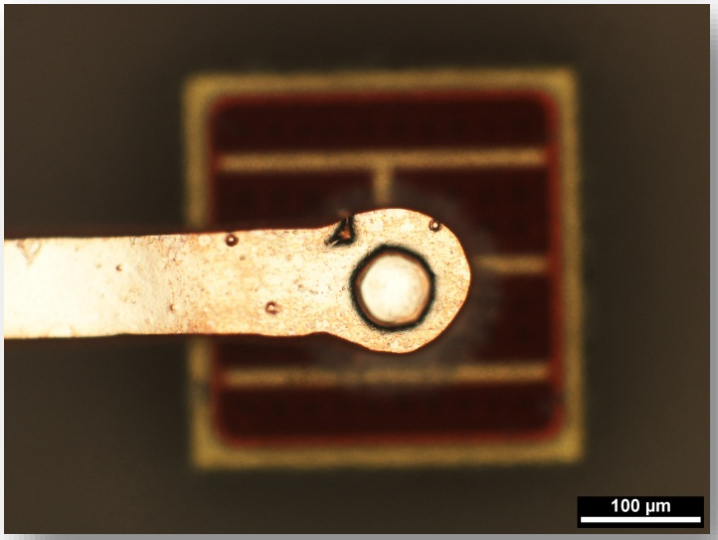


laser drilled via to LED pad

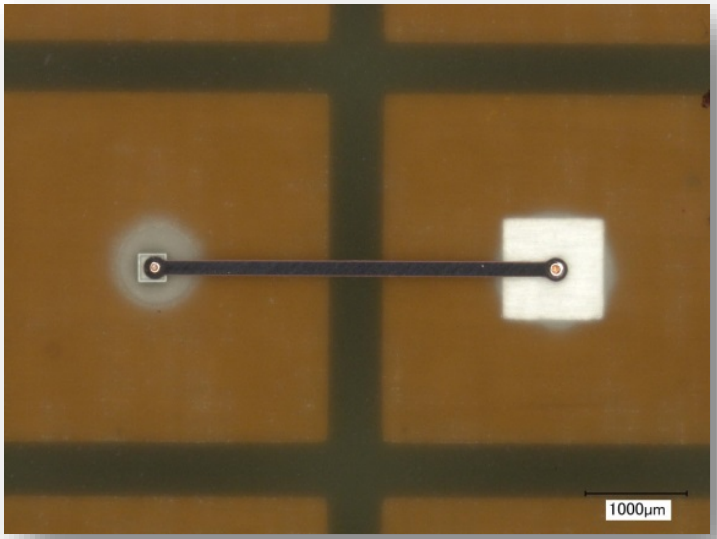


close up look to hole

Electrical Connection



structured Cu-foil with Cu-via
to contact pad of LED



structured Cu-connection between
LED and z-feedthrough

Reliable electrical connection achieved using PCB based processes

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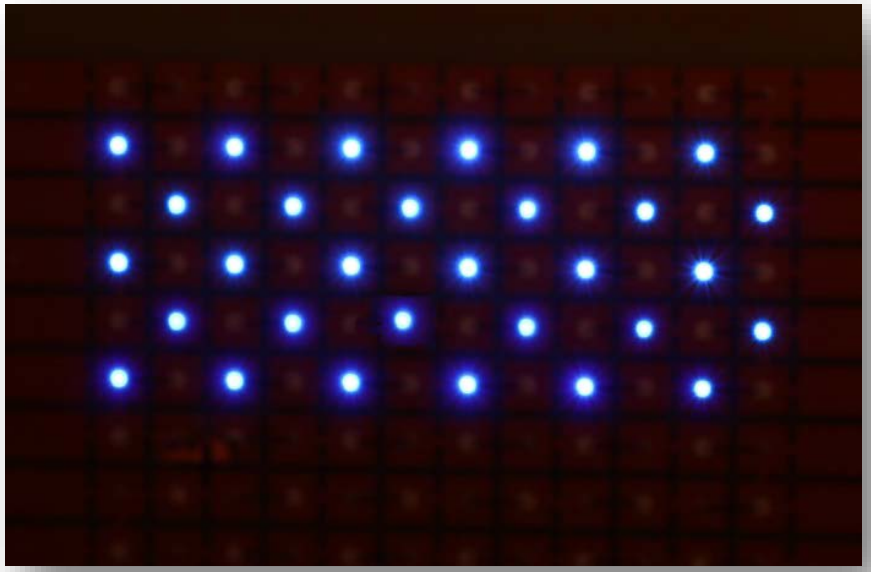
Electrical Connection



connection in series of 30
blue LEDs

- Successful proof of technology concept
- Cost-effective PCB-technology used
- Boards of variable sizes can be produced easily
- Light-forming elements (white-light converters, lenses, diffusors ..) can easily be added

Summary

- A new concept collective Transfer Bonding using a temporary Carrier was developed.
- Large LED Panels can be produced by Lamination and Board Technologies.

➢ **Both Technologies were successfully developed for a functional demonstrator and has potential for low cost and large area lightning panels up to 24“ x 18“ / 610 x 457 mm²**

Acknowledgements

Results are partially achieved in the joint project Hi-Q-LED:

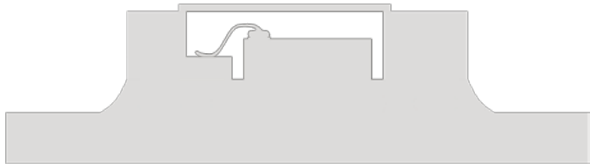
- OSRAM Opto Semiconductors GmbH, Regensburg
- Fraunhofer IAF, Freiburg
- Universität Ulm
- Fraunhofer IZM, Berlin
- ASEM Präzisionsautomaten GmbH, Dresden
- Cerion GmbH, Minden
- Fresnel Optics GmbH, Apolda
- OSRAM GmbH, München

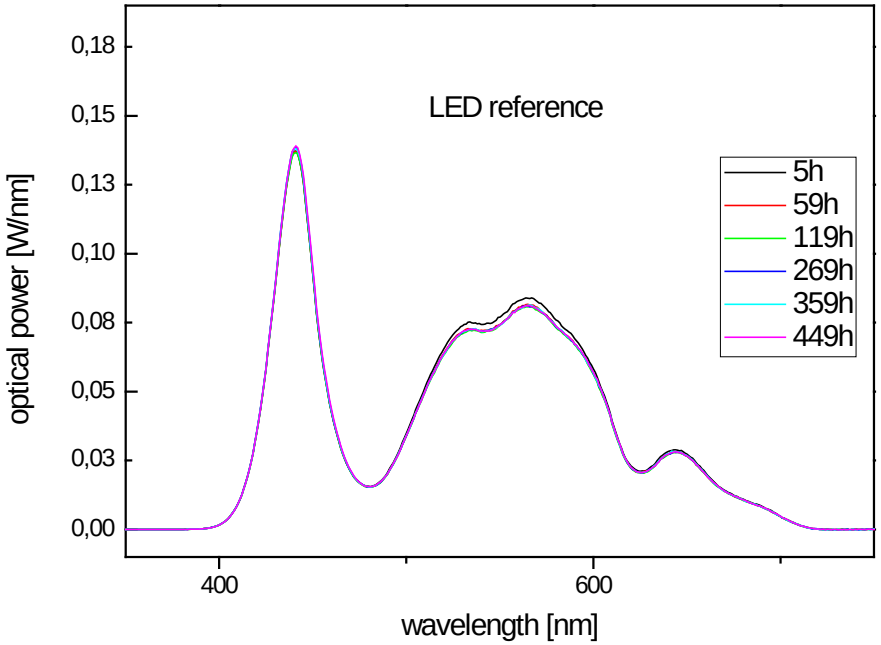
Bundesministerium für Bildung und Forschung

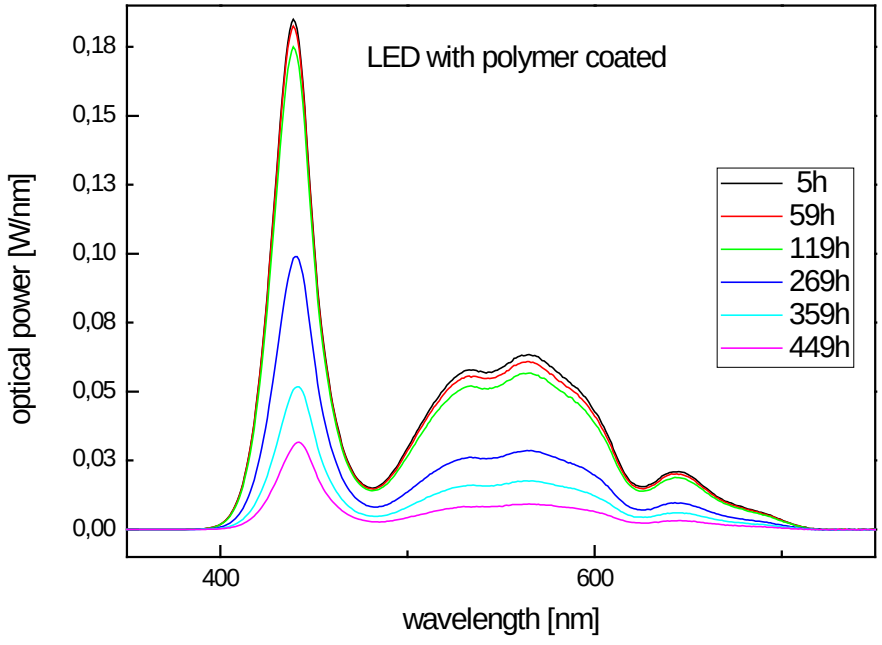
Agenda

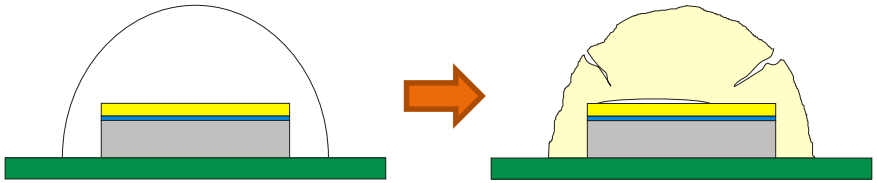
- **Introduction**
- **Hermetic Packaging**
- **Large Panel Packaging**
- **Failure Analysis**

