A LOW COST, HIGH PERFORMANCE PACKAGE FOR MICROWAVE CIRCUITS IN THE UP TO 90 GHZ FREQUENCY RANGE USING BGA I/O RF PORT FORMAT AND CERAMIC SUBSTRATE TECHNOLOGY

KOSTENGÜNSTIGES HOCHLEISTUNGSGEHÄUSE FÜR MIKROWELLENSCHALTUNGEN IM 90 GHZ-BEREICH MIT BGA EIN/AUSGANGSFORMAT UND KERAMISCHER SUBSTRATTECHNOLOGIE

BOITIER PEU ONEREUX, A HAUTE PERFORMANCE, POUR CIRCUITS HYPERFREQUENCE DANS LA GAMME DE FRÉQUENCES ALLANT JUSQU’À 90 GHZ FAISANT INTERVENIR UN FORMAT DE CIRCUIT D’ACCES À RADIOFREQUENCES A MATRICE DE GRILLE À BOULES OU À BOSSES ET UNE TECHNOLOGIE DE SUBSTRAT CÉRAMIQUE

Designated Contracting States: DE FR GB

Priority: 02.03.1995 US 398586

Date of publication of application: 26.03.1997 Bulletin 1997/13

Proprietor: CIRCUIT COMPONENTS, INCORPORATED
Tempe, Arizona 85282 (US)

Inventors:
• GREENMAN, Normal, L.
Phoenix, AZ 85016 (US)

• HERNANDEZ, Jorge, M.
Mesa, AZ 85204 (US)

• PANICKER, M., P., Ramachandra
Camarillo, CA 93012 (US)

Representative: Carpenter, David
MARKS & CLERK,
Alpha Tower,
Suffolk Street Queensway
Birmingham B1 1TT (GB)

References cited:
EP-A- 0 331 289
DE-A- 3 934 224
FR-A- 2 507 409
US-A- 4 942 076

• PATENT ABSTRACTS OF JAPAN vol. 005, no. 044 (E-050), 24 March 1981 & JP 55 166941 A (NEC CORP), 26 December 1980,

• PATENT ABSTRACTS OF JAPAN vol. 008, no. 213 (E-269), 28 September 1984 & JP 59 099745 A (NIPPON DENKI KK), 8 June 1984,
Description

Background of the Invention:

Field of the Invention:

[0001] The invention relates to the field of packaging for Microwave Microcircuits (hereinafter Microwave Circuits). More particularly, the invention is directed to the circuits operating in the frequency range up to 90 GHz, for applications such as those found in Radar, Counter-Intelligence systems, Personal Communications Services and Intelligent Vehicle Highway systems among others.

[0002] Currently, there are emerging applications that require operating frequencies up to 77 GHz and higher.

Prior Art:

[0003] Applications especially in the frequency range from 2.0 GHz and higher generally depend on GaAs microwave integrated circuits. An important drawback of the present available package technologies is that they impose a strong limitation on the ability of the system designer to fully utilize the capabilities of the GaAs microcircuit.

[0004] Present day packages, especially in the 5-12 GHz frequency range, were developed basically for Military and Aerospace applications, where cost is generally not of prime concern. The packages are generally complex and expensive.

[0005] Prior art packages are of leaded design and in order to be effective for their intended purpose, utilize expensive materials and manufacturing processes.

[0006] For example, extensive use is made of glass-to-metal seals, machined metallic cases, expensive alloys (e.g. Be O, W, MoMn, Cu W, Kovar, etc.) and large amounts of gold plating.

[0007] Other available prior art packages are based on an alumina cofired process which is generally cost effective, but has serious drawbacks. In that process, green cast alumina is punched or drilled providing vias to be filled with refractory metal pastes, see for example European Patent Specification No. 2 331 289A2.

[0008] Circuit traces and pads are then screen printed on the alumina using refractory metal inks (MoMn or Tungsten). Frequently multiple layers of punched and printed green alumina are stacked to form the package structure. Then, the entire assembly is sintered (cofired) to density all the components. Cofiring causes shrinkage of the green alumina and the package structures. Shrinkage in itself is not necessarily problematic. However, the amount of shrinkage is not uniform throughout the package due to the different via and circuit trace density on different areas of the same. This makes the final location of the vias and traces difficult to control. Strict control of these locations as well as absolute dimensions of vias and traces is extremely important in applications from about 12 GHz and higher frequencies, due to the smaller wavelength as frequency increases. Precise control of geometry and dimensional tolerances is vital for the performance of the package.

[0009] Moreover, to make the package cost effective, it may be necessary to integrate passive components (R,L,C) into the package as disclosed in French Patent Specification No. 2 507 409.

[0010] Since this cannot generally be achieved with the cofiring process, in addition to the drawbacks stated herein above, the cofiring process is not an economical-ly viable approach to fabricating packages to operate in the 12 GHz and above frequency range.

[0011] Although the above described packages of the prior art have satisfied the needs of the Military market and some other applications, the rapidly growing high volume commercial markets in wireless Personal Communications Services, Intelligent Highway Vehicle Systems and other emerging markets are demanding more and more cost effective products.

Therefore, there is a very strong need for the availability of high performance, very flat, low cost, reliable, small size, height and weight microwave packages. The disadvantages and limitations of present day leaded packages, i.e., cost, limited frequency performance, etc., are greatly reduced or eliminated by the packages of the present invention.

Summary of the Invention:

[0012] The above-discussed and other drawbacks and deficiencies of the prior art are overcome or alleviated by the microwave microcircuit circuit package of the present invention.

[0013] The invention overcomes the drawbacks of the prior art by operatively attaching a microwave circuit to a prefired single layer ceramic substrate having precisely located vias, a Ball Grid Array on the bottom of the substrate and a connection surface on a top surface of the substrate. The microwave circuit is positioned atop the substrate and electrically connected in conventional ways to the substrate (for example, wire bonding). A cover which may be of a number of compositions, and which may be coated with a thin layer of a conductive material, is bonded to the substrate primarily either by welding, solder or by electrically conductive adhesives. The package may be hermetically sealed and is operably attachable to the mother board by the Balls of the Ball Grid Array. Thus, it will be appreciated that the package will require less space on the mother board because of the absence of leads. The space savings is due both to the leadless, ball grid array design and the small physical size features in the package necessary up to 90 GHz operating frequency range. In addition the package is flatter than other prior art packages. This is particularly important for assembly of very thin, delicate GaAs devices currently emerging for use. Also, the package is lighter than other leaded packages, a very
desirable attribute in today’s personal communication device market and in the trend towards miniaturization. For frequencies in the 20 GHZ and higher range the balls are necessarily extremely small and roundness becomes an issue. Therefore, also disclosed is a bump grid array embodimen therein generally hemispherical or bell shaped bumps are employed instead of balls to retain desirable electromagnetic characteristics and increase uniformity of the product. Several embodiments are disclosed.

[0015] The above-discussed and other features and advantages of the present invention will be appreciated and understood by those skilled in the art from the following detailed description and drawings.

