A SOLDER BUMP STRUCTURE FOR A MICROELECTRONIC SUBSTRATE

Field of the Invention

This invention relates to the field of microelectronic devices and more particularly to solder bumps for microelectronic devices.

Background of the Invention

High performance microelectronic devices often use solder balls or solder bumps for electrical and mechanical interconnection to other microelectronic devices. For example, a very large scale integration (VLSI) chip may be electrically connected to a circuit board or other next level packaging substrate using solder balls or solder bumps. This connection technology is also referred to as "Controlled Collapse Chip Connection - C4" or "flip-chip" technology, and will be referred to herein as "solder bumps".

A significant advance in this technology is disclosed in U. S. Patent No. 5,162,257 to Yung entitled "Solder Bump Fabrication Method" and assigned to the assignee of the present invention. In this patent, an under bump metallurgy is formed on the microelectronic substrate including contact pads, and solder bumps are formed on the under bump metallurgy opposite the contact pads. The under bump metallurgy between the solder bumps and the contact pads is converted to an intermetallic which is resistant to etchants used to etch the under bump metallurgy between solder bumps. Accordingly, the base of the solder bumps is preserved.

In many circumstances, it may be desired to provide a solder bump on the substrate at a location remote from the contact pad and also form an electrical

connection between the contact pad and the solder bump. For example, a microelectronic substrate may be initially designed for wire bonding with the contact pads arranged around the outer edge of the substrate. At a later time it may be desired to use the microelectronic substrate in an application requiring solder bumps to be placed in the interior of the substrate. In order to achieve the placement of a solder bump on the interior of the substrate away from the respective contact pad, an interconnection or redistribution routing conductor may be necessary.

U. S. Patent No. 5,327,013 to Moore et al. entitled "Solder Bumping of Integrated Circuit Die" discloses a method for forming a redistribution routing conductor and solder bump on an integrated circuit die. This method includes forming a terminal of an electrically conductive, solder-wettable composite material. The terminal includes a bond pad overlying the passivation layer remote from a metal contact and a runner that extends from the pad to the metal contact. A body of solder is reflowed onto the bond pad to form a bump bonded to the pad and electrically coupled through the runner.

In this method, however, the solder bump is formed by pressing a microsphere of a solder alloy onto the bond pad. In addition, the spread of solder along the runner during reflow is limited. In the illustrated embodiment, a solder stop formed of a polymeric solder resist material is applied to the runner to confine the solder to the bond pad.

Notwithstanding the above mentioned references, there continues to exist a need in the art for methods of producing redistribution routing conductors and solder bumps efficiently and at a reduced cost.

Summary of the Invention

It is therefore an object of the present invention to provide an improved method of forming a redistribution routing conductor.

It is another object of the present invention to provide a method of forming a redistribution routing conductor which can be integrally formed together with an associated solder bump.

These and other objects are provided, according to the present invention, by forming an under bump metallurgy layer on the microelectronic substrate and forming a solder structure including an elongate portion and an enlarged width portion on the under bump metallurgy layer. The solder structure can be formed by electroplating on the desired portions of the under bump metallurgy layer which are defined by a mask. The excess portions of under bump metallurgy not covered by solder can then be selectively removed using the solder structure as a mask. Accordingly, a single masking step can be used to define both the solder structure and the under bump metallurgy layer.

The solder can then be made to flow. Unexpectedly, the surface tension within the solder will cause the flowing solder to form a thin solder layer on the elongate portion of the under bump metallurgy layer and a raised solder bump on the enlarged width portion of the under bump metallurgy layer. Accordingly, a single solder deposition step followed by a solder flow step (typically induced by heat) can be used to form a solder structure including both a thin elongate portion and a raised enlarged width portion.

In one embodiment, the present invention includes a method of forming a redistribution routing conductor on a microelectronic substrate including an electrical contact pad at a surface of the microelectronic substrate. This method includes the

steps of forming an under bump metallurgy layer on the surface, and forming a solder structure on the under bump metallurgy layer opposite the microelectronic substrate. The under bump metallurgy layer electrically contacts the electrical contact pad, and the solder structure includes an elongate portion and an enlarged width portion.

The step of forming a solder structure preferably includes the step of forming a solder structure including an elongate portion which extends over the electrical contact pad. This solder structure may define first (exposed) and second (unexposed) portions of the under bump metallurgy layer, and the step of forming a solder structure may be followed by the step of selectively removing the first (exposed) portion of the under bump metallurgy layer which is not covered by the solder structure. Accordingly, the solder structure can be used as a masking layer to selectively remove the first portion of the under bump metallurgy layer not covered by solder after forming the solder structure, thereby eliminating the need for separate photolithography steps to pattern the solder structure and the under bump metallurgy layer.

