



21 JAN 2003

166166

1

METHOD OF PRODUCING SOLDER BUMPS ON SUBSTRATE

FIELD OF THE INVENTION

The present invention relates to electrical connections using solder
5 bumps. In particular, the present invention relates to a method of producing
solder bumps in electrical connections in the semi-conductor industry.

BACKGROUND OF THE INVENTION

Ball grid array (BGA) packaging of integrated circuit (IC) devices is
10 gaining increasing importance in IC device production. In BGA packaging,
the conventional method is to use solder balls which are soldered onto the
pads of the substrate of the IC package. Various methods have been
described for the joining of packages with solder joints using solder balls.
US Patent no. 4,878,611 describes a solder joint assembly technique in
15 which solder balls of a defined size are reflowed to form solder joints with
desired joint shapes. US Patent no. 5,722,160 describes a packaging
method by forming solder bumps in through-holes. In both methods, solder
spheres are required to be formed on at least one of the surfaces to be
joined, and the spheres are described as being reflowed onto the
20 corresponding pads by solder paste.

The conventional method of using solder balls for solder bump
formation has certain drawbacks. Besides the high capital cost of a



G00002

sophisticated pick and place system, the cost of the balls themselves is high. In addition, high number of balls which are required for a conventional vacuum pick and place system to function properly means that even if only a few packages are needed, a large number of balls need to be dispensed
5 into the machine. As a result, for assembly houses which produces small volumes of many different types of packages, wastage becomes very high, as the balls get contaminated easily, and are not conducive to being reused extensively. Furthermore, the small sizes of the balls render them hard to manipulate, as even small air movements or motion of the substrate may
10 affect the precise positioning of the balls before they can be reflowed onto the substrate, resulting in poor yield. All these factors contribute to the high cost of producing devices with solder bumps such as BGA packages.

OBJECT OF THE INVENTION

15 It is an object of the present invention to provide a method to produce solder bump from solder paste.

It is another object of the present invention to provide a method to produce a plurality of solder bumps on a substrate which have uniform and predetermined heights.

20 It is yet another object to produce solder bumps at a reduced cost.

SUMMARY OF THE INVENTION

The present invention provides a method of producing solder bumps from solder paste. According to one aspect of the invention, the solder paste is heated by a laser beam for reflowing. If the application is in semiconductor
5 wafers or package, the solder paste is preferably applied in a defined volume onto each I/O pad, such that the resulting bump have uniform heights. According to another aspect of the invention, the paste application and the reflow steps may be performed within the same system, thereby eliminating the steps of transferring the substrate from one station to
10 another. In the most preferred embodiment, a stencil is provided to facilitate the application of the defined volume and height of solder paste. A laser beam is then directed onto the solder paste, preferably without moving the stencil. According to another aspect of the invention, an additional template is provided above to protect the stencil from being exposed to the laser
15 beam. The use of this method results in the elimination of solder balls and reflow oven, and the associated steps of transferring a substrate from the pick and place system to the oven, thereby reducing costs.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1A is a schematic illustration of one embodiment of the present invention.

Figure 1B is a longitudinal cross-sectional view of the squeezer as it is
5 swept across the substrate.

Figure 2 is a schematic illustration of another embodiment the present invention.

Figure 3 is a flow diagram to show the steps in the method according to the embodiment shown in Figure 1.

10 Figure 4 is a flow diagram to show the steps in the method according to the embodiment shown in Figure 2.

DESCRIPTION OF THE INVENTION

Conventional methods of solder paste application, such as for surface mounting, generally involve the use of a stencil. For example, the solder paste may be applied to the surface of the substrate, such as a printed circuit board, using a stencil. The IC packages are then placed on the board with the leads on the solder paste, and the entire assembly reflowed to join the package to the board.

It is possible that stencil technique may also be used in the production of solder bumps. The solder paste may be applied to the substrate using the stencil. The stencil is then removed and the substrate transferred to a reflow oven. However, the conventional PCB stencil method described above cannot be adapted directly into producing solder bumps such as for BGA packages. This method cannot be reliably produce bumps of uniform heights, which is an important requirement for BGA packages, because the removal of the stencil before the reflow step inevitably results in some solder paste adhering to the stencil, causing variability in the actual amount of paste that is reflowed. As a result, the bumps have variable heights, which is unacceptable for many types of packaging. In another variation, the stencil may be left on the substrate after solder paste application, and the oven reflow step performed with the solder paste within the stencil. This technique, however, would result in numerous stencils being required, as the assembly line from the paste application step to the oven reflow step

may be long. In addition, different packaging require different stencils, further multiplying the tooling costs involved.

The present invention provides a solution to the above problems by providing a method for solder paste reflow using laser technology. The technique is simple and cost effective, as the oven used in the conventional reflowing method may be eliminated. In order for a uniform array of bumps to be formed from the solder paste, a precisely defined volume of solder paste should be applied. This volume of solder paste should then result in solder bumps of uniform height once reflow is completed. In the most preferred embodiment, a stencil is used to in the application step. The laser head may be combined with the solder paste application or printing step into one system together, such that laser reflow occurs immediately after solder paste application without a transfer step. After the solder paste printing step, the substrate is kept in the printing position while the laser reflow proceeds. In this way, only a small number of stencils for each package type is required for each laser head.