Aging of Polymers

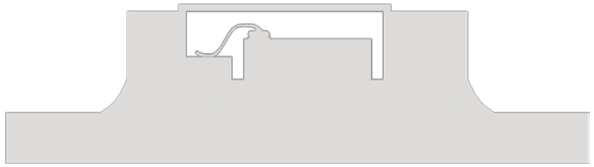


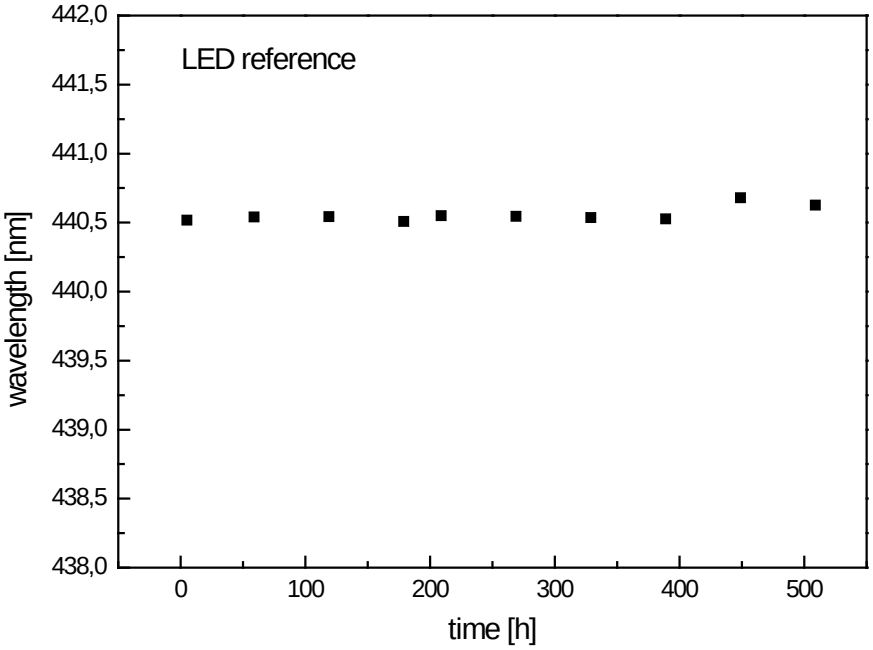


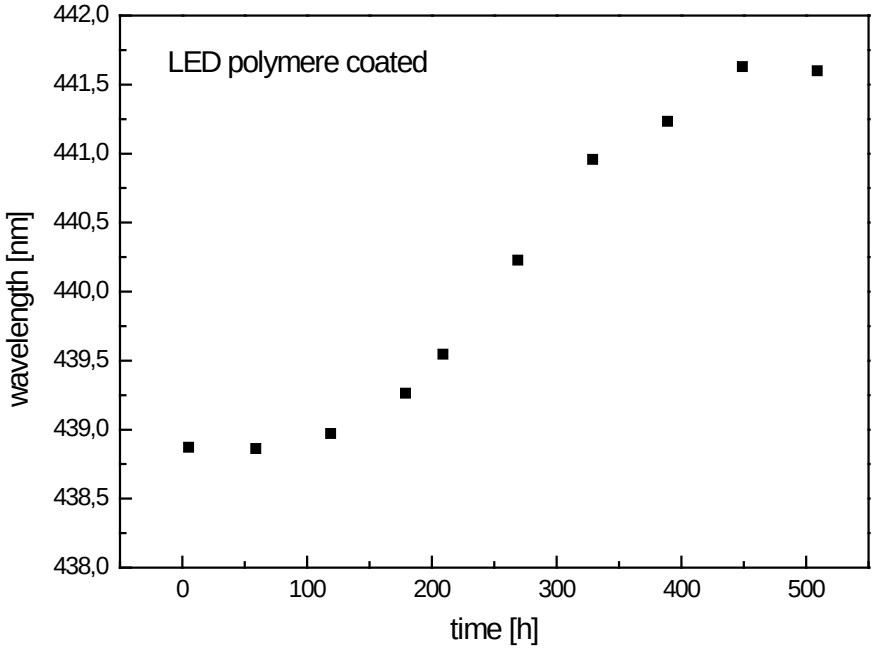


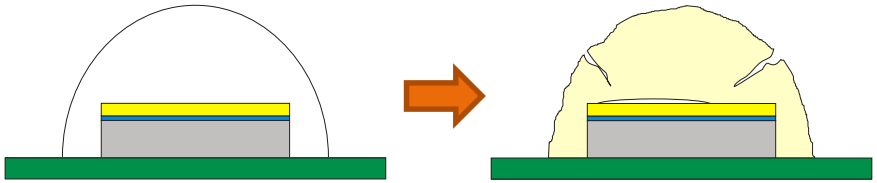


Aging of Polymers

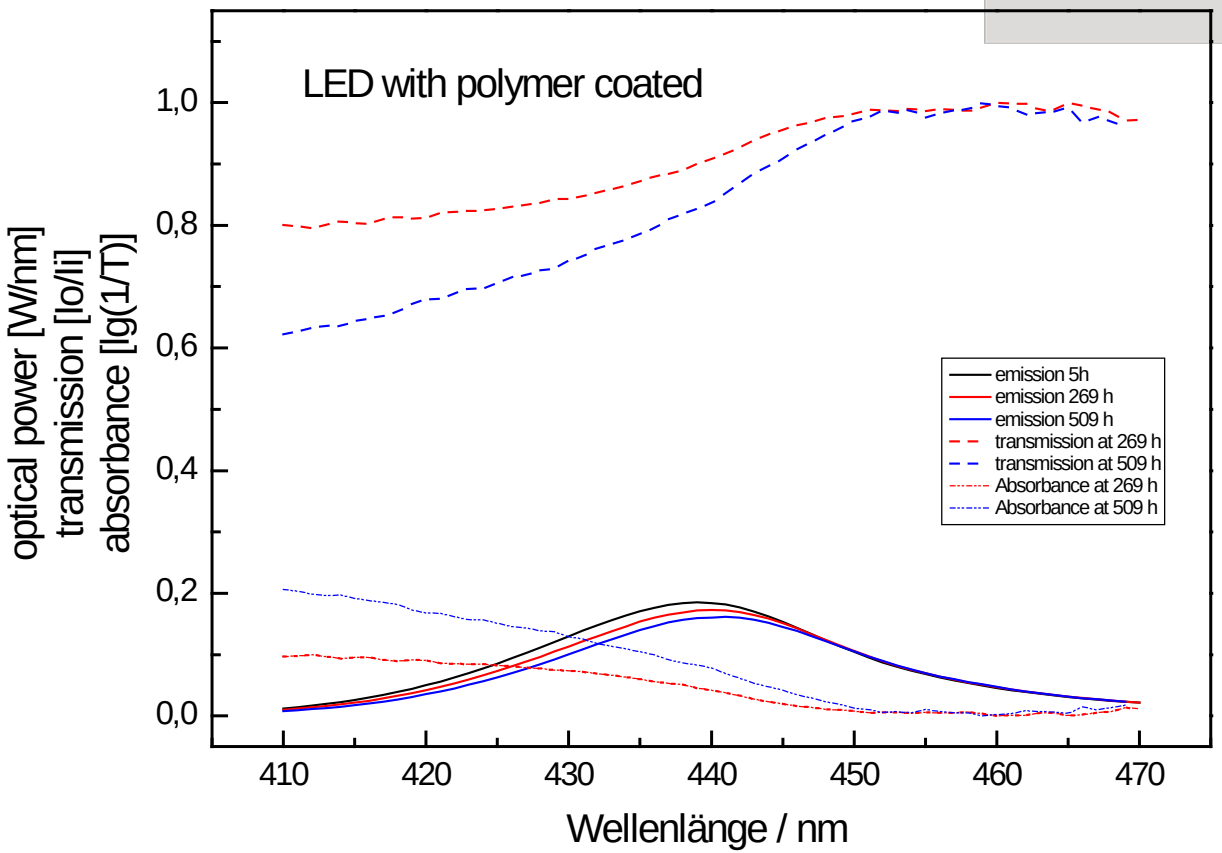


