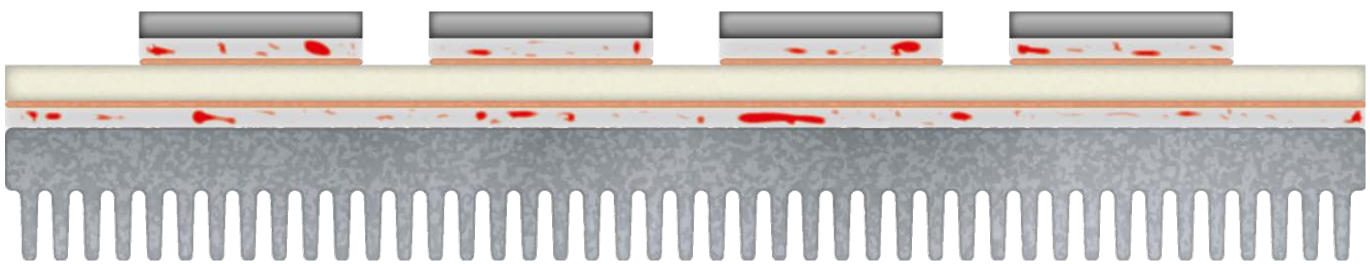
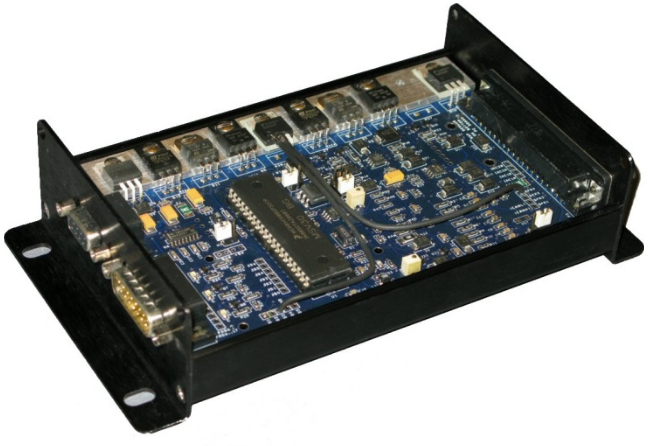
Void Detection in Large Solder Joints of Integrated Power Electronics

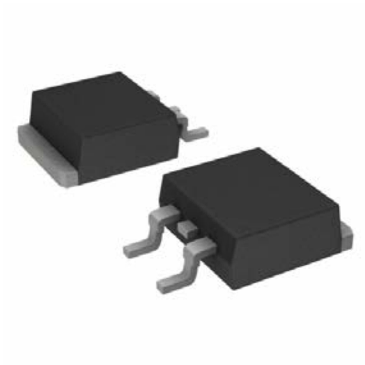


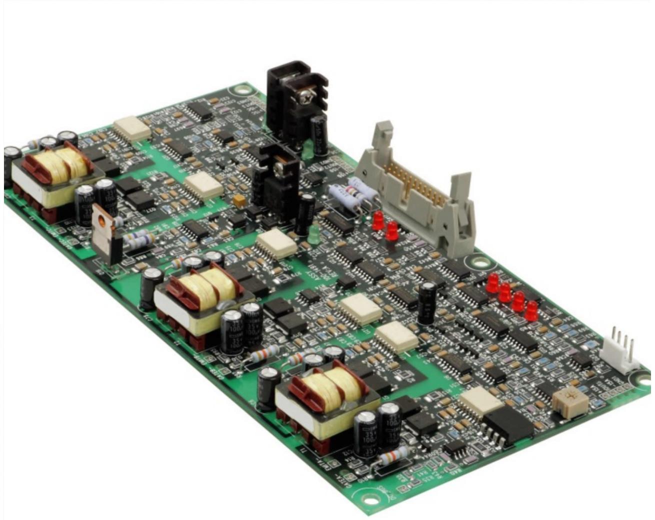
Patrick Schuchardt
Goepel electronics LLC

What are power electronics

- Solid-state electronic devices which control and convert electric power
- Engine control units, AC/DC-, DC/DC-converter

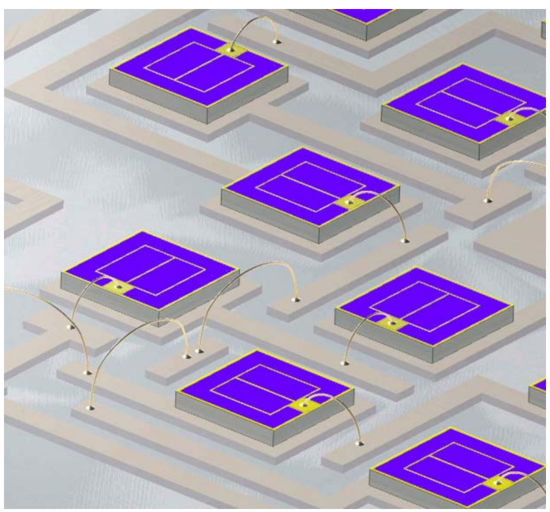






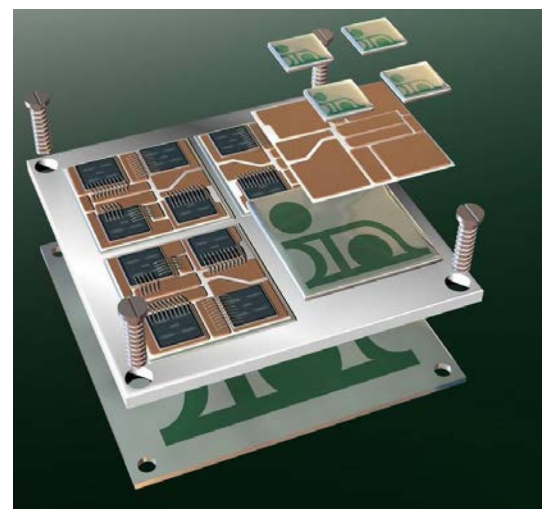
What are **integrated** power electronics

- Advanced packages of power electronics to improve efficiency and reduce size and costs
- Based on MOSFET or IGBT technology