Brief Description of the Drawings:

[0016] Referring now to the drawings wherein like elements are numbered alike in the several FIGURES:

FIGURE 1 is a perspective schematic exploded view of the invention;
FIGURE 2 is a perspective view of a panel of substrates for the invention;
FIGURE 2a is a perspective view of a top surface of the individual substrate unit exploded up from FIGURE 2;
FIGURE 2b is a perspective view of a bottom surface of the individual substrate unit exploded up from FIGURE 2;
FIGURE 3 is a flow chart of the method of making the invention;
FIGURE 4 is a cross section view of a package of the invention;
FIGURE 5 is a perspective view of a metal lid;
FIGURE 6 is a cross section of FIGURE 5;
FIGURE 7 is a perspective view of a plastic or ceramic lid;
FIGURE 8 is a cross section of FIGURE 7 with metallization on an interior surface thereof;
FIGURE 9 is a cross section of FIGURE 7 with metallization on the entirety of the lid;
FIGURE 10 is a cross section of an alternate embodiment of the lid;
FIGURE 11 is a cross section of the package of the invention utilizing IC chip bump technology;
FIGURE 12 is a cross section of the package of the invention utilizing an alternate package bump technology;
FIGURE 13 is a plan view of one layout of the substrate of the invention;
FIGURE 14 is an end view of FIGURE 13;
FIGURE 14a is a bottom view of FIGURE 13;
FIGURE 15 is an alternate plan view of a layout of the substrate of the invention;
FIGURE 15a is an end view of FIGURE 15;
FIGURE 15b is a bottom view of FIGURE 15;
FIGURE 16 is an enlarged perspective view of a RF port of the invention;
FIGURE 17 is a perspective exploded view of one package of the invention;
FIGURE 17a is a cross section taken along section line 17a-17a in FIGURE 17;
FIGURE 18 is a perspective view of a substrate with the bump grid array illustrated in the bottom thereof;
FIGURE 19 is an enlarged view of a section of FIGURE 18 illustrating an RF signal pad with a bump thereon;
FIGURE 20 is a cross section of FIGURE 19 taken along section line 20-20;
FIGURE 21 is an enlarged extracted view of an RF port illustrating the metallic paste in cylindrical form thereon;
FIGURE 22 is a sequential view to FIGURE 21 illustrating the form of the metallic paste after reflow;
FIGURES 23 and 24 are sequential views of the paste in cylindrical form and the paste in reflowed form without any flow restraint;
FIGURES 25 and 26 are sequential view of a cylinder and the reflowed paste without restraint;
FIGURES 27-29 are sequential views illustrating a restraint, a paste cylinder and an RF pad during the sequence of the invention;
FIGURES 30-32 illustrate the same sequence as illustrated in FIGURES 27-29 but on an area of the substrate other than an RF port;
FIGURES 33 and 34 illustrate alternate restraint methods; and
FIGURE 35 illustrates another alternate method of placing bumps on the bottom of a substrate.

Detailed Description of the Preferred Embodiments:

[0017] In a preferred embodiment of the present invention, referring to FIGURES 1 and 4, a prefired substrate 2 is provided which preferably contains a plurality of precisely located laser drilled vias. The substrate is most preferably composed of alumina (aluminum oxide Al2O3) or aluminum nitride ceramic which has been fully sintered prior to being laser drilled. It should be noted that the substrate technology described herein is more fully described in U.S. 4,942,076 and U.S. 5,089,881 the entire contents of which are incorporated herein by reference. The substrate 2 further contains a predesigned pattern of traces (and/or pads) 3 on a microwave circuit surface 4 thereof and a preselected pattern of ball connection pads 5 on surface 6 of substrate 2. Balls 7 are attached to pads 5 by electrically conductive methods. Substrate 2 and balls 7 provide the platform on which the microwave microcircuit 1 is mounted. The microwave circuit 1 is also electrically connected to traces (and/or pads) 3 by leads (wire bonds) 8 (or bumps 14; see FIGURES 11 and 12). It will be noted however that leads are not required for connection of the package to the mother board 9. Consequently, much space is saved on the board 9 allowing for lighter and smaller electronic
devices.

[0018] Referring to FIGURES 2, 2a and 2b, the substrate itself is easily processed in panel 21 form which substantially lowers costs of individual substrate units 2. Panels 21 may contain typically from 60-256 substrate units, however, it is certainly possible to produce fewer or more units than the specified range depending upon the size of individual units and the size of the panel 21. Panel 21 processing is also desirable because as one skilled in the art will recognize, the higher the frequency intended the smaller the circuits themselves, and the package to house them, need be. Therefore, for applications in the very high operating frequencies, many substrate units can be processed in a single panel.

[0019] The most preferred substrate material is 96% alumina, however higher purity alumina grades, glass ceramic, aluminum nitride and other materials are acceptable provided that the dielectric constant and dielectric loss of the material are comparable to those of the preferred material. Moreover, other properties such as modulus of elasticity, hardness, glass transition point, etc. are considerations for their compatibility with the processing conditions of the fabrication process. Furthermore, user conditions must be considered, e.g., microwave circuit attachment, wire bonding, encapsulation, etc.

[0020] Referring to FIGURE 3 a flow chart of the preferred process for fabrication of the packages is illustrated. It will be appreciated that the steps listed on the flow chart from drilling through annealing after lap and clean is the subject of Panicker et al which has been previously incorporated herein by reference.

[0021] Once the bulk panel 21 is fabricated, a thin film metalization process is employed to provide traces 3 for electrical connection. In the most preferred embodiment a vapor deposition process such as Enhanced Ion Plating (EIP), magnetron sputtering, straight physical vapor deposition, chemical vapor deposition or low temperature arc vapor deposition (LTAVD) is employed. Alternatively, layers of metal can also be applied by thick film, screen print and firing of metallic pastes such as inert atmosphere (N₂, forming gas) fireable Nickel, copper and other pastes. The pastes preferably are printed with very fine stainless steel mesh (400) screens for adequate pattern definition. This is particularly important at the 20 GHZ and higher frequency ranges.

[0022] The preferred metalization 29 system utilizes tantalum as an adhesion promoter. The promoter is preferably applied in a thickness of in the range of about 100 to 3000 Angstroms and most preferably about 1,000Å (angstroms). Over the tantalum a layer of preferably 1.5 - 3.0 microns of Nickel is deposited. It will be appreciated, however, that other metal combinations are equally effective including tungsten-nickel, molybdenum-nickel, chromium nickel, chromium copper nickel, or combinations thereof. The effectiveness of the different combinations of metals is due to the final gold plated layer on top of them. This is due to the skin depth penetration effect of electromagnetic fields on metals. At the operating frequencies of the microwave packages, the electric currents will flow essentially on the surface of the gold plated layer. Therefore, the requirements of very high electrical conductivity on the base metals is not as demanding as it would be at lower frequencies. Consequently, the mentioned metal combinations provide adequate electrical conductivity.

[0023] It is further important to note that the processing conditions planned after the metatization of the substrate will affect the selection of metals combinations. More specifically, patterning, for example by a photore sist/etching process; ball attachment, either by a copper/silver or AuGe brazing process in an inert or slightly reducing atmosphere or when the balls are attached by a solder reflow process, etc. require consideration of the metal combinations utilized in the metalization process for each combination's immunity to the processing outlined. Of like significant importance, care must be taken to avoid placing a metal having a high coefficient of diffusion into gold at relatively low temperatures immediately beneath the final gold plating; copper is an example of a metal not suited to be gold plated in this application. The phenomenon of copper diffusion into gold is well known in the industry, and among other problems it causes weakening and corrosion of wire bonded joints of microcircuits to the gold plated substrates.