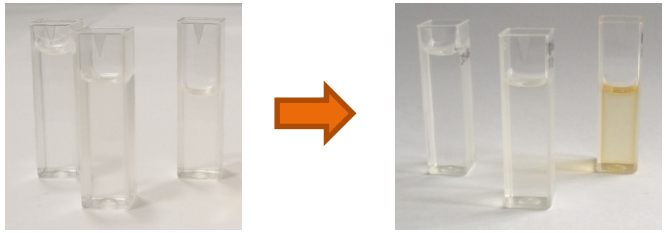






Aging of Polymers





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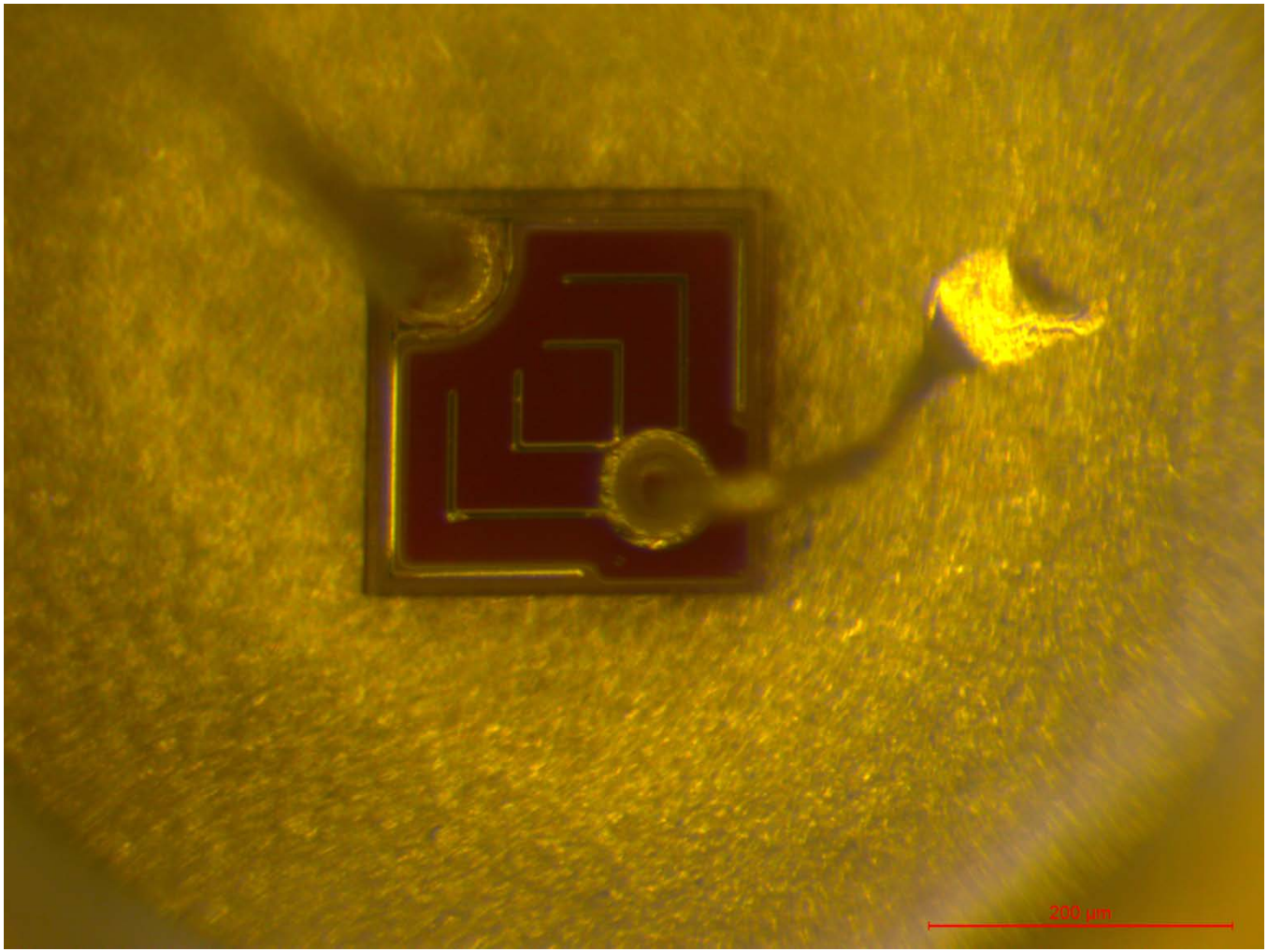
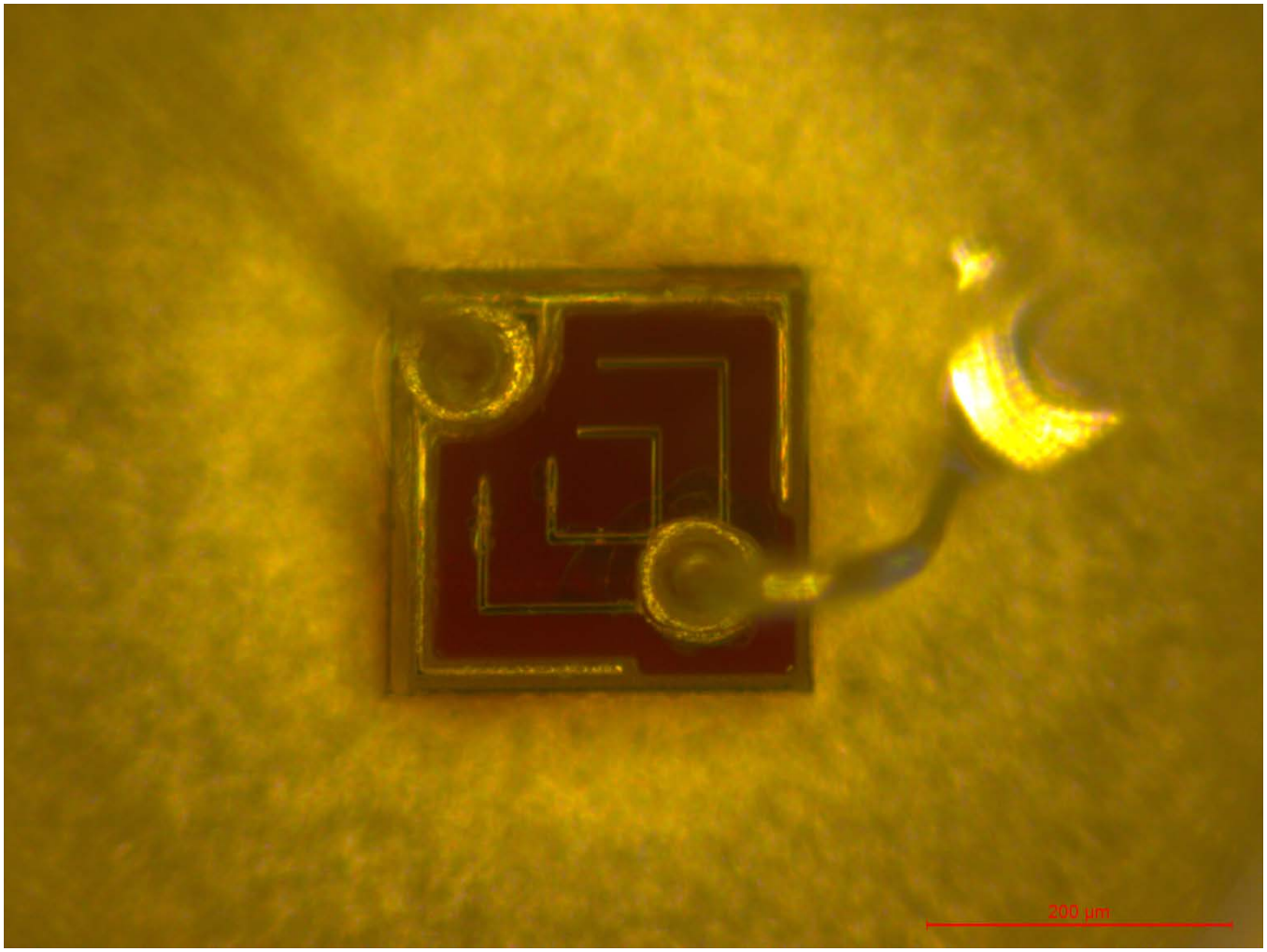
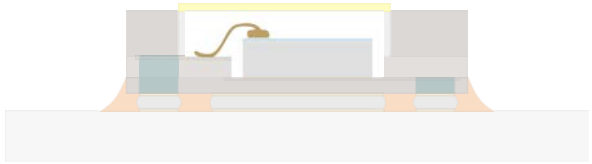
Delamination of filling

