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(54) Title: PACKAGED SEMICONDUCTOR DEVICE HAVING LEADFRAME FEATURES PREVENTING DELAMINATION

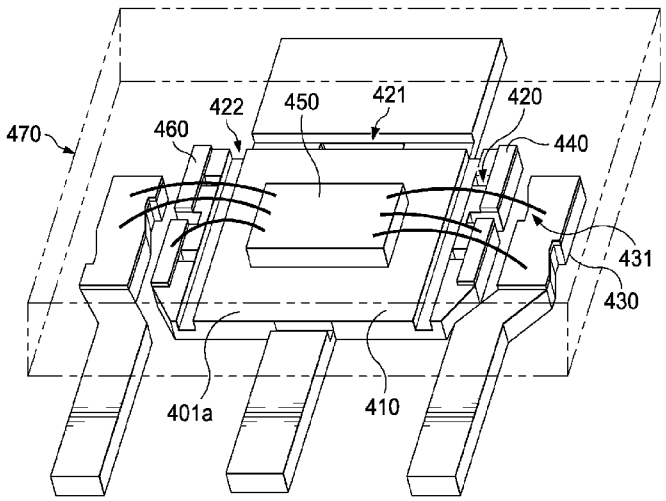

FIG. 4

(57) Abstract: In described examples, a semiconductor device has a leadframe with a first pad surface (401a) and a parallel second pad surface, and an assembly pad (410) bordered by two opposing sides, which include through-holes (420) from the first pad surface (401a) to the second pad surface. Another pad side includes one or more elongated windows (421) between the pad surfaces. The second pad surface includes grooves. The leadframe further has leads (430) with opposite elongated sides castellated by indents (431). Layers (440) of bondable metals are restricted to localized areas surrounding bond spots. A semiconductor chip (450) is attached to the pad (410) and wire-bonded (460) to the bond spots. A package (470) encapsulates the chip (450), wires, pad (410) and lead (430) portions, and secures the leadframe into the package (470) by filling the through-holes (420), windows (421), grooves and indents (431).

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PACKAGED SEMICONDUCTOR DEVICE HAVING LEADFRAME FEATURES PREVENTING DELAMINATION

[0001] This relates generally to semiconductor devices and processes, and more particularly to a structure and fabrication method of leadframes with mechanical and metallurgical features for preventing delamination of packaged semiconductor devices.

BACKGROUND

[0002] Moisture-induced failures of plastic packaged semiconductor devices have been observed and investigated for many years. For example, plastic packages made by epoxy-based molding compounds can be penetrated by discrete water molecules within a time period of approximately one day. However, this penetration does not lead to a problematic situation, so long as good adhesion exists inside the package between the plastic compound and the device components (semiconductor chip, metallic leadframe, etc.), and the penetrated water molecules cannot accumulate to form films of water on free surfaces.

[0003] In contrast, when some interfacial delamination has happened and water films have been able to form, quick rises of temperature may vaporize the water and initiate expansive internal pressures between the components and the package material. The expansive pressure may be high enough to bulge the plastic material at thin spots and eventually cause a crack of the package. For example, the temperature may rise quickly beyond the water boiling point when the packaged device is heated, in order to reflow the device solder balls for attaching the device to a board. In literature, the phenomenon of local package cracking by steam pressure has been dubbed popcorn effect.

[0004] A variety of methods have been tried to enhance adhesion between device components and prevent delamination and cracking. The efforts have included chemically purifying the molding compounds; activating metal surfaces, such as by plasma, just prior to the molding process; enhancing the affinity of leadframe metals to polymeric compounds by oxidizing the base metal or by depositing special metal layers (such as rough tin); coining the leadframes for creating dimples and other three-dimensional surface features and roughness for interlocking the plastic with the metal surfaces. However, the success of all these efforts has only been partial

and limited.

SUMMARY

[0005] In described examples, a semiconductor device has a leadframe with a first pad surface and a parallel second pad surface, and an assembly pad bordered by two opposing sides, which include through-holes from the first pad surface to the second pad surface. Another pad side includes one or more elongated windows between the pad surfaces. The second pad surface includes grooves. The leadframe further has leads with opposite elongated sides castellated by indents. Layers of bondable metals are restricted to localized areas surrounding bond spots. A semiconductor chip is attached to the pad and wire-bonded to the bond spots. A package encapsulates the chip, wires, pad and lead portions, and secures the leadframe into the package by filling the through-holes, windows, grooves and indents.

BRIEF DESCRIPTION OF THE DRAWINGS

[0006] FIG. 1 shows a perspective view of a leadframe strip according to example embodiments, the strip having multiple device sites.

