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Samples

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(54) **RF PACKAGE**

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(22) Filed: **Nov. 3, 2010**

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(51) **Int. Cl.**
H01L 23/31 (2006.01)

(52) **U.S. Cl.** **257/704**; 257/696; 257/728; 257/732; 257/E23.124; 257/E23.128; 361/719

(58) **Field of Classification Search** 257/696
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

3,387,190 A 6/1968 Winkler
3,555,375 A 11/1968 Hilbers
4,908,694 A 3/1990 Hidaka et al.
4,996,582 A 2/1991 Nagahama
5,155,575 A 10/1992 Zimmermann
5,170,337 A 12/1992 Borowiec et al.
5,524,339 A 6/1996 Gorowitz et al.
5,548,099 A 8/1996 Cole, Jr. et al.
5,683,943 A 11/1997 Yamada
5,939,774 A 8/1999 Yamada
6,008,068 A 12/1999 Yamada
6,943,293 B1 9/2005 Jeter et al.

(Continued)

FOREIGN PATENT DOCUMENTS

EP 0367680 A1 5/1990
EP 0844663 A1 5/1998

(Continued)

OTHER PUBLICATIONS

Kyocera Semiconductor Parts Power Transistor Packages, Kyocera website, 2009.

(Continued)

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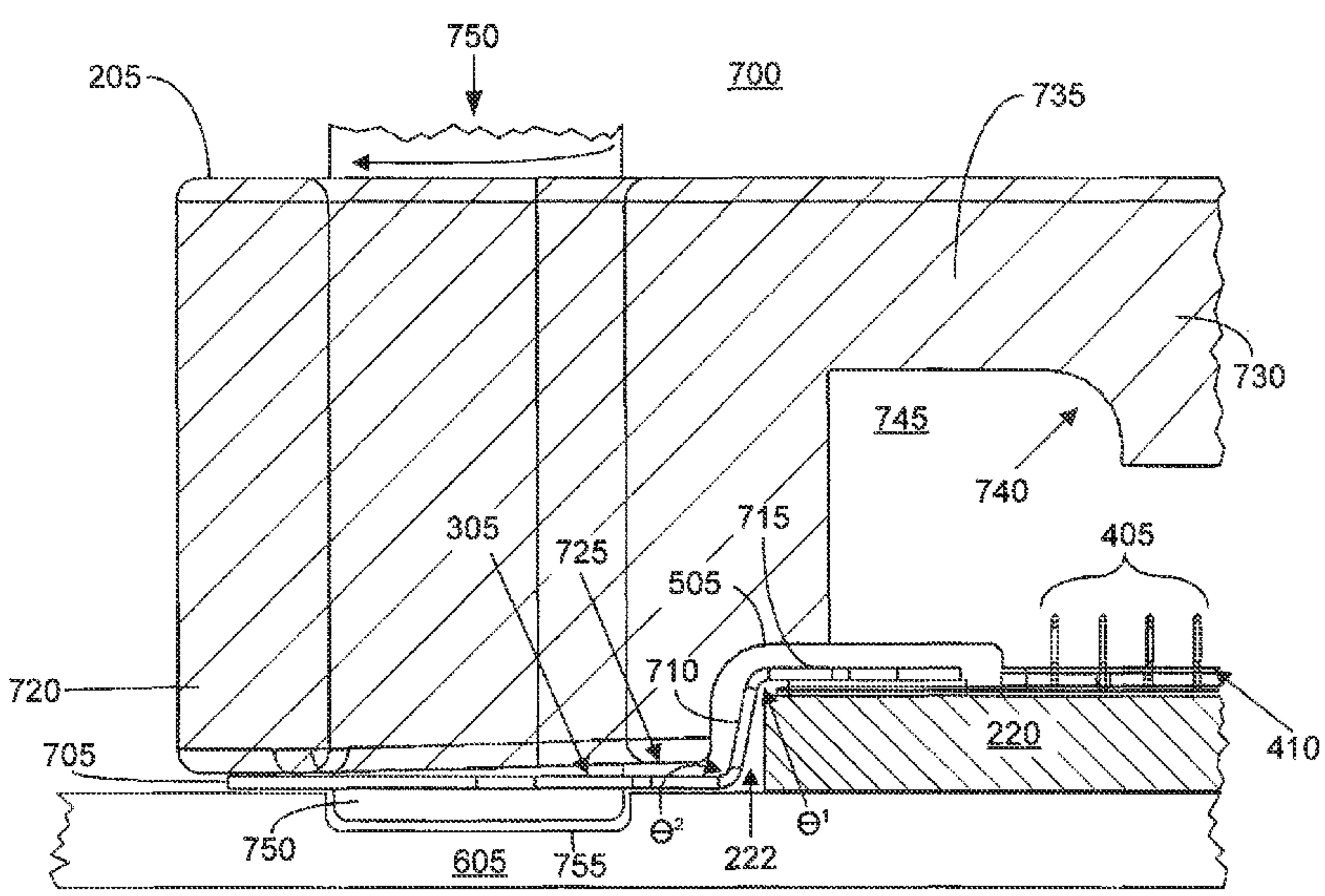
(57) **ABSTRACT**

An RF package includes a substrate mountable on a base plate, a non-conductive cover overlying the substrate, and quasi-serpentine stepped source leads attached to an upper surface of the substrate and extending from at least one of a pair of opposite sides of the upper surface of the substrate to tapered lower surfaces of the cover. The cover includes a recess to receive the substrate. The recess includes stress distribution surface areas to engage and press outer edge portions of opposite sides of the substrate against a base plate or heat sink. The tapered lower surfaces of the cover engage with and press against the stepped source leads when securing the RF package to the base plate or heat sink using one or more fasteners or bolts. The cover includes structural features to improve preferential deformation when a mounting force is applied.

9 Claims, 4 Drawing Sheets



U.S. PATENT DOCUMENTS

7,105,931	B2	9/2006	Attarwala	
7,134,197	B2	11/2006	Shiffer et al.	
7,557,434	B2	7/2009	Malhan et al.	
2004/0061221	A1	4/2004	Schaffer	
2004/0195701	A1	10/2004	Attarwala	
2005/0136569	A1	6/2005	Shiffer et al.	
2006/0084254	A1	4/2006	Attarwala	
2007/0096297	A1 *	5/2007	Frey	257/706
2007/0145473	A1	6/2007	Asano et al.	
2008/0054425	A1	3/2008	Malhan et al.	
2008/0054439	A1	3/2008	Malhan et al.	
2008/0203558	A1 *	8/2008	Tashiro et al.	257/704
2008/0237840	A1	10/2008	Alcoe et al.	
2009/0146280	A1	6/2009	Shimazaki et al.	

