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Spory

(10) **Patent No.: US 10,147,660 B2**
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(54) **REMAPPED PACKAGED EXTRACTED DIE WITH 3D PRINTED BOND CONNECTIONS**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

This patent is subject to a terminal disclaimer.

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(65) **Prior Publication Data**

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Related U.S. Application Data

(60) Continuation-in-part of application No. 14/600,733, filed on Jan. 20, 2015, now Pat. No. 9,824,948, which (Continued)

(51) **Int. Cl.**
H01L 23/20 (2006.01)
H01L 23/00 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC .... ***H01L 23/20*** (2013.01); ***H01L 21/4803*** (2013.01); ***H01L 21/4817*** (2013.01); (Continued)

(58) **Field of Classification Search**
CPC H01L 23/49513; H01L 23/49541
See application file for complete search history.

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Assistant Examiner — Wilner Jean Baptiste
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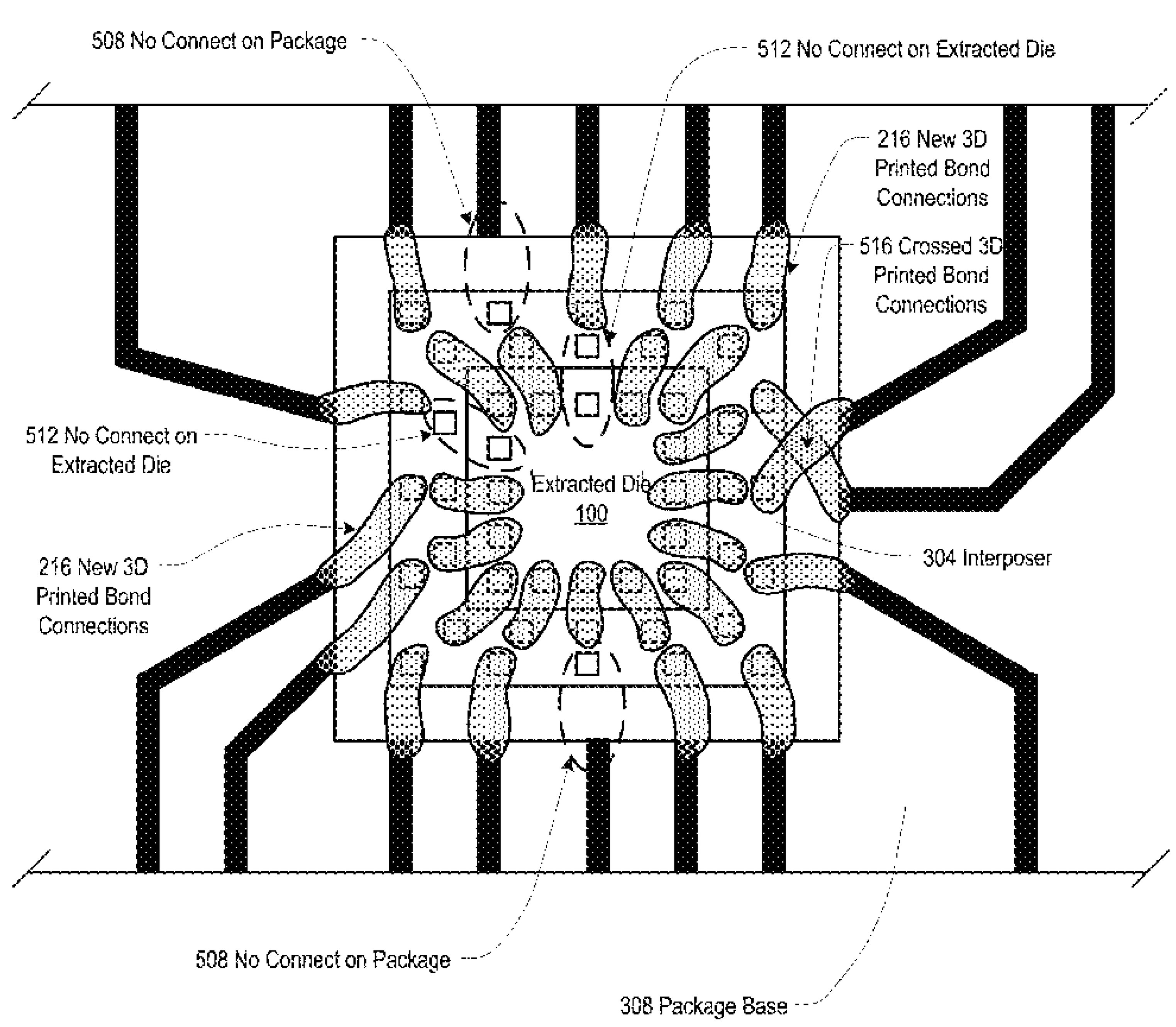
(57) **ABSTRACT**

An integrated circuit is provided. The integrated circuit includes a package base including package leads, an extracted die removed from a previous packaged integrated circuit, and an an interposer bonded to the extracted die and the package base. The extracted die includes original bond pads and one or more original ball bonds on the original bond pads. The interposer includes first bond pads electrically connected to the original bond pads with 3D printed first bond connections conforming to the shapes and surfaces of the extracted die and the interposer and second bond pads electrically connected to the package leads with 3D printed second bond connections conforming to shapes and surfaces of the interposer and package base.

19 Claims, 21 Drawing Sheets



Related U.S. Application Data

is a division of application No. 14/142,823, filed on Dec. 28, 2013, now Pat. No. 9,935,028, 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.

(51) **Int. Cl.**

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H01L 23/04	(2006.01)
H01L 23/495	(2006.01)
H01L 23/498	(2006.01)
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H01L 23/10	(2006.01)
H01L 23/057	(2006.01)

(52) **U.S. Cl.**

CPC ***H01L 21/4867*** (2013.01); ***H01L 21/50*** (2013.01); ***H01L 23/04*** (2013.01); ***H01L 23/26*** (2013.01); ***H01L 23/49513*** (2013.01); ***H01L 23/49541*** (2013.01); ***H01L 23/49838*** (2013.01); ***H01L 23/49861*** (2013.01); ***H01L 24/24*** (2013.01); ***H01L 24/25*** (2013.01); ***H01L 24/27*** (2013.01); ***H01L 24/29*** (2013.01); ***H01L 24/32*** (2013.01); ***H01L 24/82*** (2013.01); ***H01L 24/83*** (2013.01); *H01L 23/057* (2013.01); *H01L 23/10* (2013.01); *H01L 23/564* (2013.01); *H01L 2224/245* (2013.01); *H01L 2224/24011* (2013.01); *H01L 2224/24051* (2013.01); *H01L 2224/24175* (2013.01); *H01L 2224/25171* (2013.01); *H01L 2224/2731* (2013.01); *H01L 2224/2919* (2013.01); *H01L 2224/29124* (2013.01); *H01L 2224/29144* (2013.01); *H01L 2224/29147* (2013.01); *H01L 2224/32225* (2013.01); *H01L 2224/32245* (2013.01); *H01L 2224/48* (2013.01); *H01L 2224/82102* (2013.01); *H01L 2224/82103* (2013.01); *H01L 2224/82214* (2013.01); *H01L 2224/82815* (2013.01); *H01L 2224/838* (2013.01); *H01L 2224/8385* (2013.01); *H01L 2224/83192* (2013.01); *H01L 2224/92247* (2013.01); *H01L 2924/00* (2013.01); *H01L 2924/00014* (2013.01); *H01L 2924/00015* (2013.01); *H01L 2924/01013* (2013.01); *H01L 2924/01029* (2013.01); *H01L 2924/01047* (2013.01); *H01L 2924/01079* (2013.01); *H01L 2924/12042* (2013.01); *H01L 2924/14* (2013.01); *H01L 2924/157* (2013.01); *H01L 2924/15787* (2013.01); *H01L 2924/15788* (2013.01); *H01L 2924/181* (2013.01); *H01L 2924/3656* (2013.01); *H01L 2924/3861* (2013.01)

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

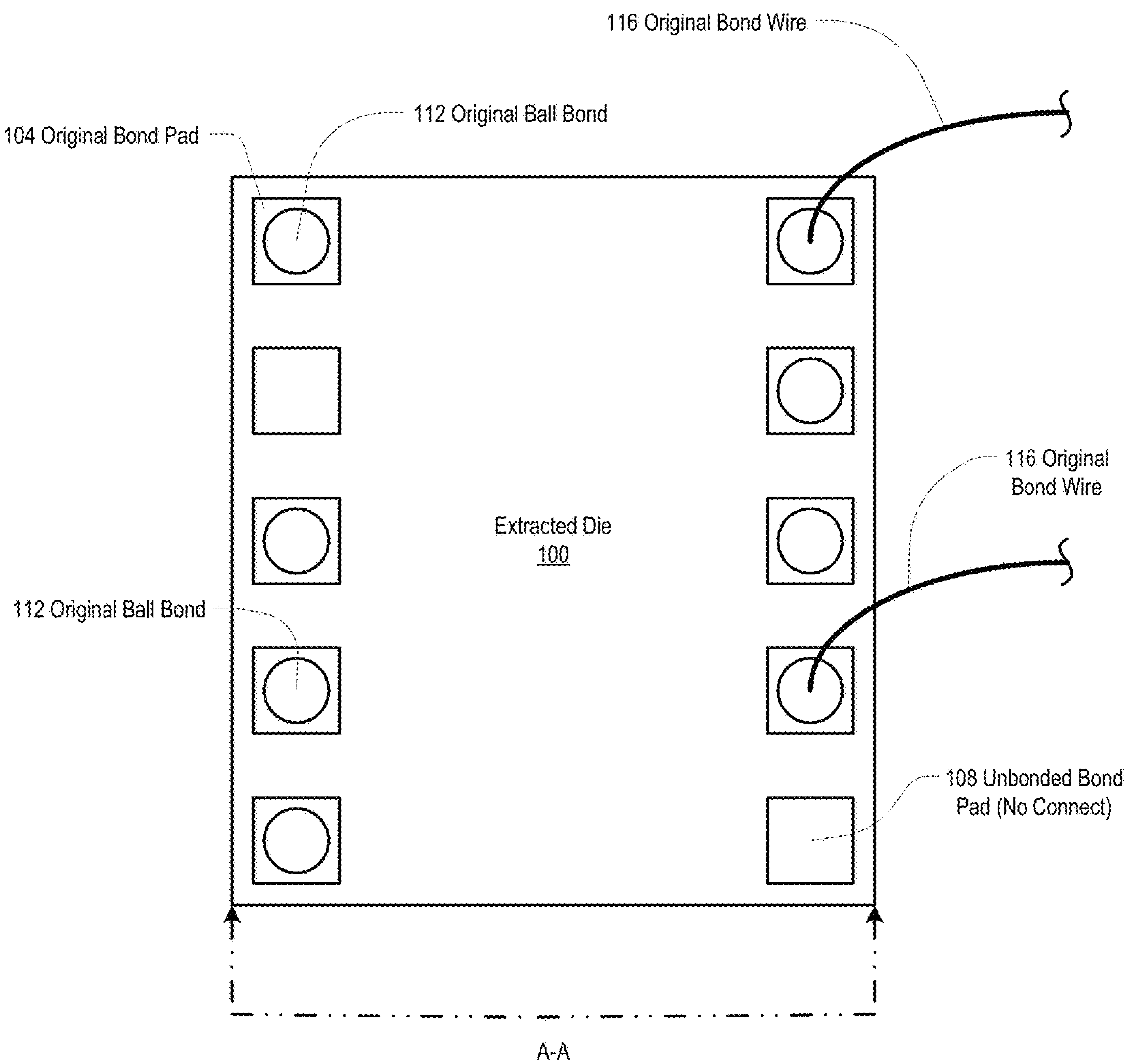


Fig. 2A Extracted Die Section A-A

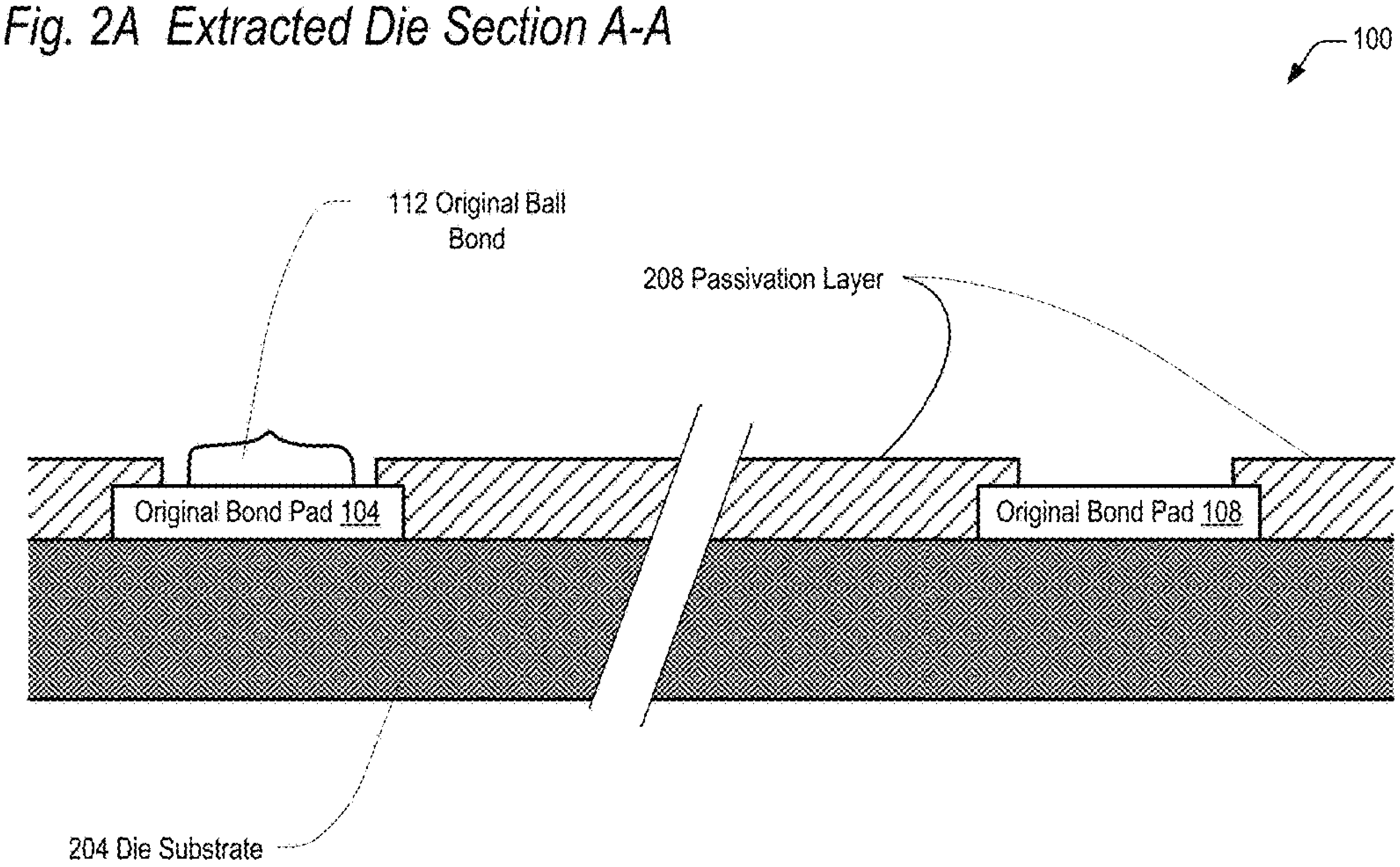


Fig. 2B Modified Extracted Die Section A-A After Original Ball Bond and Original Bond Wire Removal

