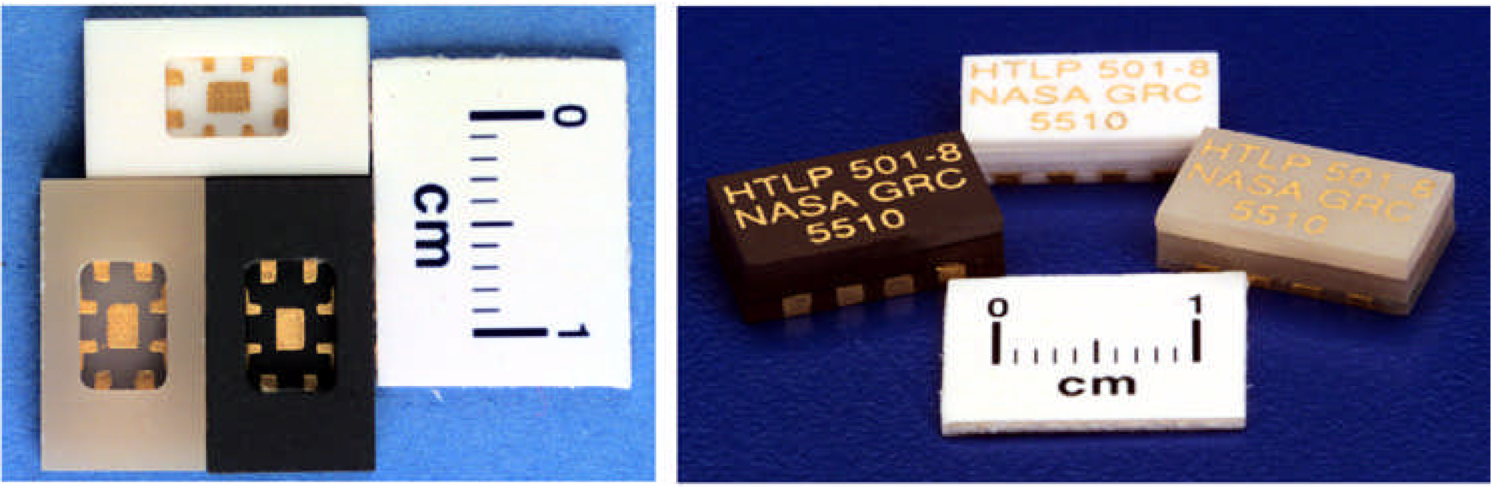
Packaging Technology Designed, Fabricated, and Assembled for High-Temperature SiC Microsystems

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[1] 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.

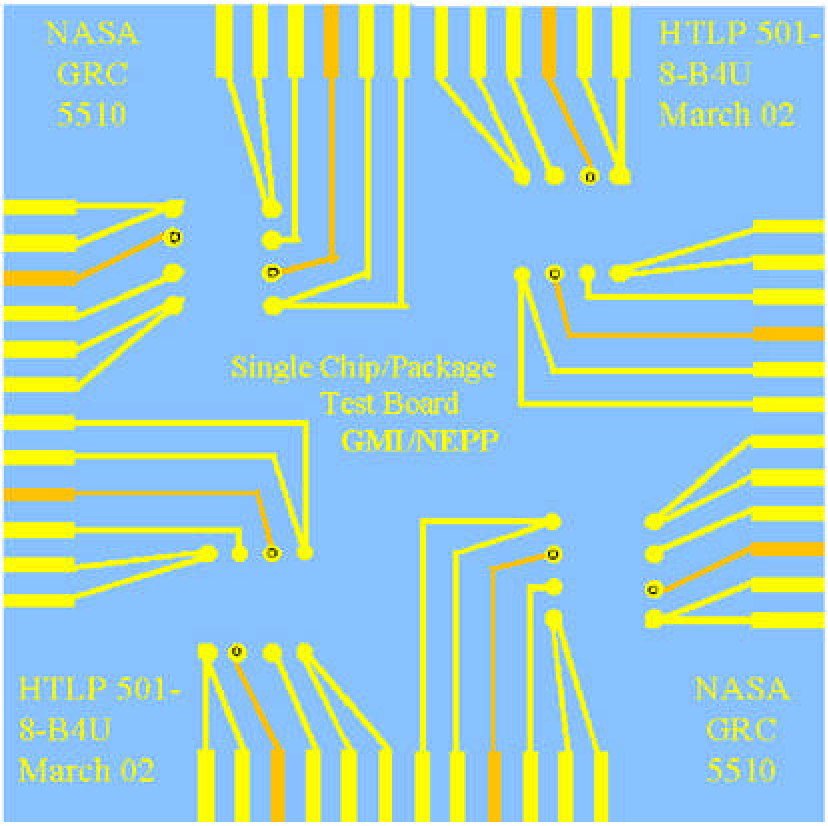


Prototype high-temperature microsystem packages composed of aluminum nitride and 96- and 90-wt% aluminum oxide substrates, and Au thick-film metalization being developed for SiC microsystems with sensors and electronic devices.

Long description of figure 1 Aluminum nitride, 96-wt% aluminum oxide, and 90-wt% aluminum oxide prototype high-temperature microsystem packages developed for SiC microsystems composed of MEMS sensors and electronic devices. Gold thick-film material is used for ceramic (package) substrate metalization. The picture on left shows the inside structure of these packages. Inside the package, there are eight wirebond spots surrounding the die-attach site for electrical interconnection between the microsystem chip to the package. The picture on right shows the outside of the package after being sealed. Outside the package, eight electrical input/output interconnections are provided by four vertical gold thick-film metalization lines along each package sidewall for connecting the packaged chip to a circuit board.

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-mm^2) 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.

Long description of figure 2 A prototype high-temperature printed circuit board is being developed for these chip-level packages, which are made of aluminum nitride or alumina substrates. 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.

Find out more about the research of Glenn's Sensors and Electronics Technology Branch
http://www.grc.nasa.gov/WWW/sensors/

Ohio Aerospace Institute (OAI) contact: Dr. Liang-Yu Chen, 216-433-6458, Liangyu.Chen@grc.nasa.gov
Glenn contact: Dr. Lawrence G. Matus, 216-433-3650, Lawrence.G.Matus@nasa.gov
U.S. Army, Vehicle Technology Directorate at Glenn contact: Dr. Jih-Fen Lei, 216-433-6328, Jih-Fen.Lei@grc.nasa.gov
Author: Dr. Liang-Yu Chen

Headquarters program office: OAT, OSS
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