FOREIGN PATENT DOCUMENTS

EP	1632998	A1	3/2006
EP	1662565	A2	5/2006
EP	1796163	A1	6/2007
GB	2444293	A	6/2008
GB	2444978	A	6/2008
WO	2005062371	A2	7/2005

OTHER PUBLICATIONS

Product Information Sheet, Standard RF Packages Jul. 1998, 1998 Kyocera America, Inc., two pages.

Product Information Sheet, Standard Microwave Package Jul. 1997, 1998 Kyocera America, Inc., two pages.

Components for Wireless Communication Devices, http://global.kyocera.com/prdct/semicon/semi/wireless/index.html, downloaded from the internet, Oct. 27, 2010, Kyocera Corporation, two pages.

RF Power Transistor Packages, Components for Wireless Communication Devices, http://global.kyocera.com/prdct/semicon/semi/wireless/fet_pkg.html, downloaded from the internet, Oct. 27, 2010, Kyocera Corporation, one page.

* cited by examiner

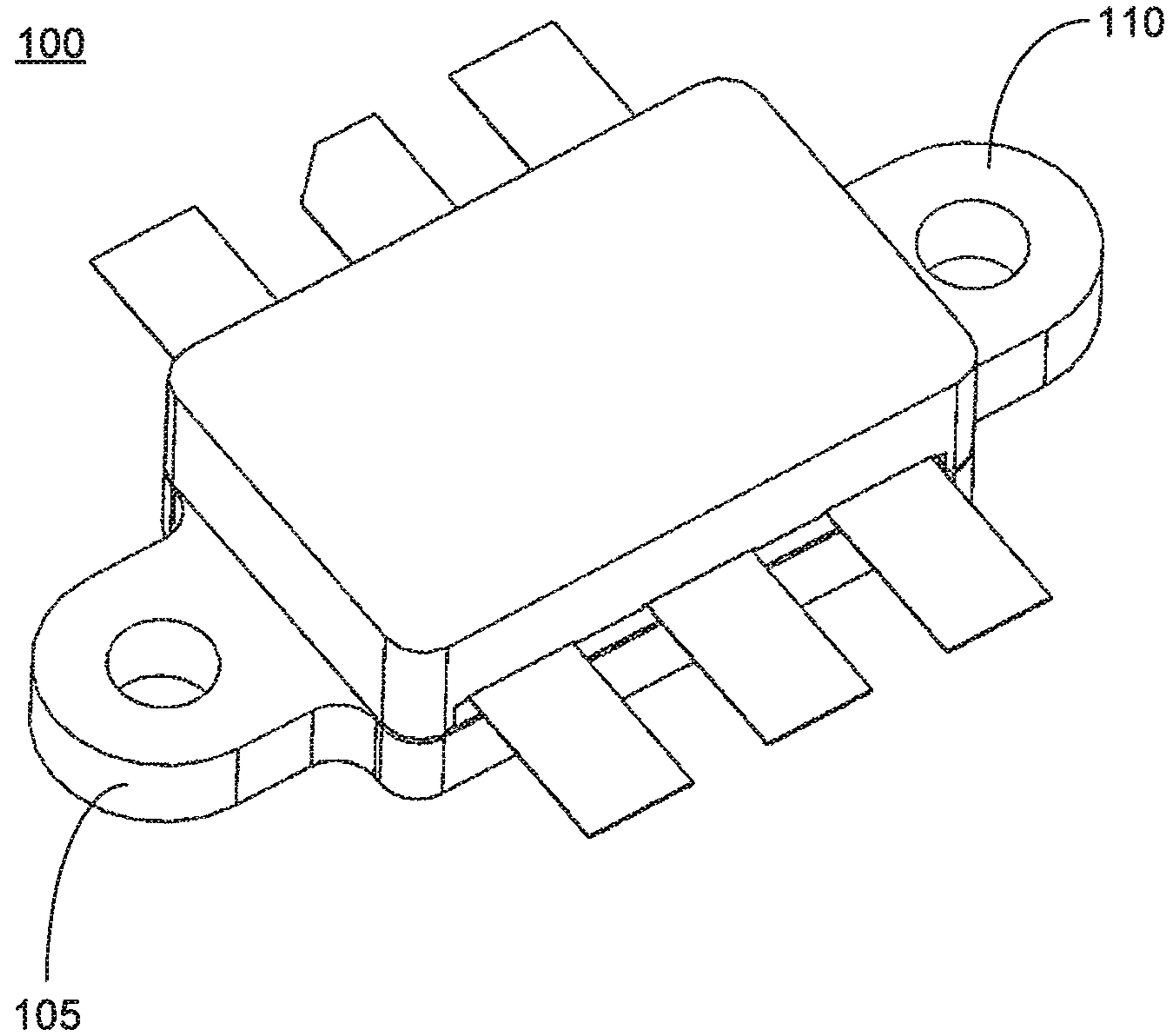


FIG. 1
(PRIOR ART)