[0024] The above considerations also apply to thick film pastes where they are selected for use.

[0025] The preferred method for producing the invention includes a number of steps set forth hereunder.

[0026] The first step begins with a ceramic polished substrate 2 containing both thermal vias 15 and ground vias 16 as well as signal/DC vias 17 (see FIGURES 2a and 2b). The substrate 2 is, as noted above, comprised of preferably 96% alumina or higher purity. It is also acceptable, however, to utilize 92% Alumina, Aluminum Nitride (AlN), glass ceramic or other material of similar electrical properties which is also compatible with via fill (Cu-W) and sintering processes. All of the vias in substrate 2 are preferably filled with Cu-W composite material which possesses desirable electrical conductivity properties and a coefficient of thermal expansion substantially similar to that of the substrate 2 material. Circuit surface 4 and PCB connection surface 6 of substrate 2 are then polished to a finish of at least about 20 microinches Ra for control of electrical properties of interconnection structures on the substrate 2. Signals are brought in the PCB to the RF port balls by means of interconnection structures such as stripe, microstrip or coplanar waveguide. A coplanar waveguide configuration is schematically illustrated in FIGURE 17 as numeral 33 on PCB 9. Many different via pattern geometries and shield loop 20 patterns are possible for use with the present invention. Those shown in the drawings are by way of illustration only; there are virtually no limits to patterns except to maintain the scattering matrix values of
the pairs of RF ports as close as possible to $S_{11} = 0$, $S_{22} = 0$, $S_{12} = 1$, $S_{21} = 1$. FIGURES 13 and 14 show an example of patterns of vias 15, 16, 17 and loops 20 and metalization free areas 32 which are effective for various applications of the present invention.

[0027] Following preparation of the polished ceramic substrate, flat metalization of both surfaces of the substrate is undertaken (seen in FIGURES 4, 4a and 4b). The preferred metalization procedure includes a first adhesion promoter layer of about 1000 Angstroms of titanium followed by a layer of nickel of about 1.0 to about 3.0 microns. It will be appreciated that these are minimum ranges for economic reasons; thicker deposits are effective if desired. It will also be appreciated that other metal combinations, for example, molybdenum-nickel (Mo-Ni), Ni alone, etc. can be employed with the proviso that adhesion of the metal to the substrate is such that after the subsequent processing to convert the substrate to a Ball Grid Array package the ball bond strength to the package will remain within accepted industry standards. It is also important criteria that the metal selected will bond with the final gold plate applied thereover, that the metal will not diffuse into the gold concomitant any of the processing conditions and that the gold to metal bond will not degrade in any of the expected conditions of processing to a functional microwave circuit or in use in a system application.

[0028] Subsequent to metalization the metalized substrate is patterned by preferably a photo resist-expose-develop-etch process which is known to the art. Alternatively, the substrate may be masked at the time of metalization to achieve the desired patterning. Patterning provides electromagnetic structures intended to provide DC Bias, RF signal input and output, a microwave circuit attachment area, ground planes, shields, capture pads for vias and any other conductive features required for proper functioning of the package. It is of course important to guard against interference with the operation of the microwave circuit. As is known to the art the parameters required to ensure that all of the foregoing occurs is mathematically described in terms of the "S" matrix for the package as a two-port passive, linear, lossless device as follows:

$$[S] = \begin{bmatrix} 0 & 1 \\ 1 & 0 \end{bmatrix},$$

for every pair of ports used for signal transmission, within the operating frequency band of the package. This is the configuration governing formula which all preferred electromagnetic structure layouts must meet. It will be understood however that devices can be made which deviate from the preferred formula, merely suffering from reduced frequency performance.

[0029] Although the foregoing may be carried out on a single substrate blank, the preferred method is to process a larger panel 21 format which typically is in the range of about 4.5 inches by 4.5 inches (FIGURE 2). The thickness of the array material is dictated by the operating frequency, with thinner substrate materials being required for higher operating frequency. Formation of the metalized and patterned substrates in panel format is economically superior to individual forming without significant loss in performance. This benefits the market in lower price per unit cost. Upon completion of substrate metalization 29 and patterning the array is diced thus providing individual substrates 2 ready for construction into packages.

[0030] To the PCB connection surface 6 (FIGURE 2b) must be attached balls 7. Construction of the balls 7 and attachment thereof is the next step in production of the package.

[0031] Referring to FIGURE 4, balls 7 are most preferably constructed of copper plated with nickel because of the inexpensive natures of the materials and the compatibility of the selected material with a selected attachment process. The preferred attachment process is via a eutectic AgCu brazing material with which the nickel plated copper balls are quite compatible. Further benefits resulting in the preferred status of these balls and attachment material is low cost and easy plateability with gold. It should be noted that other materials compatible with AgCu eutectic material (or CuAg material) include solid nickel, silver, silver copper and others which will be appreciated by those of skill in the art. The processing conditions for such material combinations are approximately 800°C for 10.0 minutes in a Nitrogen Atmosphere. The components selected therefore must be capable of withstanding, without degradation, the conditions of such processing.

[0032] Other ball construction materials are generally dictated by the attachment processes to be utilized. Au-Ge and eutectic AuSi attachment materials are also preferred thereby dictating any electrically conductive material compatible with the brazing conditions of these materials.

[0033] Additional preferred ball materials include 95% lead and 5% tin alloy; 90% lead 10% tin alloy; or any other alloy with a melting point significantly higher than the conventional eutectic 63/37 lead-tin (PbSn) alloy commonly employed in electronic soldering operations.

[0034] Clear to one of skill in the art, there is an unlimited number of possible configuration of balls on the substrate; an example of a configuration is illustrated in Figure 15b.

[0035] Subsequent to ball attachment in the predetermined configuration, the packages are gold plated employing preferably a barrel plating process both for protection of the components and for wire bondability at the RF port 22, signal and DC pads 18 and 19, respectively, (FIGURES 1, 4 and 17). The microwave circuit 1 is then wire bonded to the substrate. Connection of microwave circuit 1 is further discussed hereunder.
Referring now to FIGURES 5-9 lids 23 constructed for bonding, by a number of methods, to the substrate over the operably connected microwave circuit 1 to provide an electromagnetic shield to control impedance of the circuit and protect the microwave circuit 1 from physical and environmental damage are discussed. Several options exist for materials, profiles and types of bonding processes. In generally the choice of material and method of bonding to the package substrate is closely related to the degree of hermeticity required for the projected application and the cost incurred.

The preferred materials for forming the lid include plastic and ceramic. Among suitable plastics, epoxy molding compounds (whether semiconductor grade or other), polyphenylene sulphone (PPS) Ultem (GE tradename) and other common engineering thermosets and thermoplastics are acceptable materials. Among ceramic materials, alumina is most preferred since it is the preferred material for the substrate 2. Employing the same material for both parts ensures a matched coefficient of thermal expansion (CTE). Other ceramic materials considered desirable include Forsterite, Cordierite, glass ceramic, and other ceramic materials with a coefficient of thermal expansion similar to the substrate material. Moreover, a further preferred embodiment employs deep drawn Kovar or Nickel as lid materials. Also, W-Cu and AlSiC lids made by powder metallurgy methods are adequate.

