Improved HiPak Modules for Power Electronic Applications

Today, IGBT based power electronic modules are the devices of choice for a vast range of applications from light-rail vehicles, heavy duty multi megawatts locomotives, to hundred megawatts HVDC installations. High reliability is the key element that needs to be addressed in all applications. ABB challenges the limits of both, the electrical and reliability specifications, by means of new, well-known and established technologies.

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Since its introduction nearly two decades ago, high power IGBTs developed to be the device of choice for power electronics applications covering a wide range of voltage and current. The ABB HiPak line-up suits the needs of applications like light-rail vehicles and industrial drives in the hundred kilowatts to lower megawatt range, multi megawatt electric locomotives and industrial drives and even HVDC converters of up to several hundred megawatts. The need for energy efficient motor drive solutions and transportation together with the urge to explore alternative energy sources such as wind-power, further drive the demand of power-electronic converters. Since the up-time of such applications is crucial for the whole economics, reliability requirements are key.

Improved HiPak platform

ABB is introducing an improved package for the complete HiPak module product portfolio (Figure 1) starting with the voltage range from 1700 V up to 3300 V. This improved platform is a one-to-one replacement of the actual products and there is no change neither in the electrical nor the thermal characteristics of the module. Its improved reliability is based on established technologies and designs that where developed and tested in the past few years. This new improved HiPak platform ensures that the HiPak standard fits also for the applications of tomorrow.

Figure1: Improved HiPak 2 module

Past designs of power modules often used a hard mold, usually epoxy. For the use in modern power modules epoxy has more and more issues to fulfill the large number of requirements such as high operating temperature range (-50 to 150°C), international fire and smoke standards and a high comparative tracking index (CTI) for short creepage distance. Moreover, the expoxy's thermal expansion coefficient does not match to the corresponding coefficients of the other materials in the module. This is needed, however, to fulfill the temperature cycling requirements. Furthermore, hard molds like expoxy contain elements that may cause electro-chemical reactions inside the module. Therefore, new designs usually

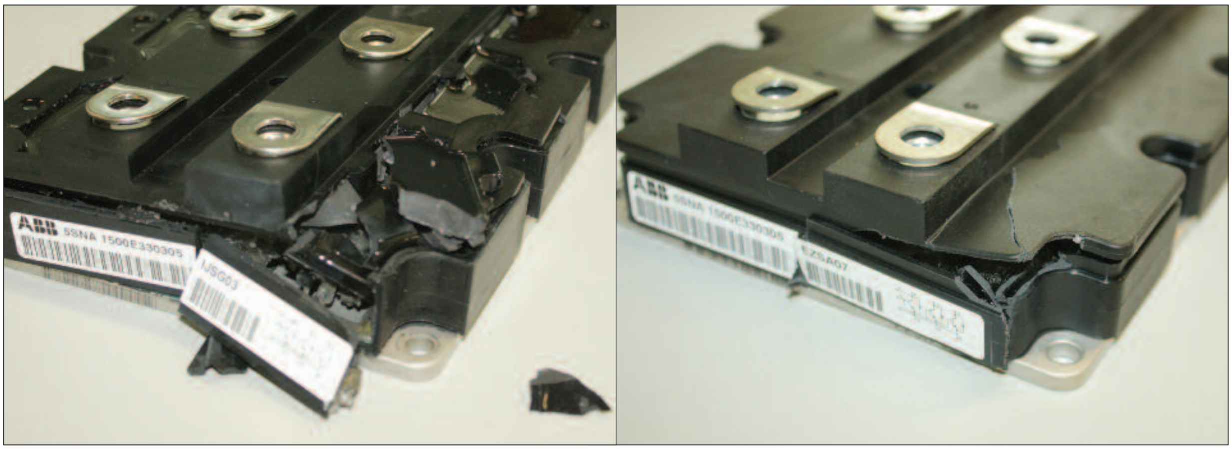

Figure 2: Old HiPak 2 module after destructive short-circuit test (left) and improved HiPak 2 module after same test

