WÜRTH ELEKTRONIK

Advances in Embedded Componentry

Where did we come from and where do we go – An overview about the possibilities of reducing the needed space of the passive components and go even further

Introduction of the Presenter

PSMA APEC

Frank Puhane

Leader Technical Engineering
eiCap / eiRis – Capacitors & Resistors Divison

+49 7942945 4033

frank.puhane@we-online.com

www.we-online.com

Background:

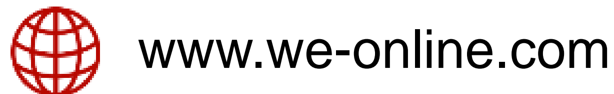
- More than 10 years of work experience in electronics industry
- Background in Electronics, Power Supply Development and formerly worked as Field Application Engineer
- In charge for technical engineering, product services and application support of capacitor division at Würth Elektronik

Introduction of the Presenter

Jürgen Wolf

Dipl.-Ing. Microsystem Technology

Head of Advanced Solution Center
Circuit Board Technology



Background:

- Responsible for the technology for embedding of components / functions in the circuit board and for stretchable circuit boards (STRETCH flex)
- Support sales for the embedding technology and new technologies
- Qualification, planning and further development of technologies

PSMA APEC

Advances in Embedded Componentry

The history of the different technology

C: up to 10mF	C: up to 33mF	C: up to 6.8mF	C: up to 560µF	C: up to 100µF
V_R: up to 450V	V_R: up to 450V	V_R: up to 450V	V_R: up to 10V	V_R: up to 3000V
∅: up to 40mm	∅: up to 22mm	∅: up to 16mm	Size: 4.2 x 7.3 [mm]	Size: 0402 to 2220
L: up to 65mm	L: up to 51mm	L: up to 17mm	Height: 1.9 [mm]	Height: up to 2.5 [mm]

Advances in Embedded Componentry

What was the next step?

Bring everything together and integrate it

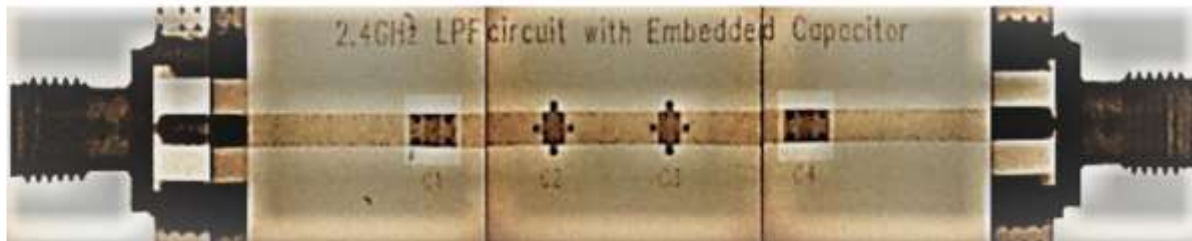
V_{out}: from 3.3V up to 24V
I_{out}: up to 6A
Package:
TO263, BQFN, LGA-16