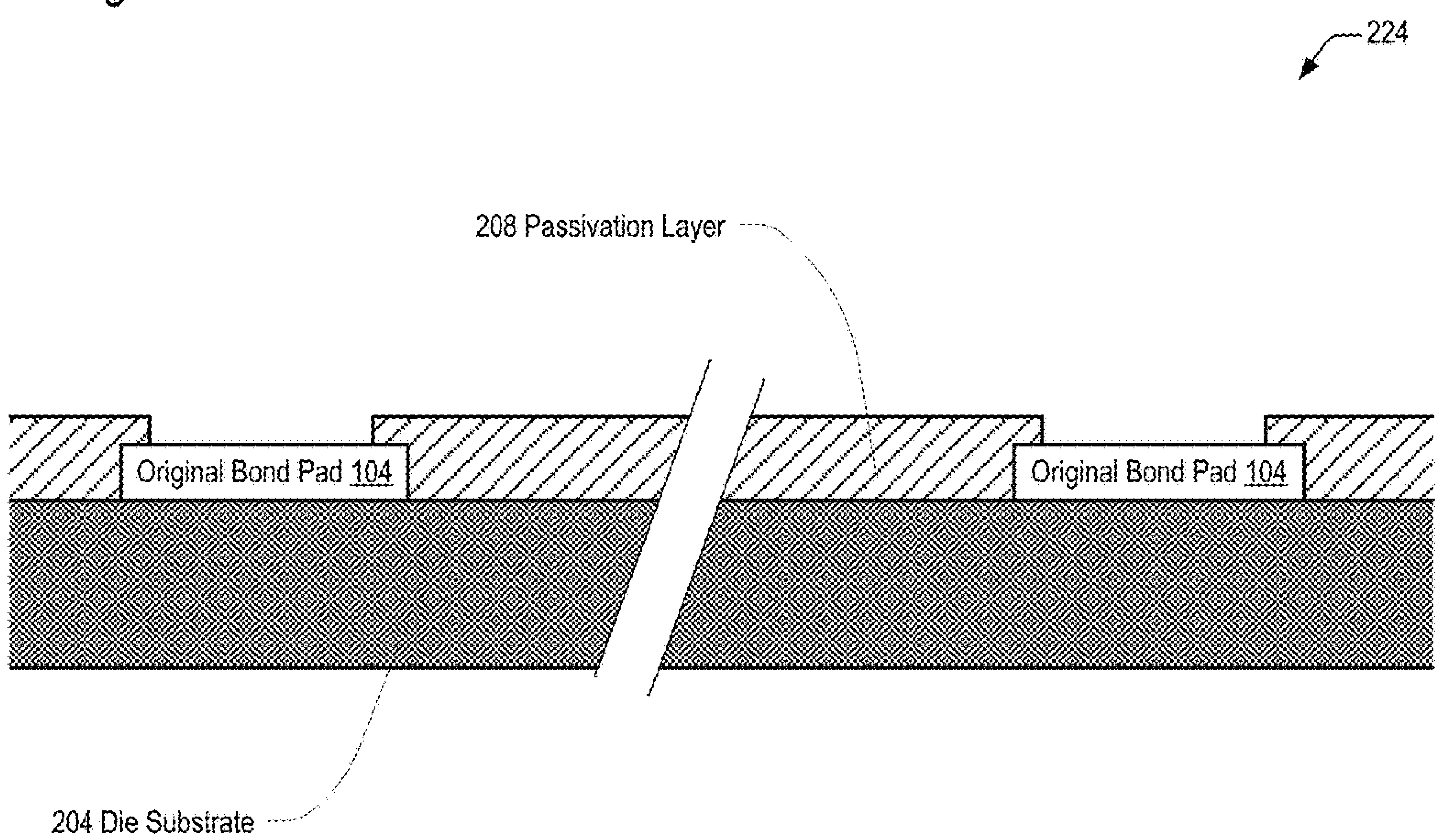


Fig. 2C Extracted Die Section A-A After 3D Printing Bond Conductor Only

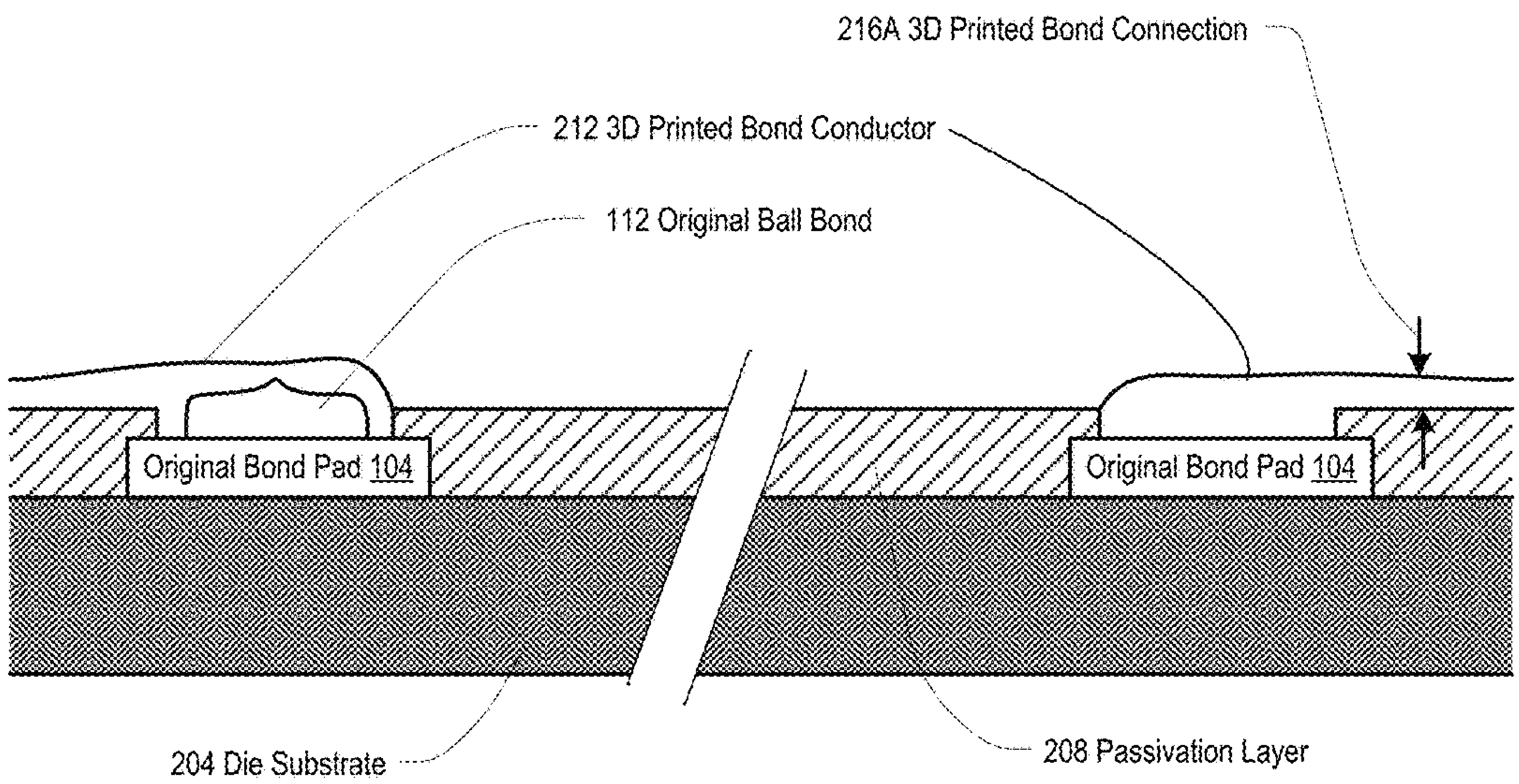


Fig. 2D Extracted Die Section A-A After 3D Printing Bond Insulator Before 3D Printing Bond Conductor