Referring to FIGURES 5-9, regardless of the type of material employed, the lids 23 must be conductive or conductively plated 30. In the case of Kovar or nickel lids 23a the material is preferably plated on the entire surface with gold for superior conductivity and corrosion protection. The attachment process for a Kovar or Nickel lid is by welding or by means of a AuGe solder preform 27 (shown in FIGURES 1, 11 and 12) placed upon the attachment area 26 of Kovar or Nickel lids 23a, where such a preform is employed it is important to carefully consider the solder versus metal selected for chemical and galvanic compatibility. Moreover a solder material having a melting temperature not deleterious to the other components of the assembly must be selected. It will be appreciated by those of skill in the art that the balls 7, microwave circuit 1, substrate 2, etc. as well as the gold plating, all have a relatively low temperature threshold for damage. The selection of many alloys would be detrimental to the package and therefore economically undesirable. In the case of the plastic or ceramic lids 23b metalization 30 can be carried out by applying a thin layer of metal (e.g., nickel or other suitable metal) by preferably a low temperature arc vapor deposition process prior to gold plating.

Electroless plating and other conventional plastic plating processes are also acceptable. It should be noted that these processes plate the entirety of the plastic lid (see FIGURE 9). This is not, in itself, problematic for the function of the lid, however it can increase materials cost without benefitting the arrangement.

Adhesives preferred for bonding the lid 23 to substrate 2 are electrically conductive and include silver filled epoxy, polyimide or other adhesives.

An alternative embodiment of the invention employs a lid 23c of two pieces (see FIGURE 10). Spacer 25 is attached to substrate 2 in any of the above described ways and plate 28 is then attached to spacer 25 in a similar way, the attachment material is illustrated as 31 in FIGURE 10. For the arrangement to be effective, it, like the lids discussed above, must be conductive. This lid 23c can be made metalized in all of the same ways.

Referring now to FIGURES 1, 4, 10, 11 and 12, the microwave circuit 1 is electrically connected to surface 4 of substrate 2 by one of two preferred methods. In the first method the device is connected using wire bonds 8 from the microwave circuit 1 to the substrate 2. This is a conventional attachment arrangement for microcircuit connections to packages.

Also employable in the present invention is "bump" (or flip chip) technology, where bumps are placed either on the microwave circuit 1 or on the traces 3 of surface 4 of substrate 2. In either case, both of which being illustrated in FIGURES 11 and 12, the bumps electrically connect the chip to the package. Bumps 14 on the microcircuit are generally constructed using PbSn solder or by vapor deposition of Cr, Cu and Au. Bumps on the package can be produced using the same procedure as for those on the microwave circuit surface. Employing bump technology can in many cases provide even smaller packages which is a desirable result. Also, better high frequency performance is achieved, due to the absence of inductive effects introduced by the wire bonds.

As will, of course, be appreciated by those of skill in the art, the microwave circuit is fully attached to the desired points before attachment of the lid.

As has been stated hereinabove, the particular arrangements of all of the component elements of the invention can be many. The guiding factor is that the [s] matrix must be as close to

\[
\begin{bmatrix}
0 & 1 \\
1 & 0
\end{bmatrix}
\]

as possible within the intended operating frequency range for every pair of signal transmission ports. Performance of the packages depends upon their physical size and their ability to, without signal reflection, or unintended coupling to other ports, transition waves from the PC Board, through the balls, vias, pads, to the microwave circuit and back to the PCB.

Referring to FIGURES 13-17 some preferred arrangements are depicted by way of illustration not lim-
In an alternate embodiment of the invention the balls 7 are substituted for by bumps 42 as illustrated in FIGURE 18 et seq. Bumps provide some advantage over balls such as when packages are small enough to require balls of a diameter in the ranges of 0.003 - 0.006 inches in diameter. In these circumstances it is desirable to provide the electrically connective function of the balls by substituting substantially hemispherical or bell shaped bumps. Bumps are especially preferred in a diametrical range of 0.004 - 0.005 inches. Bumps may be constructed of conductive materials including solder, tin-lead or other eutectic material alloys and are deposited on the substrate in contact with circuit traces or other features or vias by any of a number of ways. Methods contemplated for mass producing bumps is to screen print, stencil, gravure offset print or otherwise deposit a uniform and controlled amount of a conductive paste at the desired and predetermined position. The bumps can be printed on the substrate in a bell shaped or semi-spherical cross section but generally are printed in a more cylindrical shape as illustrated in FIGURE 21. Heating to reflow the metallic paste yields a bell or hemispherical bump profile, provided the reflowed paste is suitably contained. The reflow is conducted by raising the temperature of the environment to a few degrees above the melting point of the material being employed for a short time sufficient to reflow the paste.

The bumps are especially desirable for the > 20 GHZ frequency range because of electromagnetic performance considerations. Moreover, proper values of the S-parameters of the RF ports are maintained by reducing the gap between the bottom of the package substrate and the top surface of the PC board upon which the package is installed.

Control of the reflowed paste must be maintained or a bump profile will not form. More specifically, the paste will simply run laterally until little more than a slightly raised section of unpredictable geometry is left. As one of skill in the art will readily appreciate, the paste chosen is of a type having properties compatible with the substrate metallization. This will improve the metallurgical properties of the package including bonding of the bump material to the bottom metallization. The most preferred metal paste is an Eutectic Silver - copper alloy because this material wets the metallization well. Alternatively, lead-tin or lead-silver-tin may be employed. In other words it is desirable that the paste exhibits good wettability of the metallization. Because of this property however, the problem of uncontrolled lateral running of the paste during reflow is exacerbated. Considerations for producing desired bump geometry include careful control over the size of apertures in the printing surface (not shown) in order to control the amount of paste applied to the substrate and controlling the homogeneity and solids content of the paste. Controlling homogeneity and solids content allows accurate prediction of end bump size because the amount of metal left behind after volatilization of binders is known. Perhaps most importantly to control bump size and geometry, a discontinuity in the wettable bottom metalization relative to the bump is advantageous. This is not to say that the metalization layer must be etched, although that is a preferred method, rather it is only to say that there should be some feature which prevents wetting of further metalization than is desired. Most preferred by the inventors hereof (other methods being clearly within the scope of the invention) are to provide the mentioned discontinuity or print an annular dam of a suitable material i.e., relatively non-wettable and of a higher reflow temperature. Glass and chromium are suitable materials and are preferred. It is also expedient to carefully control the paste reflow temperature profile and eliminate mechanical vibrations and gas drafts to avoid shape abnormalities in the bump.

Referring to FIGURES 27-32, one of skill in the art will readily appreciate the annular dam 70 printed (as above noted for the bump paste) or otherwise deposited onto the RF port 72. In general, it is expedient to print dams which are identical to one another. Otherwise the dam would only need to extend across the leg 74 of the RF port because the metalization 29 has been removed around the port for other purposes. Therefore, there is a natural break which inhibits flow of the reflowed metal paste. FIGURES 28 and 29 illustrate sequential views of the creation of the bump with the cylinder 40 deposited within annular dam 70 and in FIGURE 29 with the paste cylinder 40 refloved into the bump 42 configuration. Considering FIGURES 30-32 another sequence is shown depicting similar structures i.e. the dam ,the cylinder and the reflowed bump but not associated with the RF port 72.