[0007] FIG. 2 depicts a perspective top view of a portion of a discrete device site of the leadframe strip in FIG. 1, detailing embodiments.

[0008] FIG. 3 illustrates a perspective bottom view of the discrete device site of FIG. 2.

[0009] FIG. 4 shows a perspective top view of a discrete device site of the leadframe strip of FIG. 1, with a semiconductor chip assembled on the pad and wire bonded. The outline of the package is depicted in dashed lines.

[0010] FIG. 5 illustrates a perspective view of the leadframe strip of FIG. 1 after the process of encapsulating the assembled devices in packages and plating the un-encapsulated strip portions with a metal layer.

[0011] FIG. 6 depicts a perspective view of a packaged and trimmed device with formed leads.

DETAILED DESCRIPTION OF EXAMPLE EMBODIMENTS

[0012] The polymerization process, or molecular cross linking, of thermoset compounds causes a volumetric shrinking of the polymeric material. As a consequence, the polymerized material exerts an inward-directed pressure on bodies enclosed by the thermoset compounds. In plastic encapsulated semiconductor products, this effect causes an inward directed force on the enclosed pad with the assembled semiconductor chip.

[0013] The volumetric shrinkage of packaging compound and the correlated inward-directed

pressure can be exploited to clamp leadframe parts, such as the assembly pad, between portions of the package positioned on opposite sides of the pad. This clamping pressure is thus useful to counteract and compensate the expanding pressure of vaporized water.

[0014] For plastic encapsulated semiconductor devices with metallic leadframes, the problem of package delamination and cracking is solved by clamping pressure by volumetrically shrinking compounds to the large assembly pad of the package. By forming the pad so that multiple opening through-holes and through-windows can be distributed along the perimeter of the pad, the molding compound filling these holes and windows can interconnect package portions on the top and the bottom sides of the pad and thus clamp the portions strongly against the pad. This clamp force is stronger than the force of expanding water vapor.

[0015] It is advantageous to supplement the concept of through-holes and through-windows with additional leadframe features, such as ditches, grooves and indents, which provide locations for anchoring packaging compound in the contours of leadframes. Also, as much of the leadframe base metal surface as possible should be made available for adhesion to packaging compound. It is, therefore, advantageous to restrict any areas of additional metal layers to local spots needed for attaching the wire stich bonds.

[0016] An example embodiment is a leadframe as illustrated in FIG. 1. The leadframe is based on a strip 100 stamped or etched from a flat sheet of metal selected from a group including copper, copper alloys, aluminum, iron-nickel alloys and Kovar™. When the metal sheet is made of copper, the preferred thickness of the sheet is between 100 and 300 μm. For some applications, the sheet may be thicker or thinner. As FIG. 1 shows, leadframe strip 100 includes multiple device sites 101. Each site includes the components proper for assembling and supporting a semiconductor chip, such as assembly pad 110 and leads 120, as well as rails and connection strips needed for integrating the units into a strip suitable for batch processing.

[0017] FIGS. 2 and 3 display a portion of a discrete unit 200 of example leadframe 100 (portion as marked in FIG. 1). FIG. 2 illustrates the top surface (assembly surface) of the unit. FIG. 3 depicts the opposite bottom surface of the unit. Herein, the top surface is referred to as first surface 201a, and the bottom surface as second surface 201b. As FIG. 2 shows, unit 200 includes a pad 210 for assembling a semiconductor chip. Pad 210 has in first order a rectangular outline with four sides. In other devices, the assembly pad may have the shape of a square or a circle, or any other suitable geometrical configuration. Pad 210 exhibits the base metal of the

leadframe (such as copper) in naturally oxidized mode, free of plated metal layers. For copper leadframes, oxidized copper is characterized by its affinity to adhesion to polymeric encapsulation compounds, such as epoxy-based molding compounds.

[0018] As FIG. 2 indicates, two opposing sides of pad 210 include multiple through-holes or via-holes 220 from the first pad surface 201a to the second pad surface 201b. Through-holes 210 may have square cross section, as in FIG. 2, or may have round or any other cross section. Two holes may exist on each side, as shown in the example of FIG. 2, or more holes may exist. During the encapsulation process, through-holes 210 will be filled with packaging compound, such a molding compound. After hardening by polymerization, the filled vias enable strong mechanical locking of the compound portions on the top leadframe side with the compound portions on the bottom leadframe side. Due to the volumetric shrinkage of polymeric compounds, the leadframe is clamped between the compound portions on top and on the bottom of leadframes. Strong clamps inhibit delamination of compound and leadframe.

