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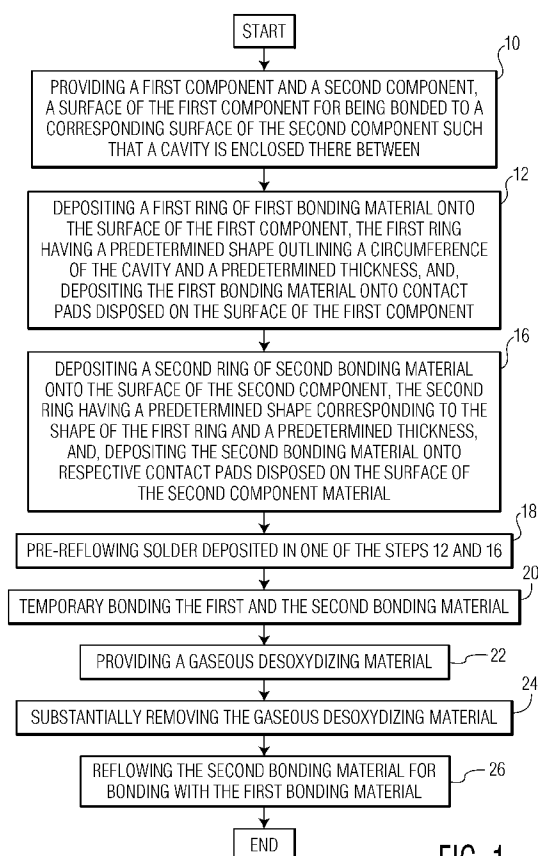


FIG. 1

(57) Abstract: The present invention relates to a method for sealing a package cavity. A first ring of first bonding material is deposited onto the surface of a first component. The first ring has a predetermined shape outlining a circumference of the cavity and a predetermined thickness. A second ring of second bonding material is deposited onto the surface of a second component. The second ring has a predetermined shape corresponding to the shape of the first ring and a predetermined thickness. The second ring further comprises a predetermined raised pattern such that an exchange of gaseous material between an atmosphere inside the cavity and an atmosphere outside the cavity is enabled prior to reflow of the second bonding material. A gaseous desoxydizing material is provided during temporary bonding of the first and the second ring. The gaseous desoxydizing material is then substantially removed inside and outside the cavity prior to reflowing of the second bonding material for bonding with the first bonding material.



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CLEAN AND HERMETIC SEALING OF A PACKAGE CAVITY

This invention relates generally to the field of integrated circuit packaging and more particularly to clean and hermetic sealing of a packaged cavity.

5 An increasingly important aspect of manufacturing Integrated Circuits (ICs) is the mounting of a semiconductor die to a substrate. With increasing integration of numerous functions in a single IC the number of Input/Output (IO) terminals is also increased. In an effort to substantially increase the number of IO terminals, flip-chip bonding has been developed for providing a high density of interconnections between the semiconductor die
10 and the substrate.

 In flip-chip bonding a solder bump is disposed onto each IO terminal of the semiconductor die. The semiconductor die is then flipped for mating the solder bumps with corresponding bonding pads located on the substrate. The semiconductor die and the substrate are then heated to reflow the solder bumps. Once reflowed each solder bump forms
15 a bond between the semiconductor die IO terminal and the substrate pad, which functions both as an electrical and physical connection.

 In numerous applications it is necessary to seal the connections in a cavity disposed between the semiconductor die and the substrate for protecting the interconnections as well as to use the cavity walls for provide a stronger physical bond between the
20 semiconductor die and the substrate than provided by the interconnections. For example, a sealed cavity is used to protect interconnections dedicated to shorten a distance between functionality of one component and redistribution of I/O terminals to other functionalities on a second component. Furthermore, a cavity is used to protect critical sensitive materials, structures or devices that specific applications require like MEMS, BAW or SAW. Sealing
25 provides cavity protection in following assembly steps as well as for the final product.

 Unfortunately, state of the art processes for providing a seal have various disadvantages such as requiring additional processing steps and supply of additional materials such as, for example, flux in the case of solder walls; exposing the IO connections enclosed in the cavity to residues from the use of flux or acid - when fluxless techniques are
30 employed; increasing the risk of improper soldering due to poor wetting conditions resulting in weak or no electrical connection; and providing improper sealing due to voids; or various combinations thereof.

