



(11) **EP 0 961 322 B9**

(12) **CORRECTED EUROPEAN PATENT SPECIFICATION**

(15) Correction information:  
**Corrected version no 1 (W1 B1)**  
**Corrections, see**  
**Description Paragraph(s) 1, 11, 13, 30**

(51) Int Cl.:  
**H01L 23/66** <sup>(2006.01)</sup>

(48) Corrigendum issued on:  
**31.08.2016 Bulletin 2016/35**

(45) Date of publication and mention  
of the grant of the patent:  
**16.03.2016 Bulletin 2016/11**

(21) Application number: **99250169.2**

(22) Date of filing: **28.05.1999**

(54) **Microwave integrated circuit multi-chip-module and mounting structure therefor**

Integriertes Mikrowellen-Mehrchipmodul und Montage-Struktur dafür

Module multi-puce intégré à micro-onde et structure de montage pour ce module

(84) Designated Contracting States:  
**DE SE**

(30) Priority: **28.05.1998 JP 14774598**

(43) Date of publication of application:  
**01.12.1999 Bulletin 1999/48**

(60) Divisional application:  
**15151436.1 / 2 884 533**

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## Description

### BACKGROUND OF THE INVENTION

[0001] The present invention relates to multi-chip-modules, in which a plurality of microwave/millimeter-wave integrated circuits (herein after referred to as MICs) utilizing electromagnetic waves in micro-band to milli-band are mounted in a package substrate.

[0002] In a prior art multi-chip-module with a plurality of MICs mounted therein, a microwave/millimeterwave transceiving circuit is constructed such that elementary circuits such as amplifiers and oscillators or composite circuits such as one in which a multiplier and an amplifier are made integral, one in which a mixer and an amplifier are made integral, and one in which a transmitting unit or a receiving unit are made integral, are interconnected by metal waveguide circuits or three-dimensional circuits.

[0003] Particularly, in a multi-chip-module, a low temperature simultaneous baking substrate such as glass ceramic substrate is used as dielectric substrate, is as low as  $3 \text{ W/m} \cdot \text{K}$  of heat conductivity. To cope with this, a multi-chip-module having heat radiation via holes for promoting heat radiation, is proposed in, K. Ikuina et. al., "Glass-Ceramic Multi-chip-module for Satellite Microwave Communication System", Proc. ICEMCM '95, 1995, pp. 483-488.

[0004] However, even in the multi-chip-module proposed in the above treatise, the thermal conductivity is at most several  $\text{W/m} \cdot \text{K}$ , and it is impossible to greatly improve the heat radiation efficiency. Accordingly, a structure in which metal is applied or buried for permitting heat dissipation from a semiconductor chip is provided as a means for improving the heat radiation efficiency.

[0005] In the above treatise is also proposed a multi-chip-module having a structure that lids as shielding members for shielding high frequency circuits and functional elements from one another are each bonded to a package substrate for each function element constituted by a monolithic MIC such as an oscillator, a mixer, an amplifier and a transceiver.

[0006] Heretofore, a ceramic package of the multi-chip-module is connected to a printed circuit board as a mounting substrate by forming solder balls on an electrode pad provided on the ceramic package and connecting the ceramic package via the solder ball to the printed circuit board. This method of connection is called BGA (Ball Grid Array) connection. As another connecting means, the ceramic package is mounted on the printed circuit board by soldering LCC (Leadless Chip Carrier) electrodes provided on the ceramic package to the printed circuit board.

[0007] However, in the multi-chip-module, in which the microwave/millimeterwave transceiving circuit is such that elementary circuits and composite circuits are interconnected by metal waveguide circuits and three-dimensional circuits, has a drawback that the metal waveguides

is complicated in shape and also such steps as screwing and welding are required for the waveguide formation. This is undesired from the standpoint of reducing the cost of the multi-chip-module.

[0008] In the multi-chip-module, in which metal is applied or buried for dispersing heat from the semiconductor chip, the metal has a thickness of at least 0.2 to 0.5 mm in view of the limit of the processing accuracy, and discontinuity of high frequency grounding surface is produced, thus deteriorating the high frequency characteristics.

[0009] In the multi-chip-module, in which lids are each bonded for each function element for electromagnetic shielding and hermetical sealing of function elements from one another, a plurality of lids should be bonded to the package substrate and hermetically sealed. In this bonding step, the yield value of the hermetical sealing is an accumulation of the yield value of the hermetical sealing of one lid by the number of lids mounted on the package substrate, and is therefore very low. In addition, when defective sealing is detected in the bonded part of either one of the lids as a result of a leak test conducted on the completed multichip module, it is difficult to determine which one of the lids has the defectively sealed bonded part because of the multiple lid structure of this multi-chip-module.

[0010] Furthermore, in the prior art structure, in which the ceramic package of the multi-chip-module is soldered to the printed circuit board, as low linear thermal expansion coefficient of the ceramic substrate, for instance of aluminum nitride, as  $3.5$  to  $4.5 \text{ ppm}/^\circ\text{C}$ , gives rise to the following problem in the connection. When the connection is made by using solder with a linear thermal expansion coefficient of  $13$  to  $16 \text{ ppm}/^\circ\text{C}$  (for instance "FR-4", manufactured by Mitsubishi Gas Chemical Co., Ltd.), cracks or fissures are generated in solder bonded parts by working ambient temperature changes, as described in, Yoji Kanuma, "Efficient Way and Actual Practice of Reliability Acceleration Testis", pp. 161-165 published on October 4, 1997. Therefore, it has been impossible to realize as large package as more than 20 mm on one side.

[0011] US 5418329 discloses a multi-chip module as defined in the pre-characterising portion of claim 1.

### SUMMARY OF THE INVENTION

[0012] An object of the present invention is to provide a microwave integrated circuit multi-chip-module, which permits simplification of the step of bonding the shielding member and improving the yield of the hermetical sealing on the bonded part of the shielding member.

[0013] Another object of the present invention is to provide a microwave integrated circuit multi-chip-module mounting structure, in which portions connected to the mounting substrate are not readily broken apart by heat generation in the microwave integrated circuit multi-chip-module.

**[0014]** According to an aspect of the present invention, there is provided a microwave integrated circuit multi-chip-module as defined in claim 1.

**[0015]** In this structure, the high frequency transmission line and each microwave integrated circuit of the microwave integrated circuit multi-chip-module are electromagnetically shielded by a single shielding member. Thus, the bonding of the shielding member to the package substrate is completed in a single step, thus simplifying the shielding member bonding process.

**[0016]** The surface of the package substrate and the outer periphery of the shielding member are hermetically sealed from each other by fillets made of a water-resistant material or a solder. Thus, the yield of the hermetical sealing on the bonded part of the shielding member is improved.

**[0017]** The package substrate has a tubular waveguide part for guiding electromagnetic waves inputted to or outputted from the high frequency transmission line. The waveguide part has a plurality of via holes formed in a predetermined interval in a tubular fashion in the package substrate.

**[0018]** According to another aspect of the present invention, there is provided a mounting structure as defined in claim 9.

**[0019]** In this structure, even when the microwave integrated circuit multi-chip-module is inflated by heat generation in the microwave integrated circuits, the inflation is absorbed by flexing deformation of the connector electrodes, thus improving the reliability of the connection between the microwave integrated circuit multi-chip-module and the mounting substrate.

