Packaging Technology Designed, Fabricated, and Assembled for High-Temperature SiC Microsystems

A series of ceramic substrates and thick-film metalization-based prototype microsystem packages designed for silicon carbide (SiC) high-temperature microsystems have been developed for operation in 500 °C harsh environments. These prototype packages were designed, fabricated, and assembled at the NASA Glenn Research Center. Both the electrical interconnection system and the die-attach scheme for this packaging system have been tested extensively at high temperatures. Printed circuit boards used to interconnect these chip-level packages and passive components also are being fabricated and tested.

NASA space and aeronautical missions need harsh-environment, especially high-temperature, operable microsystems for probing the inner solar planets and for in situ monitoring and control of next-generation aeronautical engines. Various SiC high-temperature-operable microelectromechanical system (MEMS) sensors, actuators, and electronics have been demonstrated at temperatures as high as 600 °C, but most of these devices were demonstrated only in the laboratory environment partially because systematic packaging technology for supporting these devices at temperatures of 500 °C and beyond was not available. Thus, the development of a systematic high-temperature packaging technology is essential for both in situ testing and the commercialization of high-temperature SiC MEMS.

Researchers at Glenn developed new prototype packages for high-temperature microsystems using ceramic substrates (aluminum nitride and 96- and 90-wt% aluminum oxides) and gold (Au) thick-film metalization. Packaging components, which include a thick-film metalization-based wirebond interconnection system and a low-electrical-resistance SiC die-attachment scheme, have been tested at temperatures up to 500 °C. The interconnection system composed of Au thick-film printed wire and 1-mil Au wire bond was tested in 500 °C oxidizing air with and without 50-mA direct current for over 5000 hr. The Au thick-film metalization-based wirebond electrical interconnection system was also tested in an extremely dynamic thermal environment to assess thermal reliability. The I-V curve of a SiC high-temperature diode was measured in oxidizing air at 500 °C for 1000 hr to electrically test the Au thick-film material-based die-attach assembly.
Prototype high-temperature microsystem packages composed of aluminum nitride and 96- and 90-wt% aluminum oxide substrates, and Au thick-film metalization being developed for SiC microsystems with sensors and electronic devices.

As required, the electrical resistance of a thick-film-based electrical interconnection system demonstrated low (2.5 times the room-temperature resistance of the Au conductor) and stable electrical resistance (decreased less than 5 percent during the 5000-hr continuous test). Also as required, the electrical isolation impedance between two neighboring printed wires (of the package shown in the preceding photographs) that were not electrically joined by a wire bond remained high (>0.4 GΩ) at 500 °C in air. Gold ribbon-bond samples (1 by 2 mil) survived 500 thermal cycles between room temperature and 500 °C (with 50 mA direct current), at the rate of 53 °C/min, without electrical failure. An attached SiC diode demonstrated low (<3.8 Ω-mm²) and relatively consistent forward resistance from room temperature to 500 °C. These results indicate that the prototype package and the compatible die-attach scheme meet the initial design standards for low-power, long-term, and high-temperature operation. This technology will be further developed and evaluated for various MEMS devices and systems.

Printed circuit boards to be used to interconnect these chip-level packages and passive components are being fabricated and tested. The following figure shows the design of a printed circuit board to be used to characterize eight-pin low-power (packaged) devices or packages at temperatures up to 500 °C.
A prototype high-temperature printed circuit board designed for chip-level packages made of aluminum nitride or aluminum oxide substrates is being developed. The printed circuit board shown is designed for testing a single package or a packaged device or system at high temperatures. The same ceramic substrate and thick-film metalization materials as those used for packages are used for printed circuit boards. The aluminum nitride board surface may be passivated by appropriate encapsulate materials before screen-printing thick-film metalization traces. The board design shown in the figure includes four units. Each unit provides 12 input/output interconnections to connect the board to the outside. This printed circuit board is designed for a single chip or package test at high temperatures with printed-circuit-board-level interconnections.

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