

Micro Nozzle

Field of the Invention

[0001] The present invention relates to semiconductor packages reworking. In particular, the invention relates to system and method using a micro nozzle for the semiconductor packages reworking, and method for manufacturing the same.

Background

[0002] With a high demand on density in semiconductor packaging, quality control and assurance have becoming more important than ever to reduce losses due to the dispose of defective packages. In a Ball Grid Array (BGA) packages, solder ball faults, including missing solder balls, are common problems that causing the disposed of BGA packages. Such problems are often caused by manufacturing defects, improper handling and/or reclaim processes, and etc. Therefore, it is necessary to inspect each of the BGA packages after the solder balls or bumps are deposited on bond pads. When defects are found, the packages are sent to rework to refurbish or reball as it requires.

[0003] There are solutions existing in the market today for BGA re-working applications and these cater to low and medium density grids whereas no product meets the post-processing demands of high density BGA. A summary of these solutions is as follows.

[0004] One method for reworking or reballing for small to medium volume quantities of packages is to use stencils. The stencils are custom made to correspond to the size of balls and part pads the devices to be reworked. Flux is applied to the bottom of the device, the corresponding stencil is aligned over the device. The properly sized solder balls are then poured into stencil while the stencil is affixed to and aligned with the device. The assembly is then reflowed, cleaned and inspected.

[0005] In this method, the dressing of the pads and removal of solders from the device can be done by one of the available methods, such as solder wick, solder vacuum and low temperature wave solder or solder pot techniques. An inspection is required under a stereo microscope or other optical inspection tool to make sure all of the solder balls have been removed. These techniques have their own drawback. For example, the solder vacuum process is time consuming; the braid technique can lead to lifted pads or otherwise damaged solder mask areas if not done properly or with the right size of wick; the use of the solder pot requires the ability to maintain temperature and an appropriate type of balls is desired in order not to contaminate the solder pot.

[0006] Another method for reworking and reballing packages is solder preform technique. A solder preform is an array of solder balls suspended in a removable backing material, or water soluble material. The preform is aligned and placed using the manual rework system pick and place mechanism, and reflowed. After applying flux to the bottom of the device to be reworked, the balls and part land patterns are aligned with a simple fixture holding the preform over the bottom of the device land patterns. The assembly is then reflowed. Each unique solder alloy, ball size and grid pattern of the device requires a new preform. The solder preform process is however slow and effort-intensive. The limitations of this technique are that it is suitable for low density BGA with solder balls more than 0.3 mm in diameter. This technique cannot be used for wafer level BGAs and devices with small inter-ball pitch.

[0007] Some re-balling systems remove all spheres from the component, and, using a template, replace all spheres at the same time. Contemporary Ball Array Placement products in the market, such as the Solder Ball Array Placement Module for the FINEPLACER® marketed under Finetch GmbH & Co. Kg., can handle simultaneous, precision placement of only up to **200** solder balls directly onto a substrate or wafer.

[0008] Generally, when a small number of defective soldering is found, the rework of devices is required. Thus, removal and reballing of all solder balls for the

BGA are not effective as further rework and reballing may be required when defective soldering is still existed in the rework and reballing of all solder balls. The solder balls replacement process is slow and requires alignment with the substrate in order to achieve uniform pitching. Further, rework on the entire surface area of the rework device mat subject to extensive wear and tear and thermal deformations due to reflow.

Summary

[0009] In accordance with one aspect, there is provided a nozzle for picking up micro solder balls with a solder pick and place apparatus having a vacuum suction arm, the nozzle comprises a nozzle body configured for fitting to a vacuum port of the vacuum suction arm; and an airway defines through the nozzle body, the airway having a diameter smaller than one micro solder ball.

[0010] In accordance with one embodiment, the nozzle may further comprise a catchment cup in a form of a depression around the airway. The catchment cup is adapted to receive one micro solder ball with a depth of the catchment cup less than a diameter of the solder ball. It is possible that the catchment cup is a cylindrical depression formed around the airway. The catchment cup can also form a conical mouth to the airway with a largest diameter of the conical bigger than the diameter of the solder ball.

[0011] In accordance with another embodiment, the nozzle may further comprise a cylindrical wall projected between the catchment cup and the airway, wherein said cylindrical wall has a height lesser than a depth of the catchment cup. Alternatively, the nozzle may further comprise a cylindrical depression within the catchment cup forming two tiers depression around the airway.