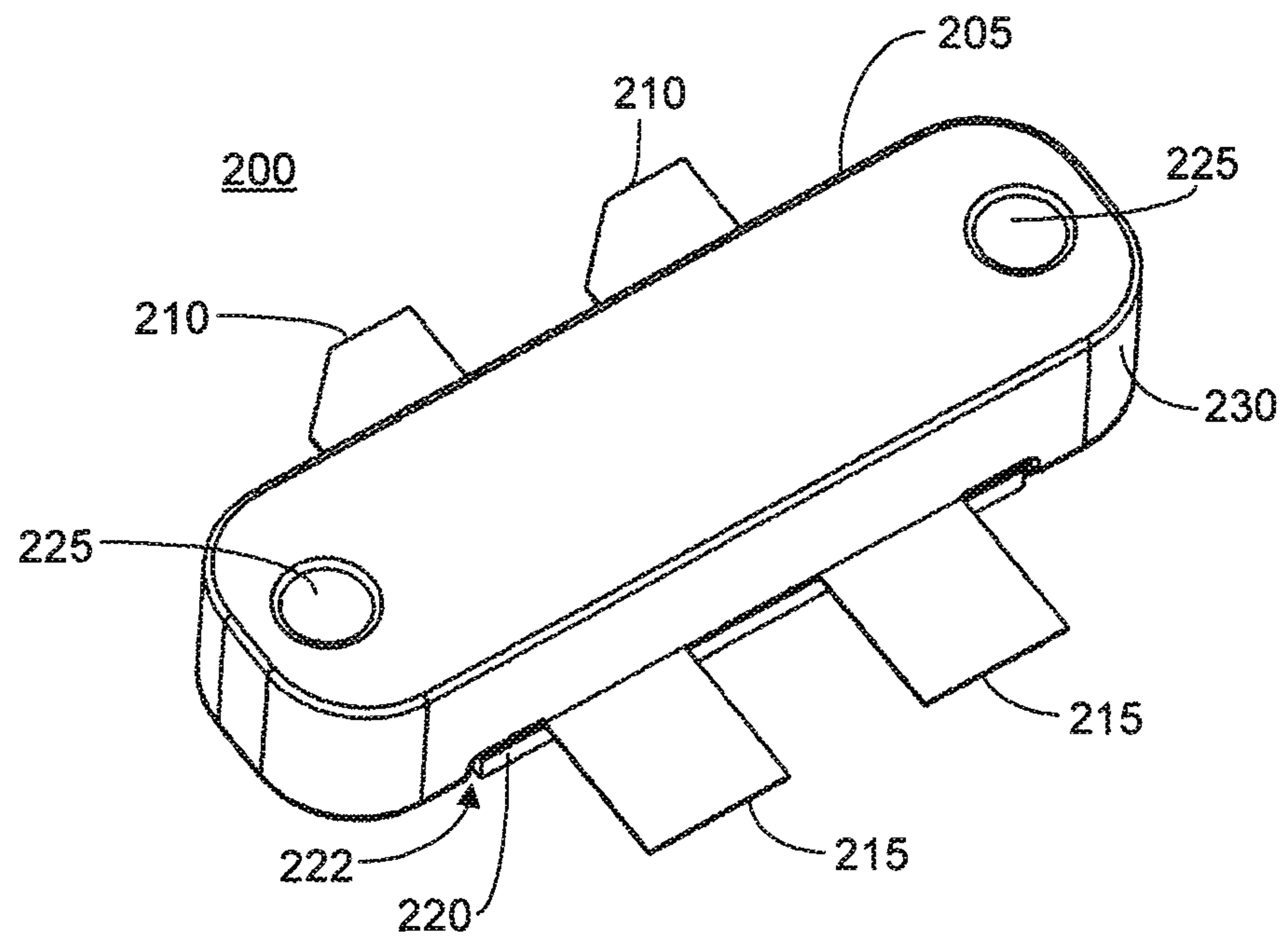

200
205
210
210
225
225
230
215
215
222
220

FIG. 2

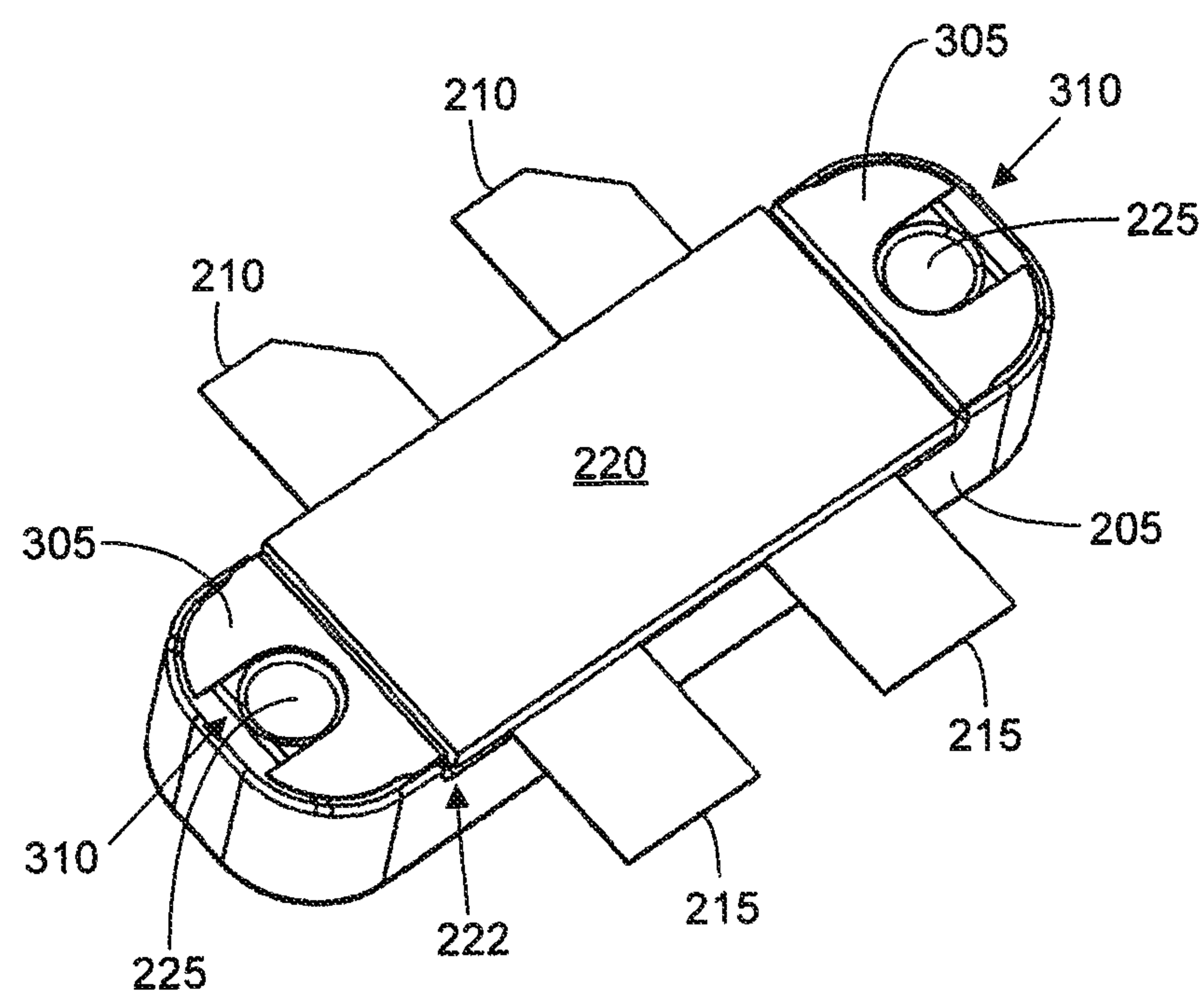

305
310
210
210
225
220
305
205
215
215
310
225
222

FIG. 3

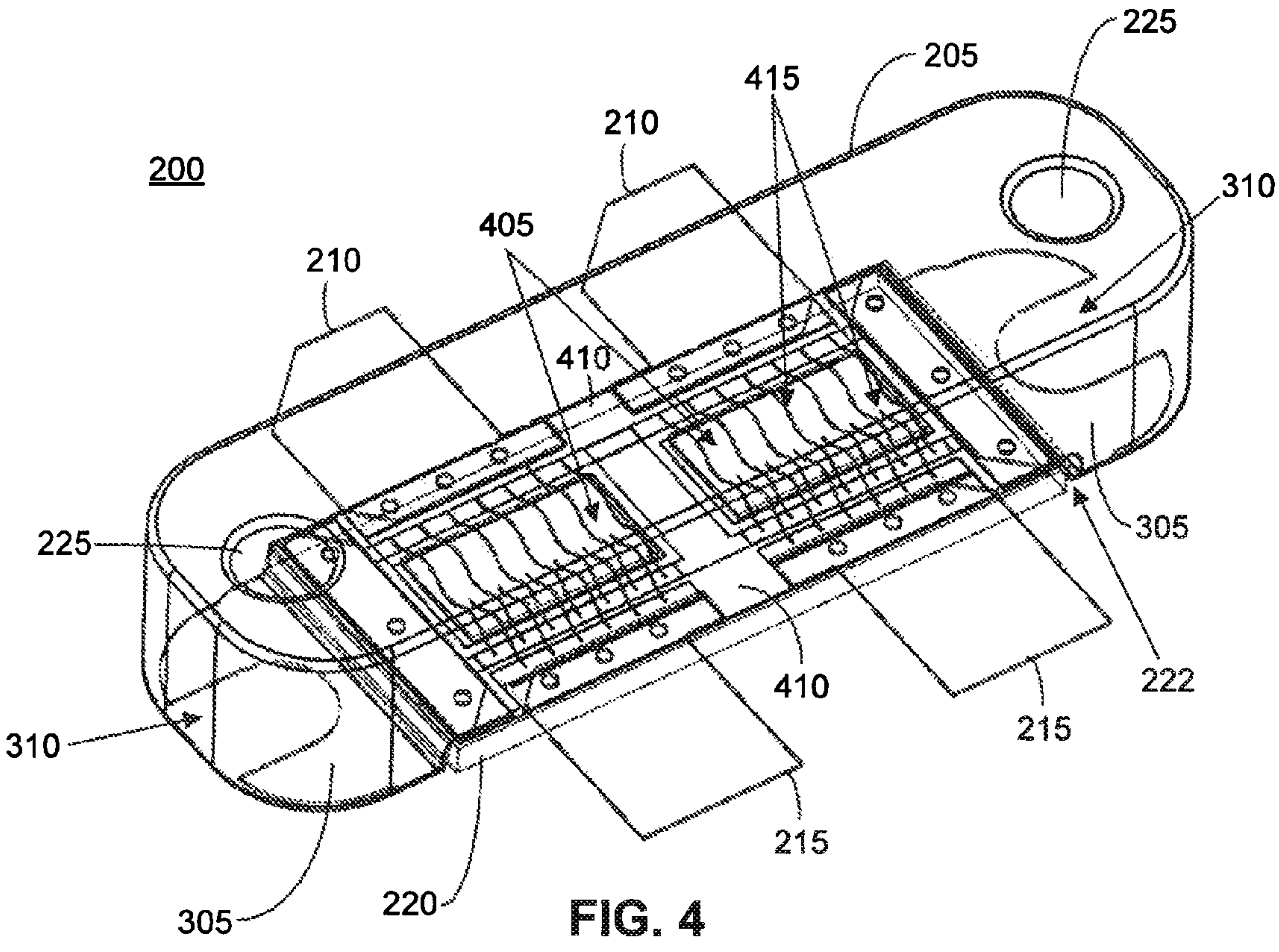

200
225
205
415
210
310
405
210
410
225
305
410
222
215
310
215
305
220

FIG. 4

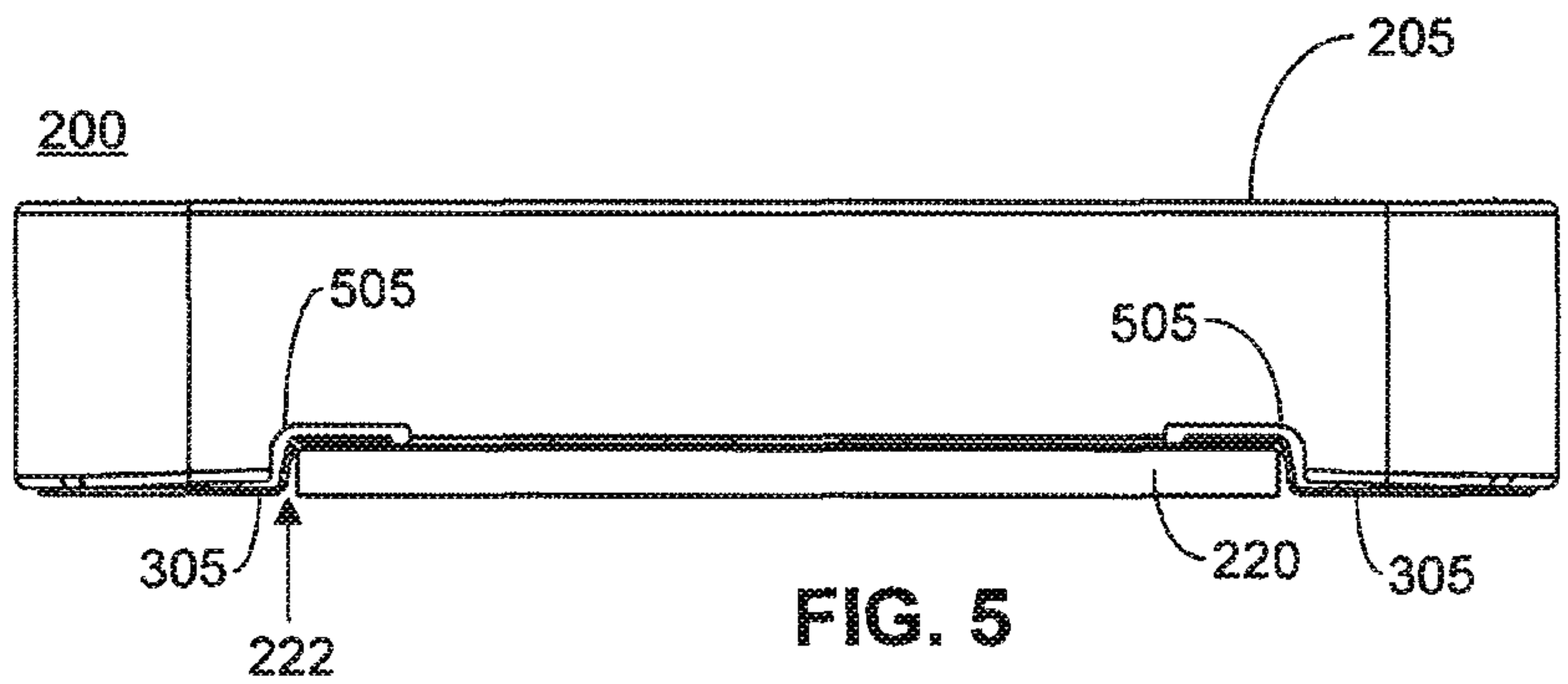


FIG. 5

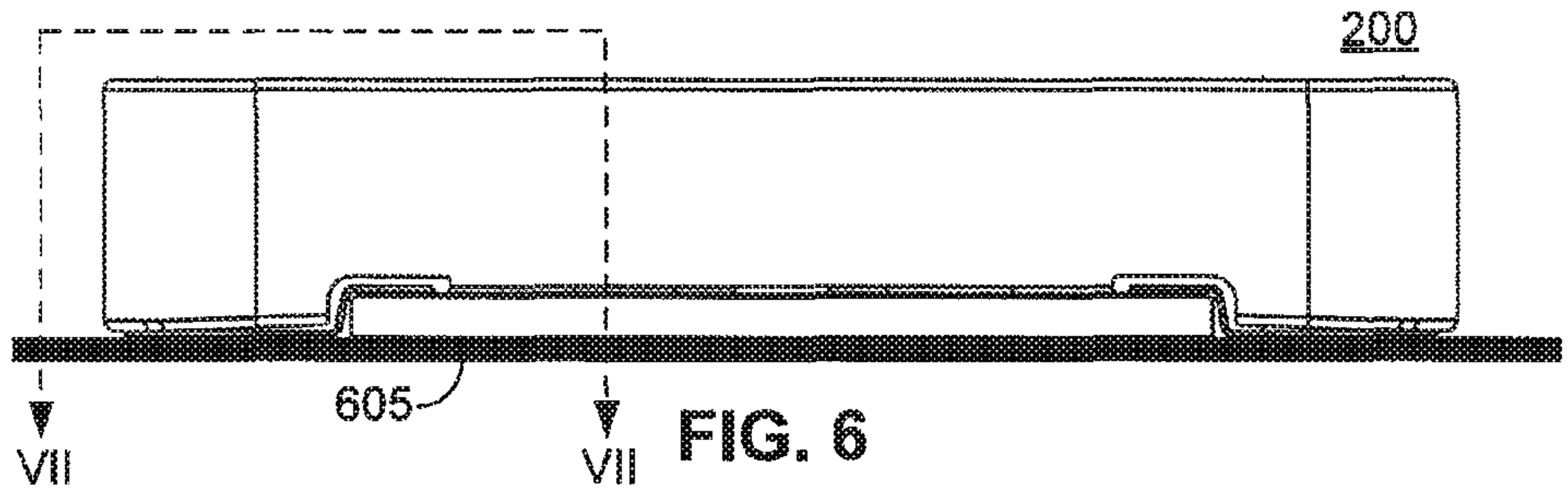


FIG. 6

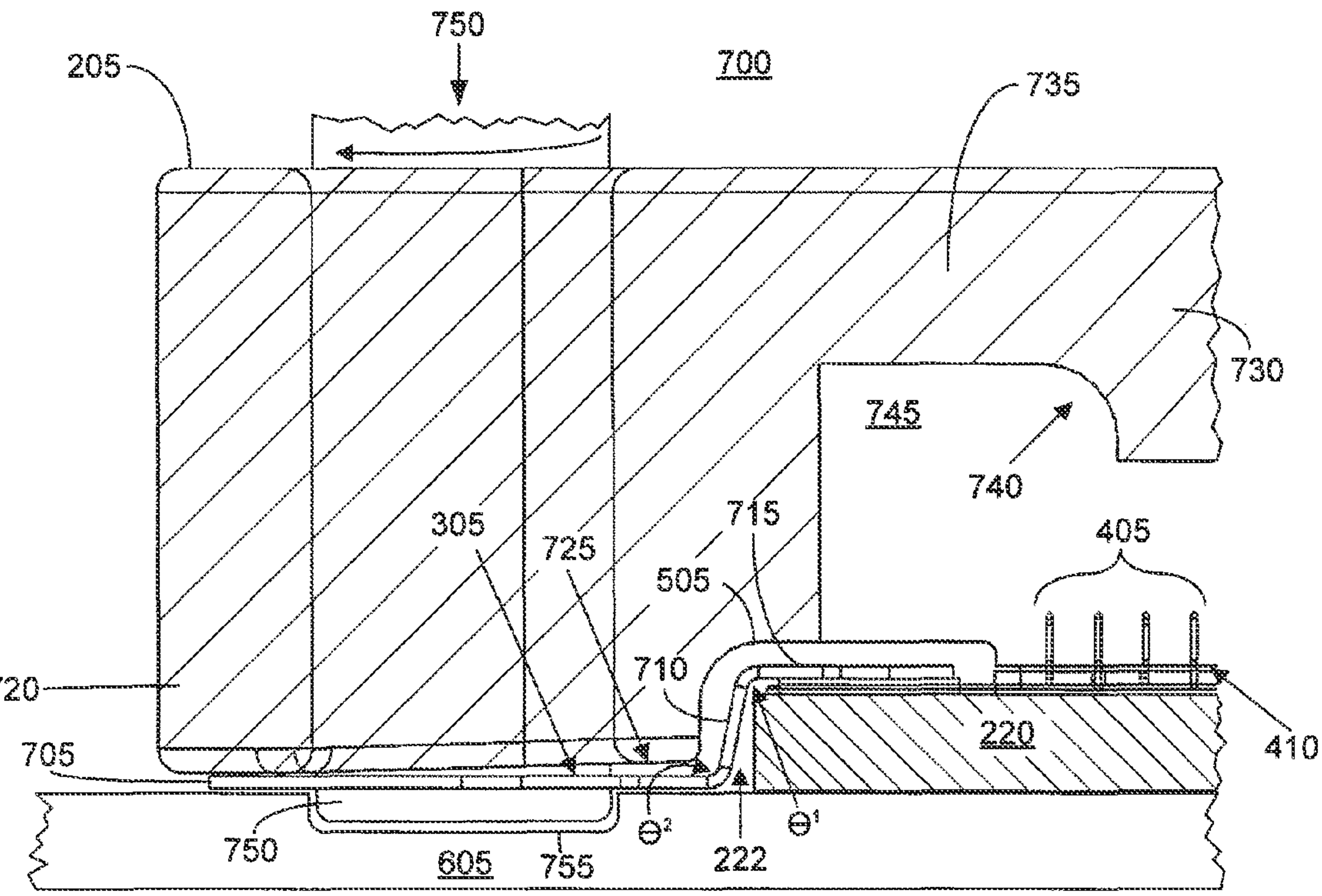


FIG. 7

RF PACKAGE

CROSS REFERENCE TO RELATED APPLICATION

This application claims the benefit of U.S. Provisional Patent Application Ser. No. 61/261,337, filed Nov. 15, 2009, herein incorporated by reference.

BACKGROUND

1. Technical Field

This disclosure relates to RF power transistors, and more particularly to power transistor packages.

2. Discussion of Related Art

Conventional high-power RF power transistor packages use metal flanges that generally protrude from multiple sides of the device. Such flanges provide source electrical interconnects and a means for affixing the device to a heat sink. The flanged connections can be beneficial for high-frequency applications and usually include bolt holes outwardly positioned from the package for clamping the device to the heat sink.