V_{out}: from 0.8V up to 5.5V
I_{out}: up to 1.2A
Package:
LGA-6

PSMA APEC

Advances in Embedded Componentry

What is in development?
Advanced manufacturing 3D printing



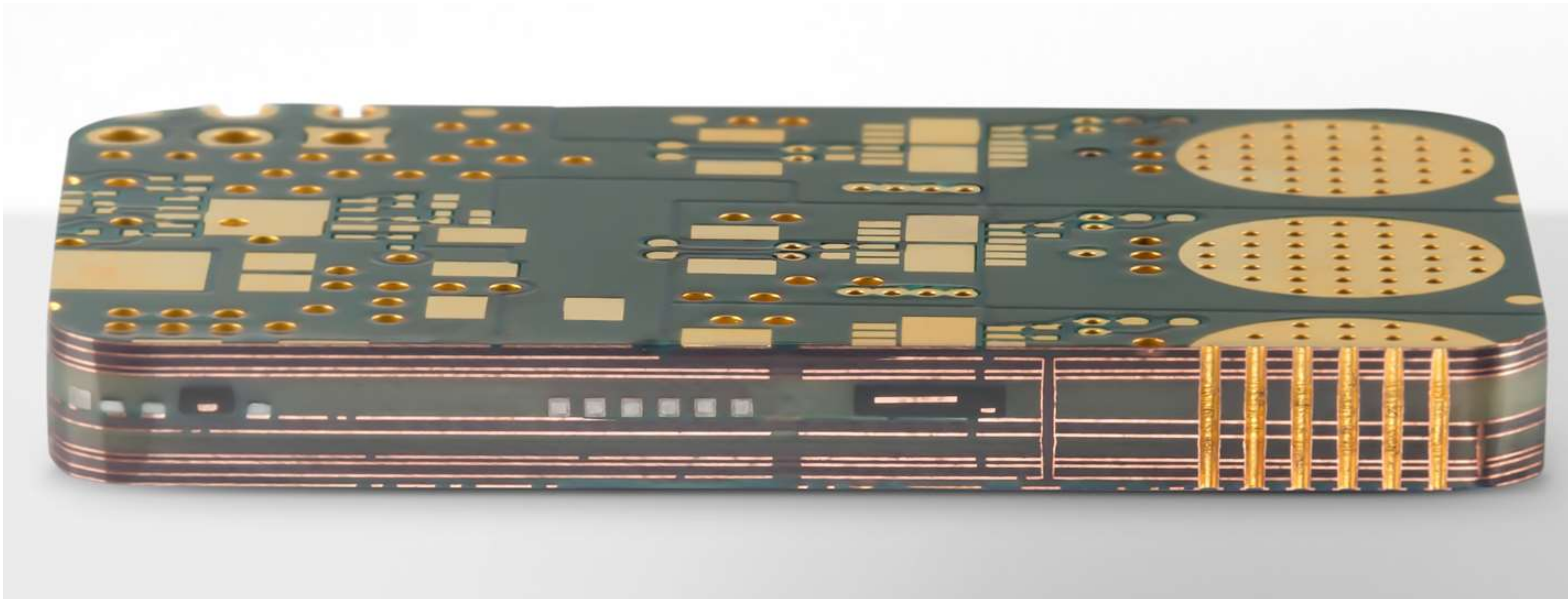
- **Low Pass Filter**
  - For the frequency range 2.4GHz WLAN
  - Printed capacitor and PCB

- **Low Power SMPS**
  - Printed PCB and air coil

PSMA APEC

Advances in Embedded Componentry

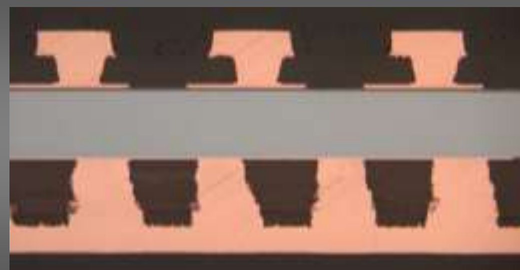
Integration in the printed circuit board?



PSMA APEC

EMBEDDING TECHNOLOGY – POWER

Options: power devices integrated into printed circuit board material



MICROVIA.embedding

Bare Dies, special passives

mounted onto inner layer core or Cu-foil

electrical contact through Microvias

highest reliability

large volumes

SOLDER.embedding

SMD components

soldered onto inner layer core

electrical contact by solder

high reliability

small, medium and large volumes

Advantages

- **Smaller package sizes**
- **Improved electrical performance**
  - Low-inductance build-ups
  - Less dynamic and static losses
- **Good thermal performance**
- **EMC protection possible**
- **May be built as a module, SiP or complete system including logics**

PSMA APEC

EMBEDDING TECHNOLOGY – THE BASICS

Process flows – MICROVIA.**embedding** – Version 1

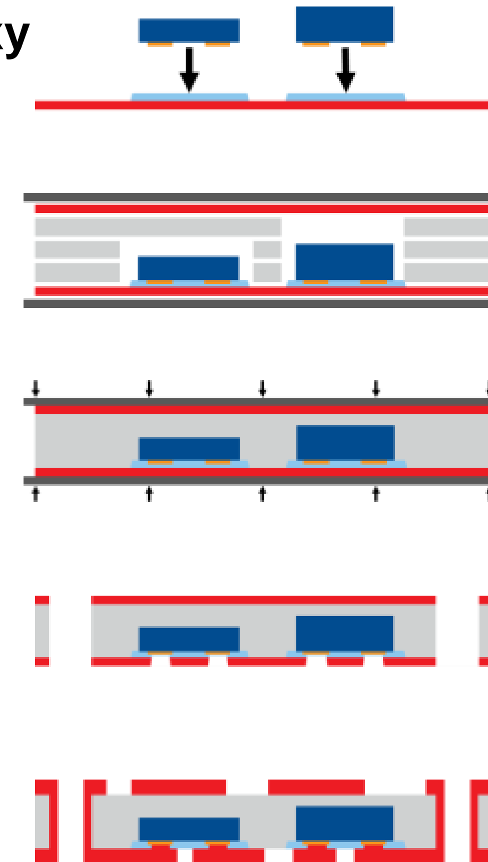
1 **Face-down assembly onto Cu-foil and into non-conductive epoxy adhesive**