It would be highly desirable to overcome these drawbacks and to provide a method for clean and hermetic sealing of a package cavity.

In accordance with the present invention there is provided a method for sealing a package cavity. A first ring of first bonding material is deposited onto the surface of a first component. The first ring has a predetermined shape outlining a circumference of the cavity and a predetermined thickness. A second ring of second bonding material is deposited onto the surface of a second component. The second ring has a predetermined shape corresponding to the shape of the first ring and a predetermined thickness. The second ring further comprises a predetermined raised pattern such that an exchange of gaseous material between an atmosphere inside the cavity and an atmosphere outside the cavity is enabled prior to reflow of the second bonding material. A gaseous desoxydizing material is provided after temporary bonding of the first and the second bonding material. The gaseous desoxydizing material is then substantially removed inside and outside the cavity prior to reflowing of the second bonding material for bonding with the first bonding material.

In accordance with the present invention there is further provided a storage medium having stored therein executable commands for execution on a processor. The processor when executing the commands performs a method for sealing a package cavity. A first ring of first bonding material is deposited onto the surface of a first component. The first ring has a predetermined shape outlining a circumference of the cavity and a predetermined thickness. A second ring of second bonding material is deposited onto the surface of a second component. The second ring has a predetermined shape corresponding to the shape of the first ring and a predetermined thickness. The second ring further comprises a predetermined raised pattern such that an exchange of gaseous material between an atmosphere inside the cavity and an atmosphere outside the cavity is enabled prior to reflow of the second bonding material. A gaseous desoxydizing material is provided during temporary bonding of the first and the second bonding material. The gaseous desoxydizing material is then substantially removed inside and outside the cavity prior to reflowing of the second bonding material for bonding with the first bonding material.

Exemplary embodiments of the invention will now be described in conjunction with the following drawings, in which:

Figs. 1 is a simplified flow diagram of a method for sealing a package cavity according to the invention;

Figs. 2a and 2b are simplified block diagrams illustrating a package cavity produced using the method illustrated in Fig. 1;

Figs. 3a to 3c are simplified block diagrams illustrating raised patterns according to the invention in a perspective view;

5 Figs. 4a to 4c are a simplified block diagrams illustrating raised patterns according to the invention as projection onto the component surface; and,

Fig. 5 is a simplified diagram illustrating a temperature profile with preheating and reflowing steps.

The following description is presented to enable a person skilled in the art to
10 make and use the invention, and is provided in the context of a particular application and its requirements. Various modifications to the disclosed embodiments will be readily apparent to those skilled in the art, and the general principles defined herein may be applied to other embodiments and applications without departing from the scope of the invention. Thus, the present invention is not intended to be limited to the embodiments disclosed, but is to be
15 accorded the widest scope consistent with the principles and features disclosed herein.

Referring to Fig. 1, a simplified flow diagram of a method for sealing a package cavity according to the invention is shown. Reference is made to the simplified block diagram illustrating a cross-sectional view of the package cavity 100, shown in Figs. 2a and 2b. At 10, a first 102 and a second component 104 are provided for being bonded such
20 that a surface 106 of the first component 102 is bonded to a corresponding surface 108 of the second component and the cavity 100 is enclosed therebetween. The first component 102 and the second component 104 are, for example, a semiconductor die for being bonded to a substrate, two semiconductor dies for being bonded together, or a cap for being bonded to a semiconductor die for protecting an active surface area thereof. Of course, one of skill in the
25 art will readily arrive at various other applications for bonding various semiconductor components as well as other components. At 12, a first ring 110 of a first bonding material is deposited onto the surface 106 of the first component. The first ring 110 comprises, for example, aluminum used in standard integrated circuit industry processes and a deposited tin solder - reflowable - from an electrolytic process with Cu between Al and Sn acting as a
30 under bump metallurgy layer, plus pre reflow of Sn deposited on 110 and 114 according to a temperature profile as shown in Fig. 5. At 16, a second ring 116 and bumps on 120 of a second bonding material is deposited onto the surface 108 of the second component 104. The second ring comprises, for example, a multilayer ENIG material. At 18, solder deposited in

