Evolution and Future of Embedding Technology

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Outline

- Past
- Presence
- Future

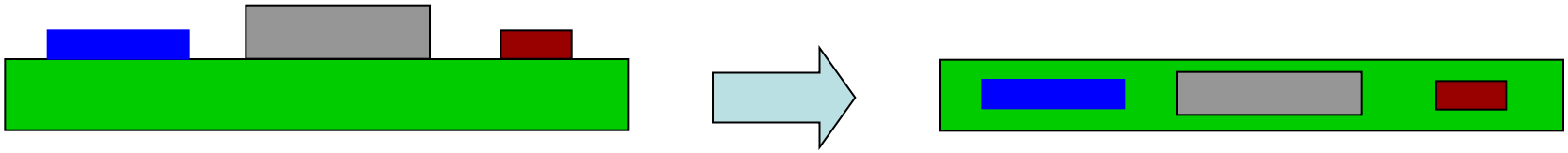
. . . of Embedded Device Technology

Past

Basic Embedding Concept

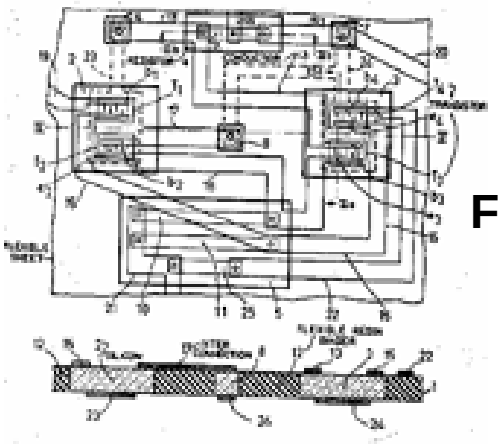
Conventional
- **SMD, Wirebond, Flip Chip**

Embedding



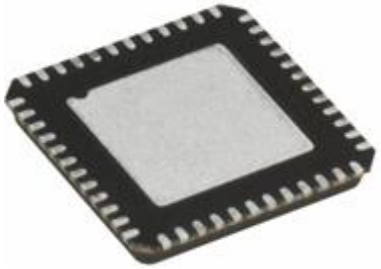
➔ **components are located on the surface of a substrate**

➔ **components are inside a substrate**



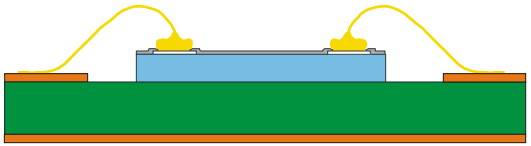
First Patent 1968

Basic Embedding Concept

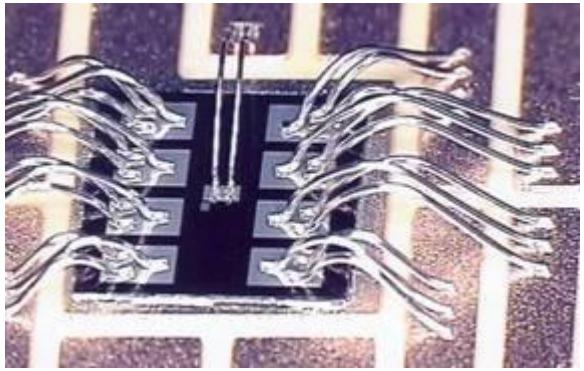


First level chip interconnection technologies inside a package:

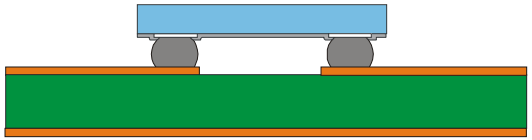
chip & wire



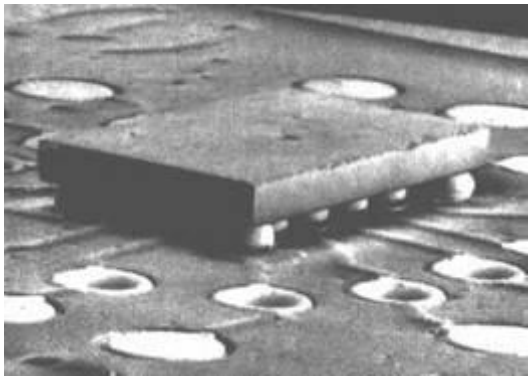
established



flip chip

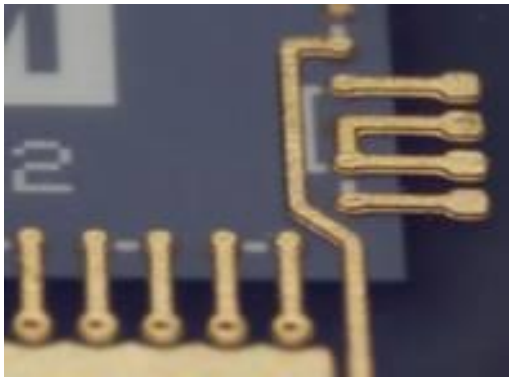


smallest in 2D

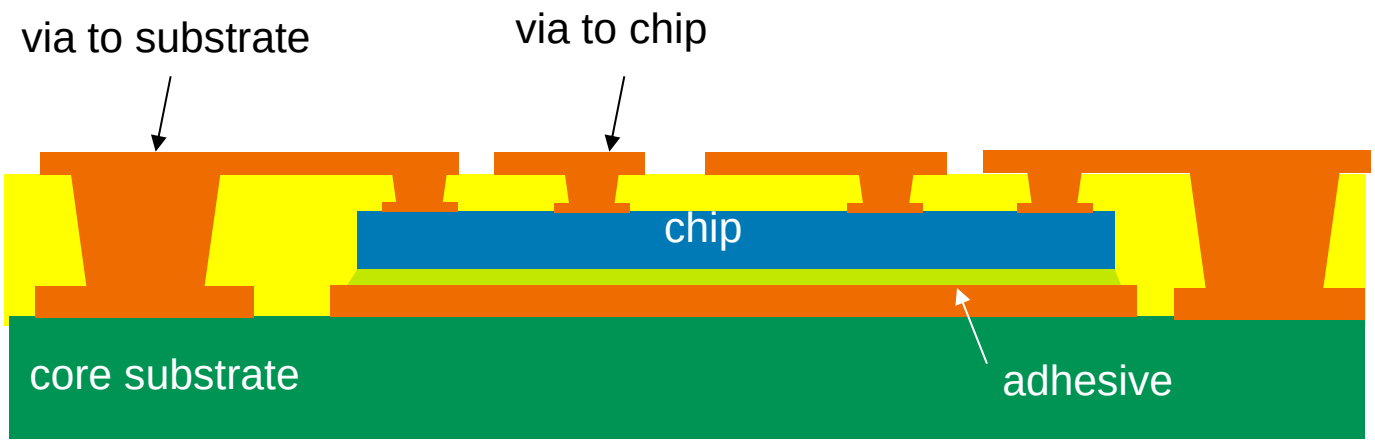


chip embedding

smallest in 3D



Why Embedding Is a Great Idea



Features

- ➔ chip embedded in planar substrate
- ➔ direct Cu contact to chip
- ➔ no wires, no solder bumps
- ➔ very thin package
- ➔ power and logic integration possible

Advantages

- reduced package thickness
- 3D stacking capability
- improved electrical performance
- good thermal performance
- EMI shielding capability

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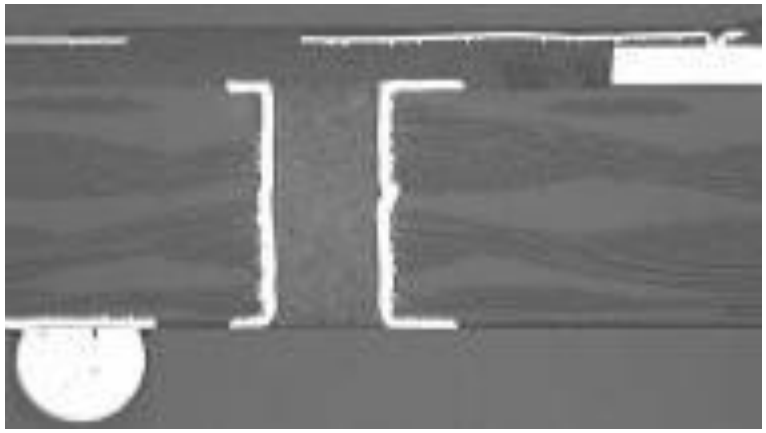
Why Embedding Will Never Work

- Si and PCB have different CTEs
- this will not be reliable
- no repair is possible
- PCB yield is too low
- PCB manufacturers can never handle chips
- this does not fit to existing value chain

Early Approaches for Chip Embedding

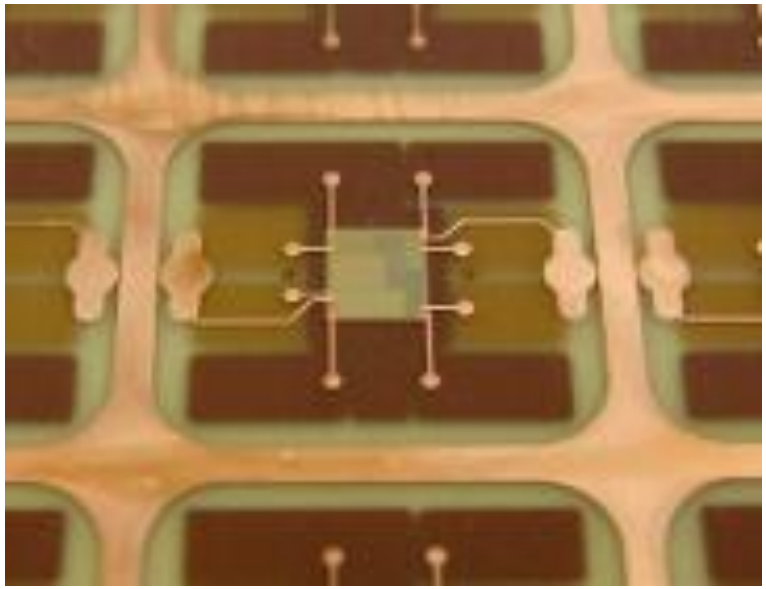
Organisations (before 2000)

- General Electrics
- Hofmann Leiterplatten
- TU Helsinki
- Fraunhofer IZM / TU Berlin



R&D Projects (selection)

- Chip in Polymer (DE)
- HIDING DIES (EU)
- TIPS (EU)
- HERMES (EU)



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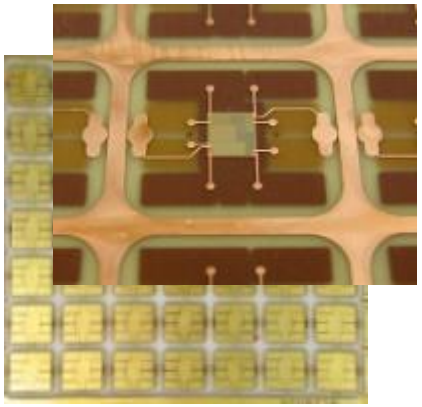
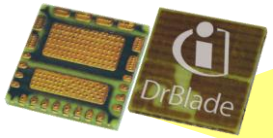
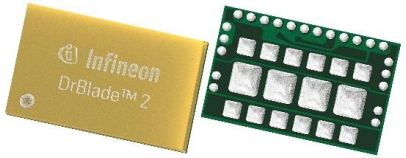
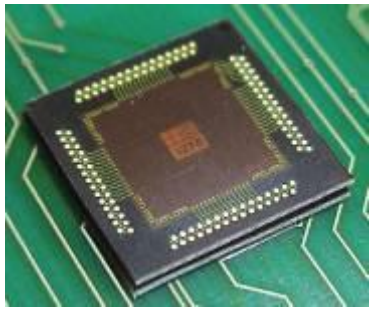
Embedding –Technology Evolution

