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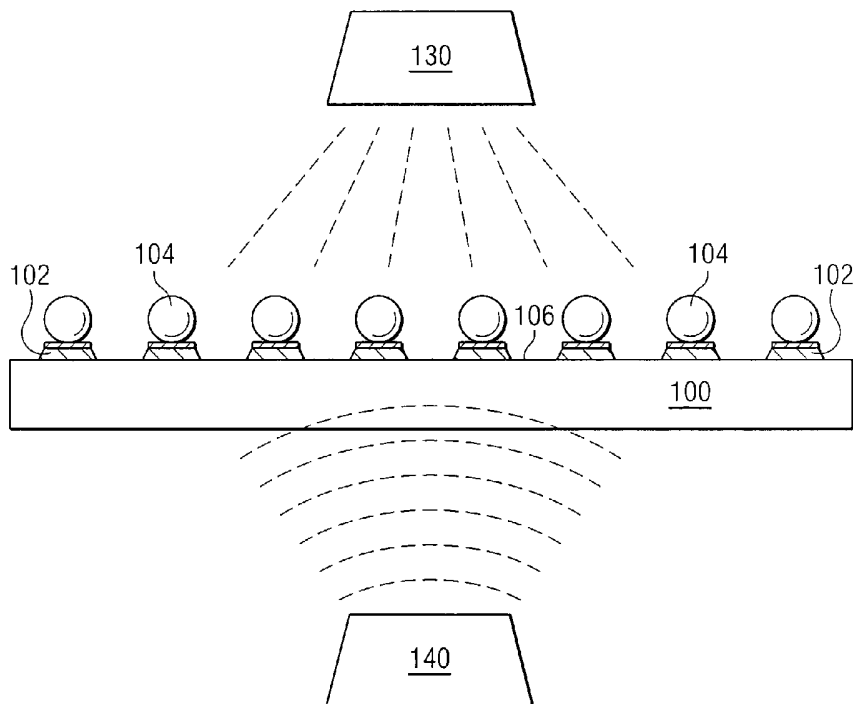
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- as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))
- as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii))

[Continued on next page]

(54) Title: ULTRASONIC AGITATION OF SOLDER DURING REFLOW



(57) Abstract: A solder bump 104 is formed by providing solder material on a conductive site 102 of a substrate 100. The solder material is reflowed to provide a solder bump on the substrate. The solder material is ultrasonically agitated during at least a part of the reflow to at least partially mitigate formation of voids in the solder bump.

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ULTRASONIC AGITATION OF SOLDER DURING REFLOW

The present invention relates generally to electronic device packaging; and, more particularly, to methods and apparatus for reflowing solder material on a substrate.

BACKGROUND

5 Modern electronics utilize numerous integrated circuits. These integrated circuits can often be electrically connected to each other or to other electronic components. One method of connecting integrated circuits to electronic components utilizes an area array electronic package, such as a ball-grid array (BGA) package or a flip-chip package. With BGA packages, various input and output ports of an integrated circuit are typically connected by
10 wire bonds to contact pads of the BGA package. Solder bumps formed on the contact pads of the BGA package are used to complete the connection to another electronic component, such as a printed circuit board (PCB).

Solder bumps can be formed using methods, such as printing of solder paste through a stencil or mask, electroplating, evaporation, and mechanical transfer of preformed solder
15 ball or spheres. While electroplating, printing of solder paste through a stencil or mask, and evaporation techniques have been typically utilized for forming solder bumps on integrated circuits, BGAs have commonly utilized printing of solder paste and mechanical transfer of preformed solder balls to form solder bumps. The solder paste and solder balls transferred to contact pads can then be thermally reflowed to form the solder bumps, which are
20 metallurgically bonded to the contact pads.

The reflowing solder process can potentially cause the introduction of gas bubbles or gas pockets within the solder itself. These gas bubbles or gas pockets can remain trapped in the solder and form defects, such as voids or cracks, once the solder hardens. Such defects are undesirable in a solder bump because they act as both electrical and thermal insulators
25 and thereby increase both the electrical impedance and thermal impedance of the solder bump.

SUMMARY

The present invention relates to methods and apparatus for forming a plurality of solder bumps arrayed on conductive sites of a surface of a substrate.

30 Described methods include forming solder bumps on the contact pads of the substrate by providing portions of solder material on each of the contacts pads and then reflowing the

solder material to bond the solder material to the contact pads. The solder material can include preformed solder balls that are adhered to the contact pads with solder flux or solder paste. Alternatively, the solder material can comprise a solder paste. During at least part of the reflow, the solder material is ultrasonically agitated to reduce the formation of voids in the solder bumps. Ultrasonic agitation of the solder material during the reflow can at least partially mitigate entrapment of gas bubbles or gas pockets and formation of voids or cracks when the solder hardens. Solder bumps that have a reduced number of voids have improved electrical and thermal properties compared with solder bumps that have more voids.

Described apparatus includes a conveyor for moving a substrate having solder material on a conductive site of the substrate; a heater configured and adapted for reflowing the solder material to provide a solder bump on the substrate as the solder is moved by the conveyor; and an agitator configured and adapted for ultrasonically agitating the solder material during at least a part of the reflow. In an embodiment, the agitator is configured and adapted to ultrasonically vibrate the conveyor, and the conveyor is configured and adapted to ultrasonically vibrate the substrate when so vibrated by the agitator.

BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing and other aspects of the present invention will become apparent to those skilled in the art to which the present invention relates upon reading the following description with reference to the accompanying drawings, wherein:

FIG. 1 is a schematic cross-section view of a substrate with a plurality of contact pads to which has been attached solder balls in accordance with an example embodiment of the present invention;

FIG. 2 is a schematic cross-section view of the substrate of FIG. 1 during a reflow process;

FIG. 3 is a schematic cross-section view of the structure of FIG. 2 after the solder balls have been reflowed to form solder bumps;

FIG. 4 is a schematic cross-section view of a substrate with a plurality of contact pads to which has been attached portions of solder paste in accordance with another example embodiment of the present invention;

FIG. 5 is a schematic cross-section view of the substrate of FIG. 2 during a reflow process; and

FIG. 6 is a schematic view of an example reflow system that can perform the reflow process in accordance with an aspect of the invention.

DETAILED DESCRIPTION OF EXAMPLE EMBODIMENTS

Principles of the invention are described in the context of example embodiments of an improved method for forming a plurality of solder bumps arrayed on conductive sites of a surface of a substrate. The term "substrate" is used in a broad generic sense herein to include any semiconductor device, including a wafer or a packaged or unpackaged bare die, as well as traditional substrates used in the formation of ball grid array (BGA) packages. The method of the present invention can be applied to the formation of solder bumps on any conductive site, whether the conductive site (e.g., a contact pad) projects from the substrate or is recessed therein. The terms "conductive site" and "contact pad" are used interchangeably herein to denote any site at which a solder bump can be formed.

FIGS. 1 - 3 illustrate an example method of forming a plurality of conductive solder bumps on a ball grid array package in accordance with the invention. In the method, the plurality of solder bumps are formed from a plurality of preformed solder balls that are provided on the surface of the substrate.

Referring to FIG. 1, a substrate 100 of a ball grid array package is provided having a plurality of exposed contact pads 102 to which preformed solder balls 104 are attached. The substrate 100 need not be restricted to a specific material. The substrate 100 can comprise a substantially planar sheet of insulative material, such as fiberglass (e.g., flame retardant fiberglass composite substrate board), polyimide tape (e.g., bismaleimide-triazine resin (BT-resin)), or ceramic. Alternatively, the substrate 100 can comprise a layer on a semiconductor die, such as silicon oxide (SiO), silicon nitride (Si₃N₄), polyimide, silicon dioxide (SiO₂), or some other insulative material formed on a die. It will be appreciated that other materials can be used to form the substrate 100.

The contact pads 102 can comprise a material that will form a metallurgical bond with the particular type of solder balls 104 which are attached. The contacts pad 102 can also be electrically connected to conductive vias or conductive traces that are formed either in or on the substrate 100. In one aspect of the invention, the contact pads 102 can be formed from a metal, for example copper, copper alloy, aluminum, aluminum alloy, tungsten, tungsten alloy, gold, silver, nickel, tin, platinum, iridium, or combinations of the foregoing. The

contact pads 102 can be formed, for example, by depositing (e.g., CVD, electroless and electrolytic plating, and evaporation techniques) or laminating a layer metal on a surface 106 of the substrate 100. The contact pads 104 can then be defined by patterning (e.g., lithography techniques) the metal layer and etching the metal layer. It will be appreciated that other methods can be used to form the contact pads 102. Moreover, it will be appreciated that, although the contacts pads 102 are illustrated as projecting from a surface 106 of the substrate 100, the contact pads 102 can be recessed in the surface 106.

The solder balls 104 are adhered to surfaces 112 of the respective contact pads 102 using a solder flux 114. The solder balls 104 are substantially spherical and can have a diameter of, for example, about 0.3 mm to about 1.0 mm. Although the solder balls 104 are illustrated as being substantially spherical, the solder balls 104 can have various forms, such as semispherical, half-dome, and truncated cone. The materials used to form the solder balls 104 can include alloys of lead, tin, indium or silver (e.g., 90/10 SnPb, 63/37 SnPb, and 63/34.5/2/0.5 Sn/Pb/Ag/Sb solder). It will be appreciated that other materials can also be used.

The solder flux 114 maintains the solder balls 104 in position on the surfaces 112 of the contact pads 102 before and during reflow or other processing of the solder balls 104 and the substrate 100. The solder flux 114 also cleans and prepares the surfaces 112 of the contact pads 102 so that a substantially metallurgical bond can be formed between the solder balls 104 and the contact pads 102. The solder flux 114 can include any type of flux commonly used in solder ball connection in semiconductor processing. Examples of solder fluxes that can be used include rosin based fluxes (R-type), rosin mildly activated fluxes (RMA-type), rosin super activated fluxes (RSA-type) water-soluble type fluxes, and no-clean type fluxes. It will be appreciated that other flux chemistry systems can also be used and are within the scope of the invention.