[0019] The example device of FIG. 2 illustrates another pad side, which has an elongated window or hole 221 between the first and the second pad surfaces. One or more elongated windows may exist, and they may have a smooth or a wavy configuration. The elongated windows 221 serve the same purpose as the through-holes 220. After filling the openings with encapsulation compound and volumetric shrinking and hardening the compound during the polymerization process, the leadframe is clamped between the compound portions and is thus inhibited from delaminating from the leadframe. In other devices, windows and through-holes may interchange positions, shape and numbers.

[0020] Other contributions to anchoring polymeric packaging compounds into the metallic leadframe are achieved by multiple grooves and ditches into the surfaces of the pad, and by indents into the sidewalls of leads. Grooves and ditches can be produced by coining the leadframe metal or by partial etching into the leadframe thickness, which is so-called half-etching. FIG. 2 shows an example of ditches 222 cut into the top surface 201a of pad 210. In this example, the ditches are parallel to the pad sides. In other devices, the ditches may have other orientations. Viewing the bottom surface 201b of the leadframe in FIG. 3, pad 210 has multiple grooves 223 cut into the bottom surface. They are sized and distributed to offer superior mechanical anchoring for the packaging compound into the leadframe pad. Also, pad 230 exposes the (slightly oxidized) base metal surface free of plated layers of additional metals.

[0021] FIGS. 2 and 3 illustrate multiple leads 230 of leadframe 230, which have opposite elongated sides. As the figures indicate, these elongated and opposite sides are castellated by indents 231 into the base metal of the leadframe. Therefore, these indents allow the molding compound to grip the leads for mechanical support and thus counteract pressures of delamination and separation.

[0022] In FIG. 2, areas 240 of leadframe first surface 201a indicate spots, which have received additional plating by a metal facilitating wire stitch bonding. The preferred choice for the additional metal is silver. However, as FIG. 2 shows, these areas are minimized to retain as much of the oxidized leadframe base metal as possible for adhesion to the encapsulation compound. Consequently, these areas surrounding spots intended for stitch bonding are selective and locally restricted.

[0023] Another embodiment is a packaged semiconductor device, which uses a metallic leadframe with features described above. An example of a device with low lead count is illustrated in FIG. 4. The leadframe has a first pad surface 401a and a second pad surface, and an assembly pad 410 bordered by two opposing sides; the first pad surface 401a is the surface for chip assembly, while the opposite surface is the second pad surface. Each pad side includes multiple through-holes 420 from the first pad surface to the second pad surface. Pad 410 is further bordered by another side, which includes one or more elongated windows 421 between the pad surfaces. Also, the first pad surface 401a of pad 410 has multiple ditches 422, which extend certain lengths across the first pad surface 401a. The opposite second pad surface includes multiple grooves. The leadframe further has multiple leads 430 with opposite elongated sides; the sides are castellated by indents 431. The leads have layers 440 of bondable metals deposited on the leadframe base metal, but layers 440 are restricted to localized areas surrounding bond spots.

[0024] In FIG. 4, a semiconductor chip 450 is attached to pad 410. The terminals of chip 450 are connected by bonding wires 460 to the bondable localized spots 440. Chip 450, wires 460, pad 410, and portions of the leads 430 are encapsulated by a packaging material 470, such as a polymerizable epoxy-based molding compound. During the process of applying the packaging compound (such as by a transfer molding technique), through-holes 420, windows 421, indents 431, ditches 422 and the grooves on the second pad surface of pad 410 are filled with packaging material. After curing and polymerizing the material, the leadframe is securely anchored in the

packaging material.

[0025] Another embodiment is a method for fabricating semiconductor devices with leadframes having safeguards against delamination of leadframe and encapsulation material, and against package cracking. Certain steps of the method are depicted in FIGS. 1 through 6. The method starts by providing a leadframe strip as depicted in FIG. 1 by example strip 100, which has a first surface and a second surface and multiple device sites 101. Each site includes an assembly pad 110 bordered by two opposing sides; each side has multiple through-holes 220 from the first pad surface to the second pad surface. Pad 110 is further bordered by another side, which includes one or more elongated windows 221 between the pad surfaces. Also, the first surface of pad 210 has multiple ditches 222, which extend certain lengths across the first surface. The opposite second pad surface includes multiple grooves. The leadframe further has multiple leads with opposite elongated sides; the sides are castellated by indents 231. The leads (and, in some devices, portions of the pad) have layers 240 of bondable metals deposited on the leadframe base metal, but layers 240 are restricted to localized areas surrounding bond spots, in order to retain as much surface of oxidized base metal as possible for adhesion to packaging compound.