one of the steps 12 and 16 is pre-reflowed. The first ring 110 and the second ring 116, as well as the solder bumps disposed on the contact pads 114 and 120, are then temporary bonded using a thermocompression process - at 20. At 22, a gaseous deoxidizing material is provided in an atmosphere surrounding the components. In order to avoid residues after the soldering process a fluxless soldering process is applied using as deoxydizing material, for example, an acid vapor such as a formic acid vapor. The thermocompression process will be described hereinbelow. At 24, the atmosphere is evacuated using, for example, a vacuum pump. By providing the second ring 116 with the predetermined raised pattern openings are left between the temporary bonded rings 110 and 116 in order to enable evacuation of the atmosphere disposed inside the cavity to remove the deoxydizing material therefrom. Optionally, a substantially inert gas such as, for example, nitrogen, or an inert gas such as, for example, argon, is provided for being enclosed in the cavity 100. After removal of the deoxydizing material, the first bonding material is bonded - at 26 - with the second bonding material by reflowing the second bonding material, simultaneously bonding the rings - 110 and 116 - and the solder bumps disposed on the contact pads. After cooling the first component 102 is bonded to the second component 104 having an enclosed cavity 100 therebetween.

For example, the reflowable solder ring is disposed on the first component or the second component assuming that the second component is the substrate with electrical input from the first component redistributed outside of the ring - by routing underneath of the ring.

The formation of the openings between the first 110 and the second 116 ring is achieved by a combination of the superficial tension properties of the solder-based material and the raised shape of the second ring by providing a greater thickness at specific ring locations. Figs. 3a to 3c illustrate 3 different raised patterns of the second ring 116 in a perspective view. Here, the second ring comprises straight portions having a first height and second portions - such as a bump - disposed in the corners having a second height greater than the first height - Figs. 3a and 3b - or a raised outer ring portion having the second height in the corner area - Fig. 3c. Figs. 4a to 4c illustrate corresponding projections onto the second surface 108. The different heights are achieved, for example, by providing the second ring 116 having a width of $30\ \mu\text{m}$ and a bump having a radius of $45\ \mu\text{m}$ - Figs. 4a and 4b - or by providing the pattern shown in Fig. 4c having an internal radius 130 of $200\ \mu\text{m}$, a mean radius 132 of $50\ \mu\text{m}$, and a ring width of $50\ \mu\text{m}$. Yet further alternatively, the straight

portions have greater height than the corner portions, for example, by providing the straight ring portions with greater width than the corner portions. Using the above dimensions a height variation of approximately $15\ \mu\text{m}$ is realized. The raised patterns are determined, for example, experimentally for various parameter combinations such as, for example, shape and size of the ring, solder material used.

Temporary bonding is usually based on the sticky effect of liquid flux used. Use of liquid flux adds an additional processing step and requires provision of additional material. Furthermore, use of liquid flux leaves harmful solid residues enclosed in the cavity after reflow and cooling, as well as a risky process regarding to gas entrapped into the cavity with such characteristic effects like quality factor downgrading or frequencies application shifted. The disadvantages of the flux are overcome by employing thermocompression together with the use of a gaseous desoxydizing material such as, for example, formic acid vapor. The thermocompression is a combination of force, time, and temperature applied at the interface of two metals in order to facilitate a diffusion mechanism. Referring to the example shown in Figs. 2a and 2b, the diffusion occurs between gold from ENIG and tin from ring and bumps of opposite metal locations. The force is applied, for example, by pressing the first component 102 towards the second component 104 on a dedicated pick & place equipment. The force applied, the temperature and the time are determined, for example, experimentally for different applications. Provision of acid vapor such as, for example, formic acid vapor during preheating leads to the same functionality as the use of liquid flux, but prevents deposition of solid residues and gas trapping.