Classic 2D-wire-bond design

→

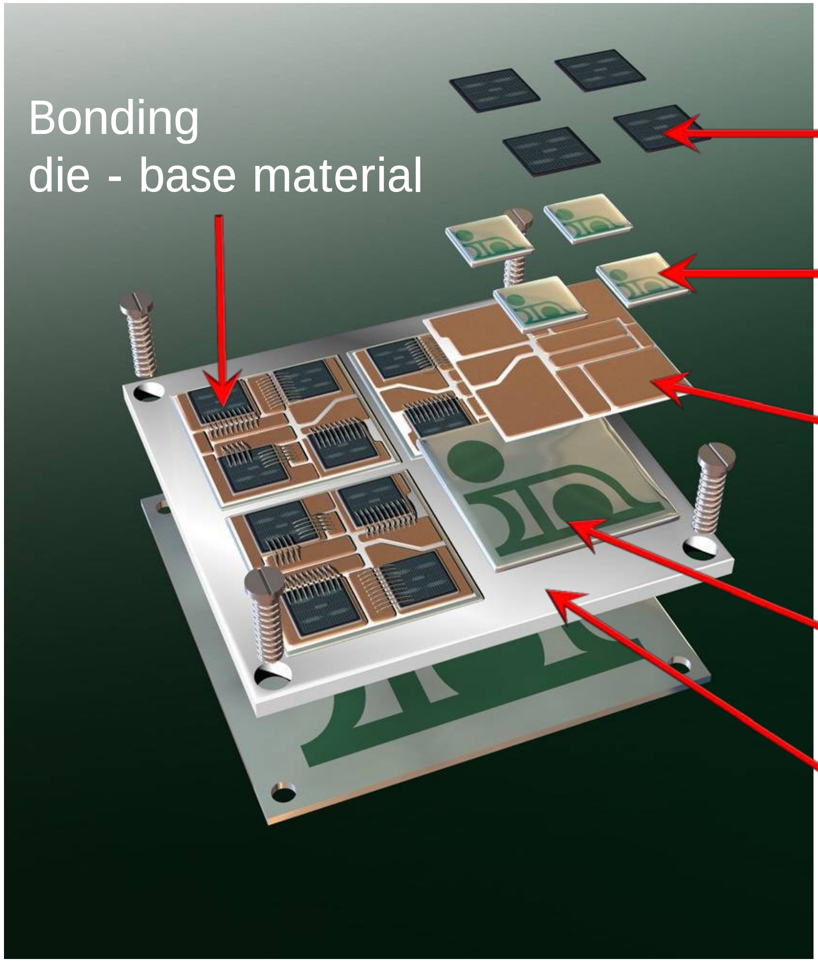


IPEMs – Integrated power electronic modules

Integrated power electronics – Applications

- Electric vehicles, hybrid vehicles, battery charger
- Uninterrupted power supplies, emergency generators
- Converters for photovoltaic and wind power stations
- Railway drives, lighting control devices

Structure of IPEMs



Die (e.g. IGBT)

Solder joint die - base material

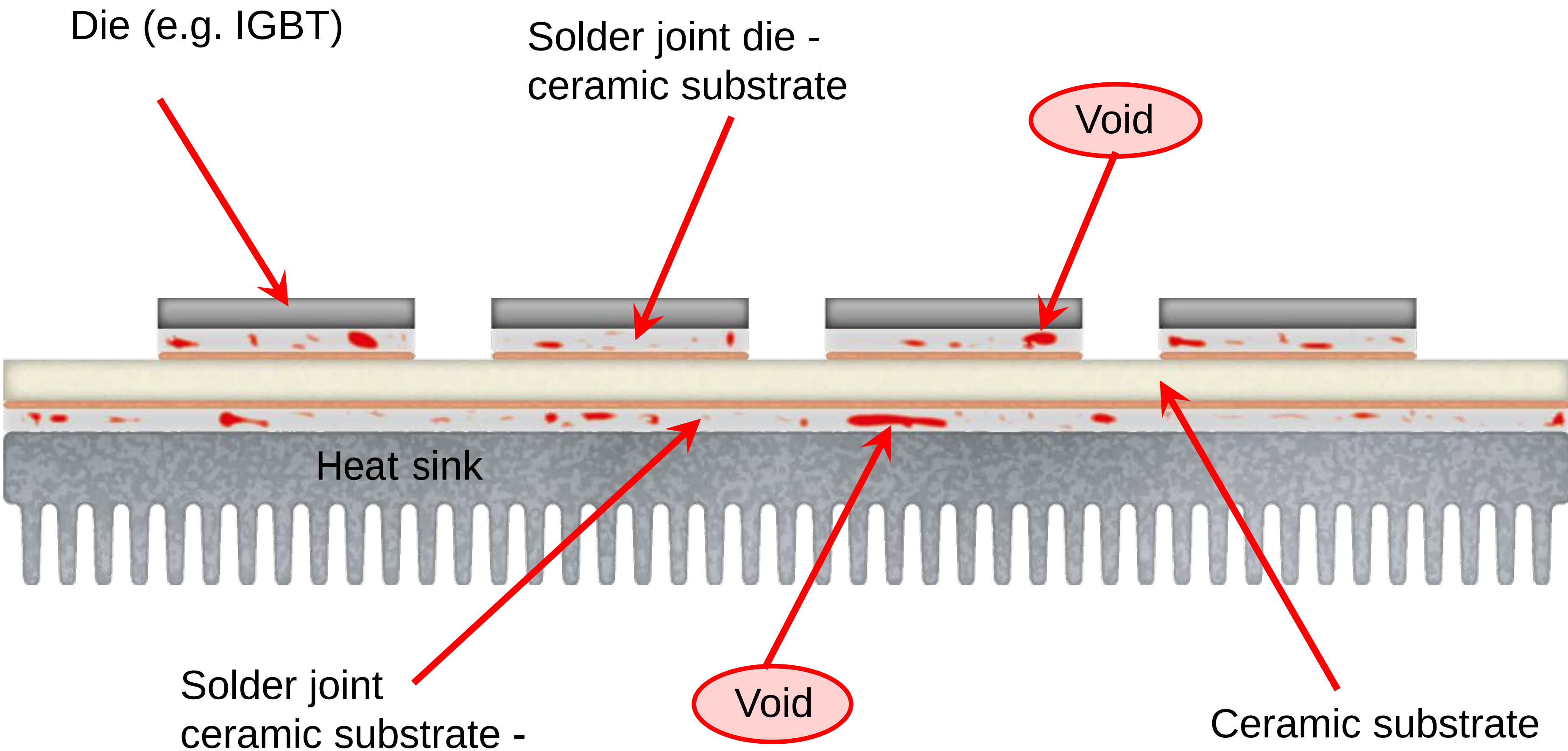
Base material
(e.g. ceramic substrate)

Solder joint base material - heat sink

Heat sink

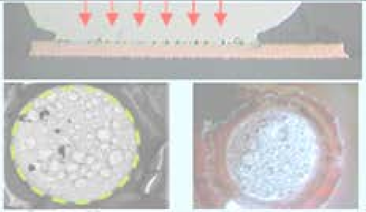
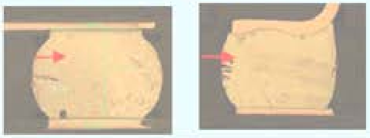
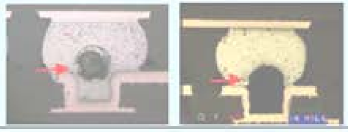
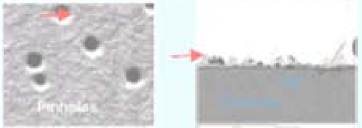
source: Indium Corporation

Structure of IPEMs



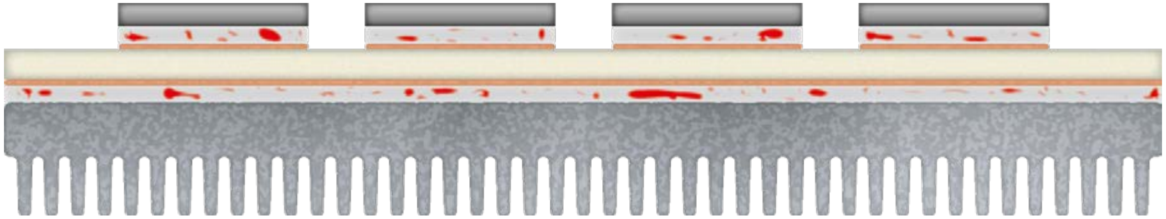
$[a_v] < 25\%$

Types of voids (source: Intel, 2005)

