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Spory

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(54) **METHOD FOR REMAPPING A PACKAGED EXTRACTED DIE WITH 3D PRINTED BOND CONNECTIONS**

(58) **Field of Classification Search**
CPC H01L 23/00; H01L 24/83; H01L 24/26;
H01L 23/04; H01L 24/80; H01L 24/98;
H01L 24/03

(71) Applicant: **Erick Merle Spory**, Colorado Springs,
CO (US)

See application file for complete search history.

(72) Inventor: **Erick Merle Spory**, Colorado Springs,
CO (US)

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(73) Assignee: **Global Circuit Innovations Incorporated**, Colorado Springs, CO
(US)

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patent is extended or adjusted under 35
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This patent is subject to a terminal dis-
claimer.

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Primary Examiner — Matthew Reames

Assistant Examiner — Wilner Jean Baptiste

(65) **Prior Publication Data**

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(74) *Attorney, Agent, or Firm* — Thomas J. Lavan

(57) **ABSTRACT**

Related U.S. Application Data

(63) Continuation-in-part of application No. 14/142,823,
filed on Dec. 28, 2013, now Pat. No. 9,935,028,
(Continued)

A method is provided. The method includes removing an
extracted die including an original ball bond from a previous
packaged integrated circuit, bonding the extracted die to an
interposer to create a remapped extracted die, 3D printing
one or more first bond connections between one or more
original bond pads of the extracted die and one or more first
bond pads of the interposer, securing the remapped extracted
die to a package base, and 3D printing one or more second
bond connections between one or more second bond pads of
the interposer and one or more package leads or downbonds
of the package base. The one or more first and second bond
connections conform to the shapes and surfaces of the
extracted die, the interposer, and the package base.

(51) **Int. Cl.**
H01L 23/00 (2006.01)
B29C 64/10 (2017.01)

(52) **U.S. Cl.**
CPC **H01L 24/80** (2013.01); **B29C 64/10**
(2017.08); **H01L 24/03** (2013.01); **H01L 24/98**
(2013.01)

20 Claims, 21 Drawing Sheets

Assembly Method for Hermetic Packaged Integrated Circuit



Related U.S. Application Data

which is a continuation-in-part of application No. 13/785,959, filed on Mar. 5, 2013, now Pat. No. 9,966,319, which is a continuation-in-part of application No. 13/623,603, filed on Sep. 20, 2012, which is a continuation of application No. 13/283,293, filed on Oct. 27, 2011.

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Fig. 1 Extracted Die With Original Bond Pads, Original Ball Bonds, and Original Bond Wires

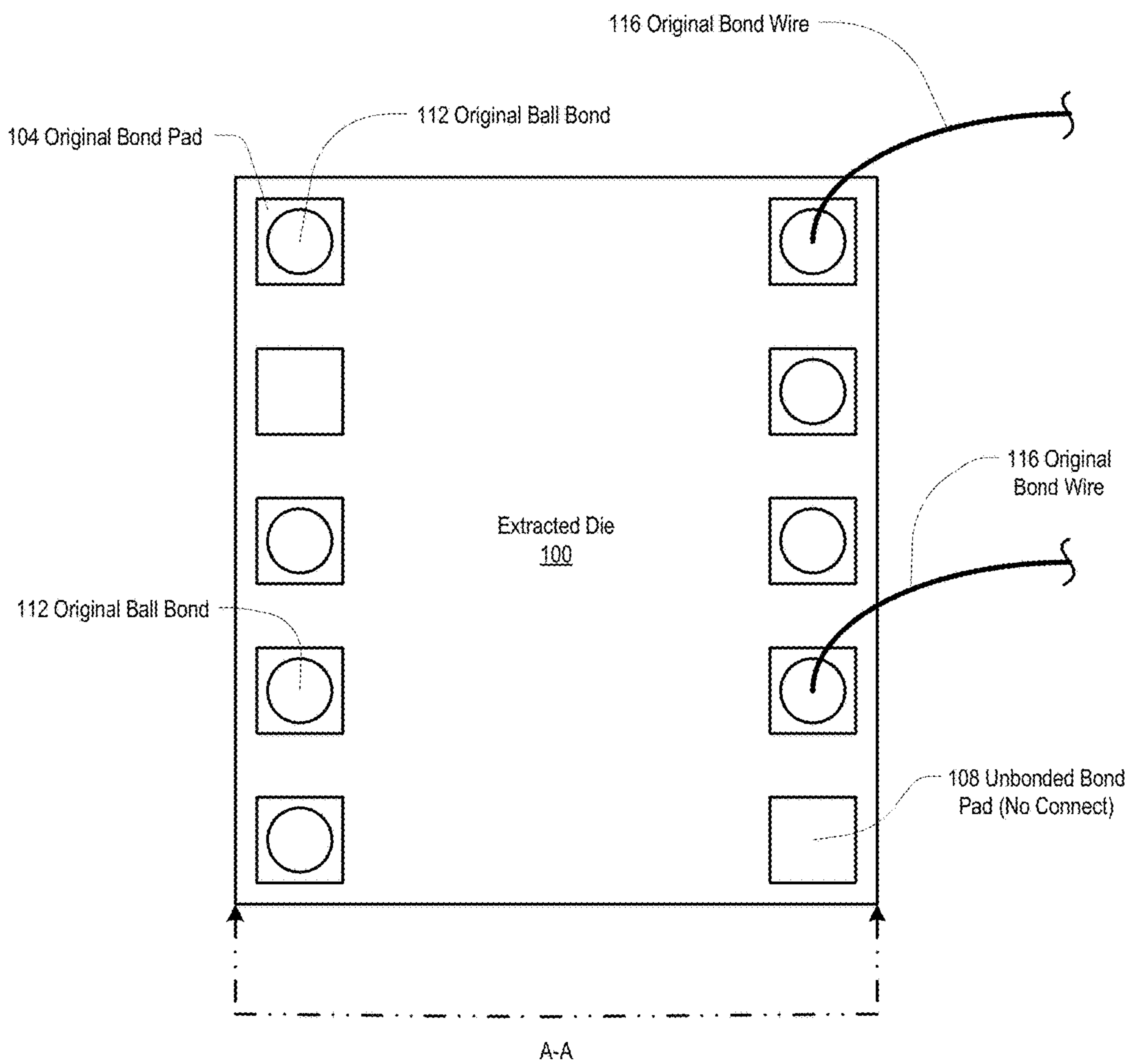


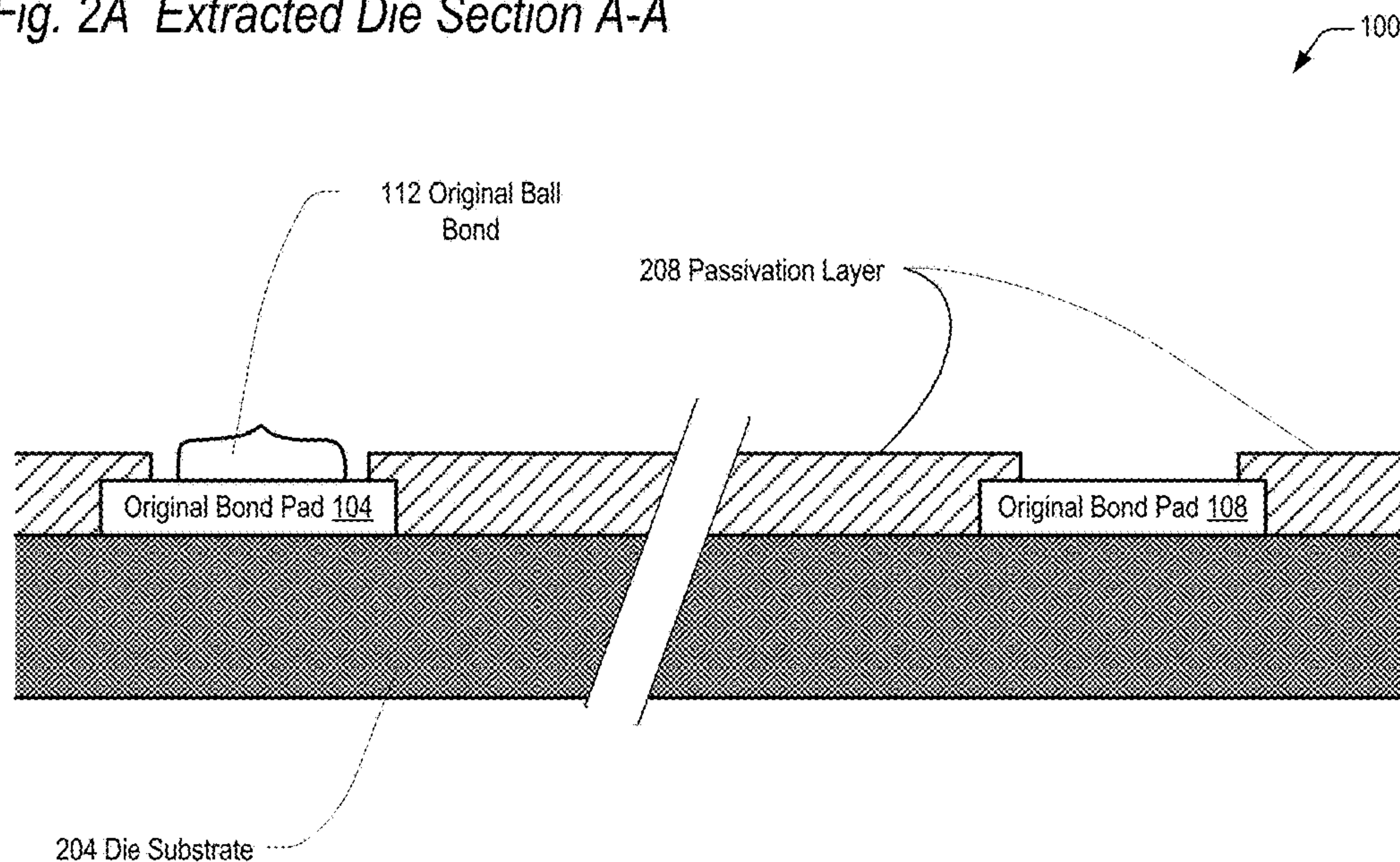
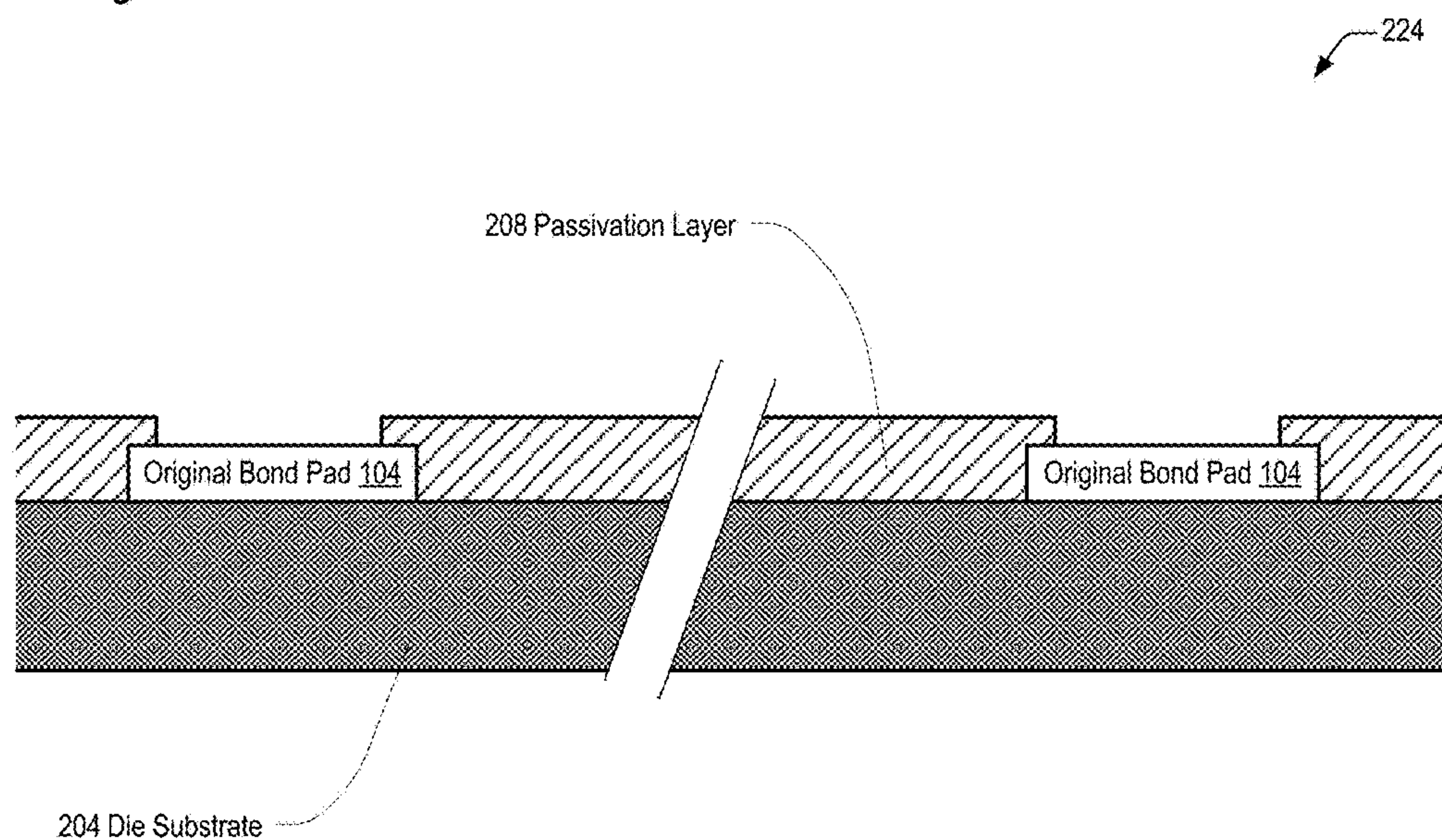
Fig. 2A Extracted Die Section A-A*Fig. 2B Modified Extracted Die Section A-A After Original Ball Bond and Original Bond Wire Removal*

Fig. 2C Extracted Die Section A-A After 3D Printing Bond Conductor Only

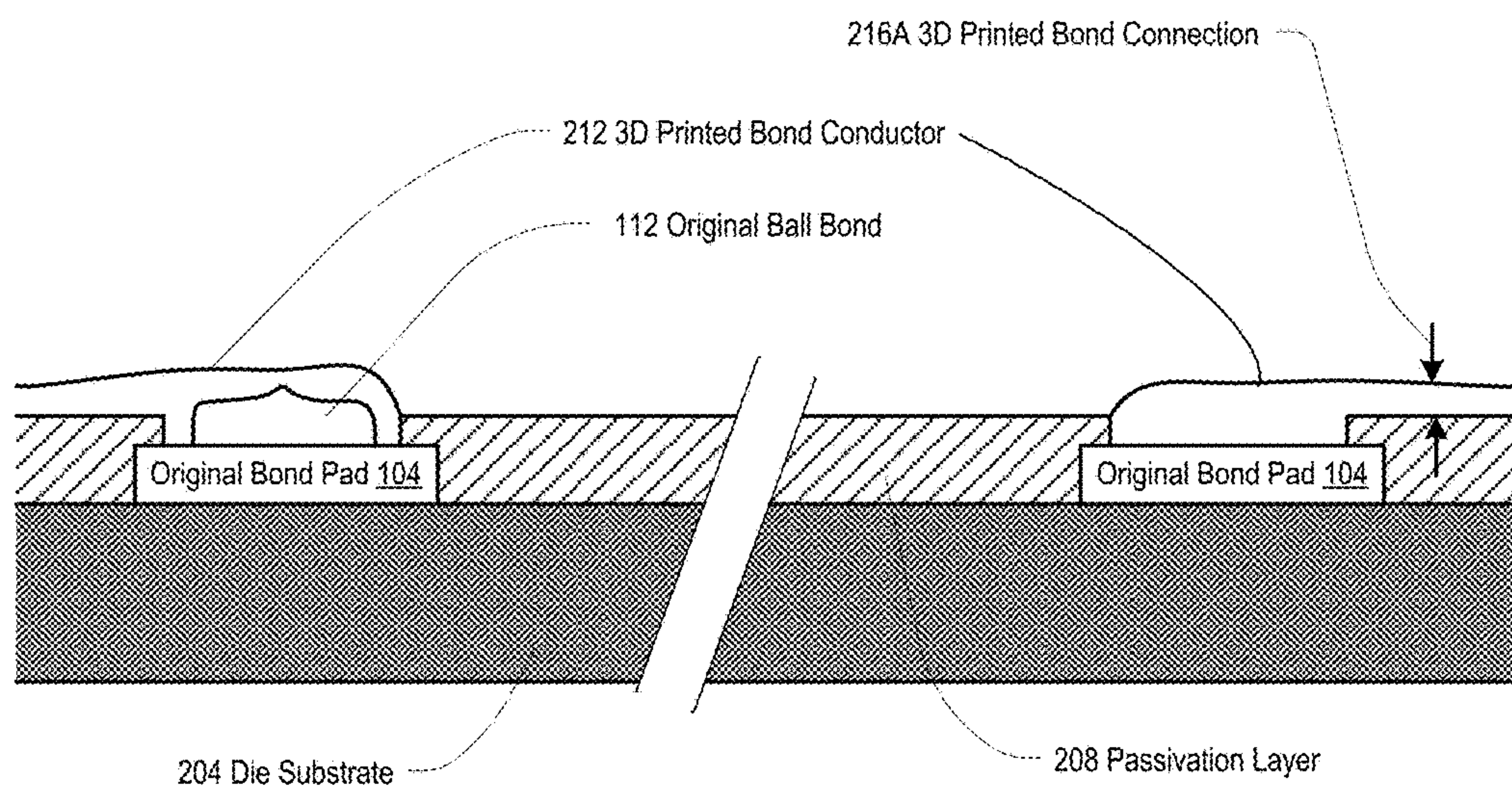


Fig. 2D Extracted Die Section A-A After 3D Printing Bond Insulator Before 3D Printing Bond Conductor

