METHOD OF MODULATING SURFACE MOUNT TECHNOLOGY SOLDER VOLUME TO OPTIMIZE RELIABILITY AND FINE PITCH YIELD

In a method of forming connectors on a substrate (202), a first patterning layer (200), being made up of mesh screen (204) and resist (206) to define a plurality of openings (208, 210, 212, 214) therein, is provided on the surface of the substrate (202), and the openings are filled with solder paste (280). A second patterning layer, also made up of a mesh screen (252) and resist (254) to define a plurality of openings (256, 258, 260, 262) therein, is provided over the first patterning layer (200), with the openings of the second patterning layer (250) communicating with respective openings of the first patterning layer. The communicating openings form passages (270, 274, 276, 278) through the patterning structure (272), with some of the passages being of different volume from others. After filling of the openings of the second patterning layer (250) with solder paste (280), the patterning layers (200, 250) are removed, leaving bodies of solder paste which vary in volume in accordance with the different volumes of the passages (270, 274, 276, 278).
— before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments

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METHOD OF MODULATING SURFACE MOUNT TECHNOLOGY SOLDER
VOLUME TO OPTIMIZE RELIABILITY AND FINE PITCH YIELD

TECHNICAL FIELD

This invention relates generally to surface mount technology, and more particularly, to a method of varying conductive connection body volume (commonly solder) on a substrate.

BACKGROUND ART

In current surface mount technology practice, a patterning layer 20 is positioned on a surface of a substrate 22 in the form of a printed circuit board (see Figure 1). The patterning layer 20 is comprised of a screen 24, typically a woven stainless-steel mesh (fibers parallel to the plane of the Figures not shown for clarity), which has a polymer film (resist) 26 applied thereto so as to define a plurality of openings (four shown at 28, 30, 32, 34), cylindrical in shape, through the patterning layer 20. A conductive connection material such as solder paste 36 is then applied on top of the structure (Figure 2), flooding the patterning layer and filling in the openings 28, 30, 32, 34. The solder paste 36 is comprised of solder balls in an organic flux matrix, as is well known. A rubber blade or squeegee 38 is run across the upper surface (Figure 2) to remove excess paste, so that cylinders of paste 40, 42, 44, 46 (in the typical embodiment right cylinders of rectangular cross-section) remain in the openings 28, 30, 32, 34 of the patterning layer 20, to the same height above the surface of the substrate 20 as the height of the resist 26 (Figure 3).

Subsequent to this step, the patterning layer 20 is removed (the screen fibers moving through the paste), leaving the cylinders of paste 40, 42, 44, 46 on the substrate 22 (Figure 4). As will be seen, the cylinders of paste 40, 42, 44, 46 are substantially equal in volume, with the volume being relatively large. The relatively large pitch (pitch = A) contacts 48, 50 of an integrated circuit 52 to be mated to the printed circuit board 22 are brought into contact with the cylinders of paste 40, 42 as shown in Figure 4. The relatively small or fine pitch (pitch = B) contacts 54, 56 of another integrated circuit 58 are brought into contact with paste cylinders 44, 46. The positioning of the resist 26 has been chosen so that the cylinders of paste 40, 42, 44, 46 are positioned to accommodate these different pitches. The resulting structure is run through a proper temperature profile which activates the flux of the paste and melts the solder thereof.

In the conventional process described above, all cylinders of paste 40, 42, 44, 46 formed on the substrate 22 would be of the same height and volume, so that solder volume would be the same for all connections to the integrated circuits 52, 58. This results in the solder connections 60, 62 between the integrated circuit 52 and the printed circuit board 22, and the solder connections 64, 66 between the integrated circuit 58 and the printed circuit board 22, all being of substantially the same volume and cross-section (in this example a relatively large volume and cross section) (Figure 5).

In order to achieve high reliability for large area devices of the integrated circuit 52, a large solder volume (and resulting larger cross-section) should be provided, as thus far described. However, the use of such large solder volumes with a fine pitch device such as integrated circuit 58 can lead to bridging or shorts between adjacent conductors 64, 66, which could be prevented by using smaller solder volumes (resulting in smaller cross-sections).