In an alternate embodiment FIGURES 33 and 34 the annular dam 70 is avoided and an etching process (i.e. chemical or other suitable etching process known to one of skill in the art) is employed which removes metalization 29 in an annular shape but leaves metal bridges 76 for electronic connection purposes. It will be understood that the exact size of the removed metalization section must be carefully determined and controlled to comport with the electromagnetic integrity of the whole of the package structure. The bridges are narrower than carefully temperature maintained reflow material can readily cross yet provide sufficient electrical continuity for the package to function as intended. Therefore, the bell shape is maintained. At least one bridge is desirable where electrical continuity is desired, however, two, three or four are preferred. Because the ceramic material of the substrate is generally difficult to wet and because of the capillarity and surface tension of the reflowed material encountering an edge 78, the metal paste is not likely to flow other than to where it was intended to flow.

Some finishing of the bumps 42 is necessary for excellent functioning in a package i.e., bumps must be solderable and protected from corrosion. The most preferred solderability modification is to coat the bumps
42 with a nickel coating of in the range of about 2-5 microns. For the purpose of oxidation protection a flash of gold plating in the range of about 1200 angstroms (2 - 5 micro inches) or less is preferred.

[0053] In yet another embodiment of the invention as illustrated in FIGURE 35, bumps are molded onto the substrate by clamping the substrate against a graphite fixture 80 having cavities 82 filled with bump metal. The entire unit is then heated to reflow temperature to reflow the metal, wetting the metalization 29 and adhering thereto. The clamping of the substrate 2 to the fixture 80 effectively reduces gaps caused by camber of the substrate against the flat surface of the graphite to below the space needed for the bump material to escape the cavity. Therefore, bumps are formed reliably. It should be noted, however, that in order to ensure coplanarity of the bumps it may be necessary to provide additional metal in areas of low bump concentration because in these areas the metal will expand slightly more than in areas of higher bump concentration. As one of skill in the art will recognize, where bump concentration is high the bumps themselves will provide some damming action against other bumps.

[0054] While preferred embodiments have been shown and described, various modifications and substitutions may be made thereto without departing from the spirit and scope of the invention. Accordingly, it is to be understood that the present invention has been described by way of illustration and not limitation.

Claims

1. A microwave circuit package comprising:
   a) a substrate (2) including a plurality of conductive structures (3,16,17);
   b) a plurality of electrical connectors (5) operatively attached to a first surface (6) of said substrate (2) for connection of the package to a printed circuit board (9);
   c) a microwave circuit (1) operatively connected to said substrate on a second surface (4) thereof; and
   d) a cover (23) attached to said substrate so as to encapsulate said microwave circuit within said cover and said substrate; characterised in that;
   e) a ball grid array (7) operatively connects said electrical connectors (5) to said printed circuit board (9).

2. A microwave circuit package as claimed in Claim 1, characterised in that one of said conductive structures is an RF port (22) including a pattern of conductively filled vias (16), shield loops (20) and contact pads (5) which pattern maintains an [s] matrix of about within the frequency range of operation for every pair of signal transmission ports.

3. A microwave circuit package as claimed in either Claim 1 or Claim 2, characterised in that said substrate (2) is a ceramic material.

4. A microwave circuit package as claimed in Claim 3, characterised in that said ceramic material is prefired.

5. A microwave circuit package as claimed in Claim 3, characterised in that said ceramic is alumina and is of a purity grade of in the range of about 90% to 100%.

6. A microwave circuit package as claimed in Claim 5, characterised in that said purity grade is about 96% to 99%.

7. A microwave circuit package as claimed in Claim 1, characterised in that said substrate includes vias (15,16), said vias being filled with an electrically conductive material.

8. A microwave circuit package as claimed in Claim 7, characterised in that said material includes at least one of tungsten and copper.

9. A microwave circuit package as claimed in Claim 7, characterised in that said substrate (2) is copper ink screened.

10. A microwave circuit package as claimed in Claim 9, characterised in that said substrate (2) is thin film metallized and patterned.

11. A microwave circuit package as claimed in Claim 1, characterised in that said plurality of connectors (5) are fixedly attached to said first surface of the substrate (2) by a AgCu brazing material.

12. A microwave circuit package as claimed in Claim 11, characterised in that said connectors (5) are comprised of one of the group consisting of nickel, copper and solder and which are plated with one of the group consisting of nickel, gold and nickel palladium.

13. A microwave circuit package as claimed in Claim 1, characterised in that said microwave circuit (1) is connected by wires (8) to the substrate (2) within the package.
14. A microwave circuit package as claimed in Claim 1, characterised in that the microwave circuit (1) is connected by bumps (14a) extending from said circuit (1).

15. A microwave circuit package as claimed in Claim 1, characterised in that the microwave circuit (1) is connected by bumps (14b) extending from said second surface of said substrate (2) said second surface being endowed with circuit traces for electrical connection of said microwave circuit (1).

16. A microwave circuit package as claimed in Claim 1, characterised in that a conductive plating (30) on said cover (25) extends to a mounting surface of said cover (23) to provide electrical connection between a ground plane of said substrate (2) and said cover (23).

17. A microwave circuit package as claimed in Claim 1, characterised in that said cover (23) and substrate (2) encapsulate the microwave circuit (1) hermetically.

18. A method for producing a microwave circuit package comprising the steps of:
   a) forming a discrete substrate unit;
   b) preparing connective elements for the substrate to connect the same to a PC board;
   c) electrically attaching said connective elements to a first surface of the substrate;
   d) electrically attaching a microwave circuit to a second surface of the substrate; and
   e) attaching a cover to said substrate around and over said microwave circuit to encapsulate said device between said cover and said substrate; characterised by;
   f) electrically connecting said connective elements and said PC board via a ball grid array.

19. A method for producing a microwave circuit package as claimed in Claim 18, characterised in that said forming step includes:
   a) prefiring a substrate bulk material;
   b) drilling said material for via holes;
   c) filling said via holes with a conductive material;
   d) sintering said substrate material with filled vias;
   e) screening both sides of said material with a conductive material;
   f) sintering and removing excess conductive material;
   g) thin metallize and pattern said substrate; and
   h) dicing said bulk material into individual discrete substrate units.

20. A method for producing a microwave circuit package as claimed in Claim 19, characterised in that said substrate (2) material is ceramic.

21. A method for producing a microwave circuit package as claimed in Claim 19, characterised in that said filling step comprises:
   a) preparing a via fill composition; and
   b) applying said composition into the via holes until a solid conductive structure is present within an entire length of the via holes (15,16).

22. A method for producing a microwave circuit package as claimed in Claim 21, characterised in that said composition includes tungsten.

23. A method for producing a microwave circuit package as claimed in Claim 21, characterised in that said composition includes copper.

24. A method for producing a microwave circuit package as claimed in Claim 21, characterised in that said composition includes a mixture of tungsten and copper.

25. A method for producing a microwave circuit package as claimed in Claim 19, characterised in that said step of thin metalizing is carried out by coating each surface of said substrate (2) with a bilayer of titanium and nickel.

26. A method for producing a microwave circuit package as claimed in Claim 18, characterised in that said substrate (2) is thick film metallized.

27. A method for producing a microwave circuit package as claimed in Claim 18, characterised in that said substrate (2) is formed by firing metallic pastes.

28. A method for producing a microwave circuit package as claimed in Claim 18, characterised in that the step of preparing connective elements (5) further includes the step of creating a plurality of elements having a metallic base structure and a conductive plating.