The solder flux 114 can be provided directly on the contact pads 102 prior to placement of the solder balls 104 on the contact pads 102. For example, in one method, the solder flux 114 can be placed on the contact pads 102 using a stamping system. In another method, the solder flux 114 can be placed on the contact pads 102 using screen printing system. It will be appreciated that other methods can be used to place the solder flux 114 on the contact pads 102 prior to placing the solder balls 104.

Following placement of the solder flux 114 on the contact pads 102, the solder balls can be placed on the contact pads using various solder ball placement techniques. For example, in one technique, a pick-up tool having a plurality of solder ball receiving cavities configured to match the arrangement of contact pads 102 on the substrate 100 can be used to position the solder balls 104 on the contact pads 102. It will be appreciated that other methods of placing the solder balls 104 on the contact pads can be used, such as screening the solder balls 104 through apertures of a template aligned over the contact pads 102 or aligning the solder balls 104 on an adhesive tape to correspond with the contact pads 102 and pressing the adhesive tape to the substrate 100. It will be further appreciated that the solder flux 114 can be provided on the solder balls 104 prior to placement of the solder balls 104 on the contact pads 102.

FIG. 2 illustrates the solder balls 104 undergoing a reflow process. During the reflow process the solder balls 104 are heated in an inert atmosphere by a heater 130 to at least partially melt the solder balls 104 and wet the contact pads 102. The inert atmosphere prevents oxidation and corrosion of the solder balls 104 during reflow. The inert atmosphere can comprise an inert gas, such as nitrogen gas (N_2). It will be appreciated, however, that other inert gases (e.g., Ar) as well as forming gas can also be used. By way of example, the heater 130 can include a halogen lamp that irradiates the solder balls 104 with infrared radiation to cause the solder balls 104 to at least partially melt and wet the contact pads 102. Alternatively, the heater 130 can include a convection heater that heats the solder balls 104 with a heated gas to allow the solder balls 104 to at least partially melt and wet the contact pads 102. It will also be appreciated that the both infrared and convection heating can be used heat solder balls 104, as well as other heating means.

The solder balls 104 can be heated by the heater 130 from a first temperature to a peak temperature. The first temperature is typically about room temperature (e.g., about 25°C) and the peak temperature is a temperature substantially higher than the first temperature and above the melting point of the solder balls 104 (e.g., about 225°C). Heating of the solder balls 104 from the first temperature to the peak temperature can be controlled so that temperature of the solder balls is increased at a substantially constant rate. The time period for this heating is dependent on the solder used and can be, for example, about 350 to about 450 seconds.

Once the temperature of the solder balls 104 has reached the peak temperature (e.g., about 225°C) and the solder balls 104 have at least partially melted, the solder balls 104 can be maintained within about 5°C of the peak temperature for a short time period (e.g., about 10 to about 25 seconds). The total time above liquidus for the solder balls 104 (that is, the total time at a temperature above which the solder material is completely melted and flowing) is that amount of time effective to allow the solder balls 104 to reshape and wet the contact pads 102. The solder balls 104 are then cooled to room temperature at a substantially uniform rate to allow the solder balls 104 to solidify and metallurgically bond to the contact pads 102.

During at least part of the reflow process, the solder balls 104 are ultrasonically agitated by an ultrasonic generator 140 to reduce formation of voids in the reflowed solder balls 104. Ultrasonic agitation of the solder balls during reflow can facilitate evacuation of gas formed upon heating the solder flux or solder paste to the peak temperature; and thereby at least partially mitigate formation of gas pockets or gas bubbles in the reflowed solder balls. At least partially mitigating the formation of gas pockets or gas bubbles in the reflowed solder balls can reduce the formation of voids in the reflowed solder balls.

The ultrasonic generator 140 can ultrasonically agitate the solder balls during reflow by applying vibrational (or acoustic) energy to the solder balls 104. The vibrational energy has frequency that can be greater than about 20 kHz (i.e., an ultrasonic frequency). In one aspect of the invention, the frequency of the ultrasonic vibration can be about 50KHz to about 90 kHz. An ultrasonic vibration with a frequency of about 50KHz to about 90 kHz is effective to cause gas to evacuate from the solder balls 104 during reflow and at least partially mitigate the formation of gas pockets or gas voids. This acoustic or vibrational energy can be applied through the substrate 100 to the solder balls in contrast to being applied directly to the solder balls 104, to prevent ball deformation.

The ultrasonic generator 140 can apply an ultrasonic vibration to the substrate 100 and hence the solder balls 104 during reflow via an ultrasonic transmitting medium. The ultrasonic transmitting medium can comprise a gas, such as an inert gas between the ultrasonic generator 140 and the substrate 100. For example, the inert gas can comprise an ambient gas between the ultrasonic generator 140 and the substrate 100. Alternatively, the ultrasonic transmitting medium can comprise a mechanical medium that is in contact with the

substrate 100. In one aspect, as shown in FIG. 6, the ultrasonic transmitting medium can comprise a conveyor assembly on which the substrate can be disposed.

The ultrasonic generator 140 can include an ultrasonic transducer that is capable of converting electrical energy to ultrasonic energy, which can be applied by the ultrasonic transmitting medium to the solder balls. By way of example, the ultrasonic transducer can include an ultrasonic generator, such as an oscillator with an oscillation source and a power supply. When the oscillator is driven, the ultrasonic generator propagates an acoustic or vibrational wave with a frequency, which can be transmitted by the ultrasonic transmitting medium.