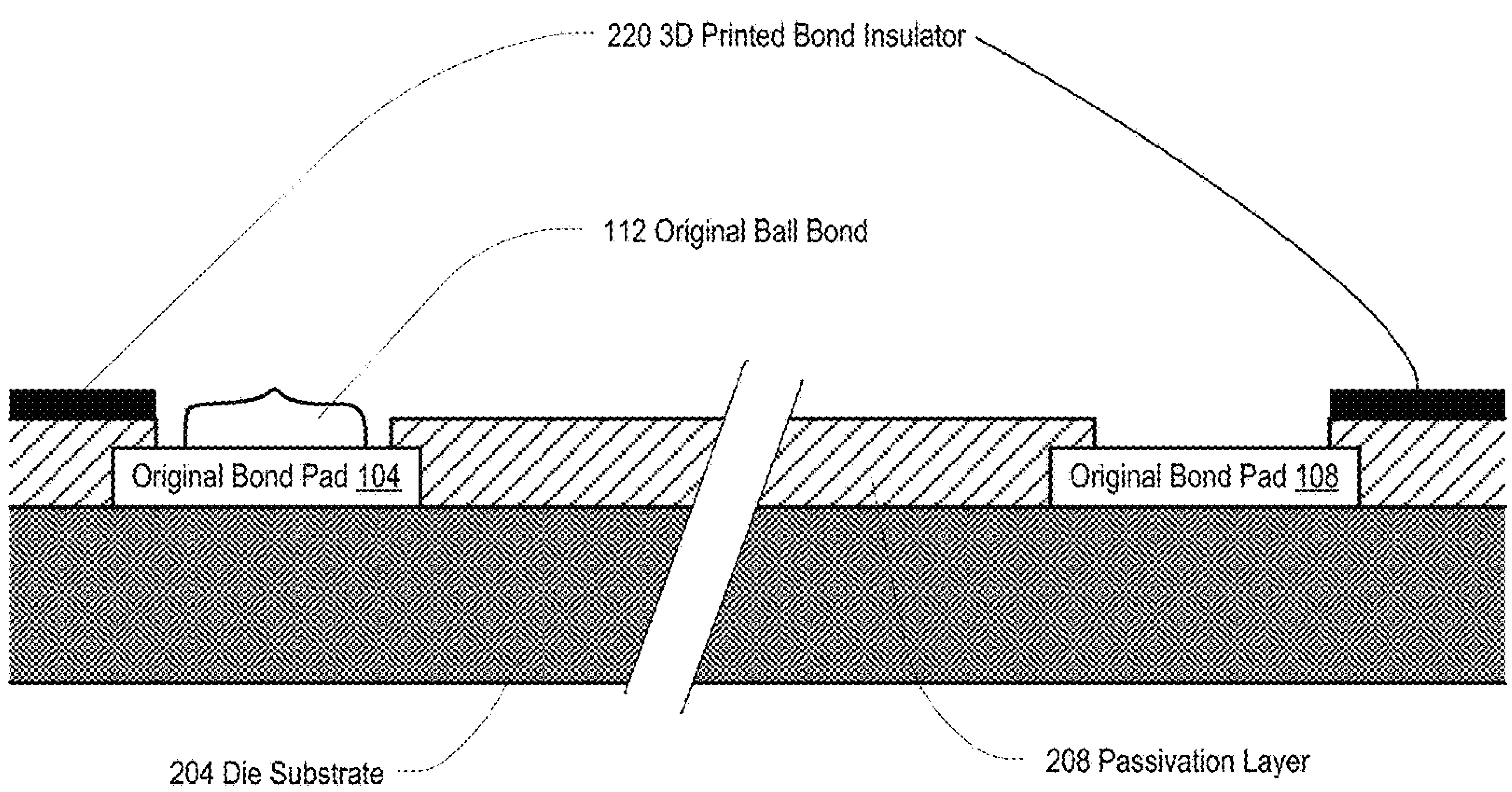


Fig. 2E Extracted Die Section A-A After 3D Printing Insulator and Conductor

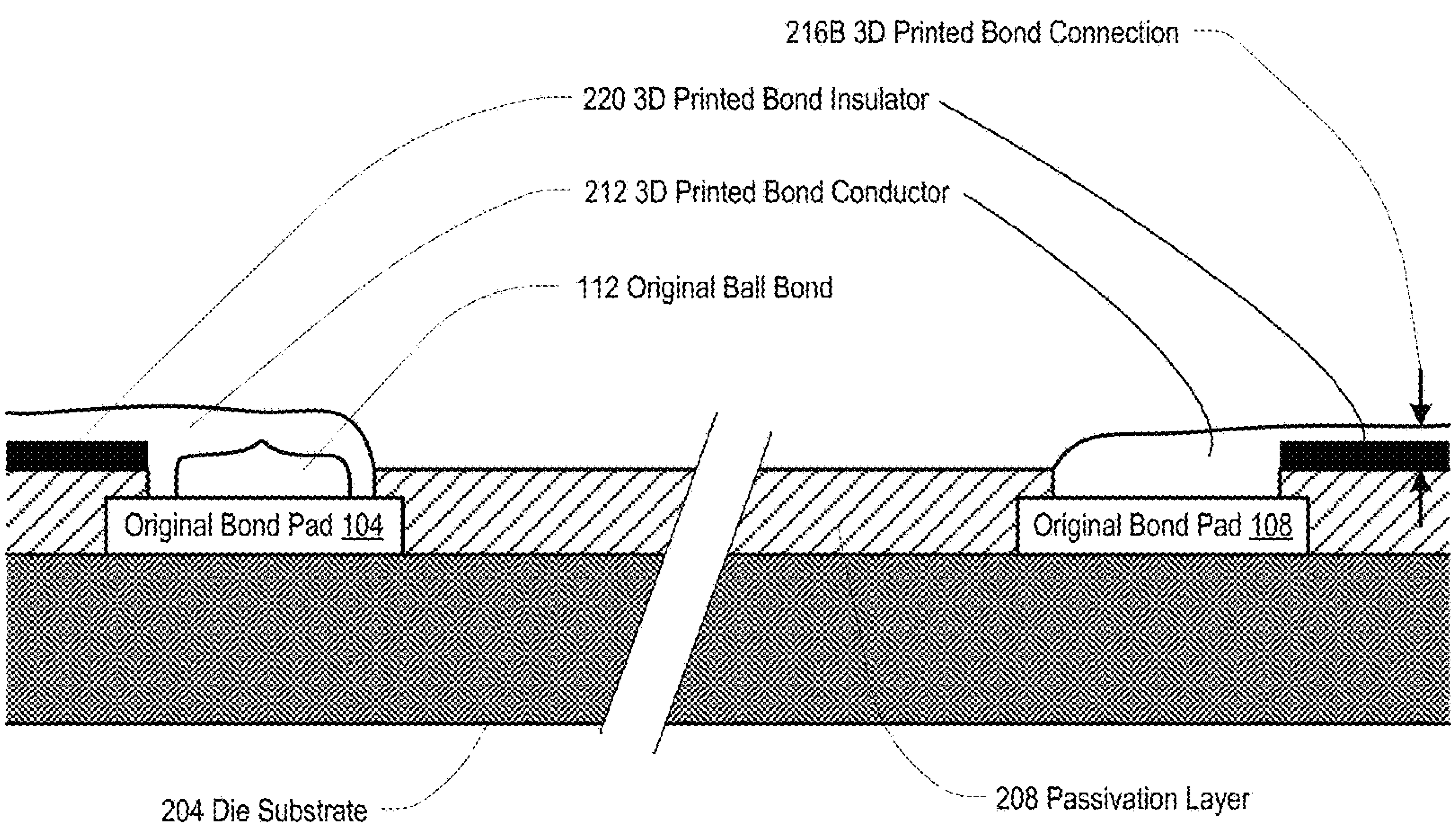


Fig. 3A Mounted Remapped Extracted Die

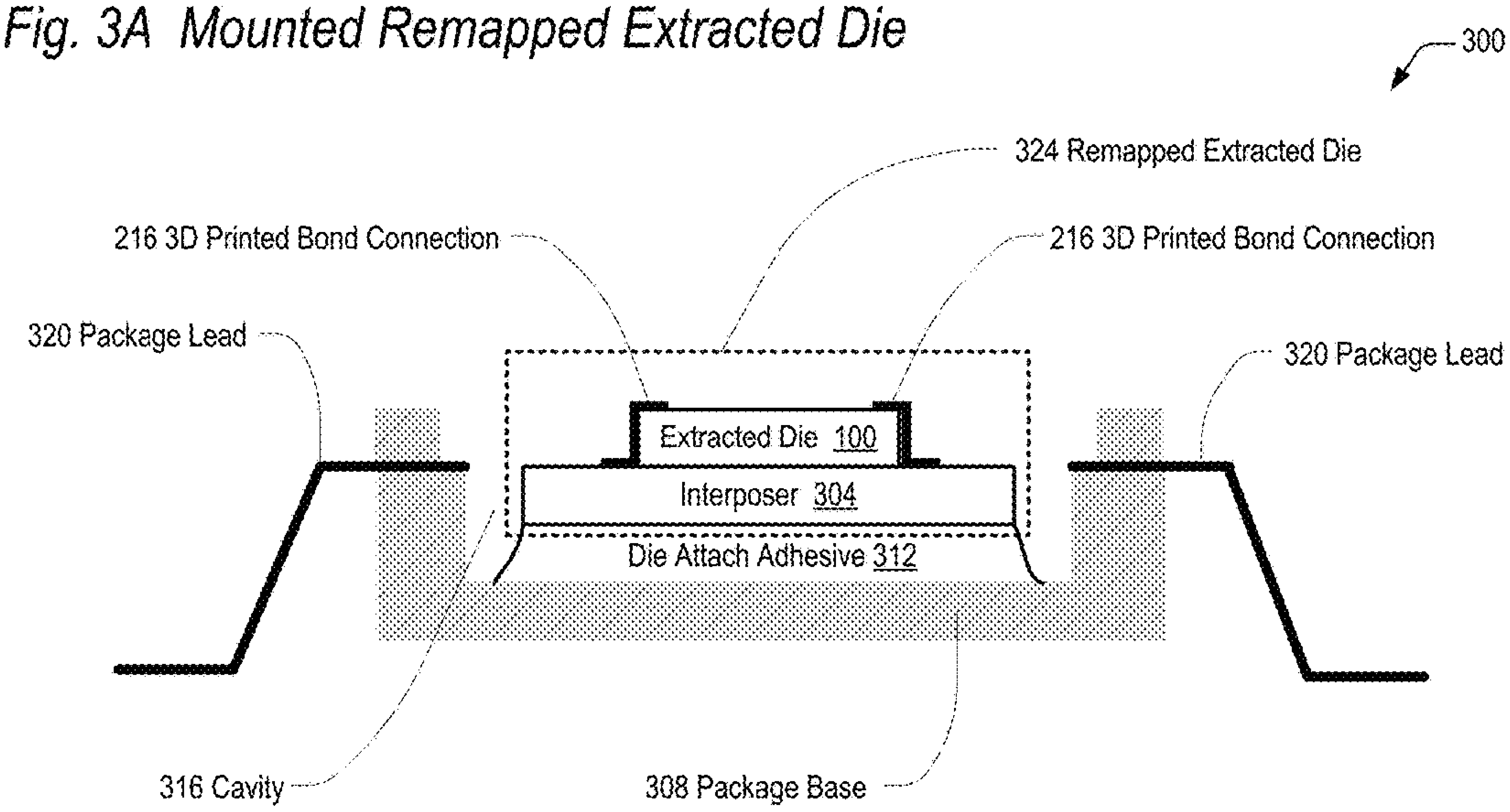


Fig. 3B Assembled Package Base With New 3D Printed Bond Connections

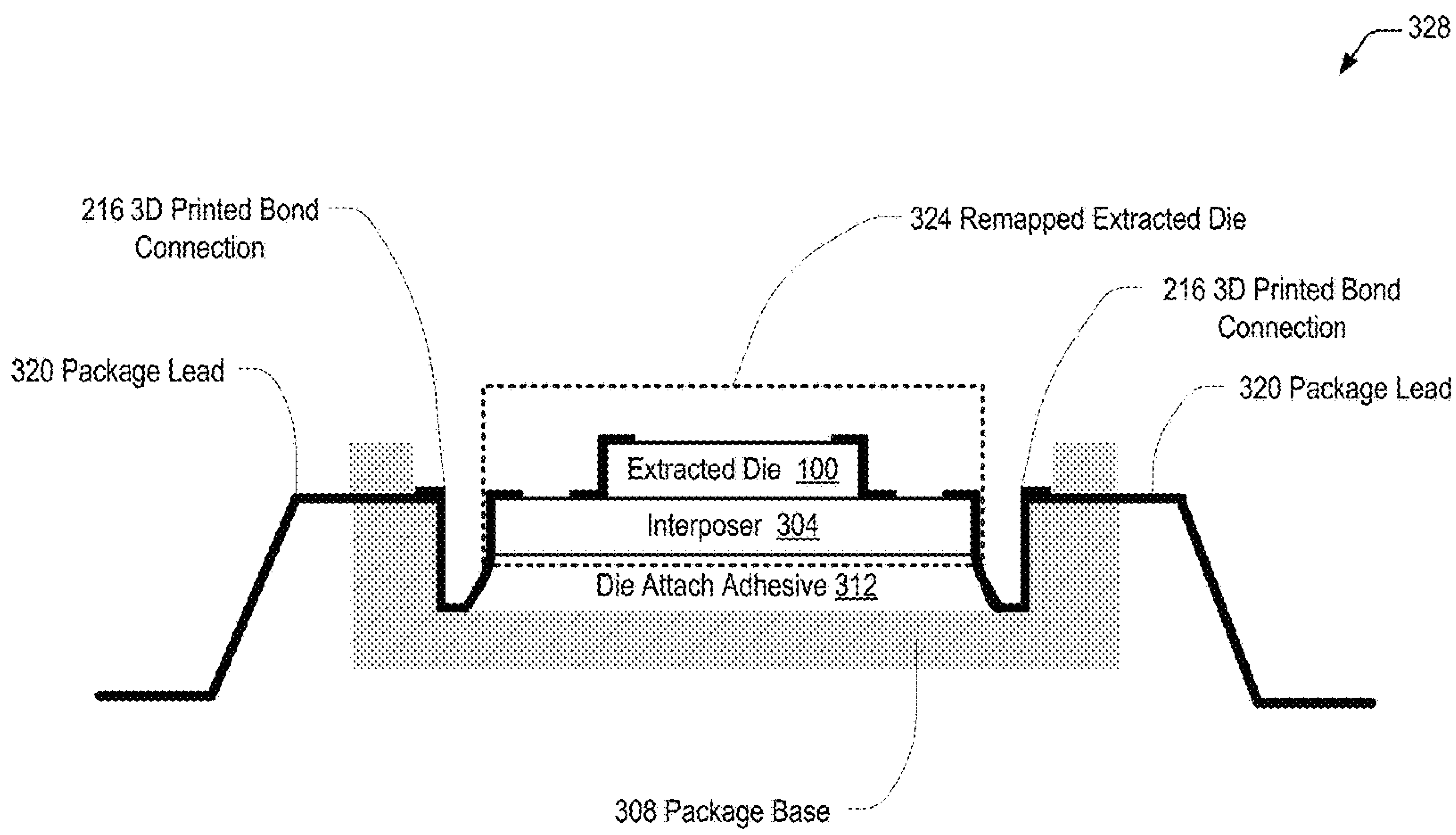


Fig. 3C Mounted Remapped Extracted Die

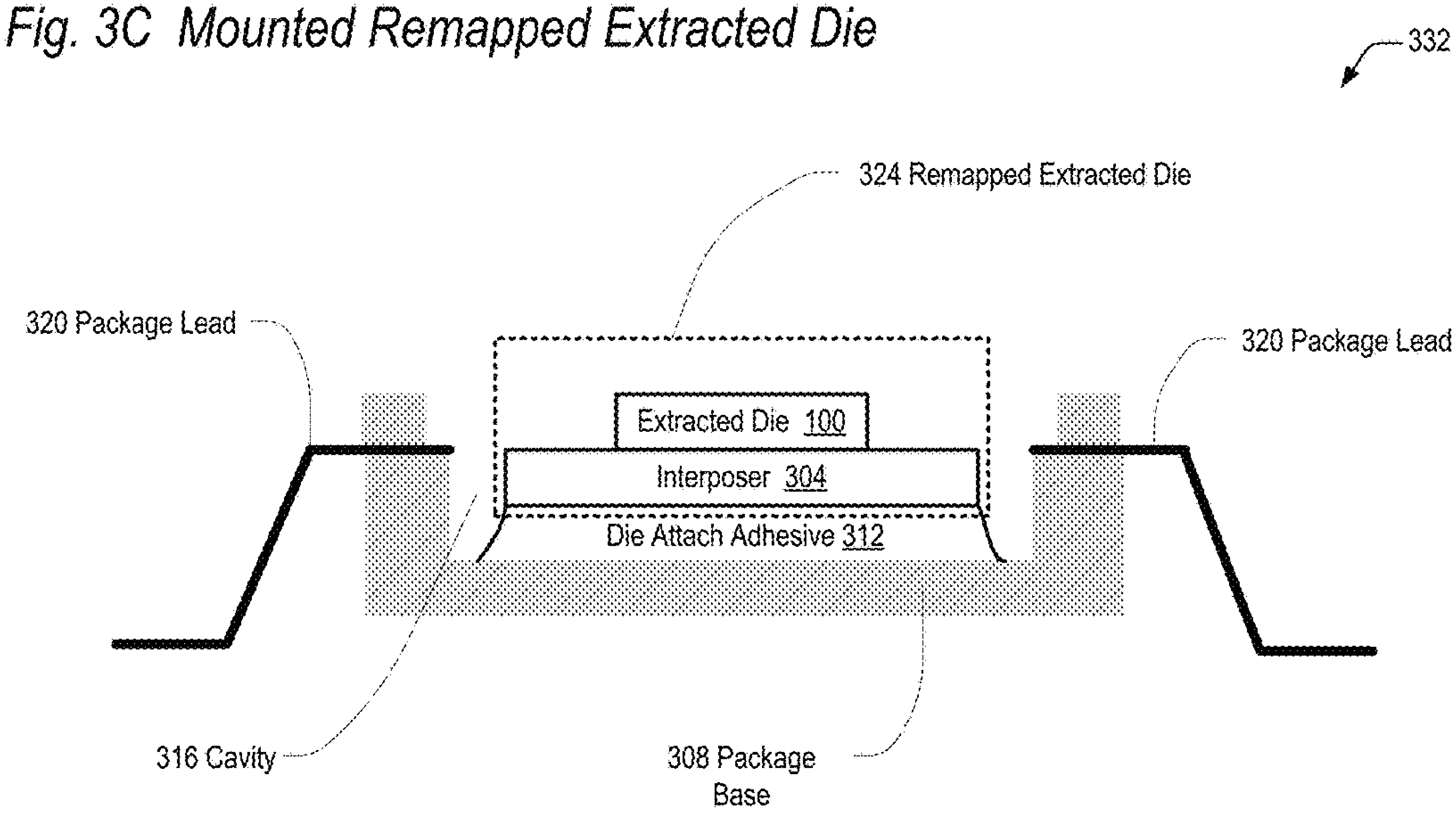


Fig. 3D Assembled Package Base With New 3D Printed Bond Connections

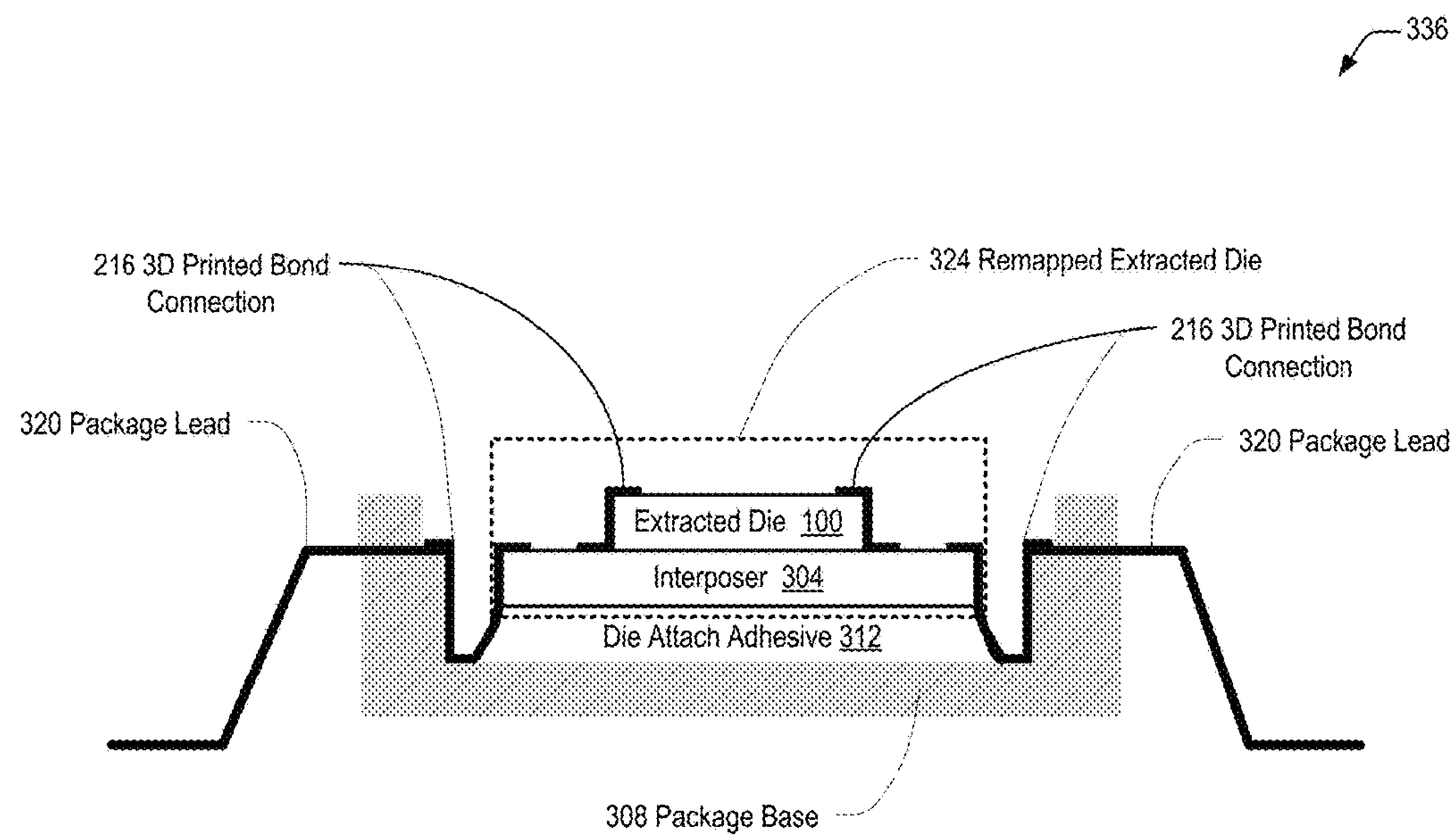


Fig. 3E Assembled Package With Remapped Extracted Die

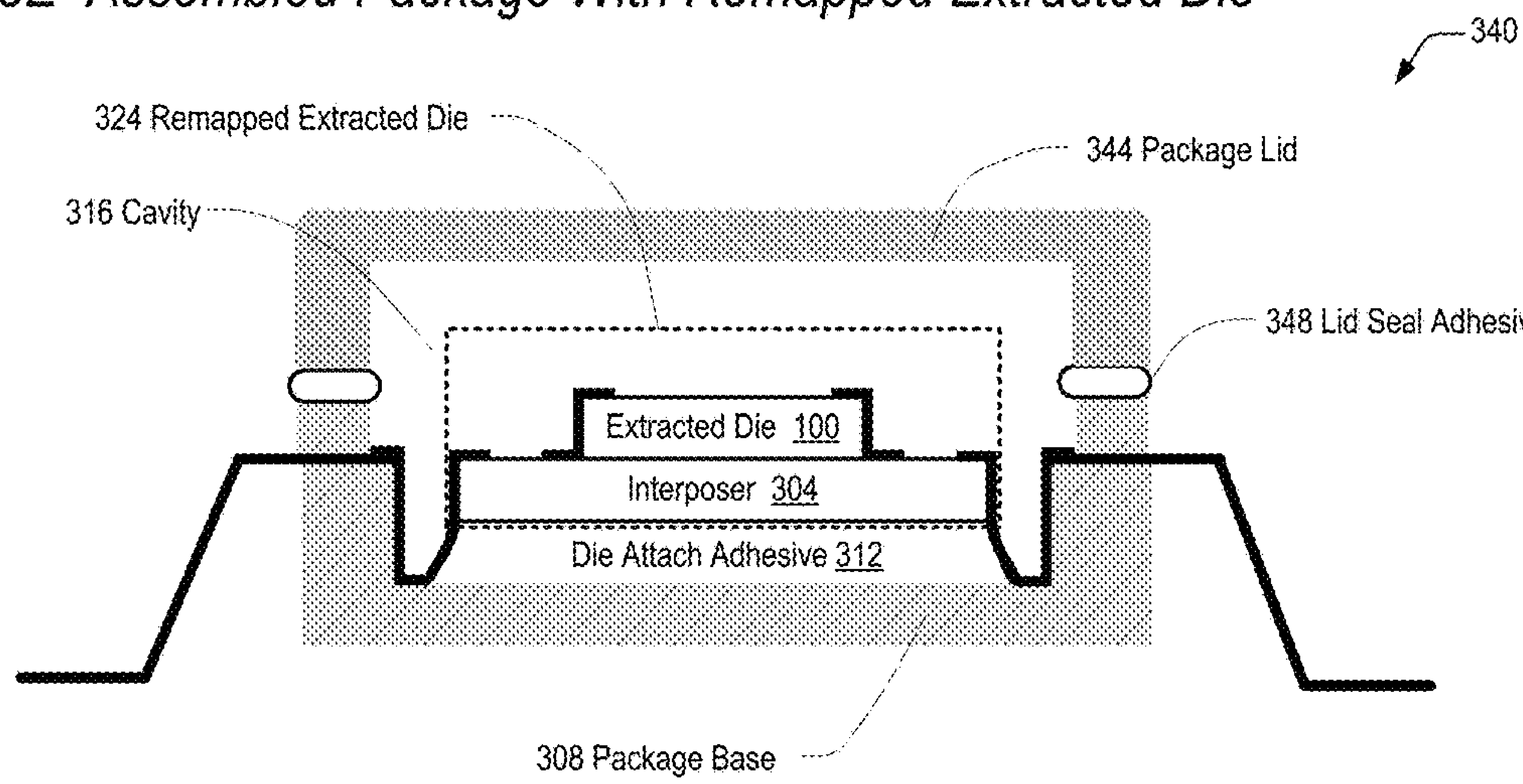


Fig. 3F Assembled Hermetic Package With Remapped Extracted Die

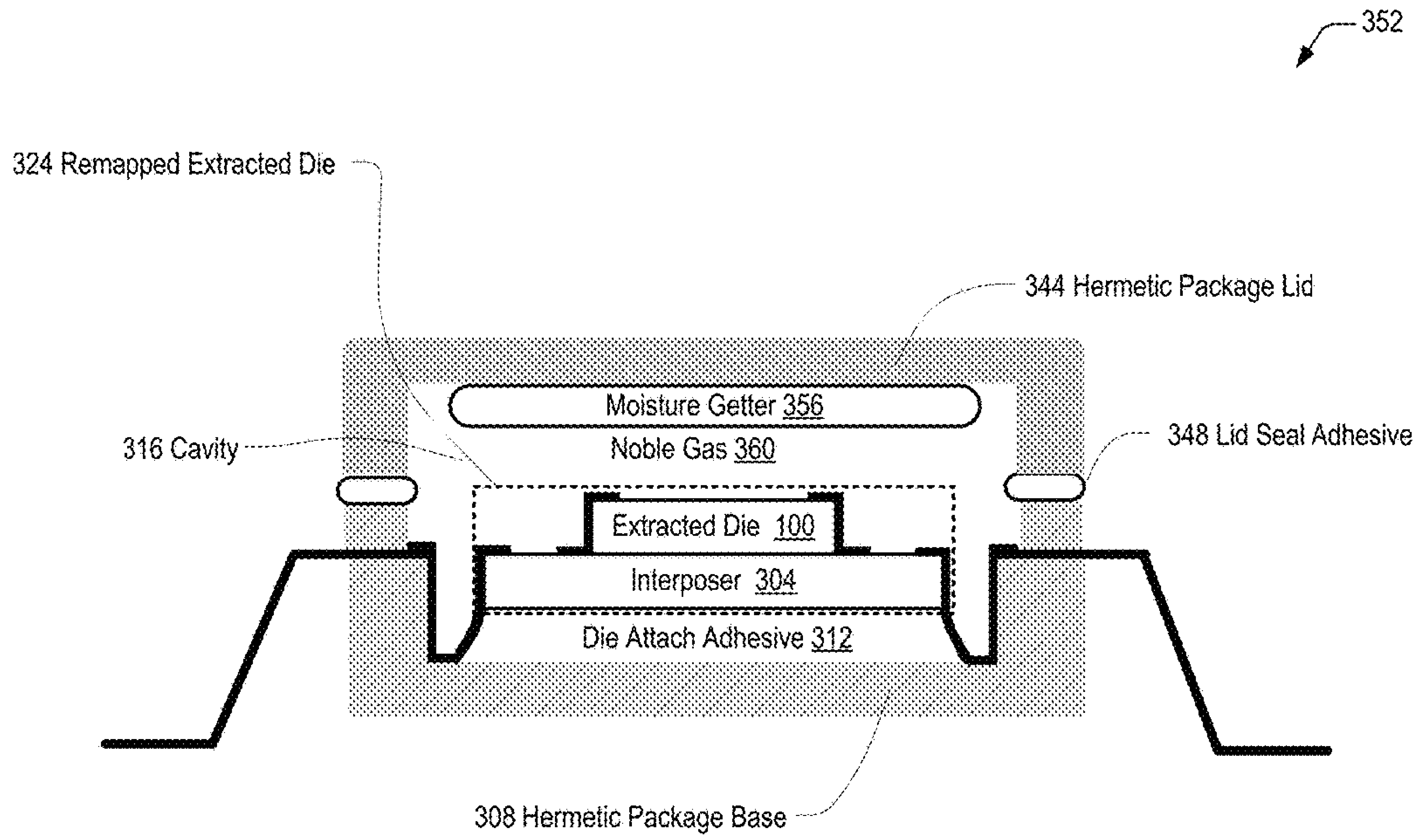


Fig. 4 Interposer for Extracted Die

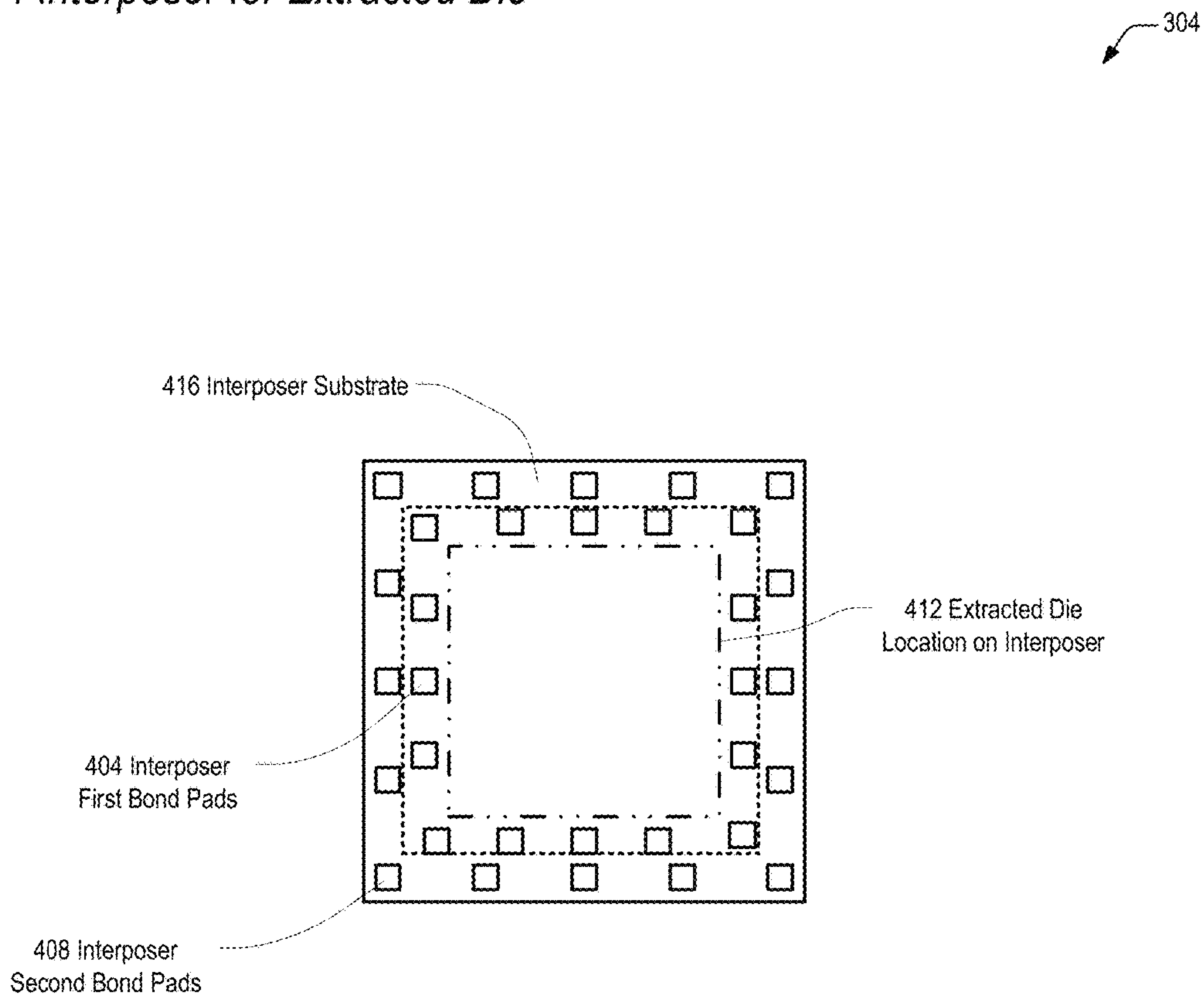


Fig. 5A Top View of New Package Base Before 3D Printing Bond Connections

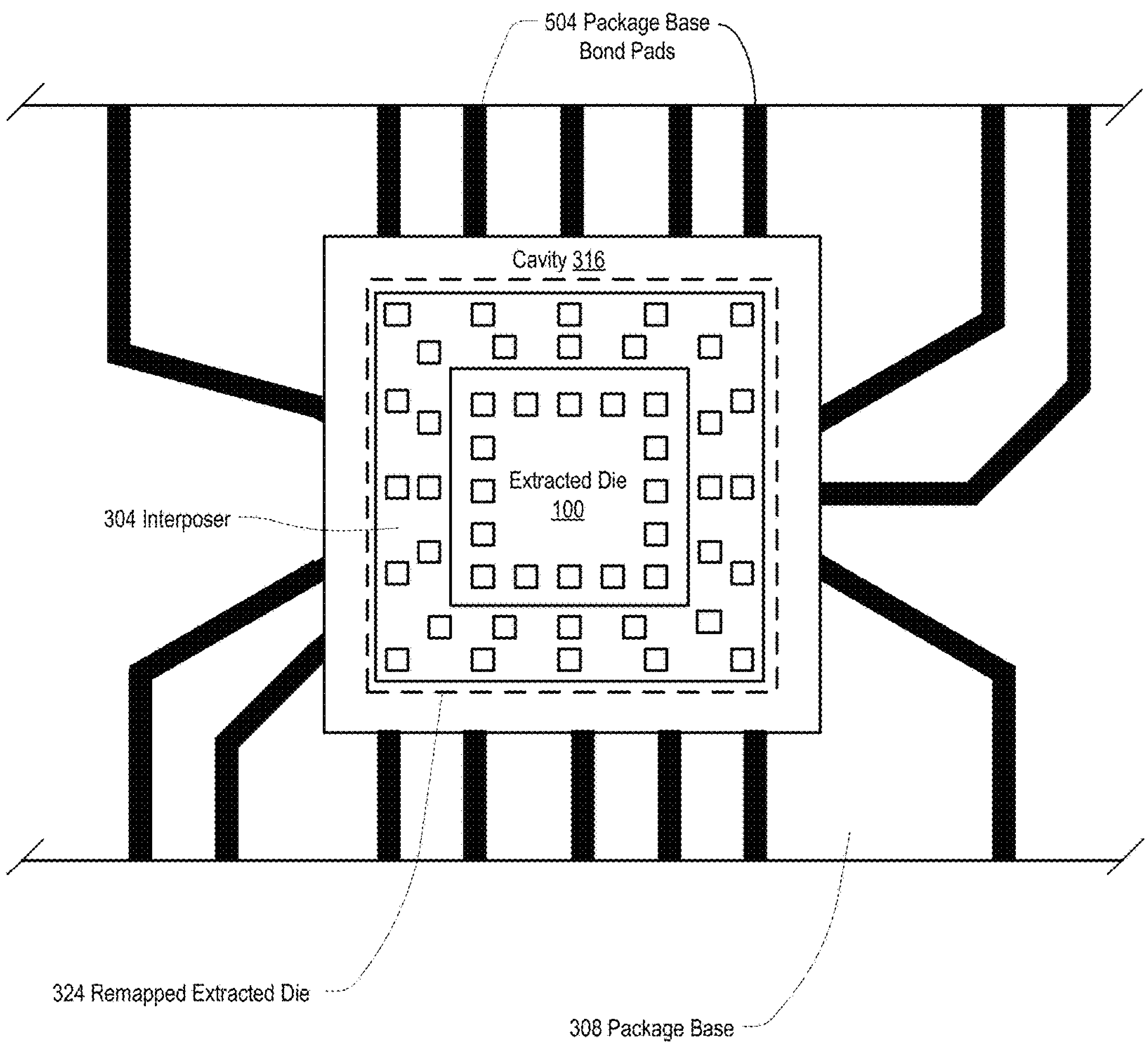


Fig. 5B Top View of New Package Base After 3D Printing Bond Connections

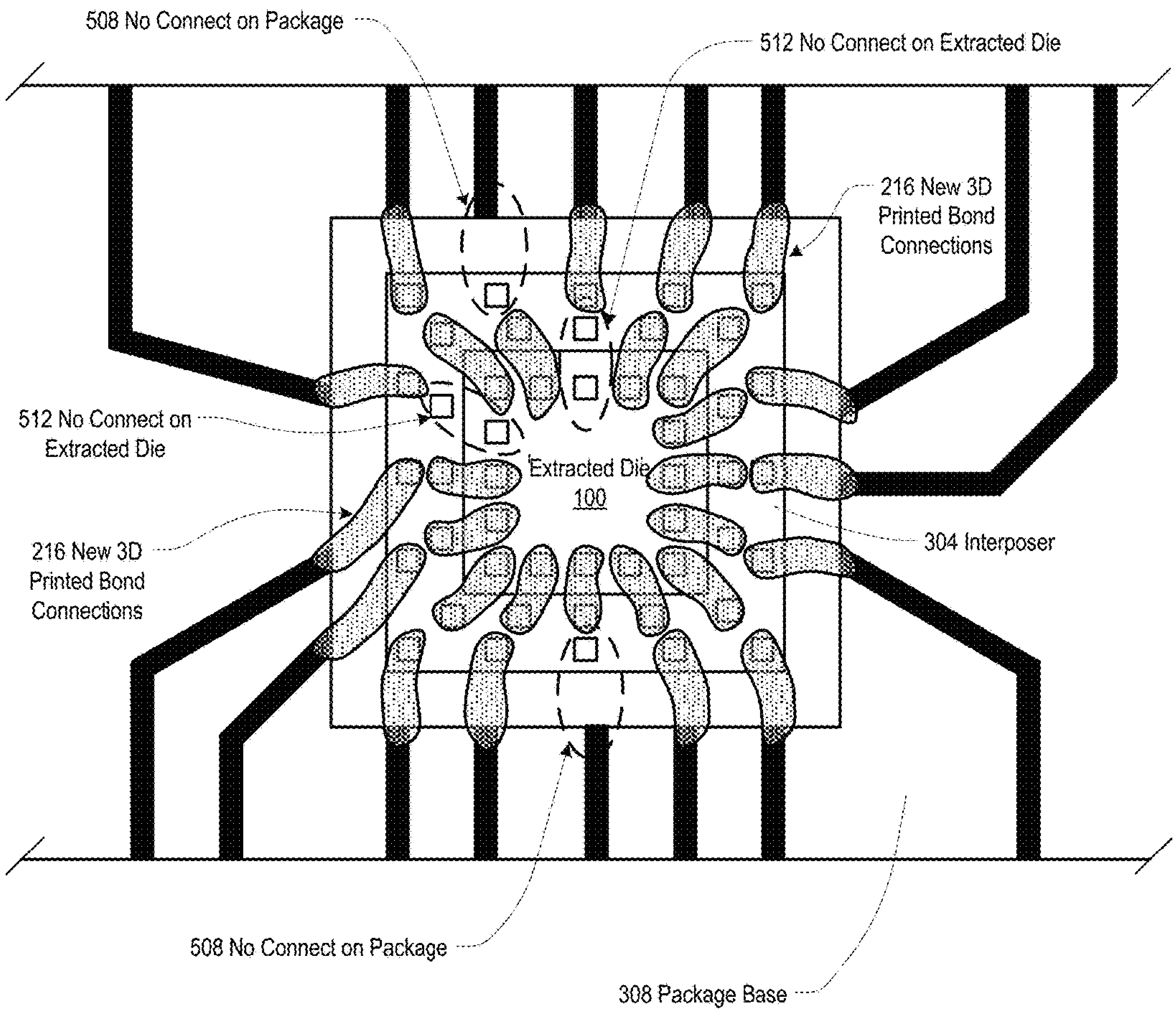


Fig. 5C Top View of New Package Base After 3D Printing Crossed Connections

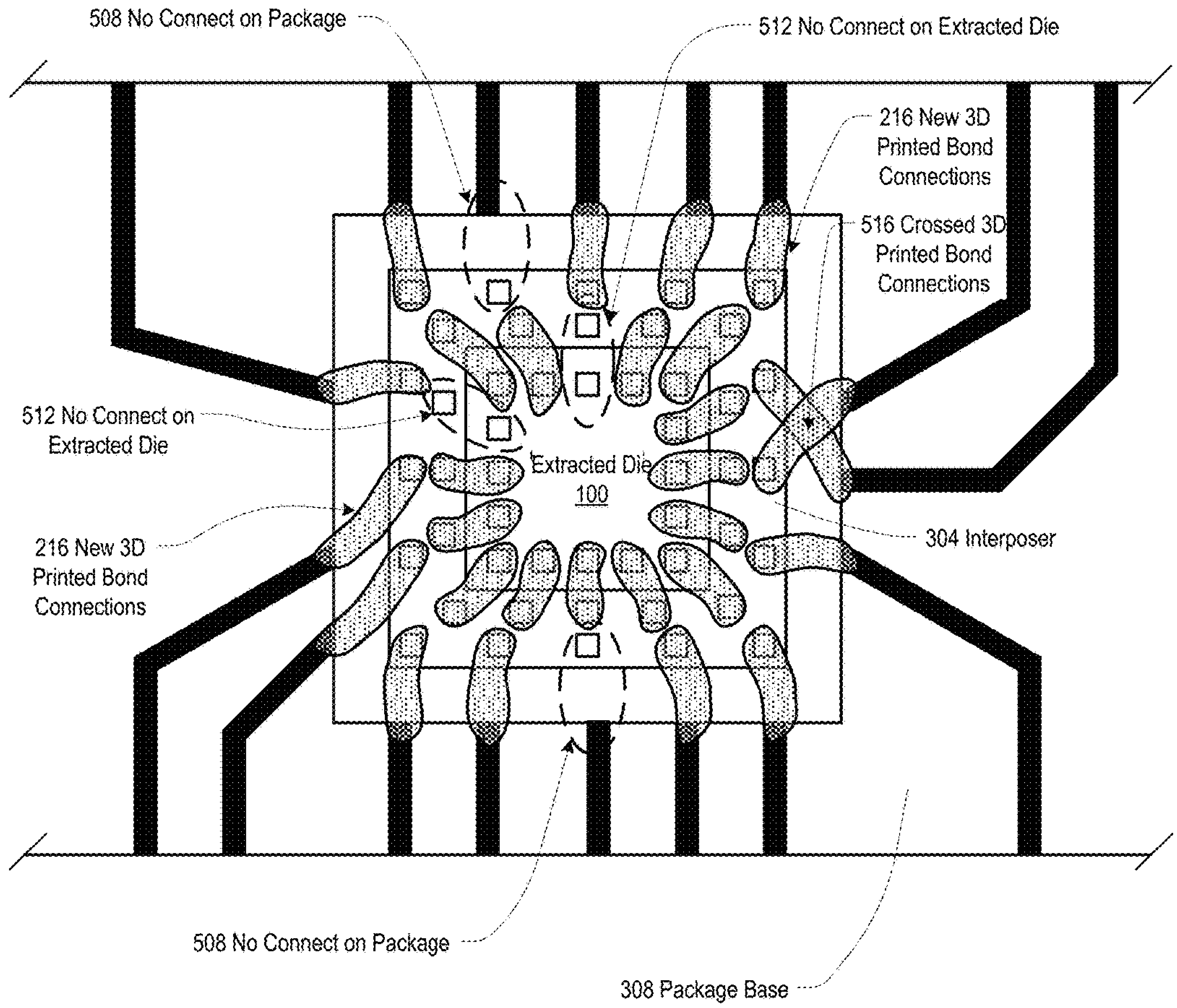


Fig. 6A Assembly Method for New Packaged Integrated Circuit

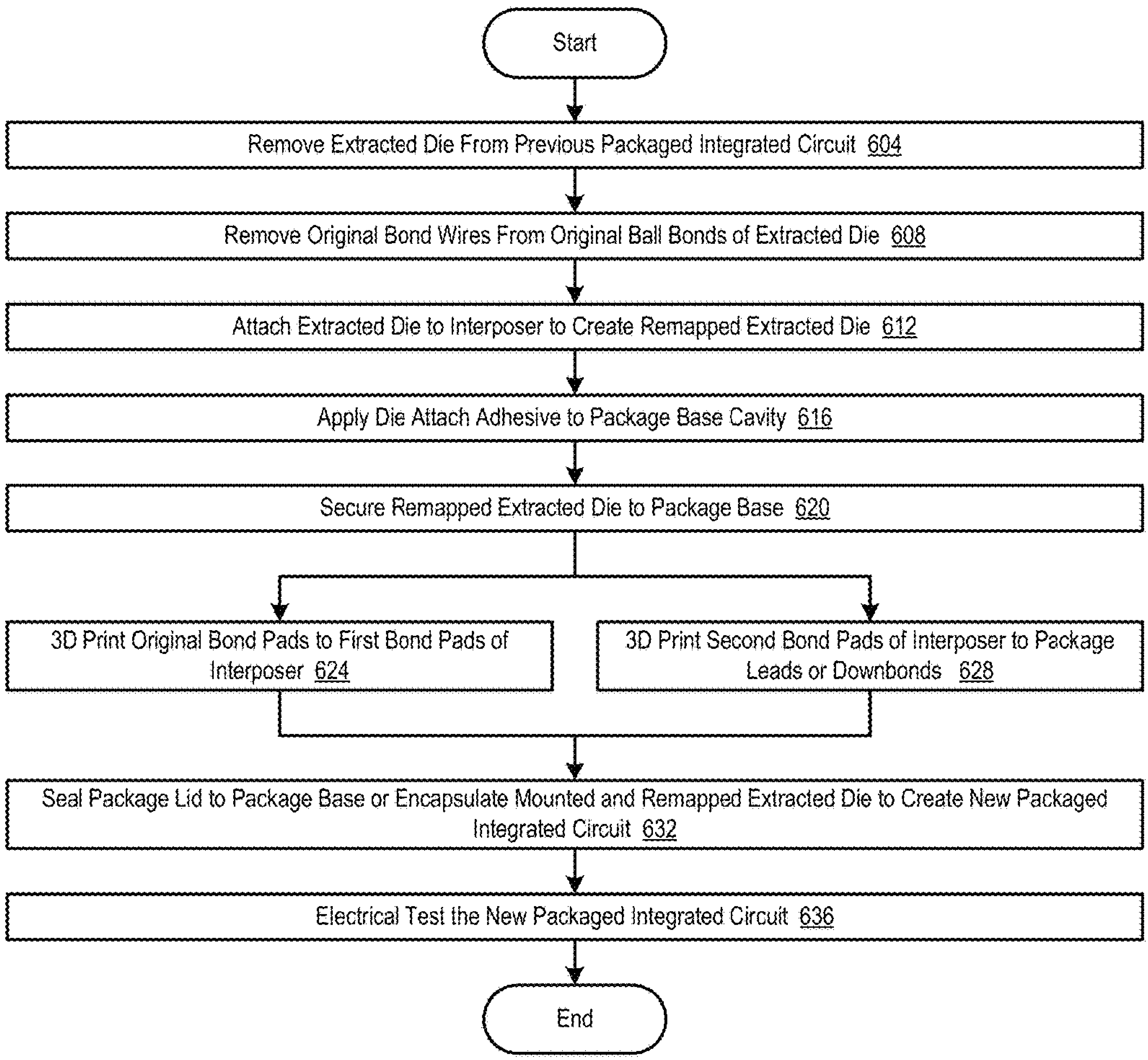


Fig. 6B Assembly Method for New Packaged Integrated Circuit

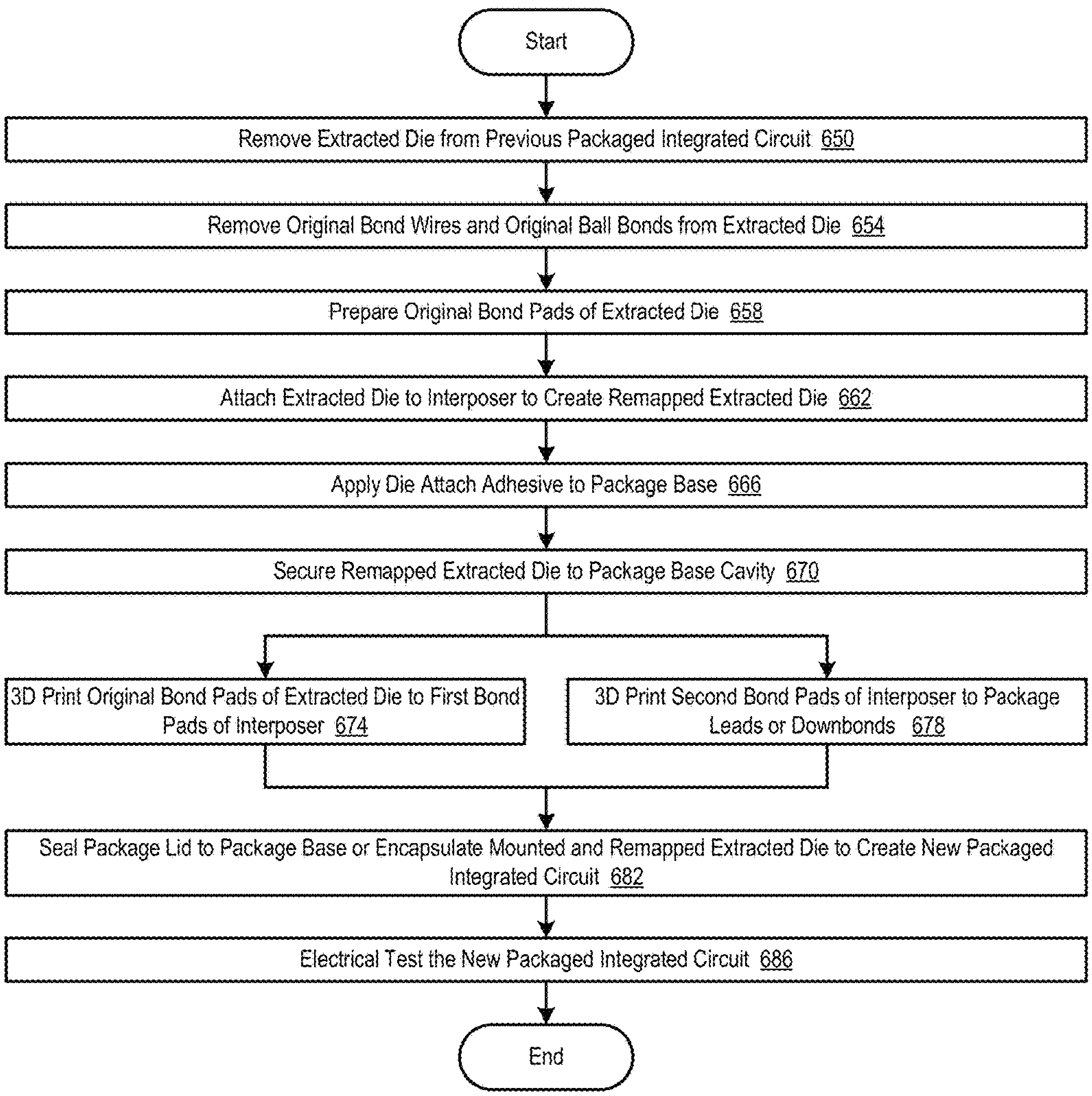


Fig. 7A Assembly Method for New Packaged Integrated Circuit

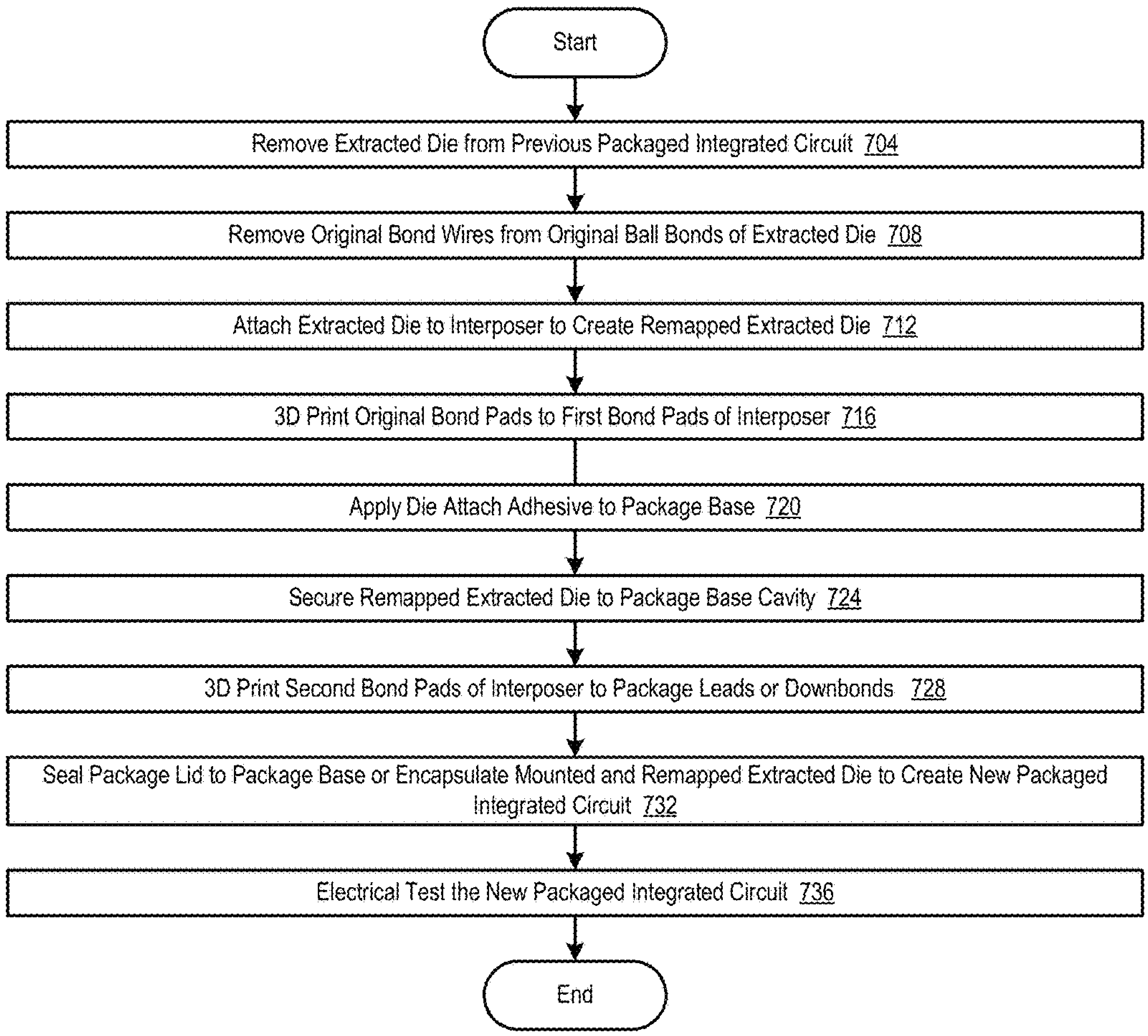


Fig. 7B Assembly Method for New Packaged Integrated Circuit

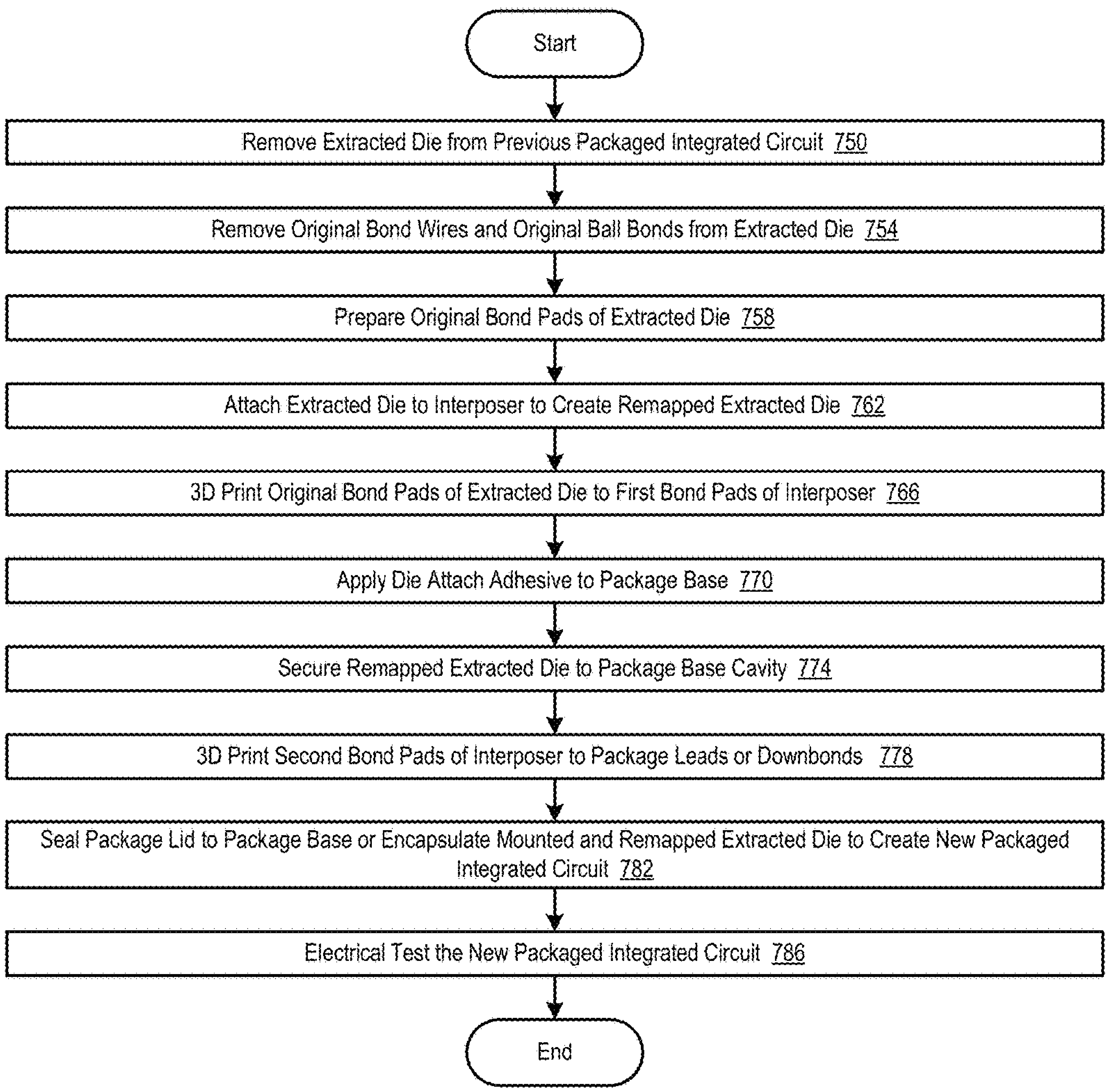


Fig. 8A Assembly Method for Hermetic Packaged Integrated Circuit

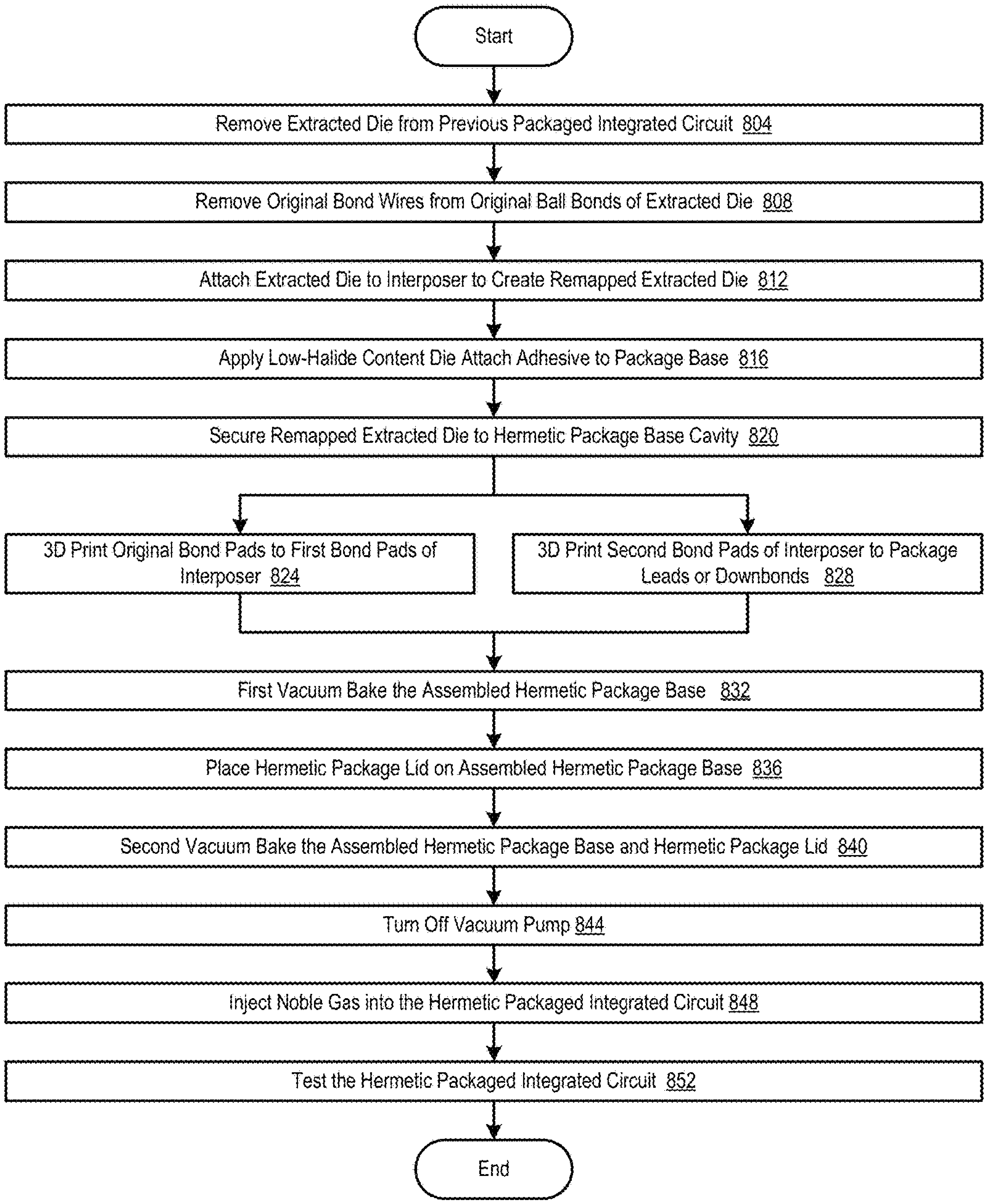


Fig. 8B Assembly Method for Hermetic Packaged Integrated Circuit

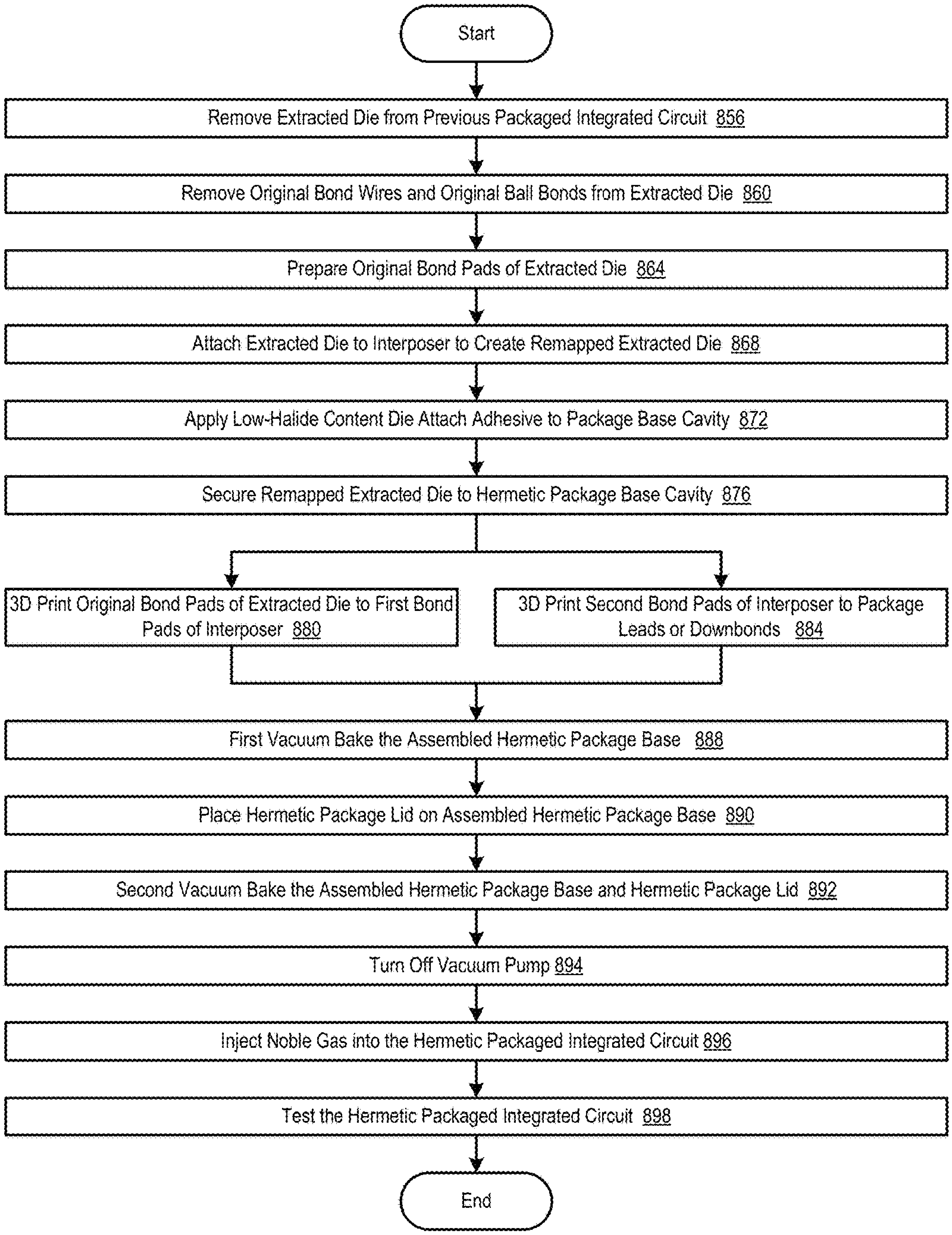


Fig. 9A Assembly Method for Hermetic Packaged Integrated Circuit

Fig. 9B Assembly Method for Hermetic Packaged Integrated Circuit

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

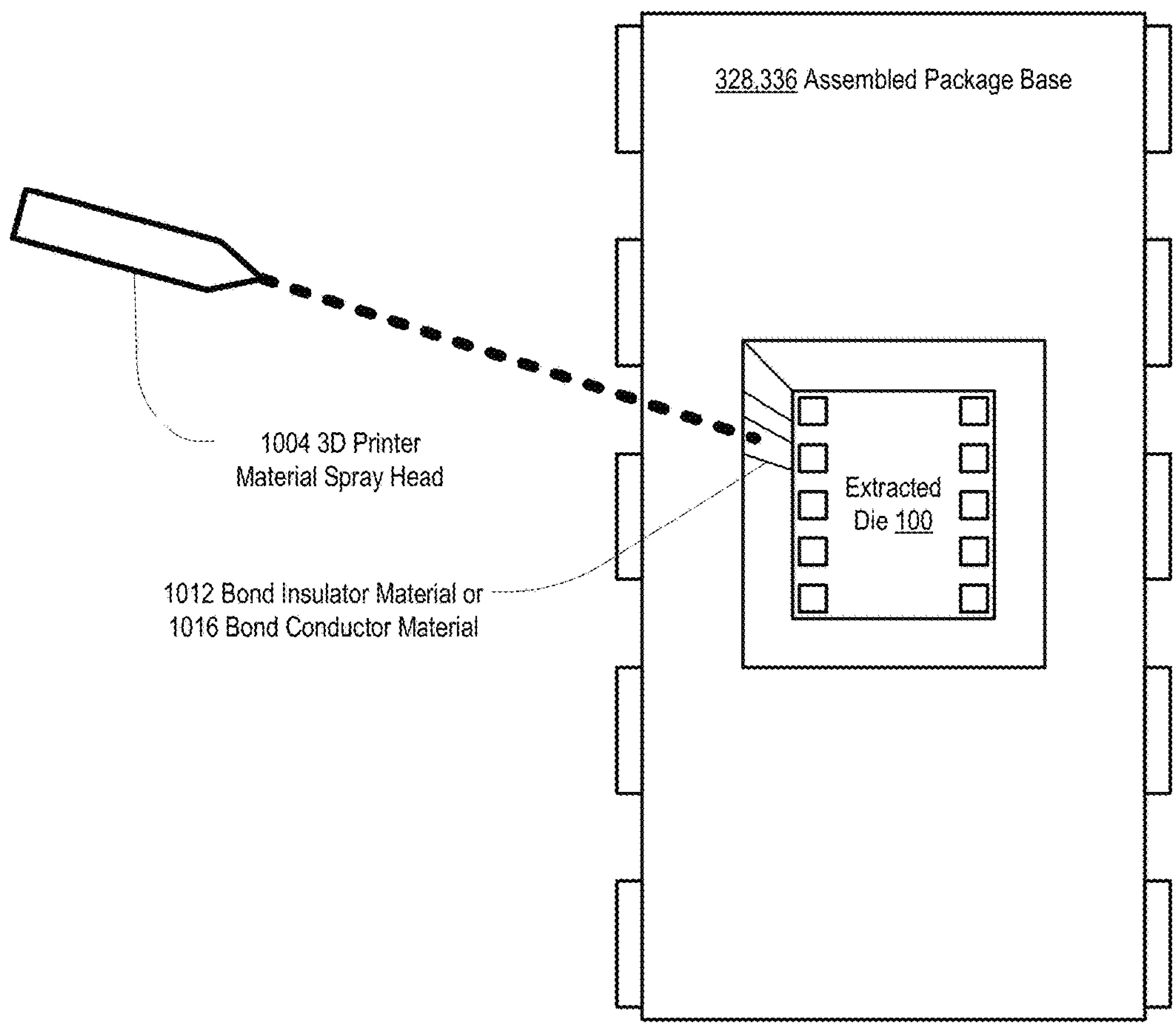
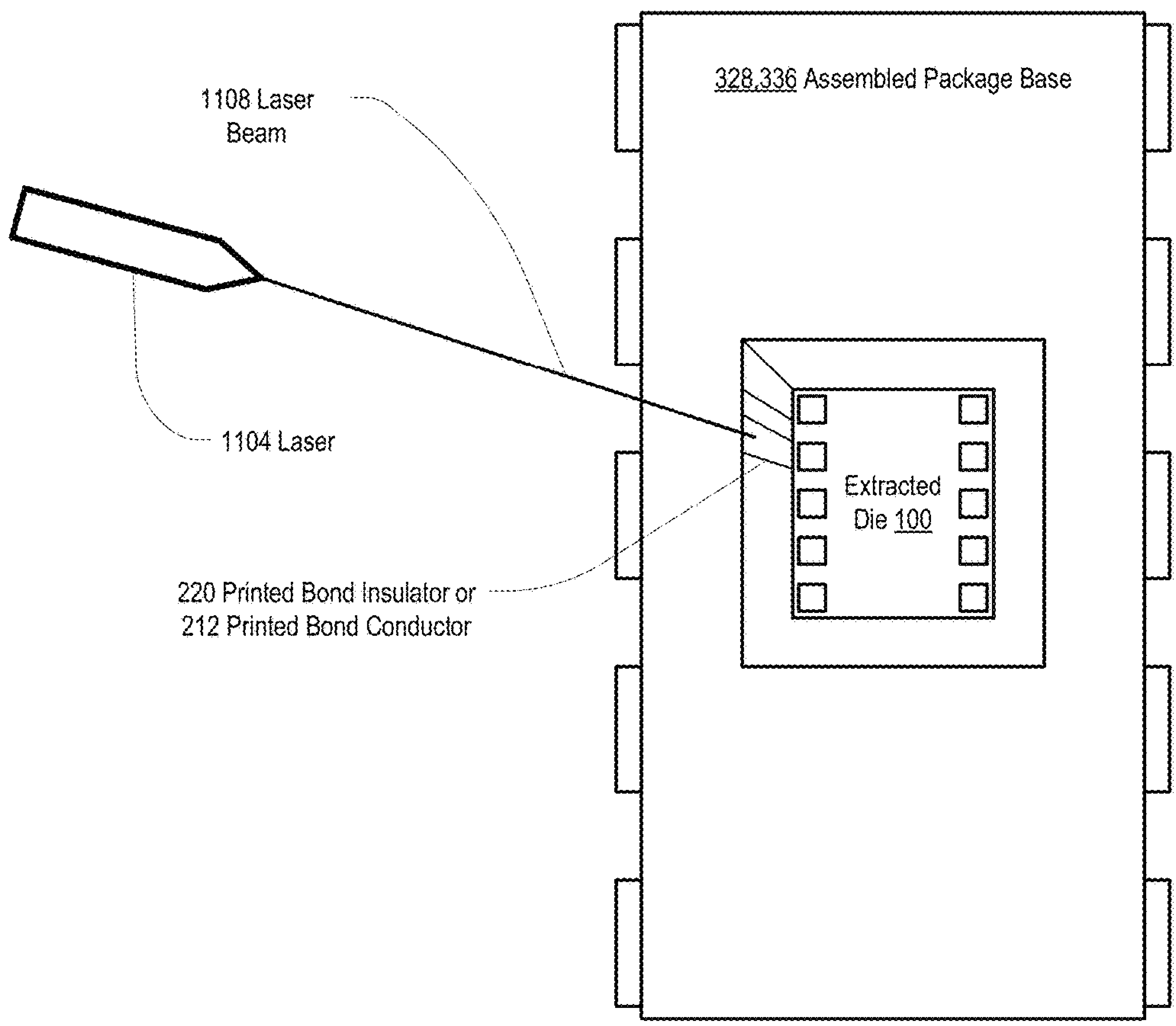


Fig. 11 Sintering Process to Form Printed Bond Insulator or Printed Bond Conductor



REMAPPED 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. 14/600,733, filed Jan. 20, 2015, entitled INTEGRATED CIRCUIT WITH PRINTED BOND CONNECTIONS, which is hereby incorporated by reference for all purposes, which is a Divisional of U.S. application Ser. No. 14/142,823, filed Dec. 28, 2013, entitled METHOD AND APPARATUS FOR PRINTING INTEGRATED CIRCUIT BOND CONNECTIONS, 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 remapped 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 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, an