Title: MICROWAVE DEVICE AND METHOD FOR MAKING SAME

Abstract: A microwave device, including a substrate (12) having a first surface and a second surface, a plurality of electrically conductive vias (24) extending through the substrate from the first surface to the second surface, a first interconnect trace (14) connected to the first surface of the substrate and electrically connected to a first of the plurality of vias, a second interconnect trace (14) connected to the first surface of the substrate and electrically connected to a second of the plurality of vias, and a microwave circuit chip (18) connected to the second surface of the substrate and electrically connected to the first and second conductive vias.
MICROWAVE DEVICE AND METHOD FOR MAKING SAME

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BACKGROUND OF INVENTION

Field of Invention

The present invention relates generally to microwave devices and, more particularly, to microwave devices having transmission lines connected to a first surface of a substrate and a microwave circuit chip connected to a second surface of the substrate.

Description of the Background

In the microwave industry, active microwave circuits, such as monolithic microwave integrated circuits (MMICs), are typically electrically connected to a substrate having peripheral circuitry according to traditional interconnect approaches using wire bonding. The performance of such traditional interconnect approaches, however, is often unacceptable for higher frequency applications, such as above 2 GHz. For example, current wire bonding technology prevents wire bonds from being formed, which are less than about ten mils. This drawback, coupled with the fact that wire bonds cannot be formed with acceptably tight tolerances at such dimensions, often results in unpredictable and/or unacceptable transmission characteristics for the resulting microwave devices. In addition, traditional interconnect approaches are highly labor intensive, thus minimizing high volume productivity and associated economies of scale benefits.

In view of these drawbacks, some microwave device manufacturers have mounted microwave circuits using flip chip technology. Flip chip mounting has found wide application in the semiconductor packaging and assembly industry for digital and low frequency analog chips because it typically provides a cost and size reduction for the resulting semiconductor package. In contrast to the conventional wire bonding interconnect approach, the flip chip mounting technique involves flipping the chip and connecting the chip’s top surface to the substrate. A number electrically conductive flip chip bumps, depending upon the complexity of the chip, are typically provided between the chip’s top surface and the
substrate to provide an electrical connection between the chip and the substrate, and hence the other components connected to the top surface of the substrate.

In the microwave industry, however, because of difficulties in matching the orientation of the transmission mode fields for the circuits and the substrate, efforts to incorporate flip chip mounting have been primarily limited to devices employing co-planar waveguide (CPW) structures as the transmission media. That is, the circuit and substrate are both designed to support CPW. Many, if not most, commercially available MMICs, however, are designed for microstrip transmission modes, and are therefore ill suited for CPW transmission structures. Accordingly, using the flip chip technology for microwave devices has ordinarily necessitated redesign or modification of existing microwave circuits to make them compatible for CPW. In addition, the CPW structure has the additional drawback that it still typically requires the use of wire bonding to balance the ground strips of the CPW transmission line structure.

Incorporating flip chip mounting for microwave devices additionally provides disadvantages with respect to thermal handling, especially for power devices. Numerous thermal flip chip bumps must ordinarily be provided between the chip and the substrate to provide a manner for dissipating heat from the chip. The use of the additional thermal flip chip bumps, however, also ordinarily requires a redesign or modification of existing microwave circuits to accommodate the additional bumps. Furthermore, the use of the additional thermal bumps has associated cost, performance, and production drawbacks.

In addition, when using either a traditional interconnect approach or flip chip mounting, external packaging is commonly required to provide electromagnetic and environmental protection for the microwave circuit. Consequently, additional processing steps are required, thereby incurring associated processing costs.

Accordingly, there exists a need for a microwave device in which the microwave circuit is interconnected to the substrate in such a manner as to be acceptable for microwave frequency applications and which does not require the redesign of microwave circuits to accommodate unpopular microwave transmission structures. There further exists a need for a microwave device, which provides reliable and efficient thermal handling. There further exists a need for microwave device, which does not require additional packaging to provide electromagnetic and environmental protection for the microwave circuit.
BRIEF SUMMARY OF INVENTION

The present invention is directed to a microwave device and a method of fabricating
the microwave device. According to one embodiment, the microwave device includes a
substrate having a first surface and a second surface, a plurality of electrically conductive vias
extending through the substrate from the first surface to the second surface, a first
interconnect trace connected to the first surface of the substrate and electrically connected to a
first of the plurality of vias, a second interconnect trace connected to the first surface of the
substrate and electrically connected to a second of the plurality of vias, and a microwave
circuit chip connected to the second surface of the substrate and electrically connected to the
first and second conductive vias. The microwave device may further include a ground plate
connected to the second surface of the substrate, wherein the ground plate includes a recessed
portion in which the microwave circuit chip is disposed.