[0026] In the next process, indicated in FIG. 4, a semiconductor chip 450 is attached to the pad 410 of each leadframe site. Thereafter, the terminals of each chip are connected by bonding wires to the bondable spots of respective leads. In the next process, indicated in FIGS. 4 and 5, multiple packages are formed by encapsulating the chip, wires, pad and certain lead portions of each site in a packaging material. The preferred process is a transfer molding technique, which uses an epoxy-based polymeric compound filled with inorganic filler particles. During the transfer molding process, the packaging compound fills through-holes 420, windows 421, ditches 422 and grooves on the second pad surface, and interlocks with indents 431. After polymerizing and hardening the compound, the leadframe of each site is securely anchored into the package. Because the polymerization process involves a volumetric shrinkage of the packaging compound, the leadframe is actually clamped by the polymerized packaging compound. The clamping force counteracts the expansion force of steaming water and thus prevents delamination of packaging compound and leadframe.

[0027] FIG. 5 shows a leadframe strip 500 after encapsulating the assembled chips of device sites 501. The packaged devices of the strip are subjected to a heat treatment at approximately

175 °C for several hours to polymerize the plastic compound by cross linking the polymeric molecules. The polymerization process of thermoset compounds causes a volumetric shrinking of the polymeric material. As a consequence, the polymerized material exerts an inward-directed pressure on leadframe portions and assembled chips enclosed by the thermoset compounds, effectively clamping the polymerized compound against these parts. The clamping pressure counteracts and at least partially compensates the expanding pressure of a vaporized water film formed during prolonged storage of the packaged device.

[0028] FIG. 5 further indicates that it is economical for certain devices to plate the un-encapsulated portions of metal strip 500 with layers of solderable metal, such as tin or a tin alloy.

[0029] Due to the interlocking of leadframe portions with indents and recesses with the packaging compound, cracking of the hardened (polymerized) compound during the mechanically stressful trim-and-form processes can be avoided. FIG. 6 shows a singulated discrete unit 600 of the devices, resulting from trimming the leadframe strip of FIG. 5. Finally, the un-encpasulated lead portions 680 are formed. With the plating of solderable metal at the process mentioned in FIG. 5, the formed leads are ready for attachment to boards.

[0030] The concept of exploiting the clamping pressure of volumetrically shrinking compounds of a plastic-packaged device to a large pad with its assembled chip has been applied to the construction of the pad, so that multiple opening through-holes and through-windows are distributed along the perimeter of the pad; the molding compound filling these holes and windows interconnect package portions on the top and the bottom sides of the pad and thus clamp the package portions strongly against the pad. This clamp force can be stronger than the force of expanding water vapor. Any still missing force difference to prevent delamination and cracking can be provided a combination of features for anchoring and tightly locking the packaging compound with leadframe parts. Examples are indents on opposite sides of leads; ditches in the pad close to the assembled chip; and grooves in the pad surface opposite the assembled chip. Also, as much of the leadframe base metal surface as possible can be made available for adhesion to the packaging compound. This can be achieved by restricting any areas of additional metal layers to local spots needed for attaching the wire stich bonds.

[0031] Modifications are possible in the described embodiments, and other embodiments are possible, within the scope of the claims. As an example, example embodiments apply to active

semiconductor devices with low and high pin counts, such as transistors and integrated circuits, and also to combinations of active and passive components on a leadframe pad.

[0032] As another example, example embodiments apply to silicon-based semiconductor devices, and also to devices using gallium arsenide, gallium nitride, silicon germanium, and any other semiconductor material employed in industry.

[0033] As another example, example embodiments apply to leadframe pads, where the pad extends on one side into more than one lead. As yet another example, example embodiments apply to pads that are offset from the plane of the leadframe.

CLAIMS

What is claimed is:

1. A leadframe comprising:

a pad for assembling semiconductor chips, the pad bordered by two opposing sides including a plurality of through-holes from a first pad surface to a second pad surface, and by another side including one or more elongated windows between the pad surfaces, the pad surface opposite the assembly surface sprinkled by a plurality of grooves; and

a plurality of leads having opposite elongated sides castellated by indents.

2. The leadframe of Claim 1 wherein the through-holes have rectangular shape.

3. The leadframe of Claim 2 wherein the elongated windows have a wavy configuration.

4. The leadframe of Claim 3 wherein the assembly surface of the pad further has ditches paralleling the pad sides.

5. The leadframe of Claim 4 wherein the pad and the leads have layers of bondable metals restricted to localized areas surrounding bond spots.