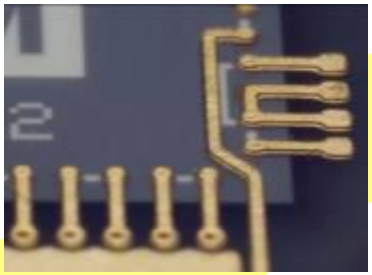
Chip Embedding in organic substrates
➔ use of PCB technology & material

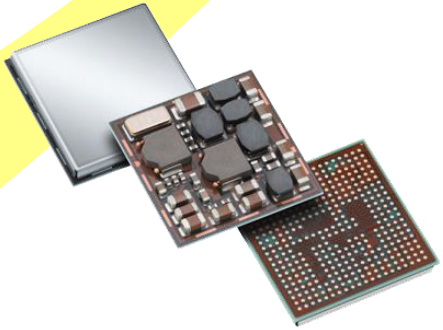


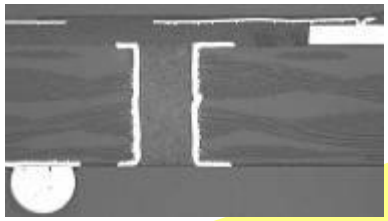


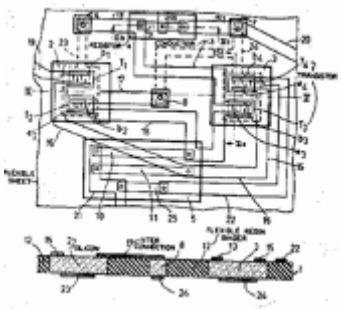












First Patent **Basic R&D** **Production Demos** **Production**

1968 **2000** **2005** **2015**

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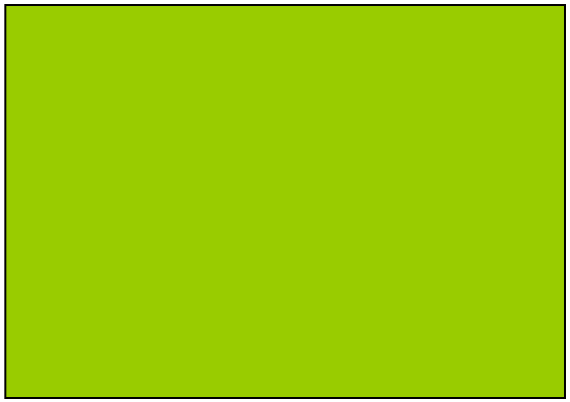
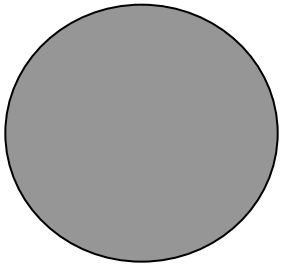
Presence

Embedding Technologies – Status Today

Embedding in PCB



Fan-out Wafer Level Package



Embedding of bare dies

Embedding of soldered SMDs

-Embedding by molding
-Thin film RDL layers

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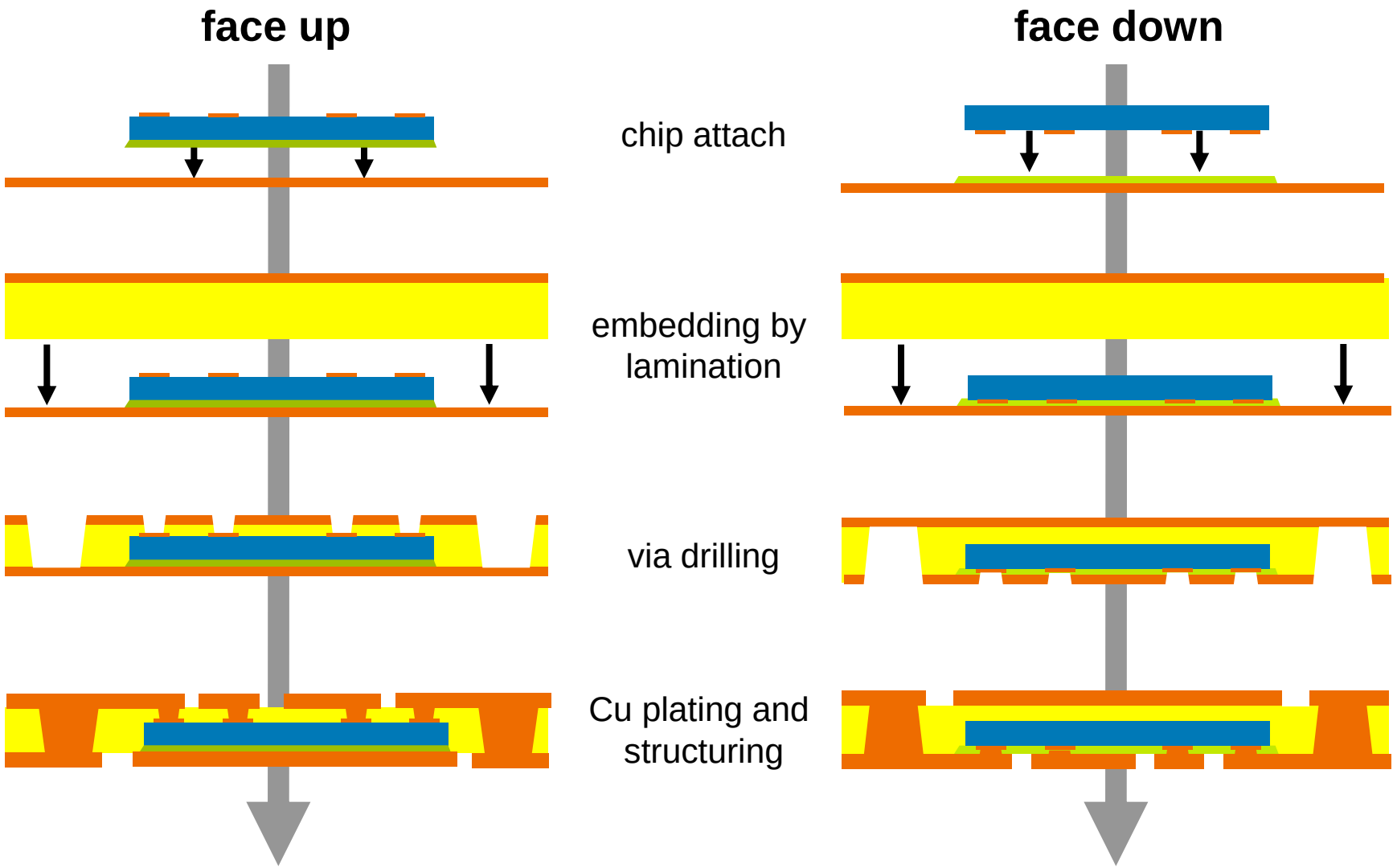
Processes – Embedding Bare Dies



➔ **electrical and thermal backside contact**

➔ **better fine pitch capability**

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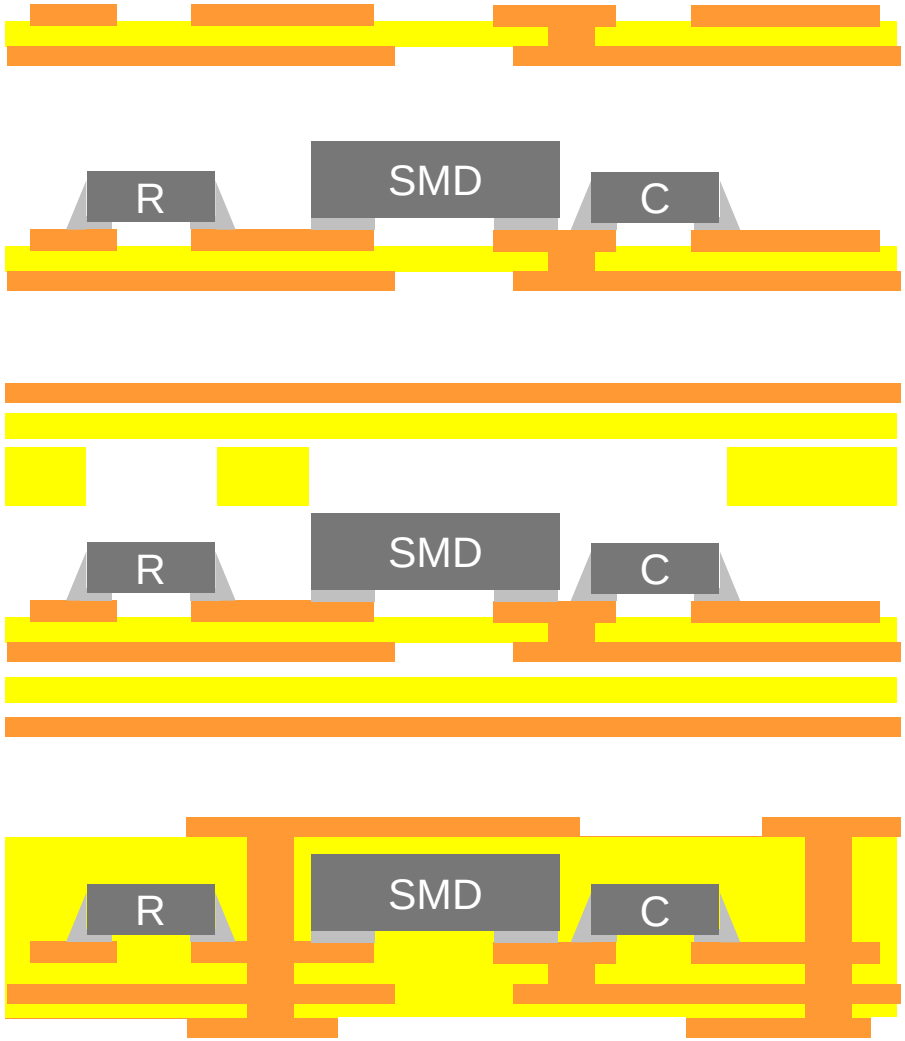
Processes – Embedding Packaged Components



PCB core

lead-free soldering of
SMD components

embedding into prepreg layers
using vacuum lamination

drilling of through-vias, electroplating
of Cu, outer layer structuring

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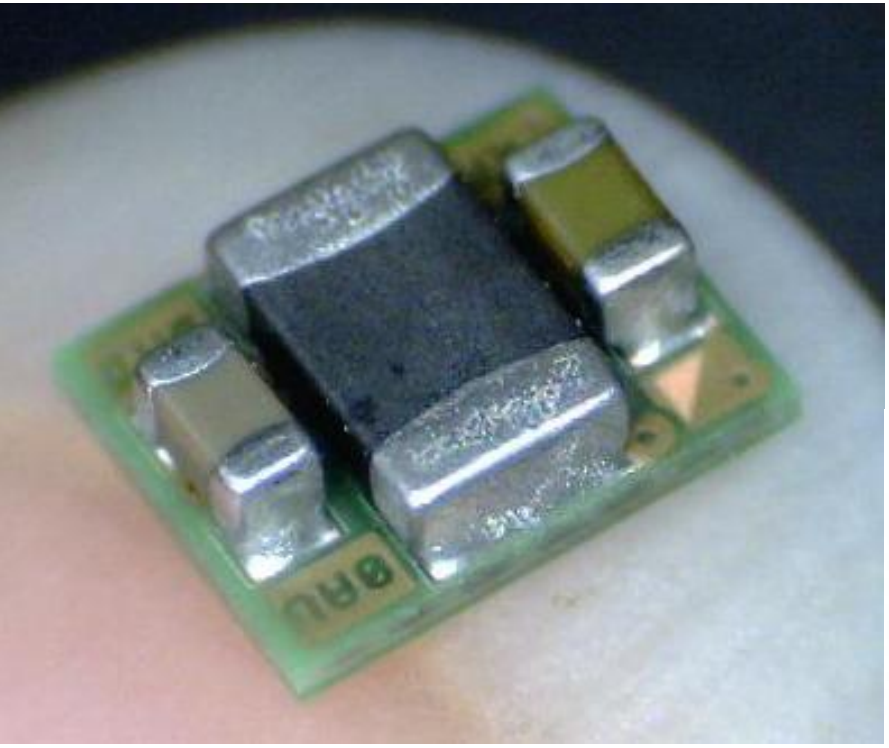
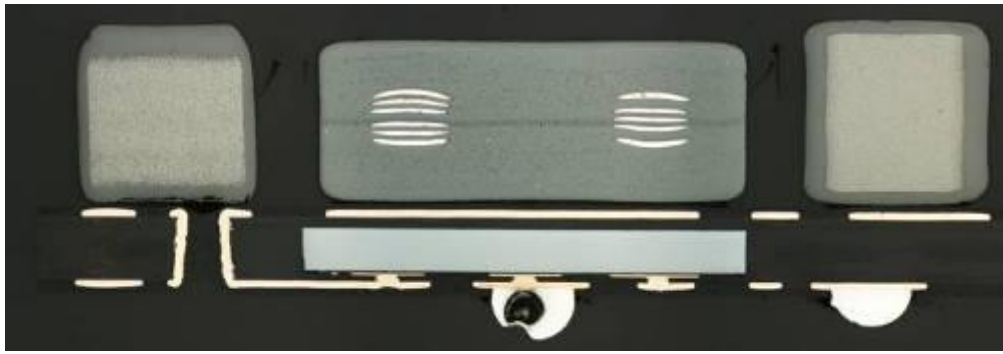
Production – AT&S