An example of a prior-art RF power transistor package **100** having flanges **105** and **110** is show in FIG. **1**. As shown in FIG. **1**, the flanges **105** and **110** extend outwardly from the package and include bolt holes external to the body of the package. Securing the package to the heat sink and dissipating heat from the source connections is accomplished by bolting the package to the heat sink using the flanges.

However, the conventional art is cost-disadvantageous due to extra materials used in the construction of the package. Prior art packages are also deficient in other areas such as manufacturing simplicity. Moreover, the prior art approach to connecting source interconnects to the heat sink does not benefit from preferential deformation of the lid when mounting the package. Accordingly, a need remains for a lower-cost high-power RF power transistor package using less material, better connectivity features, and providing for preferential deformation of the package when affixing the device to the heat sink.

SUMMARY OF EMBODIMENTS OF THE INVENTION

In an example embodiment of the invention, an RF power transistor package is provided. The RF package can include, for example, a substrate mountable on a base plate, a non-conductive cover overlying the substrate, and quasi-serpentine stepped source leads attached to an upper surface of the substrate and extending from at least one of a pair of opposite sides of the upper surface of the substrate to tapered lower surfaces of the cover. The non-conductive cover can include a recess configured to receive the substrate. The recess forms a stress distribution surface area to engage and press outer edge portions of opposite sides of the substrate against the base plate.

