



Increased Breakdown Voltage and robustness of

Embedded power module



OUTLINE



- 1. Vehicle technology: strategy update
- 2. Why Embedded PCB?
- 3. Embedded PCB assembly design for power application
- 4. Main objectif of the study
- 5. Electrical study
- 6. Thermechanical study
- 7. Current and future work





1- VEHICLE TECHNOLOGY: STRATEGY UPDATE



Green transportation: integration of electrical solutions Reliable, Ecoenergetic, Increase machine power, Limit in space

 Improve heat dissipation and performance, High integration

[1] W. Grübl, S. Gross and B. Schuch, "Embedded Components for high Temperature Automotive Applications," 2018 IEEE 68th Electronic Components and Technology Conference (ECTC), San Diego, CA, 2018, pp. 1233-1237, doi: 10.1109/ECTC.2018.00190.

[2] B. J. Hyon, Y.-S. Noh, J. S. Park, J.-H. Kim, and J.-H. Choi, "Development of High- Power Density Inverter for Automotive Applications," pp. 307–310, 2018, doi: 10.12792/iciae2018.059.





2- WHY EMBEDDED PCB?

4 Important criteria:	Standard PCB	Embedded PCB
Thermal performance		:
Electrical performance		
Volume		
Cost	\odot	<u>.</u>

How?

- ✓ Optimizing interconnections
- ✓ Reducing size, weight towards miniaturization

[3] C. Buttay, C. Martin, F. Morel, R. Caillaud, J. Le Leslé, et al. "Application of the PCB Embedding Technology in Power Electronics – State of the Art and Proposed Development", 3D-PEIM, Jun 2018, College Park, Maryland, United States. ff10.1109/3DPEIM.2018.8525236.









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3- EMBEDDED PCB ASSEMBLY DESIGN FOR POWER APPLICATIONS

- The use an insulated metal substrate (IMS) based on thick copper plate,
- Stacking of the chip between two Copper plates,
- Silver sintering for connexion,
- Layer of preimpregnated for ectrical insulation,
- Plated Through Hole vias (PTH),
- Thermal pads,
- interconnexion pads.



Figure 2: Cross section of the assembly before top IMS mounting



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The Feasibility & Functionality of an embedded power module VESA1 was validated.

The breakdown voltage of the Si MOSFET was 200 volts

The thermo-mecanical was not studied in VESA1

Increase the breakdown voltage from 200 volts to 800 volts in VESA2

Compare the estimated lifetime of the 2 solutions versions (VESA1 and VESA2)

Not included: partial discharge, humidity stress, active cycling test





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5-ELECTRICAL STUDY 5.1- ELECTRICAL SIMULATION OF THE REFERENCE MODULE AT 200V

• Objectives: Simulate the distribution of the electric field and the potential of a one side 200V die attach.



Figure 3: potential distribution of the reference module at 200V



Figure 4: Electric field results of the reference module at 200V

- Software used: Maxwell electronics
- Boundary conditions: potential of the lower copper plate is 200V and the upper Silver connection is 0V
- Results: Presence of free space above the Ag sup allows the distribution of potential lines
- Appearance of three triple points, the third is the most intense
- The triple point 3 is located at the intersection of the lower Ag, the chip and the preg.





5.2- ELECTRICAL SIMULATION OF THE REFERENCE MODULE AT 800V

Objectives: impact of the 800V voltage rise on the distribution of potential lines and electric field



Figure 5: potential distribution results of the reference module at 800V

- *Figure 6:* Electric field results of the reference module at 800V
- **Results**: a tightening of the potential lines on the top of the die, limiting the voltage rise.
- point 1 is the most intense => focus for the study of this point
- Solution: increase the distribution surface of the electric field





5.3- PROPOSED TECHNOLOGICAL SOLUTION FOR THE ATTENUATION OF THE ELECTRIC FIELD CONCENTRATION AT TRIPLE POINTS



- Realise a etch around the die edge to reduce the electric field around it
- Attenuation of the potential lines and the electric field inside the etching
- Decrease of the maximum value of the electric field in function of the size of the etching





5.4- INFLUENCE STUDY OF THE POSITIONING OF THE ETCHING ON THE DISTRIBUTION OF THE POTENTIAL LINES AND THE ELECTRIC FIELD

- The position of the etching on the chip is important => allow to attenuates the electric field inside the etch.
- The minimum value of the electric field is obtained when the etching is above the chip



Figure 10: Electric field in function of the etch alignment on the chip







5.4- PARAMETRIC STUDY OF THE ETCHING SIZE INFLUENCE ON THE AVERAGE ELECTRIC FIELD VALUES



Figure 11: cross section of the module with etching showing the variation of the etching size

- The size of the etching varies in width and depth.
- Width of the etching varies between 0 and 0.9 mm
- Depth of the etching varies between 0 and 0.9 mm
- The minimal electric field value is reached for an etching of size equal or beyond 500µm x 500µm.



Figure 12: Electric field at triple point 1 at 800V as a function of etch depth and width





12

- The electrical simulations results show that the position of the etching above the chip is important
 >it is necessary to take into consideration the alignment of the etching when manufacturing the module.
- From an etching depth of 500µm the electric field values is constant. On the other hand, this value decreases as the width increases => manufacture an assembly (VESA2) with different widths and a constant depth of 500µm.





6- THERMOMECANICAL STUDY

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6- THERMOMECHANICAL STUDY 6.1- MODULE GEOMETRY AND BOUNDARY CONDITIONS

Objectives: Simulate the thermomechanical and shear stresses for different structures. Simulate the impact of etching on the thermomechanical performance of the module



Figure 13: Module geométry with etching





6- THERMOMECHANICAL STUDY

6.2- MODULE GEOMETRY AND TRIPLE POINTS

- Many interest points
- Point 1 is the most intense => focus for the study of this point



Figure 14: cross section of the module showing the location of the interest point





16

6- THERMOMECHANICAL STUDY

6.3- SHEAR AND VONS STRESSES RESULTS FOR AN ETCHING 0.5X0.5MM²





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6- THERMOMECHANICAL STUDY

6.4- PARAMETRIC STUDY OF THE ETCHING SIZE INFLUENCE ON THE AVERAGE SHEAR STRESS VALUES



Figure 17: cross section of the module with etching showing the variation of the engraving size

- The size of the etching varies in width and depth.
- Width of the etching varies between 0 and 0.9 mm
- Depth of the etching varies between 0 and 0.9 mm
- The minimal shear stress value is reached for an etching of size equal or beyond 400µm x 100µm



Figure 18: shear stress at triple point 1 at 50°C as a function of etch depth and width







7- CURRENT AND FUTURE WORK

- Manufacture test vehicles to validate the manufacturing process
- Experimentally demonstrate the functionality and feasibility as well as the reliability of the test vehicles at 800V
- 3D thermo-mechanical simulation at various temperatures and in static states to track high stress locations
- Conduct a comparative study between numerical and experimental results.



Figure 19: Image of the copper etch which forms a 500 μ m trench around the device





Thank you for your attention

Together to accelerate the mobility of tomorrow!



3.4- INFLUENCE STUDY OF THE POSITIONING OF THE ETCHING ON THE DISTRIBUTION OF THE POTENTIAL LINES AND THE ELECTRIC FIELD

- The position of the etching on the chip is important => allow to attenuates the electric field inside the etch.
- The minimum value of the electric field is obtained when the etching is above the chip







Figure 9: Electric field results when the etch is positioned to the over the top of the chip



Figure 11: Electric field results us function of the etching size





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