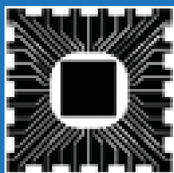

IeMRC

Abstract

Standard Project

High-performance low-cost power modules for energy smart network applications

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According to the UK Government's Low Carbon Transition Plan, by 2030 we will see a step change in intermittent generation delivered through both large and small scale renewable plants, more price responsive consumers enabled by smart meters and possible increases in demand for electricity from changes in power use, such as a move to electric vehicles. The electricity grid will to need to evolve in order to connect and integrate new technologies and enable more active management of fluctuations in supply and demand. Smart grids or networks, consisting of a collection of energy producers (generators), energy consumers, energy storage devices and power flow control elements combined with intelligent controls that adjust the operation and configuration of the network will be needed to ensure security of supply, optimal use of available energy resource and maximum efficiency. Power electronic systems enabled by the power modules that are the subject of this proposal will lie at the heart of the control elements of these smart networks.

The known requirements for IGBT modules in electricity network applications include high isolation voltage (>10 kV), excellent cooling performance, high reliability and a preference for fail-to-short-circuit behaviour in the event of device destruction. Present state-of-the-art manufacturing for plastic packaged IGBT modules involves the solder attachment of the dies to a substrate followed by ultrasonic bonding of IGBT emitter and diode anode connections, there being up to 600 individual bonds in a large module. Creation of such a large number of individual bonds is expensive, time consuming and a source of yield loss. During operation, the wires are a known reliability weak point and in the event of device destruction the bond wires typically fail open-circuit by a high energy fusing process.

This failure process is inherently unpredictable and the high energies dissipated within the module can lead to rupture of the module housing. In addition, the typical bond wire and bus-bar assembly leads to relatively high levels of parasitic inductance which compromises device switching performance leading to increased switching loss and/or over-rating of device blocking voltage. Finally, the thermal management arrangements in conventional modules take heat away from just one die surface, restricting the maximum heat flux that can be sustained for a given maximum junction temperature.

Planar or "sandwich" packages have no bond wires, can be cooled from both sides and can offer fail-to-short-circuit operation. Although potentially attractive, the assembly of such structures has historically proved complex and costly, involving a large number of piece parts and assembly processes. This project will deliver technologies to reduce the manufacturing costs and improve the performance of plastic packaged IGBT modules. Research into a high thermal performance low profile package, designed for low inductance and having fully bonded interconnects will deliver step improvements in performance/reliability and reduced manufacturing cost. An important characteristic of the package will be its capability to fail to short circuit, a unique feature which is highly beneficial in reducing electricity network system costs but is not currently available in plastic packaged IGBT modules.

The power electronic controls that form the application target of this research are excellent examples of high value systems that must be customised to meet individual customers' requirements. There is thus substantial potential for growth in the global market and the UK is in an excellent position to capitalise on this growth. Our long-term aspiration is that the step changes in technology described in this proposal will increase the competitiveness of UK power module manufacturing and enable UK system providers to rise to the challenges and opportunities presented by smart networks.