One or more tapered lower surfaces of the cover extend from the recess toward outer edge portions of the cover. The tapered lower surfaces of the cover engage with and press against the stepped source leads when securing the RF package to the base plate or heat sink. Mounting the package to base plate or heat sink can involve the use of one or more fasteners or bolts inserted into bolt holes and through corresponding openings in the stepped source leads. The fasteners or bolts are received by mounting holes in the base plate or heat sink.

The cover includes structural features to improve preferential deformation when a mounting force is applied. For instance, the recess in the cover includes one or more notches at outer edges thereof, to provide stress concentration outwardly toward edges of the cover. The cover can also include a cavity disposed within the cover to receive one or more dies, one or more conductors, and at least portions of one or more gate leads, one or more drain leads, and the one or more stepped source leads. The cover can include sections having different thicknesses to provide rigidity to some portions of the cover while evenly distributing stress of the cover during preferential deformation thereof.

The foregoing and other features and advantages of the invention will become more readily apparent from the following detailed description of a preferred embodiment of the invention that proceeds with reference to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** illustrates a conventional RF power transistor package having outwardly protruding flanges used for source connections.

FIG. **2** illustrates a top perspective view of an RF power transistor package according to some embodiments of the present invention.

FIG. **3** illustrates a bottom perspective view of the RF power transistor package of FIG. **2**, according to some embodiments of the present invention.

FIG. **4** illustrates a transparent view of the RF power transistor package of FIG. **2**, including stepped source leads and other components disposed within or beneath the package, according to some embodiments of the present invention.

FIG. **5** illustrates a side view of the RF power transistor package of FIG. **2**, including a recess in the package and the stepped source leads disposed beneath the package and extending from an upper surface of the substrate toward end portions of the package.

FIG. **6** illustrates another side view of the RF power transistor package of FIG. **2**, showing the package affixed to a base plate or heat sink.

FIG. **7** illustrates a cross-sectional view of a portion of the RF power transistor package of FIG. **6**, including a cavity internal to the package, and additional detailed features with respect to the stepped source leads.