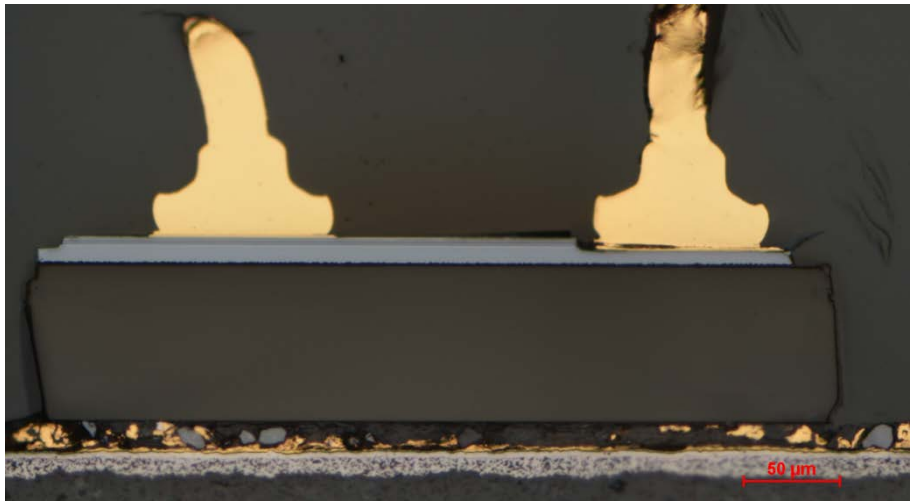


Delamination of filling

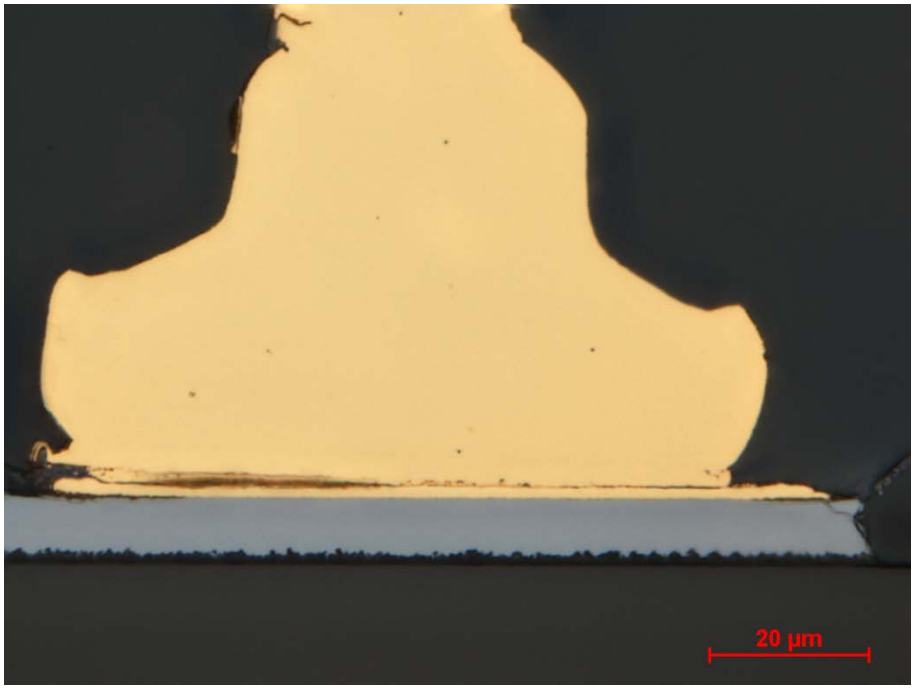


Delamination of glued interface



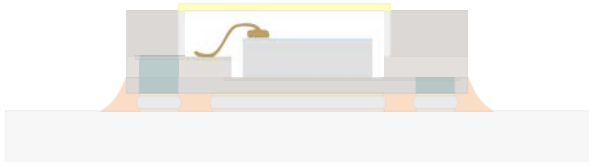


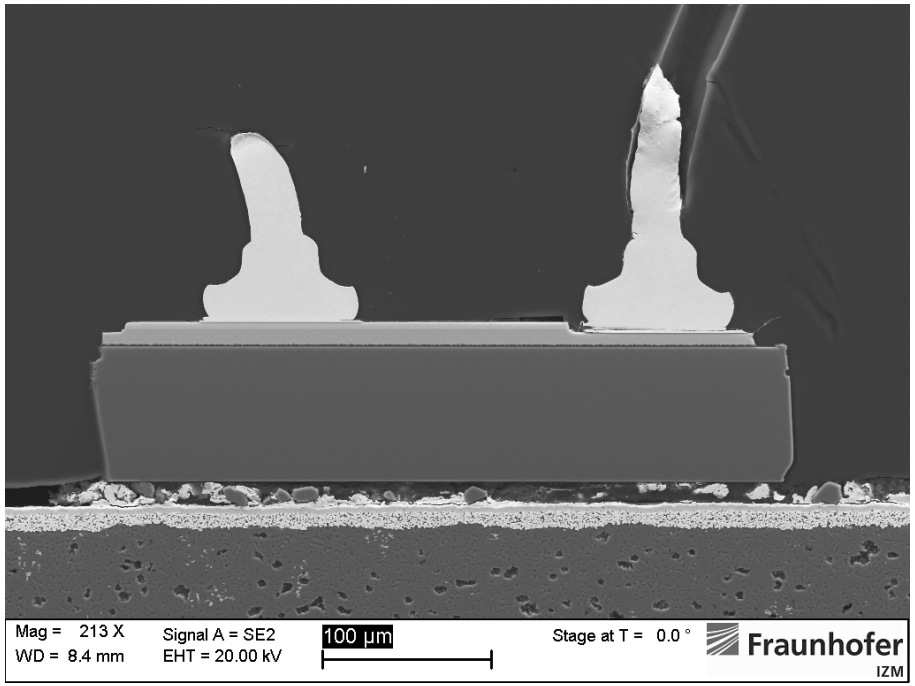
cross section



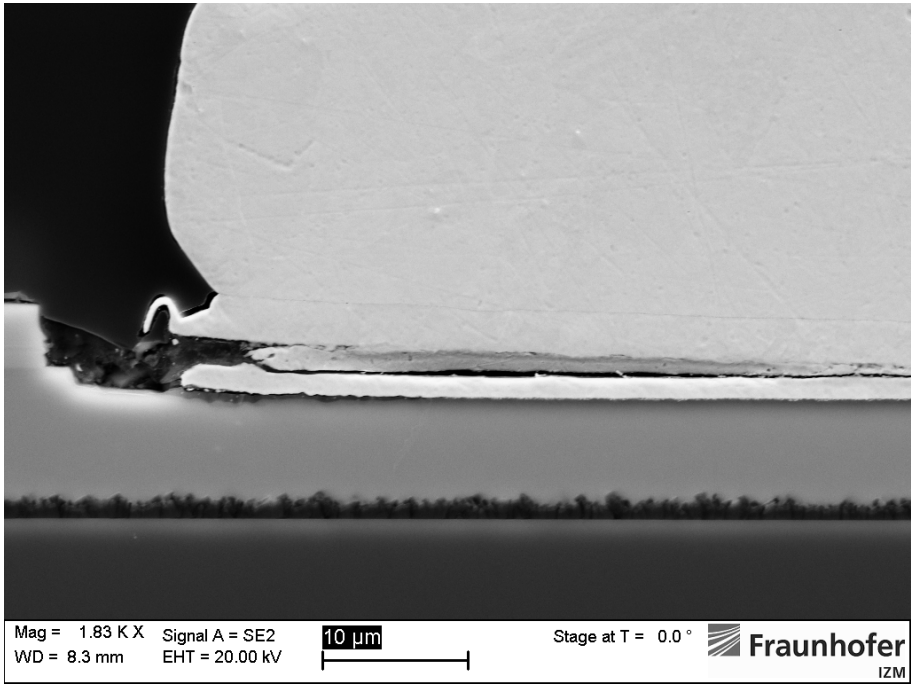
ball bond

Delamination of ball bond