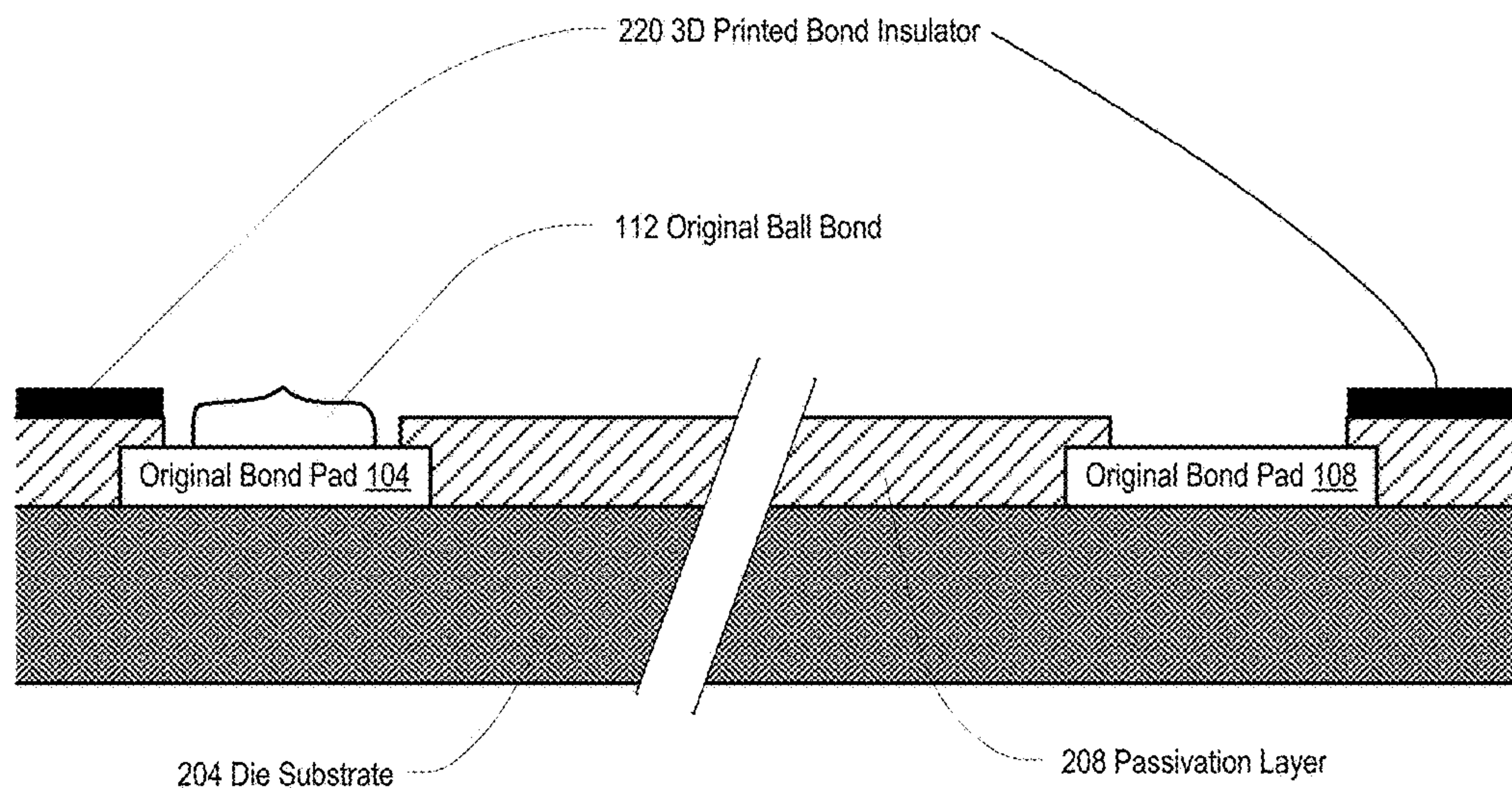


Fig. 2E Extracted Die Section A-A After 3D Printing Insulator and Conductor

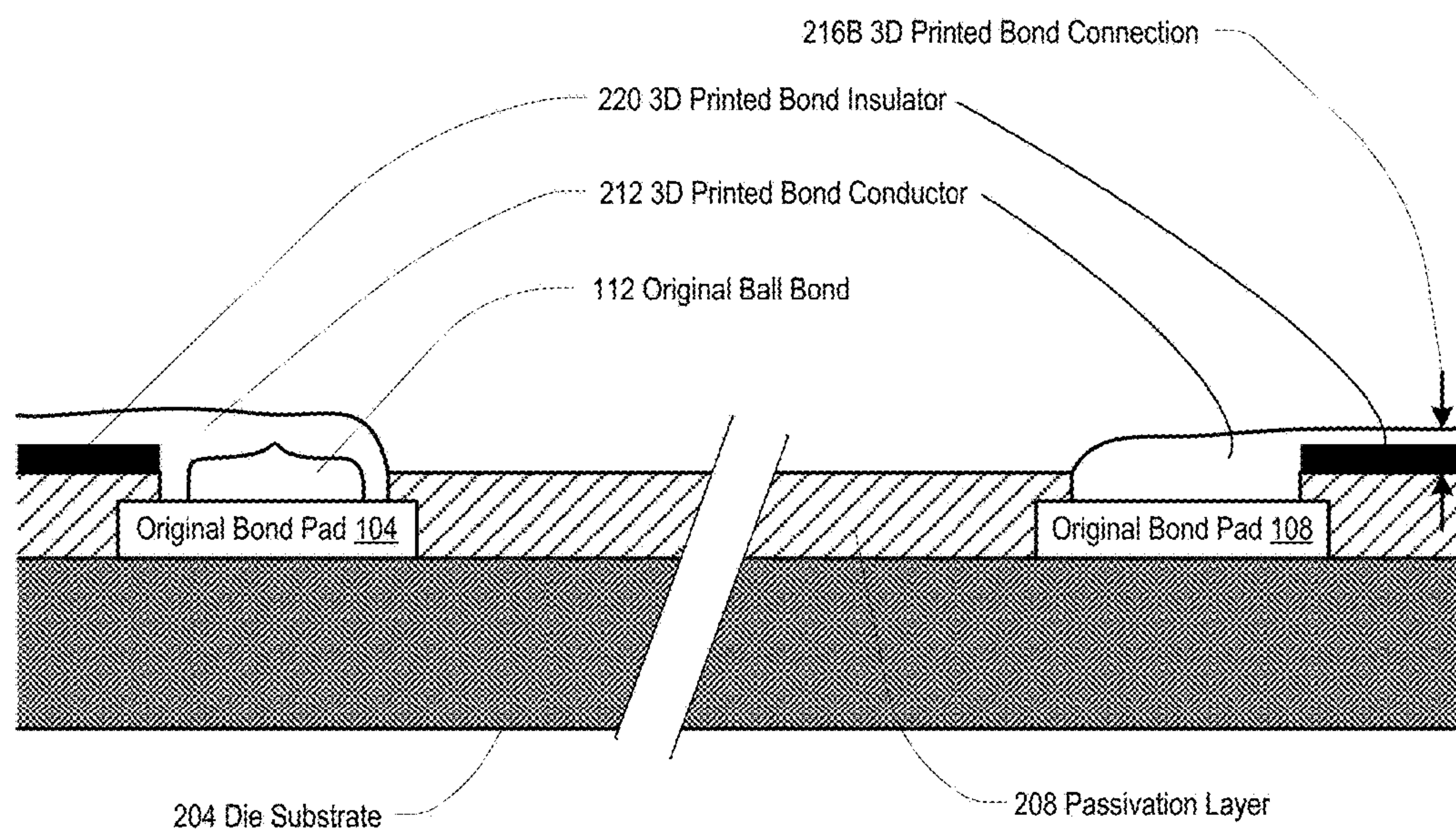


Fig. 3A Mounted Remapped Extracted Die

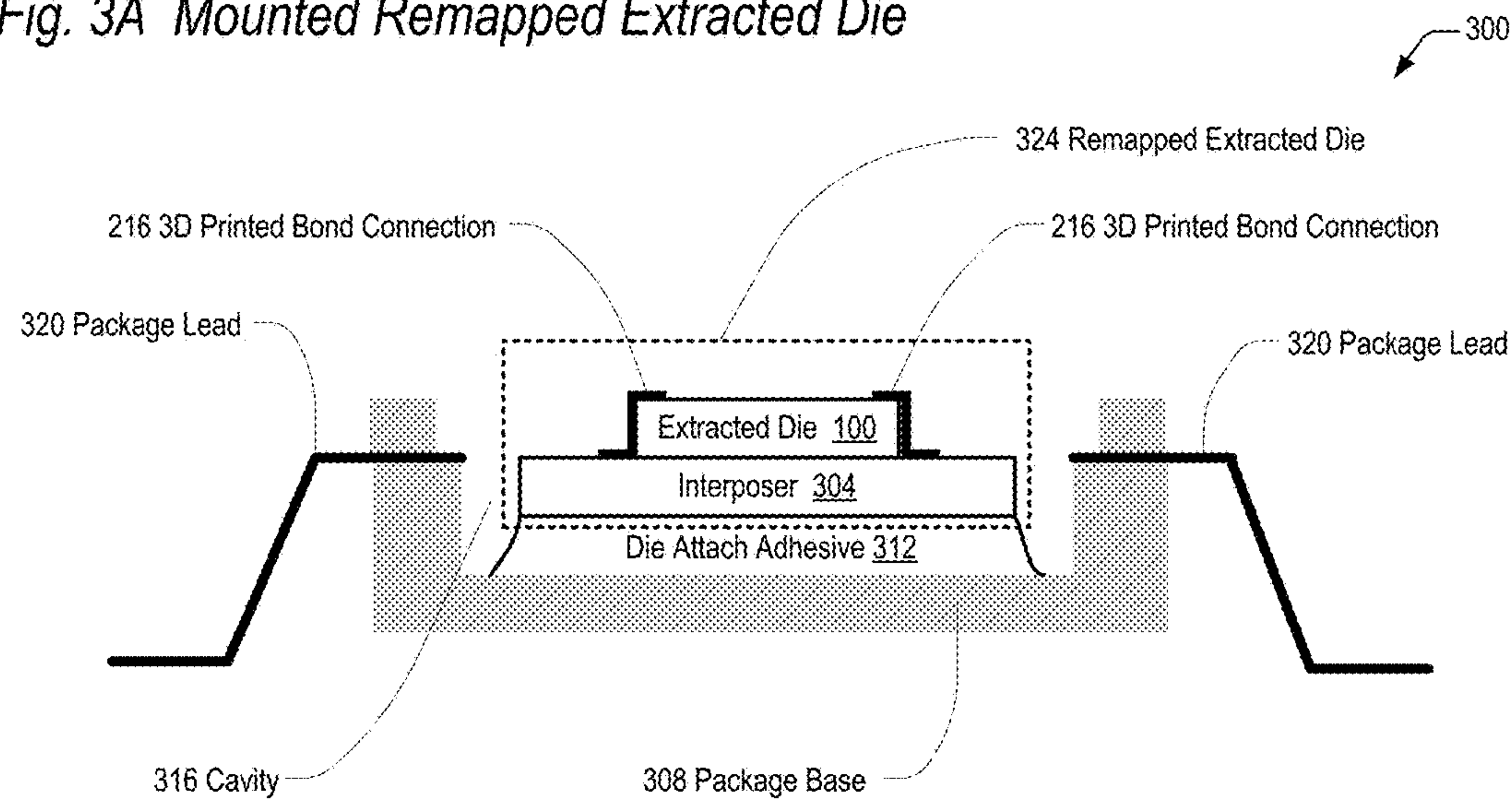


Fig. 3B Assembled Package Base With New 3D Printed Bond Connections

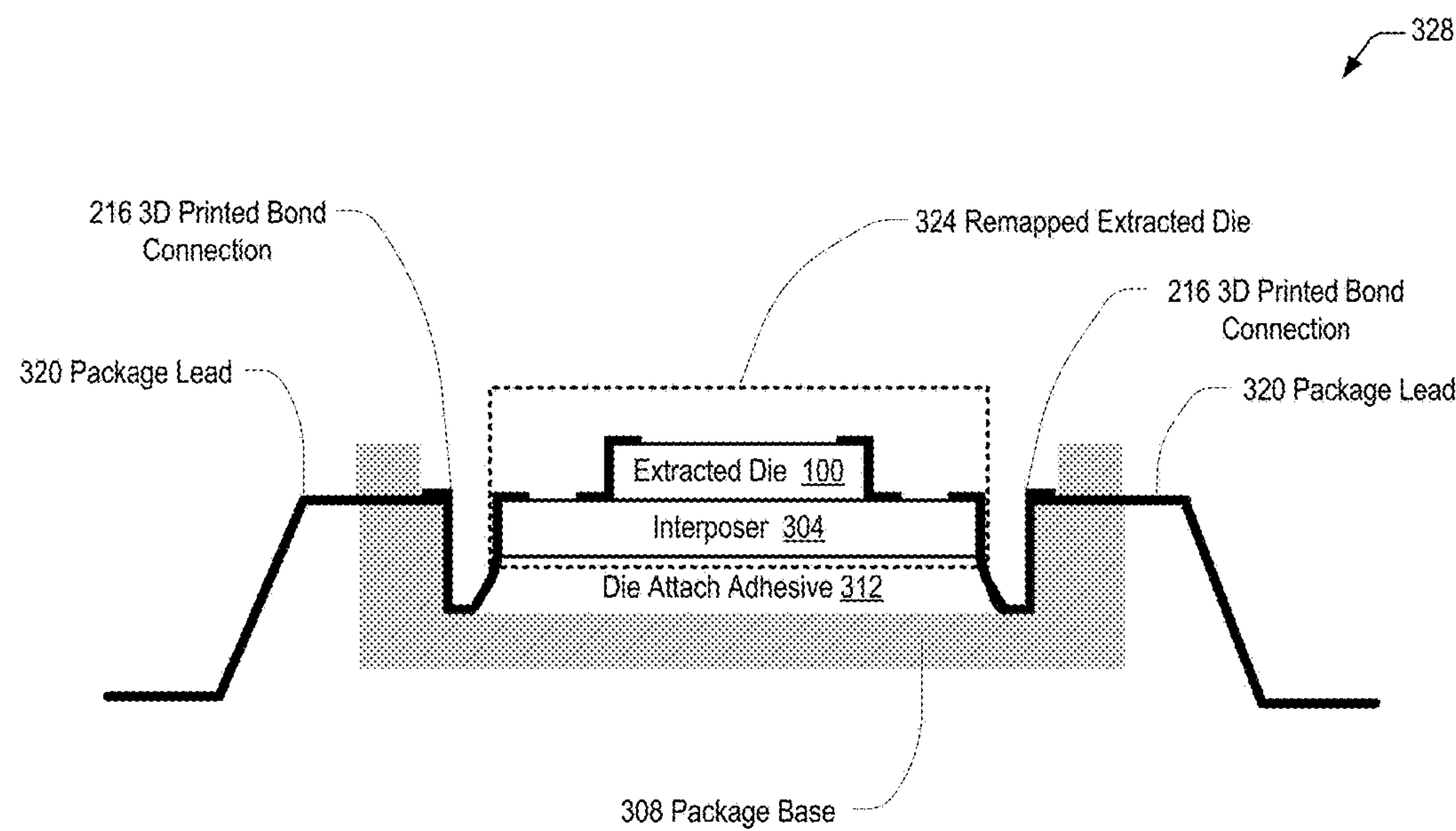


Fig. 3C Mounted Remapped Extracted Die

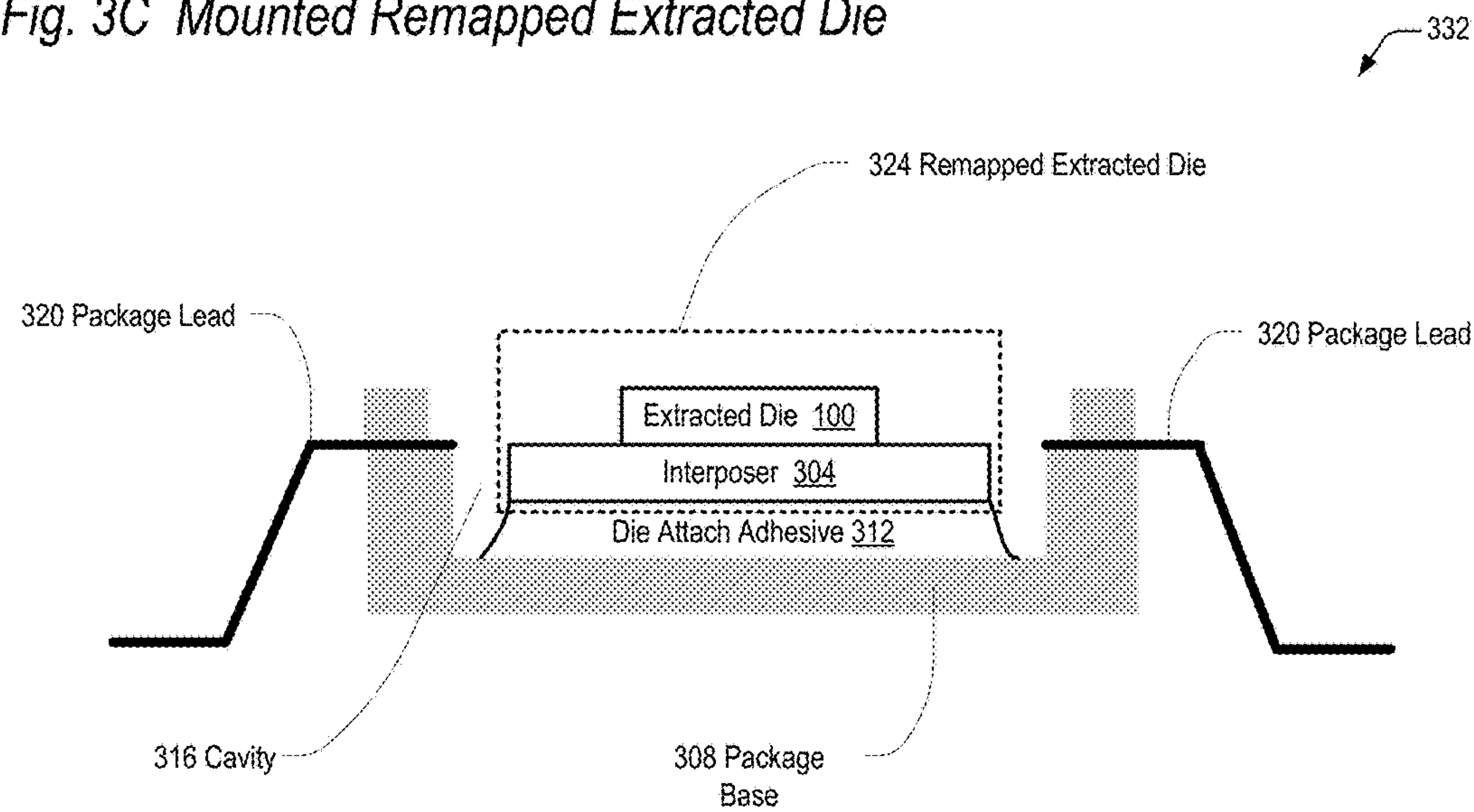