DETAILED DESCRIPTION

FIG. **2** illustrates a top perspective view and FIG. **3** illustrates a bottom perspective view of an RF power transistor package **200**, according to some embodiments of the present invention. FIG. **4** illustrates a transparent view of the RF power transistor package **200** to facilitate an understanding of the stepped source leads **305** and other inventive features and components disposed within or beneath the package **200**, according to some embodiments of the present invention. Reference is now made to FIGS. **2-4**.

The RF power transistor package **200** includes a substrate **220** mountable on a base plate or heat sink (not shown). The substrate **220** is typically made of ceramic having high yield stress properties, although any suitable material can be used. One or more silicon dies **405** forming the circuitry of the device can be disposed on and/or affixed to the upper surface of the substrate **220**.

A non-conductive cover **205** is structured to overlay and protect the substrate **220** and other components of the package. The cover **205**, sometimes referred to as a "lid" can be unitary, resilient, generally rectangular with rounded corner edges **230**, and overlying the substrate **220**, silicon dies **405**, wire bonds **415**, stepped source leads **305**, and portions of leads **210** and **215**. The cover **205** is made of a material selected to provide high electrical insulation with low dielectric loss.

The cover material preferably has a high resistance to creep to avoid non-preferential deformations caused by numerous heat cycles. Materials such as Ultem® UC1200 Polyetherimide, Lexan® 920A Polycarbonate, Makrolon® 1804 Polycarbonate, or Ultem® 2300 can be used as the base material for the cover **205**. Preferably, Ultem® 2300 is used due to its yield strength, creep resistance, and performance in an injection molding application. Injection molding applications are the preferred method for producing the cover **205** in large quantities.

The cover **205** includes a recess **222** to receive the substrate **220**. The recess **222** forms a stress distribution surface area **410** to engage and press outer edge portions **410** of opposite sides of the substrate **220** against the base plate or heat sink. The recess **222** can also receive at least portions of a lead frame and/or leads associated with the RF package **200**.

One or more stepped source leads **305** extend from at least one of a pair of opposite sides of an upper surface of the substrate **220** to the lower surfaces of the cover **205**. Each source lead **305** is attached to the top of the ceramic substrate **220** using bolts, rivets, adhesive, or other suitable attaching means, and is electrically coupled to the dies **405**. The stepped source leads **305** can be bent or folded in a quasi-serpentine fashion to form an electrical connection from the top of the substrate **220** to the base plate or heat sink, as will be further described below.

Gate leads **215** and drain leads **210** are attached to the top surface of the ceramic substrate **220** using the same or similar attaching means. The gate and drain leads are electrically coupled to the dies **405**, and protrude in opposite directions from the other two sides of the substrate **220**. The stepped source leads, gate leads and drain leads can be electrically coupled to the dies **405** using one or more electrical conductors, for example, such as wire bonds or "jumper" wires **415** illustrated in FIG. **4**, or any other suitable connection.

Mounting or bolt holes **225** are arranged in the cover **205** and are aligned with corresponding openings **310** in the stepped source leads **305**. Although the openings **310** are illustrated as elongated moon-shaped openings, other types of openings are contemplated such as circular openings that substantially match those of holes **225**, among other possibilities. The mounting or bolt holes **225** are used for securing the RF package **200** including the substrate **220** and the stepped source leads **305** directly to the base plate or heat sink. The mounting or bolt holes **225** can be arranged in a pattern that matches the mounting pattern of preexisting RF power transistor packages or in entirely new mounting arrangements.

The stepped source leads **305** are disposed entirely beneath the non-conductive cover **205** and need not extend beyond the edges of the cover. In other words, the RF package includes flangeless source connections to the base plate or heat sink, providing an electrical connection from the top side or active portion of the substrate **220** to the underside or mounting surface of the RF package **200**, entirely within and/or beneath the geometry of the cover **205**.

FIG. **5** illustrates a side view of the RF power transistor package **200** of FIG. **2**, including the recess **222** in the package and the stepped source leads **305** disposed beneath the package and extending from an upper surface of the substrate **220** toward end portions of the package. FIG. **6** illustrates another side view of the RF power transistor package **200** of FIG. **2**, showing the package affixed to a base plate or heat sink **605**. FIG. **7** illustrates an exploded cross-sectional view **700** of a portion of the RF power transistor package of FIG. **6** taken along lines VII-VII, including a cavity **745** internal to the package, and additional detailed features with respect to the stepped source leads **305**. Reference is now made to FIGS. **5**-**7**.

One or more tapered lower surfaces **725** extend from the recess **222** toward outer edge portions **720** of the cover **205**. The tapered lower surfaces **725** provide an interface between the RF package and the base plate or heat sink, which results in consistent and preferential lid deformation and/or creep resistance due to plastic relaxation of the lid. The one or more stepped source leads **305** extend from at least one of a pair of opposite sides of an upper surface of the substrate **220** to the tapered lower surfaces **725** of the cover **205**. The stepped source leads **305** can extend partially toward the outer edge portions **720** of the cover **205** as illustrated, or in an alternative embodiment, the stepped source leads **305** can extend entirely to the outer edge portions **720** of the cover **205**.

Each of the stepped source leads **305** includes a first horizontal section **715**, a slanted section **710**, and a second horizontal section **705**. The first section **715** is coupled to the upper surface of the substrate **220**, which defines a horizontal dimension of the first section **715**. The slanted section **710** extends in a sloped direction from the first section at an angle θ^1 relative to the horizontal dimension of the first section. The angle θ^1 is preferably 100 degrees or thereabout, but in some embodiments, the angle θ^1 can be any suitable angle between 90 and 170 degrees. A second horizontal section **705** extends from the slanted section at an angle θ^2 relative to the slanted direction of the slanted section. The angle θ^2 is preferably 100 degrees or thereabout, but in some embodiments, the angle θ^2 can be any suitable angle between 90 and 170 degrees.

The first horizontal section **715**, slanted section **710**, and second horizontal section **705** form a contiguous stepped source lead **305** located beneath the cover **205**. As mentioned above, the stepped source leads **305** can be bent or folded in a quasi-serpentine embodiment. The transitions from one section of a stepped source lead **305** to another is defined by angles θ^1 and θ^2, which can be rounded or sharp. The tapered lower surfaces **725** of the cover **205** provide consistent and repeatable application of mounting force on the stepped source leads **305** to ensure high surface contact area between the source leads and the base plate or heat sink **605**.