[0012] In yet another embodiment, the nozzle may further comprise a pitch control platform defined around the catchment cup. The pitch control platform may be a surface around the catchment cup. The surface of the pitch control platform may

have a relatively small pitch. In this embodiment, the nozzle body may have a plurality of the airways. The airways may have a pitch between each airway smaller than half of a diameter of the solder ball for which the nozzle is intended. Yet, the surface of the nozzle body between the catchment cups of each airway may form the pitch control platform.

[0013] In yet another embodiment of the above aspect, the nozzle body may have a plurality of the airways.

Brief Description of the Drawings

[0014] This invention will be described by way of non-limiting embodiments of the present invention, with reference to the accompanying drawings, in which:

[0015] **FIG. 1** illustrates a cross sectional view of a micro nozzle in accordance with an embodiment of the present invention;

[0016] **FIG. 2A** illustrates a micro nozzle in accordance with another embodiment of the present invention;

[0017] **FIG. 2B** illustrates a cross sectional view of a micro nozzle in accordance with an alternative embodiment of the present invention;

[0018] **FIG. 3A** exemplifies a laser setup for fabricating the micro nozzle of **FIG. 2A** in accordance with one embodiment of the present invention;

[0019] **FIG. 3B** illustrates a cross sectional view of a work piece fabricated under the laser setup of **FIG. 3A**;

[0020] **FIG. 3C** illustrates a cross sectional view of the work piece of **FIG. 3B** that is further fabricated under the laser setup of **FIG. 3A**;

[0021] FIG. 3D illustrates a cross sectional view of a micro nozzle of FIG. 2A which was fabricated from the work piece of FIG. 3A;

[0022] FIG. 4A illustrates two work pieces that are to be used for fabricating a micro nozzle in accordance with one embodiment of the present invention;

[0023] FIG. 4B shows a bonded work piece of the two work pieces of FIG. 4A;

[0024] FIG. 4C shows a laser setup for fabricating the bonded work piece of FIG. 4B;

[0025] FIG. 4D shows a cross section view of the bonded work piece fabricated in FIG. 4C;

[0026] FIG. 4E shows a top view of the bonded work piece fabricated in FIG. 4D;

[0027] FIG. 4F shows a top view of the bonded work piece of FIG. 4E that is fabricated further;

[0028] FIG. 4G illustrates a perspective view of a micro nozzle fabricated in FIGS. 4A - 4F in accordance with one embodiment of the present invention;

[0029] FIG. 5A illustrates a stencil board in accordance with one embodiment of the present invention;

[0030] FIG. 5B illustrates the stencil board of FIG. 5A bonded to a stencil base in accordance with one embodiment of the present invention;

[0031] **FIG. 5C** illustrates the bonded stencil board of **FIG. 5B** having a micro nozzle fitted thereon in accordance with one embodiment of the present invention;

[0032] **FIG. 5D** illustrates a laser setup for fabricating the bonded stencil board in accordance with one embodiment of the present invention;

[0033] **FIG. 5E** illustrates an enlarge cross section view of the bonded stencil with the airway ports fabricated thereon in accordance with another embodiment; and

[0034] **FIG. 5F** illustrates a further processed stencil in accordance with yet another embodiment of the present invention.

Detailed Description

[0035] In line with the above summary, the following description of a number of specific and alternative embodiments is provided to understand the inventive features of the present invention. It shall be apparent to one skilled in the art, however that this invention may be practiced without such specific details. Some of the details may not be described at length so as not to obscure the invention. For ease of reference, common reference numerals will be used throughout the figures when referring to the same or similar features common to the figures.

[0036] **FIG. 1** illustrates a cross sectional view of a micro nozzle **100** in accordance with one embodiment of the present invention. The micro nozzle **100** is adapted to fit to a solder ball pick up apparatus (not shown) having a vacuum pick up arm for picking up a solder ball **150**. The micro nozzle **100** comprises a micro channel airway **110**, a catchment cup **120**, a pitch control platform **130** and a cylindrical wall **140**. The catchment cup **120** is a depression defined around the one end of the micro channel airway **110**. The micro channel airway **110** is a narrow path having one end exposed to the catchment cup **120** and another end exposed to an opposing side at the micro nozzle **100**. The catchment cup **120** has an inner diameter bigger than that of the micro channel airway **110** and aligned with the micro channel airway **110** concentrically. The pitch control platform **130** is a projection defined around the catchment cup **120**. The cylindrical wall **140** is built-up within the catchment cup **130** and around the one end of the micro channel airway **110**. The micro channel airway **110**, the cylindrical wall **140** and the catchment cup **130** are aligned concentrically.