The temporary bonding using thermocompression is implemented using, for example, a standard hermetic box oven furnace used in semiconductor manufacturing enabling controlled heating in predetermined temperature ranges and for predetermined time intervals as well as provision of various atmospheres and evacuation of the same. Prior to reflow the acid vapor is substantially removed from the atmosphere outside and inside the cavity 100 in order to enable proper wetting of the opposite metal surfaces. Omission of the removal of the acid vapor results in poor wetting conditions and, for example, in open circuits between the contact pads 114 and 120. Removing vapor results also in gas-free cavity proper to product characteristics for sensitive applications. By extension, vacuum is a specific condition into the cavity one may target for specific applications too. After removal of the acid vapor the temperature is increased above the melting point - $220\text{-}230^\circ\text{C}$ of the solder material to provide reflow conditions followed by a cooling phase. The reflow is performed,

for example, in vacuum conditions or in an atmosphere comprising a substantially inert gas such as, for example, nitrogen, xenon, or argon.

Using eutectic bonding, it is possible to combine two electroplated metals - for example, tin and copper - having a low melting point – 215 to 235°C range as a function of percentage of metal additives 227 °C - with another material such as, for example, ENIG as UBM. This combination forms a high strength intermetallic based on a Solid Liquid InterDiffusion (SLID) process. It is possible to combine tin with various UBMs. A nickel layer is employed to limit the formation of Cu₃Sn, which is brittle due to Kirkendall voids. The initial stack structure Ni/Cu/Sn results in Ni, Cu₆Sn₅, which is a preferred intermetallic.

10 Application of pressure during reflow prevents formation of big voids during intermetallic growing.

The method for sealing a package cavity according to the invention is implementable using standard equipment in semiconductor manufacturing technology. The parameters of the various processing steps are, for example, controlled using a processor

15 executing executable commands stored in a storage medium. Various parameter combinations determining shape of the rings and the raised pattern, as well as control parameters for the thermocompression and reflowing are stored, for example, in the form of look up tables.

Numerous other embodiments of the invention will be apparent to persons

20 skilled in the art without departing from the spirit and scope of the invention as defined in the appended claims.

What is claimed is:

1. A method comprising:
 - providing a first component and a second component, a surface of the first component for being bonded to a corresponding surface of the second component such that a cavity is enclosed therebetween;
 - depositing a first ring of first bonding material onto the surface of the first component, the first ring having a predetermined shape outlining a circumference of the cavity and a predetermined thickness;
 - depositing a second ring of second bonding material onto the surface of the second component, the second ring having a predetermined shape corresponding to the shape of the first ring and a predetermined thickness, the second ring comprising a predetermined raised pattern such that an exchange of gaseous material between an atmosphere inside the cavity and an atmosphere outside the cavity is enabled prior to reflow of the second bonding material;
 - providing a gaseous desoxydizing material;
 - temporary bonding the first and the second bonding material;
 - substantially removing the gaseous desoxydizing material; and,
 - reflowing the second bonding material for bonding with the first bonding material.
2. A method as defined in claim 1 comprising determining the raised pattern such that predetermined first portions of the second ring are having a predetermined first height above the surface of the second component and predetermined second portions of the second ring are having a predetermined second height above the surface of the second component, wherein the second height is greater than the first height.
3. A method as defined in claim 2 wherein the raised pattern is determined such that the second ring comprises at least two first portions and at least two second portions.
4. A method as defined in claim 3 wherein the shape of the second ring is determined such that the second ring is substantially rectangular.
5. A method as defined in claim 4 wherein the portions having the second height are located substantially at corners of the rectangle.
6. A method as defined in claim 5 wherein the portions having the second height have a substantially circular projection onto the surface of the second component.