2 **Multilayer lay-up incl. cavities for components**

3 **Multilayer lamination - cavities will be filled**

4 **Laser drilling onto metal pads of the components**

5 **Electroplating and remaining process steps of the PCB**



PSMA APEC

EMBEDDING TECHNOLOGY – THE BASICS

Process flows – MICROVIA.**embedding** – Version 2

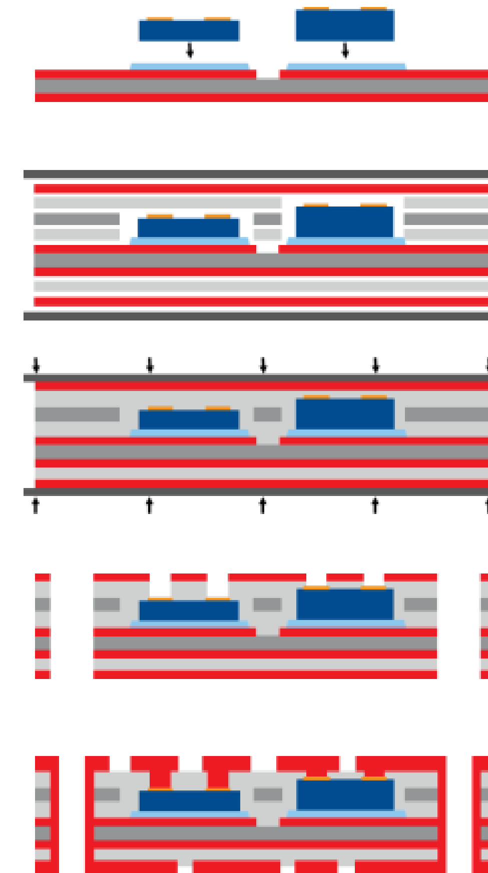
1 **Face-up assembly onto core and into (non-)conductive adhesive**