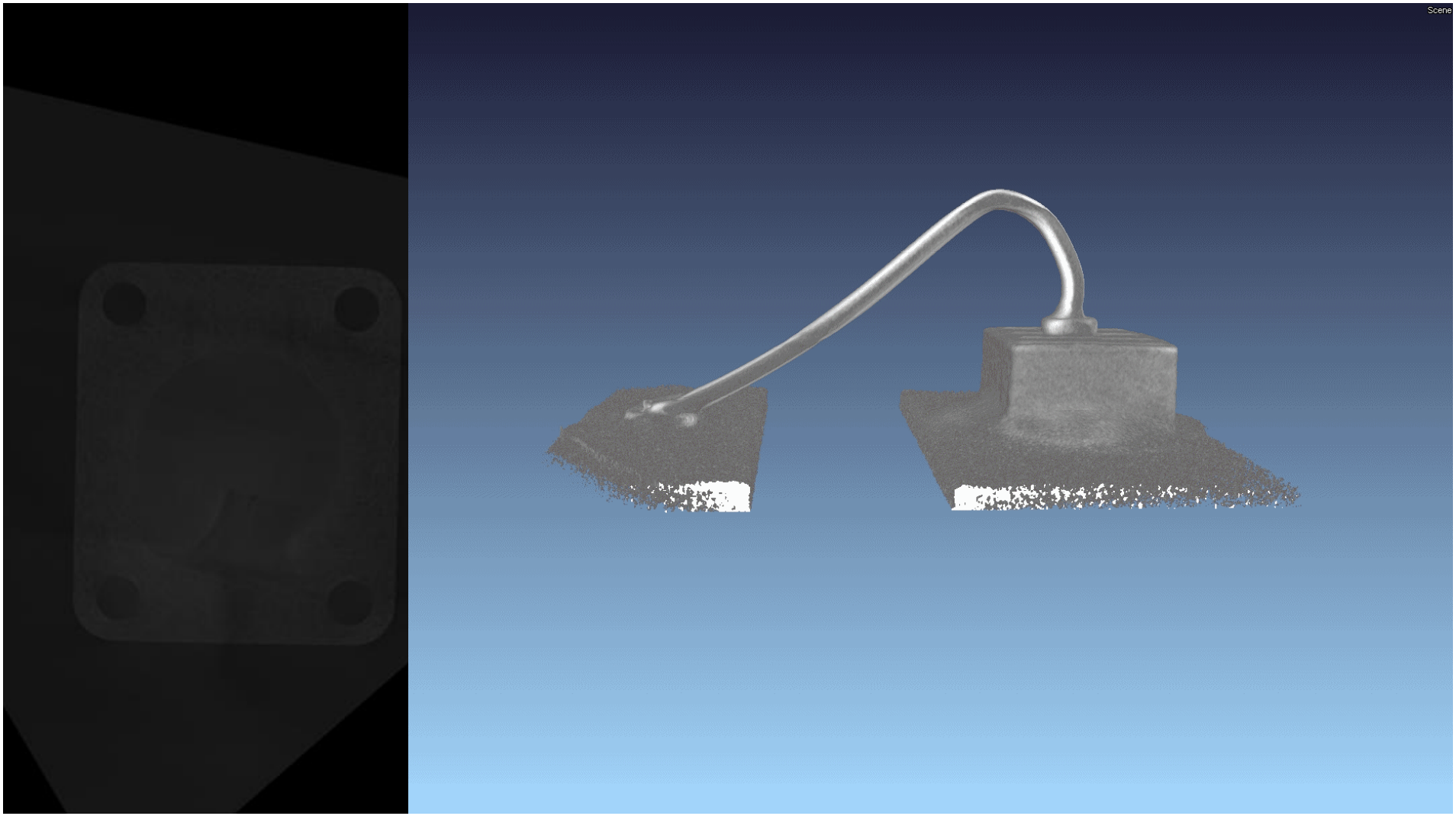


SEM of cross section

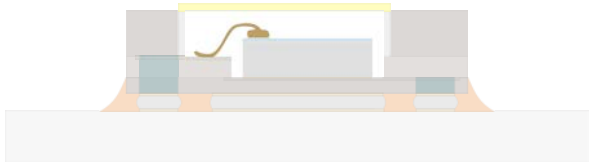


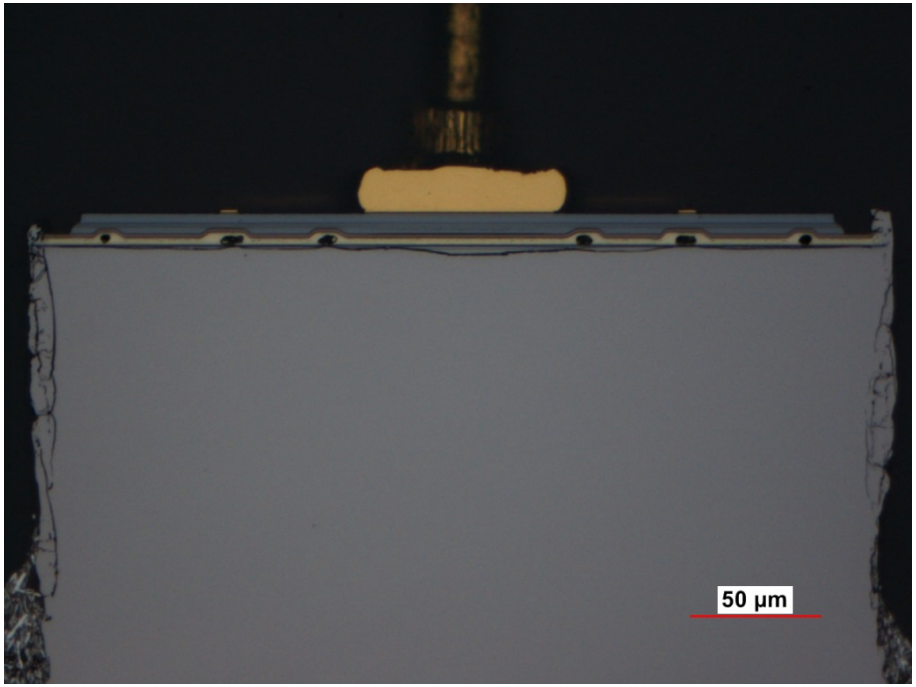
ball bond interface

Multiple interfaces to take care on

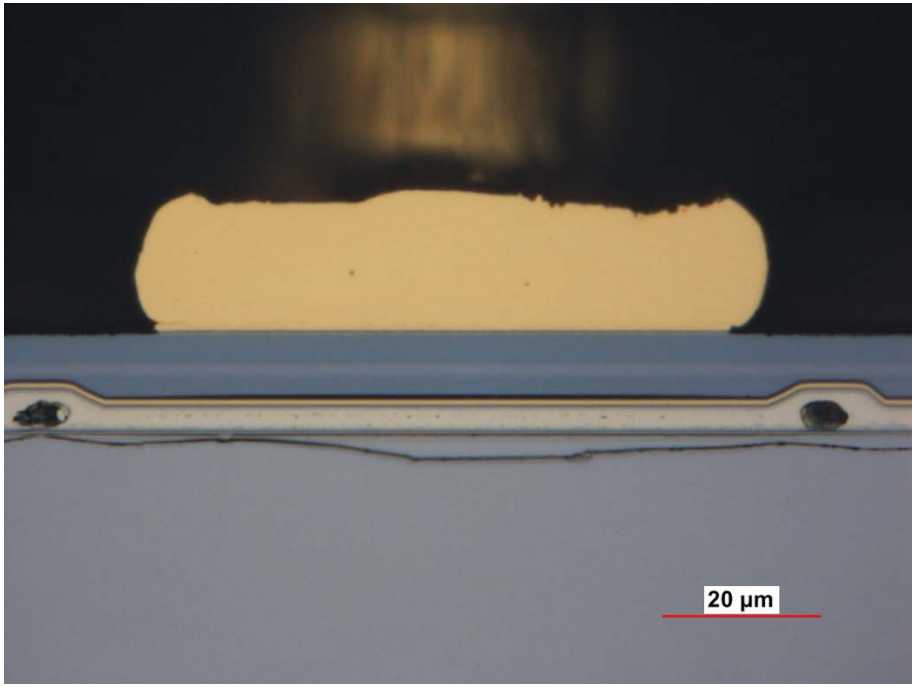


Damage of die



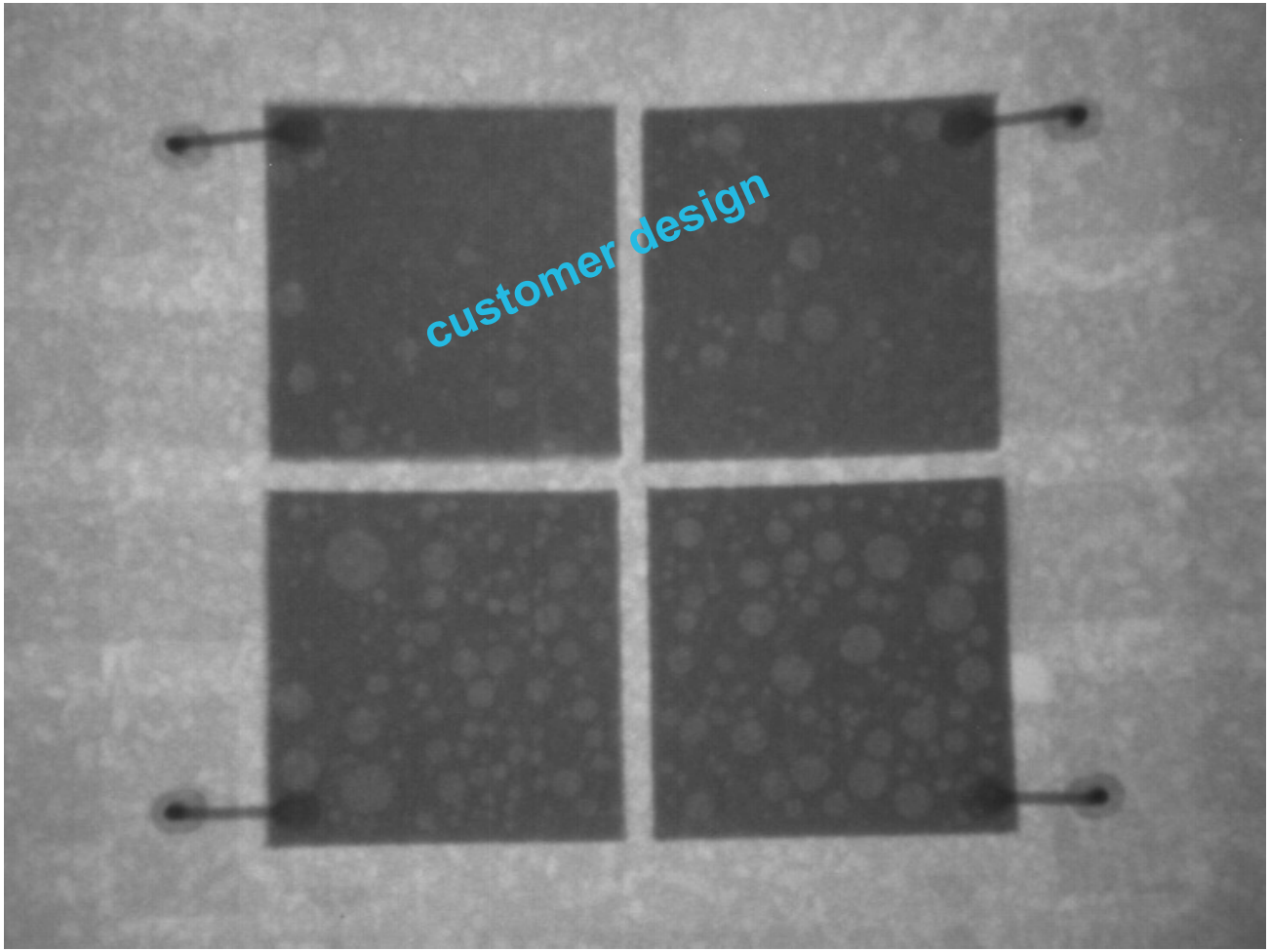


overview