The method may include, according to one embodiment: forming a first plurality of
viases a substrate, the vias extending from a first surface of the substrate to a second surface
of the substrate; forming a first plurality of interconnect traces on the first surface of the
substrate such that each interconnect trace is electrically connected to one of the vias; and
connecting a first microwave circuit chip to the second surface of the substrate such that the
first microwave circuit chip is electrically connected to the first plurality of vias.

The microwave device of the present invention provides an advantage over prior art
microwave devices in that it provides a manner for interconnecting most existing microwave
circuits, including microstrip-based MMICs, and a substrate without wire bonding or
modification of the circuit. The microwave device of the present invention further provides
for efficient and reliable thermal handling. The present invention provides the further
advantage that the microwave devices are more reproducible and consistent, thus reducing
tuning requirements and providing enhanced yield and improved performance. Another
advantage of the present invention is that the assembly technique itself provides packaging of
the microwave chip, thus obviating the need for additional packaging. Moreover, when used,
for example, in constructing a subsystem module, the present invention obviates the need to
obtain pre-packaged chips because the chips are packaged as part of the assembly process,
thereby reducing the cost and size of the module. These and other benefits of the present
invention will be apparent from the detailed description hereinbelow.
DESCRIPTION OF THE FIGURES

For the present invention to be clearly understood and readily practiced, the present invention will be described in conjunction with the following figures, wherein:

Figure 1 is a cross-sectional side-view of a microwave device according to one embodiment of the present invention;

Figure 2 is a plan view of the upper surface of the substrate of the microwave device of Figure 1 according to one embodiment of the present invention;

Figure 3 is a plan view of the lower surface of the substrate of the microwave device of Figure 1 according to one embodiment of the present invention;

Figure 4 is a cross-sectional side view of the microwave device according to another embodiment of the present invention; and

Figure 5 is a cross-sectional side view of the microwave device according to another embodiment of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

Figure 1 is a cross-sectional side view of a microwave device 10 according to one embodiment of the present invention. The device 10 includes a substrate 12 having interconnect traces 14 connected to an upper surface 16 of the substrate 12, and a microwave circuit chip 18 electrically connected to the interconnect traces 14 from a lower surface 20 of the substrate 12. The microwave circuit chip 18 is electrically connected to the interconnect traces 14 via a number of electrically conductive bumps 22 and a number of electrically conductive vias 24 extending through the substrate 12. The device 10 may also include an electrically conductive ground plate 26 having an upper portion 28 connected to the lower surface 20 of the substrate 12. The ground plate 26 includes a recessed portion 30 in which the microwave circuit chip 18 is disposed.

The substrate 12 may be an insulative material such as, for example, ceramic, glass, woven fiberglass laminates, and Teflon®-based laminates, including Duroid® microwave laminates, or any other insulative material used for microwave printed circuit boards. The lower surface 20 of the substrate 12 may have formed thereon an electrically conductive ground plane, as described further hereinbelow with respect to Figure 3. The substrate 12 may further define a number of holes extending from the upper surface 16 of the substrate 12 to the lower surface 20. The holes in the substrate 12 may be filled with electrically
conductive material, such as metal or conductive polymers, to form the conductive vias 24. The conductive vias 24 may be formed, for example, by thick film techniques (such as screen-printing of conductive paste) or doctor blading.

The ground plate 26 includes an upper portion 28 which may be connected to the bottom surface 20 of the substrate 12. The upper portion 28 of the ground plate 26 also includes a recessed portion 30 in which the microwave circuit chip 18 is disposed. The ground plate 26 is electrically conductive and may be, for example, metal, such as aluminum or copper, or an insulator having a conductive coating. The ground plate 26 may be formed from a single piece of material, or it may be formed from the bonding of several pieces, even of different material. The ground plate 26 may be mounted to the substrate 12, for example, by epoxy bonding, as discussed hereinbelow. The device 10 of the present invention will be described herein as including the ground plate 26, although certain benefits of the present invention may be realized without the ground plate 26. For example, for an embodiment of the present invention not including the ground plate 26, the ground plane formed on the lower surface 20 of the substrate 12, as described further hereinbelow with respect to Figure 3, may act as the lower conductor for a microstrip-based device.