Fig. 3D Assembled Package Base With New 3D Printed Bond Connections

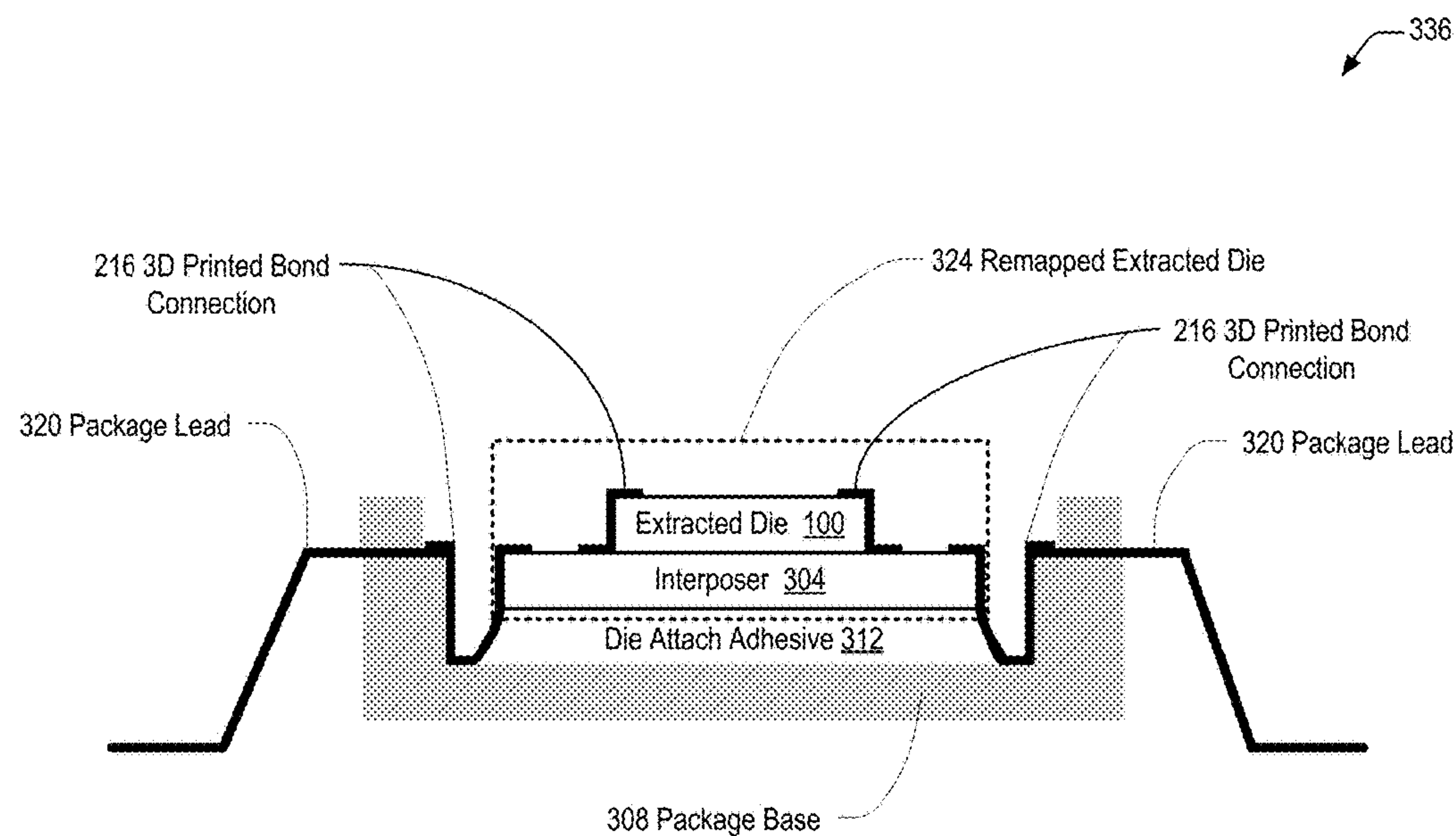


Fig. 3E Assembled Package With Remapped Extracted Die

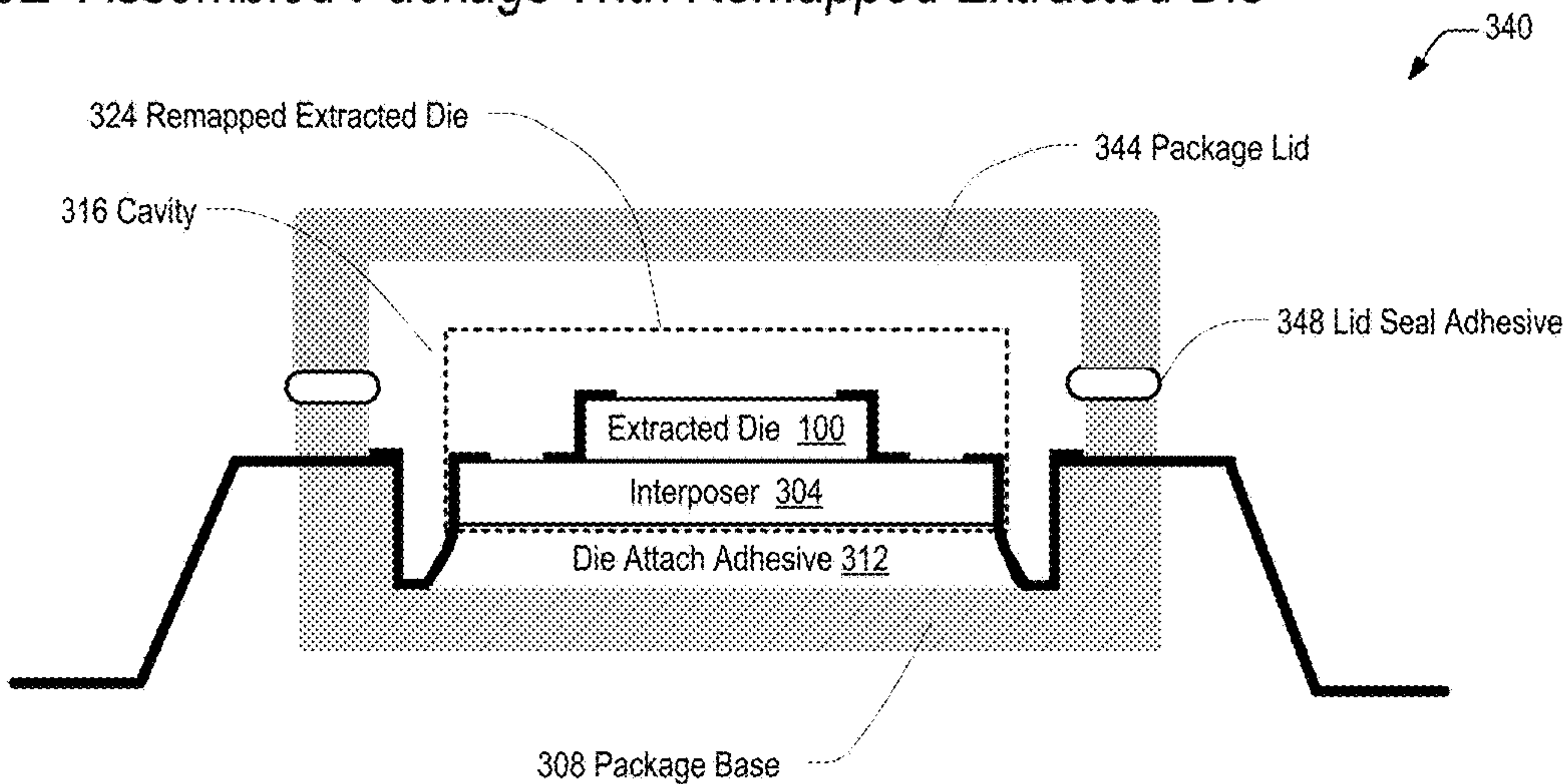


Fig. 3F Assembled Hermetic Package With Remapped Extracted Die

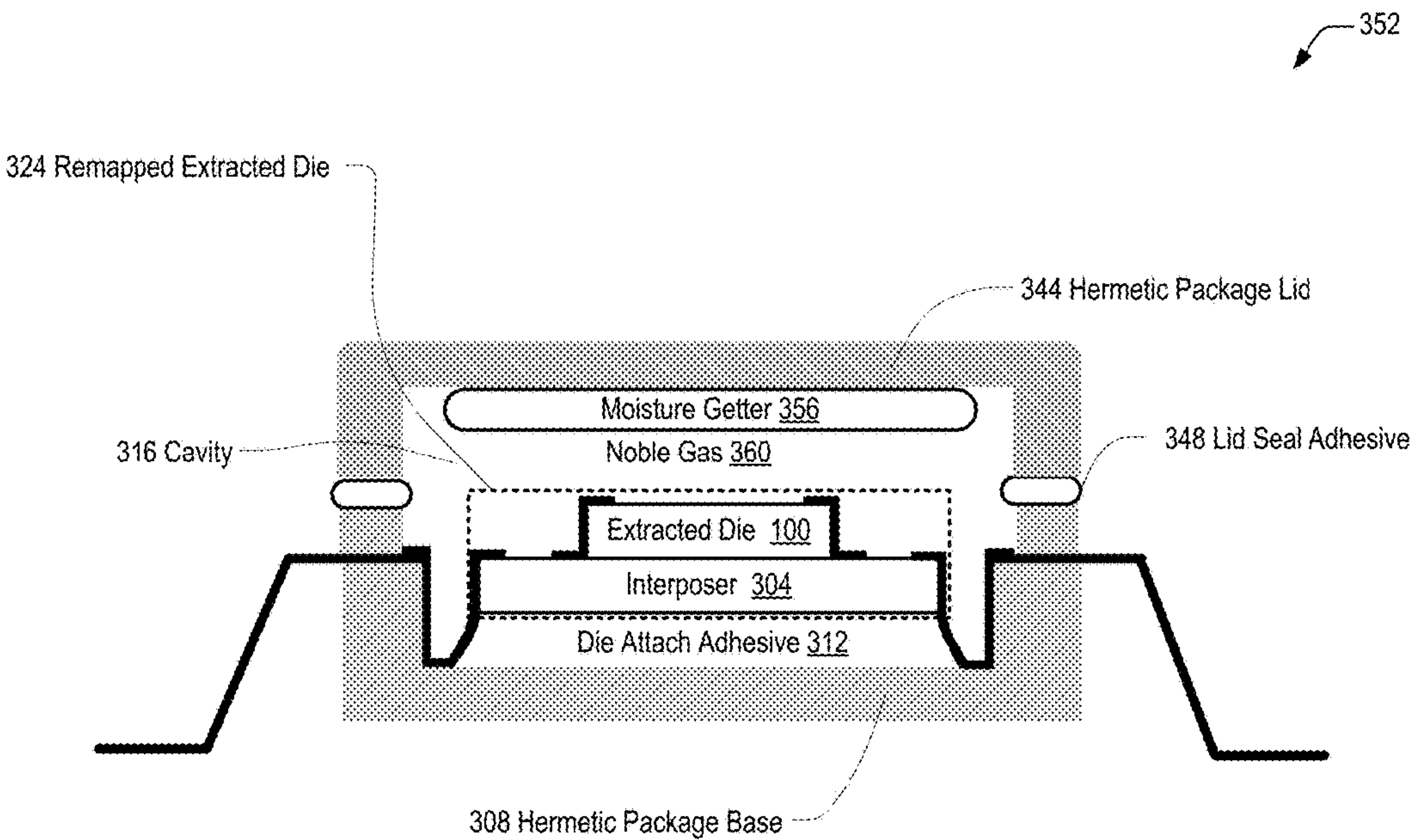


Fig. 4 Interposer for Extracted Die

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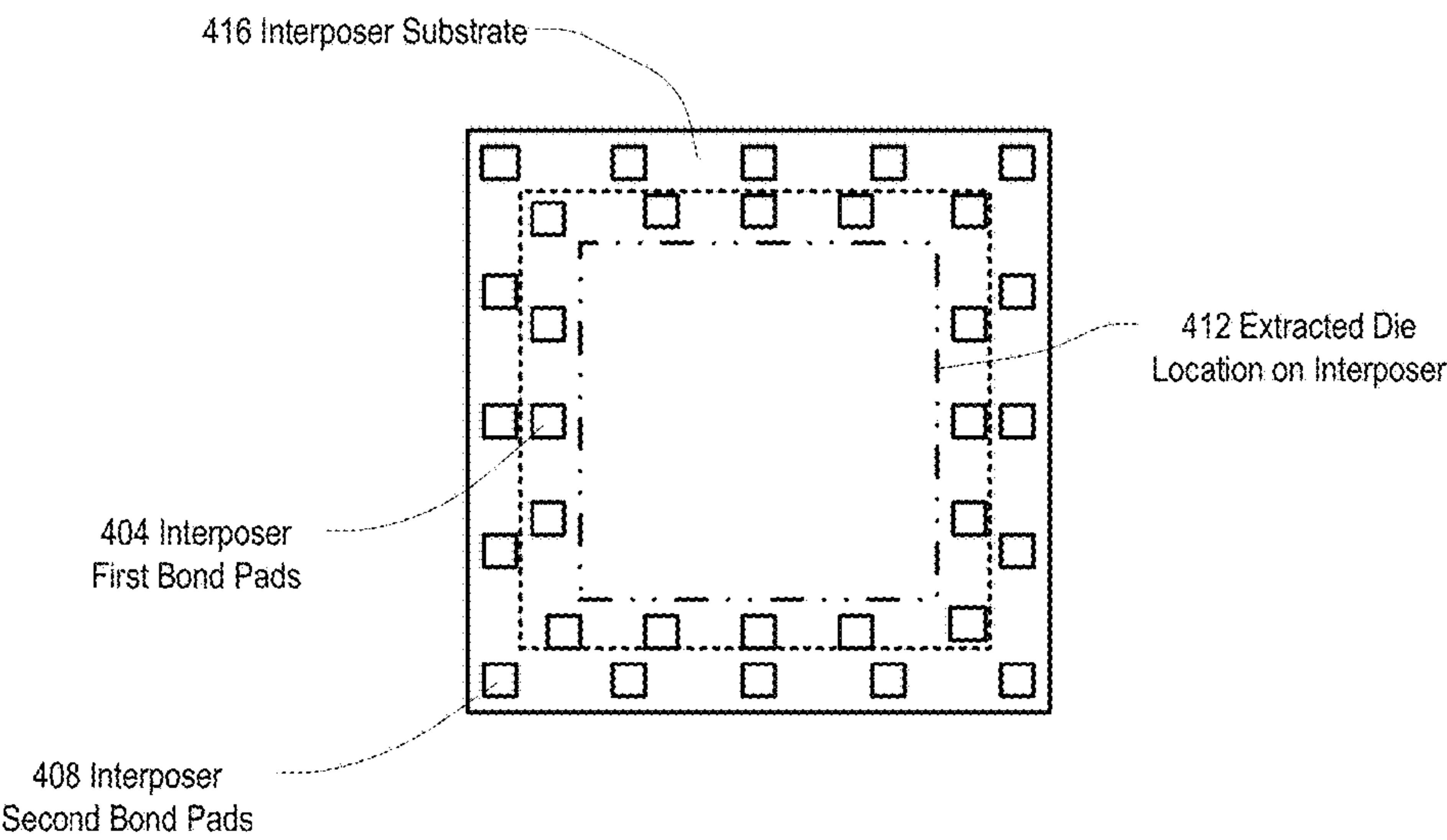