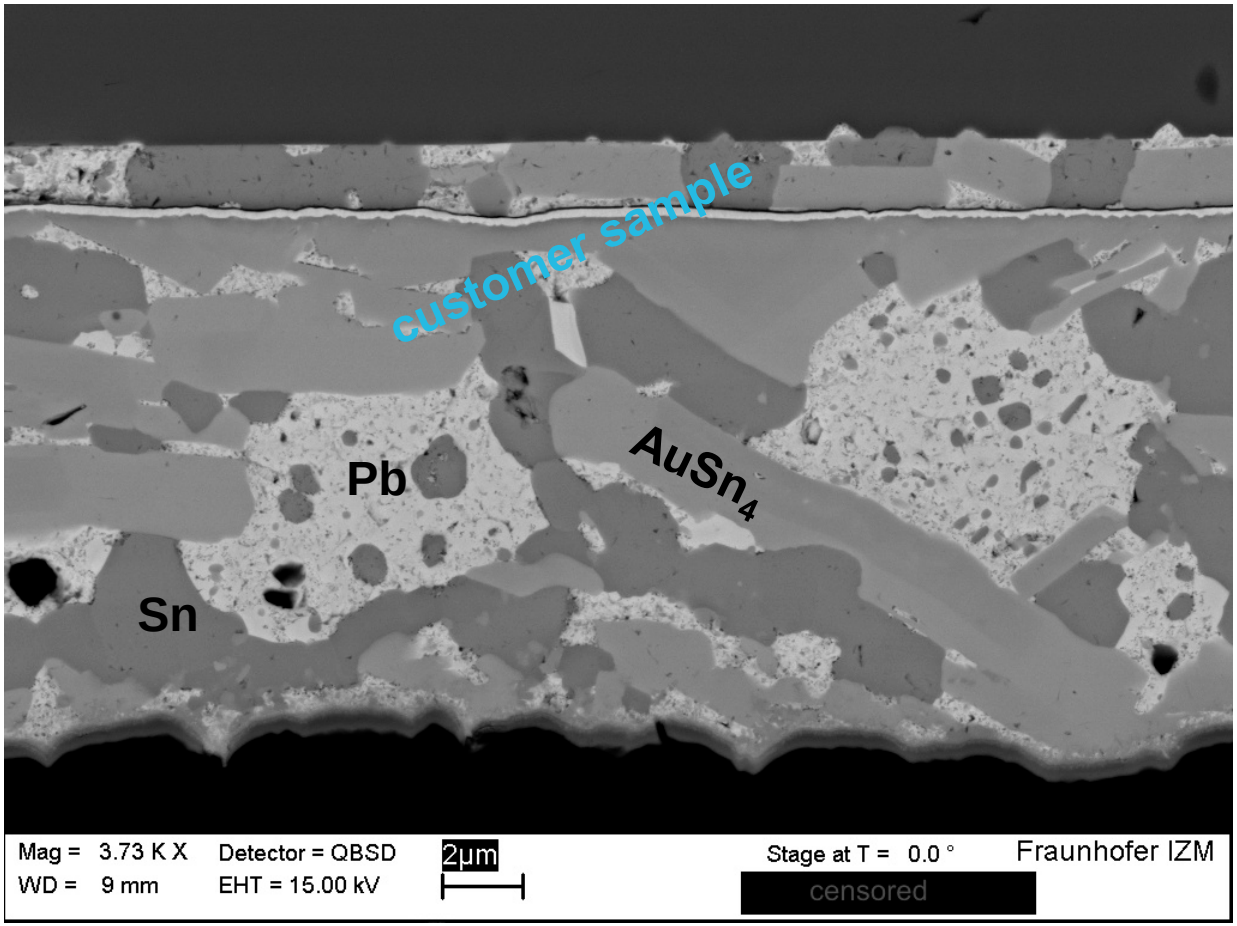


focus below epilayer

Inhomogeneous amount of pores



Brittle solder alloys



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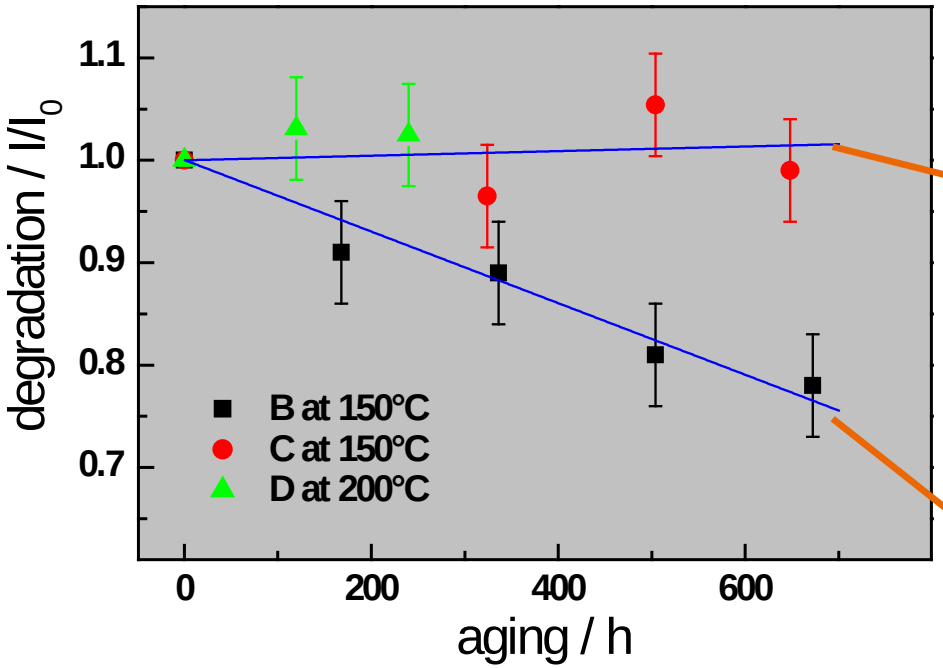
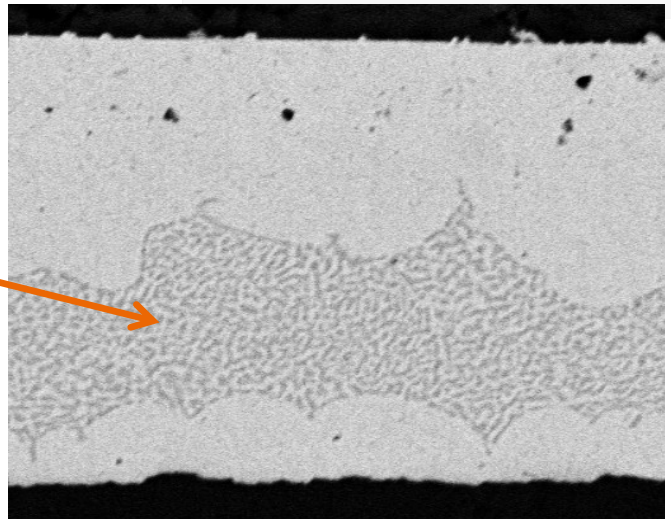
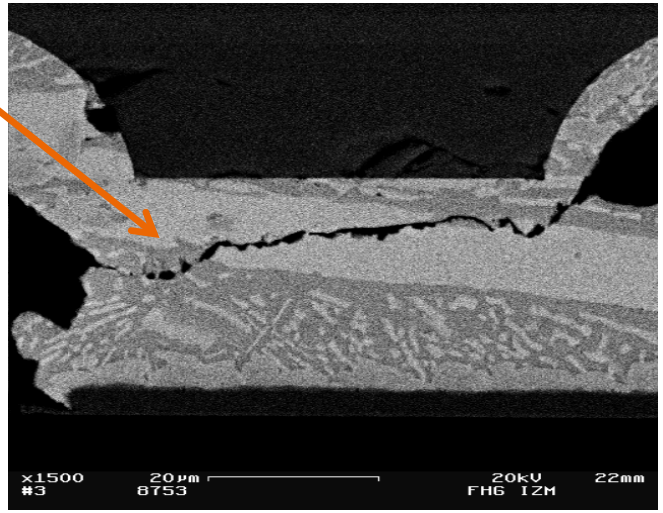
Risk of the $AuSn_4$ Phase