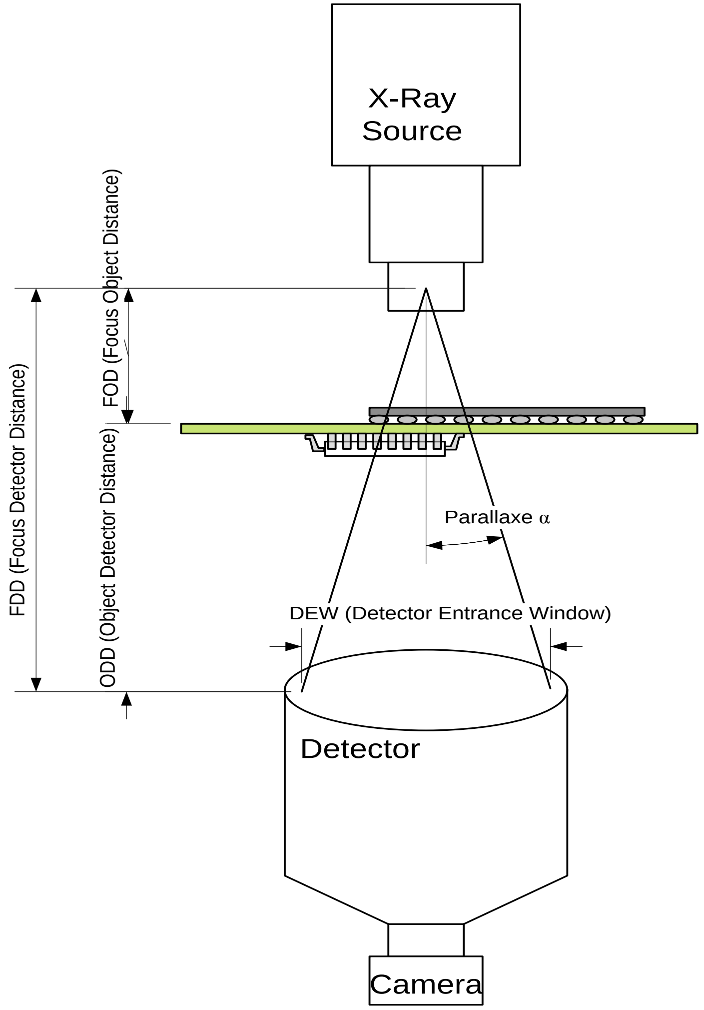
Type of Voids	Description	Photos
Macro Voids	**Voids generated by the evolution of volatile ingredients of the fluxes within the solder paste; typically 4 to 12 mils (100 to 300 µm) in diameter, these are usually found anywhere in the solder joint; IPC's 25% max area spec requirement is targeted toward process voids; NOT unique to LF solder joints. Sometimes referred to as "Process" voids**	
Planar Micro Voids	Voids smaller than 1 mil (25 µm) in diameter, generally found at the solder to land interfaces in one plane; though recent occurrence on Immersion Silver surface finish has been highlighted these voids are also seen on ENIG and OSP surface finishes; cause is believed to be due to anomalies in the surface finish application process but root cause has not been unequivocally determined. Also called "champagne" voids	
Shrinkage Voids	Though not technically voids, these are linear cracks, with rough, `dendritic` edges emanating from the surface of the solder joints; caused by the solidification sequence of SAC solders and hence, unique to LF solder joints; also called sink holes and hot tears	
Micro-Via Voids	4 mil (100 µm) and more in diameter caused by microvias in lands; these voids are excluded from 25% by area IPC spec; NOT unique to LF solder joints	
Pinhole Voids	Micron sized voids located in the copper of PCB lands but also visible through the surface finish; Generated by excursions in the copper plating process at the board suppliers	
Kirkendall Voids	Sub-micron voids located between the IMC and the Copper Land; Growth occurs at High Temperatures; Caused by Difference in Inter-diffusion rate between Cu and Sn. Also Known as "Horsting" Voids.	

Test Equipment Requirements

- Reconstruction of overlaying solder joints
- Separation of voids in different layers
- Determination of relevant parameters **for every layer**:
  - Biggest void, Sum of all voids
  - Local distribution of voids **= thermal connection**
  - Measurement accuracy: 0.1mm² - 0.3mm²
- Complete inspection within the production cycle
- Inspection in (partly-) mounted state, e.g. with heat sink



XRay Inspection Basics - Review

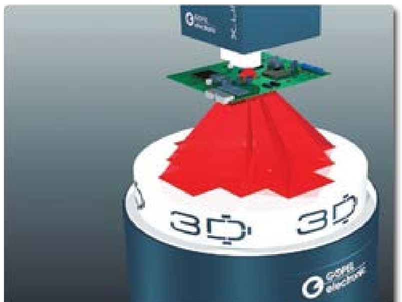


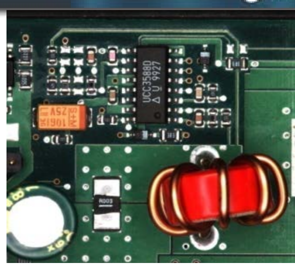
XRay Beam penetrates the pcb
-Dense material – high absorption
-Less signal on the detector