The ultrasonic agitation in accordance with the present invention can be applied during the reflow process while the solder balls 104 are at least partially molten, for a duration of time effective to mitigate the formation of gas bubbles or gas pockets in the reflowed solder balls 104. In one aspect of the invention, the ultrasonic agitation is applied to the solder balls 104 during the time above the liquidus of solder balls for a duration of time of about 50 seconds to about 150 seconds. It will be appreciated by one skilled in art that duration of time can be longer or shorter depending on the specific solder material used to form the solder balls 104 as well as the reflow temperature profile or parameters.

FIG. 3 illustrates the reflowed and ultrasonically agitated solder balls 104 when they are bonded to the contact pads 102 to form a plurality of substantially spherical shaped solder bumps 150. The solder bumps 150 have top surfaces 152 to which other devices (e.g., printed circuit board) can be attached and have bottom surfaces 154 that are in contact with the contact pads 102. The solder bumps 150 so formed have a reduced number of voids. The reduced number of voids in the solder bumps 150 provides the solder bumps 150 with improved electrical and thermal properties, which facilitate interconnection with, for example, a printed circuit board.

FIGS. 4 and 5 illustrate a method of forming a plurality of conductive solder bumps on a substrate of a ball grid array package in accordance with another example embodiment of the invention. In this method, the solder bumps are formed from a solder paste that is applied to conductive sites of the substrate. As with the above-described method, it will be appreciated that this method can also be used to form solder bumps on a wafer or a packaged or unpackaged bare semiconductor die.

Referring to FIG. 4, a substrate 200 of a ball grid array package is provided having a plurality of exposed contact pads 202 to which portions of solder paste are applied. The substrate 200 can be any substrate material, such as any previously described in connection with substrate 100. The contact pads 202 can comprise a material that will form a metallurgical bond with the solder paste, and can also be electrically connected to conductive vias or conductive traces that are formed either in or on the substrate 200. The contact pads 202 can be formed on, projecting from, or recessed in surface 206 and be of any suitable material, such as previously described in connection with contact pads 102.

The portions of solder paste 204 can be provided over the contact pads 202 using solder paste dispensing methods, such as a screen printing method. In utilizing the screen printing method, the mean particle size of the solder paste 204 should be about one-third the size of the mesh size of the screen (not shown) to ease the portions of solder paste through the screen. The screen, which is typically made from stainless steel wire, can be positioned slightly above the contact pads 202 in a plane that is parallel to the substrate 200. The contact pads 202 of the substrate 200 should be located in exact registration with the screen image. The solder paste 204 is then drawn across and through the screen by a squeegee so that individual portions of solder paste 204 are applied directly over each contact pad 202. It will be appreciated that other solder application methods can be used to apply solder paste over the contact pads, such as stencil methods.

The solder paste 204 can include alloys of lead, tin, indium or silver (e.g., 96.5/3.5 Sn/Ag solder alloy) and a solder flux. The solder flux can include any type of flux commonly used in solder pastes for semiconductor processing, such as the flux materials described in connection with solder flux 114.

FIG. 5 illustrates the portions of solder paste 204 undergoing a reflow process, similar to the process described above in connection with the reflow of solder balls 104. Here, however, the solder paste 204 is heated in an inert atmosphere by a heater 210 to at least partially melt portions of the solder paste 204, instead of the solder balls 104. Again, it will be appreciated that both infrared and convection heating can be used to heat the solder paste, as well as other heating means.

As with the heating of the solder balls 102, the portions of solder paste 204 can be heated by the heater 210, in similar manner, from a first temperature to a peak temperature.

The first temperature, peak temperature, increase in temperature, and time period for this heating is dependent on the solder paste used, and may, for example, follow similar parameters as those previously described for heating the solder balls 102. Once the temperature of the solder paste 204 has reached the peak temperature and the solder paste
5 204 has at least partially melted, the solder paste 204 can be maintained close to the peak temperature for a short time period, sufficient to allow the solder paste 204 to reshape and wet the contact pads. The portions of reflowed solder paste 204 are then cooled to room temperature at a substantially uniform rate to allow the portions of reflowed solder paste 204 to solidify and metallurgically bond to the contact pads 202.

10 As with the solder ball embodiment, during at least part of the solder paste reflow process, the portions of solder paste 204 are ultrasonically agitated by an ultrasonic generator 220 to reduce formation of voids in the reflowed portions of solder paste 204.

The ultrasonic generator 220 can ultrasonically agitate the portions of solder paste during reflow by applying vibrational (or acoustic) energy to the solder paste 204 in the same
15 way as described for the ultrasonic agitation imparted to the solder balls 102 during reflow by ultrasonic generator 140. The frequency of the vibrational energy can be the same as that previously described, effective to cause gas to evacuate from paste during reflow and at least partially mitigate the formation of gas pockets or gas voids. And, as before, the energy can be applied indirectly through the substrate 200 to the solder paste 204.