Fig. 5A Top View of New Package Base Before 3D Printing Bond Connections

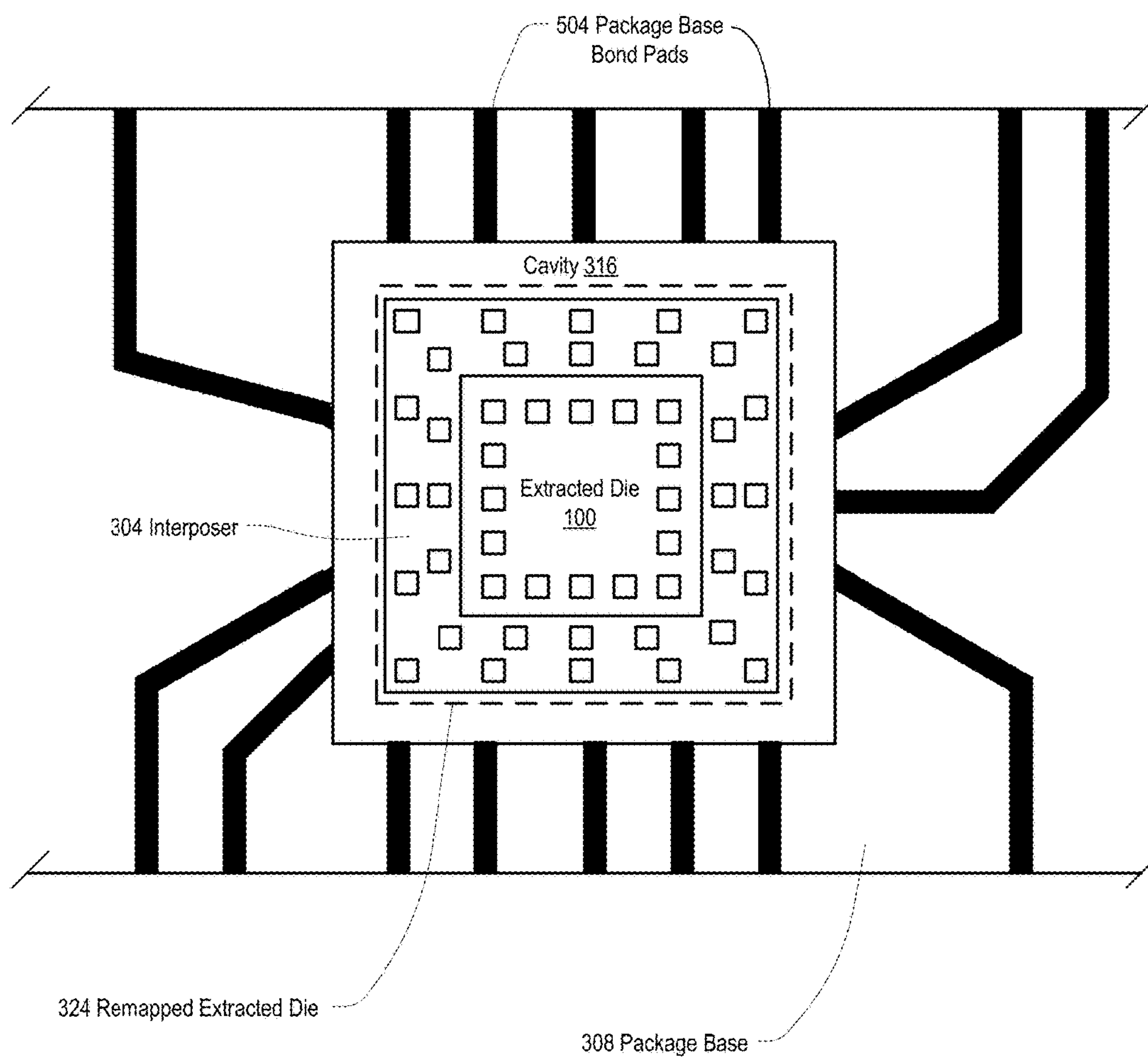


Fig. 5B Top View of New Package Base After 3D Printing Bond Connections

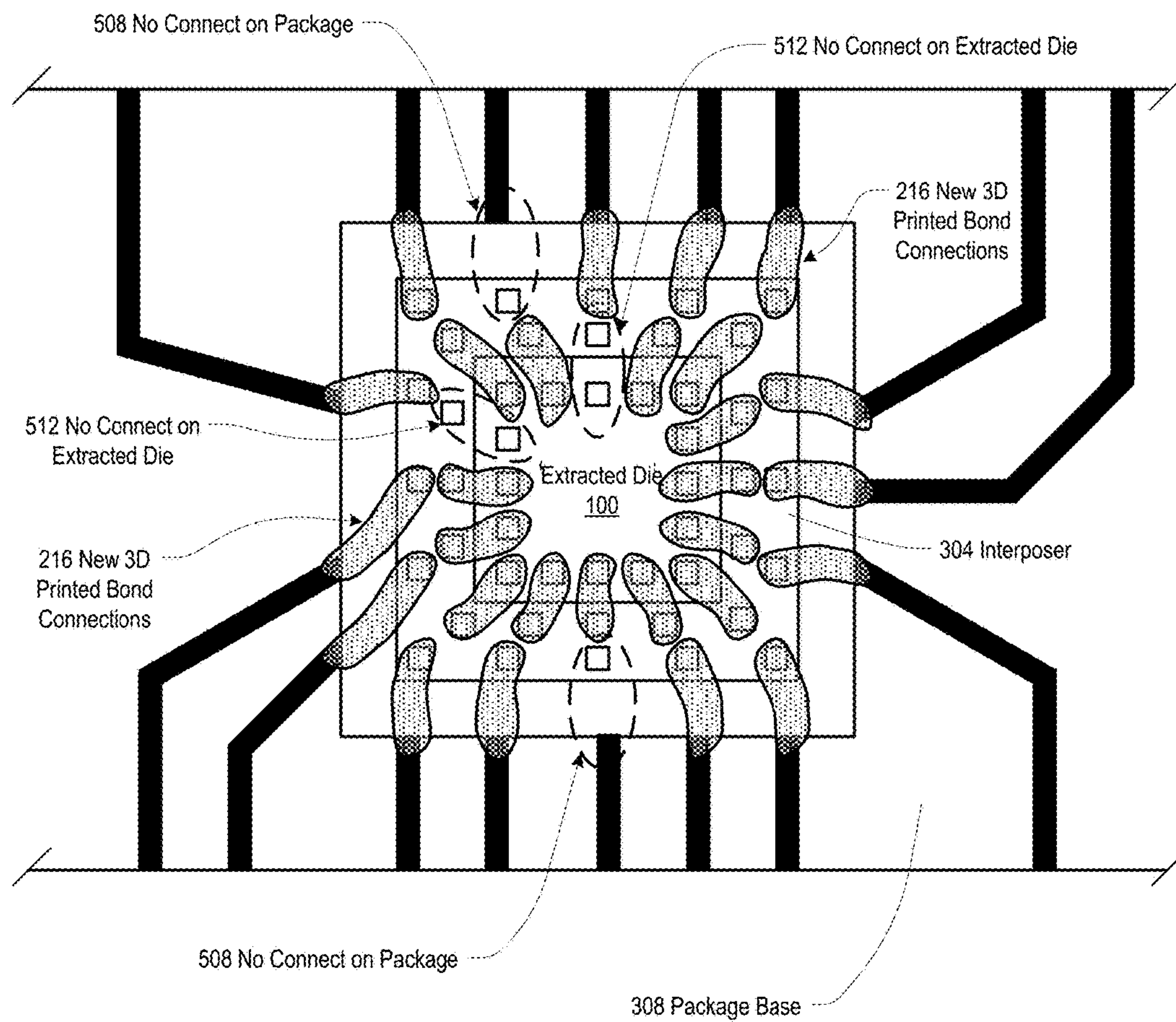


Fig. 5C Top View of New Package Base After 3D Printing Crossed Connections

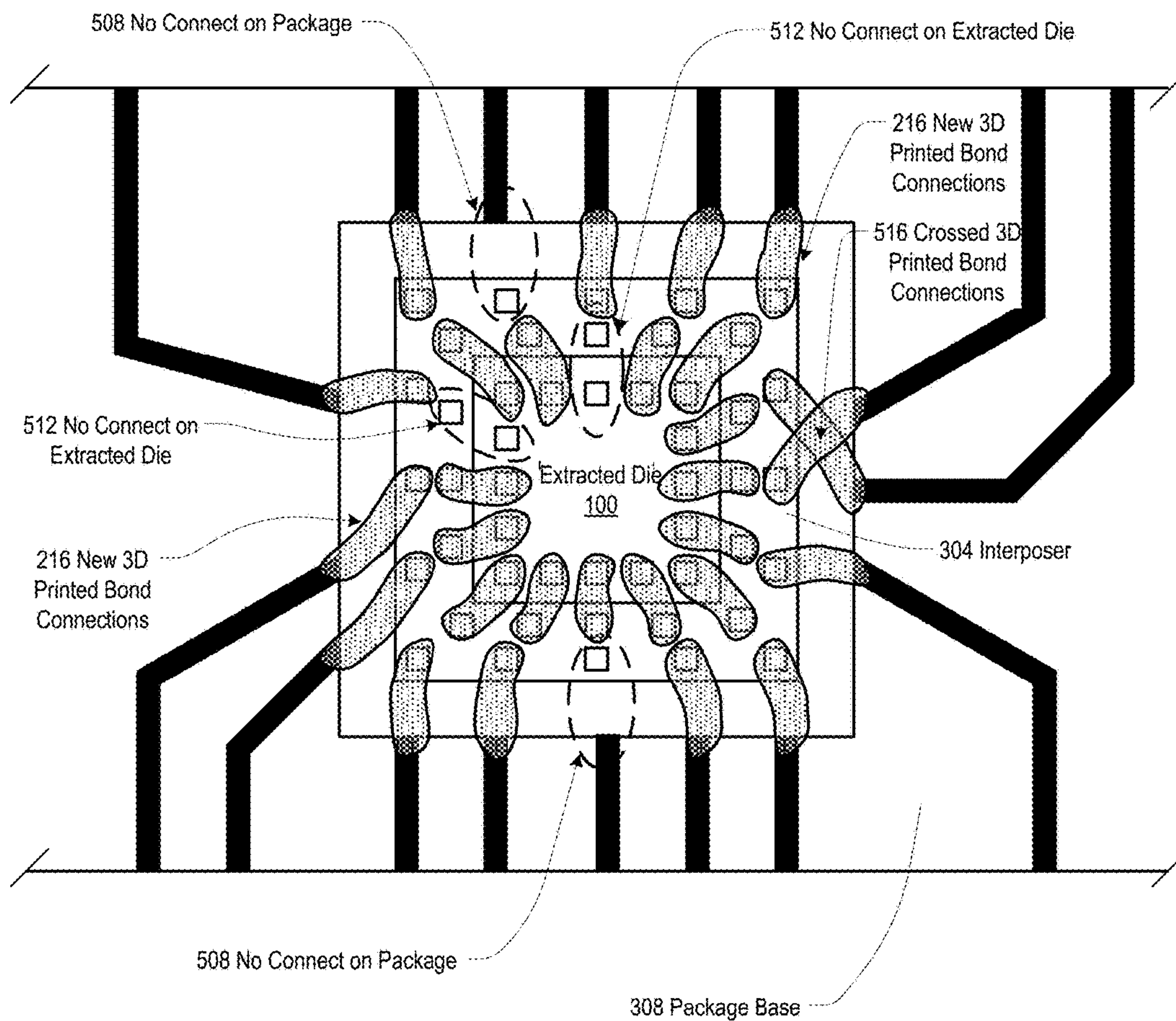


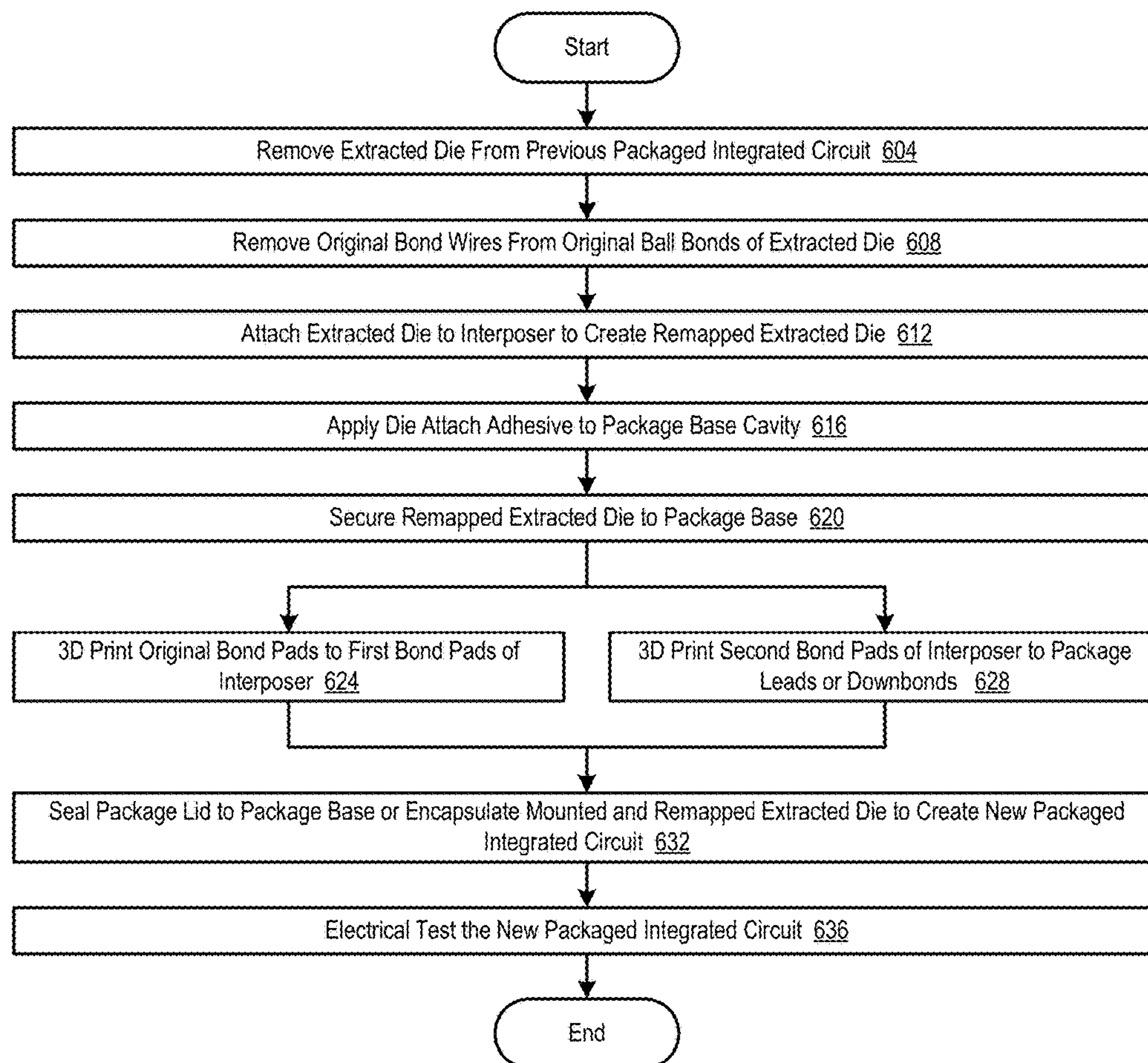
Fig. 6A Assembly Method for New Packaged Integrated Circuit

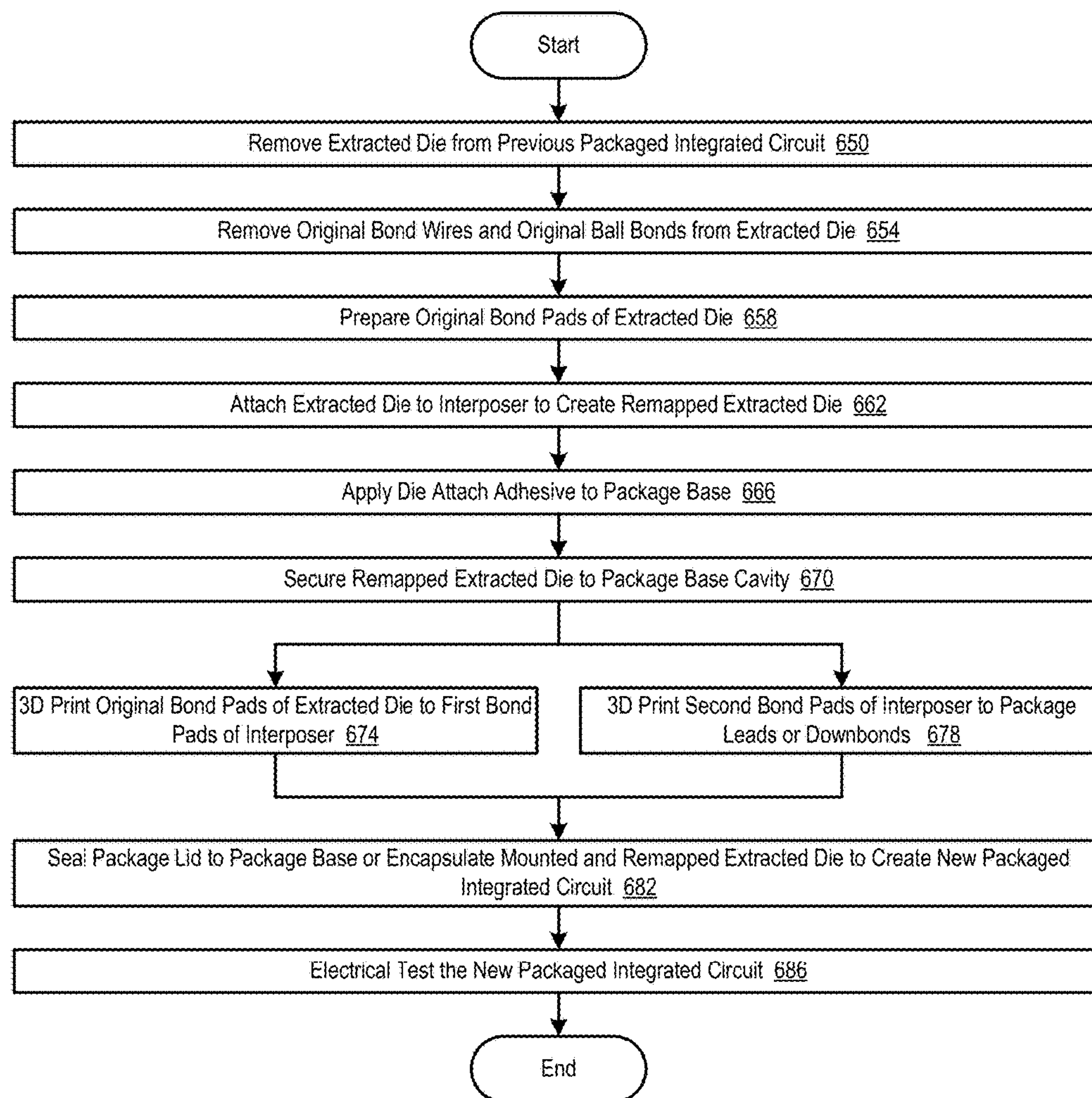
Fig. 6B Assembly Method for New Packaged Integrated Circuit

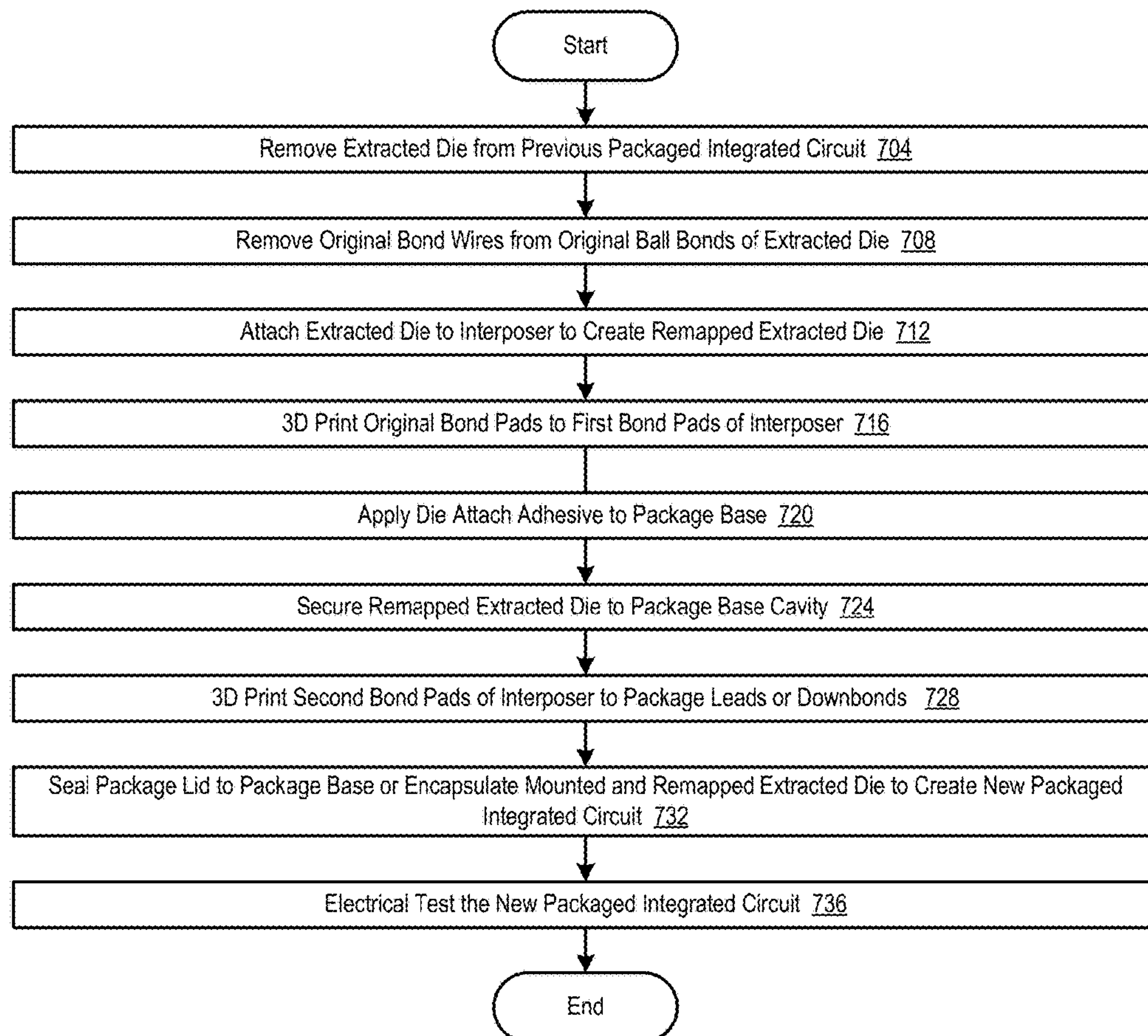
Fig. 7A Assembly Method for New Packaged Integrated Circuit

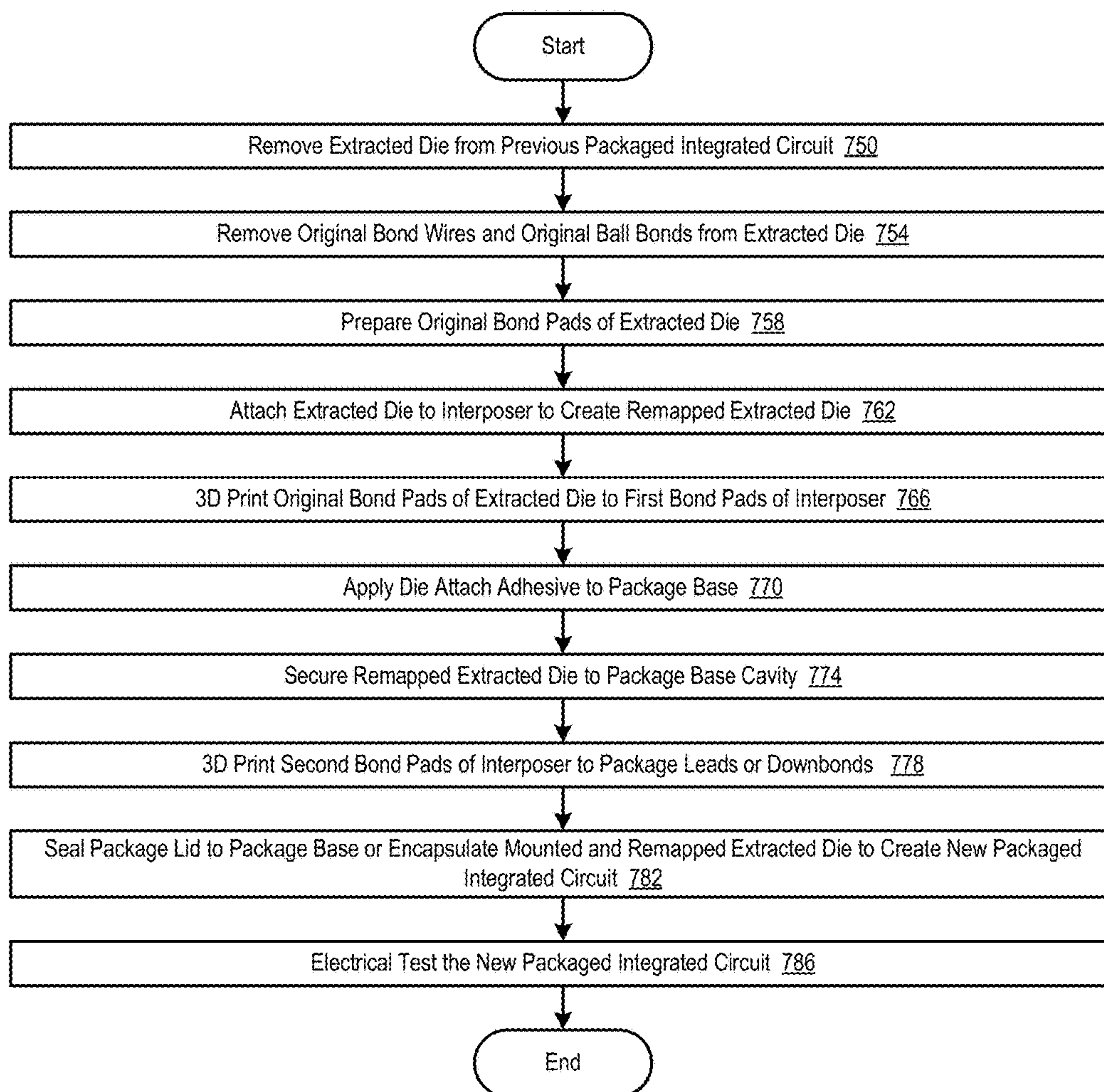
Fig. 7B Assembly Method for New Packaged Integrated Circuit

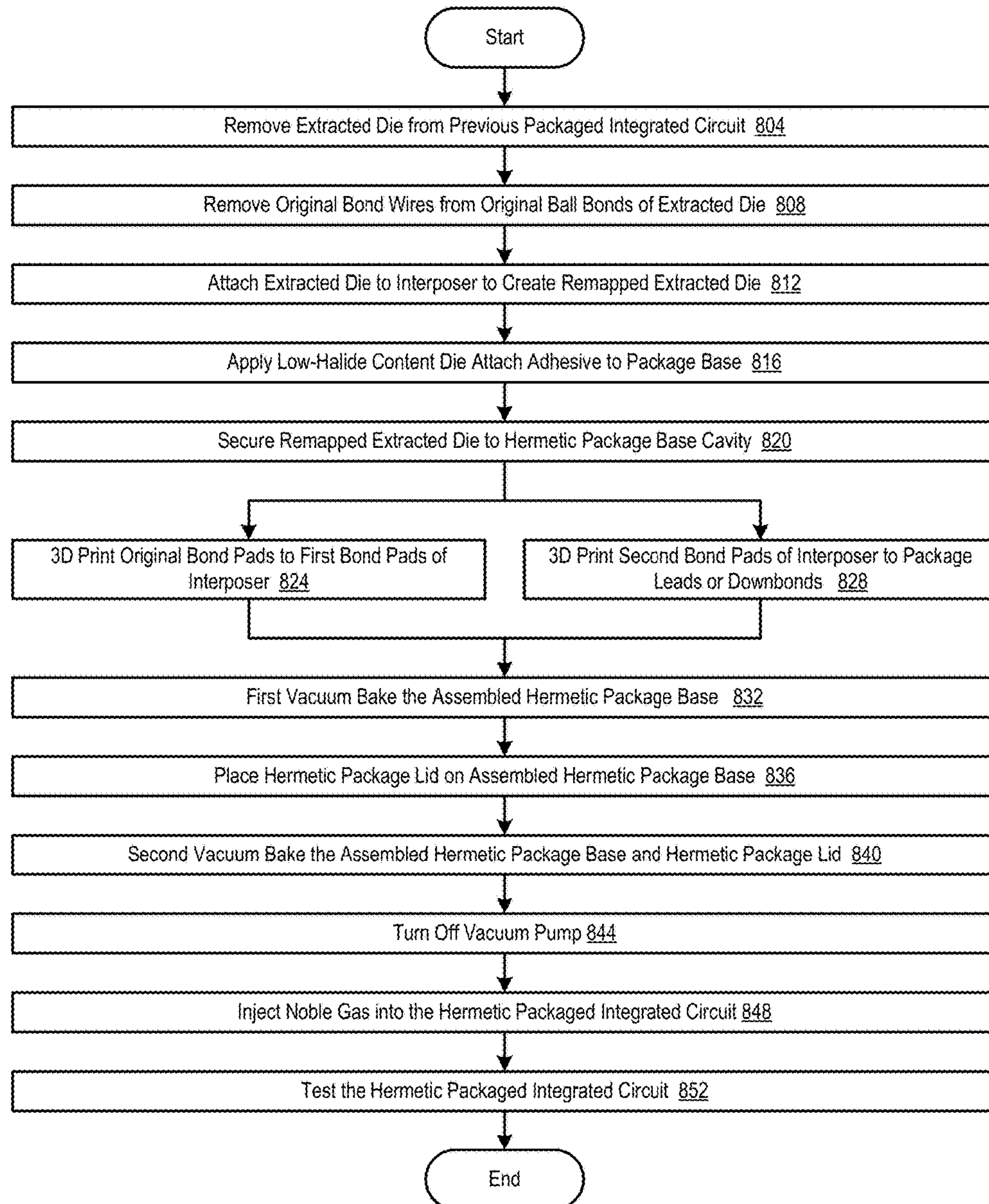
Fig. 8A Assembly Method for Hermetic Packaged Integrated Circuit

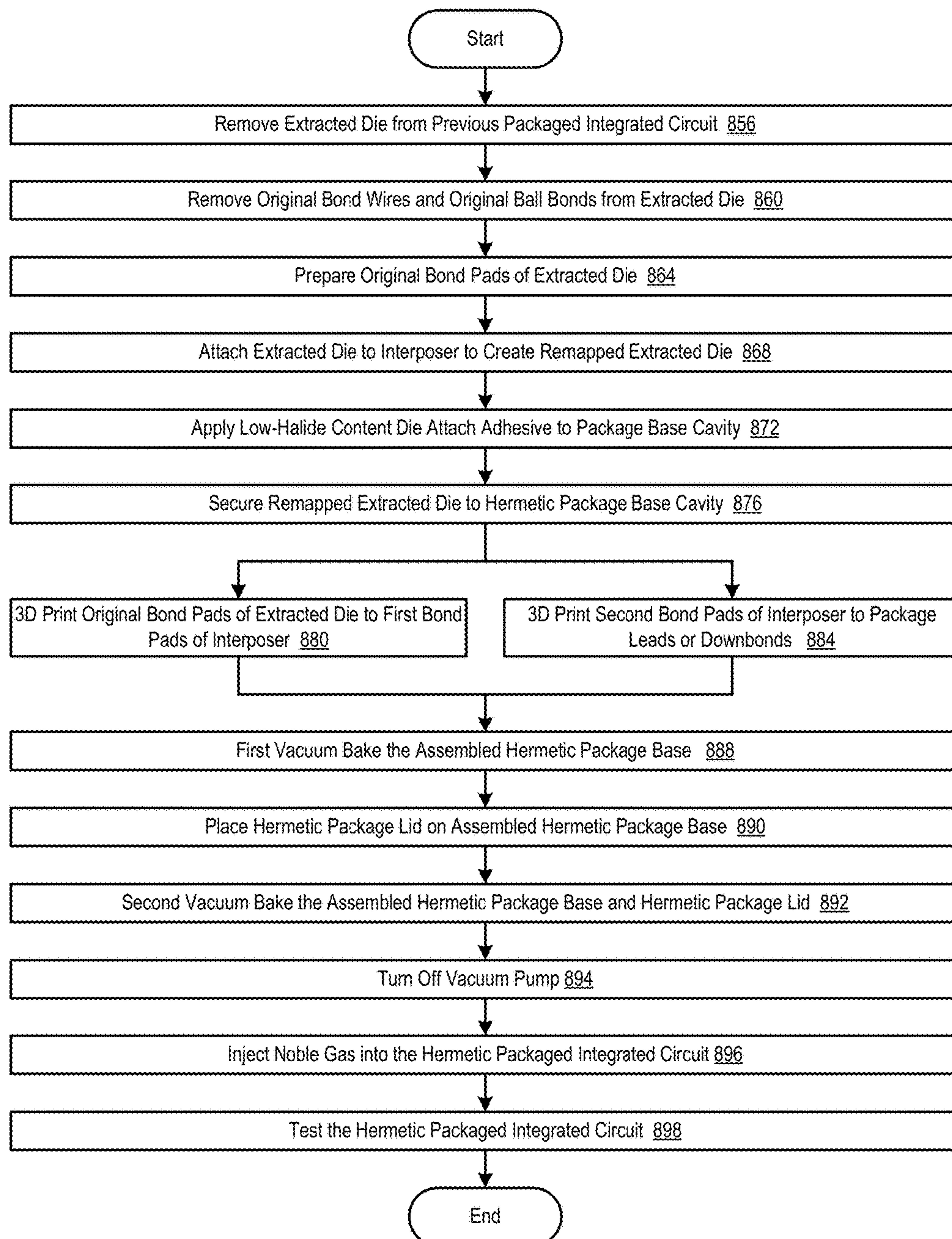
Fig. 8B Assembly Method for Hermetic Packaged Integrated Circuit