Geometry defines
-Magnification
-Parallax angle

Def: Automated Optical Inspection

Main Principle



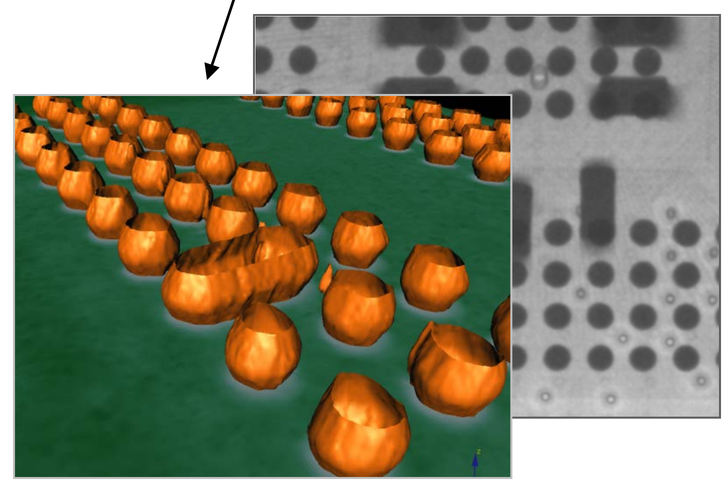


One or more images
of the Area of interest

2D / 2.5D / 3D

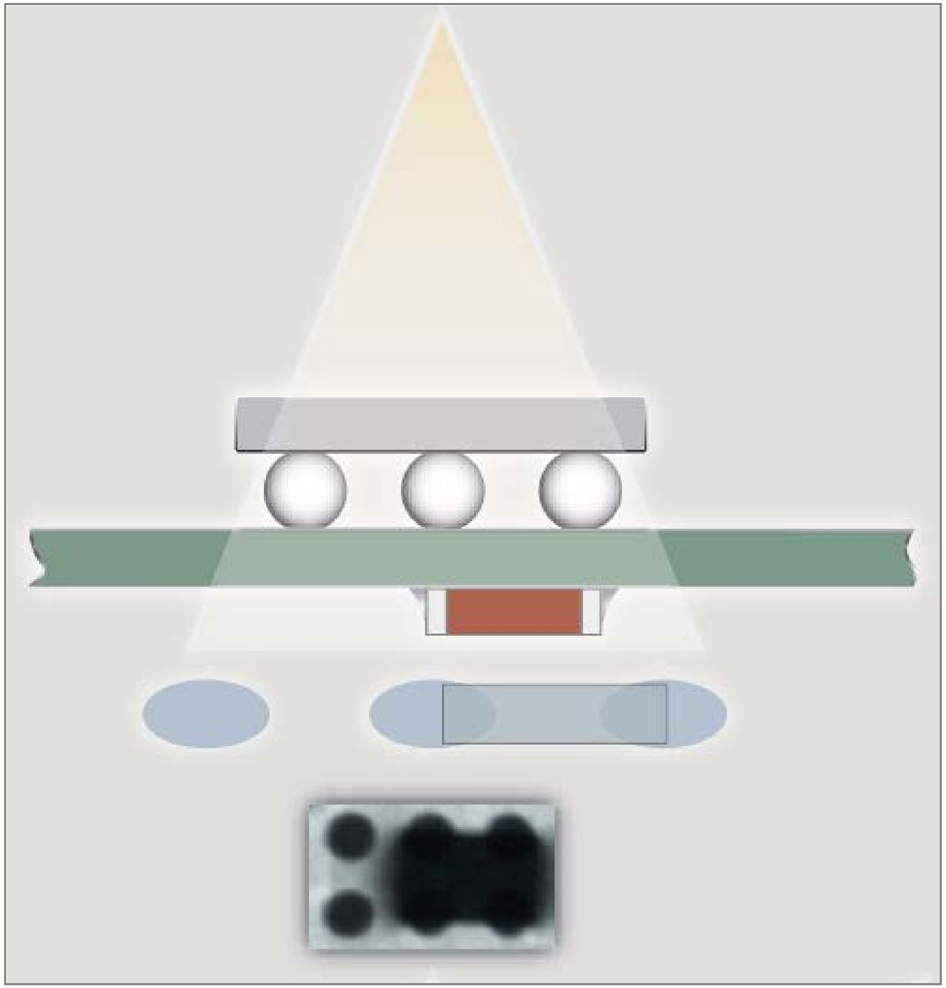
3D AXI

Software analyzes
images

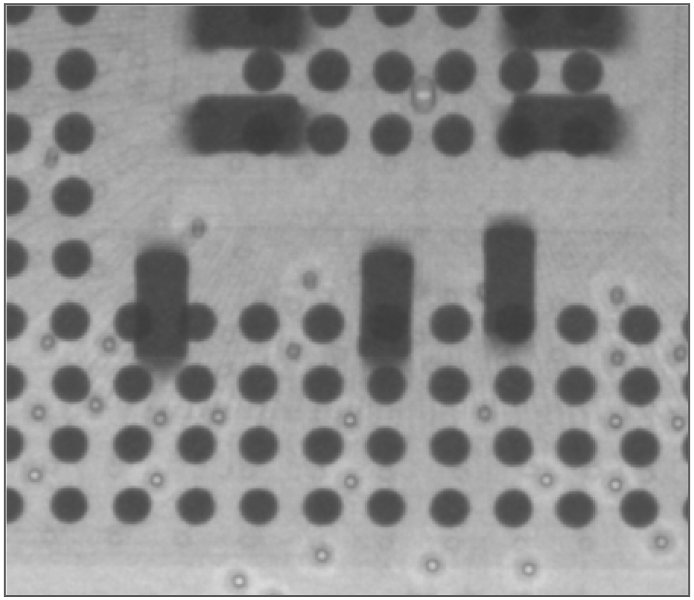


simple or one-layer analysis
or
multi-layer analysis with 3D image

2D X-ray Technology: Basic Principle



PCB is always radiated orthogonally!



2D X-ray Technology: Pros and Cons

Pros

- Cost-effective system architecture
- High speed testing
- Simple programming

Cons

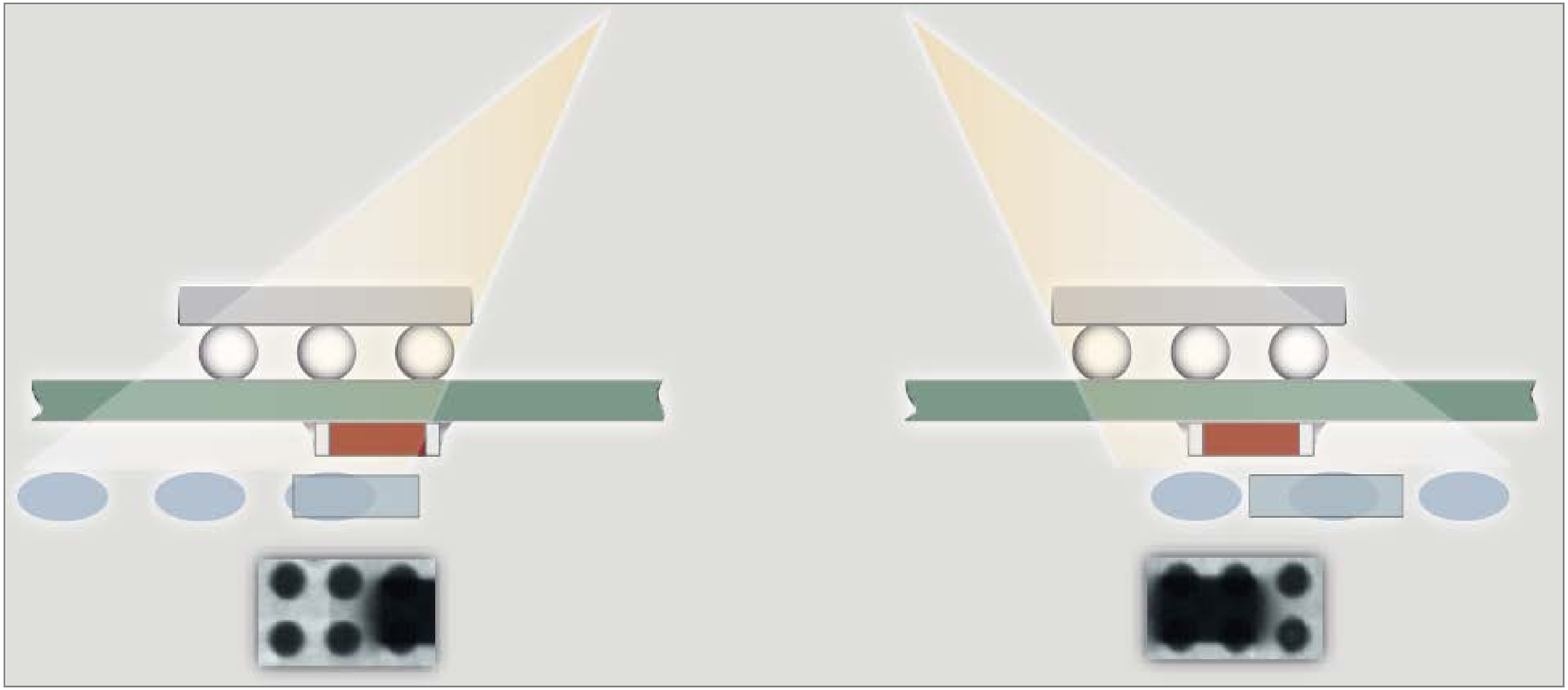
- Overlayed components and solder joints (e.g. at double-sided assembly) can‘t be inspected

