Power electronics advances

The elimination of wire bonding technology has had an impact on the advances in performance power packaging for hybrid and electric vehicle semiconductors

Semiconductor companies often place huge importance on the improvements made on successive generations of silicon. This is all well and good, but in the world of power electronics, it must not be forgotten that high currents have to be routed to and from the semiconductor, and large amounts of heat extracted.

One of the fundamental methods for making an electrical connection to the semiconductor is wire bonding – several small links of wire attached to the surface of the silicon making the connection to the rest of the system. As Figure 1 indicates, this technology is highly established but has limitations in terms of reliability, cost and power density at high current levels.

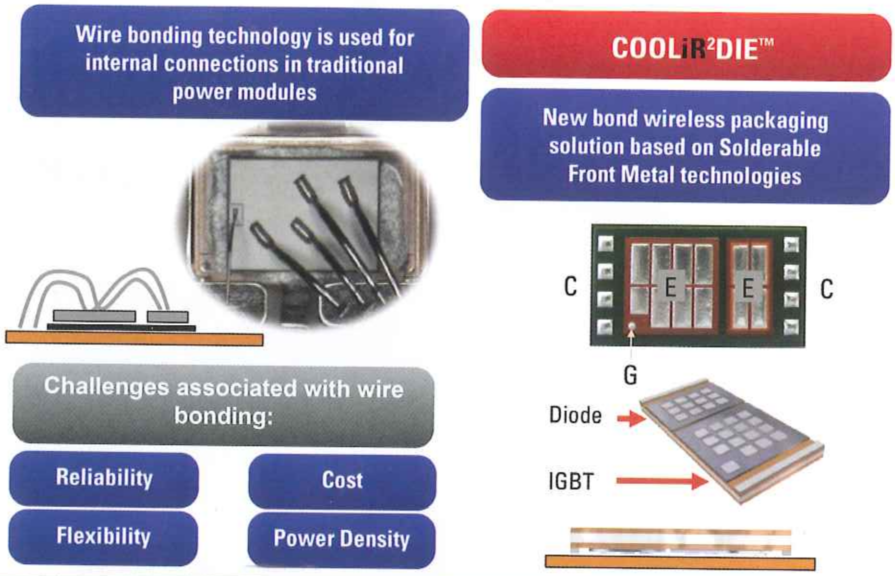

Figure 1: A comparison of traditional interconnect and new bond wireless technologies for EVs and HEVs

A new solution in development for hybrid and electric vehicles using large amounts of insulated-gate bipolar transistors (IGBTs) and diodes in the main inverter is to eliminate the wire bonding by soldering directly to the silicon. CooliR²Die, as illustrated on the right-hand side of Figure 1, is one alternative. A fully tested, robust direct bonded copper carrier holds a 300A, 680V, 175°C-capable IGBT and diode complete with a pre-soldered surface that enables direct integration into a mechatronic assembly fitting to the customer's specific system.

By eliminating the wire bonds, several advantages present themselves. Firstly, the cumbersome manufacturing step of wire bonding can be removed and replaced with a solder reflow process, improving yields and reducing manufacturing costs. The high inductances associated with the narrow wire bonds are also greatly reduced. Using the CooliR²Die technology, a 480A half-bridge module has been constructed with a loop inductance of less than 12nH (Figure 2). This enables smoother, faster switching, with reduced losses and fewer EMC challenges. At the same time this half-bridge configuration has a package resistance of less than 0.5mΩ; a 50% reduction on traditional wire bonded modules. A reduction of 0.5mΩ might not seem much, but with a phase current of 400A, such a reduction in package resistance results in a power saving of 80W per phase.

Furthermore, by eliminating the wire bonds on top of the package, both the top and bottom surfaces of the device can be used for cooling (Figure 1), improving current handling capability by up to 70%, and thus providing greater power density and efficiency.

As with any new technology, the consumer experience will either help or hinder adoption. In the automotive market, performance and reliability are essential. Although the torque provided by the electric motors gives a delightful 'wow' factor to the performance of HEVs, this must be accompanied by reliable operation. CooliR²Die was shown to achieve close to 1,000,000 active power cycles with a $\Delta T_j = 85°C$; roughly a ten-fold improvement in reliability over traditional wire-bonded modules.

Module	Rating	No. Phases	Weight (g)	A/cm³	Package Inductance (nH)	Package Resistance (mΩ)
Traditional Wire Bonded	650V /400A	3	485	8.8	30	1.0
				2X	0.4X	0.5X
COOLiR²Bridge™	680V /480A	1	225*	18.2	12	<0.5

*Weight for three single phase modules

Figure 2: A detailed performance comparison table of traditional wire bonded and CoolIR²Die bond wireless half-bridge modules for main inverter applications

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