In addition, consistent contact pressure is applied by the tapered lower surfaces **725** to the source leads **305** to also enhance contact and to prevent creep resistance that could otherwise be caused by plastic relaxation of the cover. More specifically, the tapered lower surfaces **725** of the cover **205** are structured to engage with and press against the second horizontal section **705** of the one or more stepped source leads **305**, even over the course of multiple heating and/or usage cycles.

Furthermore, one or more notches **505** in the cover **205** are disposed at outer edges of the recess **222**. The notches **505** provide stress concentration outwardly toward edges of the cover **205**. The notches **505** also provide preferential deformation of the cover **205** about the first horizontal section **715** and slanted section **710** of the stepped source leads **305**, particularly when securing the RF package **200** to the base plate or heat sink **605** using, for example, one or more fasteners or bolts **750**.

A cavity **745** is disposed within the cover **205** to receive the one or more dies **405**, one or more conductors such as the wire bonds **415**, and at least portions of the one or more gate leads

215, drain leads 210, and stepped source leads 305. The cavity 745 includes a first section 730 having a first thickness to provide rigidity to the central portion of the cover 205, one or more additional sections 735 having a second thickness less than the first thickness, and a curved section 740 connecting the first section to the one or more additional sections.

The one or more additional sections 735 and the curved section 740 are configured to evenly distribute stress of the cover 205 during preferential deformation thereof when securing the one or more stepped source leads 305 and the substrate 220 to the base plate 605 using, for example, the one or more fasteners or bolts 750. Stress is further distributed on the substrate 220 by the lid to substrate bearing area 410, which makes contact with and presses against the outer edge portions 410 of opposite sides of the substrate 220, which in turn presses the substrate 220 and stepped source leads 350 against the base plate or heat sink 605.

Fasteners or bolts 750 can be inserted through holes 225 and openings 310 into mounting holes 755 of the base plate or heat sink 605, which securely mounts the RF package 200, including the cover 205, substrate 220, leads, and other associated components of the RF package to the base plate or heat sink 605. While one section of the RF package is shown along lines VII-VII in FIG. 7, it should be understood that a mirror image of the components, or at least similar components, of such a section can be embodied in the other end portion of the RF package.

Having illustrated and described the principles of our invention in various embodiments thereof, it should be apparent that the invention can be modified in arrangement, detail and application without departing from such principles. While some embodiments described herein are especially useful in packaging RF power devices, embodiments of the invention can be configured for use with other types of devices such as lower frequency devices.

For instance, the terminology "gate," "source" and "drain" leads pertains to MOSFET type devices. It is contemplated that embodiments of the invention can also be used with bipolar type devices and IGBT devices. In the case of bipolar devices, gate corresponds to base, source corresponds to emitter and drain corresponds to collector. In the case of an IGBT device, gate remains gate, source corresponds to emitter and drain corresponds to collector. The terms gate, source and drain will be used throughout but are meant to include base-emitter-collector and gate-emitter-collector leads.

I claim all modification and variations coming within the spirit and scope of the following claims.

The invention claimed is:

1. An RF package, comprising:

a substrate mountable on a base plate;

a non-conductive cover overlying the substrate and including:

a recess configured to receive the substrate, the recess forming a stress distribution surface area to engage and press outer edge portions of opposite sides of the substrate against the base plate;

one or more tapered lower surfaces extending from the recess toward outer edge portions of the cover;

one or more stepped source leads extending from at least one of a pair of opposite sides of an upper surface of the substrate to the one or more tapered lower surfaces of the cover;

one or more gate and drain leads extending from at least one of a pair of opposite sides of an upper surface of the substrate;

one or more dies disposed on the substrate;

one or more conductors electrically coupling the one or more gate leads, drain leads, and stepped source leads to the one or more dies; and

a cavity disposed within the cover to receive the one or more dies, the one or more conductors, and at least portions of the one or more gate leads, drain leads, and stepped source leads, wherein the cover further includes:

a first section having a first thickness between the cavity and the top surface of the cover to provide rigidity to the central portion of the cover;

one or more additional sections having a second thickness between the cavity and the top surface of the cover, the second thickness less than the first thickness; and

a curved section connecting the first section to the one or more additional sections,

wherein the one or more additional sections and the curved section are configured to evenly distribute stress of the cover during preferential deformation thereof when securing the one or more stepped source leads and the substrate to the base plate.

2. The RF package of claim 1, wherein the cover further includes a bolt hole for receiving a bolt in each outer edge portion to clamp the cover against the base plate and wherein the one or more tapered lower surfaces of the cover face the base plate and are angled relative to the base plate to provide a progressively increasing mounting force on the stepped source leads as the bolts are tightened.

3. The RF package of claim 1, wherein each of the one or more stepped sources leads includes:

a first section coupled to the upper surface of the substrate, the upper surface of the substrate defining a horizontal dimension of the first section;

a second section extending in a slanted direction from the first section at an angle relative to the horizontal dimension of the first section; and

a third section extending from the second section at an angle relative to the slanted direction of the second section.

4. The RF package of claim 3, wherein the first, second, and third sections of the source leads form a contiguous stepped source lead located beneath the cover.

5. previously presented) The RF package of claim 3, wherein the one or more tapered lower surfaces of the cover are structured to engage with and press against the third section of the one or more stepped source leads.

6. The RF package of claim 3, wherein the recess includes one or more notches disposed at outer edges thereof, the one or more notches structured to provide:

stress concentration outwardly toward edges of the cover; and

deformation of the cover about the first and second sections of the one or more stepped source leads.

7. The RF package of claim 1, wherein the base plate is a heat sink attachable to the one or more stepped source leads.

8. The RF package of claim 1, wherein the cover comprises a material having a resistance to creep, high electrical insulation, high yield strength, and low dielectric loss.

9. The RF package of claim 1, further comprising one or more bolt holes arranged in the cover and aligned with corresponding openings in the one or more stepped source leads, the one or more bolt holes configured to receive one or more bolts to secure the substrate and the one or more stepped source leads to the base plate.

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