29. A method for producing a microwave circuit package as claimed in Claim 28, characterised in that said base structure (7) is a ball.

30. A method for producing a microwave circuit package as claimed in Claim 28, characterised in that said base structure is a column.

31. A method for producing a microwave circuit package as claimed in Claim 18, characterised in that the step of electrically attaching the microwave cir-
cuit (1) to the substrate (2) includes providing conductive bumps on a surface of the device (1) nearest the substrate (2), said conductive bumps (14a) providing electrical contact between the device (1) and a plurality of traces on the substrate (2).

32. A method for producing a microwave circuit package as claimed in Claim 18, characterised in that the step of electrically attaching the microwave circuit (1) to the substrate (2) includes providing conductive bumps (14b) on a surface of the substrate (2) nearest the device (1), said conductive bumps (14b) providing electrical contact between the device and a plurality of traces on the substrate (2).

33. A method for producing a microwave circuit package as claimed in Claim 18, characterised in that the step of attaching a cover (23) to said substrate (2) is by utilizing a process selected from the group consisting of brazing, welding and adhesive bonding.

34. A method for producing a microwave circuit package as claimed in Claim 18, characterised in that said method further includes the step of conductively plating said cover (23) on at least an interior surface thereof.


36. A microwave circuit package as claimed in Claim 1, characterised in that said cover (23) is of two piece construction comprising a spacer (25) defining a central void to house the microwave circuit (1) and a plate (31) overlying said spacer (25) to enclose said microwave circuit (1) between the spacer (25), the plate (31) and the substrate (2).

37. A microwave circuit package as claimed in Claim 36, characterised in that said enclosure is hermetic.

Patentansprüche

1. Mikrowellenschaltungsgehäuse mit:
   a) einem Substrat (2) einschließlich einer Vielzahl von leitfähigen Strukturen (3, 16, 17);
   b) einer Vielzahl von elektrischen Verbindern (5), die betriebsmäßig an einer ersten Oberfläche (6) des Substrates (2) für eine Verbindung des Gehäuses mit einer gedruckten Schaltungsplatine (9) angebracht sind;
   c) einer Mikrowellenschaltung (1), die betriebsmäßig mit dem Substrat auf dessen zweiter Oberfläche (4) verbunden ist; und
   d) einer Abdeckung (23), die auf dem Substrat angebracht ist, um so die Mikrowellenschaltung innerhalb der Abdeckung und des Substrats zu kapseln;
   e) Kugelgitterfeld (7) die elektrischen Verbindungen (5) mit der Schaltungsplatine (9) betriebsmäßig verbindet.

2. Mikrowellenschaltungsgehäuse nach Anspruch 1, dadurch gekennzeichnet, daß eine der leitfähigen Strukturen ein RF-Anschluß (22) einschließlich eines Muster leitfähig gefüllter Durchgänge (16), Abschirmungsschleifen (20) und Kontaktkissen (5) ist, dessen Muster eine [s]-Matrix von ungefähr

\[
\begin{bmatrix}
0 & 1 \\
1 & 0 \\
\end{bmatrix}
\]

innerhalb des Betriebsfrequenzbereiches für jedes Paar von Signalübertragungsanschlüssen aufrecht erhalten.

3. Mikrowellenschaltungsgehäuse nach Anspruch 1 oder Anspruch 2, dadurch gekennzeichnet, daß das Substrat (2) ein keramisches Material ist.


5. Mikrowellenschaltungsgehäuse nach Anspruch 3, dadurch gekennzeichnet, daß die Keramik Aluminium ist und einen Reinheitsgrad in dem Bereich von ungefähr 90% bis 100% aufweist.

6. Mikrowellenschaltungsgehäuse nach Anspruch 5, dadurch gekennzeichnet, daß der Reinheitsgrad ungefähr 96% bis 99% beträgt.

7. Mikrowellenschaltungsgehäuse nach Anspruch 1, dadurch gekennzeichnet, daß das Substrat Durchgänge (15, 16) einschließt, wobei die Durchgänge mit einem elektrisch leitfähigen Material gefüllt sind.


10. Mikrowellenschaltungsgehäuse nach Anspruch 9, dadurch gekennzeichnet, daß das Substrat (2) Dünnfilm-metallisiert und -strukturiert ist.
11. Mikrowellenschaltungsgehäuse nach Anspruch 1, dadurch gekennzeichnet, daß eine Vielzahl von Verbindern (5) fest an der ersten Oberfläche des Substrats (2) durch ein AgCu-Lötmaterial angebracht sind.


13. Mikrowellenschaltungsgehäuse nach Anspruch 1, dadurch gekennzeichnet, daß die Mikrowellenschaltung (1) über Drähte (8) mit dem Substrat (2) innerhalb des Gehäuses verbunden ist.

14. Mikrowellenschaltungsgehäuse nach Anspruch 1, dadurch gekennzeichnet, daß die Mikrowellenschaltung (1) über Erhebungen (14a), die von der Schaltung (1) vorstehen, verbunden ist.

15. Mikrowellenschaltungsgehäuse nach Anspruch 1, dadurch gekennzeichnet, daß die Mikrowellenschaltung (1) durch Erhebungen (14b), die von der zweiten Oberfläche des Substrats (2) vorstehen, verbunden ist, wobei die zweite Oberfläche mit Schaltungsbahnen für eine elektrische Verbindung der Mikrowellenschaltung (1) ausgestattet ist.

16. Mikrowellenschaltungsgehäuse nach Anspruch 1, dadurch gekennzeichnet, daß eine leitfähige Platierung (30) auf der Abdeckung (25) zu einer Befestigungssoberfläche der Abdeckung (23) vorstehen, um eine elektrische Verbindung zwischen einer Masseebene des Substrats (2) und der Abdeckung (23) bereitzustellen.

17. Mikrowellenschaltungsgehäuse nach Anspruch 1, dadurch gekennzeichnet, daß die Abdeckung (23) und ein Substrat (2) die Mikrowellenschaltung (1) hermetisch kapseln.

18. Verfahren zum Herstellen eines Mikrowellenschaltungsgehäuses mit den Schritten:
   a) Bilden einer diskreten Substrateinheit;
   b) Vorbereiten leitfähiger Elemente für das Substrat, um dieselben mit einer PC-Platine zu verbinden;
   c) elektrisches Anbringen der leitfähigen Elemente an einer ersten Oberfläche des Substrats;
   d) elektrisches Anbringen einer Mikrowellenschaltung an einer zweiten Oberfläche des Substrats; und
e) Anbringen einer Abdeckung an dem Substrat um und über die Mikrowellenschaltung, um die Vorrichtung zwischen der Abdeckung und dem Substrat zu kapseln; gekennzeichnet durch;
   f) ein elektrisches Verbinden der Verbindungselemente und der PC-Platine über ein Kugelgitterfeld;

19. Verfahren zum Herstellen eines Mikrowellenschaltungsgehäuses nach Anspruch 18, dadurch gekennzeichnet, daß der Bildungsschritt einschließt:
   a) Vorfeuern eines Substrat-Bulkmaterials;
   b) Bohren des Materials für Durchgangslöcher;
   c) Füllen der Durchgangslöcher mit einem leitfähigen Material;
   d) Sintern des Substratmaterials mit gefüllten Durchgängen;
   e) Abschirmen beider Seiten des Materials mit einem leitfähigen Material;
   f) Sintern und Entfernen von überschüssigem leitfähigem Material;
   g) dünnmes Metallisieren und Strukturieren des Substrats; und
   h) Zerteilen des Bulkmaterials in einzelne diskrete Substrateinheiten.