[0037] Still referring to **FIG. 1**, the catchment cup **120** provides a better control when the micro nozzle **100** is used for picking up the micro solder ball **150** from a pool of solder balls. It can prevent multiple balls are picking up to the nozzle at the same time. The cylindrical wall **140** is provided to further improve the solder balls **150** pickup control. The cylindrical wall **140** and the catchment cup **120** also provide a better control when placing the solder ball. The micro nozzle **100** with the catchment

cup 120 and the cylindrical wall 140 is able to hold irregularly shaped and sized solder balls as the solder balls may have irregular shape and size due to remnants of flux, physical dents, surface cracks, etc. The pitch control platform 130 is adapted to have a small surface area to avoid surface adhesion due to the external forces, such as contact electrification adhesion force. In operations, the micro nozzle 100 is mounted on a vacuum suction port to pick up the solder ball 150 for placement.

[0038] In one embodiment, instead of the cylindrical wall 140, a two tiers depression can be configured around the micro channel airway 110 within the catchment cup 120.

[0039] Still referring to FIG. 1, micro nozzle 100 is properly sized to provide sufficient suction to pick up solder balls of desire sizes. For example, for micro solder balls ranging in size from 50 μm to 500 μm , the micro channel airway 110 can have a diameter as small as 5 μm . The catchment cup 120 can have a side of 75-99% of diameter of the smallest solder ball desired for the micro nozzle 100. The catchment cup 120 can be manufactured to have smooth sidewalls to minimize wear and tear from repeated solder ball pick and place actions.

[0040] In accordance with another embodiment, the micro nozzle 100 can be adapted to include a plurality of micro channel airway 110 for picking and placing multiple solder balls. Each of the micro channel airways 110 also provides with a catchment cup 120, a cylindrical wall 140 and a pitch control platform 120 as described above. The pitch control platform 130 is sized to cover substantially a half-pitch diameter around the solder ball so that neighboring pitch control platforms are able to pick and place the solder balls without any obstacles.

[0041] In accordance with an alternative embodiment, the micro nozzle 100 is built without the cylindrical wall 140, or the two tiers depression.

[0042] FIG. 2A illustrates a micro nozzle 200 in accordance with an alternative embodiment of the present invention. The micro nozzle 200 is a single port nozzle adapted for picking and placing a solder ball 250. The micro nozzle 200 is shaped to a conical frustum having an upper surface 210 and a bottom surface 220. A channel airway 230 is defined from the upper surface 210 to the bottom surface 220. The channel airway 230 is a substantially inverted conical air path through the conical frustum nozzle body with a wider aperture defined on the top surface 210 and a narrow aperture defined on the bottom surface 220. The bottom surface 220 surrounding the narrow aperture also serves as a pitch control platform for protecting the adjacent solder balls from damage during the pick and place operation. In operation, when vacuum suction means (not shown) draw air from the narrow aperture to create a suction force, a micro solder ball can be picked up by the micro nozzle 200 through the narrow aperture.

[0043] FIG. 2B illustrates a cross sectional view of a micro nozzle 260 in accordance with an alternative embodiment of the present invention. The micro nozzle 260 is a single port nozzle adapted for picking and placing a solder ball. The micro nozzle 260 is shaped to a conical frustum having an upper surface 261 and a bottom surface 262. A channel airway 265 is defined from the upper surface 261 to the bottom surface 262. A conical mouth 266 is defined around the channel airway 265 concentrically on the bottom surface 262 of the micro nozzle 260 forming the catchment cup for picking and placing a solder ball. The remaining of the bottom surface 262 surrounding the conical mouth 266 also serves as a pitch control platform. When the micro nozzle 260 is in used, it is fitted to a vacuum suction port 270 for picking and placing a single solder ball.

[0044] FIGs. 3A-3E illustrate method of fabricating a micro nozzle 200 of FIG. 2A in accordance with one embodiment of the present invention. The micro nozzle is to be sized to have the bottom surface 220 of the micro nozzle 200 with an outer diameter of 700 μm and the top surface 210 of the micro nozzle 200 with an outer diameter of 650 μm and a vertical high of 960 μm . The narrow aperture is to be sized

to about 150 μm while the wider aperture is to be sized to about 500 μm . The micro nozzle 200 illustrates herewith is made of polymeric material. More specifically, it can be made of Polymethyl Methacrylate (PMMA), or commonly known as acrylic. The micro nozzle 200 is suitable for solder balls with a size between 80-300 μm when coupled with a vacuum suction means with a 4-10 bar suction pressure. The above sizes and figures are provided herewith by way of example, not limitation. It is understood to a skilled person that the micro nozzle 200 can be fabricated in any other sizes to suite the relevant application.