**[0020]** At least a portion of parts of the mounting substrate and the receptacle member that face the microwave integrated circuit multi-chip-module when the microwave integrated circuit multi-chip-module is mounted in the receptacle member, has an opening, a projection formed on a support member with the microwave integrated circuit multi-chip-module mounted therein being inserted through the opening. Thus it is possible to radiate the heat generated in the MMICs and to conduct the heat through the projection of the support member to the outside.

**[0021]** According to other aspect of the present invention, there is provided a microwave integrated circuit multi-chip-module comprising a package substrate of a high temperature co-fired ceramic of a dielectric property including a plurality of high frequency circuit portions formed on the surface, and a shielding member of a non-magnetic metal having plurality of recesses formed in position corresponding to the respective high frequency circuit portions, the package substrate and the shielding member being bonded for electromagnetically shielding the high frequency circuit portions.

**[0022]** The shielding member is of tungsten and the package substrate is beryllia or nitride. The package substrate is made of aluminum nitride, beryllia or silicon nitride. The package substrate and the shielding member

being bonded together by a conductive adhesive or a solder. The surface of the package substrate and edge of the shielding member are hermetically sealed to one another by fillets of moisture-resistant resin or a solder.

**[0023]** According still other aspect of the present invention, there is provided a mounting structure for mounting a microwave integrated circuit multi-chip-module comprising a package substrate of a high temperature co-fired ceramic of a dielectric property including a plurality of high frequency circuit portions formed on the surface, a shielding member of a non-magnetic metal having plurality of recesses formed in position corresponding to the respective high frequency circuit portions, the package substrate and a plurality of leadless chip carrier electrodes, the shielding member being bonded for electromagnetically shielding the high frequency circuit portions; and a receptacle having a plurality of flexible connector electrodes each connected to the corresponding leadless chip carrier electrode.

**[0024]** Other objects and features will be clarified from the following description with reference to attached drawings.

#### BRIEF DESCRIPTION OF THE DRAWINGS

**[0025]**

Fig. 1 is a sectional view showing an embodiment of the microwave IC multi-chip-module according to the present invention in a state that an LCC package and a lid of the module are separated from each other;

Fig. 2 is a plan view showing the substrate type circulator shown in Fig. 1;

Fig. 3 is a perspective view showing the LCC package of the multi-chip-module shown in Fig. 1 with some of the structure shown separately;

Fig. 4 is a sectional view showing the multi-chip-module shown in Fig. 1 in a state that the LCC package and the lid are bonded together; and

Fig. 5 is an exploded sectional view showing the multi-chip-module shown in Fig. 1 together with a printed circuit board and a mother board and so forth, in which the multi-chip-module is mounted.

#### PREFERRED EMBODIMENTS OF THE INVENTION

**[0026]** Preferred embodiments of the present invention will now be described with reference to the drawings.

**[0027]** Fig. 1 is a sectional view showing an embodiment of the microwave IC multi-chip-module according to the present invention in a state that an LCC package and a lid of the module are separated from each other.

**[0028]** As shown in Fig. 1, the microwave IC multi-chip-module (hereinafter referred to as multi-chip-module) 1 comprises an LCC package 2, which is obtained by providing a plurality of monolithic microwave ICs (hereinafter referred to as MMICs) 14 and other components on a

package substrate 3 which is formed from a high temperature co-fired ceramic having a dielectric property, such as aluminum nitride. This embodiment of the multi-chip-module 1 may utilize not only microwaves but also other electromagnetic waves ranging from the microwave band to the millimeterwave band.

**[0029]** The package substrate 3 of the LCC package 2 has a blind rectangular cavity 4 open in its back surface. The package substrate 3 also has a microstrip antenna 5 provided on its front surface portion above the rectangular cavity 4.

**[0030]** The package substrate 3 further has a plurality of through via holes 6 provided in a tubular fashion around the rectangular cavity. The rectangular cavity 4, the microstrip antenna 5 and the through holes 6 together constitute a waveguide part 7. The waveguide part 7 has the same longitudinal and transversal dimensions as those of a tubular waveguide coupled to it. The through via holes 6 constituting the waveguide part 7 are each held in a buried fashion in the dielectric ceramic of the package substrate 3. The longitudinal and transversal dimensions of the rectangular cavity are set to be smaller by 0.3 to 1.0 mm than those of the tubular waveguide.

**[0031]** The through via holes 6 are spaced apart at an interval, which is sufficiently small compared to one half the wavelength of an electromagnetic wave guided by the waveguide when the wave is propagated through the dielectric ceramic of the package substrate 3. Where the dielectric constant  $\epsilon_r$  of the dielectric ceramic is 9 when an electromagnetic wave at a frequency of 30 GHz is propagated, the one half wavelength of the electromagnetic wave propagated through the dielectric ceramic is about 1.7 mm. In this case, the through holes 6 are spaced apart at an interval of about 1/8 to 1/5 of the one half wavelength of the wave, i.e., 0.2 to 0.3 mm.

**[0032]** On the back surface of the package substrate 3 a grounding layer 10a is formed, and on the back surface thereof a high frequency circuit layer 8 having a high frequency circuit of a thin film conductor formed by a deposition or photolithographic process. The package substrate 3 further internally has a wiring layer 9 provided above the back surface grounding layer 10a, for DC bias supply and intermediate frequency signal transmission, and another grounding layer 10b provided above the wiring layer 9. The package substrate 3 in this embodiment thus has a four-layer conductive layer laminate. The package substrate 3 further has a plurality of LCC electrodes 11 provided on its side surfaces and connected to the wiring layer 9.

**[0033]** In the high frequency circuit of the high frequency circuit layer 8, a microstrip line is formed as a high frequency line by the dielectric ceramic between the high frequency circuit layer 8 and the grounding layer 10b and the grounding layer 10b. The internal layer wiring lines formed from the wiring layer 9 and the grounding layer 10b, are high frequency shielded (or isolated) by through via holes 12 which connect the internal layer wiring lines formed from the layers 9 and 10b. The grounding layer

10b has an escape hole 10c for preventing the through via holes 12 connecting the wiring layer 9 and the high frequency circuit layer 8 from being in conduction to the grounding layer 10b.

**[0034]** The front surface of the package substrate 3 has a plurality of recesses 13 as deep as to expose the surface of the grounding layer 10b. In the recesses 13, MMICs 14, circulators 15 and isolators (not shown) formed by using such semiconductor as GaAs or InP are accommodated such that they are soldered to the grounding layer 10b. The MMICs 14 are each connected by bonding wires 14a to the high frequency circuit of the high frequency circuit layer 8. The recesses 13 accommodating the circulators 15 each have a recess 13a as deep as to expose the surface of the wiring layer 9. In the recess 13a, a magnetic member 16 of a magnetic material, such as Fe-Ni-Co, is accommodated and secured in position by an adhesive or a solder.

**[0035]** In the package substrate 3, the rectangular cavity 4, the microstrip antenna 5 and the waveguide part 7 together constitute an electromagnetic wave converter 17, which leads an electromagnetic wave having been guided by the waveguide to the microstrip line or conversely leading an electromagnetic wave having been propagated along the microstrip line to the waveguide.

**[0036]** The substrate type circulator 15 shown in Fig. 1 will now be described with reference to Fig. 2. Fig. 2 is a plan view showing the substrate type circulator shown in Fig. 1.