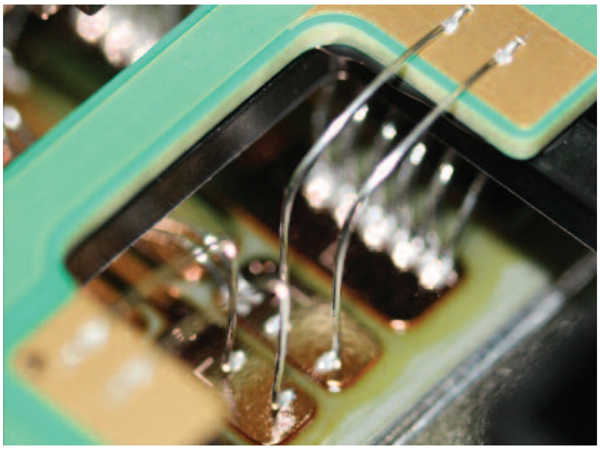

Figure 3: Improved auxiliary connection

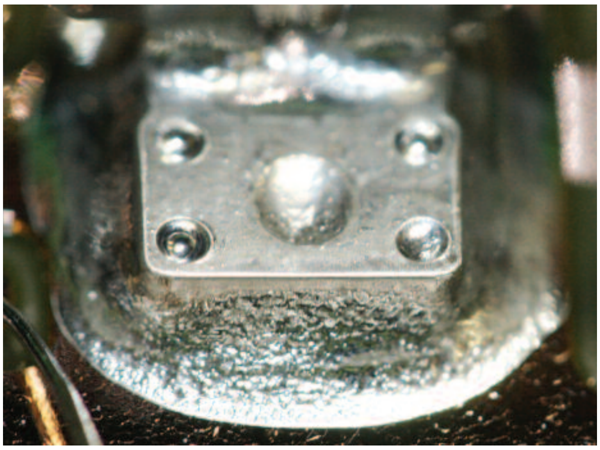

Figure 4: Improved main terminal foot

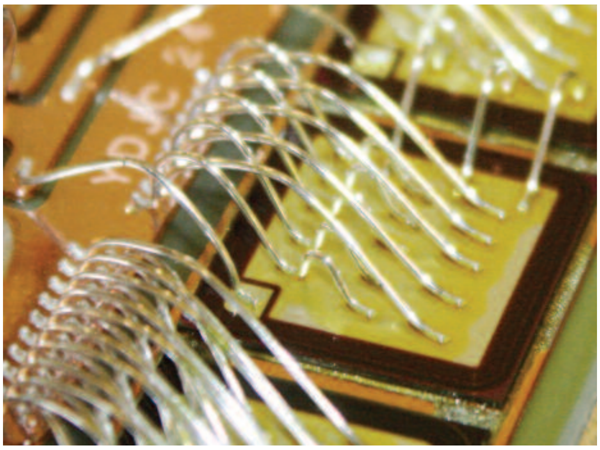

Figure 5: Improved wire-bonding layout

hold back from using epoxy.

With the help of a new housing material together with a reliable epoxy-less package design, the case temperature range for the improved HiPak is increased from -40°C to 125°C now from -50°C to 150°C. Moreover, the improved package now complies with the latest fire and smoke requirements that are needed for traction applications: NFF 16-101/102 I3 – F2 and CEN TS 45545 HL2 cat. R23. The epoxy-less module is designed such that all electric potentials are internally separated by gel and/or the housing. The mechanical robustness is guaranteed by a balanced distribution of the external mechanical load on all supporting parts. This measure also results in less damaging explosion behavior of the overall module. Figure 2 show a standard HiPak module (left) versus an improved one (right) after the destructive short circuit test. Both modules were exposed to exactly the same electrical overstress. It can clearly be seen that the improved module is less fractured.

Improved internal auxiliary connection

Internally, the formerly soldered auxiliary connections between gate-print and substrate are replaced by standard bonded aluminum wires. This well established technology allows for higher reliability and offers a redundant double wire connection (Figure 3). For an optimal bonding process, the supporting structure of the gate-print was redesigned, bringing a maximum stiffness and stability to the gate-print. The main advantage of the bonded connection is the in-line process control of the bond-joint quality by the bonding tool which measures the bond-foot deformation and thus can detect non-conformance. The soldering process on the other hand only allows a post process quality control which is usually an automated visual inspection. Nevertheless such a post process control does not guarantee a 100 % accurate inspection for instance of cold solder joints. In addition, the new design allows for a more stable gate-print assembly, improving the overall mechanical reliability of the module.