MicroSIP Technology - TPS82671, TPS82675
➔ embedded chips in SIP substrates

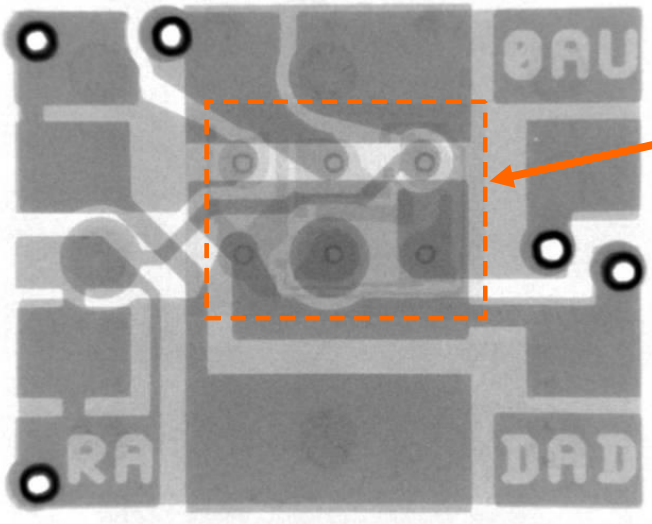
➔ product available since 2010
➔ **manufacturing by AT&S**



600-mA, MicroSi STEP-DOWN CONVERTER)



cross-section of package



embedded chip

x-ray image after solder and SMD component removal

&S/GaN Systems

Production – AT&S

source: AT&S/GaN Systems

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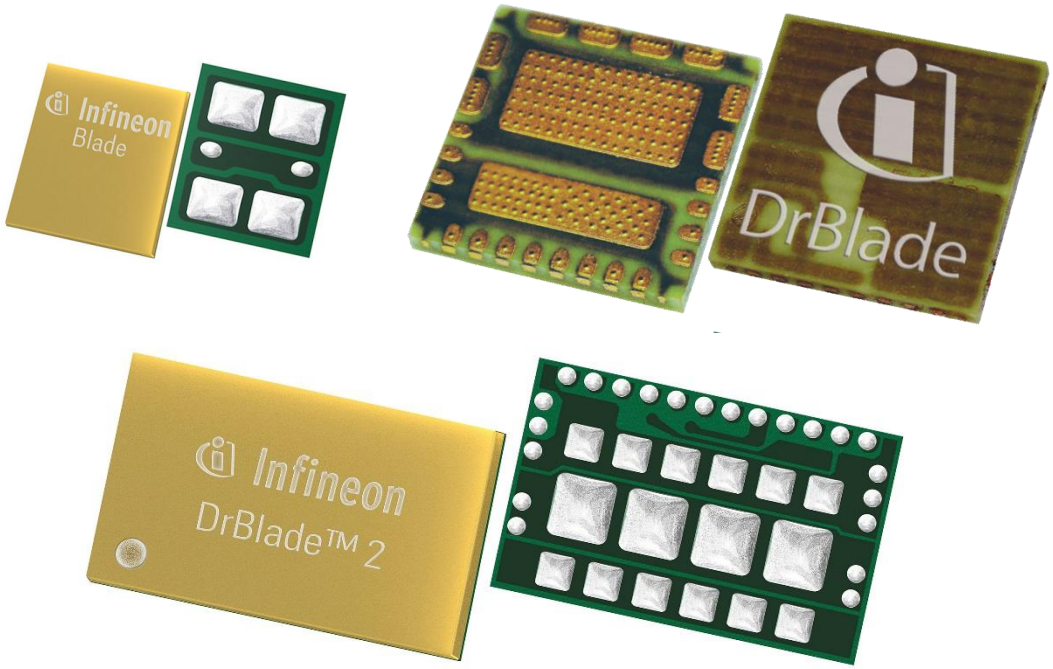
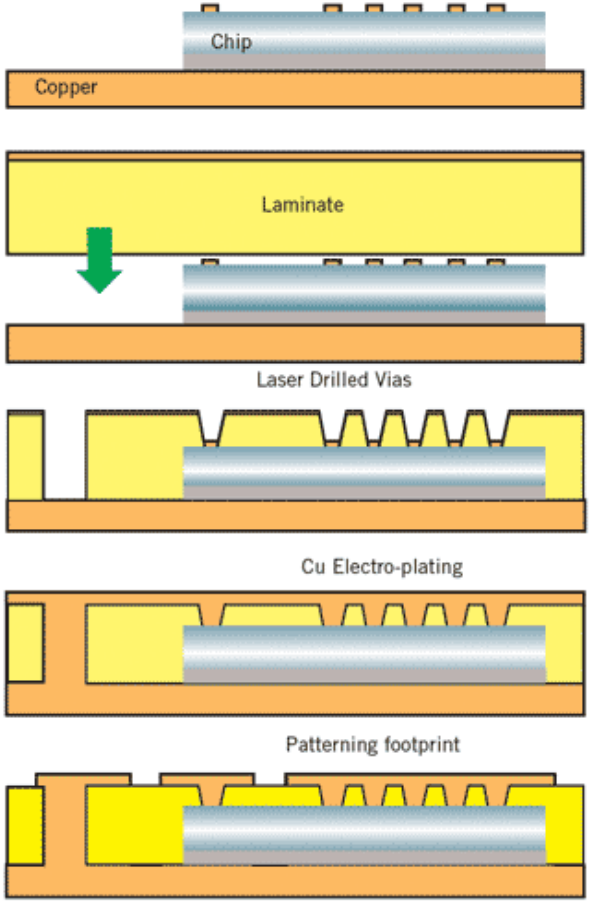
Production - Infineon

BLADE Packages

- ➔ embedded MOSFET / Driver
- ➔ manufacturing on PCB format





Licensing and process transfer from Fraunhofer IZM

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Production – Current Status

- AT&S - several products in volume
- Infineon - Blade Packages
- TDK&EPCOS - SESUB Technology
- ASE - a-EASI Technology Packaging Service
- Würth Electronics - different technologies in series
- Hofmann Leiterplatten - small volume and prototypes

- Schweizer Electrónics - Ready for volume production

R&D - Fraunhofer IZM Substrate Integration Line

Placement → **Accuracy** → **Lamination** → **Laser Drilling**

Datacon evo/
ASM Siplace CA3

Mahr OMS 600/
IMPEX proX3

Lauffer/
Bürkle

Siemens Microbeam/
Schmoll Picodrill with
HYPER RAPID 50

→ **Mech. Drilling** → **Cu Plating** → **Imaging** → **Etching**

Schmoll MX1

Ramgraber automatic
plating line

Orbotech
Paragon Ultra 200

Schmid

TU berlin

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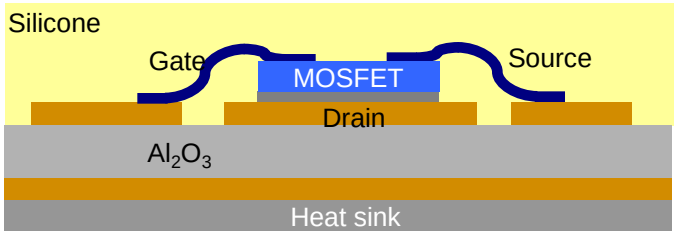
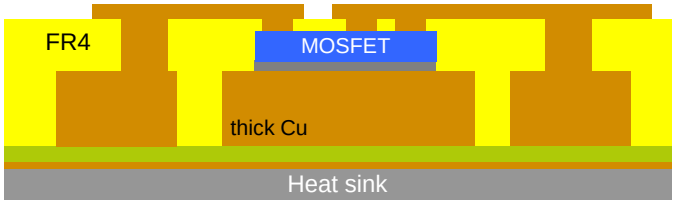
R&D - Embedded Power Modules

traditional power module



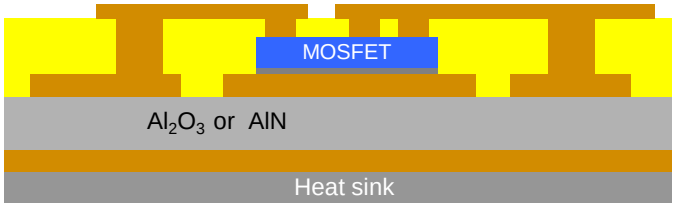
embedding on PCB substrate



- production panel 610x456 mm² (18”x24”)
- isolation and thermal conduction by high-λ laminate

➔ module with low to medium power density

embedding on ceramic substrate



- production panel 125x175 mm² (5”x7”)
- isolation and thermal conduction by Al_2O_3 or AlN DCB