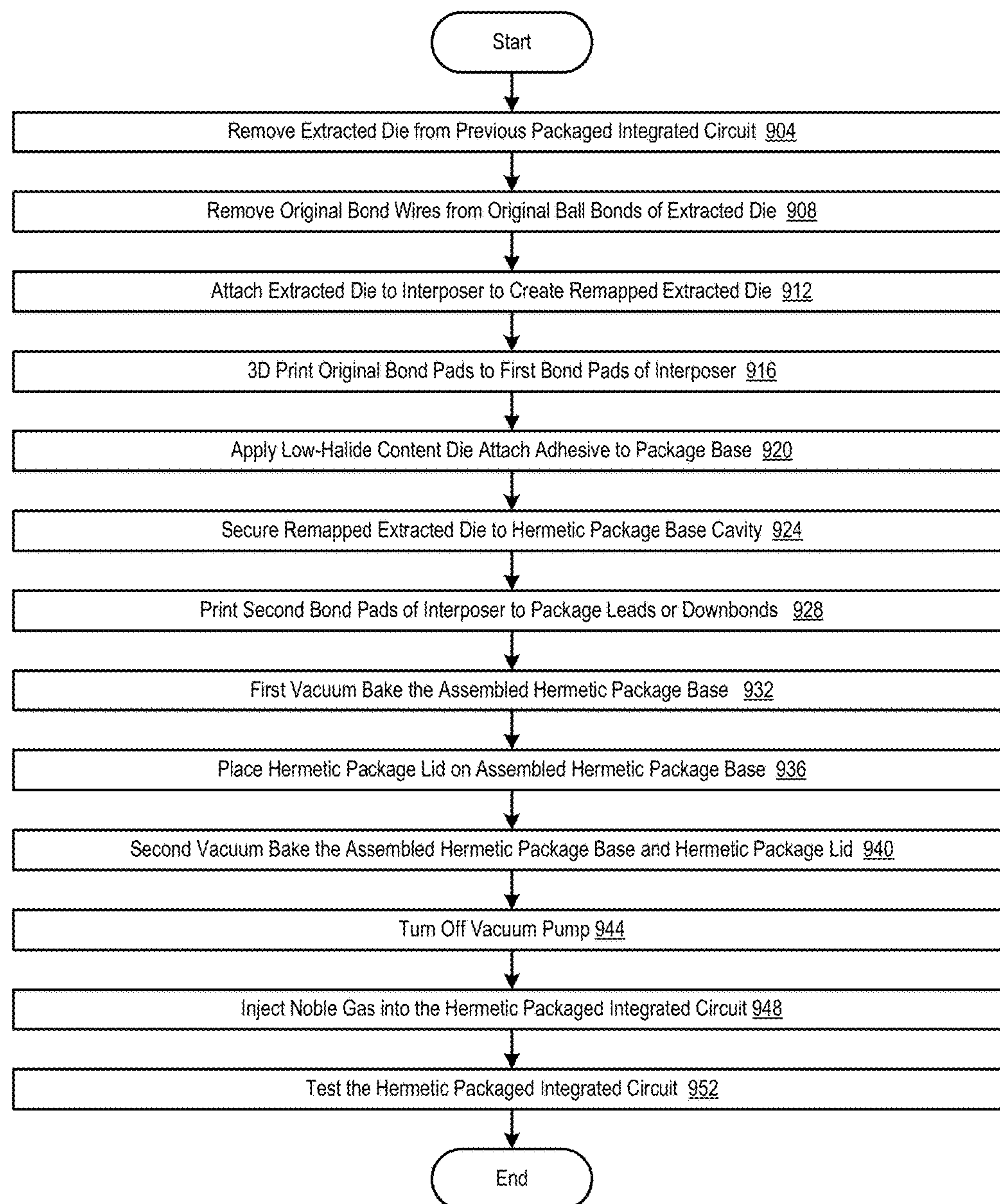
Fig. 9A Assembly Method for Hermetic Packaged Integrated Circuit

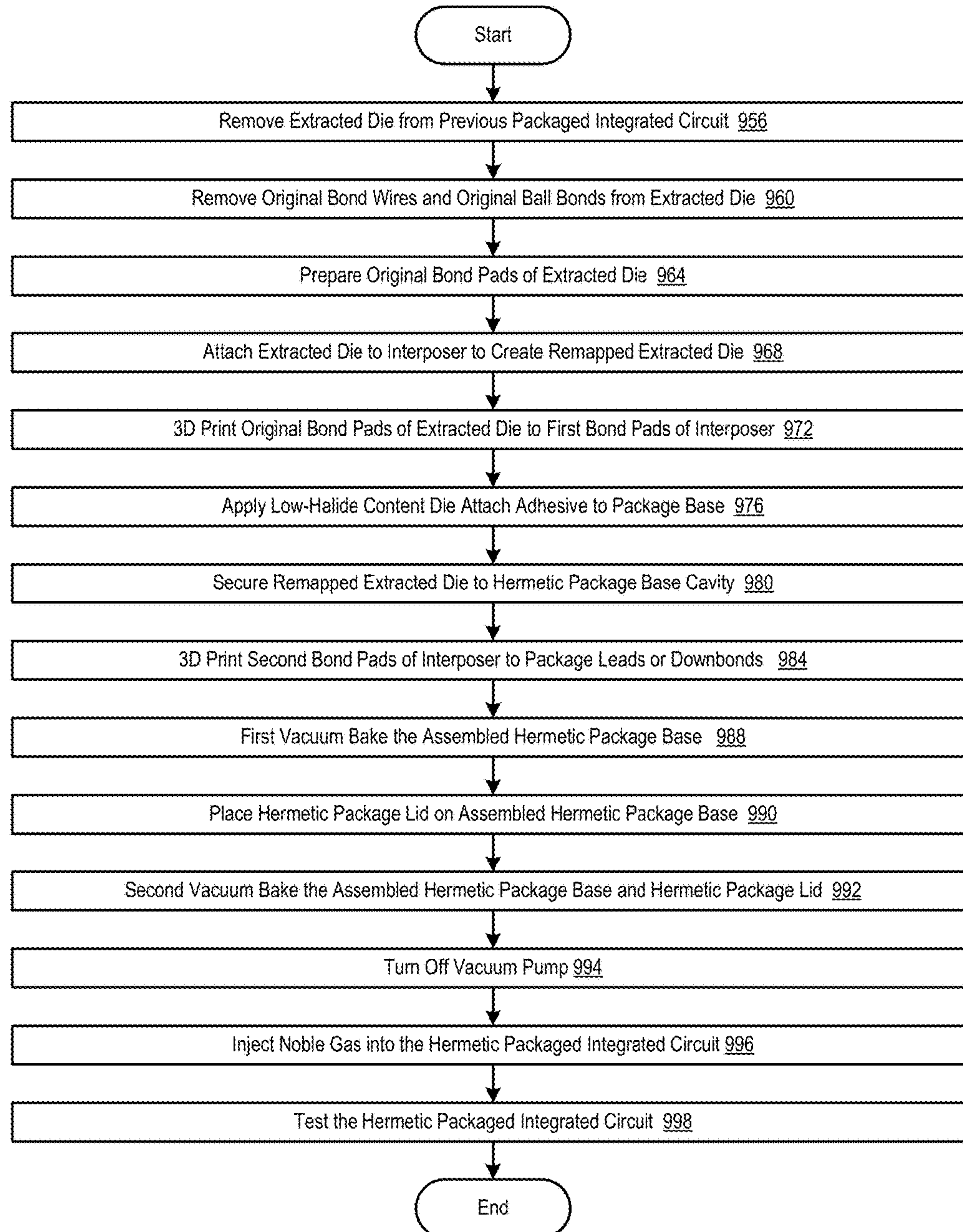
Fig. 9B Assembly Method for Hermetic Packaged Integrated Circuit

Fig. 10 Insulating and Conducting Material Spray with 3D Printer

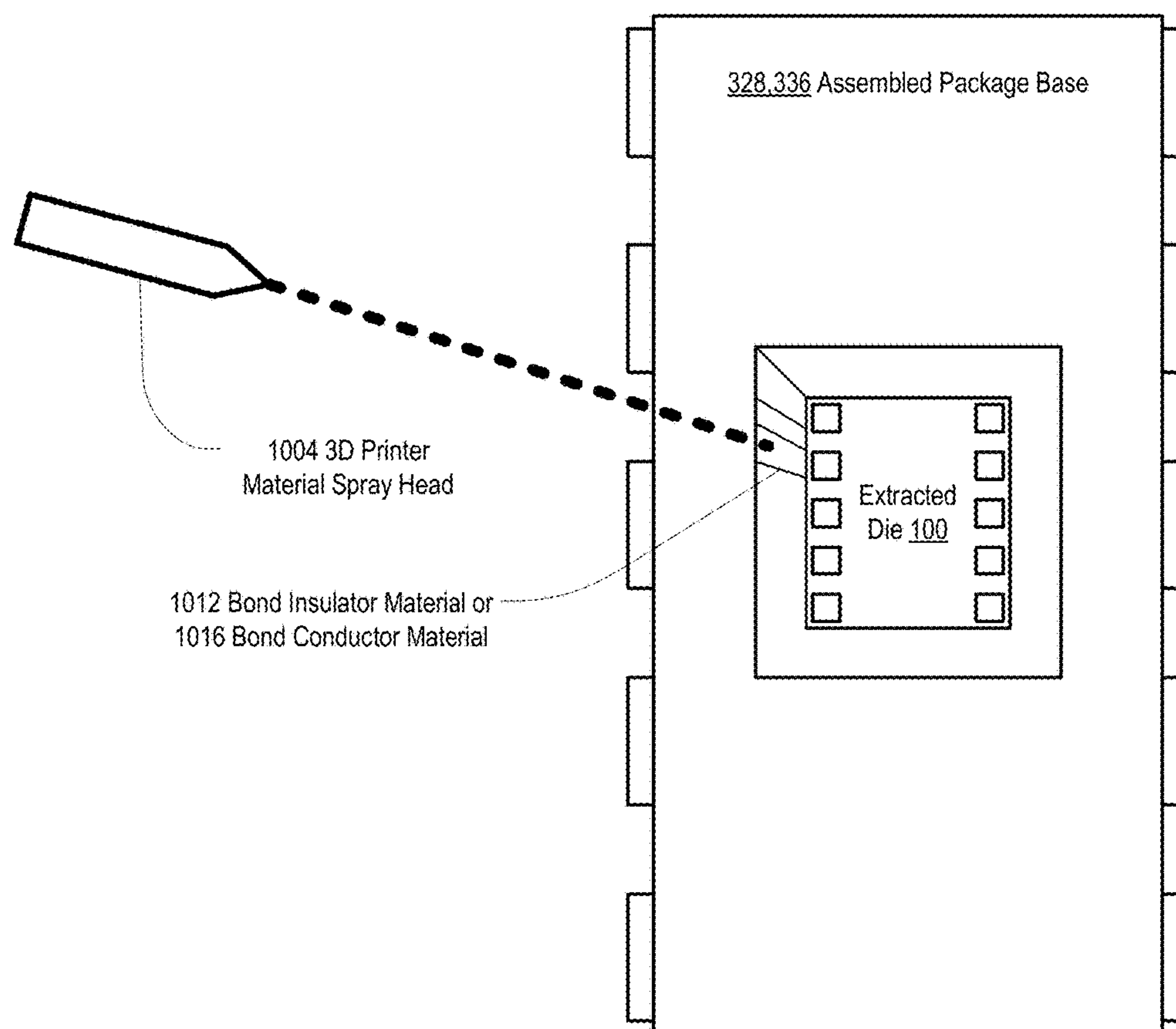
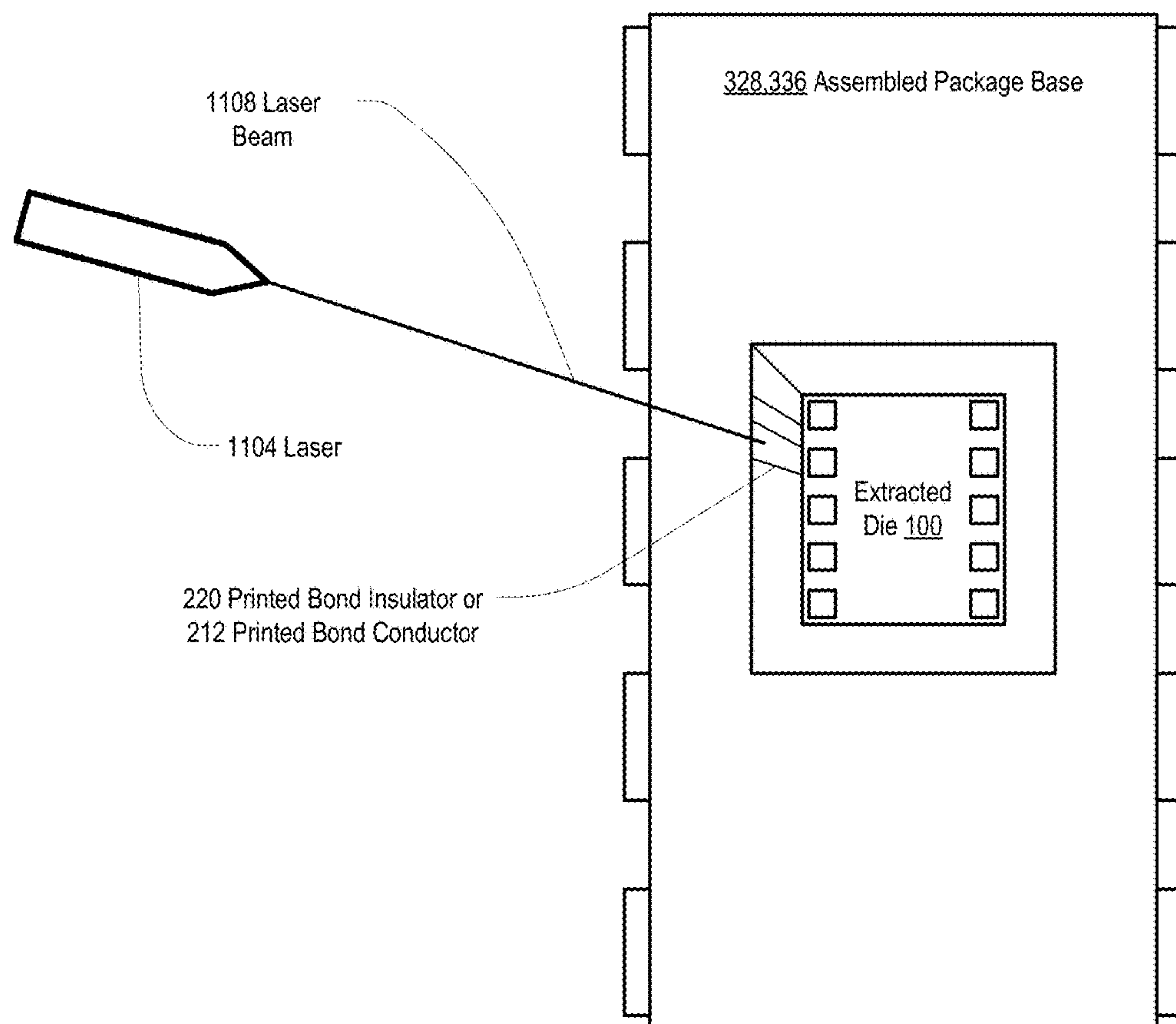


Fig. 11 Sintering Process to Form Printed Bond Insulator or Printed Bond Conductor



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METHOD FOR REMAPPING A PACKAGED EXTRACTED DIE WITH 3D PRINTED BOND CONNECTIONS

CROSS REFERENCE TO RELATED APPLICATIONS

This application is a Continuation-in-Part of pending U.S. application Ser. No. 14/142,823, filed Dec. 28, 2013, entitled METHOD AND APPARATUS FOR PRINTING INTEGRATED CIRCUIT BOND CONNECTIONS, which is hereby incorporated by reference for all purposes, which is a Continuation-in-Part of U.S. application Ser. No. 13/785,959 filed Mar. 5, 2013, entitled ENVIRONMENTAL HARDENED INTEGRATED CIRCUIT METHOD AND APPARATUS, which is a Continuation-in-Part of U.S. application Ser. No. 13/623,603 filed Sep. 20, 2012, entitled ENVIRONMENTAL HARDENING TO EXTEND OPERATING LIFETIMES OF INTEGRATED CIRCUITS AT ELEVATED TEMPERATURES, which is a Continuation of U.S. application Ser. No. 13/283,293 filed Oct. 27, 2011, entitled ENVIRONMENTAL HARDENING TO EXTEND OPERATING LIFETIMES OF INTEGRATED CIRCUITS AT ELEVATED TEMPERATURES, now abandoned.

FIELD

The present invention is directed to integrated circuit packaging. In particular, the present invention is directed to methods for utilizing extracted dice in new packaged integrated circuits.

BACKGROUND

Integrated circuits are available in many different packages, technologies, and sizes. Most integrated circuits are available in plastic packages, which are generally intended for commercial operating environments at a low cost. Commercial operating environments have a specified operating range from 0° C. to 70° C. Integrated circuits for military applications have historically been packaged in either metal or ceramic hermetic packages, which are able to work reliably in more demanding environments than commercial integrated circuits. Military operating environments have a specified operating range from -55° C. to 125° C. In order to save costs, the military has purchased integrated circuits through COTS (Commercial Off-The-Shelf) programs. However, these components are generally commercial grade components in plastic packages, and not intended for demanding environments requiring the broader temperature range reliability and durability of ceramic and metal hermetically packaged integrated circuits.

Depending on size and complexity, integrated circuits are available in a wide range of packages. Although many older integrated circuits were packaged using through-hole technology packages, surface mount packages have dominated over the past several decades. Surface mount packages generally have circuit density, cost, and other advantages over through-hole integrated circuits. Examples of through-hole packages include DIP (dual-in-line plastic) and PGA (pin grid array). Examples of surface mount packages include SOIC (small-outline integrated circuit) and PLCC (plastic leaded chip carrier).

Integrated circuit packages generally consist of a semiconductor die placed within a package base and bonded to the base with a suitable die attach adhesive. In conventional technology, the die is electrically attached to a lead frame of

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the package base with discrete bond wires, which connect individual pads of the die with package leads. In most cases, the bond wires are gold, but in other environments can be copper or aluminum. Specialized equipment is required to attach the bond wires to the die pads the lead frame. Once all of the bond wires are attached, the package lid is bonded to the package base and the integrated circuit can be tested.

SUMMARY

In accordance with embodiments of the present invention, a method is provided. The method includes one or more of removing an extracted die including an original ball bond from a previous packaged integrated circuit, bonding the extracted die to an interposer to create a remapped extracted die, 3D printing one or more first bond connections between one or more original bond pads of the extracted die and one or more first bond pads of the interposer, securing the remapped extracted die to a package base, and 3D printing one or more second bond connections between one or more second bond pads of the interposer and one or more package leads or downbonds of the package base. The one or more first and second bond connections conform to the shapes and surfaces of the extracted die, the interposer, and the package base.

In accordance with another embodiment of the present invention, a method is provided. The method includes one or more of removing an extracted die including one or more original ball bonds on one or more original bond pads from a previous packaged integrated circuit, modifying the extracted die to remove original bond wires, the one or more original ball bonds, and any oxides or residues from the original bond pads, and, reconditioning the modified extracted die. Reconditioning the modified extracted die includes adding layers of nickel, palladium, and gold over the original bond pads. The method also includes bonding the reconditioned die to an interposer to create a remapped extracted die, securing the remapped extracted die to a package base, 3D printing one or more first 3D printed bond connections between original bond pads and one or more first bond pads of the interposer, and 3D printing one or more second 3D printed bond connections between one or more second bond pads of the interposer and one or more package leads or downbonds of the package base. The one or more first and second 3D printed bond connections conform to the shapes and surfaces of the extracted die, the interposer, and the package base.