**[0037]** As shown, the substrate type circulator 15 used in this embodiment comprises a central circular microstrip conductor portion 15a and a plurality of micro strip conductive portions 15b extending from the central portion 15a.

**[0038]** Referring back to Fig. 1, this embodiment of the multi-chip-module 1 comprises a lid 18, which serves as a shield member for electromagnetically shielding and hermetically sealing the high frequency circuit and various function elements formed in the high frequency circuit layer 8 of the package module 3.

**[0039]** The lid 18 is formed from a non-magnetic metal, such as tungsten. The back side of the lid 18 has recesses 18a, which are formed in portions corresponding to the high frequency circuit and the function elements in the high frequency circuit layer 8 when the lid 18 is bonded to the package substrate 3, and shield walls 18b partitioning the recesses 18a from one another. When the lid 18 is bonded to the package substrate 3, the shield walls 18b electromagnetically shield and hermetically seal the function elements, such as oscillators and amplifiers, provided in the high frequency circuit layer 8 of the package substrate 3 from one another.

**[0040]** Of the recesses 18a formed in the lid 18, the one 18a covering the substrate type circulator 15 has a recess 18c, which accommodates a permanent magnet 19 disposed above the circular microstrip conductor portion 15a of the substrate type circulator 15. The permanent magnet 19 is held in the recess 18c such that it is

bonded by an adhesive or the like. The ceiling of the recess 18a covering the electromagnetic wave exchange circuit 17 serves as a waveguide short-circuit surface.

**[0041]** In addition, since the lid 18 is formed from the non-magnetic material, it does not constitute a cause of oscillative deterioration of the magnetic circuits such as the substrate type circulator 15 and isolators. Furthermore, with the soft magnetic member 16 provided beneath the substrate type circulator 15 and the permanent magnet 19 provided above the substrate type circulator 15, almost all the magnetic force lines from the permanent magnet 19 are directed toward the soft magnetic member 16, and a uniform static magnetic field is applied to the substrate type circulator 15 in a direction perpendicular to the surface of the substrate type circulator 15.

**[0042]** Fig. 3 is a perspective view showing the LCC package of the multi-chip-module shown in Fig. 1 with some of the structure shown separately.

**[0043]** As shown in Fig. 3, the LCC package 2 of the multi-chip-module 1 includes a transmitting part oscillator 22 serving as a function element of a transmitting part for oscillating a transmitting station signal, a transmitting part mixer 23 for generating a radio signal according to an intermediate frequency signal externally inputted via the LCC electrodes 11 and the transmitting station signal note before, a substrate type band-pass filter 24 for suppressing the transmitting station signal and unnecessary waves, and an MMIC amplifier 25 for amplifying the radio signal. Provided as function elements of a receiving part are a low noise amplifier 26 for amplifying a received signal having been inputted to the multi-chip-module 1 by being guided along the waveguide, a receiving part oscillator 27 for oscillating a receiving station signal, and a receiving part mixer 28 for generating an intermediate wave signal according to the received signal having been amplified by the low noise amplifier 26 and the receiving station signal. The above function elements are constituted by MMICs.

**[0044]** Fig. 4 is a sectional view showing the multi-chip-module shown in Fig. 1 in a state that the LCC package and the lid are bonded together.

**[0045]** As shown in Fig. 4, the lid 18 and the package substrate 3 are bonded together by a conductive adhesive 20 or a solder applied to the bonding surfaces of the lid 18 and the package substrate 3. The surface of the package substrate 3 and the edges of the lid 18 are hermetically sealed to one another by fillets of moisture-resistant resin 21 or a solder with as water absorption factor of about 0.2 % or below. The multi-chip-module 1 is obtained in the manner as described. The multi-chip-module 1 thus obtained has cavities defined by the recesses formed in the lid 18 and the package substrate 3, and the high frequency circuit and the various function elements are electromagnetically shielded and hermetically sealed relative to one another.

**[0046]** Fig. 5 is an exploded sectional view showing the multi-chip-module shown in Fig. 1 together with a printed circuit board and a mother board and so forth, in

which the multi-chip-module is mounted.

**[0047]** As shown in Fig. 5, the multi-chip-module 1 having the construction, as described above is mounted in a receptacle 29 having a plurality of flexible connector electrodes 30 connected to the LCC electrodes 11. The receptacle 29 is mounted by a solder re-flow on the printed circuit board 31 which serves as a mounting board. When the receptacle 29 is mounted, its connector electrodes 30 are connected via connection terminals led out from the connector electrodes 30 and the re-flow solder to the wiring of the printed circuit board 31. The printed circuit board 31 and the receptacle 29 have a hole 29a or 31a, respectively, which are penetrated by a boss or a projection 32a of the mother board 32 to be described later. On the printed circuit board 31, other surface mounting parts are also mounted by the solder re-flow.

**[0048]** The printed circuit board 31 with the receptacle 29 mounted thereon is secured by bolts 33 to the mother board 32 as a support member made of a metal. The lid 18 and the package substrate 3 of the multi-chip-module 1 thus have bolt holes 34, through which the bolts 33 are inserted. The bolt holes 34 formed in the lid 18 have a diameter greater by 0.1 to 0.5 mm than the diameter of those formed in the package substrate 3.

**[0049]** The mother board 32 has a boss or a projection 32a, which is inserted in the holes 29a and 31a of the printed circuit board 31 and the receptacle 29 and has its top surface held in contact with the back surface of the package substrate 3. The projection 32a of the mother board 32 has a rectangular hole 32b facing the rectangular cavity 4 of the multi-chip-module 1 and functioning as part of the tubular waveguide. The projection 32a of the mother board 32 also has threaded holes 35, in which bolts 33 are screwed.

**[0050]** With the above construction, in the multi-chip-module 1 a portion near the rectangular hole of the rectangular cavity 4 is bonded to the mother board 32. Thus, the angular cavity 4 of the multi-chip-module 1 and the rectangular hole 32b of mother board 32 can be reliably coupled to each other irrespective of slight warping, of the order of 20  $\mu\text{m}$ , produced in the package substrate 3.

**[0051]** The operation of the embodiment of the multi-chip-module 1, having the above construction will now be described. This operation is not a part of the claimed invention.

**[0052]** First, the operation when an electromagnetic wave is propagated from the multi-chip-module 1 to the external waveguide will be described.

**[0053]** The transmitting station signal from the transmitting part oscillator 22 of the LCC package 22 is inputted to the transmitting part mixer 23. Also, the intermediate wave signal transmitted from the printed circuit board 31 via the receptacle 29 to the LCC electrodes 11 of the LCC package 2, is inputted via the wiring layer 9 of the package substrate 3 to the transmitting part mixer 23. The transmitting part mixer 23 generates a radio signal according to the input transmitting station signal and intermediate wave signal. The radio signal is passed

through the substrate type band-pass filter 24, then amplified in the MIMIC amplifier 25, and then transmitted via the substrate type circulator 15 used commonly for the transmission and reception to the microstrip antenna 5. When the radio signal passes through the substrate type band-pass filter 24, transmitting station signal and other unnecessary signals are removed. The radio signal having been transmitted to the microstrip antenna 5 is emitted via the electromagnetic wave converter 17 to the waveguide part 7 and the rectangular hole 32b coupled to the angular waveguide, and propagated along the external waveguide (not shown) coupled to the multi-chip-module 1.