The interconnect traces 14 include electrically conductive material such as, for example, aluminum or copper, and may be formed on the upper surface 16 of the substrate 12 by, for example, conventional thick or thin film photolithographic deposition and etching techniques. The interconnect traces 14 are in contact with the vias 24, and hence are electrically connected to the microwave circuit chip 18 though the vias 24 and the bumps 22, as described hereinbelow. The interconnect traces 14 may include transmission lines for various microwave transmission modes including, for example, microstrip, co-planar waveguide (CPW), grounded CPW, and stripline transmission modes. For example, for an embodiment using a microstrip transmission mode, the interconnect traces 14 may be microstrip transmission lines which, in conjunction with the ground plate 26 and/or the ground plane formed on the lower surface 20 of the substrate 12, form a microstrip transmission medium, with the substrate 12 as the dielectric therebetween. The lowest order transmission mode for such a medium may be a quasi-TEM transmission mode, however, at higher frequencies, higher-order transmission modes may be supported. For an embodiment using a CPW transmission mode, the interconnect traces 14 may include a center conducting interconnect trace and two flanking conducting interconnect traces. For an embodiment of
the present invention using a stripline transmission mode, the substrate 12 may be multi-
layered, including additional insulative (dielectric) layers and ground planes to support a
stripline transmission mode.

The electrically conductive bumps 22 provide an electrical connection between the
vias 24 (and hence the interconnect traces 14) and bonding pads, or electrodes, of the
microwave circuit chip 18. The bumps 22 may be formed, for example, of metal, such as
gold, or conductive polymers, and may have a diameter of approximately four mills or less.
To facilitate the connection between the vias 24 and the bumps 22, electrically conductive
contact pads 32 may be provided on the lower surface 20 of the substrate 12. The contact
pads 32 may be formed, for example, from metal or conductive polymers, and may be
formed, for example, by conventional photolithographic film deposition and etching
techniques or conventional PCB fabrication techniques.

The microwave circuit chip 18 may be a die having fabricated thereon a microwave
circuit. The die may be fabricated from, for example, gallium arsenide (GaAs), although
other semiconductor materials, such as silicon, gallium nitride (GaN), and silicon carbide,
may also be used. The circuit may be any type of microwave circuit including, for example, a
transistor, such as a field effect transistor (FET) or a heterojunction bipolar transistor (HBT),
or a number of transistors. For example, the microwave circuit may be a power amplifier
having different amplification stages. According to another embodiment, the microwave
circuit may be a low noise amplifier. In addition, the microwave circuit may be a monolithic
microwave integrated circuit (MMIC) including, for example, a power amplifier MMIC, a
low noise amplifier MMIC, an up-down converter MMIC, a mixer MMIC, a transceiver
MMIC, and an oscillator MMIC. Further, the MMICs used in the present invention may, for
example, support a microstrip transmission mode.

The microwave circuit chip 18 may have electrically conductive bonding pads or
electrodes for connection to the interconnect traces 14 through the vias 24 and the bumps 22,
and may have a conductive portion at a lower surface 34 of the microwave circuit chip 18.
The conductive portion at the lower surface 34 may act as a signal ground for the chip 18, as
well as provide for heat dissipation. A thin, electrically conductive shim may be attached to
the conductive portion at the lower surface 34 of the chip 18, as described hereinbelow. The
chip 18 may be mounted to the substrate 12 using, for example, flip chip mounting
techniques, such as thermal compression or epoxy bonding. It should be noted, however, that
according to the present invention, unlike conventional flip chip bonding, the microwave circuit chip 18 is not "flipped." Rather, the "top" or active surface of the microwave circuit chip 18 is connected to the substrate 12, and the "bottom" or ground surface of the microwave circuit chip 18 is not, thereby maintaining the orientation of the transmission fields for the chip 18 and the substrate 12, and obviating the need for wire bonding. Additionally, the device 10 of the present invention may use most existing microwave circuit chips without having to modify the chip to support different transmission modes.