2 **Multilayer lay-up incl. cavities for components**

3 **Multilayer lamination - cavities will be filled**

4 **Laser drilling onto metal pads of the components**

5 **Electroplating and remaining process steps of the PCB**



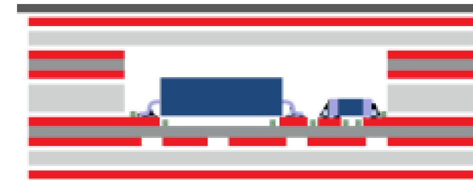
PSMA APEC

EMBEDDING TECHNOLOGY – THE BASICS

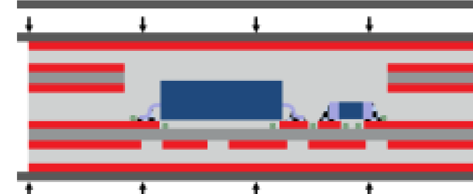
Process flows – SOLDER.**embedding**

1 **Solder assembly – SAC305-paste or high-temperature paste**

2 **Multilayer lay-up incl. cavities for components**

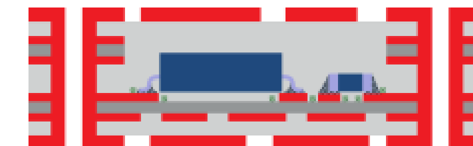


3 **Multilayer lamination - cavities will be filled**



4 **Further PCB processes such as mechanical drilling**

5 **Electroplating and remaining process steps of the PCB**

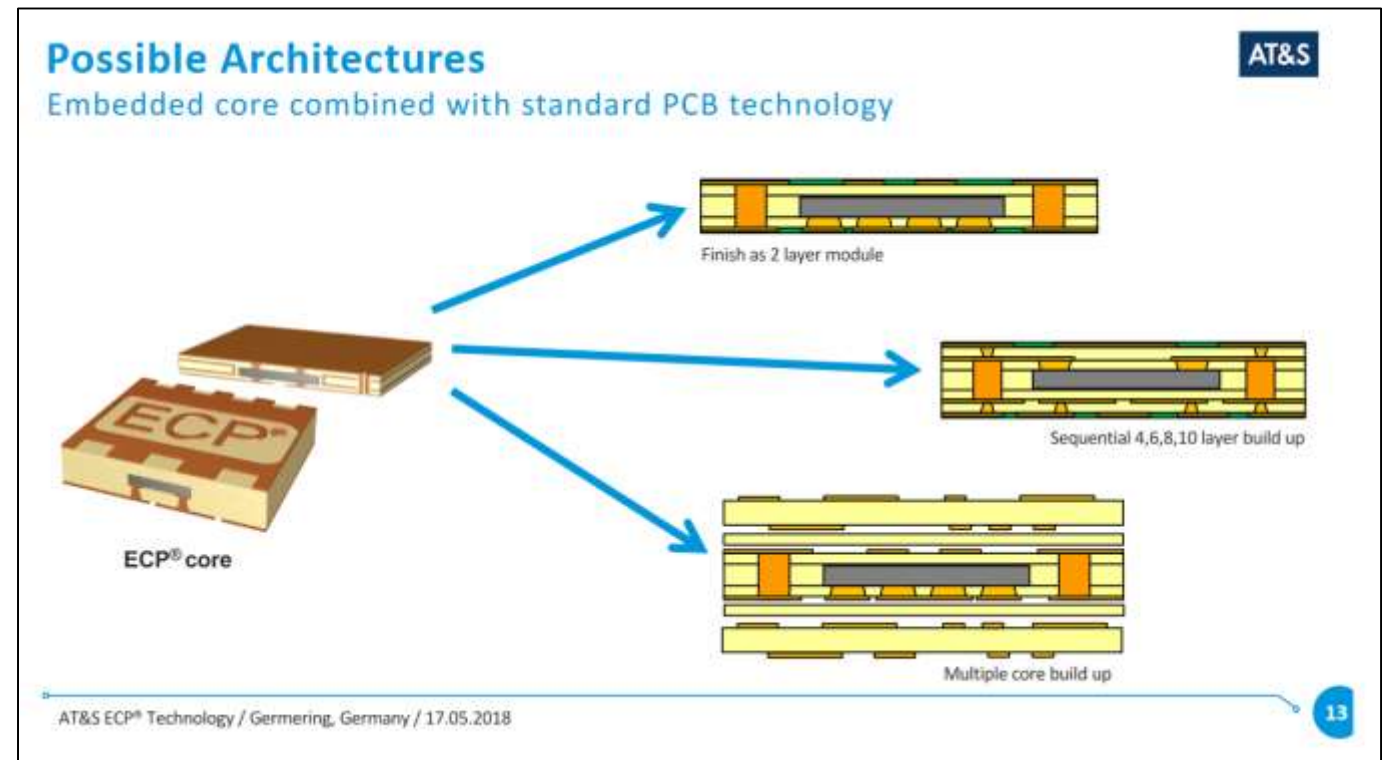


EMBEDDING TECHNOLOGY – POWER

Further opportunities on the market

ECP® Technology

Base technology:
Contacts using microvias



Source: 3D-PEIM 2018, David Warner, „Advanced PCB Solutions Supporting Next Generation Power Applications"