**[0054]** The operation for receiving the received signal having been propagated through the external waveguide by the multi-chip-module 1 will now be described.

**[0055]** The received signal having been propagated through the external waveguide, is further transmitted through the rectangular hole 32b of the mother board 32 and the waveguide part 7 of the LCC package, and is inputted to the electromagnetic wave converter 17. The received signal inputted to the electromagnetic wave converter 17 is inputted via the microstrip antenna 5, the substrate type circulator 15 and the substrate type band-pass filter 24 to the low noise amplifier 26 for amplification. The amplified signal from the low noise amplifier 26 is inputted to the receiving part mixer 28. To the receiving part mixer 28 is also inputted the receiving station signal from the receiving part oscillator 27. The receiving part mixer 28 generates the intermediate wave signal according to the input amplified received signal and receiving station signal. The generated intermediate frequency signal passes through the wiring layer 9 of the package substrate 3, and is led from the LCC electrodes 11 of the LCC package 2 via the receptacle 29 to the printed circuit board 31.

**[0056]** Heat generated in the MMICs 14 is conducted through the projection 32a of the mother board 32 in contact with the package substrate 3 and radiated from the mother board 32 to the outside.

**[0057]** Since this embodiment of the multi-chip-module 1 has the structure that the lid 18 having a plurality of recesses is bonded to the LCC package 2, the electromagnetic shielding and hermetical sealing of the individual function elements of the high frequency circuit to one another is obtainable in a single bonding step. Thus, it is possible to simplify the lid bonding process and also improve the yield of hermetical sealing in the lid bonding process compared to the prior art process, in which a plurality of lids are bonded.

**[0058]** In addition, in the multi-chip-module 1 the LCC electrodes 11 provided on the side surfaces of the LCC package 2 are connected to the connector electrodes 30 of the receptacle 29 mounted on the printed circuit board 31. Thus, even when the multi-chip-module 1 is expanded due to heat generation from the MMICs 14 and other components, the connection of the LCC electrodes 11 and the connector electrodes 22 to one another can be

maintained owing to the absorption of the expansion by flexing of the flexible connector electrodes 30. It is thus possible to improve the reliability of connection of the multi-chip-module 1 and the mounting substrate to one another, and, unlike the prior art, it is not possible that the portions where the multi-chip-module and the mounting substrate are connected to each other is ruptured by an ambient temperature change. A multi-chip-module 1 having as large size as 20 mm or above thus can be realized.

**[0059]** While the multi-chip-module 1 described above used aluminum nitride as the ceramic material of the package substrate 3, it is also possible to use other materials which have as high thermal conductivity as about 20 W/m · K or above and are capable of permitting multi-layer substrate structure formation, for instance beryllia and silicon nitride.

**[0060]** Also, while the multi-chip-module 1 described above had a structure that the microstrip antenna 5 is provided on the front surface of the package substrate 3 over the rectangular cavity 4 of the non-penetrating type open in the back surface, it may also have a different structure, for instance one which is obtained by forming the package substrate 3 with a rectangular cavity of penetrating type and bonding a dielectric ceramic substrate with a microstrip antenna formed on the front opened surface with an adhesive or by soldering to the front surface portion of the package substrate 3 with the rectangular cavity open therein. As a further alternative, it is possible to form a microstrip antenna by forming a ceramic package with a non-penetrating cavity (or waveguide part), which is open in the top surface and has a bottom constituted by a lowermost non-conductive dielectric layer, and arranging a separate dielectric substrate such as to project into the waveguide part along the side surfaces thereof.

**[0061]** As has been described in the foregoing, in the microwave integrated circuit multi-chip-module according to the present invention, to a package having a high frequency transmission line is formed on the surface and carrying a plurality of microwave integrated circuits, is bonded a shielding member, which has recesses formed such as to face the high frequency transmission line and each of the microwave integrated circuits and shielding wall portions partitioning the recesses from one another. It is thus possible to electromagnetically shield the high frequency circuit and each of the microwave integrated circuit from one another with a single shielding member, thus simplifying the process of bonding the shielding member.

**[0062]** In addition, by hermetically sealing the surface of the package substrate and the outer periphery of the shielding member from each other with fillets of a water-resistant resin or a solder, it is possible to improve the yield of the hermetically sealing.

**[0063]** Furthermore, the microwave integrated circuit multi-chip-module mounting structure according to the present invention comprises a microwave integrated cir-

cuit multi-chip-module with external connection electrodes provided on the side face of a package substrate and a mounting substrate having a receptacle member with the microwave integrated circuit multi-chip-module mounted therein, the receptacle member being provided with flexible connector terminals connected to the external connection terminals. Even when microwave integrated circuit multi-chip-module is inflated by heat generation in the microwave integrated circuits, the connection between the external connection electrodes and the connector electrodes are maintained, and it is thus possible to improve the reliability of the connection between the microwave integrated circuit multi-chip-module and the mounting substrate.

**[0064]** In the present invention, a buffer plate such as Cu/W buffer plate may be inserted between the package substrate (AlN) and the high frequency circuit portion (GaAs) in order to reduce the mechanical stress caused to the high frequency circuit portion due to the difference of the temperature expansion coefficients therebetween.

**[0065]** Changes in construction will occur to those skilled in the art and various apparently different modifications and embodiments may be made without departing from the scope of the present invention. The matter set forth in the foregoing description and accompanying drawings is offered by way of illustration only. It is therefore intended that the foregoing description be regarded as illustrative rather than limiting.

## Claims

1. A microwave integrated circuit multi-chip-module (1) comprising:

a package substrate (3) having a front surface and a back surface and a high frequency transmission line (8) formed on the front surface, the high frequency transmission line (8) being suited for transmitting microwave signals;

a plurality of microwave integrated circuits (14) mounted on the front surface ; and

a shielding member (18) bonded to the front surface substrate (3) and electromagnetically shielding the high frequency transmission line (8) and each microwave integrated circuit (14) from each other,

wherein the shielding member (18) has a recesses (18a) formed such as to face the high frequency transmission line (8) and the microwave integrated circuits (14) and shielding wall portions (18b) partitioning the recesses (18a) from one another,

**characterized in that**

the package substrate (3) has a blind rectangular cavity open on the back surface, a microstrip antenna (5) on a portion of the front surface which is above the blind rectangular cavity and

a plurality of via holes (6) formed in a tubular fashion around the blind rectangular cavity, wherein the blind rectangular cavity, the microstrip antenna and the plurality of via holes together constitute a tubular waveguide part (7) for guiding electromagnetic waves inputted to or outputted from the high frequency transmission line (8).

2. Microwave integrated circuit multi-chip-module (1) according to claim 1, wherein the front surface of the package substrate (3) and the outer periphery of the shielding member (18) are hermetically sealed to each other by fillets (21) made of a water-resistant material; or a solder.

3. Microwave integrated circuit multi-chip-module according to claim 1, wherein the package substrate (3) is formed from a high temperature co-fired dielectric ceramic, the package substrate (3) including a plurality of high frequency circuit portions formed on the surface, the shielding member (18) is formed from a non-magnetic metal, the shielding member (18) having plurality of recesses (18a) formed in position corresponding to the respective high frequency circuit portions, and the package substrate (3) and the shielding member (18) are adapted to be bonded for electromagnetically shielding the high frequency circuit portions.

4. Microwave integrated circuit multi-chip-module (1) according to claim 3, wherein the shielding member (18) is of tungsten.

