Highly integrated power electronic converters using active devices embedded in printed-circuit board

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Outline

Introduction

Review of PCB-based packaging

Proposed Embedding Technique

Summary and Conclusion
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Advantages of die embedding

The Printed-Circuit-Board technology (PCB) enables:

- higher interconnect density
  - multi-layer
  - small pitch (down to 25 $\mu$m linewidth)
- Low inductance [1]
  - small size
  - laminated busbar structure
- batch-processed manufacturing
  - all interconnects are processed at once

E. Hoene, “Ultra Low Inductance Package for SiC” ECPE workshop on power boards, 2012
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Delft TU “folded” converter [2, 3]

- Use of a flex substrate to form windings,
- wrapping around the larger components
- thermal management might prove difficult
Literature Review – Flex PCB interconnects

- Flex PCB instead of wirebonds
- Die top contact with solder/sintering
  - requires suitable finish
- backside attached to a DBC
- commercially available from Semikron
- advantages:
  - low profile, low inductance
  - higher interconnect density

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T. Stockmeier et al. “SKiN: Double side sintering technology for new packages”, ISPD 2011
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Silver-sintered interconnects and Epoxy/Kapton insulation [7]

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SiPLIT Copper electroplating, laminated isolation laser-structured in-situ [8]


Embedding of capacitive layer [9]

- Established tech. in consumer electronics
- Mostly targeted at low-voltage
- Capacitance values: 10 pF – 5nF/cm²
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Integration of passives [10]
- Capacitive layers
- Magnetic layers
- Embedded Passives Integrated Circuit (emPIC)

Literature Review – Die embedding in PCB – 1

Patents on chip embedding [11]

Very active area in recent years
Many applications to high interconnect density
Several industrial developments (A&T, Schweizer, etc.)

Low-inductance packaging for SiC [1]

- Half bridge module
- 0.8 nH loop inductance
- Embedding die using stud bumps

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Low-inductance packaging for SiC [1]

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- Power module development through german project Hi-LEVEL [12]
- 10 kW and 50 kW demonstrators
- Thick copper or DBC for thermal management

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CAD tools with embedding capability [13]

- Automatic placement of parts
- Design rules (cavity size, height check, etc.)
- Generation of the manufacturing data
  - Position of dies, cavities, laser drilling, etc.

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Overview of the process

- Start with a DBC substrate
- Die attach (silver sintering)
- PCB stacking
- PCB lamination
- Topside copper etching
- Laser ablation
- Copper electroplating
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Overview of the process – significant points

- Backside die attach with silver sintering:
  - The die does not move during assembly
  - Accurate positioning
- Ablation using a CO₂ laser
  - Very good selectivity (metal layers insensitive to laser light)
  - Use of the copper layer as an alignment mask
- Prototype-scale equipment used
  - Can manufacture prototypes from 4x4 cm² up to 21x28 cm²
  - Affordable, useful for process development.
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Effect of die finish

Two die finishes evaluated
- standard Al topside
- Ti/Cu PVD with a shadow mask
Cross section

- vertical walls in epoxy layers
- good self-alignment
- electroplated copper too thin

5 min electroplating on Al-finished die
Electrical Characterization

Tests performed in air, without additional passivation

die finish and electroplating time have a strong effect on characteristic
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  - Scalable technology
  - Allows for more compact systems
  - Attractive for fast, wide-bandgap devices
- Presentation of a prototype-scale process
  - Full details in the paper!
  - First results on large-die diode embedding
- Developments to come: embedding of an IGBT/diode half bridge:
  - Simple generation of all files from CAD (prepreg cutouts, dies opening, ...)
  - Validation of alignment accuracy with the gate of the IGBT
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Bibliography I


Thank you for your attention

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