20 Following reflow and ultrasonic agitation, the portions of solder paste 204 are bonded to the contact pads 202 to form a plurality of substantially spherical shaped solder bumps, such as shown in FIG. 3, to which other devices (e.g., printed circuit board) can be attached. As before, the solder bumps so formed have a reduced number of voids, thereby providing solder bumps with improved electrical and thermal properties.

25 FIG. 6 illustrates an example of a system 300 for reflowing solder material on a substrate in accordance with the invention. The system includes a reflow chamber 302 that contains a substantially inert ambient. The ambient can comprise a substantially inert gas (e.g., N₂) or a forming gas (e.g. 95% N₂/H₂). It will be appreciated that other inert gases can also be used.

30 The reflow chamber 302 has an input end 304 and an output end 306. The input end 304 and output end 306 respectively include ambient loading zones 310 and 312 that can be

opened to an external atmosphere to allow for respectively loading and unloading of a substrate 320 to and from the reflow chamber 302. The ambient zones provide a gas curtain that substantially seals the reflow chamber from the external atmosphere. The substrate 320, which can be loaded and unloaded from the reflow chamber 302, can comprise a part of a ball grid array package having a plurality of exposed conductive sites to which portions of solder material 322 are applied.

The reflow system 300 also includes a plurality of heating zones 332, 334, 336, 338 and a conveyor assembly 340. The conveyor assembly 340 is designed to move the substrate 320 through the plurality of heating zones 332, 334, 336, 338 in the reflow chamber 302. The heating zones 332, 334, 336, 338 include separate heaters 350, 352, 354, 356 (e.g., radiant, convection, or conduction) that control the temperature of the respective heating zone 332, 334, 336, 338, so that the temperature of the substrate 320 and solder material 322 can be adjusted as the substrate 320 moves through the reflow chamber 302. Although the reflow chamber 302 includes four individual heating zones 332, 334, 336, 338, the reflow chamber 302 can include more (e.g., five) or fewer (e.g., one) heating zones.

The conveyor assembly 340 includes an input portion 360, an agitation portion 362, and an output portion 364. The input portion 360, the agitation portion 362, and the output portion 364 comprise separate feed belts 370, 372, 374 that can advance the substrate 320 respectively through at least part of the reflow chamber 302 and the heating zones 332, 334, 336, 338. The feed belt 372 of the agitation portion 362 is coupled to an ultrasonic generator 380. The ultrasonic generator can ultrasonically agitate during at least part of the reflow process the feed belt 372 of the agitation portion 362 of the conveyor assembly 340, which in turn can ultrasonically agitate the substrate 320 and solder material 322. By way of example, the ultrasonic generator can include an ultrasonic generating unit 382, such as an oscillator with an oscillation source and a power supply. When the oscillator is driven, the ultrasonic generating unit propagates an acoustic or vibrational wave with a frequency, which can be transmitted by feed belt 372 of the agitation portion 362 to the solder material 322.

During operation of the reflow system, the substrate 320 is positioned through the ambient zone 310 of the input end 304 of the reflow chamber 302 on the feed belt 370 of the input portion 360 of the conveyor assembly 340. The substrate 320 is advanced by the feed belt 370 through the heating zones 332, 334 of the reflow chamber 302. While being

advanced through the heating zones 332, 334, the substrate 320 and solder material 322 are heated by the heaters 350, 352 from about room temperature to the liquidus of solder material 322.

5 The substrate 320 is then advanced by the feed belt 370 of the input portion 360 to the feed belt 372 of the agitation portion 362 of the conveyor assembly 340. The feed belt 372 further advances the substrate 320 through the heating zone 336. While being advanced by the feed belt 372, the substrate 320 and solder material 322 are maintained at the liquidus of the solder material 322 by heater 354 of the heating zone 336 and subjected to ultrasonic agitation. The ultrasonic agitation is applied by the ultrasonic generator 380 that is coupled
10 to ultrasonically vibrate the feed belt 372, which in turn ultrasonically vibrates the substrate 320 and the solder material 322, which is at liquidus.

The substrate 320 is advanced by the feed belt 372 to the feed belt 374 of the output portion 364. The feed belt 374 further advances the substrate 320 to output end 306 of the reflow chamber 302, where the substrate 320 and reflowed solder material 322 are allowed to
15 cool to the solidus of the reflowed solder material 322. The cooled reflowed solder material 322 forms a plurality of solder bumps that are metallurgically bonded to the conductive sites. The substrate 320 and solder bumps are subsequently removed from the reflow chamber 300 through the ambient zone 312 and allowed to cool to room temperature.

Those skilled in the art will also understand and appreciate that variations in the
20 processing operations can be utilized in the formation of the solder bumps. For example, it is to be appreciated that instead of forming the solder bumps on contact pads, the solder bumps could be formed on the terminus of a conductive via, a portion of a conductive trace, or a portion of a metal interconnect. Moreover, it will be appreciated that the solder flux can be applied using other solder flux dispensing methods. For example, these other methods can
25 include other solder flux dipping methods as well as other solder flux transfer methods.

What has been described above includes examples and implementations of the present invention. Because it is not possible to describe every conceivable combination of components, circuitry or methodologies for purposes of describing the present invention, one of ordinary skill in the art will recognize that many further combinations and permutations of
30 the present invention are possible. Accordingly, the present invention is intended to embrace all such alterations, modifications and variations.