Figures 6-10 illustrate the process wherein such smaller solder volumes are provided.
Again, a patterning layer 70 in the form of a screen 71 with resist 72 applied thereto is positioned on a surface of a substrate 74 in the form of the printed circuit board (Figure 6). The patterning layer 70 defines a plurality of cylindrical openings 76, 78, 80, 82 therethrough. A solder paste 84 is then applied on top of the structure (Figure 7), flooding the patterning layer 70 and filling in the openings 76, 78, 80, 82. A rubber blade or squeegee 85 is run across the upper surface to remove excess paste, and cylinders of paste 86, 88, 90, 92 remain in the openings 76, 78, 80, 82 of the patterning layer 70, to the same height above the surface of the substrate 74 as the height of the resist 72, all as described above (Figure 8). The patterning layer 70 is then removed, leaving the cylinders of paste 86, 88, 90, 92 on the substrate 74 (Figure 9).

As will be seen, the cylinders of paste 86, 88, 90, 92 are again substantially equal in volume, but with the resist 72 being configured so that this volume is relatively small as compared to the previously described embodiment.

The relatively large pitch contacts 94, 96 (pitch = A) of integrated circuit 98 are brought into contact with the cylinders of paste 86, 88 as shown in Figure 9. The relatively small pitch contacts 100, 102 (pitch = B) of integrated circuit 104 are brought into contact with paste cylinders 90, 92. The positioning of the resist 72 has again been chosen so that the cylinders of paste 86, 88, 90, 92 are positioned to accommodate the different pitches, as shown. The resulting structure is run through a proper temperature profile which activates the flux of the paste and melts the solder thereof.

Using the prior art single patterning layer 70 of constant thickness, with cylinders of paste 86, 88, 90, 92 formed on the substrate 74 being of equal height and volume (Figure 10), solder volume is the same for all connections 106, 108, 110, 112 to the integrated circuits 98, 104. This results in the solder connections 106, 108 between the integrated circuit 98 and the printed circuit board 74, and the connections 110, 112 between the integrated circuit 104 and the printed circuit board 74, all being of substantially the same, relatively small volume and cross-section. While this approach effectively deals with the problem of bridging or shorting of connections described above, the reduction in volume and cross-section of the connections 106, 108 between integrated circuit 98 and printed circuit board 74 leads to connection reliability problems.

Therefore, what is needed is a process for applying conductive connection material such as solder paste to a substrate wherein the volume thereof may be varied as chosen to overcome the problems cited above.

DISCLOSURE OF THE INVENTION

In the present method of forming connectors on a substrate, a first patterning layer is provided on a surface of a substrate, the patterning layer being made up of a mesh screen and resist to define at least first and second openings therein. The first and second openings of the first patterning layer are filled with solder paste, and then a second patterning layer is provided on the first patterning layer, the second patterning layer defining at least first and second openings which communicate respectively with the first and second openings of the first patterning layer. The first and second openings of the second patterning layer are then filled with solder paste. The combined volume of the first opening of the first patterning layer and first opening of the second patterning layer is different from the combined volume of the second opening of the first patterning layer and the second opening of the second patterning layer.

The present invention is better understood upon consideration of the detailed description below, in conjunction with the accompanying drawings. As will become readily apparent to those skilled in the art from
the following description, there are shown and described embodiments of this invention simply by way of the illustration of the best mode to carry out the invention. As will be realized, the invention is capable of other embodiments and its several details are capable of modifications and various obvious aspects, all without departing from the scope of the invention. Accordingly, the drawings and detailed description will be regarded as illustrative in nature and not as restrictive.

BRIEF DESCRIPTION OF THE DRAWINGS

The novel features believed characteristic of the invention are set forth in the appended claims. The invention itself, however, as well as said preferred mode of use, and further objects and advantages thereof, will best be understood by reference to the following detailed description of illustrative embodiments when read in conjunction with the accompanying drawings, wherein:

Figure 1 is a sectional view showing a step in the process of the prior art, wherein a patterning layer is applied to a surface of a substrate;

Figure 2 is a sectional view similar to that shown in Figure 1, and showing a further step in the process of the prior art, wherein solder paste is applied to the structure, and excess paste is removed;

Figure 3 is a sectional view similar to that shown in Figure 2, and showing a further step in the process of the prior art, showing the state of the structure after removal of excess paste;