7. A method as defined in claim 4 wherein the portions having the first height are located substantially at corners of the rectangle.
8. A method as defined in claim 1 comprising:
 - depositing the first bonding material onto contact pads disposed on the surface of the first component; and,
 - depositing the second bonding material onto respective contact pads disposed on the surface of the second component.
9. A method as defined in claim 8 wherein the first and the second bonding material are deposited onto contact pads that are disposed on a respective surface area enclosed by the first and the second ring.
10. A method as defined in claim 9 wherein providing the gaseous desoxydizing material comprises providing acid vapor.
11. A method as defined in claim 10 wherein providing the acid vapor comprises providing formic acid vapor.
12. A method as defined in claim 9 wherein temporary bonding the first and the second ring comprises thermocompressing.
13. A method as defined in claim 9 wherein depositing the first bonding material comprises depositing nickel followed by depositing gold.
14. A method as defined in claim 9 wherein depositing the first bonding material comprises an electroless nickel immersion gold process.
15. A method as defined in claim 9 wherein depositing the second bonding material comprises depositing copper followed by depositing tin.
16. A method as defined in claim 15 comprising depositing nickel prior to depositing copper.
17. A method as defined in claim 16 wherein the second bonding material is deposited using an electroplating process.
18. A method as defined in claim 1 comprising applying a predetermined amount of pressure on the first and second bonding material during reflowing.
19. A method as defined in claim 1 comprising providing one of a substantially inert gas and a substantially vacuum prior to reflowing.
20. A method as defined in claim 1 wherein the first and the second component are made of semiconductor material.

21. A storage medium having stored therein executable commands for execution on a processor, the processor when executing the commands performing:

- controlling provision of a first component and a second component, a surface of the first component for being bonded to a corresponding surface of the second component such that a cavity is enclosed therebetween;
- controlling deposition of a first ring of first bonding material onto the surface of the first component, the first ring having a predetermined shape outlining a circumference of the cavity and a predetermined thickness;
- controlling deposition of a second ring of second bonding material onto the surface of the second component, the second ring having a predetermined shape corresponding to the shape of the first ring and a predetermined thickness, the second ring comprising a predetermined raised pattern such that an exchange of gaseous material between an atmosphere inside the cavity and an atmosphere outside the cavity is enabled prior to reflow of the second bonding material;
- controlling provision of a gaseous desoxydizing material;
- controlling temporary bonding of the first and the second bonding material;
- controlling substantial removal of the gaseous desoxydizing material; and,
- controlling reflowing of the second bonding material for bonding with the first bonding material.

22. A storage medium as defined in claim 21 having stored therein executable commands for execution on a processor, the processor when executing the commands performing:

- controlling deposition of the first bonding material onto contact pads disposed on the surface of the first component; and,
- controlling deposition of the second bonding material onto respective contact pads disposed on the surface of the second component.

23. A storage medium as defined in claim 22 having stored therein executable commands for execution on a processor, the processor when executing the commands performing:

- controlling application of a predetermined amount of pressure on the first and second bonding material during reflowing.

24. A storage medium as defined in claim 23 having stored therein executable commands for execution on a processor, the processor when executing the commands performing:

- controlling provision of a substantially inert gas prior to reflowing.