➔ modules with high power density

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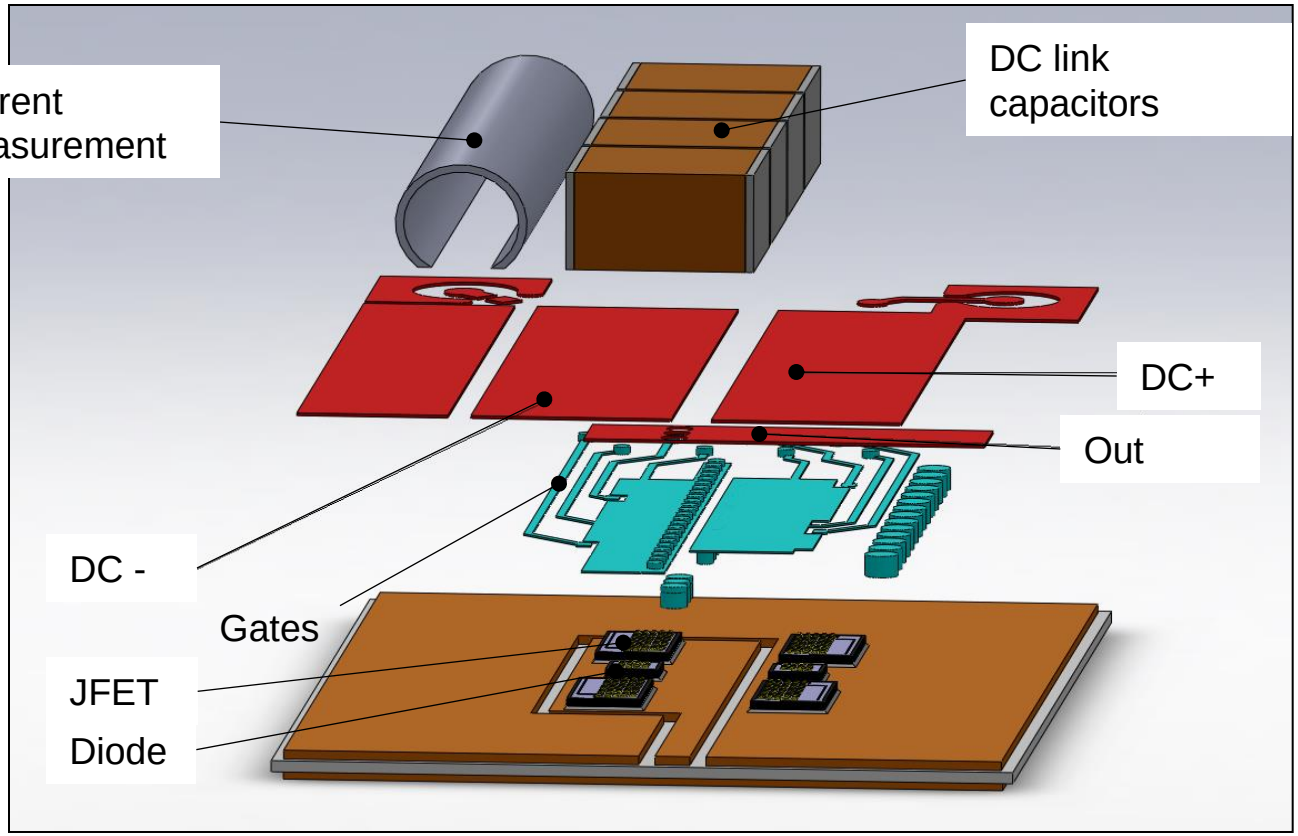
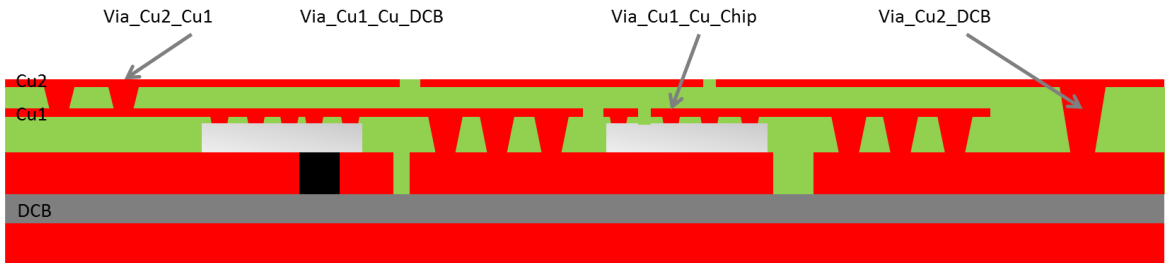
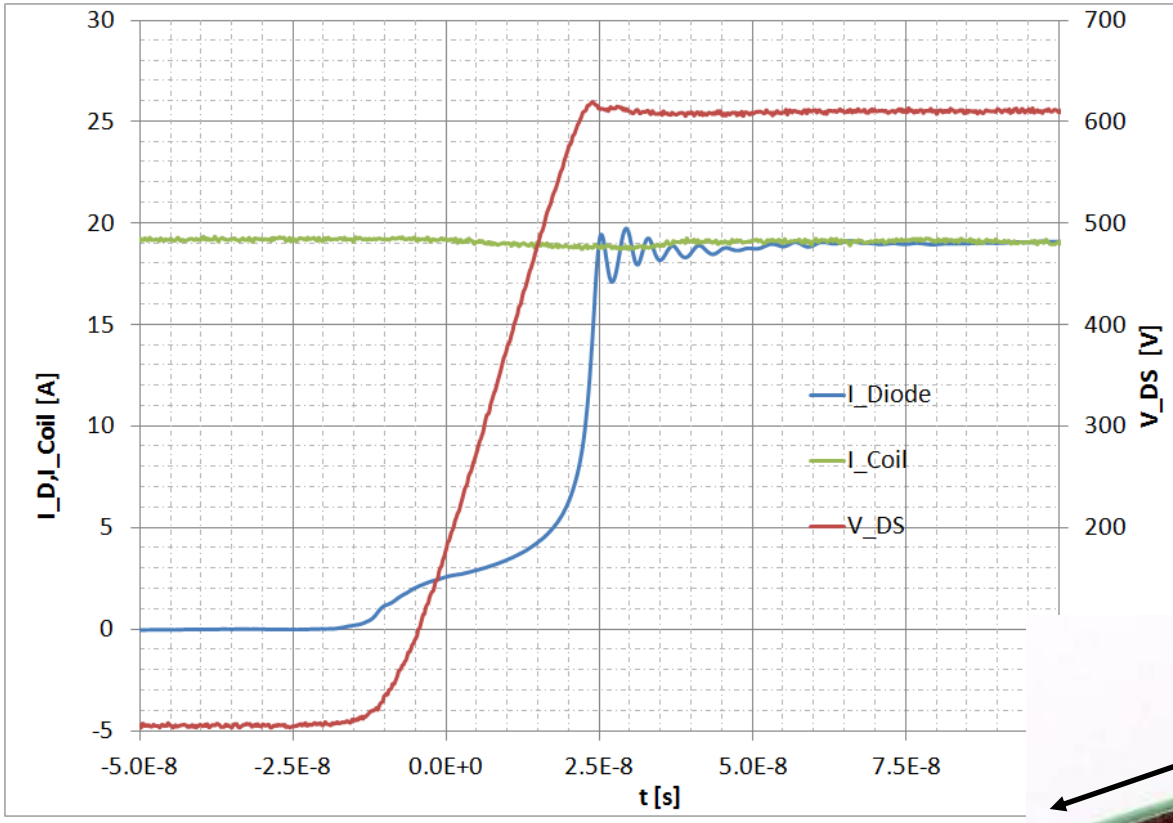
R&D - Ultra Low Inductance Package for SiC



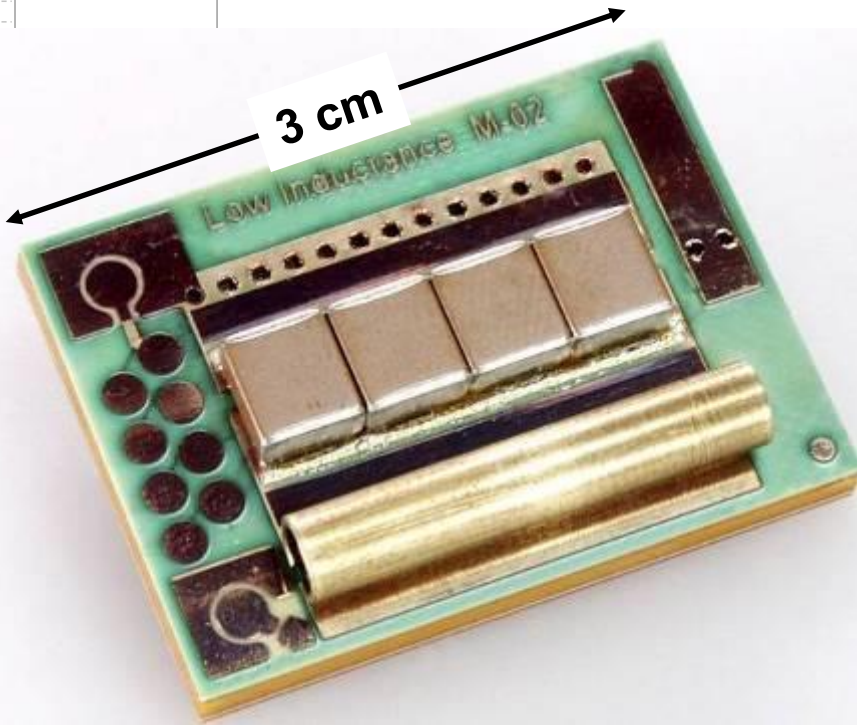


- Full bus bar structure using PCB Process on a DBC
- DC capacitors on the module
- DC link current measurement included

R&D - Ultra Low Inductance Package for SiC



- Switch off at 20 A:
  Voltage slope 19 V/ns
  current slope max. 4 A/ns
  (50% to 90%)
- Low overshot (appr. 10 V)
- very little ringing
  (frequency 240 MHz)

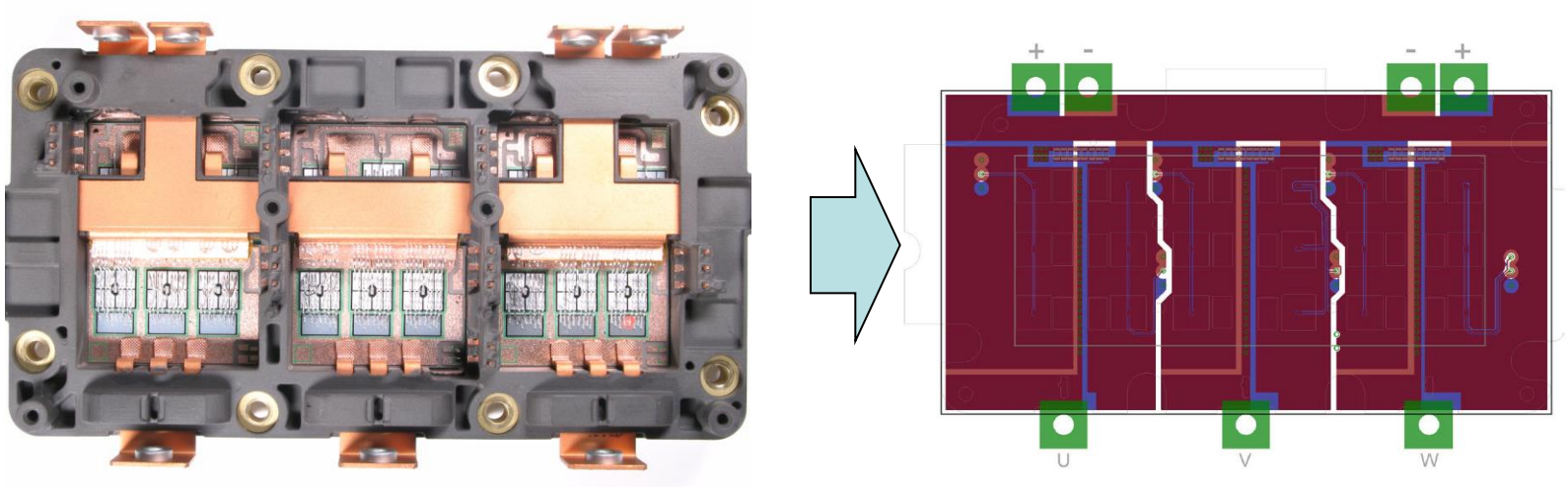


0.8 nH DC-link inductance

(comparison: wirebond 10-20 nH)

R&D - Project HI-LEVEL

Development of planar power modules for 50 kW motor inverter



Features

- Reduction of height by 10 mm
- Cost efficient production without expensive packaging
- Integration of control electronics
- Capability for double-side (water) cooling

Project Partners
The project consortium offers research activities through the whole supply chain:

