Microwave Module Interconnection and Packaging Using Multilayer Thin Film/Thick Film Technology

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Abstract

This paper describes a multichip T/R module packaging technique that combines thin film and multilayer thick film metalizations on a single alumina substrate with ceramic seal ring technology to provide a high density, wide bandwidth, high performance package.

Introduction

The package for a MMIC-based microwave module is expected to perform several functions. It must protect the components inside from the outside environment, shield the contents from outside electrical interference, prevent radiation of electrical interference from the module, and provide signal lines in and out of the enclosure. In addition to these basic requirements, a multichip module package can provide DC/logic distribution and chip-to-chip interconnection. Conventional microwave packages have traditionally met these needs by enclosing a substrate or substrates in a metal box. This paper describes a multichip MMIC T/R module packaging technique that combines thin film and multilayer thick film metalizations on a single alumina substrate with ceramic seal ring technology to provide a high density, wide bandwidth, high performance package.

A 3.0 to 6.0 GHz transmit/receive module was designed using this packaging technique [1]. This module contains eight GaAs MMIC chips and four digital GaAs Element Control Interface (ECI) chips, as well as off-chip matching networks for the power amplifiers and RF bypass capacitors. The resulting T/R module features two independent 16-bit receive channels and required only three input voltages and six data and control lines. Prototype units were fabricated with satisfactory results.

Package Description

The wideband module package is 3.3 inches long by 1.17 inches wide with the width constrained by the element spacing of the phased array antenna. A photograph of the package is shown in Figure 1.

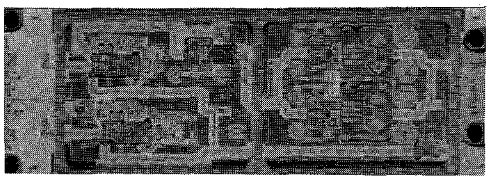

Figure 1. Wideband T/R Module Package

Voltage and data line pads are located at the left end of the package, along with right angle microstrip-to-stripline transitions which connect the module to the stripline distribution circuit. Transmit and receive lines at the right end of the package connect to an external circulator.

The cross section of the module is shown in Figure 2. The 25 mil thick, 99.6% alumina substrate serves as a "motherboard" for the module and has a thin film circuit on top and a four-metal layer, thick film circuit on the bottom. Connections between thick and thin film layers are made through holes laser drilled in the substrate. The substrate is soldered to a copper-molybdenum-copper base with gold-tin solder and a metalized ceramic seal ring is hermetically attached to the top of the substrate with seal glass. The package is sealed after chip population with a 10 mil thick Kovar lid. MMIC chips and other components are mounted on copper-molybdenum-copper carriers which are attached to the package base with solder or epoxy through cutouts in the alumina substrate.

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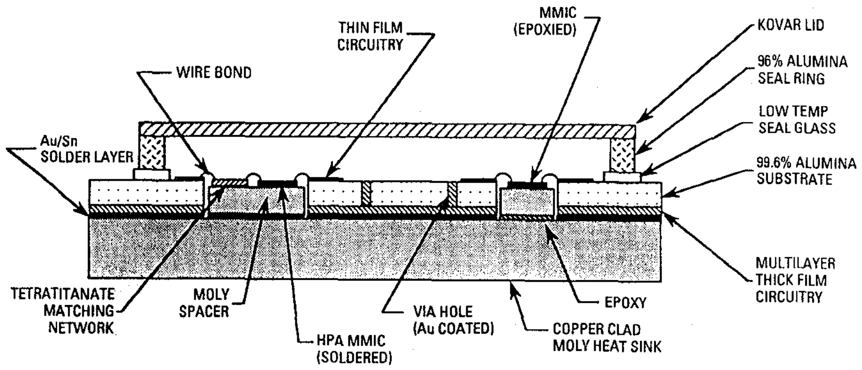

Figure 2. Package Cross Section

One key to this packaging technique is the use of a thin film circuit on the top of the substrate. The smooth substrate, high purity gold conductors, and accurate feature definition provide the usual benefits of a thin film microwave circuit, including wideband, low loss, circuit elements with small features such as Lange couplers, spiral inductors, and high impedance DC bias lines. In addition to the microwave benefits, the use of 0.003 inch wide lines for DC and logic traces allows for increased circuit density, making it possible to enclose two wideband receive channels within the available width. The use of thin film resistors for voltage conditioning greatly reduces the number of input voltages, simplifying the power supply design and making optimum use of limited I/O pad space.