20. Verfahren zum Herstellen eines Mikrowellenschaltungsgehäuses nach Anspruch 19, dadurch gekennzeichnet, daß das Substrat (2)-Material eine Keramik ist.

21. Verfahren zum Herstellen eines Mikrowellenschaltungsgehäuses nach Anspruch 19, dadurch gekennzeichnet, daß der Füllungsschritt umfaßt:
   a) Vorbereiten einer Durchgangsfüllungs-Zusammensetzung; und
   b) Einbringen der Zusammensetzung in die Durchgangslöcher, bis eine feste leitfähige Struktur innerhalb einer gesamten Länge der Durchgangslöcher (15, 16) vorhanden ist.

22. Verfahren zum Herstellen eines Mikrowellenschaltungsgehäuses nach Anspruch 21, dadurch gekennzeichnet, daß die Zusammensetzung Wolfram...
einschließt.

23. Verfahren zum Herstellen eines Mikrowellenschalungsgehäuses nach Anspruch 21, dadurch gekennzeichnet, daß die Zusammensetzung Kupfer einschließt.


27. Verfahren zum Herstellen eines Mikrowellenschalungsgehäuses nach Anspruch 18, dadurch gekennzeichnet, daß das Substrat (2) Dickfilm-metalisiert wird.


29. Verfahren zum Herstellen eines Mikrowellenschalungsgehäuses nach Anspruch 28, dadurch gekennzeichnet, daß die Basisstruktur (7) eine Kugel ist.

30. Verfahren zum Herstellen eines Mikrowellenschalungsgehäuses nach Anspruch 28, dadurch gekennzeichnet, daß die Basisstruktur eine Säule ist.

31. Verfahren zum Herstellen eines Mikrowellenschalungsgehäuses nach Anspruch 18, dadurch gekennzeichnet, daß der Schritt eines elektrischen Anbringens der Mikrowellenschaltung (1) an dem Substrat (2) ein Bereitstellen leitfähiger Erhebungen (14b) auf der Oberfläche des Substrats (2) nächstliegend zu der Vorrichtung (1) einschließt, wobei die leitfähigen Erhebungen (14b) einen elektrischen Kontakt zwischen der Vorrichtung und einer Vielzahl von Bahnen auf dem Substrat (2) bereitstellen.

32. Verfahren zum Herstellen eines Mikrowellenschalungsgehäuses nach Anspruch 18, dadurch gekennzeichnet, daß das Verfahren weiter den Schritt eines leitfähigen Plattierens der Abdeckung (23) auf zumindest einer inneren Oberfläche davon einschließt.

33. Verfahren zum Herstellen eines Mikrowellenschalungsgehäuses nach Anspruch 18, dadurch gekennzeichnet, daß das Verfahren weiter den Schritt eines Anbringens einer Abdeckung (23) an dem Substrat (2) durch Verwenden eines Prozesses geschieht, der aus der Gruppe gewählt wird, die aus Löten, Schweißen und Klebebondieren besteht.

34. Verfahren zum Herstellen eines Mikrowellenschalungsgehäuses nach Anspruch 18, dadurch gekennzeichnet, daß der Schritt eines elektrischen Anbringens der Mikrowellenschaltung (1) an dem Substrat (2) ein Bereitstellen leitfähiger Erhebungen (14b) auf der Oberfläche des Substrats (2) nächstliegend zu der Vorrichtung (1) einschließt, wobei die leitfähigen Erhebungen (14b) einen elektrischen Kontakt zwischen der Vorrichtung und einer Vielzahl von Bahnen auf dem Substrat (2) bereitstellen.

35. Mikrowellenschalungsgehäuse, das durch das Verfahren von Anspruch 18 hergestellt ist.

36. Mikrowellenschalungsgehäuse nach Anspruch 1, dadurch gekennzeichnet, daß die Abdeckung (23) von zweistückigem Aufbau ist, der einen Abstandshalter (25), der eine zentrale Lücke definiert, um die Mikrowellenschaltung (1) unterzubringen, und eine Platte (31) umfaßt, die über dem Abstandshalter (35) liegt, um die Mikrowellenschaltung (1) zwischen dem Abstandshalter (25), der Platte (31) und dem Substrat (2) einzuschließen.

37. Mikrowellenschalungsgehäuse nach Anspruch 36, dadurch gekennzeichnet, daß der Einschluß hermetisch ist.

Revendications

1. Module de circuit hyperfréquence comprenant:
   a) un substrat (2) incluant une pluralité de structures conductrices (3, 16, 17);
   b) une pluralité de connecteurs électriques (5) liés de façon opérationnelle à une première surface (6) dudit substrat (2) pour une connexion du module à une carte de circuit imprimé (9);
   c) un circuit hyperfréquence (1) connecté de opérationnelle audit substrat sur une seconde surface (4) de celui-ci; et
   d) un couvercle (23) lié audit substrat de ma-
nière à encapsuler ledit circuit hyperfréquence dans ledit couvercle et ledit substrat, caractérisé en ce que:
e) un réseau de grille à billes (7) connecte de façon opérationnelle lesdits connecteurs électriques (5) à ladite carte de circuit imprimé (9).

2. Module de circuit hyperfréquence selon la revendication 1, caractérisé en ce que l'une desdites structures conductrices est un port RF (22) incluant un motif constitué par des vias remplies de façon conductrice (16), des boucles de blindage (20) et des plots de contact (5), lequel motif maintient une matrice [s] approximativement dans la plage de fréquences de fonctionnement pour chaque paire de ports d'émission de signal.

3. Module de circuit hyperfréquence selon la revendication 1 ou 2, caractérisé en ce que ledit substrat (2) est un matériau de céramique.

4. Module de circuit hyperfréquence selon la revendication 3, caractérisé en ce que ledit matériau de céramique est soumis à une précombustion.

5. Module de circuit hyperfréquence selon la revendication 3, caractérisé en ce que ladite céramique est de l'alumine et est d'une classe de pureté dans la plage d'environ 90% à environ 100%.

6. Module de circuit hyperfréquence selon la revendication 5, caractérisé en ce que ladite classe de pureté est d'environ 96% à environ 99%.

7. Module de circuit hyperfréquence selon la revendication 1, caractérisé en ce que ledit substrat inclut des vias (15, 16), lesdites vias étant remplies d'un matériau électriquement conducteur.

8. Module de circuit hyperfréquence selon la revendication 7, caractérisé en ce que ledit matériau inclut au moins un élément pris parmi le tungstène et le cuivre.

9. Module de circuit hyperfréquence selon la revendication 7, caractérisé en ce que ledit substrat (2) est traité par dépôt en écran d'une encre au cuivre.

10. Module de circuit hyperfréquence selon la revendication 9, caractérisé en ce que ledit substrat (2) est un film mince métallisé et conforme.

11. Module de circuit hyperfréquence selon la revendication 1, caractérisé en ce que les connecteurs de ladite pluralité de connecteurs (5) sont liés de façon fixe à ladite première surface du substrat (2) à l'aide d'un matériau de brasage AgCu.