6. A semiconductor device comprising:

a leadframe having a first pad surface and a second pad surface, and an assembly pad bordered by two opposing sides including a plurality of through-holes from the first pad surface to the second pad surface, and by another side including one or more elongated windows between the pad surfaces; the second pad surface including a plurality of grooves; the leadframe further having a plurality of leads with opposite elongated sides castellated by indents, and layers of bondable metals restricted to localized areas surrounding bond spots;

a semiconductor chip attached to the pad and wire bonded to the bond spots; and

a package encapsulating the chip, wires, pad and lead portions, and securing the leadframe into the package by filling the through-holes, windows, grooves and indents.

7. A method for fabricating a semiconductor device comprising:

providing a leadframe strip having a first pad surface and a second pad surface, and a plurality of device sites, each site patterned into an assembly pad bordered by two opposing sides including a plurality of through-holes from the first pad surface to the second pad surface, and by another side including one or more elongated windows between the pad surfaces; the second pad surface including a plurality of grooves; each site further having a plurality of leads with opposite elongated sides castellated by indents, and layers of bondable metals restricted to

localized areas surrounding bond spots;

attaching semiconductor chips onto the pads;

connecting each chip to respective leads using bonding wires;

forming a plurality of packages by encapsulating the chip, wires, pad and certain lead portions of each site in a packaging material, thereby securing the leadframe of each site into the package by filling the through-holes, windows, grooves and indents, leaving other lead portions un-encapsulated;

trimming the leadframe strip by severing the leads at the surface of the packages and singulating the strip into discrete packages; and

forming the un-encapsulated portions of the leads.

8. The method of Claim 7 further including, before the process of trimming, the process of plating the un-encapsulated portions of the leadframe with at least one solderable metal layer.