Even with the increased circuit density permitted by the thin film metalization, it is impossible to route all of the necessary signals on a single circuit layer. Some technique for multilayer signal distribution is required. Because of its maturity and low cost, multilayer gold thick film was chosen over other candidates. The thick film assembly on the current package provides four metalization layers, separated with layers of dielectric. Inner and outer ground planes shield a DC and logic distribution layer and a power amplifier drain bias plane. The use of an entire layer for drain bias lines minimizes voltage drop during the high current pulses required for high power output. Vias from layer to layer implement signal connections and the important inner-to-outer ground connections. The outer ground plane forms the soldering surface for the metal base. Figure 3 shows the DC/logic layer and Figure 4 shows the drain bias layer.

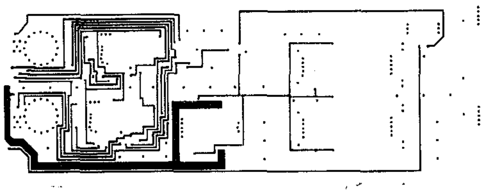

Figure 3. DC/Logic Circuit Layer

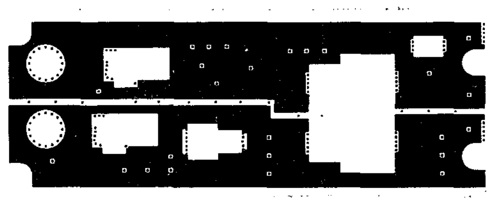

Figure 4. Drain Bias Circuit Layer

The 0.040 inch thick copper-molybdenum-copper base acts as a heat sink for the MMIC chips attached to it and allows the package to be attached to the next higher assembly with screws. The copper-molybdenum-copper composite material was chosen for its close thermal expansion match to alumina. This close match results in a package which is flat to within 0.002 in./in. after gold/tin eutectic base attach.

The hermetic enclosure is formed with a partially metalized ceramic seal ring which is attached to the mother substrate with seal glass. The "figure-eight" shaped ring forms two separate cavities, improving RF isolation between high gain stages. After the ring is attached, low temperature gold thick film ink is painted down the wall and onto the thin film circuit to complete the wall and lid grounding. The enclosure is completed with a Kovar lid attached using a gold/tin solder preform and conventional seam sealing techniques.

Package Fabrication

This package begins as a single piece of alumina, slightly thicker than the final thickness of 0.025 inch, which is laser drilled with a multi-up pattern of via holes. The multilayer thick film circuit is formed using a conventional print-fire process for each layer. After the thick film circuit is complete, the top surface of the substrate is lapped and polished to the final thickness and flatness.

The application of thin film metalization to a substrate with thick film on the back side is not a simple process. The chemical processes associated with thin film circuit definition are incompatible with the thick film layer, which must be protected. This includes all of the top-to-bottom via holes. Additionally, the thin film metalization must survive later processing of the package at glass sealing temperatures. Development of a reliable thin film process was one of the keys to the success of this technique.

Once the multi-up substrate has been patterned with both thick and thin film circuits, it is laser machined to its final shape, including internal cutouts for the MMIC chips and carriers. After machining, the seal wall is attached with low temperature seal glass and painted with gold ink to complete the wall grounding. With the wall attached, the package is completed by the gold-tin solder attachment of the metal base.

Package Performance

The use of the ceramic wall attached with seal glass allows the use of a simple microwave feed through the package wall. Package isolation for a multi-chip module is difficult to define and even more difficult to test. Many possible leakage paths exist due to the substrate circuit complexity. Isolation measurements of a package loaded with 50Ω resistors are shown in Figure 5. These measurements show end-to-end isolation in excess of 60 dB over most of the octave band, with worst case isolation greater than 45 dB. End-to-end measurements of an empty package may miss internal paths around individual chip sites that could result in module problems. Perhaps the most significant measurement made so far has been of the populated module which, with over 50 dB of small signal gain in the transmit path, has shown no signs of oscillation.

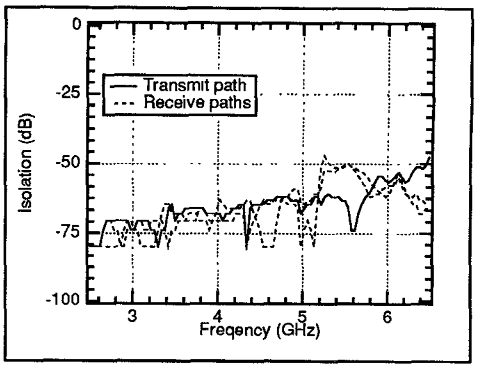

Figure 5. Isolation of Loaded Package

References

1. J.J. Komiak and A.K. Agrawal, "Design and Performance of Octave S/C-Band MMIC T/R Modules for Multifunction Phased Arrays", IEEE Trans. on Microwave Theory and Techniques, Vol. 39, No. 12, pp. 1955-1963, December 1991.

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