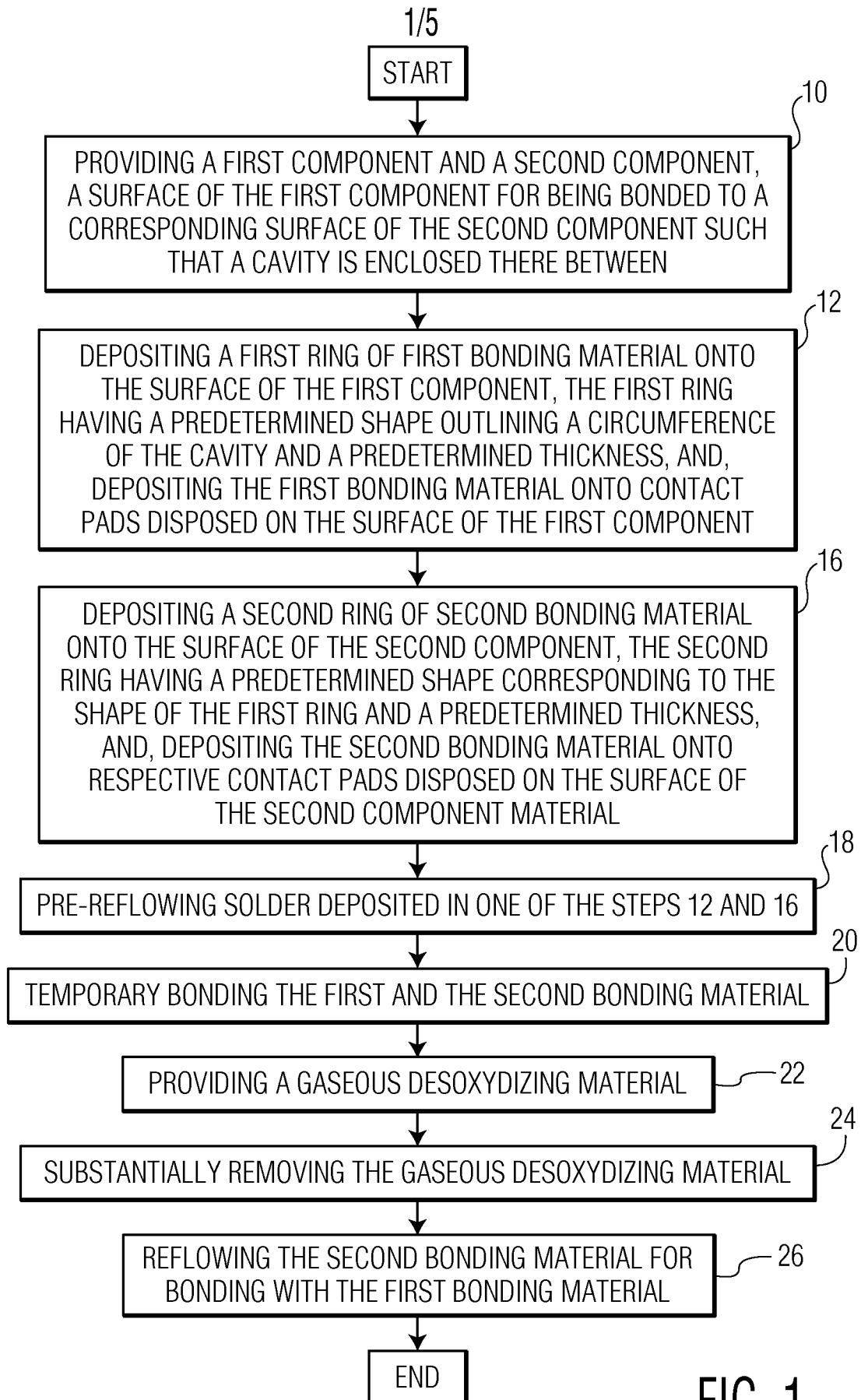


FIG. 1

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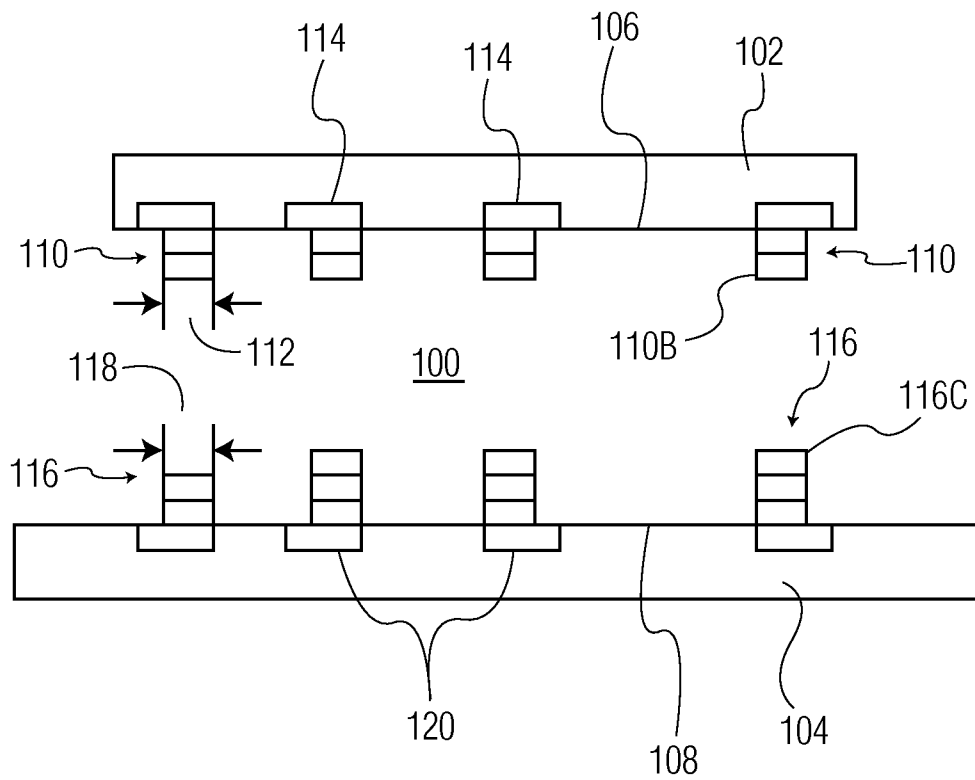