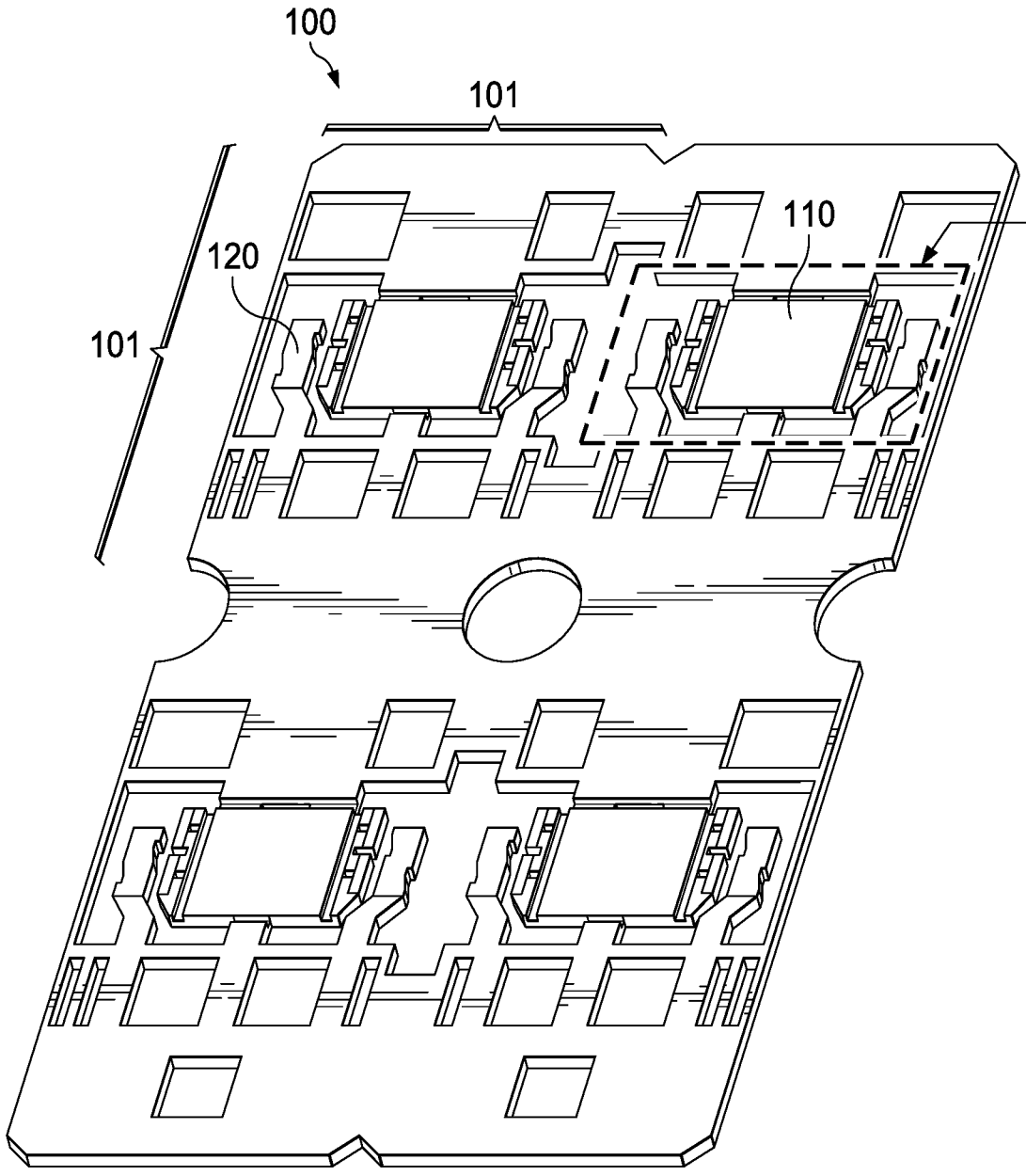

FIG. 1

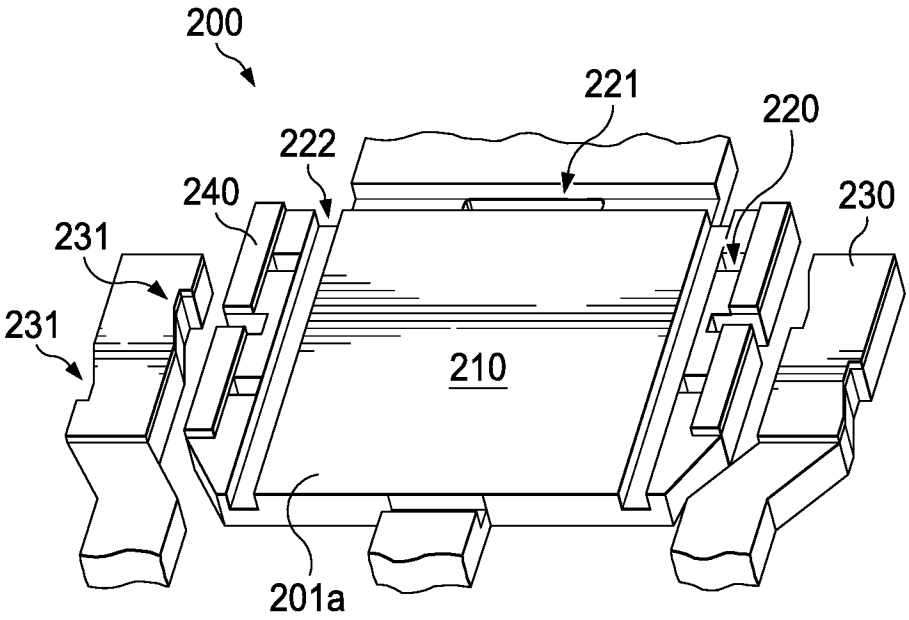
200
221
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FIG. 2

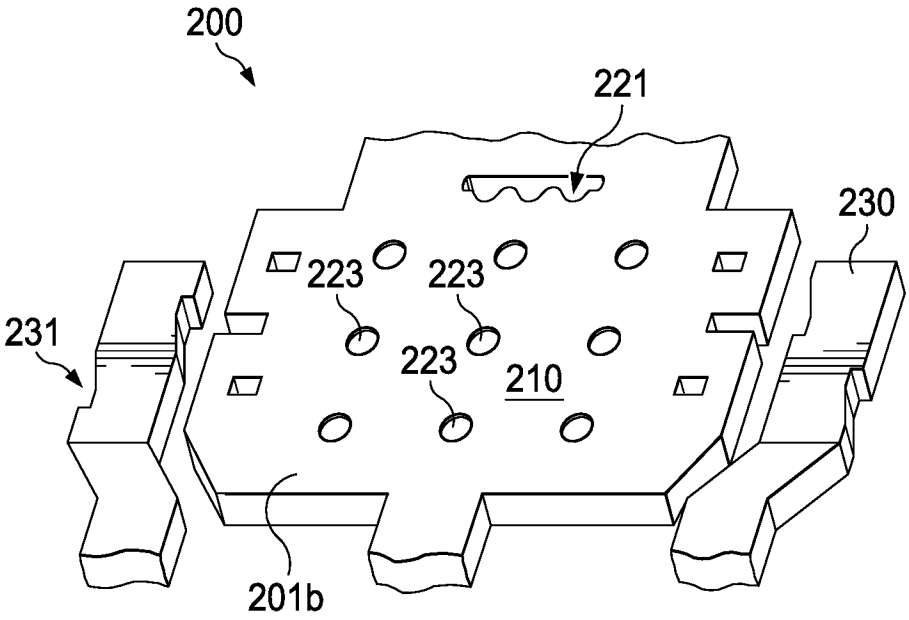
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FIG. 3