SCHWEIZER

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Relaiability: AMIC

Components: Infineon

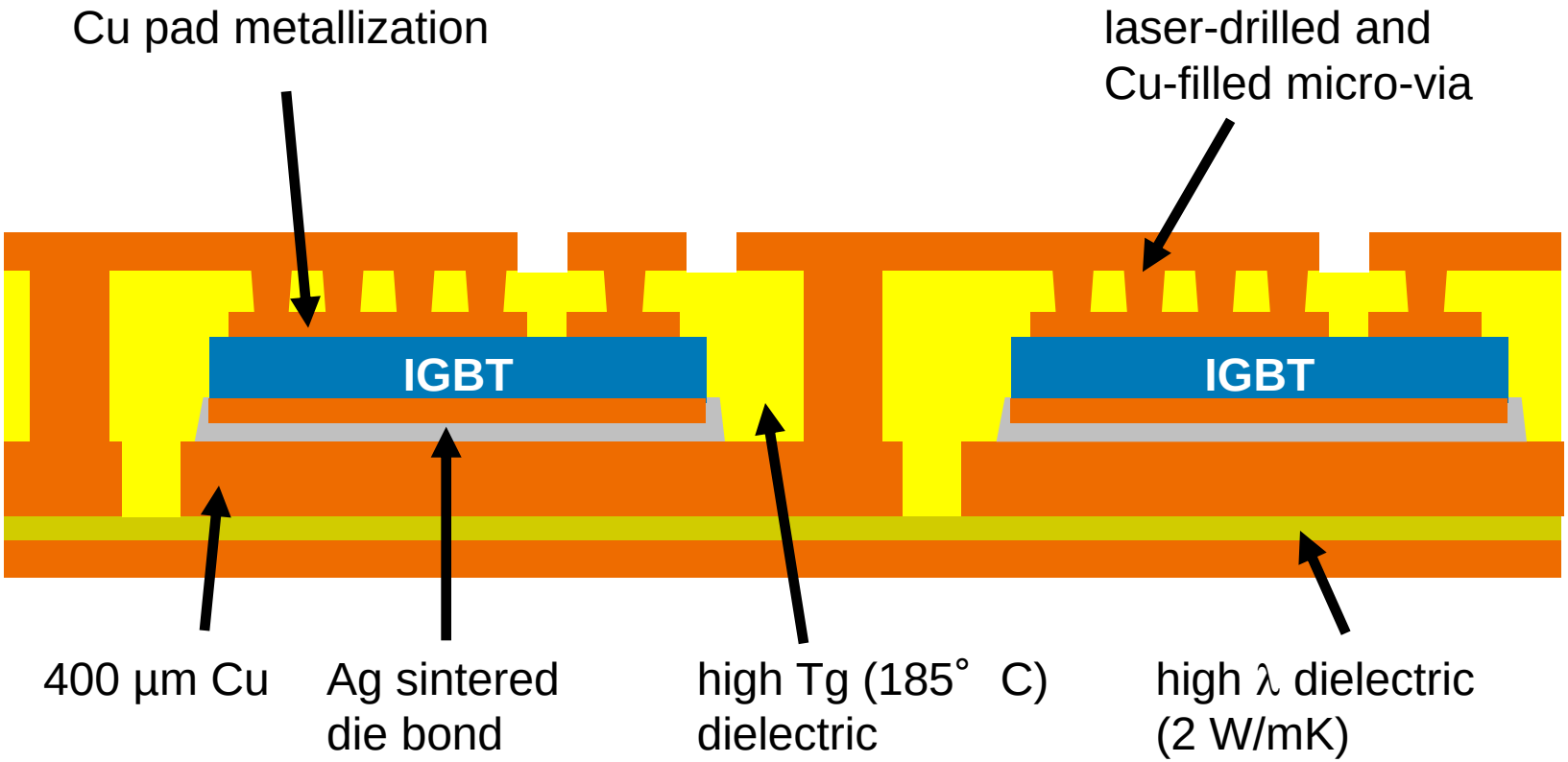
System Design: RWTH AACHEN

Materials: Heraeus

Product: Continental

End-user: DAIMLER

R&D - Project HI-LEVEL



Topics of current investigations

- pressure-less / low-pressure sintering on large panels
- application of 5 µm Cu bumps on thin IGBT wafers
- high voltage isolation of thermally conductive dielectric

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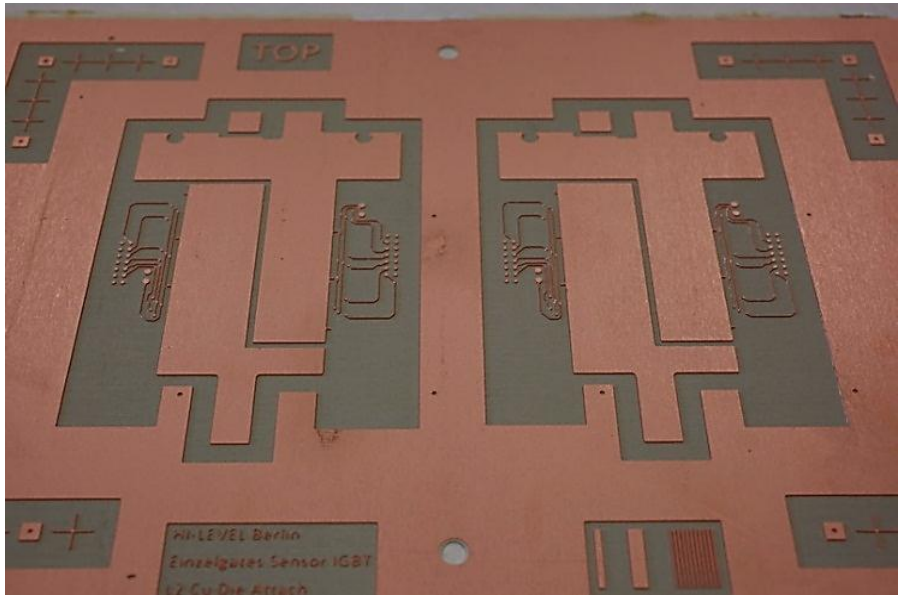
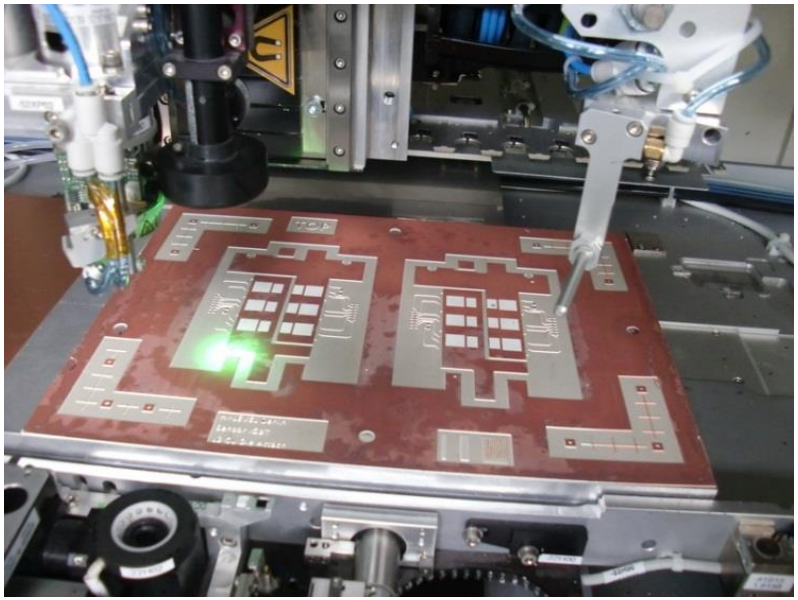
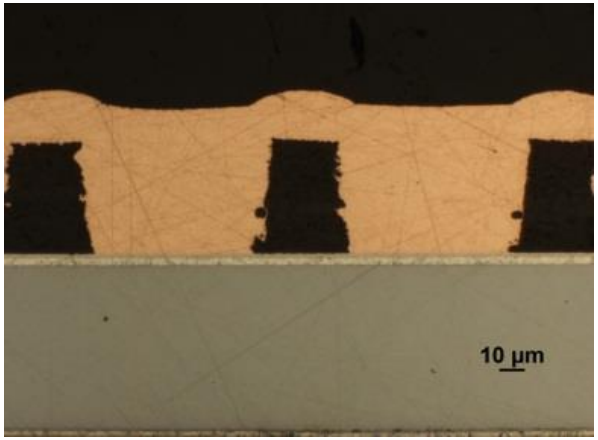
R&D - Project HI-LEVEL



400 µm Cu on thermal laminate substrate.



Die bonding on sinter paste.



Microvias on top of IGBT

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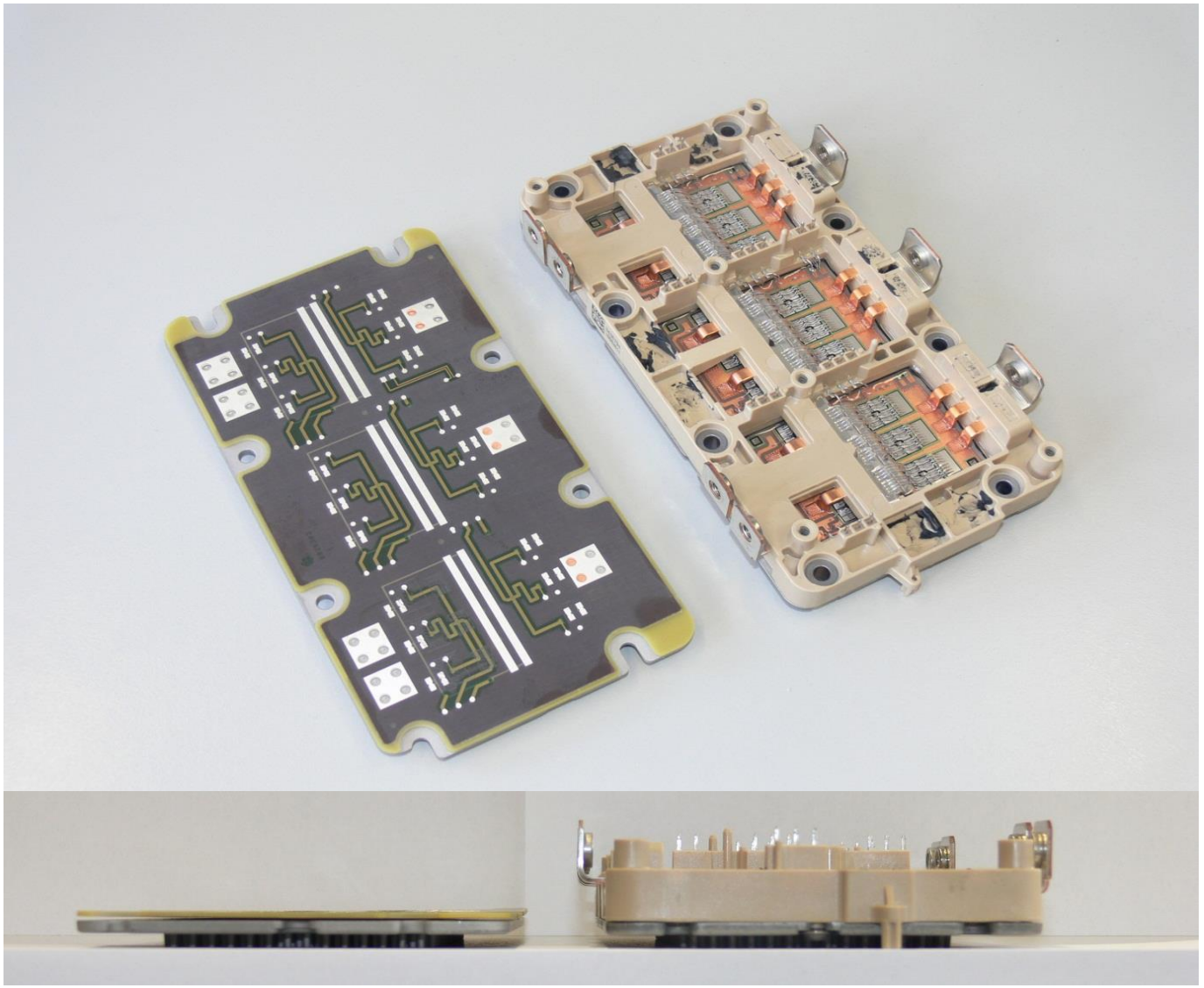
R&D - Project HI-LEVEL