In addition, with the microwave device 10 of the present invention, the ground plate 26 may provide a signal ground for the microwave circuit chip 18, as well as a thermal conductor to facilitate the dissipation of heat from the microwave circuit chip 18, if needed. In addition, with the microwave circuit chip 18 disposed in the recessed portion 30 of the ground plate 26, the ground plate 26 provides electromagnetic and environmental protection for the microwave circuit chip 18. Consequently, the ground plate 26 may prevent electromagnetic radiation from the chip 18 from interfering with other devices, as well as prevent radiation from other devices from interfering with the operation of the chip 18. In addition, the ground plate 26 may prevent environmental conditions, such as moisture, from interfering with the operation of the chip 18.

Figure 2 is a plan view of the upper surface 16 of the substrate 12 according to one embodiment of the present invention. The upper surface 16 of the substrate 12 includes the interconnect traces 14 and some distributed and lumped circuit elements 36. The circuit elements 36 may be, for example, thick film resistors and capacitors. The interconnect traces 14 and the circuit elements 36 may be formed, for example, by thick or thin film technology. Some of the interconnect traces 14, in conjunction with the circuit elements 36, may provide impedance matching or bias circuitry for the microwave circuit chip 18. In addition, discrete components, such as resistors, capacitors, and integrated circuits, may be surface-mounted to the upper surface 16 of the substrate 12.

Figure 3 is a plan view of the lower surface 20 of the substrate 12 according to one embodiment of the present invention. As shown in Figure 3, the substrate 12 includes a ground plate 38 of electrically conductive material covering the entire lower surface 20 of the substrate 12 except for a window 39. The location of the window 39 corresponds to the location of the recessed portion 30 of the ground plate 26 when the ground plate 26 is attached to the lower surface 20 of the substrate 12. Located within the window 39 are the
contact pads 32, which correspond in position to the location of the bonding pads of the microwave circuit chip 18. According to another embodiment of the present invention, the lower surface 20 of the substrate 12 does not include the ground plane 38. For such an embodiment, the ground plate 26 is connected directly to the lower surface 20 of the substrate 12.

Figure 4 is a cross-sectional side-view of the microwave device 10 according to another embodiment of the present invention. The device 10 of Figure 4 is similar to that of Figure 1, except that it includes an isolation device 40 extending from the upper surface 16 of the substrate 12 to the lower surface 20 and between the interconnect traces 14. The isolation device 40 may be used, for example, to provide electromagnetic isolation between interconnect traces 14 of the device 10. It may be beneficial to provide the isolation device 40 between certain interconnect traces 14, such as when the interconnect traces 14 are sufficiently proximate that coupling therebetween may occur. Coupling between interconnect traces 14 may result, for example, when the microwave circuit chip 18 is relatively small, such as when the chip 18 includes, for example, only a single transistor, or where the chip 18 has a very high gain.

According to one embodiment, the isolation device 40 may include microwave frequency radiation absorbing material such as, for example, Eccosorb® microwave absorber (Eccosorb is a federally registered trademark of Emerson & Cuming, Inc., Randolph, Massachusetts). According to another embodiment, the isolation device 40 may include an electrically conductive material, such as metal or conductive polymers. For such an embodiment, the isolation device 40 may be coupled to ground, such as the interface between the lower surface 20 of the substrate 12 and the ground plate 26.

Benefits of the present invention may be realized not only for microwave devices 10 including a single microwave circuit chip 18, as discussed hereinbefore with respect to Figures 1-4, but may also be realized in microwave devices 10 including a plurality of microwave circuit chips 18, such as may be used for multi-chip modules (MCM) or subsystem modules. Figure 5 is a cross-sectional side-view of the microwave device 10 according to such an embodiment. The device 10 illustrated in Figure 5 includes two microwave circuit chips 18a, 18b, although the benefits of the present invention may be realized with any number of microwave circuit chips 18. In the illustrated embodiment, the microwave circuit chips 18a, 18b are disposed in separate recessed portions 30a, 30b of a
common ground plate 26. According to other embodiments, multiple ground plates 26 may be attached to the lower surface 20 of the substrate 12, each including one or more recessed portions 30 for containing at least one microwave circuit chip 18. Other embodiments of the device 10 illustrated in Figure 5 may include the isolation device 40, as described hereinbefore with respect to Figure 4, to isolate certain interconnect traces 14. Thus, the present invention obviates the need to obtain pre-packaged chips in constructing a subsystem module, as is currently customary in the industry, since the chips 18 are packaged as part of the assembly process, thereby reducing the cost and size of the module.