FIG. 2a

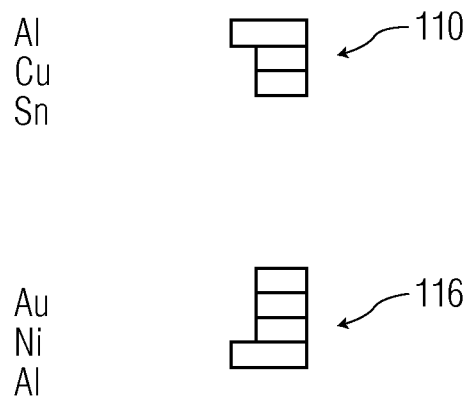


FIG. 2b

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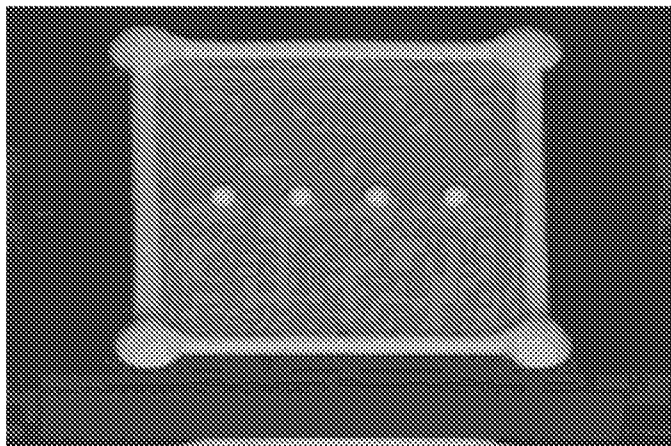