CLAIMS

1. A method of forming a solder bump, the method comprising:
providing solder material on a conductive site of a substrate;
reflowing the solder material to provide a solder bump on the substrate; and
ultrasonically agitating the solder material during at least a part of the reflow.
2. The method of claim 1, the reflow including heating the solder material to a temperature effective to at least partially melt the solder material, the solder material being ultrasonically agitated while at least partially melted.
3. The method of claim 2, wherein:
the solder material is provided at each of a plurality of conductive sites on a surface of the substrate, the substrate comprising at least a portion of a ball grid array package;
the solder material is reflowed to form a plurality of solder bumps, each solder bump including a surface connected to one of the plurality of solder contacts; and
the material of the solder bumps is ultrasonically agitating during at least a part of the reflow.
4. The method of claim 2 or 3, wherein the solder material is ultrasonically agitated by ultrasonic vibration provided through mechanical contact to the substrate.
5. The method of claim 4, wherein the substrate is provided on a conveyor assembly during reflow, and the conveyor assembly is ultrasonically vibrated to ultrasonically agitate the solder material.
6. The method of claim 2 or 3, wherein the ultrasonic agitation is provided at a frequency of about 50 kHz to about 90 kHz.
7. The method of claim 2 or 6, wherein the ultrasonic agitation is provided for about 50 seconds to about 150 seconds during the reflow.
8. Apparatus for forming a solder bump, the apparatus comprising:
a conveyor for moving a substrate having solder material on a conductive site of the substrate;
a heater configured and adapted for reflowing the solder material to provide a solder bump on the substrate as the solder is moved by the conveyor; and
an agitator configured and adapted for ultrasonically agitating the solder material during at least a part of the reflow.

9. The apparatus as in claim 8, wherein the agitator is configured and adapted to ultrasonically vibrate the conveyor, and the conveyor is configured and adapted to ultrasonically vibrate the substrate when so vibrated by the agitator.

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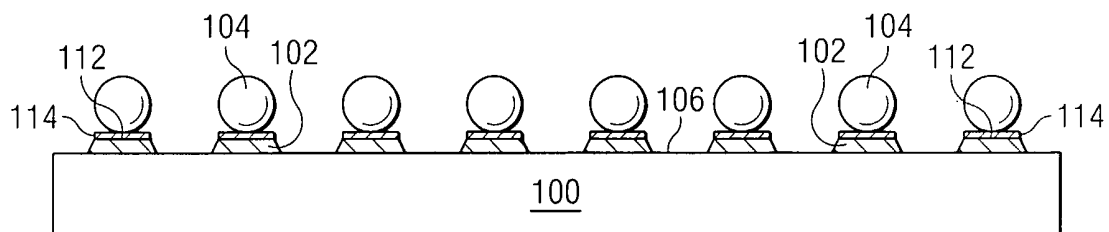


