COOLING OF PASSIVE POWER ELECTRONICS

by Jaco Dirker

Today power electronics form an integrated part of daily life and can be found in almost all electric powered residential, commercial and industrial devices and equipment. Power electronics refers to electronic processing of electrical power. In this process, electrical power is controlled by switching of power semiconductor devices (active power electronics) as well as electromagnetically storing energy in electrical and magnetic fields (passive power electronics) while the energy flow is directed through selective conduction paths. The losses/power efficiency of all these actions is of paramount importance in the processing. The lack for standardisation and the absence of a modular approach have been identified as a barrier to the development of more compact systems.

By the ongoing integration of power electronic components, an increase in the power density has been achieved, which unfortunately has led to higher internal heat generation densities and higher operating temperatures. Having an unfavourable effect on electronic behaviour and the reliability of the structures, thermal limitations rather than an electromagnetic limit is becoming a major stumbling block. In order to maintain the advances made in volume reduction of integrated power electronics, efficient and cost-effective methods for removing heat is of essence.

Recently an investigation was conducted where the performance of rectangular cross-section embedded solid-state heat extraction inserts were evaluated theoretically and experimentally. The purpose of these inserts was to increase thermal heat spreading and thus reducing steady-state peak temperatures by enabling less restricted heat transfer to the environment while at the same time enabling higher power densities within inner regions. Theoretically, the cross-sectional aspect ratio of such inserts was thermally optimised in three dimensions for a wide range of dimensional, thermal, and material property conditions.

In the dimensional range for application in power electronics, thin embedded continuous heat extraction layers were found to provide a maximised temperature reduction and optimised use of volume. Due to their relatively low electrical and high thermal conductivities, possible materials suitable for use as heat extractors in power electronics include aluminium nitride, beryllium oxide, and even, though costly at present, synthetic diamond.

The theoretical models drawn up for the heat-spreading performance of embedded heat extraction layers were validated experimentally using aluminium nitride to reduce the peak temperatures of ferrite, a ceramic material commonly used in power passive modules, operated at a load frequency of 1 MHz. Initial tests revealed an increase of 187% in the effective power density which could be accommodated with the use of embedded aluminium nitride heat extraction layers.

With improved manufacturing methods, interfacial thermal resistances within the new type structures can be reduced, further increasing the effectiveness of embedded heat extraction schemes. Also, due to the recent reduction in cost of synthetic diamond, its use might become feasible allowing for even more effective heat extraction.

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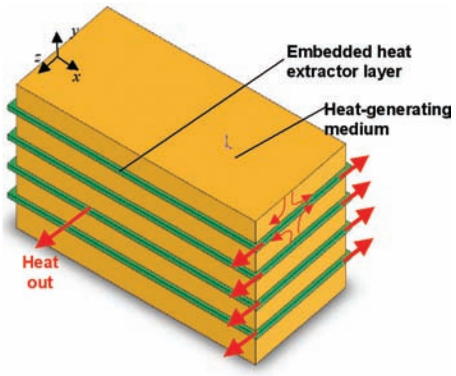

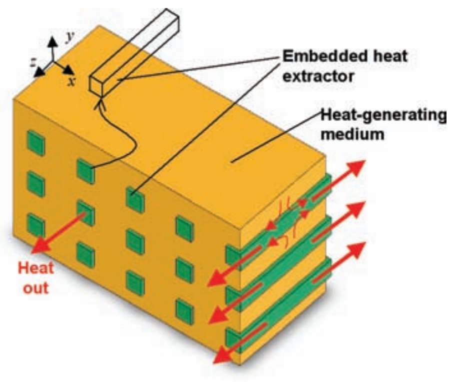

→ Schematic representations of embedded heat extraction insert schemes indicating the aided flow of heat to the environment.