[0045] FIG. 3A exemplifies a laser setup 300 for fabricating the micro nozzle 200 in accordance with one embodiment of the present invention. The laser setup 300 uses a carbon dioxide laser to fabricate the micro nozzle out of an acrylic work piece 310 with a thickness of 1 mm. The carbon dioxide laser 300 is located above the work piece 310 with a laser pointed down at the work piece 310. The carbon dioxide laser 300 performs a first cut to form a circle of the required diameter on the surface of the work piece 310. In the first cut, the overall shape of the micro nozzle 200 can be formed. The cutting is performed in a multiple laser cutting process with intervals to avoid overheating in a small area. For the work piece 310, the laser cut is repeated for 20 times with an interval of 10 seconds between each cut to form a desired cut as shown in FIG. 3B.

[0046] FIG. 3B is a cross sectional view of the work piece 310 showing the work piece 310 after the first cut. A conical frustum block 320 is formed after the laser cut. The laser does not cut through the work piece 310 forming a circular well 330 around the conical frustum block 320. The conical frustum block 320 remains attached to the work piece 310. The carbon dioxide laser 300 performs a second cut on the conical frustum block 320 to cut a channel airway 340 as show in FIG. 3C. The channel airway 340 is also cut by repeated laser pulse to form an inverted conical through hole.

[0047] To form a micro nozzle of FIG. 2B, the work piece 310 is flipped over and the carbon dioxide laser 300 is used to create the conical mouth 266.

[0048] After the channel airway 340 is formed, the conical frustum block 320 is removed from the work piece 310. The conical frustum block 320 removed from the work piece 310 is shown in FIG. 3D. The conical frustum block 320 may require further process to produce a smooth surface, and the micro nozzle 200 is formed.

[0049] FIGs. 4A-4G illustrate a method of fabricating a multiple ports micro nozzle in accordance with one embodiment of the present invention. As shown in FIG. 4A, two work pieces 412 and 414 of the same size are bonded together with a laser-welding machine. The bonded work piece 416 is shown in FIG. 4B. The bonded work piece 416 is then placed under a carbon dioxide laser 420 as shown in FIG. 4C. The carbon dioxide laser 420 performs a first cut to form a circular depression 418 of a desired diameter at a desired depth, where airways are to be arranged therein. The circular depression 418 is sized to fit a tube that connects to a vacuum suction means. The circular depression 418 is cut by hatch-ablation. FIG. 4D is a cross sectional view of the bonded work piece 416 showing the cut of the circular depression 418 on the bonded work piece 416. The cut does not cut through the bonded work piece 416 so that the circular depression 418 remains attached to the bonded work piece 416. FIG. 4E shows a top view of the bonded work piece 416. Markings 422 are provided to pre-mark the exact location of the multi ports. A 3 by 3 ports array of airway ports is desired herein. The carbon dioxide laser 420 is used to ablate airway ports of desired depth. An excimer laser is used to cut through the markings 422 to form the airway ports. Each of the airway ports is provided with a catchment cup, pitch control platform and/or the cylindrical wall similar to the embodiments described above.

[0050] As shown in FIG. 4F, the circular depression 418 is cut out from the bonded work piece 416 by cutting a larger circular disk 424 around the circular depression 418 concentrically with one segment of the larger circular disk 424 is removed. The segment can be removed after the larger circular disk 424 is cut out

from the bonded work piece **416**, or during the cut of the larger circular disk **424**. **FIG. 4G** shows a completed piece of the multiple ports micro nozzle **450**.

[0051] In the above embodiment, two work pieces are bonded together to form the nozzle. Preferably, the two work pieces are in different colors that would help in identifying the depth of laser cutting. In accordance with an alternative embodiment, only one solid work piece of the similar thickness can be used.

[0052] For the pick and place operation of solder ball arrays of specific quantity and pitch, a stencil can be provided to hold the arrayed solder balls for the purpose of picking and placing onto BGA substrates and wafers. In accordance with one embodiment, the stencil is provided to hold the micro solder balls in an arrangement that corresponds to the multiple ports micro nozzle **450** array. That could facilitate the solder balls pickup during the BGA rework. The stencil can be fabricated in yet another embodiment which is shown in **FIG. 5A-5F**.