EMBEDDING TECHNOLOGY – POWER

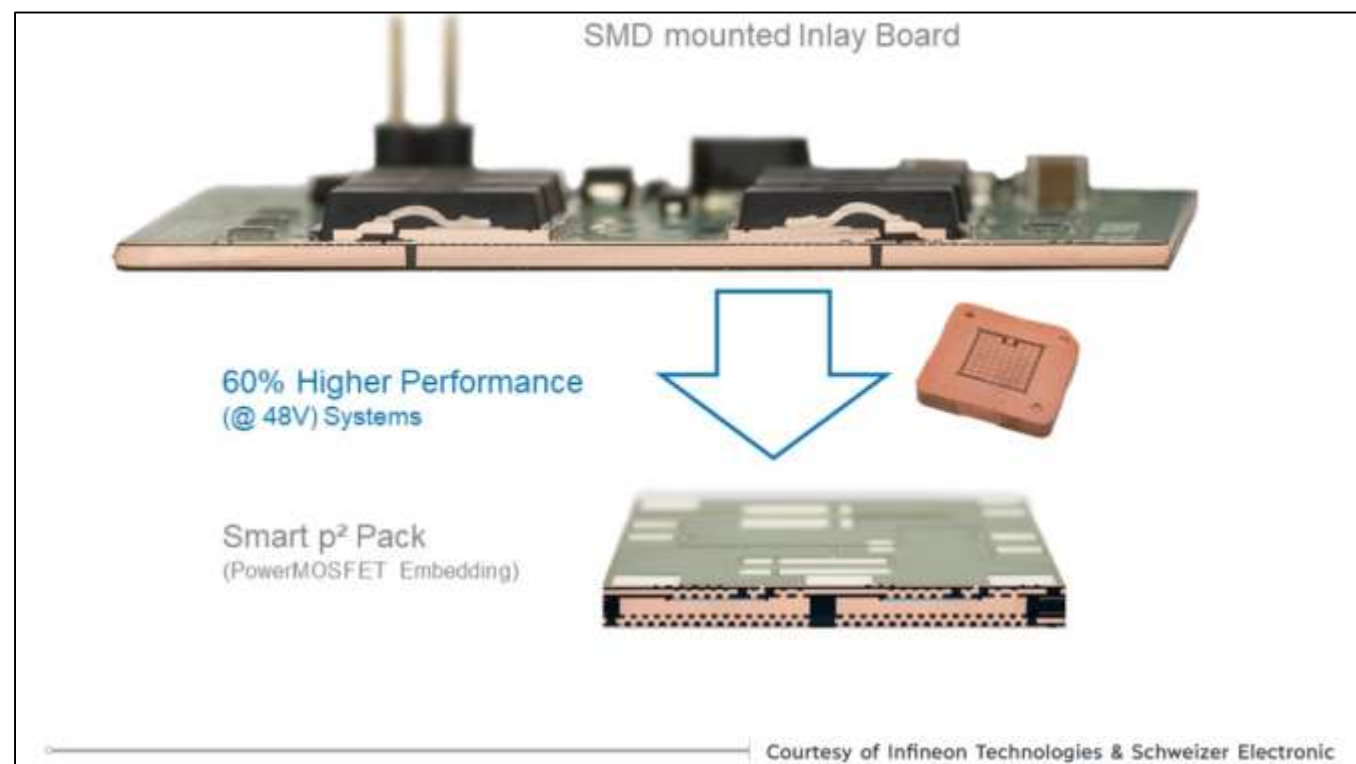
Further opportunities on the market

p²Pack Embedding

Base technology:

Components on/in special Cu-inlay

Contacts using microvias



Source: Interview of i-micronews with Schweizer and Infineon in 2018

PSMA APEC

EMBEDDING TECHNOLOGY – POWER

What is there to consider?

Challenges

- **Build-ups have to be planned very precisely**
- **Availability of bare dies that are compatible with the technologies, e.g. copper surface for contacting**
- **Test concepts must be planned individually and well in advance, depending on module and build-ups**
- **Combination of components in SiPs: availability of all components for the particular process**
- **Performance of components for** SOLDER.**embedding not as good as for directly contacted components**
  BUT: Availability possibly higher and possibly more options in thermal management and further processing
- **Material combinations must be well coordinated (geometries, CTEs, thermal load, etc.), otherwise there is a risk of early cracking in the PCB material at component edges**

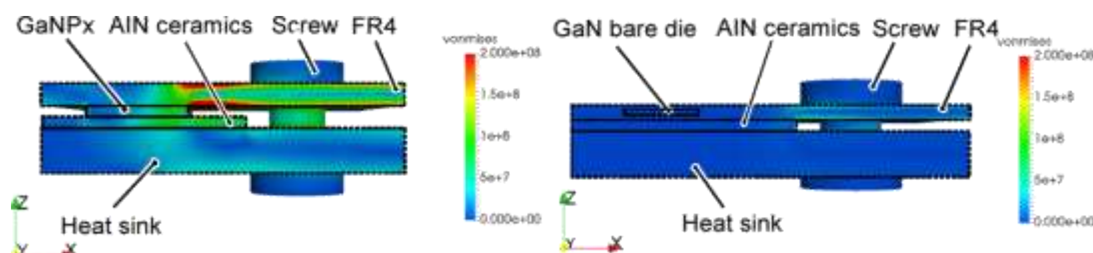
PSMA APEC

EMBEDDING TECHNOLOGY – POWER

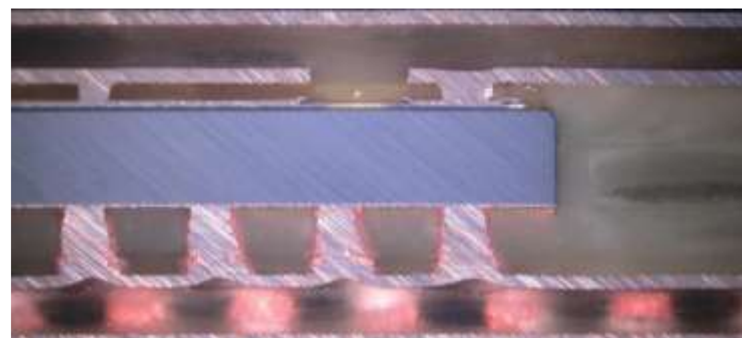
Examples MICROVIA.embedding

Automotive: Embedded GaN Half Bridge Switching Cell

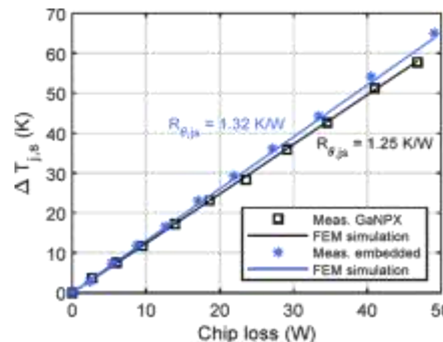
Source:
Dechant et. al.,
"Performance of an Ultra Low Inductance GaN Half Bridge Switching Cell with Substrate Integrated Bare Dies", PCIM 2019