Improved power terminals

To improve the temperature cycling performance and the process reliability of the soldered terminal connection, an improved solder foot was designed for the main terminals. Specifically designed spacers guarantee a homogenous solder layer thickness. A similar concept with spacers was already successfully introduced a couple of years ago for soldering the substrate to the baseplate. In addition, the main terminal foot size and shape are designed in order to allow for a nice and reproducible solder meniscus (Figure 4). Moreover, the coating of the terminal has been changed. Meticulous analyses of the intermetallic layer have led to the conclusion, not to use nickel plated terminal feet. Nickel can lead to micro cavities in the intermetallic phase, resulting in a more sensitive solder interface with respect to cracking or delamination.

Improved wire-bonding

To improve the power cycling capability the emitter side wire-bonding parameters have been improved and optimized by using the latest in-process control options offered by new bonder generations. In addition, so called stich-bonds (Figure 5) are used. This design is a trade-off between utility (better fatigue behavior) and the needed bond area. The result is a boosted power cycling capability of about a factor 4 (Figure 6). The targeted 10 % capability is 2 million cycles for $\Delta T = 60$ K and at T_{vj}, max = 150°C. Our actual achievement indicates even better results.

Many small improvements

Besides the main technological and design improvements, many small improvements have been realized to ensure both, a reliable and producible fabrication process. Boosting the overall quality of our fabrication processes we achieved a major overall module quality increase. Some of these small improvements are for example

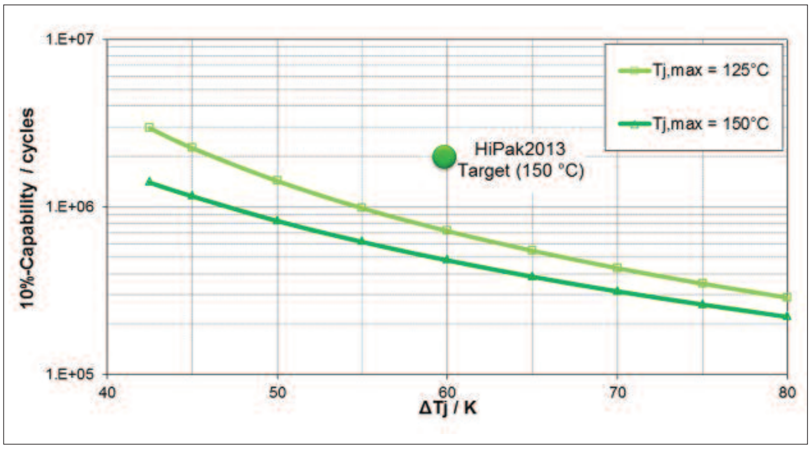

Figure 6: Improved power cycling capability

the solder-stop-free substrates allowing for a cleaner soldering process, the improved gate-print contact metallization for a better auxiliary terminal lead-free soldering process and a reliable bonding connection.

Qualification of the improved platform

The qualification of the improved HiPak platform is on-going and close to completion. Of course, all the relevant tests are performed. These include shock and vibration, temperature cycling, power cycling and temperature humidity bias. All incorporated technologies and design elements have successfully passed the verification tests and the final product already passed most of the qualification tests. The results are better or at least equal for every test compared to the current package.

The roll out will start with the 3300 V 1500 A HiPak2 SPT+ module and will be followed by the 1700 V SPT+ modules. In a first step, all low-voltage housings (E, N and M) will be replaced. In a second step, the improvements will be made available for the high-voltage housings (G, J and P). The roll out of the first module type will start in the third quarter 2013.

Conclusion

In the scope of improving the overall reliability performance of the HiPak module platform, ABB has developed an improved package based on well-known and established technologies. This package satisfies the increased reliability expectations without changing the electrical and thermal behavior, thus allowing the costumer for a one-to-one replacement without any need for requalification. This concept of improving well established processes and design elements and roll out on an existing product platform proves that substantial quality and reliability gain can be achieved without the need for the customer to redo a costly and time consuming design-in.