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R&D - Project EmPower

- Embedded power components for electric vehicle applications
- Started in September 2013, duration 3 years
- Project goals:
  - Industrialize double sided copper plating on wafer level
  - Industrialize next generation automotive power modules
- Benefits:
  - High performance power products with embedded MOSFET, IGBT, GaN, etc.
  - Smallest form factor power supplies
- Partners:

AT&S, ILFA Feinstleitertechnik, ATOTECH, Continental, TU berlin, TU WIEN, ST, TU berlin, Fraunhofer IZM

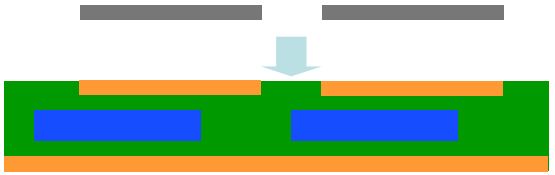
http://catrene-empower.ats.net

R&D - Project EmPower

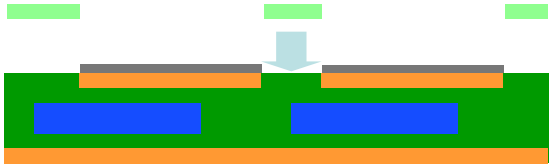
Stacking by combined sinter/lamination ➔ Process Flow

- Stacking of Functional Layers by combined sinter/lamination technology

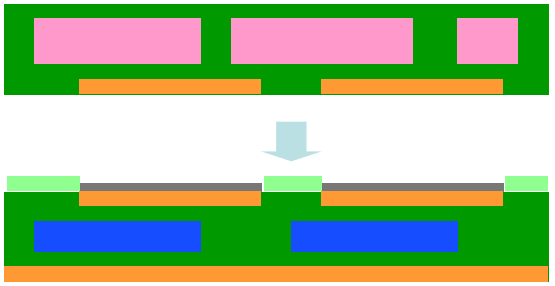
1. stencil printing of Ag sinter paste on Functional Layer, paste drying



2. lay-up of prepreg sheet with opening for paste locations



3. lay-up of 2. Functional Layer on top, vacuum lamination at 3 MPa, 10 min./230 °C, 60 min./200 °C



Result: a monolithic stack, thermally and electrically interconnected by high-reliable Ag joints, all gaps are filled by an isolating dielectric

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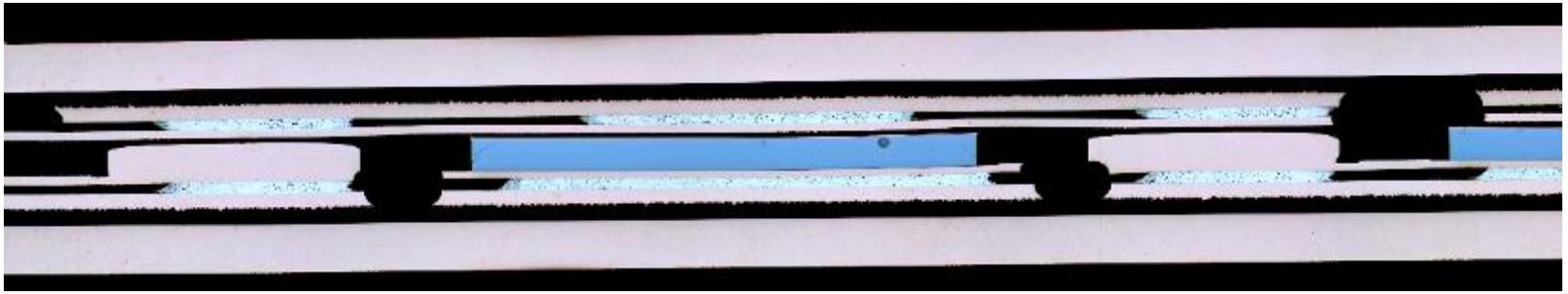
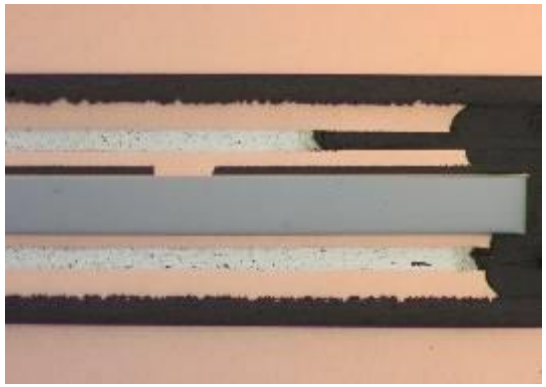
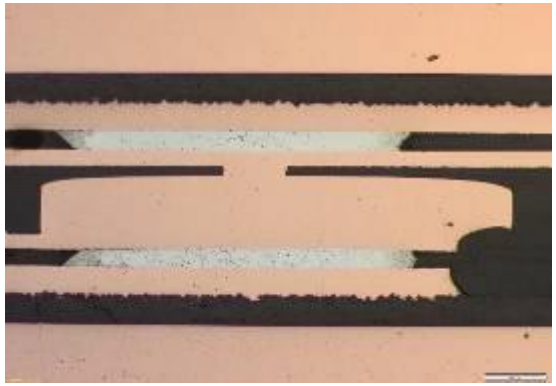
R&D - Project EmPower



cross section of IMS/power core/IMS sinter interconnects



sinter connection die area



sinter connection copper inlay area

➔ **no large voids in Ag sinter interconnects**

Fraunhofer IZM

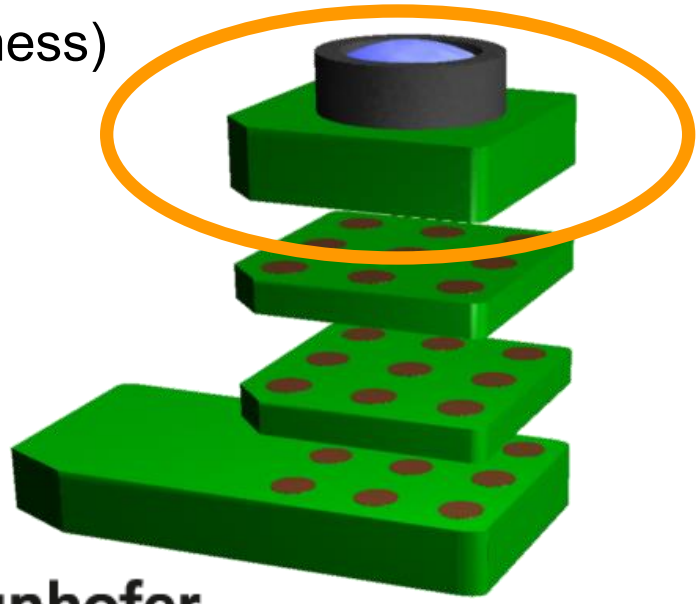
R&D - Project MoMiCa

Motivation: to demonstrate the realization of a complex module using Panel Level Packaging with embedded components

Demonstrator: a stand-alone Modular Micro Camera (MoMiCa) with integrated real-time image processing

Technology: SMD component embedding on PCB panel format

Components: commercially available components in small packages (≤ 1 mm thickness)



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R&D - Project MoMiCa

System component selection

- CV2201 image cognition processor from CogniVue
  - 32 bit ARM9 processor core. 350 MHz
  - 96 parallel Computational Units
  - 16 MByte stacked DDR SDRAM
  - 15 – 30 frames per second rwal time image processing
- 3 MPixel CMOS image sensor from Omnivision, CSP wizh solder balls
- 16 MByte flash memory for firmware storage
- USB 2.0 module interface

Software (module firmware)

- Nucleus 32 bit RTOS (real time operation system) from Mentor

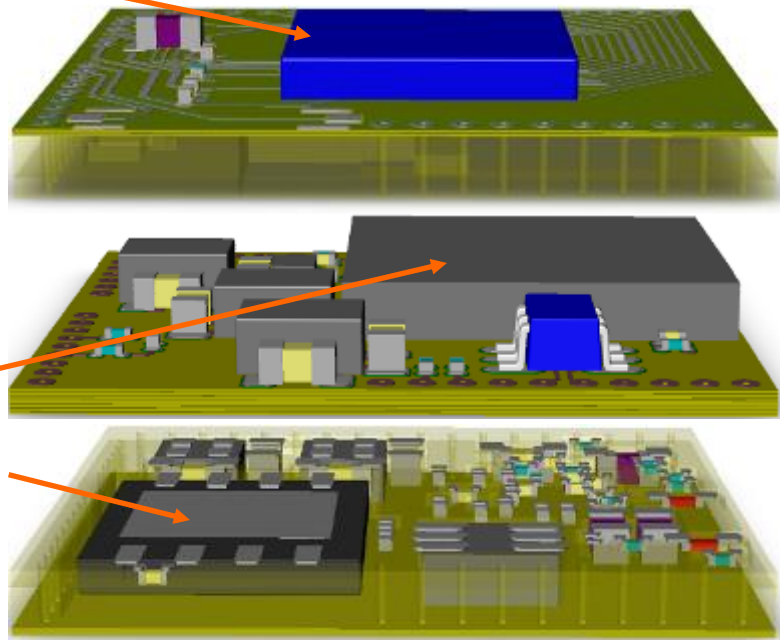
R&D - Project MoMiCa

13 Components on top

- 3 MPixel Image Sensor Omnivision 3642
- lens CMT746 + lens holder
- 7 capacitors (0201)
- 1 resistor (0201)
- 1 inductor (0603)
- 1 microswitch

74 Embedded Components

- 32 bit microcontroller with image sensor interface (CogniVue CV2201 BGA 236)
- 256 Mbit Flash Memory (Macronix 8WSON
- MOSFET switch (IRF SOIC)
- USB ESD protection (NXP SOT457)
- 5 DC/DC-converters (Murata)
- oscillator 24 MHz (NXP
- 2 LEDs (0402)
- 34 capacitors (0201, 0603)
- 25 resistors (0201)
- 3 inductors (0603)



➔ 13 active components from 8 different manufacturers

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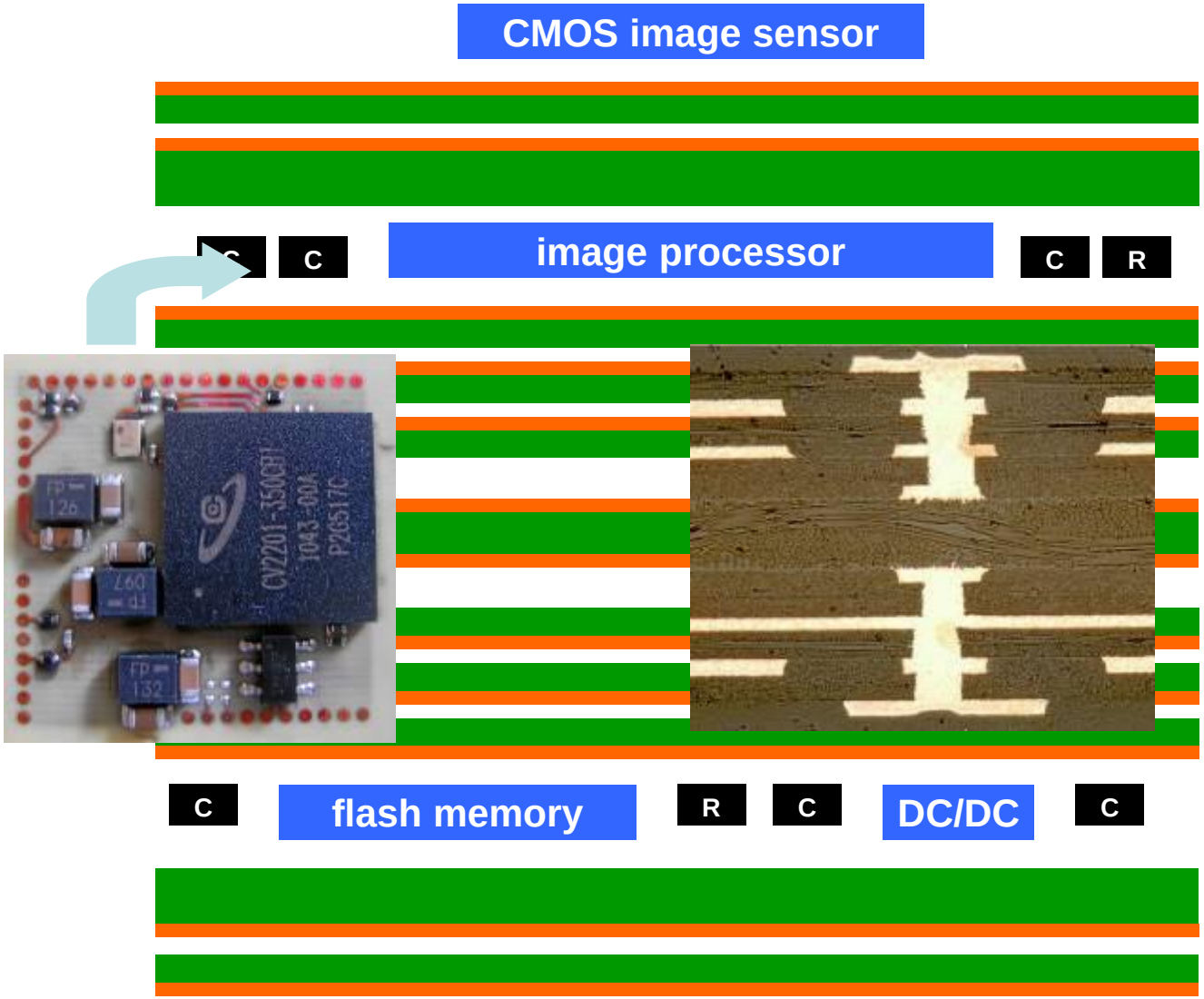
R&D - Project MoMiCa