Figure 4 is a sectional view similar to that shown in Figure 3, and showing a further step in the process of the prior art, wherein the patterning layer has been removed, and wherein connectors of integrated circuits are applied to the paste;

Figure 5 is a sectional view similar to that shown in Figure 4, and showing a further step in the process of the prior art, showing the connections between the integrated circuits and the substrate;

Figure 6 is a sectional view showing a step in another process of the prior art, wherein a patterning layer is applied to a surface of a substrate;

Figure 7 is a sectional view similar to that shown in Figure 6, and showing a further step in this prior art process, wherein solder paste is applied to the structure, and excess paste is removed;

Figure 8 is a sectional view similar to that shown in Figure 7, and showing a further step in this prior art process, showing the state of the structure after removal of excess paste;

Figure 9 is a sectional view similar to that shown in Figure 8, and showing a further step in this prior art process, wherein the patterning layer has been removed, and wherein connectors of integrated circuits are applied to the paste;

Figure 10 is a sectional view similar to that shown in Figure 9, and showing a further step in this prior art process, and showing the connections between the integrated circuits and the substrate;

Figure 11 is a sectional view showing a first step in the present process, wherein a patterning layer is applied to a substrate;

Figure 12 is a sectional view similar to that shown in Figure 11, and showing a further step in the present process, wherein solder paste is applied to the structure, and excess paste is removed;

Figure 13 is a sectional view similar to that shown in Figure 12, and showing a further step in the present process, showing the state of the structure after removal of the excess paste;
Figure 14 is a sectional view similar to that shown in Figure 13, and showing a further step in the present process, showing the application of a second patterning layer on the first patterning layer;

Figure 15 is a view similar to that shown in Figure 14, and showing a further step in the present process, wherein solder paste is applied to the structure, and excess paste is removed;

Figure 16 is a view similar to that shown in Figure 15, and showing a further step in the present process, showing the state of the structure after removal of the excess paste;

Figure 17 is a view similar to that shown in Figure 16, and showing a further step in the present process, wherein the patterning layers have been removed, and wherein connectors of integrated circuits are applied to the paste;

Figure 18 is a view similar to that shown in Figure 17, and showing a further step in the present process, showing the connections between the integrated circuits and the substrate;

Figure 19 is a view similar to that shown in Figure 17, but showing the present process as applied to a warped substrate; and

Figure 20 is a view similar to that shown in Figure 19, but showing a further step in the process, showing the connections between the integrated circuit and a warped substrate.

BEST MODE(S) FOR CARRYING OUT THE INVENTION

Reference is now made in detail to specific embodiments of the present invention which illustrate the best mode presently contemplated by the inventors for practicing the invention.

As shown in Figure 11, a patterning layer 200 is positioned on a surface of a substrate 202 in the form of a printed circuit board. The patterning layer 200 is comprised of a screen 204, typically a woven stainless-steel mesh, which has a polymer film (resist) 206 applied thereto to as to define a plurality of openings (four shown at 208, 210, 212, 214) through the patterning layer 200, cylindrical in shape, and shown as substantially equal in volume. A conductive connection material such as solder paste 216 is then applied on top of the structure (Figure 12), flooding the patterning layer 200 and filling in the openings 208, 210, 212, 214. As described above, the solder paste 216 is comprised of solder balls in an organic flux matrix. A rubber blade or squeegee 218 is run across the upper surface (Figure 12) to remove excessive paste, so that cylinders of paste 220, 222, 224, 226 remain in the openings 208, 210, 212, 214 of the patterning layer 200, to the same height above the surface of the substrate 202 as the height of the resist 206 (Figure 13).

Next, a second patterning layer 250 is provided on the patterning layer 200 (Figure 14). The patterning layer 250 is also comprised of a screen 252 and a polymer film (resist) 254, and defines a plurality of openings therethrough (four shown at 256, 258, 260, 262), cylindrical in shape, communicating with respective openings 208, 210, 212, 214 of the patterning layer 200. As shown in Figure 14, the opening 256 in the patterning layer 250 is of substantially the same volume as the opening 208 in the patterning layer 200 directly therebelow and communicating therewith. Similarly, the opening 258 in the patterning layer 250 is of substantially the same volume as the opening 210 in the patterning layer 200 directly therebelow and communicating therewith. Meanwhile, the opening 260 in the patterning layer 250 is of less volume and smaller cross-section than the opening 212 in the patterning layer 200 directly therebelow and communicating therewith. Likewise, the opening 262 in the patterning layer 250 is of less volume and smaller cross section than the opening 214 in the patterning layer 200 directly therebelow and communicating therewith. The opening 256 and opening 208
together define a passage 270 through the patterning structure 272 made up of patterning layer 250 and patterning layer 200, and the opening 258 and opening 210 together define a passage 274 through the patterning structure 272. The opening 260 and the opening 212 together define a passage 276 through patterning structure 272, and the opening 262 and opening 214 together define a passage 278 through the patterning structure 272.