FIG. 1

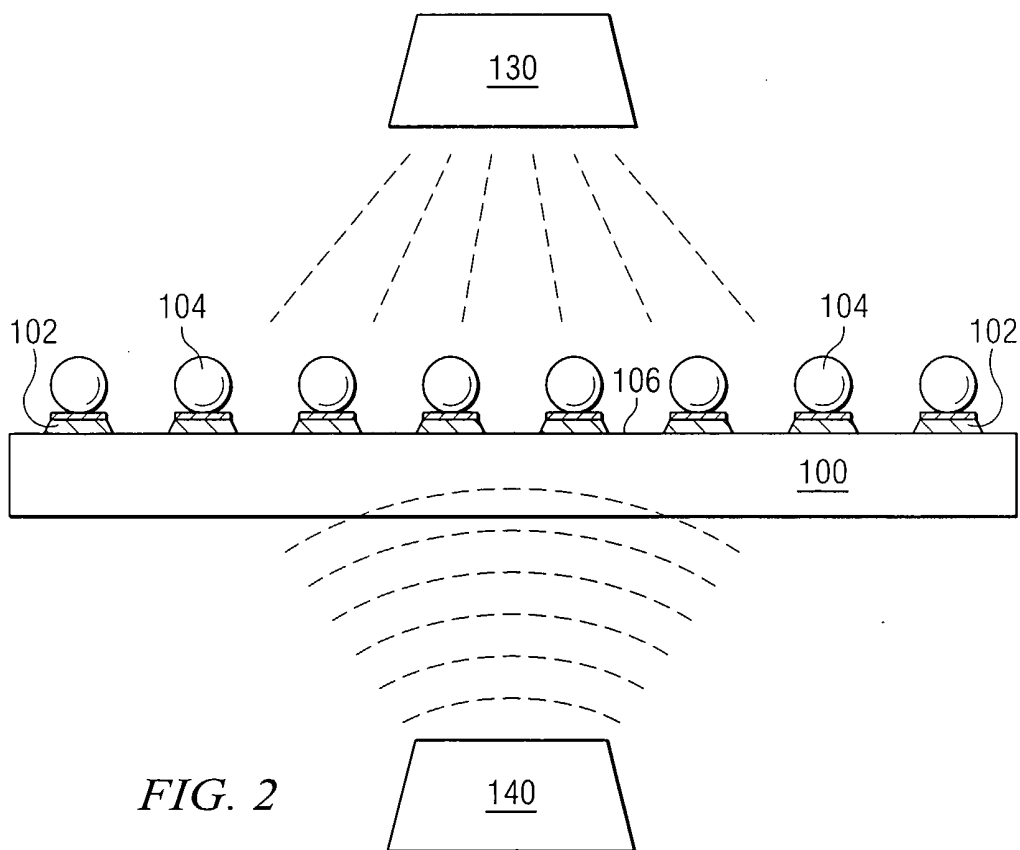


FIG. 2

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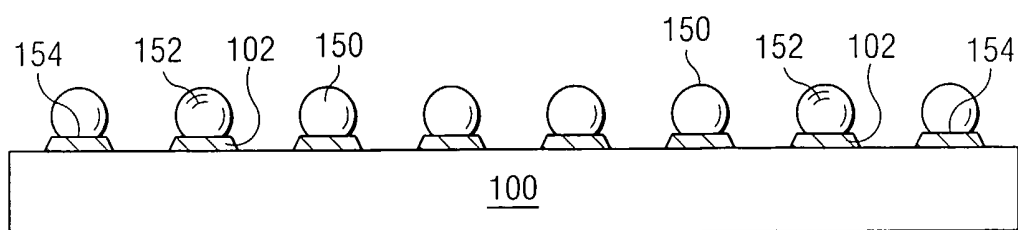