Build-up and comparison of mechanical stress / Primary package vs. Embedding



Microsection of the printed circuit board



Simulated and measured Junction-Temperature

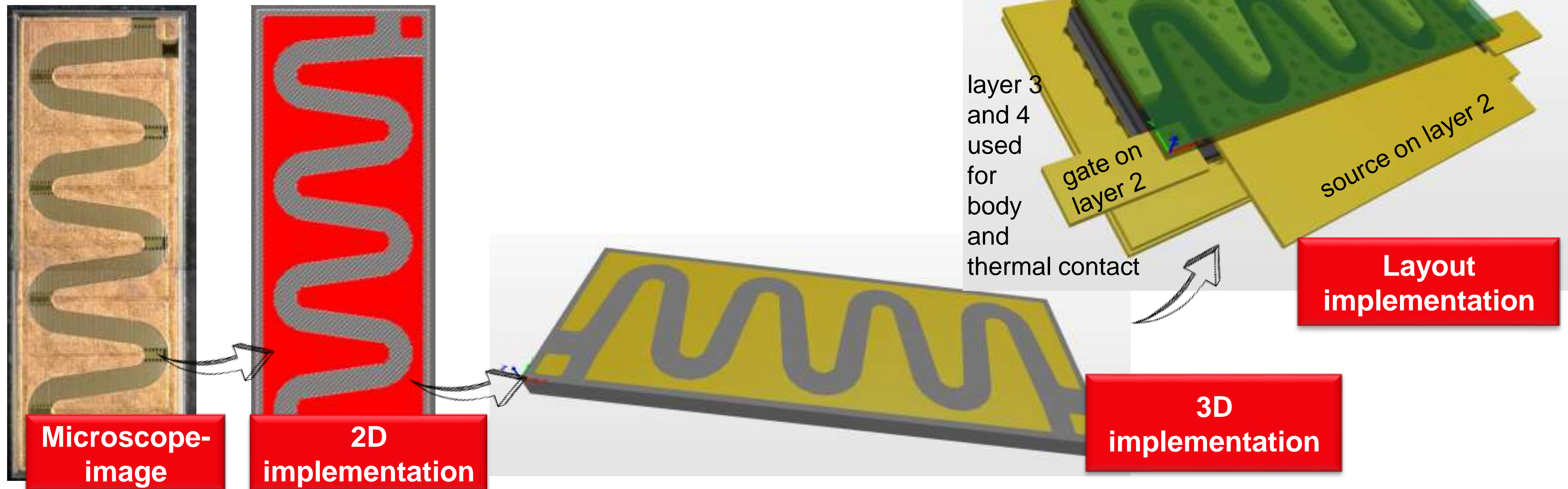
For even better performance, the number
of microvias could be still doubled