Each such passage 276, 278 has a volume which is less than that of passage 270 or passage 274.

A solder paste 280 is then applied on top of the structure (Figure 15), flooding the patterning layer 250 and filling the openings 256, 258, 260, 262. A rubber blade or squeegee 282 is run across the upper surface (Figure 15) to remove excess paste, so that paste remains in and fills the passages 270, 274, 276, 278 of the patterning structure 272 to the same height as the resist 254 (Figure 16).

The patterning layers 250, 200 are then removed (the screen fibers moving through the solder paste), leaving the bodies of solder paste 290, 292, 294, 296 on the substrate 202 (Figure 17). As will be seen, the bodies of solder paste 290, 292 each have greater volume than the bodies of solder paste 294, 296.

As an alternative, both patterning layers 200, 250 could be placed down prior to any application of solder paste, and then the paste would be applied to fill the openings 208, 210, 212, 214 in the patterning layer 200 and the openings 256, 258, 260, 262 in the patterning layer 250 in a single step, resulting (after application of squeegee) in the structure shown in Figure 16.

Then, the (large pitch A) contacts 300, 302 of an integrated circuit 304 to be mated to the printed circuit board 202 are brought into contact with the solder paste bodies 290, 292 as shown in Figure 17, and the (fine pitch B) contacts 306, 308 of an integrated circuit 310 are brought into contact with the solder paste bodies 294, 296, the resist 206, 254 of the patterning layers 200, 250 being properly positioned so the contacts 300, 302, 306, 308 of the integrated circuits 304, 310 are so received. The resulting structure is run through a proper temperature profile which activates the flux of the paste and melts the solder thereof, providing solder connections 312, 314 between the printed circuit board 202 and the integrated circuit 304, and solder connectors 316, 318 between the printed circuit board 202 and the integrated circuit 310 (Figure 18).

Because of the different volumes of the solder bodies 290, 292 on the one hand and the solder bodies 294, 296 on the other, as provided through the above process, the volumes of the connections 312, 314 (and their cross-sections) are different from the volumes (and cross sections) of the connections 316, 318. It will readily be seen that the process can be practiced to provide larger solder volume connections between the printed circuit board 202 and integrated circuit 304 for connection to large area devices of the integrated circuit 304, in order to achieve high reliability thereof. Meanwhile, for connection from the printed circuit board 202 to small, fine pitch devices of the integrated circuit 310, smaller volume (and cross-section) connections can with advantage be used to prevent shorts.

It will also be seen that by varying the size of the openings in the patterning layers 200, 250, a wide variety of different volumes of solder paste bodies (and in turn solder bodies) can be achieved to fit the particular application. Indeed, as a further example, if desired, an opening (for example opening 260) in the patterning layer 250 need not exist, so that the volume of the solder paste body in this area is determined only by the volume of the opening 212 in the patterning layer 200.

Figures 19 and 20 show another application of the invention. As shown in Figure 19, the printed circuit board 400 is in a warped state. A plurality of solder paste bodies (three shown at 402, 404, 406) are formed on the printed circuit board 400 as described above, and the contacts 408, 410, 412 of the integrated circuit 414 are
brought into contact with the respective solder paste bodies 402, 404, 406. The volume of the solder paste body 404, positioned on the warped printed circuit board 400 in an area thereof more distant from the integrated circuit 414, is formed to have a volume greater than the respective volumes of the solder paste body 402 and a solder paste body 406, both of which are positioned on the warped printed circuit board 400 in areas thereof closer to the integrated circuit 414.

The resulting structure is run through a proper temperature profile which activates the flux of the paste and melts the solder thereof, providing solder connections 420, 422, 424 between the printed circuit board 400 and integrated circuit 414 (Figure 20).