FIG. 3a

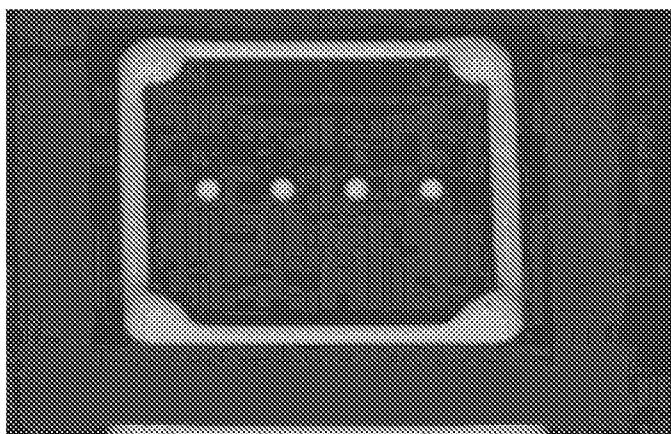


FIG. 3b

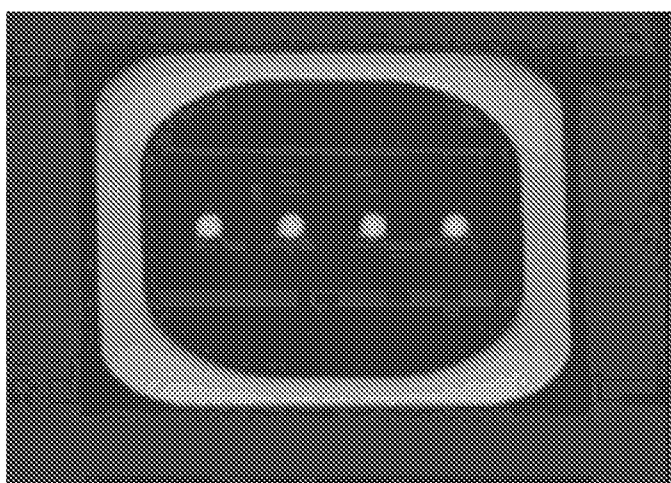


FIG. 3c

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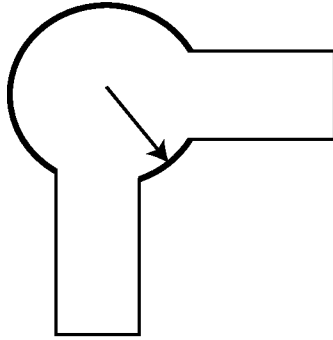


FIG. 4a

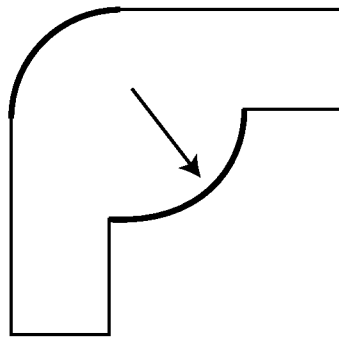


FIG. 4b

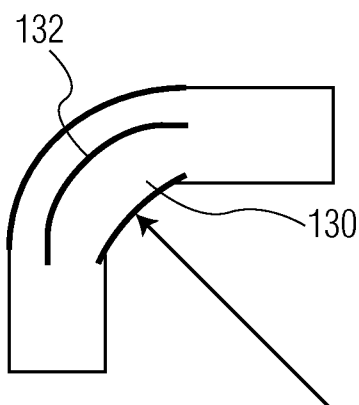


FIG. 4c

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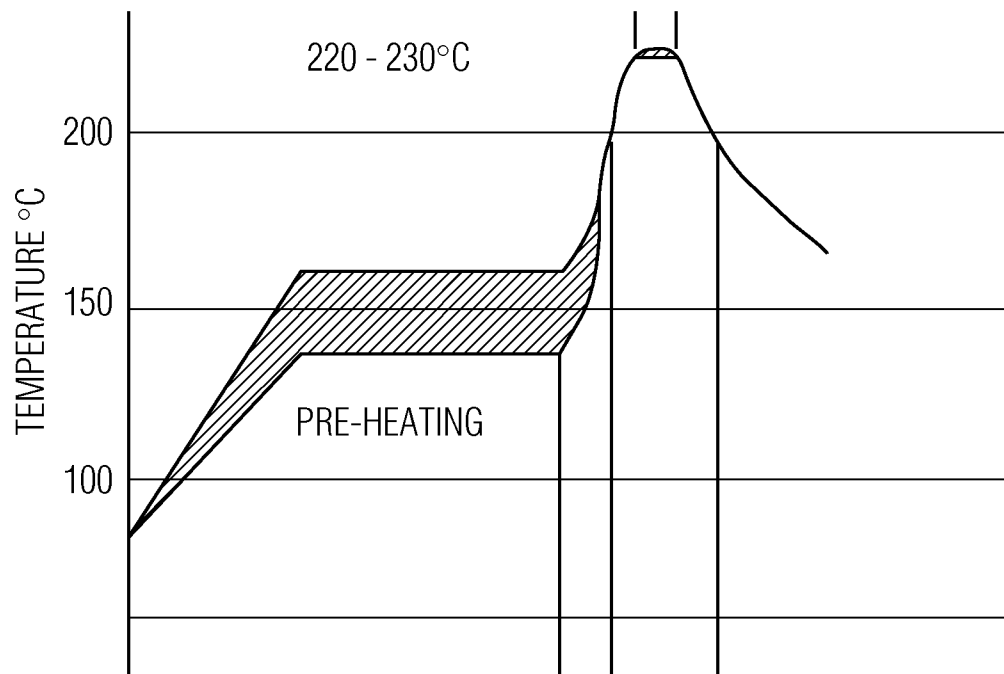


FIG. 5