5. Microwave integrated circuit multi-chip-module (1) according to claim 1 or 3, wherein the package substrate (3) is of aluminum nitride, beryllia or silicon nitride.

6. Microwave integrated circuit multi-chip-module (1) according to claim 3, wherein the package substrate (3) and the shielding member (18) are adapted to be bonded together by a conductive adhesive or a solder (20).

7. Microwave integrated circuit multi-chip-module (1) according to claim 3, wherein surface of the package substrate (3) and edge of the shielding member (18) are hermetically sealed to one another by fillets of moisture-resistant resin or a solder (21).

8. Microwave integrated circuit multi-chip-module (1) according to claim 1 or 3, wherein a buffer plate is inserted between the package substrate (3) and the high frequency circuit portion in order to reduce the mechanical stress caused to the high frequency circuit portion due to the difference of the temperature expansion coefficients.

9. A mounting structure for mounting a microwave integrated circuit multi-chip-module (1), the mounting structure comprising the microwave integrated circuit multi-chip-module (1) according to claim 1 or 2, and a mounting substrate (31) with the microwave integrated circuit multi-chip-module (1) mounted therein, wherein:
- the side surfaces of the package substrate (2) of the microwave integrated circuit module (1) has external connection electrodes (11) connected to the microwave integrated circuits (14), and the mounting substrate (31) has a receptacle member (29) with the microwave integrated circuit multi-chip-module (1) mounted therein and having flexible connector terminals (30) connected to the external connection electrodes (11) of the microwave integrated circuit multi-chip-module (1).
10. Mounting structure according to claim 9, wherein at least a portion of parts of the mounting substrate (31) and in particular the receptacle member (29) that face the microwave integrated circuit multi-chip-module (1) when the microwave integrated circuit multi-chip-module is mounted (1) in the receptacle member (29), has an opening (29a, 21a) through which a projection (32a) formed in a support member is inserted with the microwave integrated circuit multi-chip-module (1) mounted in the receptacle member (29).
11. Mounting structure according to claim 9, wherein the package substrate (3) is of aluminum nitride, beryllia or silicon nitride.
12. Mounting structure according to claim 9, wherein a buffer plate is inserted between the package substrate (3) and the high frequency circuit portion in order to reduce the mechanical stress caused to the high frequency circuit portion due to the difference of the temperature expansion coefficients.

#### Patentansprüche

1. Integriertes Mikrowellen-Mehrchipmodul (1), umfassend:
- ein Paketsubstrat (3) mit einer Vorderfläche und einer Rückfläche und einer Hochfrequenzübertragungsleitung (8), die auf der Vorderfläche gebildet ist, wobei die Hochfrequenzübertragungsleitung (8) zum Übertragen von Mikrowellensignalen geeignet ist; eine Mehrzahl integrierte Mikrowellenschaltungen (14), die auf der Vorderfläche angebracht sind; und ein Abschirmelement (18), das an das Vorderflächensubstrat (3) gebunden ist und die Hochfrequenzübertragungsleitung (8) und jede integrierte Mikrowellenschaltung (14) voneinander abschirmt, wobei das Abschirmelement (18) eine Ausnehmung (18a) aufweist, die so gebildet ist, dass sie der Hochfrequenzübertragungsleitung (8) und den integrierten Mikrowellenschaltungen (14) zugewandt ist und Wandabschnitte (18b), die die Ausnehmungen (18a) teilen, voneinander abschirmt, dadurch gekennzeichnet, dass das Paketsubstrat (3) einen verdeckten rechteckigen Hohlraum, der sich an der Rückfläche öffnet, eine Mikrostreifenantenne (5) an einem Abschnitt an der Vorderfläche, der sich über dem verdeckten rechteckigen Hohlraum befindet, und eine Mehrzahl Durchgangslöcher (6), die in rohrartiger Weise um den verdeckten rechteckigen Hohlraum gebildet sind, aufweist, wobei der verdeckte rechteckige Hohlraum, die Mikrostreifenantenne und die Mehrzahl Durchgangslöcher zusammen ein rohrartiges Wellenleiterstück (7) zum Leiten von elektromagnetischen Wellen bilden, die der Hochfrequenzübertragungsleitung (8) eingegeben oder von ihr ausgegeben werden.

2. Integriertes Mikrowellen-Mehrchipmodul (1) nach Anspruch 1, wobei die Vorderfläche des Paketsubstrats (3) und der Außenumfang des Abschirmelements (18) durch Leisten (21), die aus einem wasserfesten Material hergestellt sind, oder durch ein Lötmedium hermetisch aneinander gedichtet sind.
3. Integriertes Mikrowellen-Mehrchipmodul (1) nach Anspruch 1, wobei das Paketsubstrat (3) aus einer dielektrischen Hochtemperatur-Mehrlagenkeramik gebildet ist, wobei das Paketsubstrat (3) eine Mehrzahl Hochfrequenzschaltungsabschnitte umfasst, die auf der Oberfläche gebildet sind, wobei das Abschirmelement (18) aus einem nichtmagnetischen Metall gebildet ist, das Abschirmelement (18) eine Mehrzahl Ausnehmungen (19a) aufweist, die in Position entsprechend den jeweiligen Hochfrequenzschaltungsabschnitten gebildet sind und das Paketsubstrat (3) und das Abschirmelement (18) eingerichtet sind, um verbunden zu werden, um die Hochfrequenzschaltungsabschnitte elektromagnetisch abzuschirmen.
4. Integriertes Mikrowellen-Mehrchipmodul (1) nach Anspruch 3, wobei das Abschirmelement (18) aus Wolfram ist.



5. Integriertes Mikrowellen-Mehrchipmodul (1) nach Anspruch 3, wobei das Paketsubstrat (3) aus Aluminiumnitrid, Berylliumoxid oder Siliziumnitrid ist.
6. Integriertes Mikrowellen-Mehrchipmodul (1) nach Anspruch 3, wobei das Paketsubstrat (3) und das Abschirmelement (18) eingerichtet sind, um durch einen leitfähigen Klebstoff oder ein Lötmedium (20) verbunden zu werden.
7. Integriertes Mikrowellen-Mehrchipmodul (1) nach Anspruch 3, wobei die Oberfläche des Paketsubstrats (3) und der Rand des Abschirmelements (18) durch Leisten aus feuchtigkeitsresistentem Harz oder ein Lötmedium (21) hermetisch aneinandergedichtet sind.
8. Integriertes Mikrowellen-Mehrchipmodul (1) nach Anspruch 1 oder 3, wobei zwischen dem Paketsubstrat (3) und dem Hochfrequenzschaltungsabschnitt eine Pufferplatte eingefügt ist, um die mechanische Spannung zu verringern, die aufgrund der Differenz der Temperaturexpansionskoeffizienten an dem Hochfrequenzschaltungsabschnitt verursacht wird.
9. Montagestruktur zum Montieren eines integrierten Mikrowellen-Mehrchipmoduls (1), wobei die Montagestruktur umfasst:
- das integrierte Mikrowellen-Mehrchipmodul (1) nach Anspruch 1 oder 2, und
- ein Montagesubstrat (31), in dem das integrierte Mikrowellen-Mehrchipmodul (1) montiert ist, wobei:
- die Seitenflächen des Paketsubstrats (2) des integrierten Mikrowellenmoduls (1) äußere Verbindungselektroden (11) aufweist, die mit den integrierten Mikrowellenschaltungen (14) verbunden sind, und
- das Montagesubstrat (31) ein Aufnahmeelement (29) aufweist, in dem das integrierte Mikrowellen-Mehrchipmodul (1) montiert ist und das flexible Verbindungsanschlüsse (30) aufweist, die mit den äußeren Verbindungselektroden (11) des integrierten Mikrowellen-Mehrchipmoduls (1) verbunden sind.
10. Montagestruktur nach Anspruch 9, wobei mindestens ein Abschnitt von Teilen der Montagestruktur (31) und insbesondere das Aufnahmeelement (29), die dem integrierten Mikrowellen-Mehrchipmodul (1) zugewandt sind, wenn das integrierte Mikrowellen-Mehrchipmodul (1) in dem Aufnahmeelement (29) montiert ist, eine Öffnung (29a, 21a) aufweist, durch die ein Vorsprung (32a), der in einem Stützelement gebildet ist, eingeführt wird, wobei das integrierte Mi-

krowellen-Mehrchipmodul (1) in dem Aufnahmeelement (29) montiert ist.