components

outer layer (top)

embedding layer

components

3 build-up layers

2 layer core

3 build-up layers

components

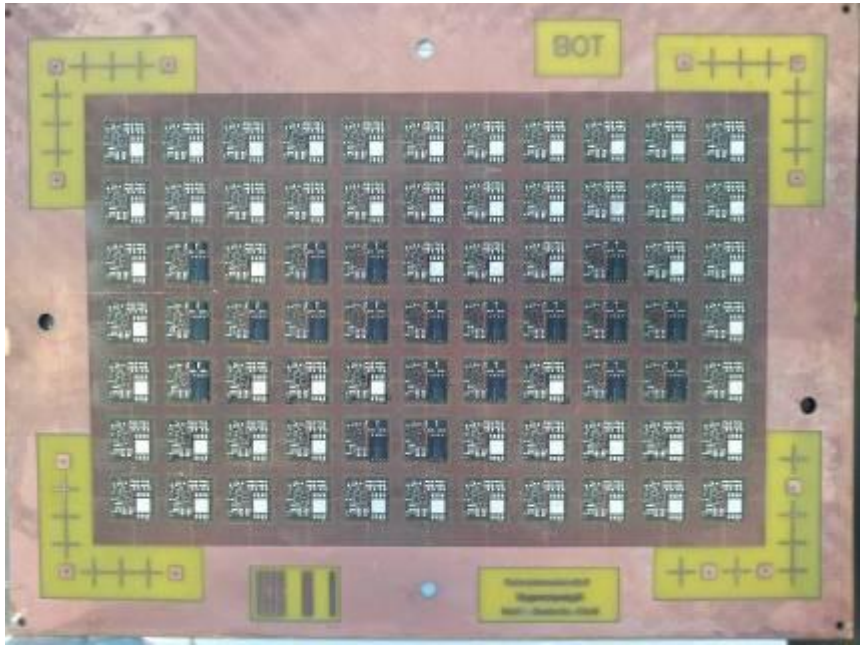
embedding layer

outer layer (interface)

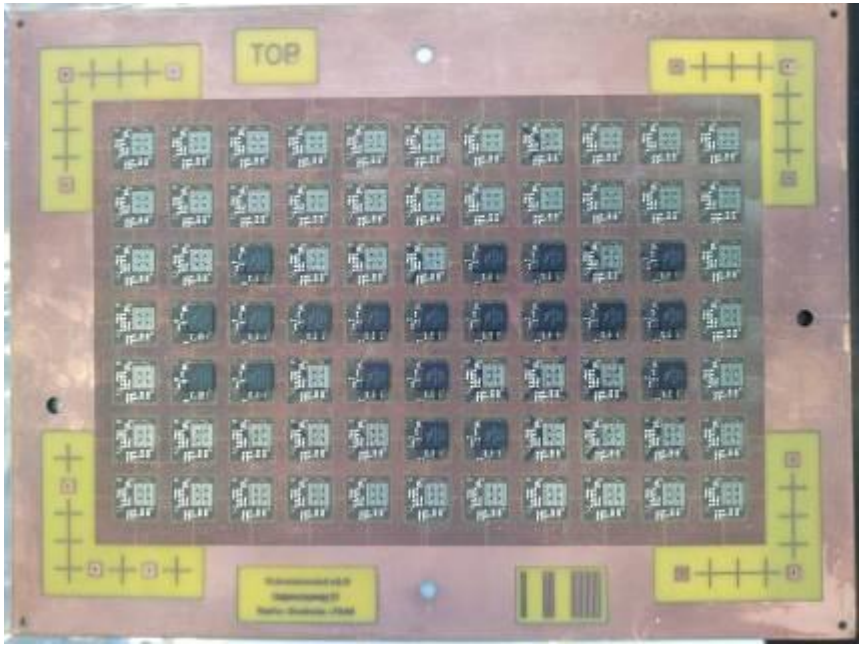
Fraunhofer IZM

R&D - Project MoMiCa

- manufacturing on quarter format (12" x 9")
- 77 modules per panel (only partially with components)
- double-side component assembly on PCB core
- embedding by prepreg lamination
- assembly of image sensor on top
- testing on panel-level



assembled components on bottom PCB core



assembled components on top PCB core

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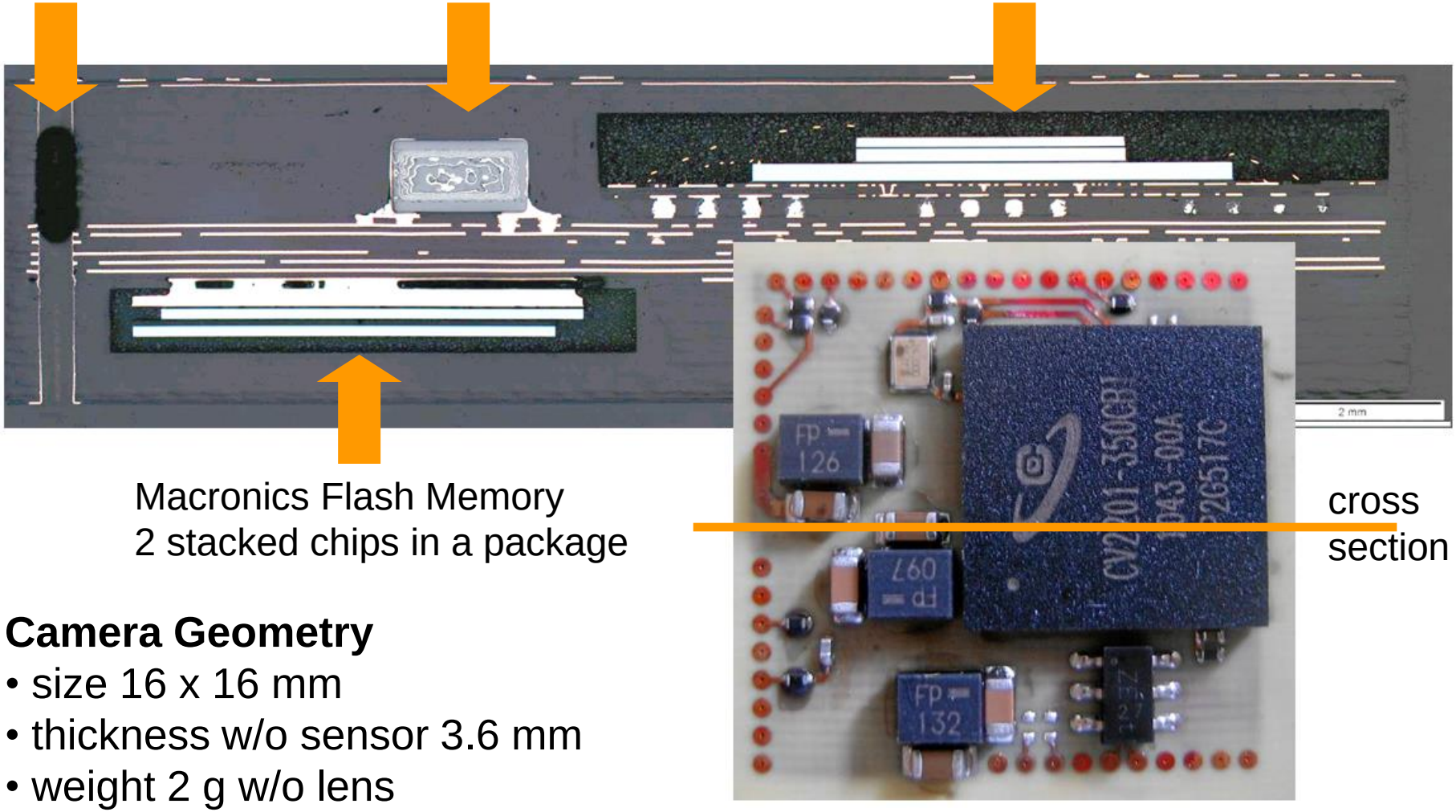
R&D - Project MoMiCa