integrated circuit is provided. The integrated circuit includes a package base including package leads, an extracted die removed from a previous packaged integrated circuit, and an interposer bonded to the extracted die and the package base. The extracted die includes original bond pads and one or more original ball bonds on the original bond pads. The interposer includes first bond pads electrically connected to the original bond pads with 3D printed first bond connections conforming to the shapes and surfaces of the extracted die and the interposer and second bond pads electrically connected to the package leads with 3D printed second bond connections conforming to shapes and surfaces of the interposer and package base.

In accordance with another embodiment of the present invention, an integrated circuit is provided. The integrated circuit includes a package base including package leads, a reconditioned die including a modified extracted die with reconditioned bond pads, the modified extracted die including an extracted die with no ball bonds on original bond pads of the extracted die, the extracted die including a fully functional semiconductor die with one or more ball bonds on one or more original bond pads, the reconditioned bond pads comprising layers of nickel, palladium, and gold over the original bond pads. The integrated circuit also includes an interposer bonded to the reconditioned die and the package base. The interposer includes first bond pads electrically connected to the reconditioned bond pads with 3D printed first bond connections conforming to the shapes and surfaces of the reconditioned die and the interposer and second bond pads electrically connected to the package leads or downbonds with 3D printed second bond connections conforming to shapes and surfaces of the interposer and package base.

In accordance with further embodiments of the present invention, an integrated circuit is provided. The integrated circuit includes a package base including package leads, a modified extracted die removed from a previous packaged integrated circuit, and an interposer bonded to the extracted die and the package base. The modified extracted die includes an extracted die with original bond pads and no original ball bonds or bond wires on the original bond pads, while the extracted die has been removed from a previous packaged integrated circuit and includes one or more original ball bonds on the original bond pads. The interposer includes first bond pads electrically connected to the original bond pads with first 3D printed bond conductors conforming to the shapes and surfaces of the modified extracted die and the interposer, and second bond pads electrically connected to the package leads with second 3D printed bond conductors conforming to shapes and surfaces of the interposer and 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.