11. Montagestruktur nach Anspruch 9, wobei das Paketsubstrat (3) aus Aluminiumnitrid, Berylliumoxid oder Siliziumnitrid ist.
12. Montagestruktur nach Anspruch 9, wobei zwischen dem Paketsubstrat (3) und dem Hochfrequenzschaltungsabschnitt eine Pufferplatte eingefügt ist, um die mechanische Spannung zu verringern, die aufgrund der Differenz der Temperaturexpansionskoeffizienten an dem Hochfrequenzschaltungsabschnitt verursacht wird.

### Revendications

1. Module multipuce de circuit intégré hyperfréquence (1) comprenant :

un substrat de boîtier (3) ayant une surface avant et une surface arrière et une ligne de transmission haute fréquence (8) formée sur la surface avant, la ligne de transmission haute fréquence (8) étant adaptée pour transmettre des signaux hyperfréquences ;

une pluralité de circuits intégrés hyperfréquences (14) montés sur la surface avant ; et

un organe de blindage (18) lié au substrat de surface avant (3) et blindant électromagnétiquement la ligne de transmission haute fréquence (8) et chaque circuit intégré hyperfréquences (14) les uns par rapport aux autres,

dans lequel l'organe de blindage (18) comprend un évidement (18a) formé de façon à faire face à la ligne de transmission haute fréquence (8) et les circuits intégrés hyperfréquences (14) et blindant les portions de paroi (18b) cloisonnant les évidements (18a) les uns des autres,

#### **caractérisé en ce que**

le substrat de boîtier (3) a une cavité rectangulaire borgne ouverte sur la surface arrière, une antenne de microruban (5) sur une portion de la surface avant qui est au-dessus de la cavité rectangulaire borgne et une pluralité de trous traversants (6) formés de façon tubulaire autour de la cavité rectangulaire borgne, dans lequel la cavité rectangulaire borgne, l'antenne de microruban et la pluralité de trous traversants constituent ensemble une partie de guide d'onde tubulaire (7) destinée à guider des ondes électromagnétiques fournis en entrée à ou fournis en sortie par la ligne de transmission haute fréquence (8).

2. Module multipuce de circuit intégré hyperfréquence (1) selon la revendication 1, dans lequel la surface

avant du substrat de boîtier (3) et la périphérie externe de l'organe de blindage (18) sont hermétiquement scellées l'une à l'autre par des filets (21) constitués d'un matériau résistant à l'eau ; ou une soudure.

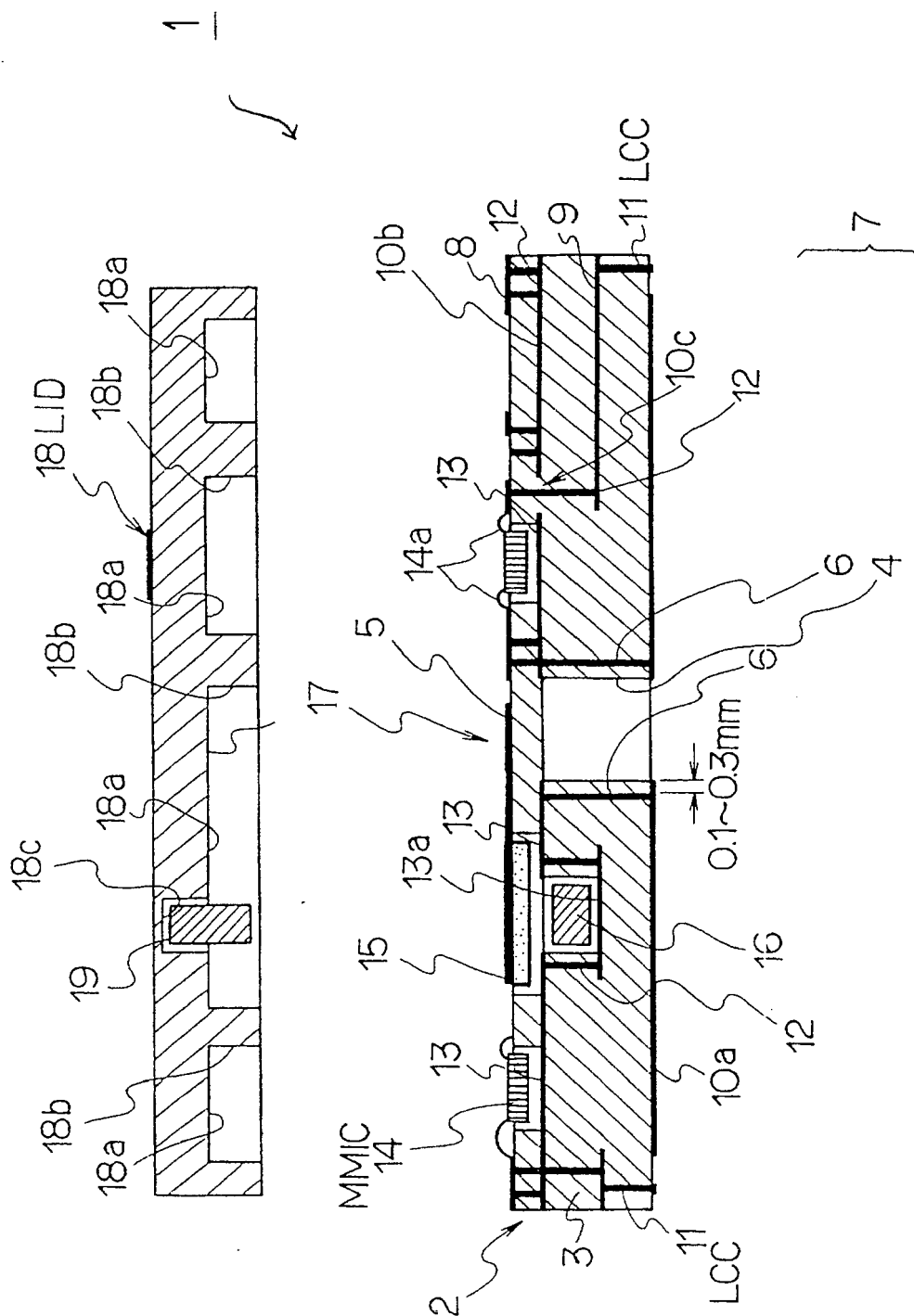
3. Module multipuce de circuit intégré hyperfréquence selon la revendication 1, dans lequel le substrat de boîtier (3) est formé d'une céramique diélectrique ayant fait l'objet d'une cuisson à haute température, le substrat de boîtier (3) incluant une pluralité de portions de circuit haute fréquence formées sur la surface, l'organe de blindage (18) est formé à partir d'un métal non magnétique, l'organe de blindage (18) ayant une pluralité d'évidements (18a) formés en une position correspondant aux portions de circuit haute fréquence respectives, et le substrat de boîtier (3) et l'organe de blindage (18) sont adaptés pour être liés pour blindage électromagnétiquement les portions de circuit haute fréquence.
4. Module multipuce de circuit intégré hyperfréquence (1) selon la revendication 3, dans lequel l'organe de blindage (18) est en tungstène.
5. Module multipuce de circuit intégré hyperfréquence (1) selon la revendication 1 ou 3, dans lequel le substrat de boîtier (3) est en nitrure d'aluminium, oxyde de béryllium ou nitrure de silicium.
6. Module multipuce de circuit intégré hyperfréquence (1) selon la revendication 3, dans lequel le substrat de boîtier (3) et l'organe de blindage (18) sont adaptés pour être liés ensemble par un adhésif conducteur ou une soudure (20).
7. Module multipuce de circuit intégré hyperfréquence (1) selon la revendication 3, dans lequel la surface du substrat de boîtier (3) et un bord de l'organe de blindage (18) sont hermétiquement scellés l'un à l'autre par des filets de résine résistant à l'humidité ou une soudure (21).
8. Module multipuce de circuit intégré hyperfréquence (1) selon la revendication 1 ou 3, dans lequel une plaque tampon est insérée entre le substrat de boîtier (3) et la portion de circuit haute fréquence afin de réduire la contrainte mécanique provoquée sur la portion de circuit haute fréquence en raison de la différence des coefficients de dilatation thermique.
9. Structure de montage destinée à monter un module multipuce de circuit intégré hyperfréquence (1), la structure de montage comprenant le module multipuce de circuit intégré hyperfréquence (1) selon la revendication 1 ou 2, et un substrat de montage (31) à l'intérieur duquel le module multipuce de circuit intégré hyperfréquence