through hole

capacitor

CogniVue Image Procesor
3 stacked chips in a package



Macronics Flash Memory
2 stacked chips in a package

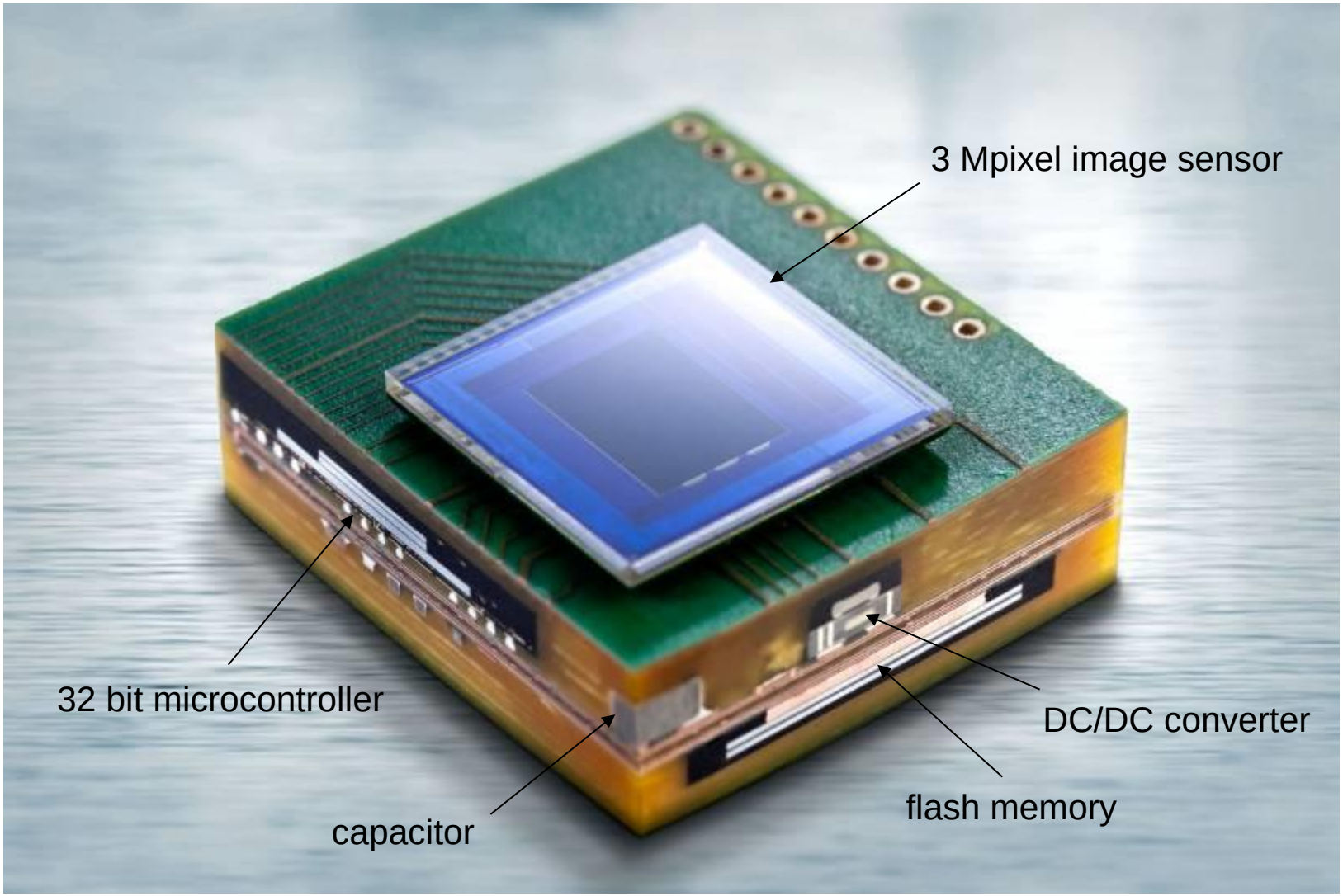
cross section

Camera Geometry

- size 16 x 16 mm
- thickness w/o sensor 3.6 mm
- weight 2 g w/o lens

Fraunhofer IZM

R&D - Project MoMiCa



Modular camera with integrated 32 bit image processor and memory

berlin

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Future

Electronic System - Quo Vadis?

board from Zuse Z23 computer, 1963

SMD board with 01005 components, early 21. century

1950 2000 2050

Electronic System - Quo Vadis?

board from Zuse Z23 computer, 1963

SMD board with 01005 components, early 21. century

Modular Electronics ?

1950 2000 2050

berlin

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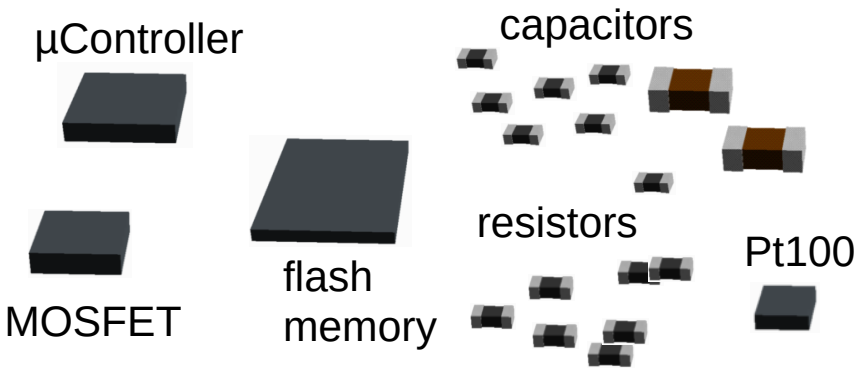
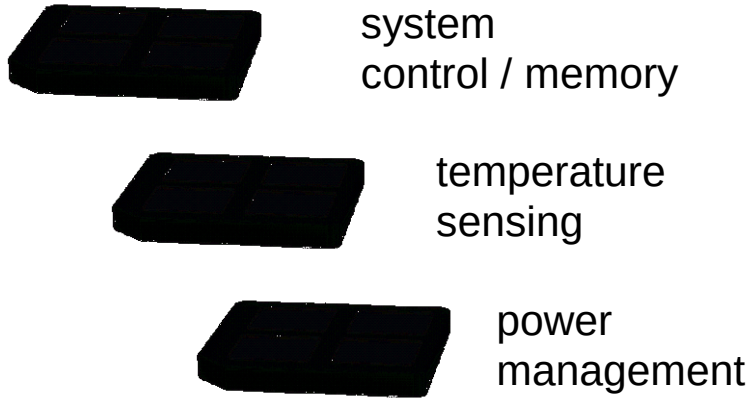
Modular Microelectronics – Concept

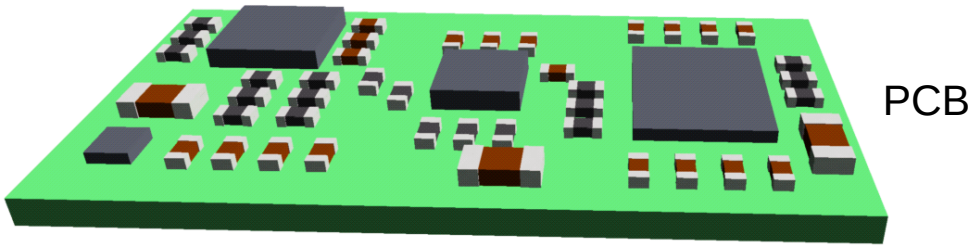
Traditional electronic system

Vision

Modular System







components on a PCB

stacked modules

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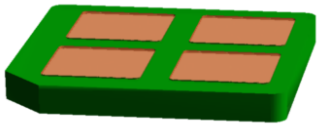
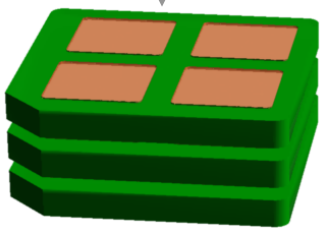
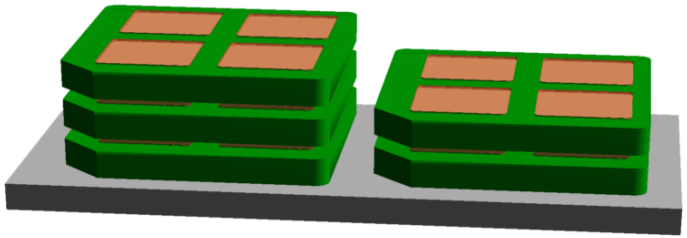
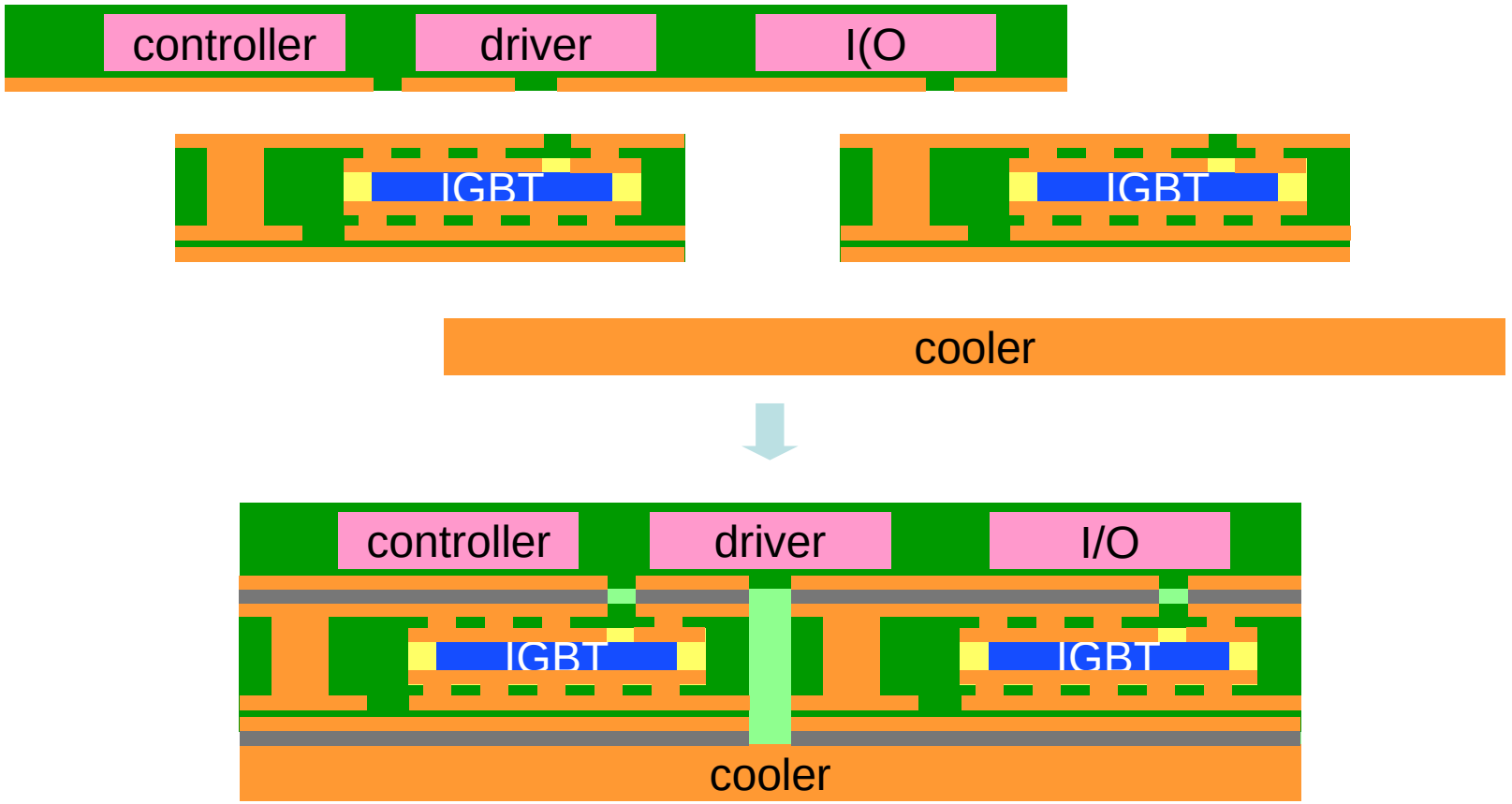
Modular Microelectronics – From Chip to System

Software	Hardware	Level	Manufacturing
		component	• Semiconductor Manufacturer
Bootloader (Firmware)		module	• Packaging House • PCB Manufacturer
Application Program (Runtime)		sub-system	• Packaging House • OEM
		system	• OEM

Modular Power Electronics

What is a Modular 3D Power Stack?

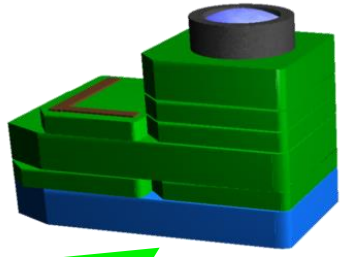
- Stacking of Functional Layers by combined sinter/lamination technology



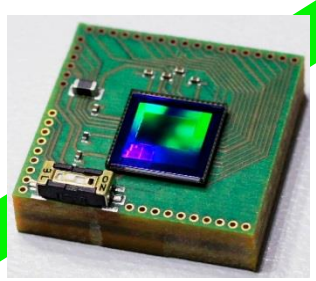
Fraunhofer IZM

Outlook

- Embedding technology opens a way over small and robust SiPs towards Modular Microelectronics
- Modular Microelectronics offer much shorter design cycle times
- It can simplify the realisation of complex systems by use of tested functions



Modular System Architecture

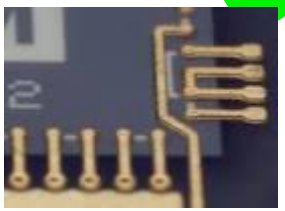


Modular System Software

Modular System

Module Stacking

Embedded SiP



Embedding Technology

The Vision:
System construction as easy as Lego

Fraunhofer IZM

Thanks for Your Attention