In accordance with a further embodiment of the present invention, a method is provided. The method includes one or more of removing an extracted die from a previous packaged integrated circuit, the extracted die including one or more original ball bonds on one or more original bond pads, modifying the extracted die to remove original bond wires and the one or more original ball bonds from the original bond pads, bonding the modified extracted die to an interposer to create a remapped extracted die, securing the remapped extracted die to a package base, 3D printing one or more first 3D printed bond conductors between one or more original bond pads of the modified extracted die and one or more first bond pads of the interposer, and 3D printing one or more second 3D printed bond conductors between one or more second bond pads of the interposer and one or more package leads or downbonds of the package base. The one or more first and second 3D printed bond conductors conform to the shapes and surfaces of the modified extracted die, the interposer, and the package base.

An advantage of the present invention is that it allows a packaged integrated circuit to be produced even if the die or wafers needed are out of production. Sometimes, the only way to obtain new packaged integrated circuits is to reuse extracted dice from previous packaged integrated circuits.

Another advantage of the present invention is it provides a way to repackage an extracted die for a different package and pinout than the extracted die was originally packaged for. There is no limit to the pinouts that may be thusly created, and by using different interposers, extracted dice may be utilized in many different packages and pinouts.

Yet another advantage of the present invention is it allows a generic interposer to be used for various pinouts required in various new packages. Differences in package pinout is easily accommodated by 3D printing crossed bond connections, with a 3D printed insulating layer between crossed 3D printed bond conductors. Crossed 3D printed bond conductors do not have the same reliability concerns as conventional ball bonds and bond wires.

Additional features and advantages of embodiments of the present invention will become more readily apparent from the following description, particularly when taken together with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a diagram illustrating an extracted die with original bond pads, original ball bonds, and original bond wires in accordance with embodiments of the present invention.

FIG. 2A is an illustration depicting a section A-A of an extracted die in accordance with embodiments of the present invention.

FIG. 2B is an illustration depicting a section A-A of a Modified extracted die after original ball bond and original bond wire removal in accordance with embodiments of the present invention.

FIG. 2C is an illustration depicting a section A-A of an extracted die after 3D printing only bond conductors in accordance with embodiments of the present invention.

FIG. 2D is an illustration depicting a section A-A of an extracted die after 3D printing bond insulators before 3D printing bond conductors in accordance with embodiments of the present invention.

FIG. 2E is an illustration depicting a section A-A of an extracted die after 3D printing insulators and conductors in accordance with embodiments of the present invention.

FIG. 3A is an illustration depicting a mounted remapped extracted die in accordance with embodiments of the present invention.

FIG. 3B is an illustration depicting an assembled package base with new 3D printed bond connections in accordance with embodiments of the present invention.

FIG. 3C is an illustration depicting a mounted remapped extracted die in accordance with embodiments of the present invention.

FIG. 3D is an illustration depicting an assembled package base with new 3D printed bond connections in accordance with embodiments of the present invention.

FIG. 3E is an illustration depicting an assembled package with a remapped extracted die in accordance with embodiments of the present invention.

FIG. 3F is an illustration depicting an assembled hermetic package with a remapped extracted die in accordance with embodiments of the present invention.

FIG. 4 is an illustration depicting an interposer for an extracted die in accordance with embodiments of the present invention.

FIG. 5A is an illustration depicting a top view of a new package base before 3D printing bond connections in accordance with embodiments of the present invention.

FIG. 5B is an illustration depicting a top view of a new package base after 3D printing bond connections in accordance with embodiments of the present invention.

FIG. 5C is an illustration depicting a top view of a new package base after 3D printing with some crossed connections in accordance with embodiments of the present invention.

FIG. 6A is a flowchart illustrating an assembly method for a new packaged integrated circuit in accordance with a first embodiment of the present invention.

FIG. 6B is a flowchart illustrating an assembly method for a packaged integrated circuit in accordance with a second embodiment of the present invention.

FIG. 7A is a flowchart illustrating an assembly method for a new packaged integrated circuit in accordance with a third embodiment of the present invention.

FIG. 7B is a flowchart illustrating an assembly method for a packaged integrated circuit in accordance with a fourth embodiment of the present invention.

FIG. 8A is a flowchart illustrating an assembly method for a hermetic packaged integrated circuit in accordance with a first hermetic embodiment of the present invention.

FIG. 8B is a flowchart illustrating an assembly method for a hermetic packaged integrated circuit in accordance with a second hermetic embodiment of the present invention.

FIG. 9A is a flowchart illustrating an assembly method for a hermetic packaged integrated circuit in accordance with a third hermetic embodiment of the present invention.

FIG. 9B is a flowchart illustrating an assembly method for a hermetic packaged integrated circuit in accordance with a fourth hermetic embodiment of the present invention.

FIG. 10 is an illustration depicting insulating and conducting material spray with a 3D printer in accordance with the present invention.

FIG. 11 is an illustration depicting a sintering process to form a 3D printed bond insulator **220** or a 3D printed bond conductor **212** in accordance with embodiments of the present invention.

DETAILED DESCRIPTION

Integrated circuits are most commonly packaged in plastic packages using dice with Aluminum (Al) bond pads and Gold (Au) bond wires from the bond pads to the package leads and package cavity. Bond wires are attached to bond pads and package leads using thermosonic bonding, wedge bonding, or other processes well understood in the art.

In some cases, bare dice and wafers are generally not available. It is therefore highly desirable to obtain dice from previously packaged integrated circuits. Integrated circuit dice are then extracted from an existing package—usually plastic—and repackaged into a suitable package according to the component needs of the market. These extracted dice retain the original Au ball bonds on the Al bond pads. In some cases, extracted dice are repackaged into commercial plastic packages. In other cases, often military or environmentally hardened applications, extracted dice are repackaged into hermetic ceramic or metal packages.

The present invention is directed to integrated circuits and methods for removing extracted dice from a previous pack-

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age and repackaging into a different package, often with a different pinout from the previous package.

Referring now to FIG. 1, an extracted die 100 with original bond pads 104, 108, original ball bonds 112, and original bond wires 116 in accordance with embodiments of the present invention is shown. Each previously used original bond pad 104 of the extracted die 100 may have an original ball bond 112 present, although one or more unbonded bond pads 108 may not have an original ball bond 112 present. In some cases, this is due to a no-connect in the previous package. When the extracted die 100 was present in whatever previous integrated circuit package was used for the extracted die 100, original bond wires 116 connected each of the original ball bonds 112 to a lead or a downbond of the previous integrated circuit package.

FIG. 1 illustrates the extracted die 100, after it has been removed from the previous integrated circuit package. Therefore, some original bond wires 116 have been removed and some original bond wires 116 remain. In current technology packaged integrated circuits, the vast majority of bond wire interconnections are made with Au thermosonic ball bonding. Section A-A is used in FIGS. 2A-2E to illustrate a side view of extracted die 100.

Referring now to FIG. 2A, an illustration depicting a section A-A of an extracted die 100 in accordance with embodiments of the present invention is shown. extracted die 100 includes a die substrate 204 supporting a passivation layer 208 and original bond pads 104, 108. Extracted die 100 includes one or more original bond pads 104, which include an original ball bond 112. Extracted die 100 may also include one or more original bond pads 108, which do not include an original ball bond 112. It is likely that original bond pads 108 were a no connect bond pad in the previous integrated circuit package.

Referring now to FIG. 2B, a diagram illustrating a section A-A of a modified extracted 224 die after original ball bond 112 and original bond wire 116 removal in accordance with embodiments of the present invention is shown. A modified extracted die 224 is an extracted die 100 with the original ball bonds 108 and original bond wires 116 removed. Although in some embodiments original gold ball bonds 112 may be removed by mechanical means, in most cases it is preferable to use chemical removal means by known processes. FIG. 2B illustrates the original ball bond 112 and original bond wire 116 removed from the original bond pad 104. Not shown in FIG. 2B is that after removing the original ball bond 112 and original bond wire 116, some amount of intermetallic residue and/or oxides will be present on the original bond pads 104. This generally requires removal to make sure there are no impurities, residues, or oxides on the original bond pads 104, 108. Removal is preferably performed using a mild acid wash. The acid wash is followed by an acid rinse that removes surface oxides present on the original bond pads 104, 108. For plating on an Aluminum surface, a Zincate process is used to etch away a very fine layer of Aluminum from the original bond pads 104, 108 and redeposit a layer of Zinc (Zn) on the original bond pads 104, 108. The fine layer of Zinc will then act as a catalyst for the Nickel plating to follow. Once residues and oxides have been removed from the original bond pads 104, 108, in some embodiments the surface of the original bond pads 104, 108 is rendered to an increased degree of flatness by applying a lapping process. This has the added benefit of providing a uniformly smooth and consistent bond pad 104, 108 surface in preparation for following reconditioning/metallization (ENEPIG, for example) or ball bonding operations.

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Once in a clean and flat state, the original bond pads 104, 108 are considered bare original bond pads 104, 108 and are ready to be reconditioned. Reconditioning of the present invention is a process whereby the original bond pads 104, 108 are cleaned as described above and built up by successive and ordered application of specific metallic layers prior to new wire bonding or 3D printing processes. Following the ordered application of specific metallic layers (Nickel, followed by Palladium, followed by Gold, for example), the die is a reconditioned die.

In one embodiment, after an extracted die 100 is removed from a packaged integrated circuit, only original bond wires 116 are removed—thus leaving original ball bonds 112 on less than all original bond pads 104 of the extracted die 100. Original ball bonds 112 must be removed prior to reconditioning original bond pads 104. Therefore, in some embodiments the metallic layers of the present invention are provided not to empty original bond pads 108, but rather original bond pads 104 following original ball bond 112 removal, or to any original bond pad 104, 108 intended to receive a 3D printed bond connection 216.

Referring now to FIG. 2C, an illustration depicting a section A-A of an extracted die 100 after 3D printing a bond conductor 212 only in accordance with embodiments of the present invention is shown. 3D printed bond conductors 212 provide similar electrical conduction properties as conventional bond wires, and are able to adhere to exposed surfaces of the extracted die 100, any other substrates, and interior surfaces of integrated circuit packages. In some embodiments, 3D printed bond connections 216 include only 3D printed bond conductors 212.

For embodiments where there is no electrical shorting concern with surfaces of the extracted die 100 and other substrates, the 3D printed bond conductor 212 may be 3D printed directly to those surfaces. Bond conductors 212 are 3D printed in successive layers to build up a preferred thickness of material to resist cracking and still allow electrical conduction even if moderately scratched. Printed bond conductor 212 thickness can be less than 2 microns and is preferably 0.5-1 microns. Printed bond conductors 212 substantially cover original bond pads 108, and both original ball bonds 112 and original bond pads 104 where a reconditioning process has not been used.

Referring now to FIG. 2D, an illustration depicting a section A-A of an extracted die 100 after 3D printing bond insulators 220 prior to 3D printing bond conductors 212 in accordance with embodiments of the present invention is shown. For embodiments where there is an electrical shorting concern with surfaces of the extracted die 100 and other substrates, the bond insulator 220 may be 3D printed directly to those surfaces. Bond insulators 220 are 3D printed in successive layers to build up a preferred thickness of material to resist cracking and still allow electrical conduction even if moderately scratched. Printed bond insulator 220 thickness can be less than 2 microns and is preferably 0.5-1 microns. Bond insulators 220 substantially cover electrically conductive areas of the extracted die 100, substrates, and package base where a 3D printed bond conductors 212 will later be applied. It is therefore important to apply 3D printed bond insulators 220 in such a way that edges of 3D printed bond conductors 212 have no possibility of making contact with undesired conductive surfaces. This may be avoided by spraying 3D bond insulators 220 with a greater width than 3D printed bond conductors 212 to provide an insulating margin at the edge of each 3D printed bond insulator/bond conductor 220, 212.

Referring now to FIG. 2E, an illustration depicting a section A-A of an extracted die **100** after 3D printing bond conductors **212** and bond insulators **220** in accordance with embodiments of the present invention is shown. 3D printed bond insulators **220** cover at least conductive portions of the extracted die **100**, substrates including Interposers **304**, and interior surfaces of the package. 3D bond conductors **212** are 3D printed over the bond insulators **220**, and provide the same electrical interconnection function as original bond wires **116**. In this embodiment, the 3D printed bond connections **216** include the 3D printed bond conductors **212** and 3D printed bond insulators **220**.

Referring now to FIG. 3A, an illustration depicting a mounted remapped extracted die **300** in accordance with embodiments of the present invention is shown. The mounted remapped extracted die **300** is an intermediate assembly step for a new assembled integrated circuit. The assembled package base includes a package base **308** or new package base **308**. In one embodiment, the package base **308** is a non-hermetic package base **308**. In another embodiment, the package base **308** is a hermetic package base **308**. In non-hermetic applications, package base **308** is generally plastic. If the package base **308** is a hermetic package base **308**, it may be formed from ceramic, metal, or glass materials.

After preparing or reconditioning any original bond pads **104**, **108** of the extracted die **100**, the extracted die **100** is bonded to an interposer **304** with a die attach adhesive **312** or other suitable adhesive compound. The extracted die **100**, modified extracted die **224**, or reconditioned die bonded to the interposer **304** is referred to herein as a remapped extracted die **324**. In one embodiment, the original bond pads **104**, **108** are prepared by removing original bond wires **116** and leaving original ball bonds **112** on the original bond pads **104**. In other embodiments, the original bond pads **104**, **108** are prepared by removing original ball bonds **112** and original bond wires **116**, and removing any traces of original ball bonds **112**, chemical residues, and other deposits from the original bond pads **104** (modified extracted die **224**). In some embodiments, the original bond pads **104**, **108** are lapped, buffed, or polished before adding 3D printed bond insulators **220** or 3D printed bond conductors **212**. In some embodiments, Nickel Palladium, and Gold layers are added to the original bond pads **104**, **108** as detailed in related application Ser. No. 15/088,822 following ball bond/bond wire removal, oxide/residue removal, and/or lapping, buffing, or polishing before adding 3D printed bond insulators **220** or 3D printed bond conductors **212** (reconditioned die).

The package base **308** includes a cavity **316** into which the remapped extracted die **324** is placed. Die attach adhesive **312** is applied to the package base **308** such that when the extracted die **100** is inserted into the cavity **316**, the die attach adhesive **312** makes simultaneous contact with both the package base **308** and the extracted die **100**. In embodiments where the package base **308** is a component of a hermetic package, die attach adhesive **312** is a low-halide compound die attach adhesive, where a low halide compound has less than 10 parts per million (ppm) halides. Die attach adhesive **312** therefore bonds the extracted die **100** to the package base **308**, and protects the integrity of the interior of the mounted remapped extracted die **300**. It has been well established that halogens in an Au—Al bond interface degrade Au—Al bond strength since out-gassed products from adhesives containing halogens rapidly corrode Al metallization in integrated circuits at high temperatures, thus reducing product lifetime at high temperatures.

Associated with the package base **308** are a series of package leads **320**, which provide interconnection between circuitry of the extracted die **100** and circuitry of a printed circuit board on which the packaged integrated circuit is eventually mounted. For example, if an S0-24 ceramic package is used for the packaged integrated circuit, 24 package leads **320** would be present, configured as 12 package leads **320** on each of two opposite sides of the package base **308**. If a PLCC-68 ceramic package is used for the integrated circuit, 68 package leads **320** would be present, configured as 17 package leads **320** on each of the four sides of the package base **308**. The present invention may be used for any type of previous integrated circuit package or any type of new hermetic or non-hermetic integrated circuit package.

After mounting the remapped extracted die **324** into the package base **308** using die attach adhesive **312**, 3D printed bond connections **216** may then be attached as described herein. Alternatively, 3D printed bond connections **216** may be provided between the extracted die **100** and the interposer **304** on the remapped extracted die **324** prior to securing the remapped extracted die **324** to the package base **308** with die attach adhesive **312**.

Referring now to FIG. 3B, an illustration depicting an assembled package base **328** with new 3D printed bond connections **216** in accordance with embodiments of the present invention is shown. After the remapped extracted die **324** is secured to the package base **308** using a die attach adhesive **312**, 3D printed bond connections **216** are applied between bond pads of the Interposer **304** and Package leads **320** or downbonds. 3D printed bond connections **216** between original bond pads **104**, **108** of the extracted die **100** and first bond pads **404** of the interposer were applied prior to the step shown in FIG. 3B, when the remapped extracted die **324** was not secured to the package base **308**. Thus, FIG. 3B reflects an assembly process where the previous step is as shown in FIG. 3A.

In a first embodiment, 3D printed bond insulators **220** are provided over at least electrically conductive areas of the interposer **304** and the package base **308**. After the 3D printed bond insulators **220** have been applied, in a secondary operation 3D printed bond conductors **212** are provided over the 3D printed bond insulators **220** and/or non-electrically conductive portions of the interposer **304** and the package base **308**. In a second embodiment, only 3D printed bond conductors **212** are provided over non-electrically conductive portions of the interposer **304** and the package base **308**.

Referring now to FIG. 3C, an illustration depicting a mounted remapped extracted die **332** in accordance with embodiments of the present invention is shown. The mounted remapped extracted die **332** is an intermediate assembly step for a new assembled integrated circuit, and serves as an assembled package base. The assembled package base includes a package base **308** or new package base **308**. In one embodiment, the package base **308** is a non-hermetic package base **308**. In another embodiment, the package base **308** is a hermetic package base **308**. In non-hermetic applications, package base **308** is generally plastic. If the package base **308** is a hermetic package base **308**, it may be formed from ceramic, metal, or glass materials.

The mounted remapped extracted die **332** is similar to the mounted remapped extracted die **300** of FIG. 3A, but lacks 3D printed bond connections **216** between the extracted die **100** and the interposer **304**. This means that all 3D printing of bond connections **216** is performed at the stage of the

assembled package base, rather than 3D printed bond connections **216** of the remapped extracted die **324** applied prior to securing the remapped extracted die **324** to the package base **308**. One advantage of this is that only a single fixture is required to position the package base **308** for 3D printing operations, rather than one fixture of the remapped extracted die **324** and a separate fixture for the package base **308**.

Referring now to FIG. 3D, an illustration depicting an assembled package base **328** with new 3D printed bond connections **216** in accordance with embodiments of the present invention is shown. The assembled package base shown in FIG. 3D has the same components as the assembled package base shown in FIG. 3B. However, in FIG. 3D all 3D printed bond connections **216** are applied, rather than only the 3D printed bond connections **216** between the interposer **304** and the package leads **320** or downbonds. Thus, FIG. 3D reflects an assembly process where the previous step is as shown in FIG. 3C.

In a first embodiment, 3D printed bond insulators **220** are provided over at least electrically conductive areas of the extracted die **100**, interposer **304**, and the package base **308**. After the 3D printed bond insulators **220** have been applied, in a secondary operation 3D printed bond conductors **212** are provided over the 3D printed bond insulators **220** and/or non-electrically conductive portions of the extracted die **100**, interposer **304**, and the package base **308**. In a second embodiment, only 3D printed bond conductors **212** are provided over non-electrically conductive portions of the extracted die **100**, interposer **304**, and the package base **308**.

Referring now to FIG. 3E, an illustration depicting an assembled package **340** with a remapped extracted die **324** in accordance with embodiments of the present invention is shown. Packaged integrated circuit **340** is assembled package base **328** or **336** with a package lid **344** or new package lid **344** attached. Where the package base **308** and package lid **344** are non-plastic materials, lid seal adhesive **348** is generally required. In non-hermetic applications, package lid **344** is generally plastic and is molded to a plastic package base **308** with an encapsulation process. In such cases, a lid seal adhesive **348** may not be required. Thus, FIG. 3E reflects an assembly process where the previous step is as shown in either FIG. 3B or 3D.

Referring now to FIG. 3F, an illustration depicting an assembled hermetic package **352** with a remapped extracted die **324** in accordance with embodiments of the present invention is shown. Assembled hermetic package **352** includes an assembled hermetic package base **328**, **336** of FIGS. 3B and 3D and additional components described below.

For a hermetic integrated circuit package **352** including a hermetic package base **308**, once all new 3D printed bond connections **216** are applied between package leads **320** and downbonds and the remapped extracted die **324**, the assembled package base **328**, **336** including remapped extracted die **324**, die attach adhesive **312**, package base **308**, package leads **320**, and new 3D printed bond connections **216**, is first and second vacuum baked according to the processes of parent application Ser. No. 13/623,603.

In addition to a low-halide die attach adhesive **312**, the assembled hermetic package **352** may also optionally include moisture getter **356** and/or a Noble gas **360** within the cavity **316** at the time the hermetic package lid **344** is secured to the hermetic package base **308** using a lid seal adhesive **348**.

Referring now to FIG. 4, an illustration depicting an interposer **304** for an extracted die **100** in accordance with embodiments of the present invention is shown. Interposer

304 includes a substrate **416** that the extracted die **100** is mounted on one side of, and translates original bond pad **104**, **108** locations into bond pad locations that match a desired pinout/pin assignments of packaged integrated circuits **340**, **352**. Interposer **304** is a substrate or other material such as FR-4, Capton, Teflon, or Polyamide suitable for mounting within a package base **308** and carrying electrical signals to and from the extracted die **100** and package leads **320** or downbonds.