Test of integrated power electronics

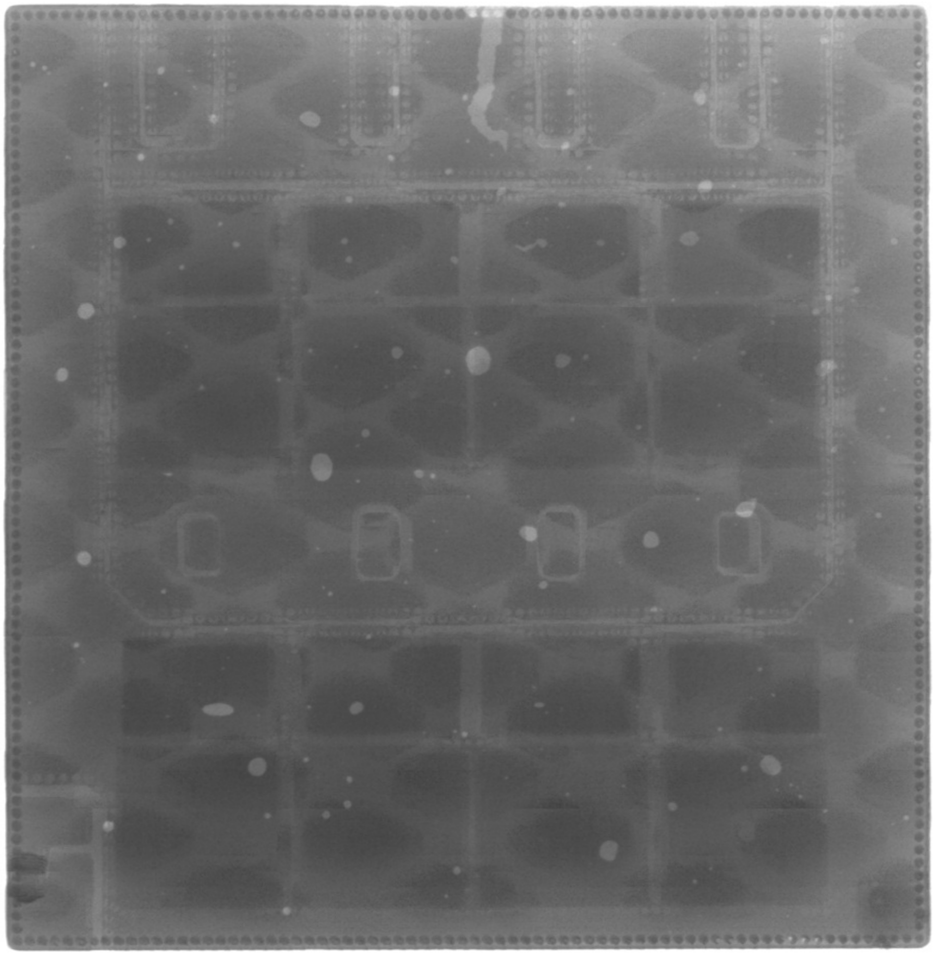
- Test of **<u>one</u>** solder layer (die - ceramic substrate) possible after first solder process, **<u>but:</u>**
- No separation of overlaid (second) solder joint possible !

2.5D X-ray Inspection: Basic Principle

Hidden solder joints are “separated” by off-axis view.



2D / 2.5D X-ray technology:
Inspection of integrated Power Electronics



- Inhomogeneity by heat sink, ceramic substrate and die
- Voids can‘t be assigned to a certain layer

2.5D X-ray Inspection: Pros and Cons

Pros

- Overlayed components (e.g. at double-sided assembly) possibly testable

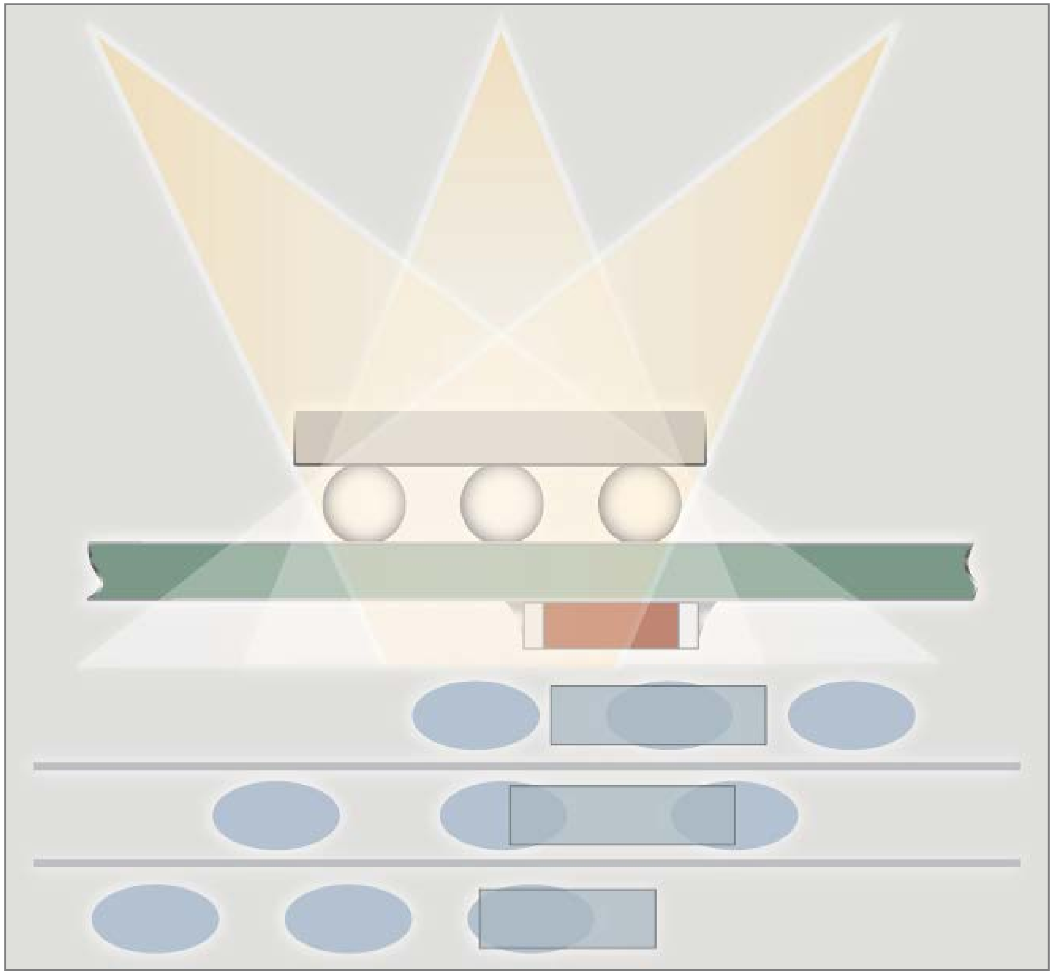
Cons

- Very high programming effort
- Consistent library not usable
- High testing times

Test of integrated power electronics

- Test of **<u>one</u>** solder layer (die - ceramic substrate) possible after first solder process, **<u>but</u>** changes after the second solder process likely!
- Separation of overlaid solder layers impossible (random positions of voids)

3D X-ray Technology: Basic Principle

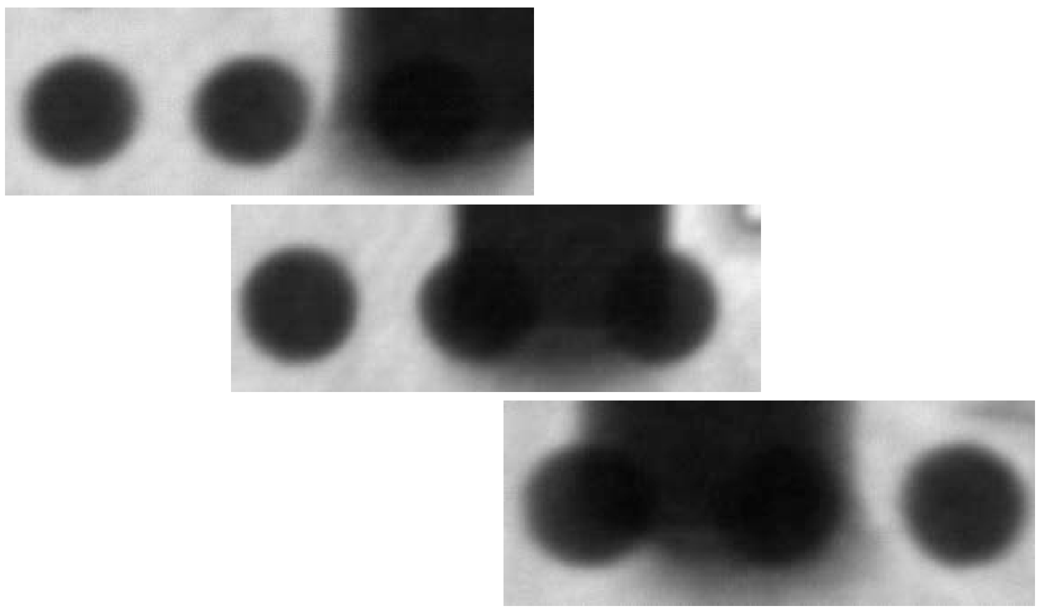


PCB is radiated from different angles.