EMBEDDING TECHNOLOGY – POWER

Examples MICROVIA.**embedding**

Automotive: Embedded GaN Half Bridge Switching Cell

- **The path from Die to virtual component and layout recommendation**

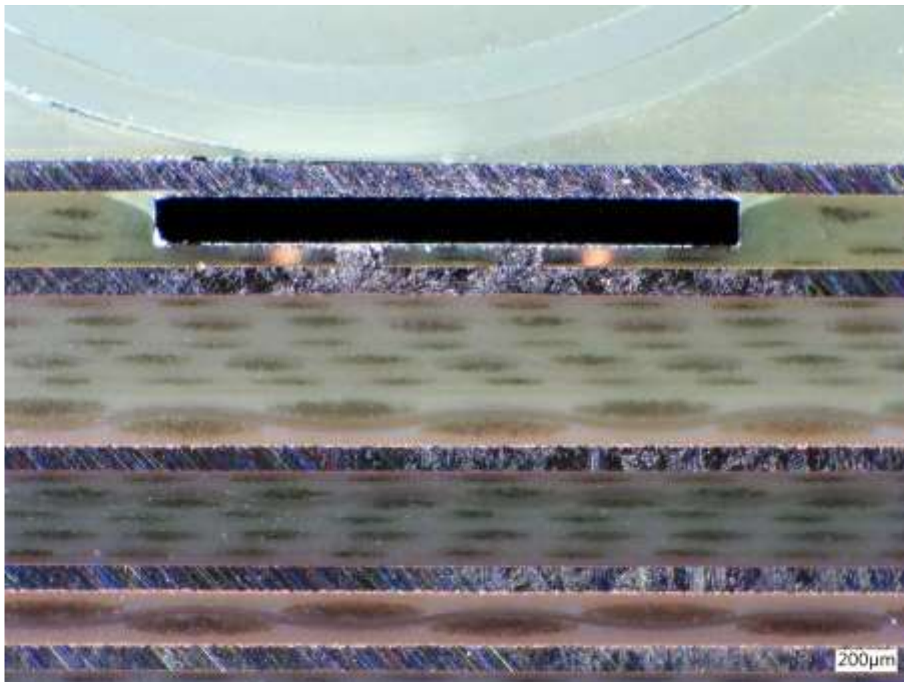


PSMA APEC

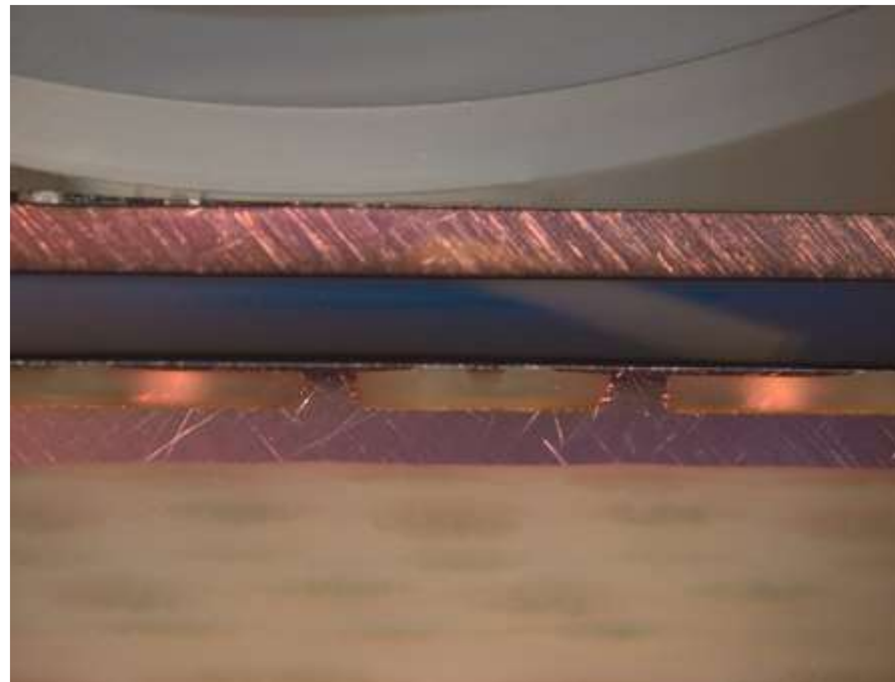
EMBEDDING TECHNOLOGY – POWER

Examples MICROVIA.**embedding**

200 KW Embedded SiC PCB for industrial Inverter Module



SiC under the top layer of an 8-layer build-up



SiC directly contacted with copper on both sides - full-surface backside contact

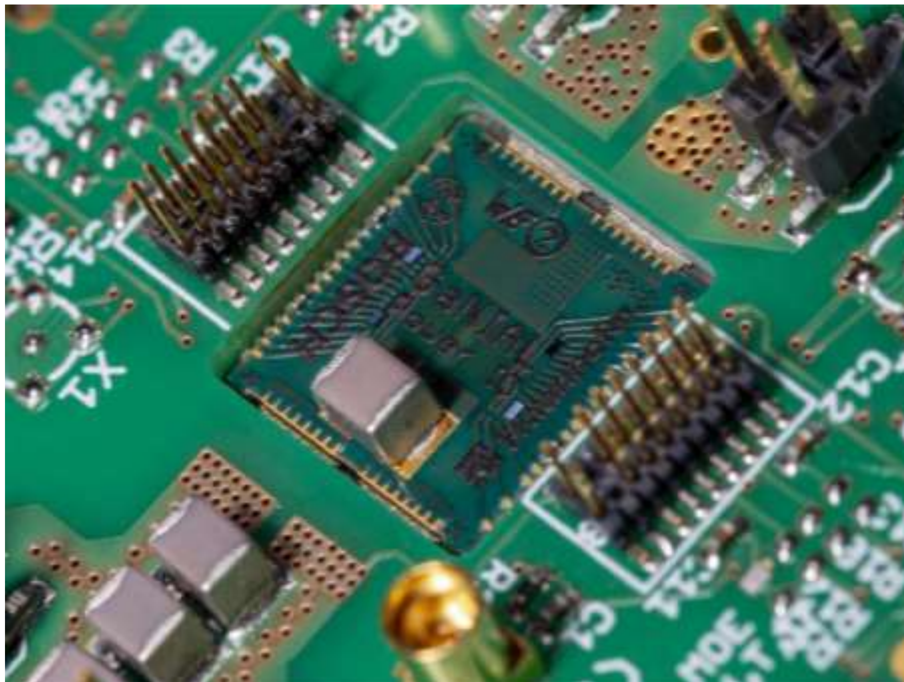
PSMA APEC

EMBEDDING TECHNOLOGY – POWER

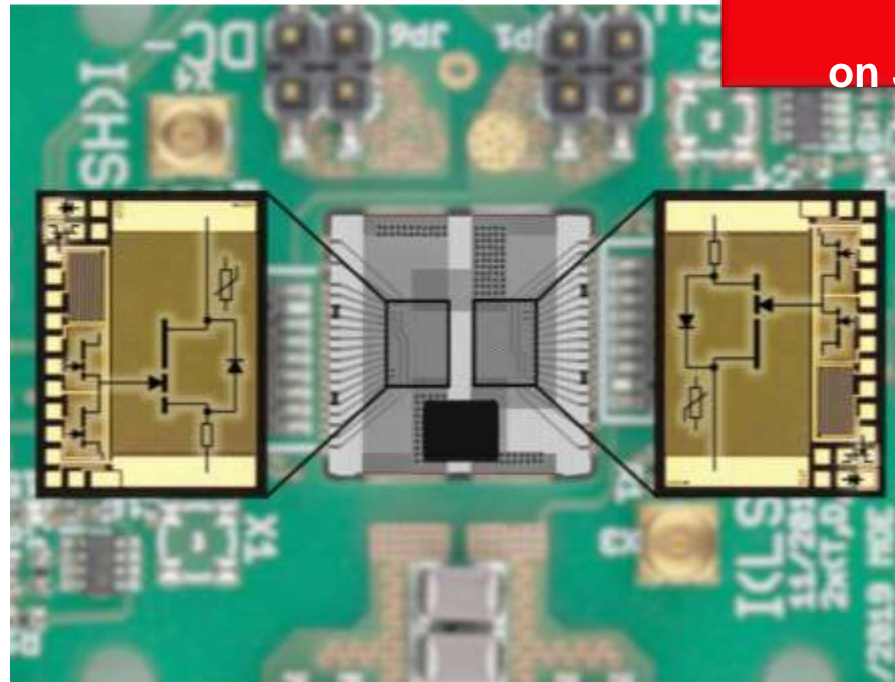
Examples MICROVIA.**embedding**

Source:
Press Release
Fraunhofer IAF for PCIM 2020
on July 06, 2020

Modular GaN-on-Si half bridge circuits / voltage converter of the 600 volts class



