Reliability Verification of Direct Water-Cooled Power Modules for xEVs

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Introduction

The market for EV/HEV is growing by increasing global environmental protection awareness. The power semiconductor module has become an important part to determine vehicle performance. Along with the increase in the market size, the system of the operation is also diversified, means compact module has become a requirement especially for EV/HEV applications. A new versatile compact power module family named “J1-Series power module” has been developed in response to the automotive market essential requirements which are “wide range line-up”, “high power”, “high reliability”, “compact size” and “high efficiency” [1, 2]. This power module features a direct lead bond (DLB) structure and a direct water-cooling structure, which contribute to its long lifespan.

Experimental Procedures

The J1 module was mounted on a real vehicle and subjected to driving loads in a field environment. The electrical characteristics, thermal resistance, and internal structure of the module subjected to field driving loads (hereafter referred to as Sample A) were examined to assess the degree of degradation. Subsequently, a power cycle test was conducted (Test conditions: T_{vjmax} = 150°C, ΔT_{vj} = 100°C) to evaluate the degradation of electrical characteristics and internal structure during the product warranty cycle. Testing continued beyond the product warranty cycle to confirm the failure cycles and failure modes.

Results and Discussion

Result 1: Field Driving Load Application Results. It was confirmed that there is no significant difference in electrical characteristics and internal structure before and after the application of field driving loads. Although a 1-3% increase in thermal resistance was observed compared to the product design value, it is considered that there is little degradation since the product sufficiently meets the specifications at the time of delivery.

Result 2: Power Cycle Test Results (Product Warranty). A power cycle test was conducted on Sample A, and it was confirmed that there is no significant difference in electrical characteristics before and after the test. It was also confirmed that the degree of degradation in the internal structure showed changes like those observed in normal power cycle tests.

Result 3: Power Cycle Test Results (Limit Evaluation). A limit evaluation was conducted on Sample A, which was tested up to the guaranteed cycles, and it failed at approximately 2.5 times the required guaranteed cycles. It was confirmed that the failure mode is the same as that observed in normal power cycle tests.

Due to the direct water-cooling type (grease-less structure), there was no deterioration in thermal resistance caused by grease leakage, which has minimized the fluctuation in thermal resistance after field operation to the utmost limit. Additionally, the DLB + resin sealing structure prevents environmental impacts while providing high thermal stress resistance, contributing to a longer lifespan.

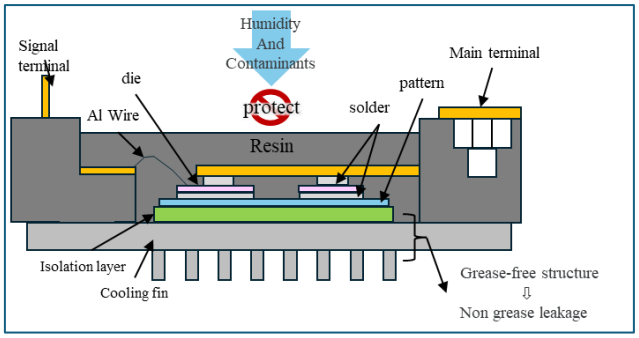

Figure 1 The cross-section of J1

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References

[1] K. Hussein, et al., “IPMs Solving Major Reliability Issues in Automotive Applications”, IEEE-ISPSD 2004, Proceedings, pp. 89-92.

[2] S. Inokuchi et al., “A new versatile high power Intelligent Power Module (IPM)”, PCIM –ASIA 2015 pp.205-209