(1) est monté, dans lequel :

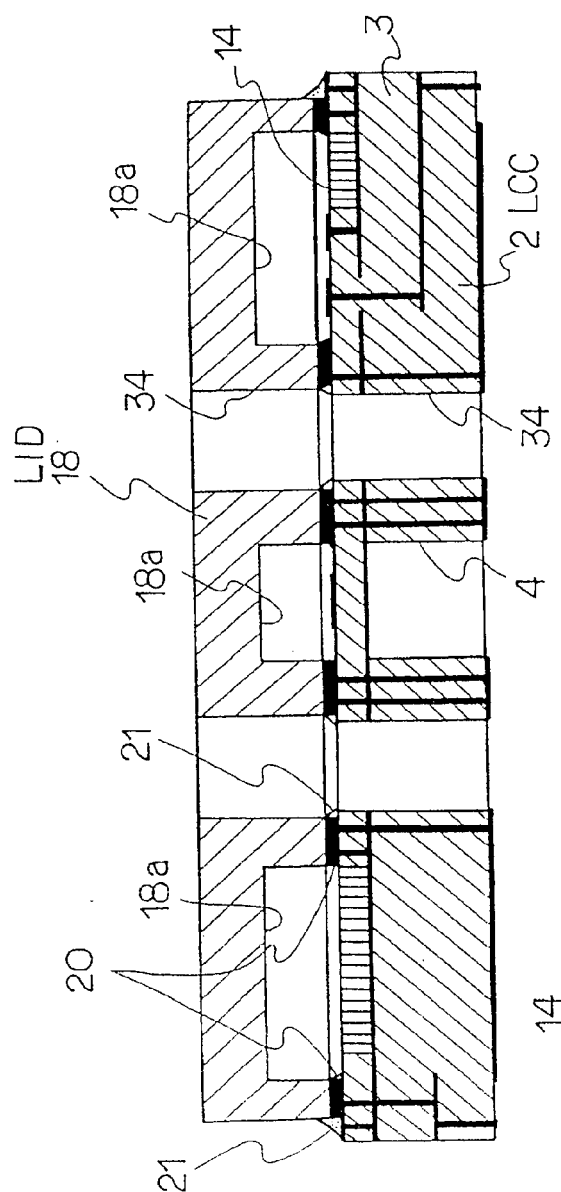
les surfaces latérales du substrat de boîtier (2) du module de circuit intégré hyperfréquence (1) a des électrodes de connexion externes (11) connectées aux circuits intégrés hyperfréquences (14), et le substrat de montage (31) a un organe de réceptacle (29) à l'intérieur duquel le module multipuce de circuit intégré hyperfréquence (1) est monté et ayant des bornes de connecteur flexibles (30) connectées aux électrodes de connexion externes (11) du module multipuce de circuit intégré hyperfréquence (1).

10. Structure de montage selon la revendication 9, dans laquelle au moins une portion de parties du substrat de montage (31) et en particulier l'organe de réceptacle (29) qui fait face au module multipuce de circuit intégré hyperfréquence (1) lorsque le module multipuce de circuit intégré hyperfréquence (1) est monté dans l'organe de réceptacle (29), a une ouverture (29a, 21a) à travers laquelle une protubérance (32a) formée dans un organe de support est insérée, avec le module multipuce de circuit intégré hyperfréquence (1) monté dans l'organe de réceptacle (29).
11. Structure de montage selon la revendication 9, dans laquelle le substrat de boîtier (3) est en nitrure d'aluminium, oxyde de béryllium ou nitrure de silicium.
12. Structure de montage selon la revendication 9, dans laquelle une plaque tampon est insérée entre le substrat de boîtier (3) et la portion de circuit haute fréquence afin de réduire la contrainte mécanique provoquée sur la portion de circuit haute fréquence en raison de la différence des coefficients de dilatation thermique.