Interposer **304** includes a location **412** for mounting the extracted die **100** on a specified side of interposer **304**. Extracted die **100** may be secured to interposer **304** with die attach adhesive **312**, an epoxy, or other chemical and/or mechanical means known in the art. In most embodiments, extracted die **100** is mounted centrally on the interposer **304** in order to facilitate 3D printing the bond connections **216**. However, in some embodiments the extracted die **100** may not be centrally mounted on interposer **304** for various reasons.

Interposer **304** includes first bond pads **404** generally oriented around the periphery of the extracted die Location **412**. The first bond pads **404** provide new 3D printed bond conductor **212** attachment points between original bond pads **104**, **108** of the extracted die **100** and the interposer **304**.

In general, each of the first bond pads **404** is electrically connected to a second bond pad **408** through rerouting circuitry within the interposer **304**. However, it is not a requirement that every such pad **404**, **408** be thusly connected. The second bond pads **408** are generally oriented around the periphery of the interposer **304**. The second bond pads **408** provide new 3D printed bond conductor **212** attachment points between the interposer **304** and package leads **320** and downbonds of the new integrated circuit package base **308**.

In most applications, the interposer **304** is designed so that the second bond pads **408** are as close as possible to the package lead **320** that each second bond pad **408** becomes bonded to. This may require routing connections between some first bond pads **404** and second bond pads **408** across most of the interposer **304**. To some extent the routing length of such connections may be mitigated by orienting the extracted die location **412** clockwise or counterclockwise on the interposer **304**, and this must be independently evaluated for each extracted die **100** and interposer **304** combination.

It is important to match the interposer pad **404**, **408** geometry and spacing to the printing capabilities of the 3D printing apparatus being used to apply the 3D printed bond connections **216**. The manufacturer of such devices specifies printing tolerances and variation based on many factors, including environmental conditions and following a prescribed maintenance schedule.

Referring now to FIG. 5A, an illustration depicting a top view of a new package base **308** before 3D printing bond connections **216** in accordance with embodiments of the present invention is shown. The remapped extracted die **324** is securely mounted in the cavity **316** of the new package base **308** with die attach adhesive **312**. The new package base **308** has a plurality of package base bond pads **504**, which provide a conduction path to the package leads **320** on the exterior of the new package base **308**. One package lead **320** is provided on the exterior of the new package base **308** for every package base bond pad **504**. FIG. 5A reflects the same level of assembly as shown in FIG. 3C.

Referring now to FIG. 5B, an illustration depicting a top view of a new package base **308** after 3D printing bond connections **216** in accordance with embodiments of the present invention is shown. FIG. 5B illustrates the same

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point in the assembly process as also shown in FIGS. 3B and 3D. The new package base **308** is fully assembled, and is ready for a package lid **344** to be added or else encapsulation as a molded packaged integrated circuit **340**.

As shown in FIG. 5B, the new package base **308** has new 3D printed bond connections **216** added. New 3D printed bond connections **216** connect original bond pads **104**, **108** of the extracted die **100** to the first bond pads **404** (usually but not necessarily, closest to the extracted die **100**) of the interposer **304**. Other new 3D printed bond connections **216** connect the second bond pads **408** (usually but not necessarily, closest to the edge of the interposer **304**) of the interposer **304** to package base bond pads **504**.

It is possible that some original bond pads **104**, **108** of the extracted die **100** and package base bond pads **504** will be no connects **508**, **512**. No connects **508**, **512** will not have a new 3D printed bond connection **216** attached. In FIG. 5B, there are two no connects **512** on the original bond pads **104**, **108** of the extracted die **100**, and two no connects **508** on the package base bond pads **504**. However, there may practically be any number of no connects **508**, **512**, even zero.

Since 3D printed bond connections **216** include 3D printed bond conductors **212** and possibly 3D printed bond insulators **220**, it should be understood that 3D printed bond insulators **220** may possibly be present or not present in every such 3D printed bond connections **216** shown. Additionally, 3D printed bond insulators **220** may only be present for a portion of the length of a given 3D printed bond connection **216**.

Referring now to FIG. 5C, an illustration depicting a top view of a new package base **308** after 3D printing some crossed bond connections **516** in accordance with embodiments of the present invention is shown. FIG. 5C is similar to FIG. 5B, but illustrates a crossed 3D printed bond connection **516** between a pair of interposer second bond pads **408** and package leads **320**. One of the advantages of the present invention is by providing conformal sprayed bond connections **216** it is possible to overlap 3D printed bond connections and cross connections **516** as long as a 3D printed bond insulator **220** isolates the crossed pair of 3D printed bond conductors **212**. In contrast, crossed bond wires are at least not recommended if not forbidden (military applications, for example). Conventional bond wires have a free mass that may be able to move depending on shock and vibration intensity and duration. This may either result in shorting to adjacent bond wires or weakening of bond wire/ball bond junctions. Because 3D printed bond connections **216** are conformal and adhere to surfaces over which they are applied, they have no such free mass and risk of shorting or weakening.

Crossed 3D printed bond conductors **516** allows great flexibility by not requiring different interposers **304** for each package type or package pinout variation. Therefore, a single interposer **304** may be used to relocate a majority of signals while crossed 3D printed bond connections **516** remap a smaller number of difference signals.

Referring now to FIG. 6A, a flowchart illustrating an assembly method for a new packaged integrated circuit **340** in accordance with a first embodiment of the present invention is shown. Flow begins at block **604**.

At block **604**, an extracted die **100** is removed from previous packaged integrated circuit. The extracted die **100** will have at least one original ball bond **112** and one original bond wire **116**. It is possible that some or all original bond wires **116** will be removed during the die extraction process. Flow proceeds to block **608**.

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At block **608**, original bond wires **116** are removed from original ball bonds **112** of extracted die **100**, if any original bond wires **116** are still present. Flow proceeds to block **612**.

At block **612**, the extracted die **100** is bonded to the interposer **304** to create a remapped extracted die **324**. Flow proceeds to block **616**.

At block **616**, die attach adhesive **312** is applied to the cavity **316**. Flow proceeds to block **620**.

At block **620**, the remapped extracted die **324** is placed into the cavity **316** to secure the remapped extracted die **324** to the new package base **308**. As an alternative to blocks **612-620**, the interposer **304** may first be bonded to the new package base **308**, then the extracted die **100** may be bonded to the interposer **304**. Flow proceeds to blocks **624** and **628**.

At block **624**, new 3D printed bond connections **216** are provided between original bond pads **104**, **108** of the extracted die **100** and the first set of bond pads **404** of the interposer **304**. If there is an original ball bond **112** on an original bond pad **104** of the extracted die **100**, a 3D printed bond conductor **212** covers the original ball bond **112** and original bond pad **104**. Flow proceeds to block **632**.

At block **628**, new 3D printed bond connections **216** are provided between the second bond pads **408** of the interposer **304** and package leads **320** or downbonds, as required. It should be noted that steps **624** and **628** may be completed in any order, depending on what new 3D printed bond connection **216** installation produces the most efficient and reliable process. Flow proceeds to block **632**.

At block **632**, the package lid **344** is sealed to the assembled package base **340**, or alternatively, the non-hermetic packaged integrated circuit **340** is encapsulated. Flow proceeds to block **636**.

At block **636**, the packaged integrated circuit **340** is electrically tested. Electrical testing includes continuity tests or functional tests, or both. If the packaged integrated circuit **340** has passed the electrical tests, and the package leads **320** are properly trimmed, the packaged integrated circuit **340** is marked and is a complete new packaged integrated circuit **340** ready for use. Flow ends at block **636**.

Referring now to FIG. 6B, a flowchart illustrating an assembly method for a new packaged integrated circuit **340** in accordance with a second embodiment of the present invention is shown. Flow begins at block **650**.

At block **650**, an extracted die **100** is removed from previous packaged integrated circuit. The extracted die **100** will have at least one original ball bond **112** and possibly at least one original bond wire **116**. It is possible that some or all original bond wires **116** will be removed during the die extraction process. Flow proceeds to block **654**.

At block **654**, original bond wires **116** and original ball bonds **112** are removed from extracted die **100**. Flow proceeds to block **658**.

At block **658**, the original bond pads **104**, **108** of the extracted die **100** are prepared for rebonding. In one embodiment, preparation includes removing any impurities from original bond pads **104**, **108** and prepares the original bond pads **104**, **108** to accept new 3D printed bond connections **216**. Residues and/or oxides are removed. In some embodiments, the original bond pads **104**, **108** are lapped in order to create a flatter pad bonding surface. In yet another embodiment, the original bond pads **104**, **108** are reconditioned using an ENEPIG or similar layered metallization process, usually after removing residues and/or oxides, and possibly following lapping. Flow proceeds to block **662**.

At block **662**, the extracted die **100** is bonded to the interposer **304** to create a remapped extracted die **324**. Flow proceeds to block **666**.

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At block 666, die attach adhesive 312 is applied to the cavity 316. Flow proceeds to block 670.

At block 670, the remapped extracted die 324 is placed into the cavity 316 to secure the remapped extracted die 324 to the new package base 308. As an alternative to blocks 662-670, the interposer 304 may first be bonded to the new package base 308, then the extracted die 100 may be bonded to the interposer 304. Flow proceeds to blocks 674 and 678.

At block 674, new 3D printed bond connections 216 are provided between original bond pads 104, 108 of the extracted die 100 and the first bond pads 404 of the interposer 304. Flow proceeds to block 682.

At block 678, new 3D printed bond connections 216 are provided between the second bond pads 408 of the interposer 304 and package leads 320 or downbonds, as required. It should be noted that steps 674 and 678 may be completed in any order, depending on what new 3D printed bond connection 216 installation produces the most efficient and reliable process. Flow proceeds to block 682.

At block 682, the package lid 344 is sealed to the assembled package base 340, or alternatively, the non-hermetic packaged integrated circuit 340 is encapsulated. Flow proceeds to block 686.

At block 686, the packaged integrated circuit 340 is electrically tested. Electrical testing includes continuity tests or functional tests, or both. If the packaged integrated circuit 340 has passed the electrical tests, and the package leads 320 are properly trimmed, the packaged integrated circuit 340 is marked and is a complete new packaged integrated circuit 340 ready for use. Flow ends at block 686.

Referring now to FIG. 7A, a flowchart illustrating an assembly method for a new packaged integrated circuit 340 in accordance with a third embodiment of the present invention is shown. Flow begins at block 704.

At block 704, an extracted die 100 is removed from previous packaged integrated circuit. The extracted die 100 will have at least one original ball bond 112 and possibly at least one original bond wire 116. It is possible that some or all original bond wires 116 will be removed during the die extraction process. Flow proceeds to block 708.

At block 708, original bond wires 116 are removed from original ball bonds 112 of extracted die 100, if any original bond wires 116 are still present. Flow proceeds to block 712.

At block 712, the extracted die 100 is bonded to the interposer 304 to create a remapped extracted die 324. Flow proceeds to block 716.

At block 716, new 3D printed bond connections 216 are provided between original bond pads 104, 108 of the extracted die 100 and the first bond pads 404 of the interposer 304. If there is an original ball bond 112 on an original bond pad 104 of the extracted die 100, a 3D printed bond conductor 212 covers the original ball bond 112 and original bond pad 104. Flow proceeds to block 720.

At block 720, die attach adhesive 312 is applied to the cavity 316. Flow proceeds to block 724.

At block 724, the remapped extracted die 324 is placed into the cavity 316 to secure the remapped extracted die 324 to the new package base 308. Flow proceeds to block 728.

At block 728, new 3D printed bond connections 216 are provided between the second bond pads 408 of the interposer 304 and package leads 320 or downbonds, as required. Flow proceeds to block 732.

At block 732, the package lid 344 is sealed to the assembled package base 340, or alternatively, the non-hermetic packaged integrated circuit 340 is encapsulated. Flow proceeds to block 736.

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At block 736, the packaged integrated circuit 340 is electrically tested. Electrical testing includes continuity tests or functional tests, or both. If the packaged integrated circuit 340 has passed the electrical tests, and the package leads 320 are properly trimmed, the packaged integrated circuit 340 is marked and is a complete new packaged integrated circuit 340 ready for use. Flow ends at block 736.

Referring now to FIG. 7B, a flowchart illustrating an assembly method for a new packaged integrated circuit 340 in accordance with a fourth embodiment of the present invention is shown. Flow begins at block 750.

At block 750, an extracted die 100 is removed from previous packaged integrated circuit. The extracted die 100 will have at least one original ball bond 112 and one original bond wire 116. It is possible that some or all original bond wires 116 will be removed during the die extraction process. Flow proceeds to block 754.

At block 754, original bond wires 116 and original ball bonds 112 are removed from the extracted die 100. Flow proceeds to block 758.

At block 758, the original bond pads 104, 108 of the extracted die 100 are prepared for rebonding. In one embodiment, preparation includes removing any impurities from original bond pads 104, 108 and prepares the original bond pads 104, 108 to accept new 3D printed bond connections 216. Residues and/or oxides are removed. In some embodiments, the original bond pads 104, 108 are lapped in order to create a flatter pad bonding surface. In yet another embodiment, the original bond pads 104, 108 are reconditioned using an ENEPIG or similar layered metallization process, usually after removing residues and/or oxides, and possibly following lapping. Flow proceeds to block 762.

At block 762, the extracted die 100 is bonded to the interposer 304 to create a remapped extracted die 324. Flow proceeds to block 766.

At block 766, new 3D printed bond connections 216 are provided between original bond pads 104, 108 of the extracted die 100 and the first bond pads 404 of the interposer 304. Flow proceeds to block 770.

At block 770, die attach adhesive 312 is applied to the cavity 316. Flow proceeds to block 774.

At block 774, the remapped extracted die 324 is placed into the cavity 316 to secure the remapped extracted die 324 to the new package base 308. Flow proceeds to block 778.

At block 778, new 3D printed bond connections 216 are provided between the second bond pads 408 of the interposer 304 and package leads 320 or downbonds, as required. Flow proceeds to block 782.

At block 782, the package lid 344 is sealed to the assembled package base 340, or alternatively, the non-hermetic packaged integrated circuit 340 is encapsulated. Flow proceeds to block 786.

At block 786, the packaged integrated circuit 340 is electrically tested. Electrical testing includes continuity tests or functional tests, or both. If the packaged integrated circuit 340 has passed the electrical tests, and the package leads 320 are properly trimmed, the packaged integrated circuit 340 is marked and is a complete new packaged integrated circuit 340 ready for use. Flow ends at block 786.

Referring now to FIG. 8A, a flowchart illustrating an assembly method for a hermetic packaged integrated circuit 352 in accordance with a first hermetic embodiment of the present invention is shown. Flow begins at block 804.

At block 804, an extracted die 100 is removed from previous packaged integrated circuit. The extracted die 100 will have at least one original ball bond 112 and one original

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bond wire 116. It is possible that some or all original bond wires 116 will be removed during the die extraction process. Flow proceeds to block 808.

At block 808, original bond wires 116 are removed from original ball bonds 112 of extracted die 100, if any original bond wires 116 are still present. Flow proceeds to block 812.

At block 812, the extracted die 100 is bonded to the interposer 304 to create a remapped extracted die 324. Flow proceeds to block 816.

At block 816, a low-halide content die attach adhesive 312 is applied to the cavity 316. Flow proceeds to block 820.

At block 820, the remapped extracted die 324 is placed into the cavity 316 to secure the remapped extracted die 324 to the new package base 308. As an alternative to blocks 812-820, the interposer 304 may first be bonded to the new package base 308, then the extracted die 100 may be bonded to the interposer 304. Flow proceeds to blocks 824 and 828.

At block 824, new 3D printed bond connections 216 are provided between original bond pads 104, 108 of the extracted die 100 and the first bond pads 404 of the interposer 304. Flow proceeds to block 832.

At block 828, new 3D printed bond connections 216 are provided between the second bond pads 408 of the interposer 304 and package leads 320 or downbonds, as required. It should be noted that steps 824 and 828 may be completed in any order, depending on what new 3D printed bond connection 216 installation produces the most efficient and reliable process. Flow proceeds to block 832.

At block 832, the assembled hermetic package base 328, 336 is first vacuum baked. The assembled hermetic package base 328, 336 includes the hermetic package base 308, package leads 320, remapped extracted die 324, the die attach adhesive 312, and new 3D printed bond connections 216. The process of first vacuum baking is illustrated in FIG. 11 of application Ser. No. 13/623,603. Flow proceeds to block 836.

At block 836, the assembled hermetic package base 328, 336 is removed from the vacuum baking apparatus and the hermetic package lid 344 is placed on the assembled hermetic package base 328, 336. The hermetic package lid 344 is placed in proper orientation such that the combination of the hermetic package lid 344 and the assembled hermetic package base 328, 336 is hermetically sealed following block 840. A moisture getter 356 in some embodiments is applied to the interior of the hermetic package lid 344. In a preferred embodiment, the moisture getter 356 is uniformly applied with a thickness of three or more microns to the interior surface of the hermetic package lid 344 using a deposition process. Flow proceeds to block 840.

At block 840, the assembled hermetic package base 328, 336 and hermetic package lid 344 are placed into the vacuum baking apparatus and second vacuum baked. Unlike block 832, where only the assembled hermetic package base 328, 336 is first vacuum baked, block 840 requires the hermetic package lid 344 to be placed on the assembled hermetic package base 328, 336 prior to initiating the second vacuum bake process. The second vacuum bake process is illustrated in FIG. 12 of application Ser. No. 13/623,603. Flow proceeds to block 844.

At block 844, a vacuum pump in the vacuum baking apparatus is turned off. Turning the vacuum pump off prevents gases from being evacuated from the vacuum baking apparatus, and is required in order for Noble gas 360 injected in block 848 to remain in the packaged hermetic integrated circuit 352 after the hermetic package lid 344 is sealed to the assembled hermetic package base 328, 336. Flow proceeds to block 848.

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At block 848, a Noble gas 360 is injected into the packaged hermetic integrated circuit 352, while the packaged hermetic integrated circuit 352 is in the vacuum baking apparatus, and immediately following the second vacuum bake process. In a preferred embodiment, the Noble gas 360 is Argon, and the Noble gas 360 is injected into the cavity 316 to a pressure of between 0.1 to 2 Atmospheres (ATM), preferably 1 ATM, at a temperature between 200° C. and 275° C., preferably 255° C. Flow proceeds to block 852.

At block 852, the packaged hermetic integrated circuit 352 is hermetically and/or electrically tested. Hermetic testing is generally performed according to MIL-SPEC-883H. Electrical testing includes either continuity tests or functional tests, or both. If the packaged hermetic integrated circuit 352 has passed the hermeticity and electrical tests and the package leads 320 are properly trimmed to the appropriate length, the packaged hermetic integrated circuit 352 is marked and is a complete hermetic integrated circuit 352 ready for use. Flow ends at block 852.

The process illustrated and described in FIG. 8A is most suitable for applications with temperatures over 150 degrees Celsius where either original ball bonds 112 have not been removed from the extracted die 100 or the original bond pads 104, 108 have not been reconditioned as described herein.

Referring now to FIG. 8B, a flowchart illustrating an assembly method for a hermetic packaged integrated circuit 352 in accordance with a second hermetic embodiment of the present invention is shown. Flow begins at block 856.

At block 856, an extracted die 100 is removed from previous packaged integrated circuit. The extracted die 100 will have at least one original ball bond 112 and possibly at least one original bond wire 116. It is possible that some or all original bond wires 116 will be removed during the die extraction process. Flow proceeds to block 860.

At block 860, original bond wires 116 are removed from original ball bonds 112 of extracted die 100. Flow proceeds to block 864.

At block 864, the original bond pads 104, 108 of the extracted die 100 are prepared for rebonding. In one embodiment, preparation includes removing any impurities from original bond pads 104, 108 and prepares the original bond pads 104, 108 to accept new 3D printed bond connections 216. Residues and/or oxides are removed. In some embodiments, the original bond pads 104, 108 are lapped in order to create a flatter pad bonding surface. In yet another embodiment, the original bond pads 104, 108 are reconditioned using an ENEPiG or similar layered metallization process, usually after removing residues and/or oxides, and possibly following lapping. Flow proceeds to block 868.

At block 868, the extracted die 100 is bonded to the interposer 304 to create a remapped extracted die 324. Flow proceeds to block 872.

At block 872, a low-halide content die attach adhesive 312 is applied to the cavity 316. Flow proceeds to block 876.

At block 876, the remapped extracted die 324 is placed into the cavity 316 to secure the remapped extracted die 324 to the new package base 308. As an alternative to blocks 868-876, the interposer 304 may first be bonded to the new package base 308, then the extracted die 100 may be bonded to the interposer 304. Flow proceeds to blocks 880 and 884.

At block 880, new 3D printed bond connections 216 are provided between original bond pads 104, 108 of the extracted die 100 and the first bond pads 404 of the Interposer 304. Flow proceeds to block 888.

At block 884, new 3D printed bond connections 216 are provided between the second bond pads 408 of the inter-

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poser **304** and package leads **320** or downbonds, as required. It should be noted that steps **880** and **884** may be completed in any order, depending on what new 3D printed bond connection **216** installation produces the most efficient and reliable process. Flow proceeds to block **888**.