Image basis results from several 2D projections.

XRay Inspection - Basics

Multiple projections from several angles



+35°

0°

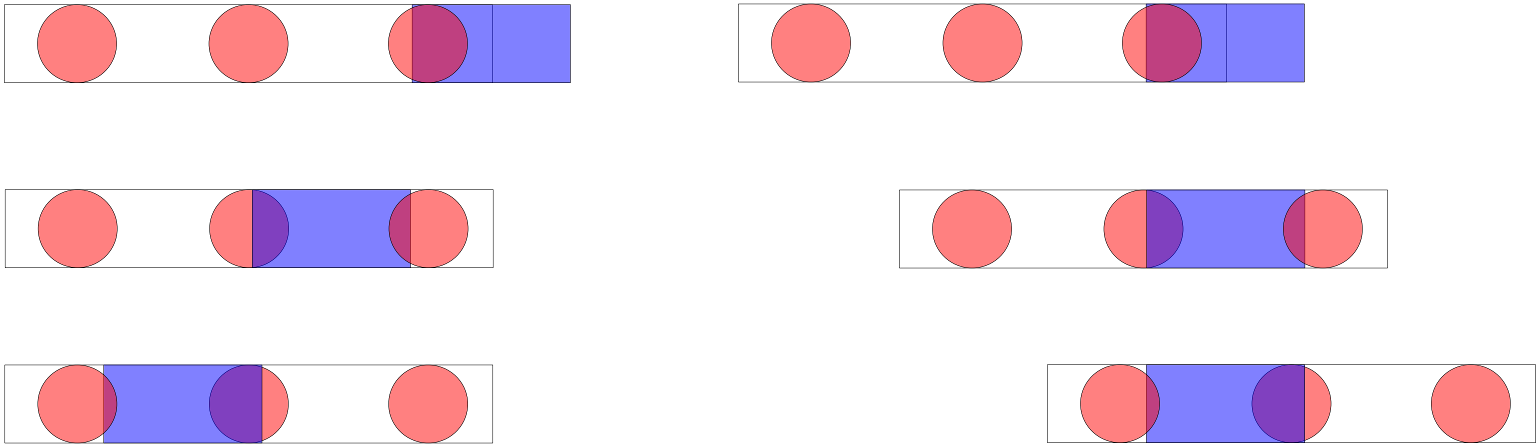
-35°

XRay Inspection - Basics

Simultaneous reconstruction of top and bottom side

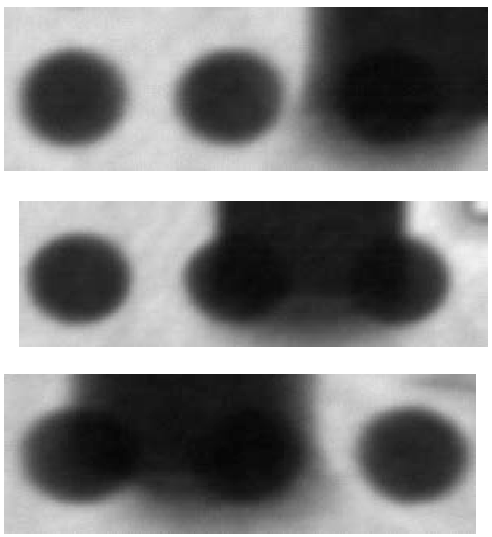
Top Side

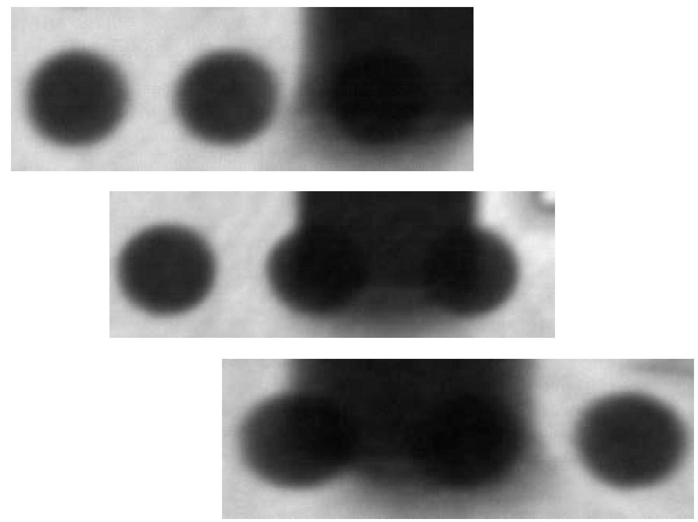
Bottom Side



XRay Inspection - Basics

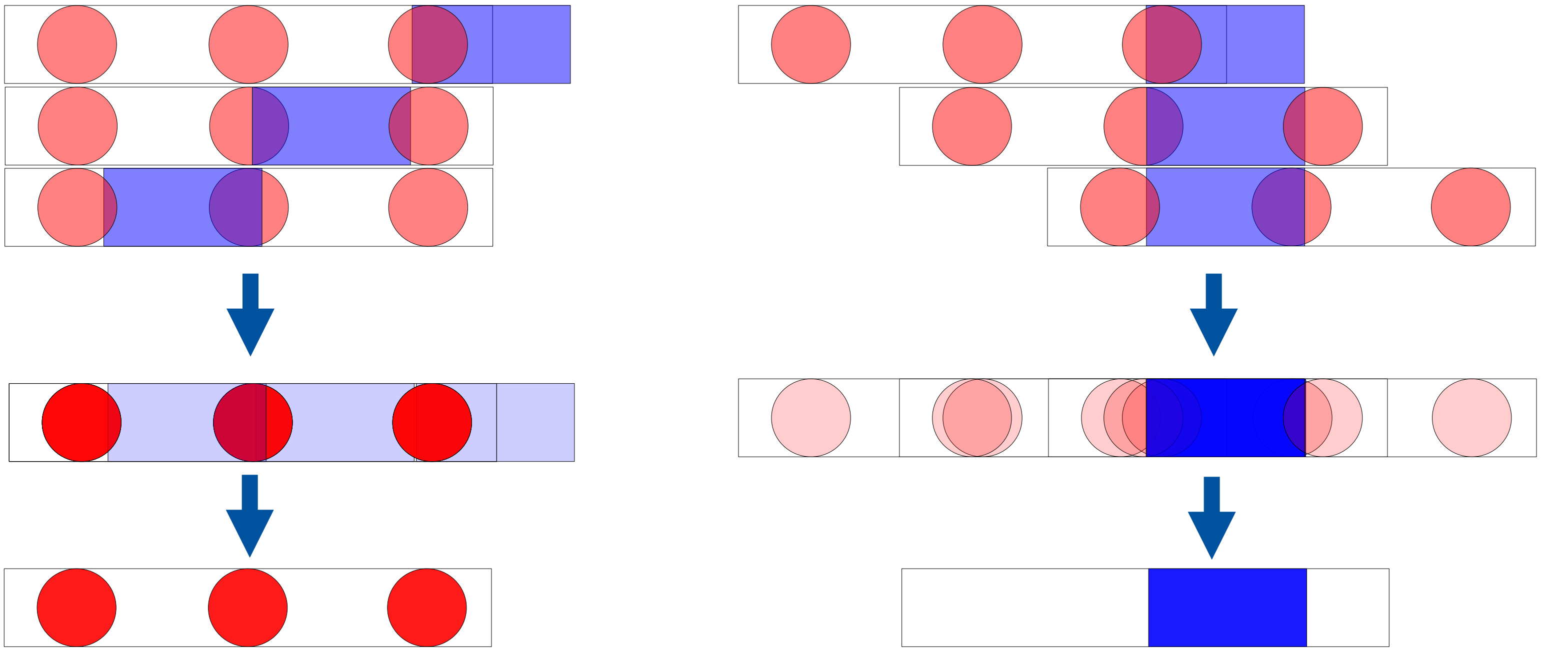
Reconstruction of individual slices (i.e. PCB Sides)