The laser beam may be generated from conventional laser heads, such as neodymium:yttrium-aluminium-garnet (Nd:YAG) laser. If a single head is used, reflow may proceed sequentially from one stencil hole to another. If multiple heads are used, reflow may proceed from one row of holes to the next. Useful applications of this invention includes the production of BGA packages, and the production of bumps on wafers. These applications involve the placement of the solder paste onto the I/O pads of the substrate

involved in order to form a bump for electrical connections. For the present description, a substrate and the pads thereon include substrates for semiconductor packages such as ceramics, Bismaleimide Triazine (BT), tape, and also surfaces of wafers. Solder paste may be any solder paste
5 with flux, solder particles, including those with water based or no-clean flux.

Figure 1A shows one method of how a defined volume of solder paste may be applied onto a substrate. In this embodiment, a stencil 20 with holes 22 is provided. The position of the holes correspond to the pad positions on the substrate 24 in which the solder paste is to be applied. For
10 semiconductor substrates, the position of the holes correspond to the I/O pads of the substrates. A squeezer 26 containing solder paste is moved across the top surface of the stencil in the direction as shown by arrow 27. As shown in Figure 1B, the squeezer is preferably provided with a sharpened leading edge 29 which may be used to sweep or scrape the
15 successful solder paste off from the top surface of the stencil. As the squeezer moves across the stencil, a laser beam 28 delivered from a laser head 30 is used to reflow the solder paste directly inside the stencil, to allow an intermetallic layer of solder joint to form between the paste and the pad to form a bump, preferably without first moving the stencil away. The
20 partially spherical bump is then allowed to cool before the stencil is removed. This prevents the defined volume of solder paste from being disturbed before reflowing, and eliminates problems of the paste sticking onto the stencil.

A good material for the stencil is stainless steel or any other material which can withstand the heat of the reflow process and do not readily bond with the solder paste during reflowing such as chromium oxide coating. This allows the stencil to be moved away with ease after reflowing because
5 metals such as stainless steel and chromium oxide do not form an intermetallic bond readily with the solder paste. The thickness of the stencil is preferably thicker than the conventional stencil used in the typical surface mounting techniques (SMT), as the volume of the paste used in SMT is meant only to facilitate soldering of the device to the board, and are not
10 meant to form bumps. The thickness of the stencil in the present invention is proportional to the size of the bump desired after reflow, and may be determined by one of ordinary skill in the art without undue experimentation. For example, for a bump of 0.2 mm diameter, a stencil of 0.2-0.3mm may be used, with 0.2-0.25mm being the preferred range. The solder paste may
15 contain a water-based flux or a no-clean flux. If water-based flux is used, a conventional washing step may be used after the reflow step.

Figure 2 shows another embodiment of the present invention. This embodiment is similar to the one described in Figure 1, except for the addition of a template 32 with apertures 34 corresponding to the holes of
20 the stencil. The purpose of the template is to prevent the surface of the stencil from the laser beam, as residual solder paste may be present on it. This prevents the reflow of these residual solder paste onto the surface of

the stencil, increasing the life of the stencil. Figures 3 and 4 shows the preferred steps involved in these two embodiments.

The use of the stencil in the reflow process also has the added advantage of preventing bridges from forming between the bumps, especially where the pitch between the pads is small. The melted paste is prevented from flowing away from the pad by the presence of the stencil, and the bumps form substantially spherical bumps into the stencil hole.

Although the present invention has been described specifically with reference to Figures 1-4, it is clear that other techniques may also be used to deposit the solder paste of a defined volume or height onto the substrate pads. For example, advanced injection technology may be used to render this a stencil-less method. In such a case, a block of solder paste would be injected onto the substrate pad directly, and the laser reflow performed without the stencil. Many other variations are possible given the teachings of the present invention.

CLAIMS

- 1 1. A method of forming solder bumps onto a plurality of electrically
2 conducting pads of a substrate comprising :
 - 3 a) applying a predetermined volume of solder paste onto each
4 pad on said substrate;
 - 5 b) reflowing each of said volume of solder paste with a laser
6 beam;
 - 7 c) cooling said reflowed solder paste to form a solder bump of a
8 preset height.
- 1 2. A method of forming solder bumps according to claim 1 wherein said
2 volume of said solder paste is defined by placing a stencil with holes
3 corresponding to said pads above said substrate, such that said
4 holes are directly above said pads such that said step (a) involves
5 applying a predetermined amount of solder paste into said hole.
- 1 3. A method of forming solder bumps according to claim 2 wherein said
2 application step involves applying excess solder paste into said hole;
3 and sweeping the top surface of said stencil to remove excess solder
4 paste.
- 1 4. A method of forming solder bumps according to claim 2 wherein the
2 reflow step is performed without moving the stencil away after solder
3 paste application, said method further includes an additional step (d)
4 of removing said stencil after step (c).

- 1 5. A method of forming solder bumps according to claim 2 wherein an
2 additional template with apertures is placed above said stencil, said
3 apertures corresponding to said holes and positioned directly above
4 said holes such that said aperture protects said stencil surface from
5 being exposed to said laser beam.
- 1 6. A method of forming solder bumps according to claim 2 wherein said
2 solder paste is applied onto said stencil by a squeezer
- 1 7. A method of forming solder bumps according to claim 1 wherein said
2 predetermined volume of solder paste is applied by an injector.
- 1 8. A method of forming solder bumps according to claim 7 wherein said
2 injector has a plurality of injecting needles.
- 1 9. A method of forming solder bumps according claim 1 wherein step (b)
2 comprises the step of reflowing each of said volume of solder paste
3 with a Nd:YAG laser beam.