In addition, according to such an embodiment, the first chip 18a may include a first type of semiconductor material, such as GaAs, and the second chip 18b may include, for example, a second, less expensive, type of semiconductor material, such as silicon. According to such an embodiment, those components requiring the first semiconductor material for performance purposes, such as active and/or high frequency components, may be concentrated on the first chip 18a, and other components not requiring the first type of semiconductor material may be concentrated on the second chip 18b.

To fabricate the device 10 according to one embodiment of the present invention, the vias 24 may be formed in holes of the substrate 12 as discussed hereinbefore, and the substrate 12 may be processed using, for example, thick or thin film technology, to produce the interconnect traces 14 and the circuit elements 36 on the upper surface 16 of the substrate. The bottom surface 20 of the substrate 12 may then be coated with the conductive ground plate 38, except for the window 39 where the microwave circuit chip 18 is to be attached. The ground plate 38 may be formed, for example, by using vacuum metallization or sputtering. Before, after, or simultaneously with the coating of the lower surface 20 of the substrate 12, the contact pads 32 may be formed on the lower surface 20 of the substrate 12 within the window 39.

To attach the chip 18 to the substrate 12, a thin, electrically conductive shim may be eutectically attached to the lower surface 34 of the chip 18. The shim may have a surface area slightly larger than the chip 18, and may be made, for example, of a material having a coefficient of thermal expansion (CTE) matching the material comprising the chip 18. The shim may include, for example, elemental metal or composite metal such as molybdenum, CuW, Cu/Mo/Cu, or aluminum silicon carbide. The shim facilitates chip handling during the fabrication process and provides a buffer for thermal expansion mismatch. The bumps 22
may then be attached to the bonding pads of the chip 18 by ball bonders. The chip 18 may then be attached to the lower surface 20 of the substrate 12 by, for example, thermal compression using a flip-chip die attach machine. The ground plate 26 may then be attached to the lower surface 20 of the substrate 12 and the shim on the lower surface 34 of the chip 18 with, for example, conductive epoxy. Consequently, the manufacture of the device 10 of the present invention may be fully automated. Thereafter, discrete components, such as resistors, capacitors, and integrated circuits, may be connected to the upper surface 16 of the substrate 12 as desired. A lid (not shown) of, for example, ceramic or plastic, may be placed over the device 10, although it is not necessary. In addition, lead frames (not shown) may be bonded to the upper surface 16 of the substrate 12 during the processing to provide for external connectivity of the device 10 if desired.

Accordingly, the microwave device 10 of the present invention provides a manner for interconnecting existing types of microwave circuits chips 18, including microstrip-based MMICs, and a substrate 12 without the use of wire bonding or modification of the circuit. In addition, by using flip chip mounting techniques to interconnect the microwave circuit chip 18 and the substrate 12, the manufacturing process may be automated and the yield increased. Moreover, by eliminating wire bonding, the device 10 is more reproducible and consistent, thus reducing tuning requirements and providing enhanced yield and improved performance. Additionally, by connecting the ground plate 26 to the lower surface 34 of the chip 18, efficient and reliable thermal handling of the chip 18 is provided. Furthermore, the assembly technique of the present invention itself provides packaging for the microwave circuit chip 18, thus obviating the need for additional packaging.

In addition, another benefit of the present invention is that for an embodiment in which the microwave circuit chip 18 includes an expensive semiconductor material such as GaAs, the chip 18 may only include the active elements of the circuit formed on the chip 18, and the passive elements, such as the impedance matching and bias circuitry, may be formed on the substrate 12. Accordingly, the chip 18 does not need to include the passive elements of the circuit, which normally occupy a large chip area, thereby minimizing the amount of expensive semiconductor material needed by the chip 18.