At block **888**, the assembled hermetic package base **328**, **336** is first vacuum baked. The assembled hermetic package base **328**, **336** includes the hermetic package base **308**, package leads **320**, remapped extracted die **324**, the die attach adhesive **312**, and new 3D printed bond connections **216**. The process of first vacuum baking is illustrated in FIG. 11 of application Ser. No. 13/623,603. Flow proceeds to block **890**.

At block **890**, the assembled hermetic package base **328**, **336** is removed from the vacuum baking apparatus and the hermetic package lid **344** is placed on the assembled hermetic package base **328**, **336**. The hermetic package lid **344** is placed in proper orientation such that the combination of the hermetic package lid **344** and the assembled hermetic package base **328**, **336** is hermetically sealed following block **892**. In some embodiments, a moisture getter **356** is applied to the interior of the hermetic package lid **344**. In a preferred embodiment, the moisture getter **356** is uniformly applied with a thickness of three or more microns to the interior surface of the hermetic package lid **344** using a deposition process. Flow proceeds to block **892**.

At block **892**, the assembled hermetic package base **328**, **336** and hermetic package lid **344** are placed into the vacuum baking apparatus and second vacuum baked. Unlike block **888**, where only the assembled hermetic package base **328**, **336** is first vacuum baked, block **892** requires the hermetic package lid **344** to be placed on the assembled hermetic package base **328**, **336** prior to initiating the second vacuum bake process. The second vacuum bake process is illustrated in FIG. 12 of application Ser. No. 13/623,603. Flow proceeds to block **894**.

At block **894**, a vacuum pump in the vacuum baking apparatus is turned off. Turning the vacuum pump off prevents gases from being evacuated from the vacuum baking apparatus, and is required in order for Noble gas **360** injected in block **896** to remain in the packaged hermetic integrated circuit **352** after the hermetic package lid **344** is sealed to the assembled hermetic package base **328**, **336**. Flow proceeds to block **896**.

At block **896**, a Noble gas **360** is injected into the packaged hermetic integrated circuit **328**, **336**, while the packaged hermetic integrated circuit **328**, **336** is in the vacuum baking apparatus, and immediately following the second vacuum bake process. In a preferred embodiment, the Noble gas **360** is Argon, and the Noble gas **360** is injected into the cavity **316** to a pressure of between 0.1 to 2 Atmospheres (ATM), preferably 1 ATM, at a temperature between 200° C. and 275° C., preferably 255° C. Flow proceeds to block **898**.

At block **898**, the packaged hermetic integrated circuit **352** is hermetically and/or electrically tested. Hermetic testing is generally performed according to MIL-SPEC-883H. Electrical testing includes either continuity tests or functional tests, or both. If the packaged hermetic integrated circuit **352** has passed the hermeticity and electrical tests and the package leads **320** are properly trimmed to the appropriate length, the packaged hermetic integrated circuit **352** is marked and is a complete hermetic integrated circuit **352**, ready for use. Flow ends at block **898**.

The process illustrated and described in FIG. 8B is most suitable for applications with temperatures over 150 degrees Celsius where either original ball bonds **112** have not been

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removed from the extracted die **100** or the original bond pads **104**, **108** have not been reconditioned as described herein.

Referring now to FIG. 9A, a flowchart illustrating an assembly method for a hermetic packaged integrated circuit **352** in accordance with a third hermetic embodiment of the present invention is shown. Flow begins at block **904**.

At block **904**, an extracted die **100** is removed from previous packaged integrated circuit. The extracted die **100** will have at least one original ball bond **112** and possibly at least one original bond wire **116**. It is possible that some or all original bond wires **116** will be removed during the die extraction process. Flow proceeds to block **908**.

At block **908**, original bond wires **116** are removed from original ball bonds **112** of extracted die **100**, if any original bond wires **116** are still present. Flow proceeds to block **912**.

At block **912**, the extracted die **100** is bonded to the interposer **304** to create a remapped extracted die **324**. Flow proceeds to block **916**.

At block **916**, new 3D printed bond connections **216** are provided between original bond pads **104**, **108** of the extracted die **100** and the first bond pads **404** of the interposer **304**. Flow proceeds to block **920**.

At block **920**, a low-halide content die attach adhesive **312** is applied to the cavity **316**. Flow proceeds to block **924**.

At block **924**, the remapped extracted die **324** is placed into the cavity **316** to secure the remapped extracted die **324** to the new package base **308**. Flow proceeds to block **928**.

At block **928**, new 3D printed bond connections **216** are provided between the second bond pads **408** of the interposer **304** and package leads **320** or downbonds, as required. Flow proceeds to block **932**.

At block **932**, the assembled hermetic package base **328**, **336** is first vacuum baked. The assembled hermetic package base **328**, **336** includes the hermetic package base **308**, package leads **320**, remapped extracted die **324**, the die attach adhesive **312**, and new 3D printed bond connections **216**. The process of first vacuum baking is illustrated in FIG. 11 of application Ser. No. 13/623,603. Flow proceeds to block **936**.

At block **936**, the assembled hermetic package base **328**, **336** is removed from the vacuum baking apparatus and the hermetic package lid **344** is placed on the assembled hermetic package base **328**, **336**. The hermetic package lid **344** is placed in proper orientation such that the combination of the hermetic package lid **344** and the assembled hermetic package base **328**, **336** is hermetically sealed following block **940**. In some embodiments, a moisture getter **356** is applied to the interior of the hermetic package lid **344**. In a preferred embodiment, the moisture getter **356** is uniformly applied with a thickness of three or more microns to the interior surface of the hermetic package lid **344** using a deposition process. Flow proceeds to block **940**.

At block **940**, the assembled hermetic package base **328**, **336** and hermetic package lid **344** are placed into the vacuum baking apparatus and second vacuum baked. Unlike block **932**, where only the assembled hermetic package base **328**, **336** is first vacuum baked, block **940** requires the hermetic package lid **344** to be placed on the assembled hermetic package base **328**, **336** prior to initiating the second vacuum bake process. The second vacuum bake process is illustrated in FIG. 12 of application Ser. No. 13/623,603. Flow proceeds to block **944**.

At block **944**, a vacuum pump in the vacuum baking apparatus is turned off. Turning the vacuum pump off prevents gases from being evacuated from the vacuum baking apparatus, and is required in order for Noble gas **360**

injected in block 948 to remain in the packaged hermetic integrated circuit 952 after the hermetic package lid 344 is sealed to the assembled hermetic package base 328, 336. Flow proceeds to block 948.

At block 948, a Noble gas 360 is injected into the packaged hermetic integrated circuit 352, while the packaged hermetic integrated circuit 352 is in the vacuum baking apparatus, and immediately following the second vacuum bake process. In a preferred embodiment, the Noble gas 360 is Argon, and the Noble gas 360 is injected into the cavity 316 to a pressure of between 0.1 to 2 Atmospheres (ATM), preferably 1 ATM, at a temperature between 200° C. and 275° C., preferably 255° C. Flow proceeds to block 952.

At block 952, the packaged hermetic integrated circuit 352 is hermetically and/or electrically tested. Hermetic testing is generally performed according to MIL-SPEC-883H. Electrical testing includes either continuity tests or functional tests, or both. If the packaged hermetic integrated circuit 352 has passed the hermeticity and electrical tests and the package leads 320 are properly trimmed to the appropriate length, the packaged hermetic integrated circuit 352 is marked and is a complete hermetic integrated circuit 352 ready for use. Flow ends at block 952.

The process illustrated and described in FIG. 9A is most suitable for applications with temperatures over 150 degrees Celsius where either original ball bonds 112 have not been removed from the extracted die 100 or the original bond pads 104, 108 have not been reconditioned as described herein.

Referring now to FIG. 9B, a flowchart illustrating an assembly method for a hermetic packaged integrated circuit 352 in accordance with a fourth hermetic embodiment of the present invention is shown. Flow begins at block 956.

At block 956, an extracted die 100 is removed from previous packaged integrated circuit. The extracted die 100 will have at least one original ball bond 112 and possibly at least one original bond wire 116. It is possible that some or all original bond wires 116 will be removed during the die extraction process. Flow proceeds to block 960.

At block 960, original bond wires 116 are removed from original ball bonds 112 of extracted die 100. Flow proceeds to block 964.

At block 964, the original bond pads 104, 108 of the extracted die 100 are prepared for rebonding. In one embodiment, preparation includes removing any impurities from original bond pads 104, 108 and prepares the original bond pads 104, 108 to accept new 3D printed bond connections 216. Residues and/or oxides are removed. In some embodiments, the original bond pads 104, 108 are lapped in order to create a flatter pad bonding surface. In yet another embodiment, the original bond pads 104, 108 are reconditioned using an ENEPIG or similar layered metallization process, usually after removing residues and/or oxides, and possibly following lapping. Flow proceeds to block 968.

At block 968, the extracted die 100 is bonded to the interposer 304 to create a remapped extracted die 324. Flow proceeds to block 972.

At block 972, new 3D printed bond connections 216 are provided between original bond pads 104, 108 of the extracted die 100 and the first bond pads 404 of the interposer 304. Flow proceeds to block 976.

At block 976, a low-halide content die attach adhesive 312 is applied to the cavity 316. Flow proceeds to block 980.

At block 980, the remapped extracted die 324 is placed into the cavity 316 to secure the remapped extracted die 324 to the new package base 308. Flow proceeds to block 984.

At block 984, new 3D printed bond connections 216 are provided between the second bond pads 408 of the interposer 304 and package leads 320 or downbonds, as required. It should be noted that steps 880 and 884 may be completed in any order, depending on what new 3D printed bond connection 216 installation produces the most efficient and reliable process. Flow proceeds to block 988.

At block 988, the assembled hermetic package base 328, 336 is first vacuum baked. The assembled hermetic package base 328, 336 includes the hermetic package base 308, package leads 320, remapped extracted die 324, the die attach adhesive 312, and new 3D printed bond connections 216. The process of first vacuum baking is illustrated in FIG. 11 of application Ser. No. 13/623,603. Flow proceeds to block 990.

At block 990, the assembled hermetic package base 328, 336 is removed from the vacuum baking apparatus and the hermetic package lid 344 is placed on the assembled hermetic package base 328, 336. The hermetic package lid 344 is placed in proper orientation such that the combination of the hermetic package lid 344 and the assembled hermetic package base 328, 336 is hermetically sealed following block 992. In some embodiments, a moisture getter 356 is applied to the interior of the hermetic package lid 344. In a preferred embodiment, the moisture getter 356 is uniformly applied with a thickness of three or more microns to the interior surface of the hermetic package lid 344 using a deposition process. Flow proceeds to block 992.

At block 992, the assembled hermetic package base 328, 336 and hermetic package lid 344 are placed into the vacuum baking apparatus and second vacuum baked. Unlike block 988, where only the assembled hermetic package base 328, 336 is first vacuum baked, block 992 requires the hermetic package lid 344 to be placed on the assembled hermetic package base 328, 336 prior to initiating the second vacuum bake process. The second vacuum bake process is illustrated in FIG. 12 of application Ser. No. 13/623,603. Flow proceeds to block 994.

At block 994, a vacuum pump in the vacuum baking apparatus is turned off. Turning the vacuum pump off prevents gases from being evacuated from the vacuum baking apparatus, and is required in order for Noble gas 360 injected in block 996 to remain in the packaged hermetic integrated circuit 352 after the hermetic package lid 344 is sealed to the assembled hermetic package base 328, 336. Flow proceeds to block 996.

At block 996, a Noble gas 360 is injected into the packaged hermetic integrated circuit 328, 336, while the packaged hermetic integrated circuit 328, 336 is in the vacuum baking apparatus, and immediately following the second vacuum bake process. In a preferred embodiment, the Noble gas 360 is Argon, and the Noble gas 360 is injected into the cavity 316 to a pressure of between 0.1 to 2 Atmospheres (ATM), preferably 1 ATM, at a temperature between 200° C. and 275° C., preferably 255° C. Flow proceeds to block 998.

At block 998, the packaged hermetic integrated circuit 352 is hermetically and/or electrically tested. Hermetic testing is generally performed according to MIL-SPEC-883H. Electrical testing includes either continuity tests or functional tests, or both. If the packaged hermetic integrated circuit 352 has passed the hermeticity and electrical tests and the package leads 320 are properly trimmed to the appropriate length, the packaged hermetic integrated circuit 352 is marked and is a complete hermetic integrated circuit 352, ready for use. Flow ends at block 998.

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The process illustrated and described in FIG. 9B is most suitable for applications with temperatures over 150 degrees Celsius where either original ball bonds **112** have not been removed from the extracted die **100** or the original bond pads **104**, **108** have not been reconditioned as described herein.

Referring now to FIG. 10, an illustration depicting insulating and conducting material spray with a 3D printer in accordance with the present invention is shown. 3D printers are able to precisely deposit insulating or conducting material on complex shapes, and are able to build up or layer the insulating or conducting material to a precise thickness.

The 3D printer includes a 3D printer conductive material spray head **1004**, which applies bond insulator material **1012** or bond conductor material **1016** to selected areas of the assembled package base **328**, **336**. 3D printers typically deposit material in layers, and build up a desired thickness of material by depositing multiple layers. The 3D printer is computer controlled equipment, and sprays material according to a file or files prepared beforehand designating specific locations that material will be applied to.

In one embodiment, the 3D printer uses an extrusion process to apply either the bond insulator material **1012** or the bond conductor material **1016**, or both. The extrusion process, sometimes referred to as Fused Deposition Modeling (FDM) uses a heated nozzle to extrude molten material.

In another embodiment, the 3D printer uses a Colorjet Printing (CJP) process to apply either the bond insulator material **1012** or the bond conductor material **1016**, or both. The CJP process utilizes an inkjet-based technology to spread fine layers of a dry substrate material. The dry substrate is most often in a powder form. The inkjet applies a binder to the substrate after applying the dry substrate material in order to solidify and cure the dry substrate.

In the preferred embodiment, the 3D printer uses a selective laser sintering process. Either bond insulator material **1012** or bond conductor material **1016** is applied in powder form to the assembled package base **328**, **336**.

The bond insulator material **1012** is a material able to be applied in powder form or extruded, and is generally a polymer or plastic. However, any material having suitable insulation properties, able to adhere to the assembled package base **328**, **336**, and able to be applied with a 3D printer material spray head **1004** is suitable as bond insulator material **1012**.

The bond conductor material **1016** is also a material able to be applied in powder form or extruded, and includes at least conductive metal and possibly polymer or plastic content in order to provide elastomeric or resilient properties. In the preferred embodiment, the metal content is silver. In other embodiments, the material may include alone or in combination gold, aluminum, or copper.

Referring now to FIG. 11, an illustration depicting a sintering process to form a 3D printed bond insulator **220** or a 3D printed bond conductor **212** in accordance with embodiments of the present invention is shown. The sintering process is a second step of the 3D printing process used in the preferred embodiment of the invention. A laser **1104** aims a laser beam **1108** at the applied bond insulator material **1012** or bond conductor material **1016** to convert the applied material **1012**, **1016** into a 3D printed bond insulator **220** or a 3D printed bond conductor **212**, respectively. The laser beam **1108** converts the powder form applied material **1012**, **1016** into a molten compound with liquid properties that forms a smooth solid compound when it cools. The smooth solid compound is either the 3D printed bond insulator **220** or 3D printed bond conductor **212**.

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Finally, those skilled in the art should appreciate that they can readily use the disclosed conception and specific embodiments as a basis for designing or modifying other structures for carrying out the same purposes of the present invention without departing from the spirit and scope of the invention as defined by the appended claims.

I claim:

1. A method, comprising:

removing an extracted die comprising an original ball bond from a previous packaged integrated circuit;
bonding the extracted die to an interposer to create a remapped extracted die;

3D printing, by a 3D printer, one or more first bond connections between one or more original bond pads of the extracted die and one or more first bond pads of the interposer;

securing the remapped extracted die to a package base;
and

3D printing, by the 3D printer, one or more second bond connections between one or more second bond pads of the interposer and one or more package leads or downbonds of the package base, the one or more first and second bond connections conforming to the shapes and surfaces of the extracted die, the interposer, and the package base.

2. The method of claim 1, wherein each of the one or more 3D printed bond connections comprises a 3D printed bond insulator and a 3D printed bond conductor, wherein 3D printed bond insulators prevents electrical conduction between 3D printed bond conductors and at least one of the extracted die, the interposer, other 3D printed bond conductors, and the package base.

3. The method of claim 2, wherein each of the 3D printed bond insulators comprises a polymer material having elastomeric properties, wherein the interposer comprises one or more conductive traces between the one or more first bond pads and the one or more second bond pads.

4. The method of claim 2, wherein each of the 3D printed bond conductors comprises an elastomeric material and at least one of gold, aluminum, and copper, wherein for original bond pads having original ball bonds present 3D printed bond conductors cover and conform to the surfaces of the original ball bonds and original bond pads.

5. The method of claim 2, wherein 3D printed bond conductors are applied over and conform to the surface of the 3D printed bond insulators, wherein the 3D printed bond conductors and conductive traces of the interposer make electrical contact between the original bond pads and the package leads.

6. The method of claim 1, wherein the extracted die is a fully functional semiconductor die that has been removed from a finished packaged integrated circuit.

7. The method of claim 1, wherein in response to 3D printing the bond connections, no bond wires interconnect any original bond pads and any leads of the package base.

8. The method of claim 1, wherein in response to 3D printing the bond connections, the method further comprising:

securing a package lid to the package base to create a packaged integrated circuit.

9. The method of claim 8, wherein the package base is a hermetic package base, the package lid is a hermetic package lid, and the packaged integrated circuit is a hermetic packaged integrated circuit.

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10. A method, comprising:
 removing an extracted die comprising one or more original ball bonds on one or more original bond pads from a previous packaged integrated circuit;
 modifying the extracted die to remove original bond wires, the one or more original ball bonds, and any oxides or residues from the original bond pads;
 reconditioning the modified extracted die, comprising:
 adding layers of nickel, palladium, and gold over the original bond pads;
 bonding the reconditioned die to an interposer to create a remapped extracted die;
 securing the remapped extracted die to a package base;
 3D printing, by a 3D printer, one or more first 3D printed bond connections between original bond pads and one or more first bond pads of the interposer; and
 3D printing, by the 3D printer, one or more second 3D printed bond connections between one or more second bond pads of the interposer and one or more package leads or downbonds of the package base, the one or more first and second 3D printed bond connections conforming to the shapes and surfaces of the extracted die, the interposer, and the package base.
11. The method of claim 10, wherein in response to 3D printing the bond connections, the method further comprising:
 securing a package lid to the package base to create a packaged integrated circuit.
12. The method of claim 10, wherein the interposer comprises a substrate comprising the first and second bond pads and predetermined electrical interconnections between the first and second bond pads.
13. The method of claim 10, wherein 3D printed bond connections comprises 3D printed bond conductors, each comprising an elastomeric material and at least one of gold, aluminum, and copper.
14. The method of claim 10, wherein at least one 3D printed bond connection comprises a 3D printed bond conductor applied over a 3D printed bond insulator.
15. The method of claim 14, wherein the 3D printed bond insulator comprises polymer material that prevents electrical conduction between the 3D printed bond conductor and at least one of the package base, a package lid, another 3D printed bond conductor, the interposer, and areas of the reconditioned die other than a bond pad.
16. The method of claim 15, wherein at least one 3D printed bond insulator covers at least a portion of a first 3D printed bond conductor and prevents electrical conduction between the first 3D printed bond conductor and a second 3D printed bond conductor above and conforming to the shape of the at least one 3D printed bond insulator.

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17. A method, comprising:
 removing an extracted die comprising one or more original ball bonds on one or more original bond pads from a previous packaged integrated circuit;
 modifying the extracted die to remove original bond wires and the one or more original ball bonds from the original bond pads;
 bonding the modified extracted die to an interposer to create a remapped extracted die;
 securing the remapped extracted die to a package base;
 3D printing, by a 3D printer, one or more first 3D printed bond conductors between one or more original bond pads of the modified extracted die and one or more first bond pads of the interposer; and
 3D printing, by the 3D printer, one or more second 3D printed bond conductors between one or more second bond pads of the interposer and one or more package leads or downbonds of the package base, the one or more first and second 3D printed bond conductors conforming to the shapes and surfaces of the modified extracted die, the interposer, and the package base.
18. The method of claim 17, further comprising:
 prior to 3D printing at least one of the first and second 3D printed bond conductors,
 3D printing, by the 3D printer, at least one 3D printed bond insulator over electrically conductive surfaces of the modified extracted die, interposer, and package base, wherein the 3D printed bond insulator prevents electrical conduction between 3D printed bond conductors and electrically conductive surfaces of the extracted die, interposer, and package base, wherein one or more 3D printed bond conductors are applied directly over a 3D printed bond insulator.
19. The method of claim 18, wherein the one or more 3D printed bond conductors comprises an elastomeric material and at least one of gold, aluminum, and copper, wherein the interposer comprises one or more conductive traces between the one or more first bond pads and the one or more second bond pads, wherein the one or more first and second 3D printed bond conductors and interposer provides one or more electrical conduction paths between the plurality of original bond pads and the one or more package leads or downbonds.
20. The method of claim 18, wherein the one or more 3D printed bond insulators comprises a polymer material with electrical insulation properties, wherein the at least one 3D printed bond insulator covers at least a portion of a first 3D printed bond conductor and prevents electrical conduction between the first 3D printed bond conductor and a second 3D printed bond conductor above and conformal with the at least one 3D printed bond insulator.

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