C & D : Au80Sn20
B : Au10Sn90

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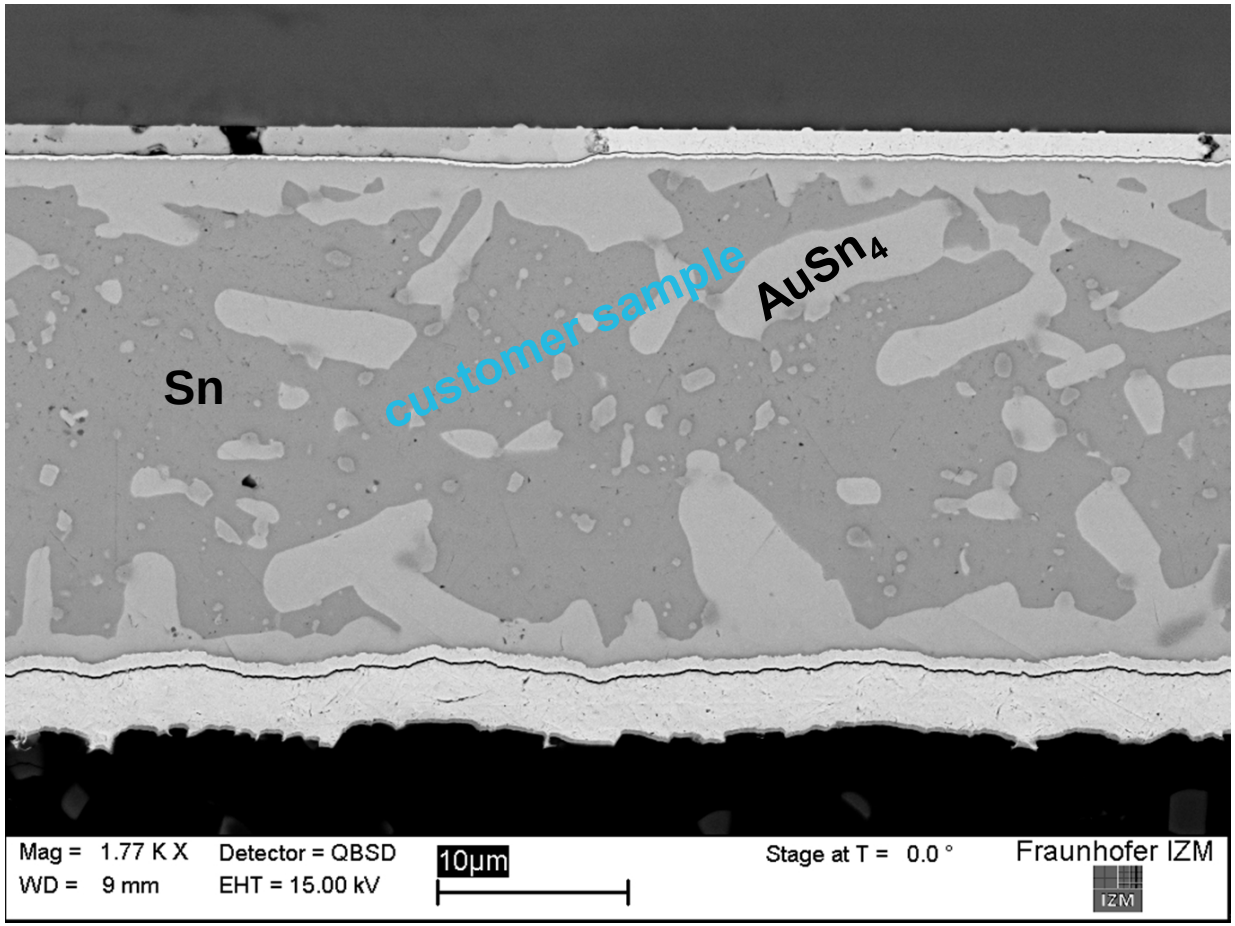
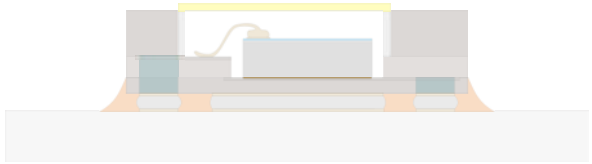
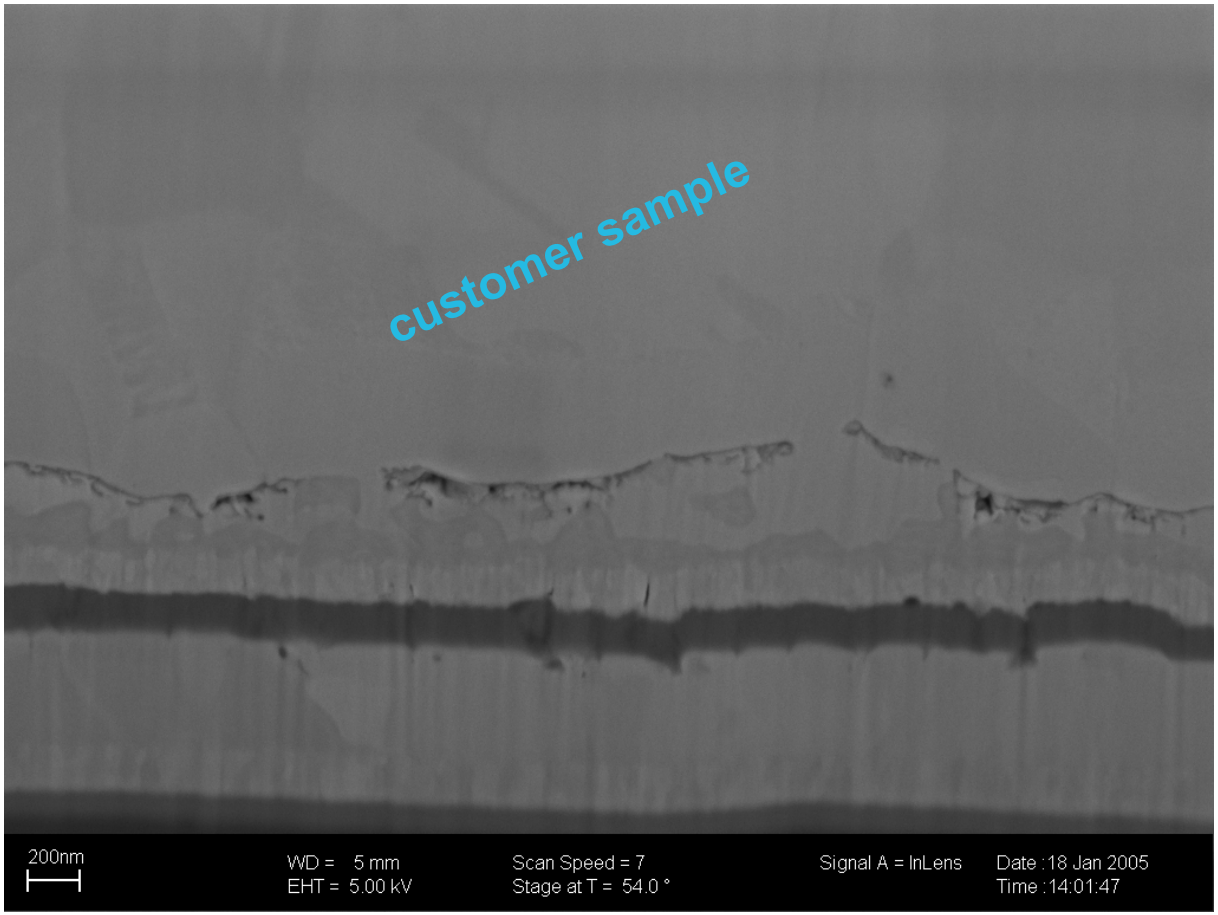
Brittle solder alloys