[0053] As shown in **FIG. 5A**, a stencil board **502** is cut through to provide an aperture **504** with a laser ablation. The aperture **504** is in a shape adapted to fit the larger circular disk **424**, i.e. a circular aperture having a chord side. The stencil board **502** is bonded to a stencil base **506** of the same size by laser welding to form the stencil **501** as shown in **FIG. 5B**.

[0054] The multiple ports micro nozzle **450** is then mounted to fit to the aperture **504** of the stencil **501** as shown in **FIG. 5C**. The micro nozzle **450** is used as a template to form shallow pockets for holding solder balls in place on the stencil **501**. The stencil **501** is then placed under an excimer laser table. As shown in **FIG. 5D**, an excimer laser **530** is focused on the airway ports of the micro nozzle **450** and the array of pockets can be formed thereon.

[0055] Still referring to **FIG. 5D**, it is possible that the airway ports of the multiple ports micro nozzle **450** are formed together with the array of pockets in accordance with an alternative embodiment of the present invention.

[0056] **FIGs. 5E and 5F** are enlarged cross sectional views of the stencil **501**, where the micro nozzle **450** is removed from the stencil **501** in **FIG. 5F**. As shown in **FIG. 5E**, the array of pockets **508** are created while drilling the airway ports. The pockets **508** have substantially the same diameter size as the airway ports. As shown in **FIG. 5F**, after the micro nozzle is removed therefrom, the pockets **508** are further processed under the excimer laser to provide a slightly bigger diameter than that of the airway ports of the micro nozzle **450**.

[0057] The above micro nozzles (single and multi ports) are fabricated accordingly for fitting onto any known pick and place units for soldering rework. Such pick and place units may comprise a micro nozzle holder for holding micro nozzles, an x-y-z axis table, a vacuum generator with purge option, a suction-purge controller, a power supply unit, an air pressure gauge and valve and compressed air line and etc.

[0058] The micro nozzles described above are made of PMMA or acrylic. It is possible that other polymers/plastics such as polycarbonate (PC), polyvinylchloride (PVC), polyetheretherketones (PEEK) and etc. may be desired.

[0059] With the micro nozzle, rework of BGA can be carried out based on a single solder ball, or an array of a predetermined size solder balls. The BGA components that fail capillarity tests can be revived under the BGA rework.

[0060] While specific embodiments have been described and illustrated, it is understood that many changes, modifications, variations and combinations thereof could be made to the present invention without departing from the scope of the invention.

Claims

1. A nozzle for picking up micro solder balls with a solder pick and place apparatus having a vacuum suction arm, the nozzle comprising:
a nozzle body configured for fitting to a vacuum port of the vacuum suction arm; and
an airway defines through the nozzle body, the airway having a diameter smaller than one micro solder ball.
2. The nozzle according to claim 1, further comprising a catchment cup in a form of a depression around the airway.
3. The nozzle according to claim 2, wherein the catchment cup is adapted to received one micro solder ball with a depth of the catchment cup less than a diameter of the solder ball.
4. The nozzle according to claim 2, wherein the catchment cup is a cylindrical depression formed around the airway.
5. The nozzle according to claim 2, wherein the catchment cup forms a conical mouth to the airway with a largest diameter of the conical bigger than the diameter of the solder ball.
6. The nozzle according to claim 2, further comprising a cylindrical wall projected between the catchment cup and the airway, wherein said cylindrical wall has a height lesser than a depth of the catchment cup.
7. The nozzle according to claim 2, further comprising a cylindrical depression within the catchment cup forming two tiers depression around the airway.

8. The nozzle according to claim 2, further comprising a pitch control platform defined around the catchment cup.
9. The nozzle according to claim 8, wherein the pitch control platform is a surface around the catchment cup.
10. The nozzle according to claim 8, wherein the surface of the pitch control platform has a relatively small pitch.
11. The nozzle according to claim 8, wherein the nozzle body having a plurality of the airways.
12. The nozzle according to claim 11, wherein the airways have a pitch between each airways smaller than half of a diameter of the solder ball for which the nozzle is intended for.
13. The nozzle according to claim 11, wherein the surface of the nozzle body between the catchment cups of each airway forms the pitch control platform.
14. The nozzle according to claim 1, wherein the nozzle body having a plurality of the airways.