Assembled module



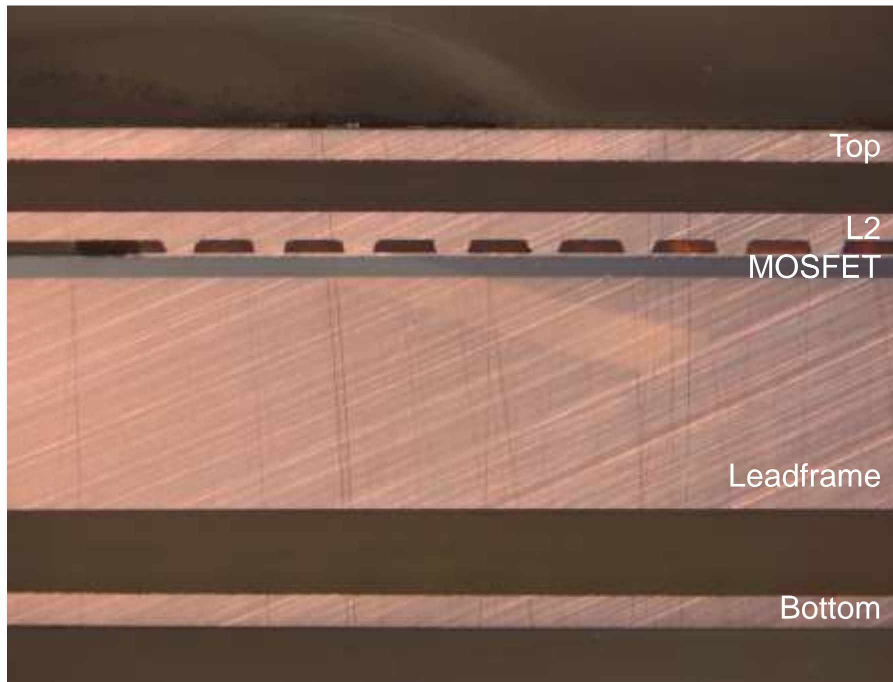
X-ray image of the half-bridge circuit and overlay of circuit diagram

PSMA APEC

EMBEDDING TECHNOLOGY – POWER

Examples MICROVIA.**embedding**

Custom switching module (SiP) with 650V N-channel power MOSFET on leadframe and gate series resistor



Microsection of the layer stack

Microsection of gate resistor on L2

Surface polishing down to microvia contacts

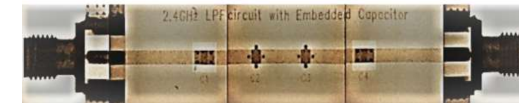
PSMA APEC

Conclusion

How can we achieve the embedding of components?

- **Shrinking the size of the components**
  - Different technologies available
  - Ceramic Capacitors
  - Aluminum Polymer horizontal chip

- **Using new technologies like advanced manufacturing like 3D printing**



- **Integrate the components or circuit into the printed circuit board**