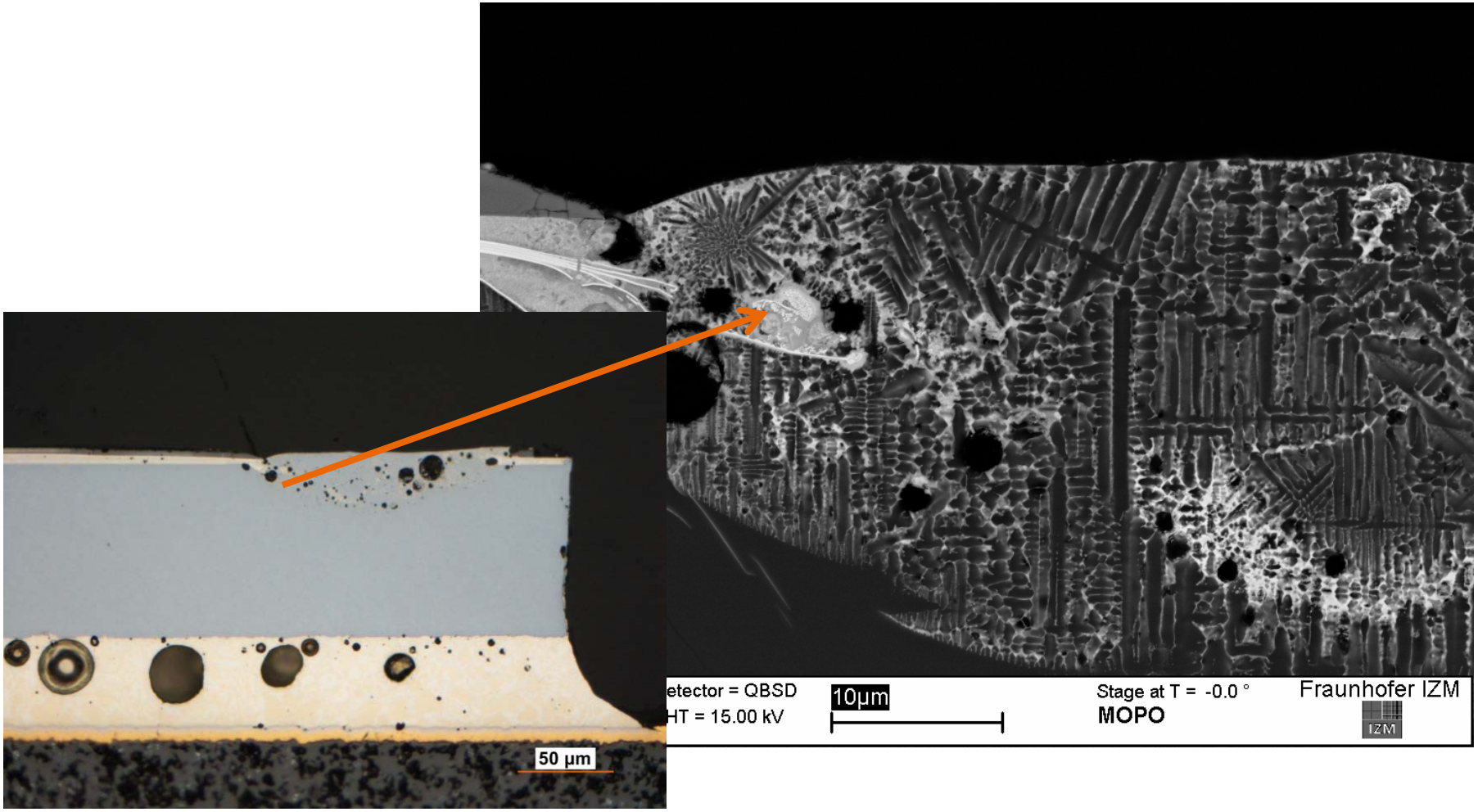


Gap inside solder interconnect

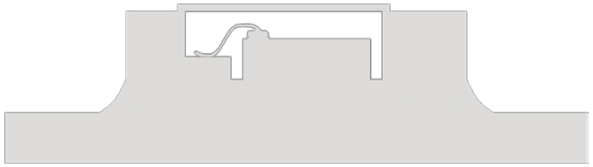


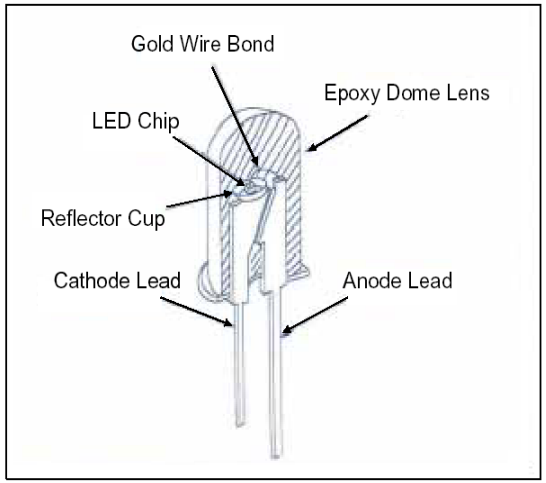


Local overheating

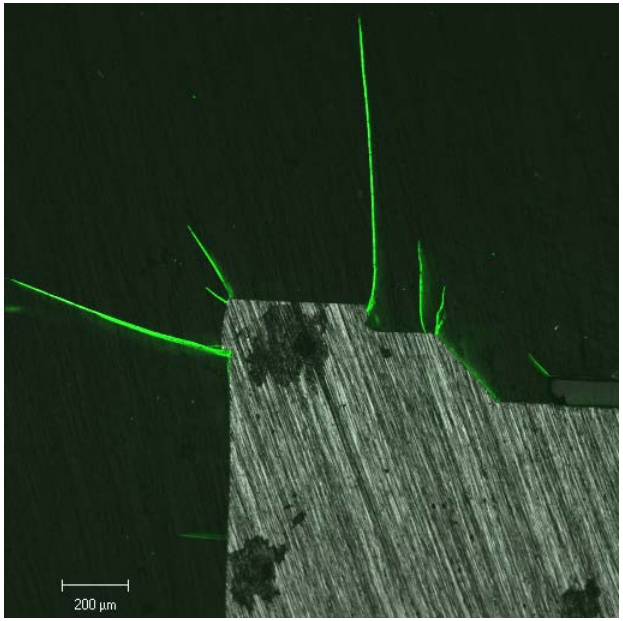


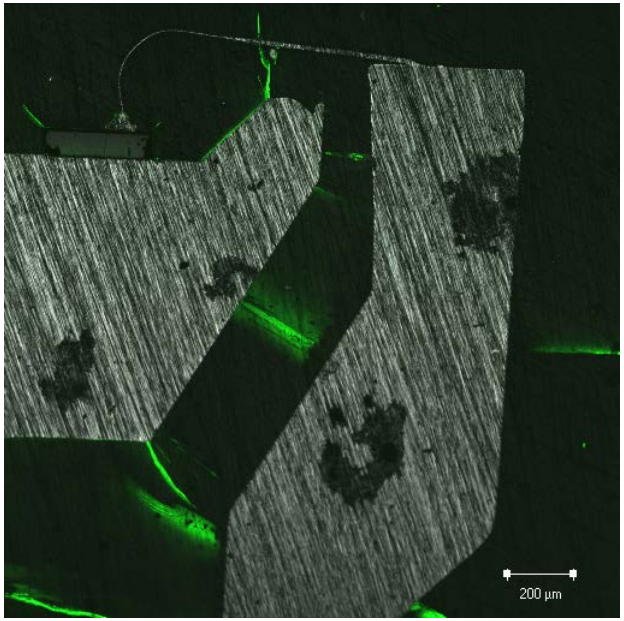
Cracks in encapsulant





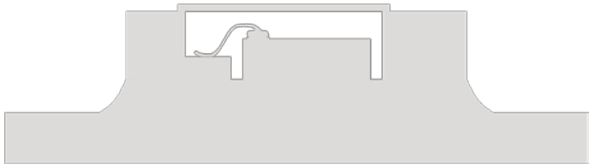
Failure due to overheating:
cracks in the epoxy mold due to CTE mismatch

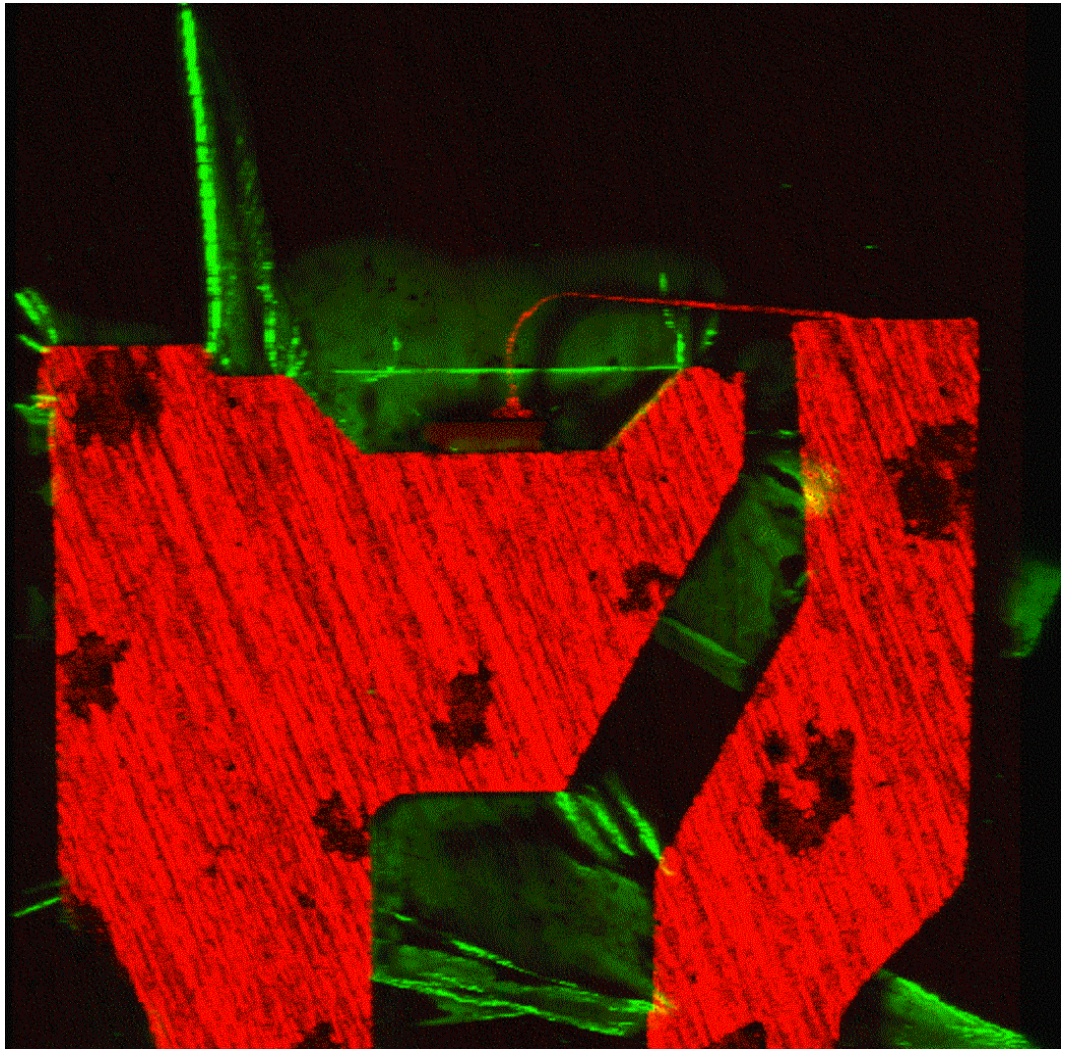


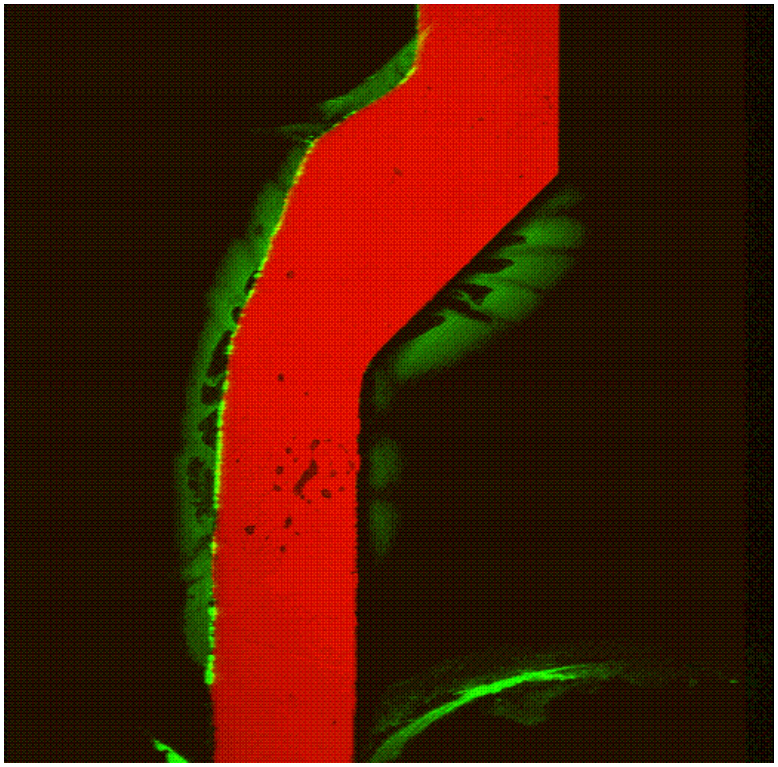


laser scanning fluorescence microscopic analysis of cracks

Cracks and collapsed pores







Thank you for you Attention!

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www.izm.fraunhofer.de

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