

Summary

The research presented in this work of thesis was carried out in VISHAY Semiconductor Italiana S.P.A. at Borgaro Torinese - Italy.

The aim of this thesis consists of the evaluation of new materials and the development of modern process technologies to be integrated into power modules. To validate these innovations, it has been necessary to conduct a characterization of their thermal and electrical properties and satisfy the required reliability tests.

Power modules are responsible for processing and transferring electrical power between a source and a load, according to customer requirements. Due to recent advancements in semiconductors, the demanded efficiency of these systems is getting higher, making the performances of the materials and the reliability, the focus of a new generation of power devices. Power modules are made up mainly by two parts: a substrate, whose purpose is to accommodate the semiconductors, to provide the electrical connections and the insulation between the components, and a package, whose aim is to protect the inner components from the environment and to enhance the mechanical robustness of the system.

The experimental output of this research into the power module framework can be divided into two parts: the first one where some alternative substrates to ceramic have been investigated, assembled and characterized; the second one where a molded package has been developed, analyzed and compared to a standard Vacuum Potting Gel (VPG) package. The methods involved have been schematized in chapter 3.

Direct Bonded Copper (DBC) is a multilayered copper/ceramic substrate that found large application for its good thermal conductivity and electrical insulation.

However, the new thermal requirements are leading to an increase in the mismatch between the copper and ceramic causing higher thermal stresses at the interfaces. For this reason, Insulated Metal Substrates (IMSS) were chosen as valid substrates. IMS is a multilayered structure made up of copper/polymer/copper or aluminum with good mechanical properties.

The selected power module is a silicon diode-based device with a full bridge configuration in an Emipak 1B package (VPG). It was used as a vehicle to validate four different IMS substrates, obtained by varying various design parameters. In chapter 4 the assembly process of these components is shown step by step. Subsequently a thermal evaluation about the capability of dissipating heat was conducted through a thermal resistance measurement. Also, the electrical properties were tested for evaluating if a different substrate could influence the dice performances. Furthermore, all the IMS substrates were submitted to power cycling test in order to understand in an accelerated way their number of cycles to failure for investigating their lifetime.

Finally, the existing packages are based on two main encapsulation technologies: Vacuum Potting Gel (VPG), with a gel as sealing, and Transfer Molding (TM), with Epoxy Molding Compound (EMC) as encapsulant. TM is a more recent technology that consists in injecting thermosetting pellets of EMC at high temperature (175°C) in a mold, where the substrates, with the assembled dice and passive elements, are placed into dedicated cavities connected by channels. The epoxy creates a unique and protective compact body.

This part of the work aims at demonstrating if power modules, with the same substrate and electrical configuration but different sealing materials, may have different behaviors at the same operating conditions. Therefore, the same substrates with the same dice have been assembled in both VPG and TM package. Furthermore, two EMC materials with different properties have been used. The assembly process for the molding package is illustrated step by step in Chapter 5. The different encapsulation methods have been evaluated from the thermal, electrical and reliability point of view to understand the performances of a molding package, the eventual differences between different epoxies and to demonstrate that molding does not damage the dice.