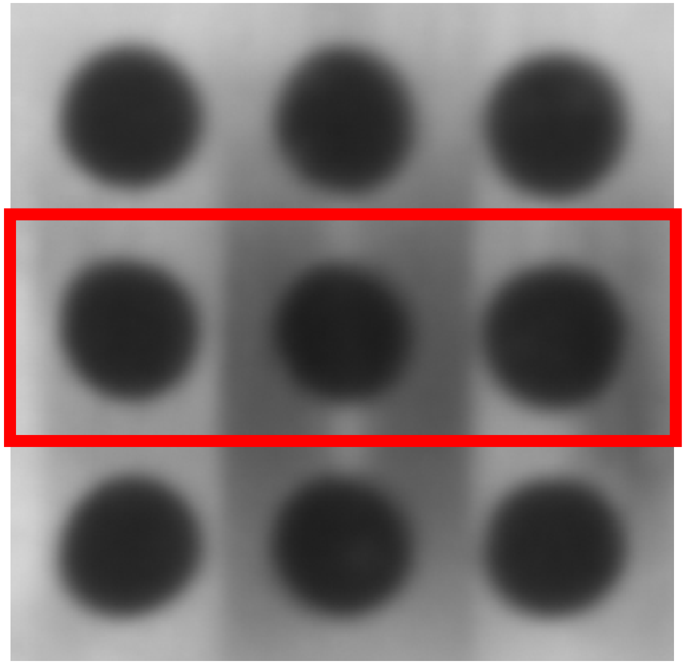
XRay Inspection - Basics

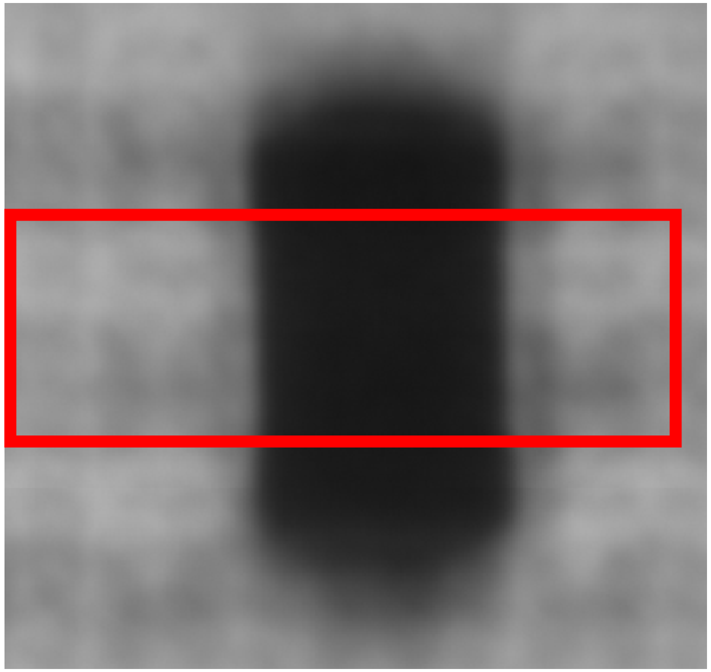
Simultaneous reconstruction of top and bottom side



XRay Inspection - Basics

Reconstruction of individual slices (i.e. PCB Sides)

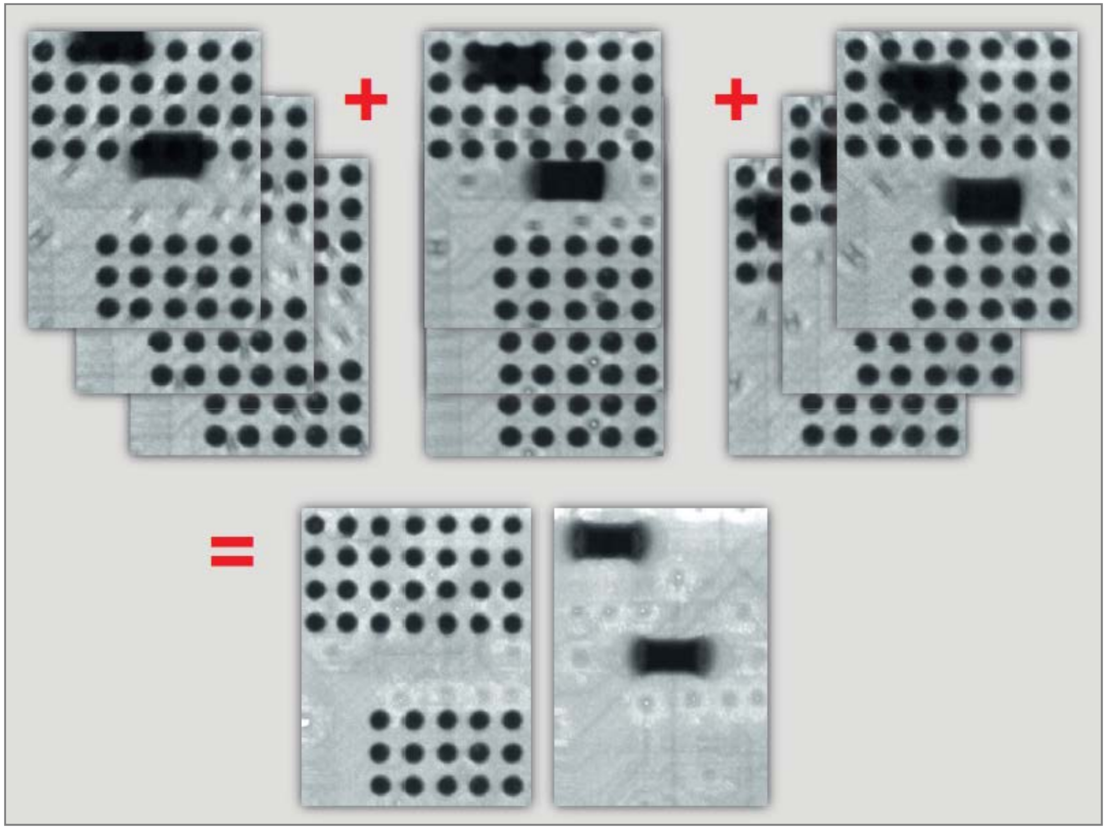




3D X-ray Technology: Opportunities

Algorithmic reconstruction of any layers.

Inspection of double-sided assembled PCBs.