FIG. 1



**FIG. 4**



**FIG. 2**

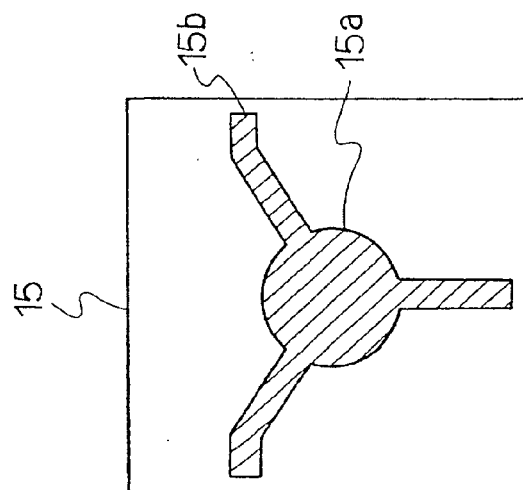
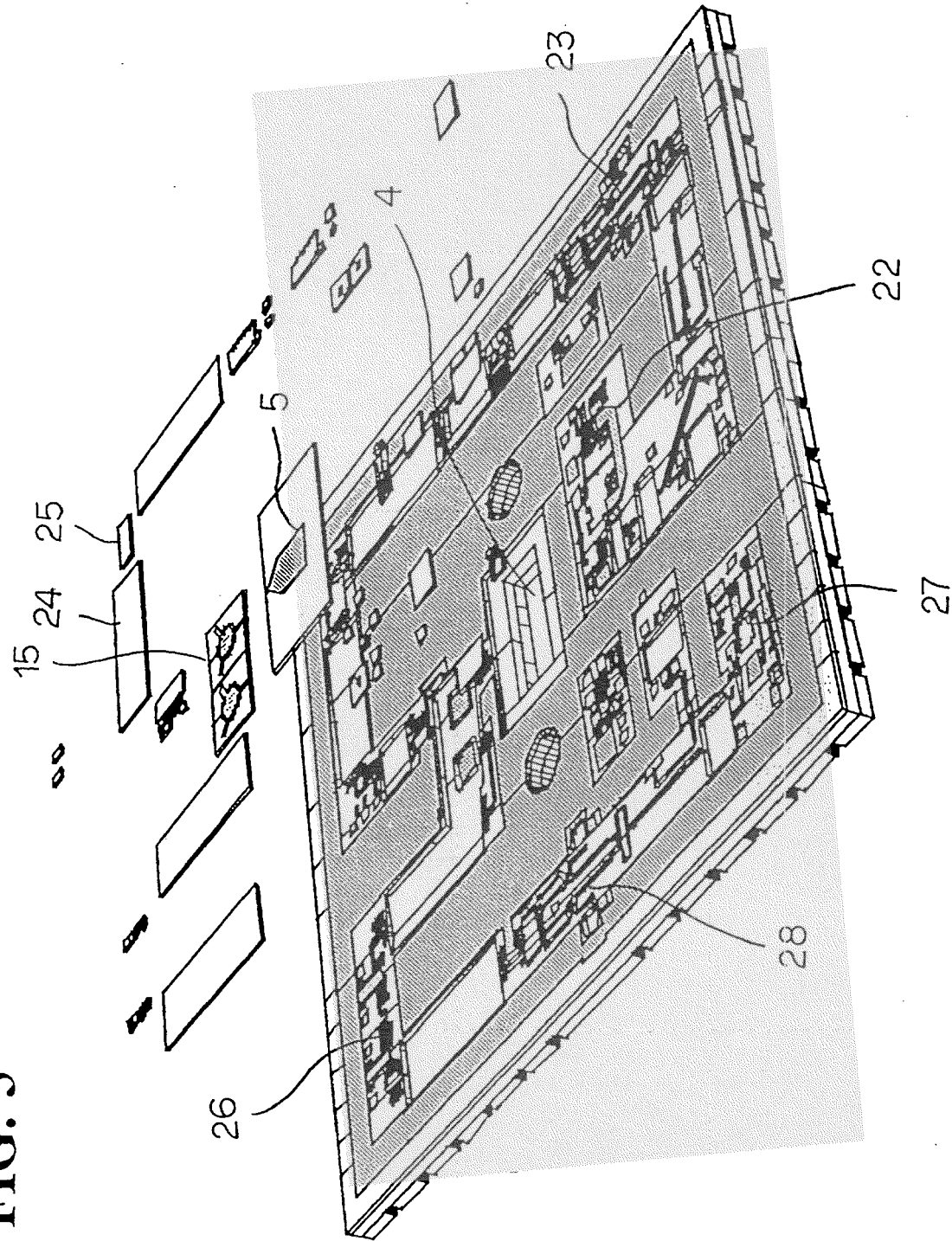
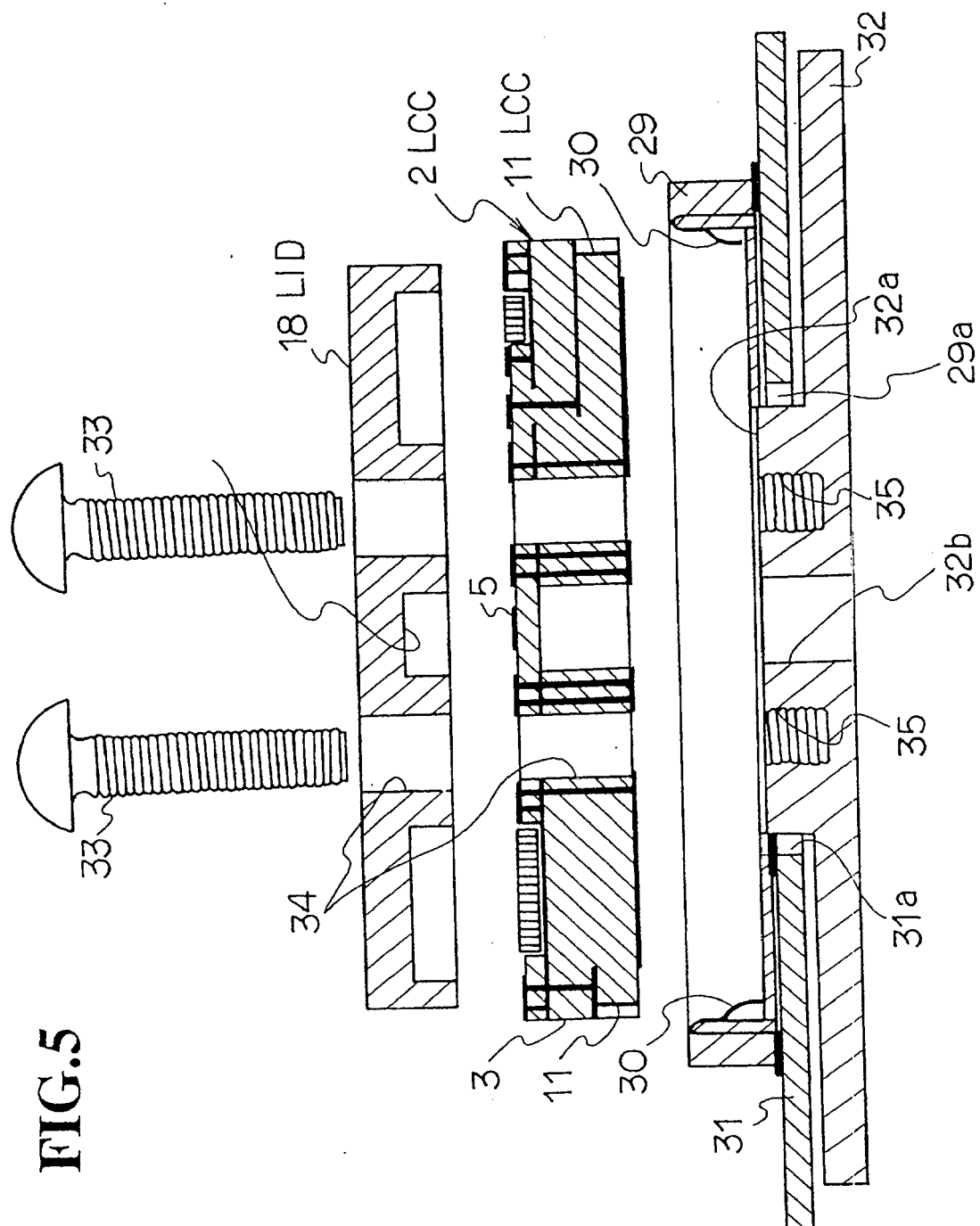


FIG. 3



**FIG. 5**



## REFERENCES CITED IN THE DESCRIPTION

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