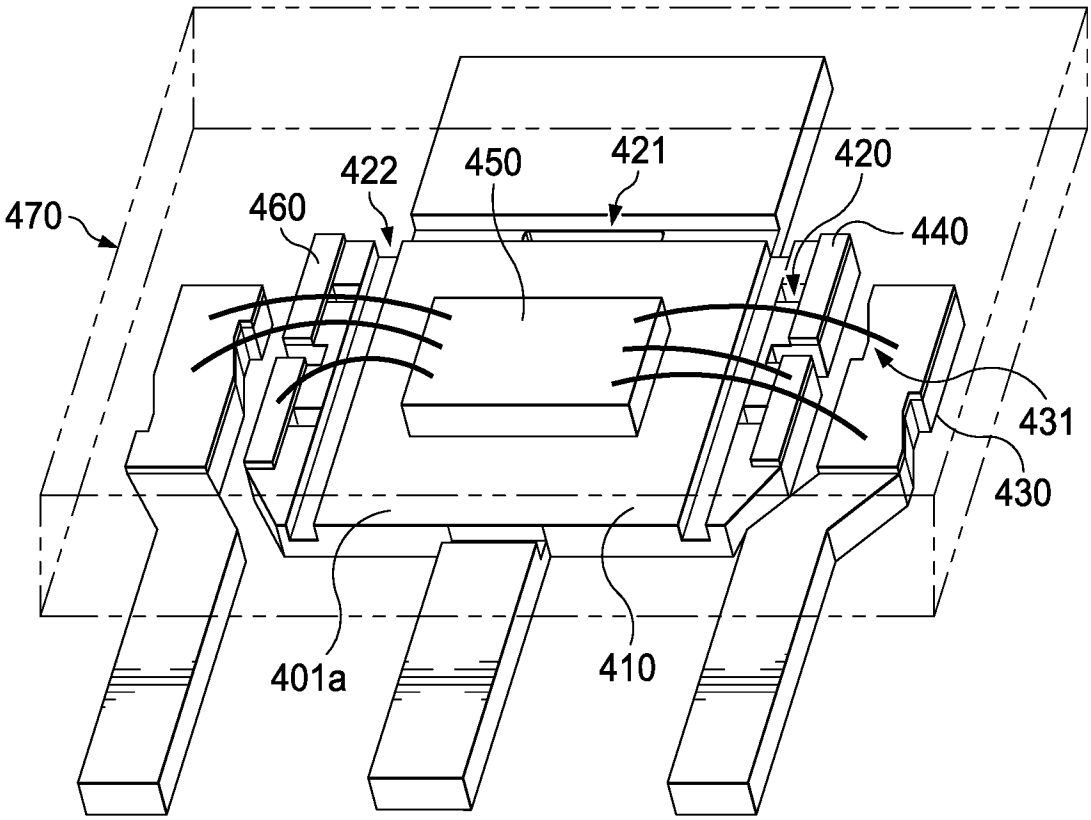

FIG. 4

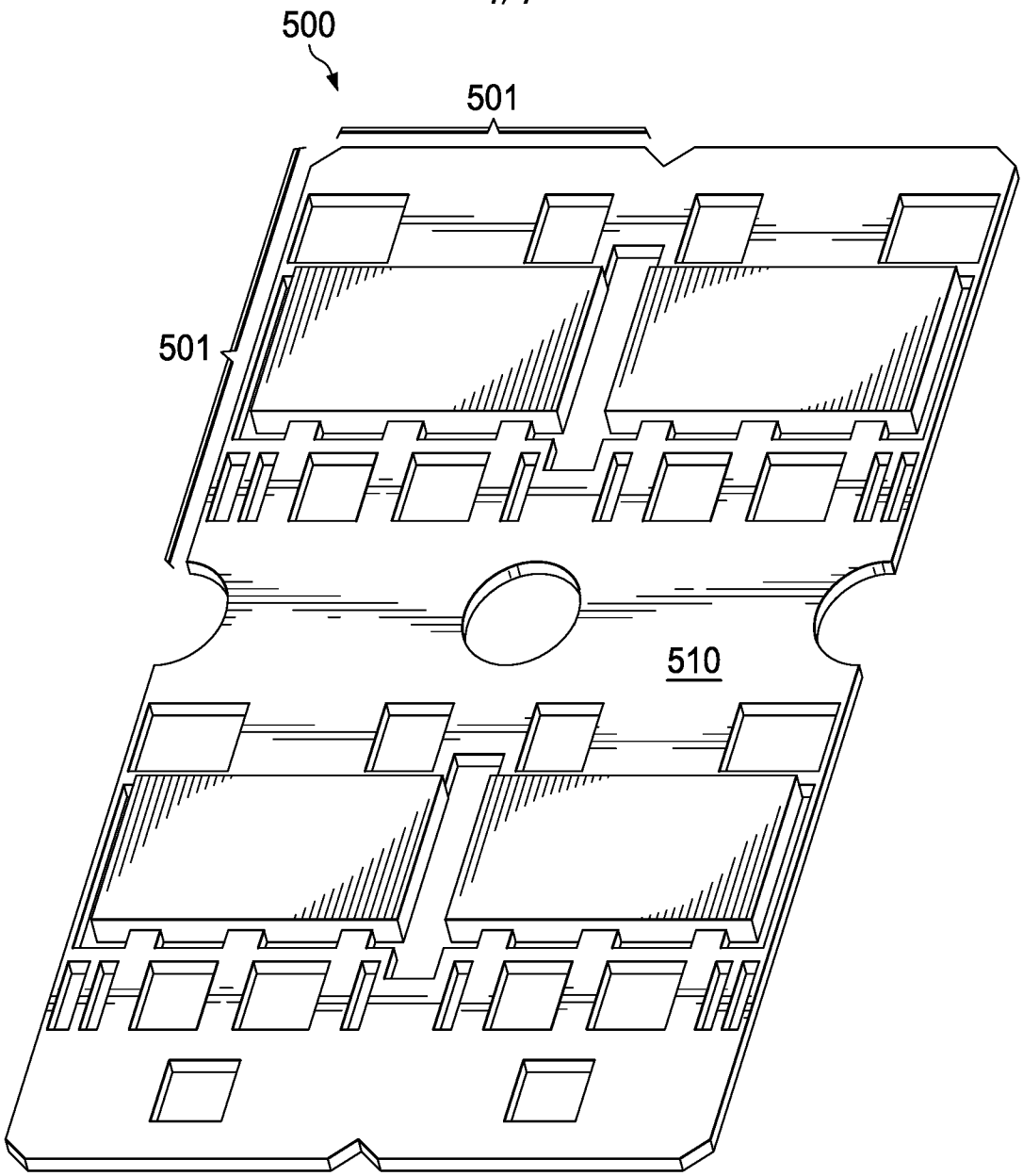

FIG. 5

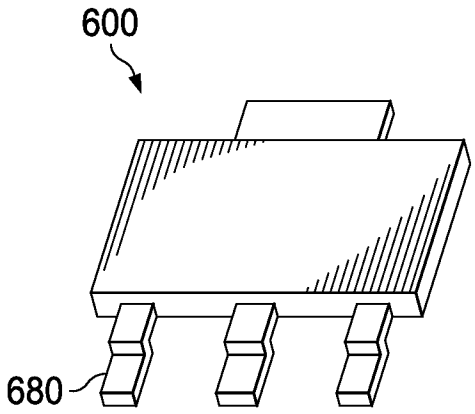

FIG. 6

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 2016/012714

A. CLASSIFICATION OF SUBJECT MATTER

H01L 23/495 *(2006.01)*

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

H01L 29/00, 29/02, 29/04, 29/18, 29/20, 29/40, 23/00, 23/02, 23/28, 23/48, 23/488, 23/495, 23/52, H05K 3/00, 3/30

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

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

EAPATIS, Espace, Espacenet, Google, KIPRIS, PAJ, PatSearch (RUPTO internal), RUPAT, RUPTO, USPTO, Patentscope, Elibrary

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2014/0191380 A1 (TEXAS INSTRUMENTS INCORPORATED) 10.07.2014	1-8
A	US 2012/0080781 A1 (NATIONAL SEMICONDUCTOR CORPORATION) 05.04.2012	1-8
A	US 2009/0032917 A1 (M/A-COM, INC.) 05.02.2009	1-8
A	US 8089145 B1 (AMKOR TECHNOLOGY, INC.) 03.01.2012	1-8
A	US 2009/0250795 A1 (FREESCALE SEMICONDUCTOR, INC.) 08.10.2009	1-8

☐ Further documents are listed in the continuation of Box C.

☐ See patent family annex.

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
12 May 2016 (12.05.2016)	20 June 2016 (20.06.2016)
Name and mailing address of the ISA/RU: Federal Institute of Industrial Property, Berezhkovskaya nab., 30-1, Moscow, G-59, GSP-3, Russia, 125993 Facsimile No: (8-495) 531-63-18, (8-499) 243-33-37	Authorized officer M. Adireeva Telephone No. (495)531-64-81