Through appropriate choice of the different volumes of the solder paste bodies, solder connections between the warped printed circuit board 400 and integrated circuit 414 can be chosen to have similar cross-sections. This can be achieved because the warping of the printed circuit board 400 can be compensated for by varying the volumes of the solder paste bodies 402, 404, 406 in accordance with the above method.

The foregoing description of the embodiments of the invention has been presented for purposes of illustration and description. It is not intended to be exhaustive or to limit the invention to the precise form disclosed. Other modifications or variations are possible in light of the above teachings.

The embodiments were chosen and described to provide the best illustration of the principles of the invention and its practical application to thereby enable one of ordinary skill of the art to utilize the invention in various embodiments and with various modifications as are suited to the particular use contemplated. All such modifications and variations are within the scope of the invention as determined by the appended claims when interpreted in accordance with the breadth to which they are fairly, legally and equitably entitled.
What is claimed is:

1. A method of forming connectors on a substrate (202) characterized by:
   providing a patterning structure (272) on the substrate (202), the patterning structure (272) defining a
   plurality of passages (270, 274, 276, 278) therethrough, at least one of the passages (276, 278) having a volume
   different from at least another of the passages (270, 274); and
   filling the plurality of passages (270, 274, 276, 278) with conductive connection material (280).

2. The method of claim 1 and further comprising the step of removing the patterning structure (272) after
   filling the plurality of passages (270, 274, 276, 278) with conductive connection material (280).

3. The method of claim 3 and further comprising the step of providing that the patterning structure (272)
   is made up of the screen structure (204, 252) and a polymer film (206, 254) mounted to the screen structure (204,
   252).

4. A method of forming connectors on a substrate (202) characterized by:
   providing a first patterning layer (200) on a surface of the substrate (202), the first patterning layer (200)
   defining a plurality of openings (208, 210, 212, 214) therethrough;
   providing a second patterning layer (250) on the first patterning layer (200), the second patterning layer
   (250) defining at least one opening (256, 258, 260, 262) therethrough and communicating with an opening of the
   first patterning layer (200); and
   filling the openings (208, 210, 212, 214, 256, 258, 260, 262) of the first and second patterning layers
   (200, 250) with conductive connection material (280).

5. The method of claim 4 and further comprising the step of providing that the plurality of openings
   (208, 210, 212, 214) of the first patterning layer (200) are filled with conductive connection material (280) prior
   to providing a second patterning layer (250) on the first patterning layer (200).

6. The method of claim 5 and further comprising the step of removing the first and second patterning
   layers (200, 250) after filling the plurality of openings of the first patterning layer (200) and opening of the
   second patterning layer (250) with conductive connection material (280).

7. The method of claim 6 and further comprising step of providing that each patterning layer (200, 250)
   is made up of the screen structure (204, 252) and a polymer film (206, 254) mounted to the screen structure.
8. A method of forming a connector on a substrate (202) characterized by:

providing a first patterning layer (200) on a surface of the substrate (202), the first patterning layer (200) defining an opening (212, 214) therethrough;

providing a second patterning layer (250) on the first patterning layer (200), the second patterning layer (250) defining an opening (260, 262) therethrough, communicating with the opening (212, 214) of the first patterning layer (200), the opening (212, 214) of the first patterning layer (200) having a greater volume than the opening (200, 262) of the second patterning layer (250); and

filling the openings of the first and second patterning layers (200, 250) with conductive connection material (280).

9. The method of claim 8 and further comprising the step of providing that the conductive connection material (280) comprises solder paste.

10. The method of claim 8 and further comprising the step of providing that the opening (212, 214) in the first patterning layer (200) is filled with conductive connection material (280) prior to providing the second patterning layer (250) on the first patterning layer (200).
FIGURE 4 (PRIOR ART)

FIGURE 5 (PRIOR ART)
FIGURE 9 (PRIOR ART)

FIGURE 10 (PRIOR ART)
INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER

| IPC 7 | H05K3/12 | H05K3/34 | B41M1/12 |

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)

| IPC 7 | H05K |

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 practical, search terms used)

PAJ, EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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[X] Further documents are listed in the continuation of box C.  
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Date of the actual completion of the international search: 30 July 2002

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