3D X-ray Technology: Pros and Cons

Pros

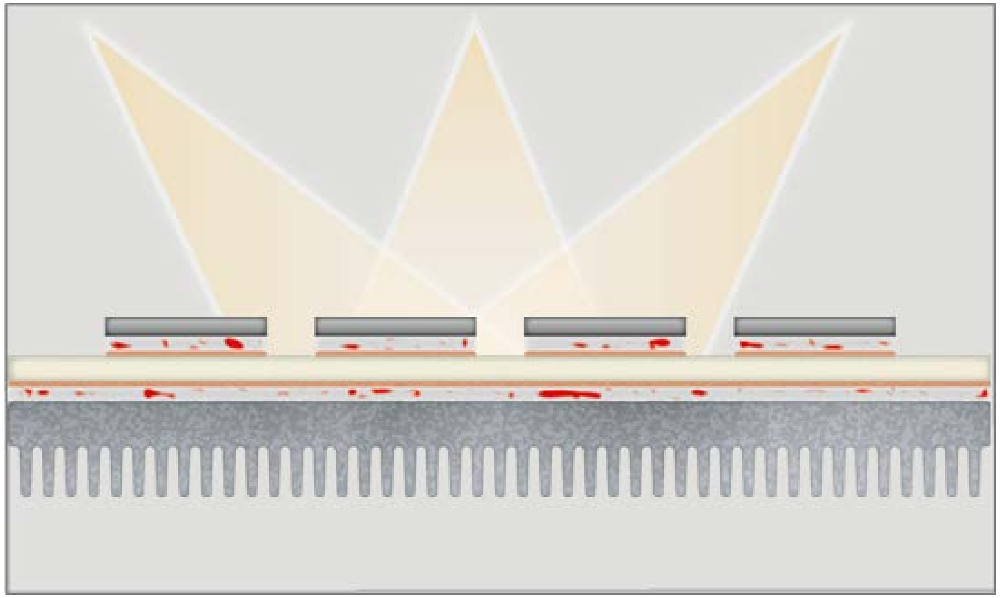
- Safe inspection of overlaid components and solder joints
- Inspection of single layers for improved results
- Reconstruction enables a safe and convenient fault analyses
- Simple test program generation by consistent library

Cons

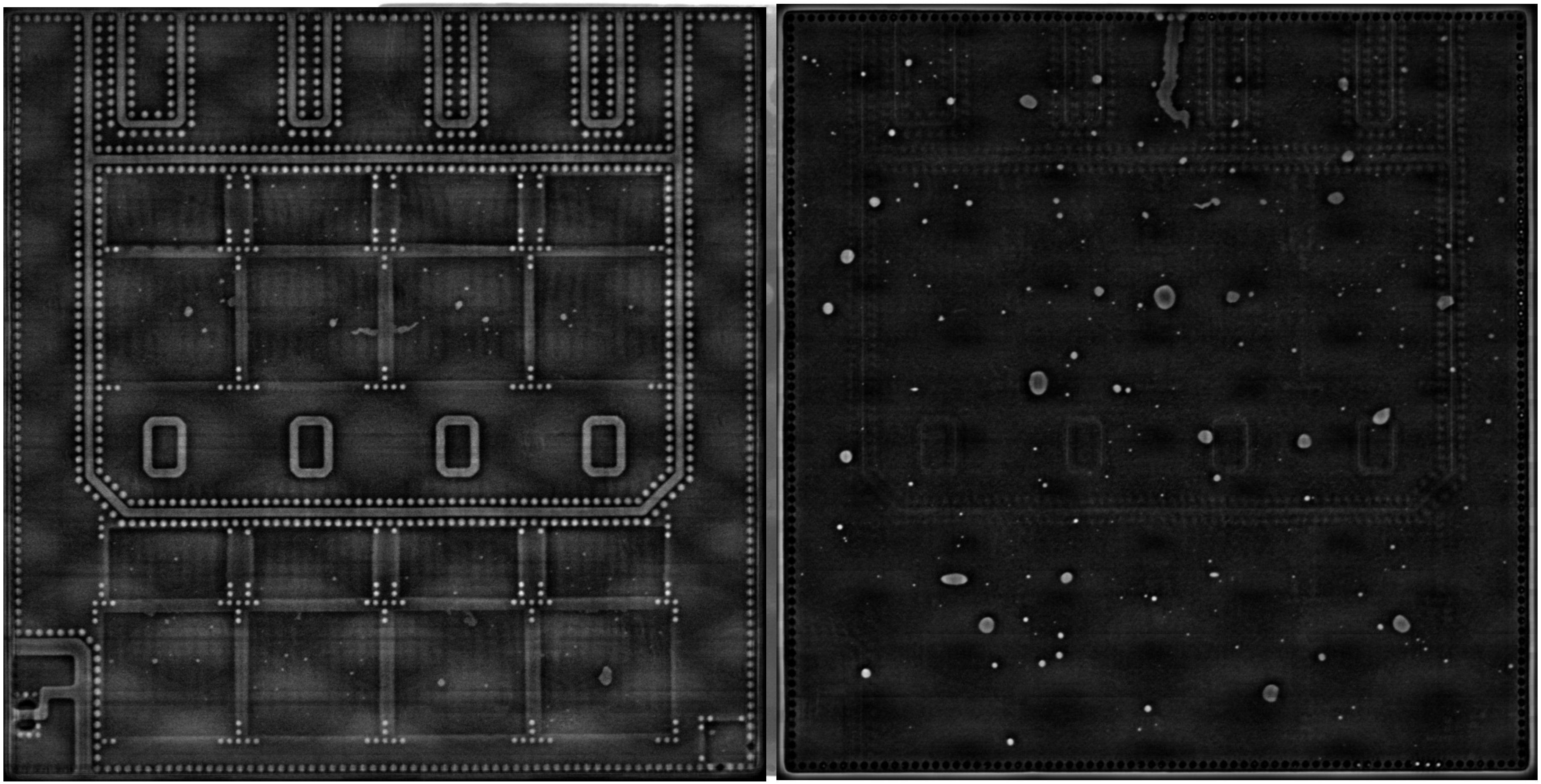
- Higher initial price

3D X-ray technology: IPEMs

- Inspecting the assembled IPEM –through heat-sink and housing
- Separating the area of interest in several vertical layers
- Analysis of voids – number, distribution, dimensions…



3D X-ray Technology with adapted Image Capturing and Reconstruction



14 February 2012
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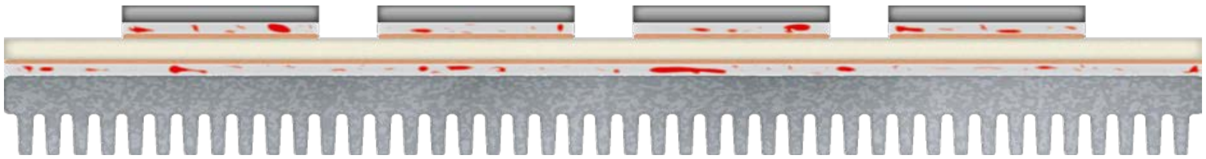
Application example

- PCB size 220mm x 90mm
- Assembling top side: 24 IGBTs, 24 diodes
- Solder joints top side: 48 / ∑ 37cm²
- Assembling bottom side: heat sink
- Solder joints bottom side: 3 / ∑ 108cm²
- Resolution: 11µm / Pixel



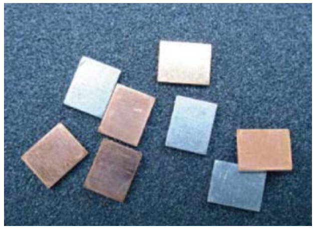
- Cycle time (double-sided inspection): 47s

Experiences and Limitations

Experiences

- Soldering process based on printed solder paste
- Heat sink made of AlSiC (Aluminium Silicon Carbide)
- High inspection quality and measurement accuracy possible

Limitations / Challenges



- Heat sink made of copper or stainless steel
- Soldering process effects very thin voids (reduced detectability)
- System modification (x-ray tube, intensifier) is needed

Summary

- Inspection of integrated power electronics = sophisticated test task
- X-ray inspection based on 2D / 2.5D principles not utilisable
- Full 3D inspection with adapted image capturing and reconstruction is necessary for test task