12. Module de circuit hyperfréquence selon la revendication 11, caractérisé en ce que lesdits connecteurs (5) sont constitués en un élément pris parmi le groupe comprenant le nickel, le cuivre et une soudure et sont plaqués à l'aide d'un élément pris parmi le groupe comprenant le nickel, l'or et le nickel-palladium.

13. Module de circuit hyperfréquence selon la revendication 1, caractérisé en ce que ledit circuit hyperfréquence (1) est connecté par des fils (8) au substrat (2) dans le module.

14. Module de circuit hyperfréquence selon la revendication 1, caractérisé en ce que le circuit hyperfréquence (1) est connecté par des bossements (14a) qui s'étendent depuis ledit circuit (1).

15. Module de circuit hyperfréquence selon la revendication 1, caractérisé en ce que le circuit hyperfréquence (1) est connecté par des bossements (14b) qui s'étendent depuis ladite seconde surface dudit substrat (2), ladite seconde surface étant dotée de pistes de circuit pour une connexion électrique dudit circuit hyperfréquence (1).

16. Module de circuit hyperfréquence selon la revendication 1, caractérisé en ce qu'un placage conducteur (30) sur ledit couvercle (23) s'étend jusqu'à une surface de montage dudit couvercle (23) afin d'assurer une connexion électrique entre un plan de masse dudit substrat (2) et ledit couvercle (23).

17. Module de circuit hyperfréquence selon la revendication 1, caractérisé en ce que ledit couvercle (23) et ledit substrat (2) encapsulent le circuit hyperfréquence (1) de façon hermétique.

18. Procédé de fabrication d'un module de circuit hyperfréquence comprenant les étapes de:
   a) formation d'une unité de substrat discrète;
   b) préparation d'éléments de connexion pour le substrat afin de connecter celui-ci à une carte PC;
   c) liaison de façon électrique desdits éléments de connexion sur une première surface du substrat;
   d) liaison de façon électrique d'un circuit hyper-
fréquence sur une seconde surface du substrat; et
e) liaison d’un couvercle sur ledit substrat autour et au-dessus dudit circuit hyperfréquence afin d’encapsuler ledit dispositif entre ledit couvercle et ledit substrat, caractérisé par:
f) la connexion de façon électrique desdits éléments de connexion et de ladite carte PC via un réseau de grille à billes.

19. Procédé de fabrication d’un module de circuit hyperfréquence selon la revendication 18, caractérisé en ce que ladite étape de formation inclut:
   a) la précombustion d’un matériau en masse de substrat;
b) le perçage dudit matériau pour des trous de via;
c) le remplissage desdits trous de via avec un matériau conducteur;
d) le frittage dudit matériau de substrat avec des vias remplies;
e) le dépôt en écran d’un matériau conducteur sur les deux côtés dudit matériau;
f) le frittage et l’enlèvement dudit matériau conducteur en excès;
g) la métallisation en film mince et la conforma-
tion dudit substrat; et
h) le tranchage dudit matériau en masse selon des unités de substrat discrètes individuelles.

20. Procédé de fabrication d’un module de circuit hyperfréquence selon la revendication 19, caractérisé en ce que le matériau dudit substrat (2) est de la céramique.

21. Procédé de fabrication d’un module de circuit hyperfréquence selon la revendication 19, caractérisé en ce que ladite étape de remplissage comprend:
   a) la préparation d’une composition de remplissage de via; et
b) l’application de ladite composition dans les trous de via jusqu’à ce qu’une structure conductrice solide soit présente dans une longueur complète des trous de via (15, 16).

22. Procédé de fabrication d’un module de circuit hyperfréquence selon la revendication 21, caractérisé en ce que ladite composition inclut du tungstène.

23. Procédé de fabrication d’un module de circuit hyperfréquence selon la revendication 21, caractérisé en ce que ladite composition inclut du cuivre.

24. Procédé de fabrication d’un module de circuit hyperfréquence selon la revendication 21, caractérisé en ce que ladite composition inclut un mélange de tungstène et de cuivre.

25. Procédé de fabrication d’un module de circuit hyperfréquence selon la revendication 19, caractérisé en ce que ladite étape de préparation d’éléments de connexion (5) inclut en outre l’étape de création d’une pluralité d’éléments comportant une structure de base métallique et un placage conducteur.

26. Procédé de fabrication d’un module de circuit hyperfréquence selon la revendication 18, caractérisé en ce que ledit substrat (2) est formé en soumettant à combustion des pâtes métalliques.

27. Procédé de fabrication d’un module de circuit hyperfréquence selon la revendication 19, caractérisé en ce que ladite structure de base (7) est une bille.

28. Procédé de fabrication d’un module de circuit hyperfréquence selon la revendication 18, caractérisé en ce que ladite étape de métallisation en film mince est mise en oeuvre en déposant sur chaque surface dudit substrat (2) une bicouche en titane et nickel.

29. Procédé de fabrication d’un module de circuit hyperfréquence selon la revendication 28, caractérisé en ce que ladite structure de base (7) est une colonne.

30. Procédé de fabrication d’un module de circuit hyperfréquence selon la revendication 28, caractérisé en ce que ladite structure de base est une colonne.

31. Procédé de fabrication d’un module de circuit hyperfréquence selon la revendication 18, caractérisé en ce que l’étape de liaison de façon électrique du circuit hyperfréquence (1) au substrat (2) inclut la constitution de bossements conducteurs sur une surface du dispositif (1) au plus près du substrat (2), lesdits bossements conducteurs (14a) assurant un contact électrique entre le dispositif (1) et une pluralité de pistes sur le substrat (2).

32. Procédé de fabrication d’un module de circuit hyperfréquence selon la revendication 18, caractérisé en ce que l’étape de liaison de façon électrique du circuit hyperfréquence (1) au substrat (2) inclut la
constitution de bossements conducteurs (14b) sur une surface du substrat (2) au plus près du dispositif (1), lesdits bossements conducteurs (14b) assurant un contact électrique entre le dispositif et une pluralité de pistes sur le substrat (2).

33. Procédé de fabrication d'un module de circuit hyperfréquence selon la revendication 18, caractérisé en ce que l'étape de liaison d'un couvercle (23) sur ledit substrat (2) est effectuée en utilisant un processus choisi parmi le groupe comprenant un brasage, un soudage et une liaison par adhésif.

34. Procédé de fabrication d'un module de circuit hyperfréquence selon la revendication 18, caractérisé en ce que ledit procédé inclut en outre l'étape de placage de façon conductrice dudit couvercle (23) sur au moins une surface intérieure de celui-ci.

35. Module de circuit hyperfréquence fabriqué au moyen du procédé selon la revendication 18.

36. Module de circuit hyperfréquence selon la revendication 1, caractérisé en ce que ledit couvercle (23) est d'une construction en deux pièces comprenant un élément d'espacement (25) définissant une cavité centrale permettant de loger le circuit hyperfréquence (1) et une plaque (31) recouvrant ledit élément d'espacement (25) afin de former une enceinte pour ledit circuit hyperfréquence (1) entre l'élément d'espacement (25), la plaque (31) et le substrat (2).

37. Module de circuit hyperfréquence selon la revendication 36, caractérisé en ce que ladite enceinte est hermétique.