FIG. 3

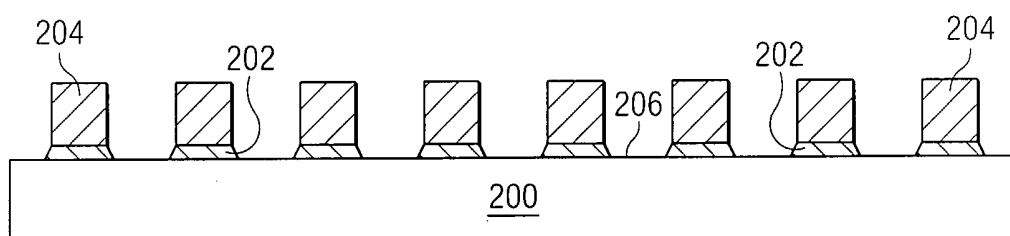


FIG. 4

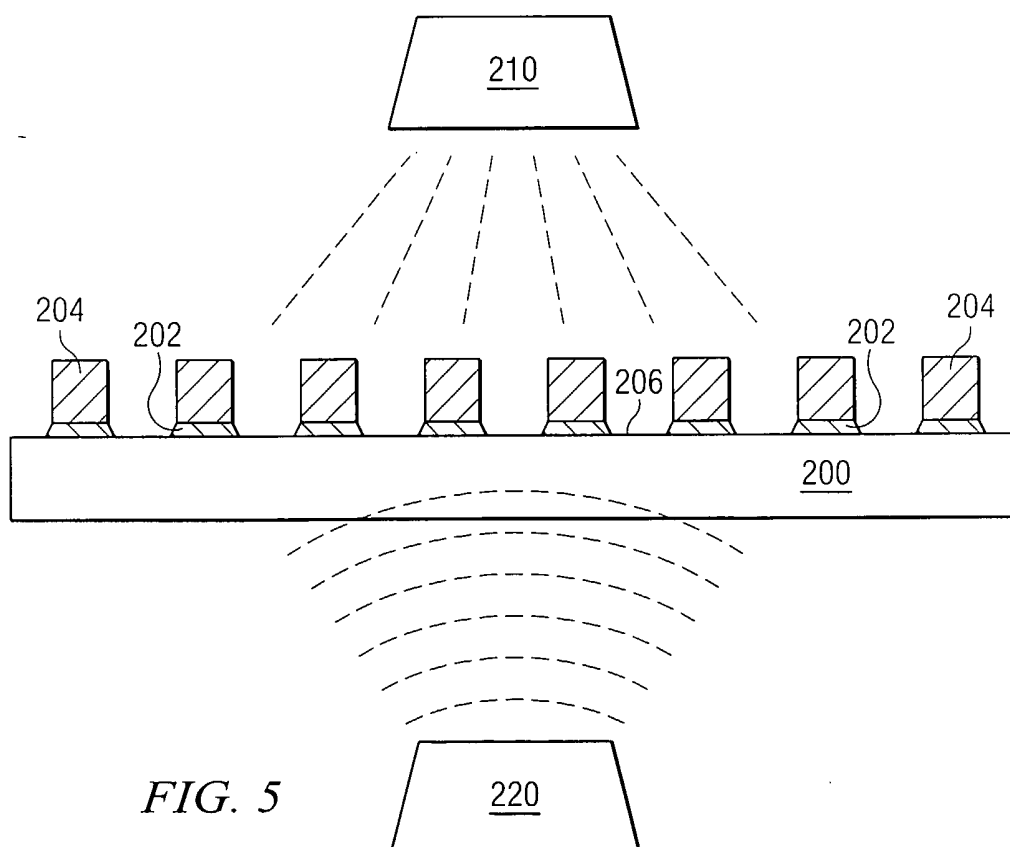


FIG. 5

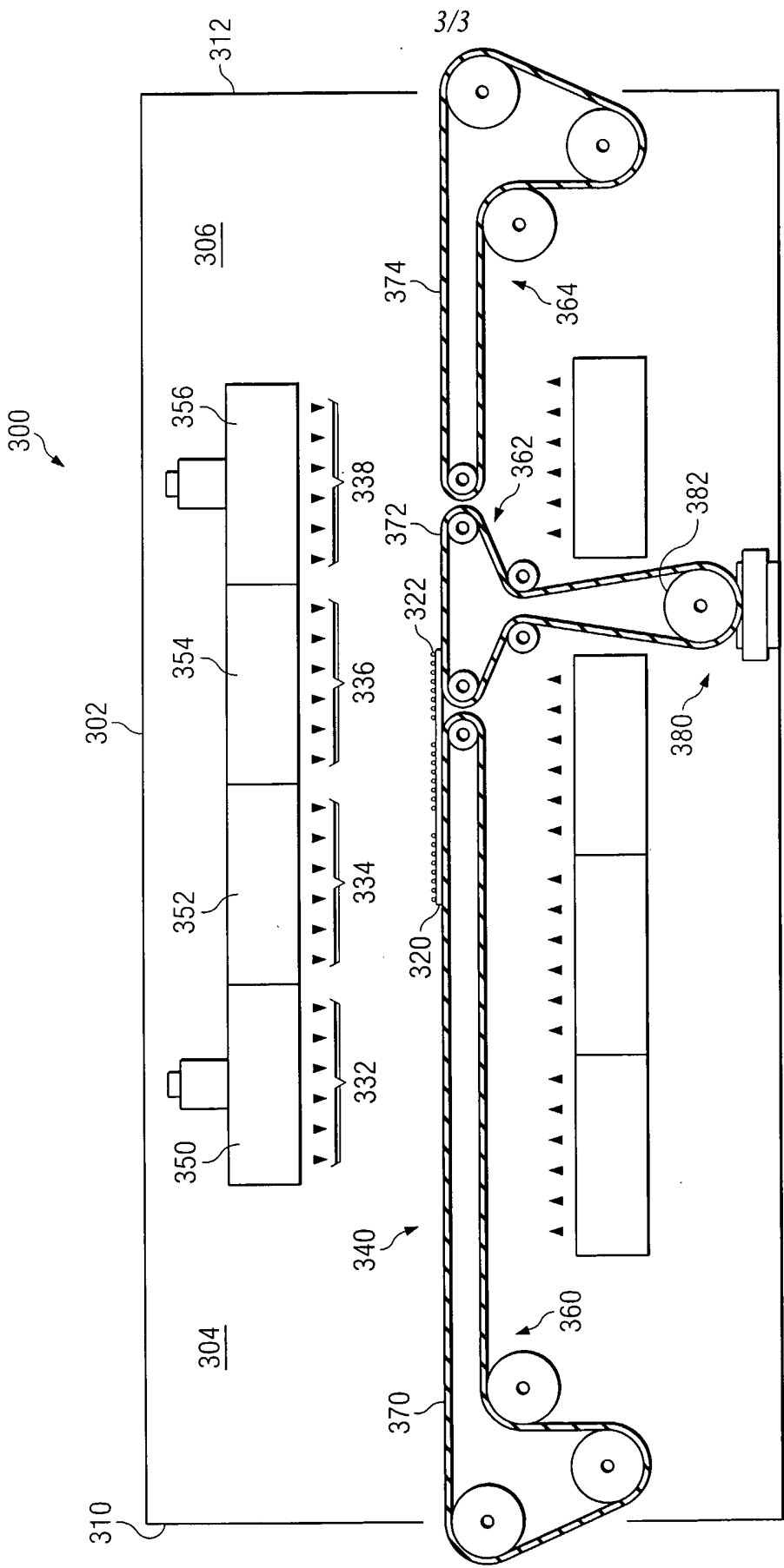


FIG. 6

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US05/37551

A. CLASSIFICATION OF SUBJECT MATTER

IPC(7) : B23K 1/06, 5/20, 20/10, 31/00, 31/02

US CL : 228/1.1, 110.1, 111.5, 180.22

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 228/1.1, 110.1, 111.5, 180.22

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

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 6761302 B1 (KANEYAMA) 13 July 2004 (13.07.2004), abstract, figures 3A-3C, 5 and column 4 lines 1-38.	1-4
X	US 6620722 B2 (KUO et al.) 16 September 2003 (16.09.2003), abstract, figure 2B and column 9 lines 11-63.	1-6, 8 and 9
X	US 2002/0056740 A1 (HAYASHI) 16 May 2002 (16.05.2002), abstract and paragraphs 18-25.	1-4
X,P	US 2005/0001014 A1 (TAKEUCHI et al.) 6 January 2005 (06.01.2005), abstract, figure 1B and paragraphs 57 and 58.	1-4 and 6

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

☐ See patent family annex.

* Special categories of cited documents:

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05 January 2006 (05.01.2006)

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