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

FIG. **2**B 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. **2**C 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. **2**D 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. **2**E 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. **3**A is an illustration depicting a mounted remapped extracted die in accordance with embodiments of the present invention.

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

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

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

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

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

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

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

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

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

FIG. **8**A 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. **8**B 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. **9**A 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. **9**B 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 or a 3D printed bond conductor 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 package 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. **2**A-**2**E to illustrate a side view of extracted die **100**.

Referring now to FIG. **2**A, 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. **2**B, a diagram illustrating a section A-A of a modified extracted die **224** 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. **2**B illustrates the original ball bond **112** and original bond wire **116** removed from the original bond pad **104**. Not shown in FIG. **2**B 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.

Once in a clean d 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. **2**C, 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. **2**D, 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. **2**E, 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. **3**A, 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 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. **3**B, 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. **3**B, when the remapped extracted die **324** was not secured to the package base **308**. Thus, FIG. **3**B reflects an assembly process where the previous step is as shown in FIG. **3**A.

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. **3**C, 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. **3**A, 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. **3**D, 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. **3**D has the same components as the assembled package base shown in FIG. **3**B. However, in FIG. **3**D 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. **3**D reflects an assembly process where the previous step is as shown in FIG. **3**C.

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. **3**E, 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. **3**E reflects an assembly process where the previous step is as shown in either FIG. **3**B or **3**D.

Referring now to FIG. **3**F, 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. **3**B and **3**D 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. **5**A, 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. **5**A reflects the same level of assembly as shown in FIG. **3**C.

Referring now to FIG. **5**B, 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. **5**B illustrates the same point in the assembly process as also shown in FIGS. **3**B and **3**D. 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. **5**B, 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. **5**B, 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. **5**C, 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. **5**C is similar to FIG. **5**B, 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. **6**A, 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**.

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. **6**B, 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**.

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**.

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 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**.

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. **8**A 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. **8**B, 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 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 **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. **8**B 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. **9**A, 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. **9**A 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. **9**B, 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**.

The process illustrated and described in FIG. **9**B 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**.

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.

We claim:

1. An integrated circuit, comprising:
- a package base comprising package leads;
- an extracted die removed from a previous packaged integrated circuit, comprising:
  - original bond pads; and
  - one or more original ball bonds on the original bond pads;
- layers of nickel, palladium, and gold over one or more original bond pads or the one or more original ball bonds;
- an interposer bonded to the extracted die and the package base, comprising:
  - first bond pads electrically connected to the original bond pads with 3D printed first bond connections conforming to the shapes and surfaces of the extracted die, the one or more original ball bonds, and the interposer; and
  - second bond pads electrically connected to the package leads with 3D printed second bond connections conforming to shapes and surfaces of the interposer and package base.

2. The integrated circuit 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, and the package base.

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

4. The integrated circuit of claim **2**, wherein each of the 3D printed bond insulators comprises a polymer material having elastomeric properties.

5. The integrated circuit 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.

6. The integrated circuit 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.

7. The integrated circuit of claim **1**, wherein after 3D printing the bond connections, there are no bond wires attached to the integrated circuit.

8. The integrated circuit of claim **1**, further comprising:
- one of a package lid secured to the package base or the integrated circuit encapsulated within an encapsulation compound to create a new packaged integrated circuit.

9. The integrated circuit 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.

10. An integrated circuit, comprising:
- a package base comprising package leads;
- a reconditioned die, comprising:
  - a modified extracted die with reconditioned bond pads, the modified extracted die comprising an extracted die with no ball bonds on original bond pads of the extracted die, the extracted die comprising a fully functional semiconductor die with one or more ball bonds on one or more original bond pads, the reconditioned bond pads comprising layers of nickel, palladium, and gold over the original bond pads;
- an interposer bonded to the reconditioned die and the package base, comprising:
  - first bond pads electrically connected to the original bond pads with 3D printed first bond connections

conforming to the shapes and surfaces of the reconditioned die and the interposer; and

second bond pads electrically connected to the package leads or downbonds with 3D printed second bond connections conforming to shapes and surfaces of the interposer and package base, 3D printed first and second bond connections each comprising 3D printed bond conductors, comprising a compound comprising an elastomeric material and at least one of gold, aluminum, or copper.