Although the present invention has been described herein with respect to certain embodiments, those of ordinary skill in the art will recognize that many modifications and variations of the present invention may be implemented. The foregoing description and the
following claims are intended to cover all such modifications and variations. Furthermore, the materials and processes disclosed are illustrative, but are not exhaustive. Other materials and processes may also be used to make devices embodying the present invention. In addition, the described sequences of the processing may also be varied.
CLAIMS

What is claimed is:

1. A microwave device, comprising:
   a substrate having a first surface and a second surface;
   a plurality of electrically conductive vias extending through the substrate from the
   first surface to the second surface;
   a first interconnect trace connected to the first surface of the substrate and electrically
   connected to a first of the plurality of vias;
   a second interconnect connected to the first surface of the substrate and electrically
   connected to a second of the plurality of vias; and characterized by
   a microwave circuit chip connected to the second surface of the substrate and
   electrically connected to the first and second conductive vias.

2. The device of claim 1, wherein the microwave circuit chip includes a
   transistor.

3. The device of claim 1, wherein the microwave circuit chip includes a MMIC.

4. The device of claim 3, wherein the microwave circuit chip includes a
   microstrip-based MMIC.

5. The device of claim 4, wherein the first and second interconnect traces include
   first and second microstrip transmission lines.

6. The device of claim 1, wherein the microwave circuit chip is electrically
   connected to the first and second vias by a plurality of electrically conductive bumps.

7. The device of claim 6, wherein the microwave circuit chip includes a plurality
   of bonding pads on a first surface of the microwave circuit chip, wherein the bonding pads are
   electrically connected to the bumps.

8. The device of claim 1, wherein a portion of the second surface of the substrate
   is coated with an electrically conductive material.

9. The device of claim 1, further comprising a ground plate connected to the
   second surface of the substrate, the ground plate including a recessed portion, wherein the
   microwave circuit chip is disposed in the recessed portion.

10. The device of claim 1, further comprising an isolation device connected to the
    first surface of the substrate and between the first and second interconnect traces.
11. The device of claim 10, wherein the isolation device includes a microwave frequency absorbing material.

12. The device of claim 10, wherein the isolation device extends from the first surface of the substrate to the second surface of the substrate and between the first and second vias.

13. The device of claim 1, further comprising a thick film circuit element connected to the first surface of the substrate.

14. The device of claim 13, wherein the thick film circuit element is selected from the group consisting of a resistor and a capacitor.

15. The device of claim 1, further comprising a thin film circuit element connected to the first surface of the substrate.

16. The device of claim 15, wherein the thin film circuit element is selected from the group consisting of a resistor and a capacitor.

17. The device of claim 1, further comprising a discrete electrical component connected to the first surface of the substrate.

18. A microwave device, comprising:
   a substrate having a first surface and a second surface;
   a first plurality of electrically conductive vias extending through the substrate from the first surface to the second surface;
   a first plurality of interconnect traces connected to the first surface of the substrate, wherein each of the first plurality of interconnect traces is electrically connected to one of the first plurality of vias; and characterized by
   a ground plate connected to the second surface of the substrate, the ground plate including a recessed portion; and
   a microwave circuit chip disposed in the recessed portion of the ground plate and electrically connected to the first plurality of the conductive vias.

19. The device of claim 18, wherein the microwave circuit chip includes a transistor.

20. The device of claim 18, wherein the microwave circuit chip includes a MMIC.

21. The device of claim 20, wherein the microwave circuit chip includes a microstrip-based MMIC.
22. The device of claim 21, wherein the first plurality of interconnect traces includes a first plurality of microstrip transmission lines.

23. The device of claim 18, further comprising a first isolation device connected to the first surface of the substrate and between the first plurality of interconnect traces.

24. The device of claim 23, wherein the first isolation device includes a microwave frequency absorbing material.

25. The device of claim 23, wherein the first isolation device extends from the first surface of the substrate to the second surface of the substrate and between the first plurality of vias.

26. The device of claim 18, wherein the microwave circuit chip is electrically connected to the first and second vias by a plurality of electrically conductive bumps.

27. The device of claim 26, wherein the microwave circuit chip includes a plurality of bonding pads on a first surface of the microwave circuit chip, wherein the bonding pads are electrically connected to the bumps.

28. The device of claim 26, wherein a second surface of the microwave circuit chip is in electrical and thermal communication with the ground plate.

29. The device of claim 28, wherein a portion of the second surface of the substrate includes an electrically conductive coating, wherein the coating is in electrical and thermal communication with the ground plate.

30. The device of claim 28, further comprising an electrically conductive shim interposed between the second surface of the microwave circuit chip and the ground plate.

