

Thermal and Thermo-Mechanical Analyses of Wire Bond vs. Three-dimensionally Packaged Power Electronics Modules

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To mom, dad and brother

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Abstract

The goal of more efficiently and more reliably realizing energy conversion in the power electronics industry is pushing the limits of current wire bonding packaging technology. Emerging three-dimensional power packaging techniques have shown their potential to replace wire bonding technology down the road. However, these innovative technologies have not yet been fully understood in terms of thermal and thermo-mechanical performance. Therefore, a comparative evaluation between the thermally induced response in conventional wire bonding (a 2-Dimensional technology) and 3-Dimensional packaging technologies is essential.

Thermal and thermo-mechanical analysis using the Finite Element Method (FEM) has been performed to evaluate a three-dimensional power module packaged in a Metal Post Interconnected-Parallel Plate Structure (the MPIPPS), and the result is compared with that of a wire bond module.

Under the same single-sided cooling conditions, thermal modeling results show a significantly lower junction temperature of 17°C in the MPIPPS module than that in the wire bond module, due to the more uniform heat flow distribution in the MPIPPS module. The top DBC (direct bonded copper) substrate in the MPIPPS module helps direct the excessive heat generated from IGBT (Insulated Gate Bipolar Transistor) chips to diode chips (which dissipates less heat). The maximum junction temperature is reduced to 108 °C in the MPIPPS module by the implementation of double-sided cooling, which the wire bonding technique can not achieve. Subsequent thermo-mechanical analysis reveals the weak points in both modules during temperature cycling and power cycling. In the wire bond module, temperature cycle results have shown more severe stress and strain than that those of the power cycling conditions in the regions where the wires attach the device emitter pads. In the MPIPPS module, the solder joints exhibit high plastic and creep deformation. Power cycling produces more inelastic deformation at the solder joints between the posts and device, due to local over-heating, which causes more severe high-temperature creep deformation. Using a deformation-based thermal fatigue theory, the solder joint fatigue lives are predicted. Compared with the commercial wire bond module temperature cycle test, the fatigue life of MPIPPS is limited.

We conclude that the MPIPPS module is better in thermal management but is thermo-mechanically less reliable than the wire bond module.

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