11. The integrated circuit of claim **10**, wherein the nickel layer being in direct contact with the original bond pads, the palladium layer between the nickel and gold layers, and the gold layer over the palladium layer.

12. The integrated circuit of claim **10**, wherein at least one 3D printed first or second bond connection comprises a 3D printed bond conductor applied over a 3D printed bond insulator.

13. The integrated circuit of claim **12**, 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, a die attach adhesive between the interposer and package base, the interposer, and areas of the extracted die other than an original bond pad.

14. The integrated circuit of claim **12**, wherein the 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.

15. The integrated circuit of claim **10**, further comprising:

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

16. The integrated circuit of claim **15**, wherein the interposer comprises a substrate comprising a plurality of first and second bond pads and predetermined interconnections between the plurality of first and second bond pads.

17. An integrated circuit, comprising:

a package base comprising package leads;

a modified extracted die, comprising original bond pads and no original ball bonds or bond wires on the original bond pads, comprising:

an extracted die removed from a previous packaged integrated circuit, comprising:

one or more original ball bonds on the original bond pads;

layers of nickel, palladium, and gold over one or more original bond pads;

an interposer bonded to the modified extracted die and the package base, comprising:

first bond pads electrically connected to the original bond pads with first 3D printed bond conductors conforming to the shapes and surfaces of the modified extracted die and the interposer; and

second bond pads electrically connected to the package leads with second 3D printed bond conductors conforming to shapes and surfaces of the interposer and package base.

18. The integrated circuit of claim **17**, further comprising:

at least one 3D printed bond insulator preventing electrical conduction between a 3D printed bond conductor and at least one of the modified extracted die, interposer, and package base, wherein the at least one 3D printed bond insulator separates the 3D printed bond conductors from conductive surfaces of the modified extracted die, interposer, package base, or other 3D printed bond conductors.

19. The integrated circuit of claim **18**, 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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