31. The device of claim 18, wherein the ground plate includes a second recessed portion, and further comprising:

- a second plurality of conductive vias extending through the substrate from the first surface to the second surface;

- a second plurality of interconnect traces, wherein each of the second plurality of interconnect traces is connected to one of the second plurality of conductive vias; and

- a second microwave circuit chip disposed in the second recessed portion of the ground plate and electrically connected to the second plurality of conductive vias.

32. The device of claim 31, further comprising a second isolation device connected to the first surface of the substrate and between the second plurality of interconnect traces.
33. The device of claim 18, further comprising a thick film circuit element connected to the first surface of the substrate.

34. The device of claim 33, wherein the thick film circuit element is selected from the group consisting of a resistor and a capacitor.

35. The device of claim 15, further comprising a thin film circuit element connected to the first surface of the substrate.

36. The device of claim 35, wherein the thin film circuit element is selected from the group consisting of a resistor and a capacitor.

37. A method of fabricating a microwave device, comprising:

   forming a first plurality of vias in a substrate, the vias extending from a first surface of the substrate to a second surface of the substrate;

   forming a first plurality of interconnect traces on the first surface of the substrate such that each interconnect trace is electrically connected to one of the vias; and characterized by connecting a first microwave circuit chip to the second surface of the substrate such that the first microwave circuit chip is electrically connected to the first plurality of vias.

38. The method of claim 37, wherein connecting the first microwave circuit chip includes connecting the first microwave circuit chip to the second surface of the substrate such that the first microwave circuit chip is electrically connected to the first plurality of vias through a first plurality of electrically conductive bumps.

39. The method of claim 37, further comprising coating a portion of the second surface of the substrate with an electrically conductive material.

40. The method of claim 37, further comprising connecting a ground plate having a recessed portion to the second surface of the substrate such that the first microwave circuit chip is disposed in the recessed portion of the ground plate.

41. The method of claim 37, further comprising forming an isolation device of a microwave frequency absorbing material on the first surface of the substrate and between the first plurality of interconnect traces.

42. The method of claim 41, wherein forming the isolation device includes forming the isolation device such that the isolation device extends from the first surface of the substrate to the second surface of the substrate and between the first plurality of conductive vias.
43. The method of claim 37, further comprising forming a thick film circuit element on the first surface of the substrate.

44. The method of claim 37, further comprising:

forming a second plurality of vias in the substrate, the second plurality of vias extending from a first surface of the substrate to a second surface of the substrate;

forming a second plurality of interconnect traces on the first surface of the substrate such that each of the second plurality of interconnect traces is electrically connected to one of the second plurality of vias; and

connecting a second microwave circuit chip to the second surface of the substrate such that the second microwave circuit chip is electrically connected to the second plurality of the vias.

45. The method of claim 44, further comprising:

connecting a first ground plate having a recessed portion to the second surface of the substrate such that the first microwave circuit chip is disposed in the recessed portion of the first ground plate; and

connecting a second ground plate having a recessed portion to the second surface of the substrate such that the second microwave circuit chip is disposed in the recessed portion of the second ground plate.

46. The method of claim 44, further comprising connecting a ground plate having first and second recessed portions to the second surface of the substrate such that the first microwave circuit chip is disposed in the first recessed portion and the second microwave circuit chip is disposed in the second recessed portion.
INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER

IPC 7 H01P1/04

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 H01P

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search forms used)

PAJ, EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

<table>
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<th>Category</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
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<td>X</td>
<td>US 4 739 448 A (ROWE DAVID A ET AL) 19 April 1988 (1988-04-19)</td>
<td>1-5, 8-10, 18-23, 37, 39, 40</td>
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<tr>
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<td>column 3, line 54 - column 5, line 47; figures 1-5</td>
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D. OTHER DOCUMENTS CONSIDERED TO BE RELEVANT

- Further documents are listed in the continuation of box C.

E. PATENT FAMILIES

- Patent family members are listed in annex

- Special categories of cited documents:
  - "A" document defining the general state of the art which is not considered to be of particular relevance
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Date of the actual completion of the international search: 10 July 2001

Date of mailing of the international search report: 17/07/2001

Name and mailing address of the ISA:
European Patent Office, P. B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel: (+31-70) 340-3040, Tx: 31 651 epo nl Fax: (+31-70) 340-3016

Authorized officer: Den Otter, A
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