The elongate solder portion preferably has one end that is positioned on the under bump metallurgy layer opposite the contact pad and a second end that is connected to the enlarged width portion. Accordingly, the solder structure defines respective elongate and enlarged width portions of the under bump metallurgy layers, and one end of the elongate portion of the under bump metallurgy layer preferably makes electrical contact with the contact pad. It will be understood that other elongate solder portions may extend across the under bump metallurgy layer in other directions from the point opposite the contact pad, and also that the elongate portion may extend slightly beyond the point opposite the contact pad.

This method may also include the step of causing the solder in the solder structure to flow from the elongate portion to the enlarged width portion. Accordingly, a raised solder bump may be formed in the enlarged width portion of the solder structure and a thin solder layer may be formed in the elongate portion of the solder structure. This step is preferably accomplished by heating the solder above its liquidus temperature and confining it to the elongate and enlarged width portions of the under bump metallurgy layer so that surface tension induced internal pressures cause the solder to flow to the enlarged width portions. The flowing solder may be confined by forming a solder dam layer on the first (exposed) portion of the under bump metallurgy layer which is not covered by the solder structure.

The step of causing the solder structure to flow may form an intermetallic region between the under bump metallurgy layer and the solder structure. This intermetallic region includes a constituent of the metallurgy layer and a constituent of the solder structure. This intermetallic region is resistant to etchants used to remove the first (exposed) portion of the under bump metallurgy layer thereby reducing undercutting of the solder structure.

The step of forming the under bump metallurgy layer preferably includes the steps of forming a chromium layer on the microelectronic substrate, forming a phased layer of chromium and copper on the chromium layer, and forming a copper layer on the phased layer opposite the chromium layer. This structure provides an electrically conductive base that will adhere to the microelectronic substrate and contact pad as well as the solder structure. The step of forming the under bump metallurgy layer may also include the step of forming a titanium layer between the microelectronic substrate and the chromium layer.

The step of forming the solder structure may include the steps of forming a patterned mask layer on the under bump metallurgy layer, forming the solder structure on the second portion of the under bump metallurgy layer, and selectively removing the patterned mask layer. The patterned mask layer preferably covers the first portion of the under bump metallurgy layer and defines the second portion of the under bump metallurgy layer on which the solder structure is formed.

In addition, the step of forming the solder structure includes the step of electroplating solder on the second portion of the under bump metallurgy layer. By forming an under bump metallurgy layer that extends across the microelectronic substrate, the under bump metallurgy layer can be used as an electroplating electrode for a plurality of solder structures. Accordingly, a plurality of solder structures can be formed in a single electroplating step with each solder structure having a common uniform height.

The present invention also includes a solder bump structure on a microelectronic substrate including an electrical contact having an exposed portion. This solder bump structure includes an under bump metallurgy structure on the microelectronic substrate, and a solder structure on the under bump metallurgy structure opposite the microelectronic substrate. The metallurgy structure includes an elongate portion having a first end which electrically contacts the exposed portion of the electrical contact and an enlarged width portion connected to a second end of the elongate portion. The solder structure includes an elongate portion on the metallurgy structure and an enlarged width portion on the enlarged width portion of the metallurgy structure. Accordingly, the enlarged width portion of the solder structure can be formed on a portion of the

microelectronic substrate other than the contact pad and still be electrically connected to the pad.

The elongate portion of the solder structure may have a first predetermined thickness and the enlarged width portion of the solder structure may have a second predetermined thickness. The first predetermined thickness is preferably thin relative to the second predetermined thickness. Accordingly, the enlarged width portion of the solder structure preferably forms a raised solder bump which can be used to connect the microelectronic substrate, both electrically and mechanically, to a printed circuit board or other next level packaging substrate. Alternately, the elongate portion of the solder structure and the enlarged width portion of the solder structure may have a common predetermined thickness.

The solder bump structure may also include an intermetallic region between the under bump metallurgy structure and the solder structure, and this intermetallic region includes a constituent of the metallurgy structure and a constituent of the solder structure.

Alternately, a solder bump structure may include an under bump metallurgy layer on the microelectronic substrate and electrically contacting the exposed portion of the electrical contact. This solder bump structure also includes a solder structure on the under bump metallurgy layer opposite the microelectronic substrate. The solder structure includes an elongate portion having a first end opposite the exposed portion of the electrical contact and an enlarged width portion connected to a second end of the elongate portion. This under bump metallurgy layer may extend across the microelectronic substrate with the solder structure defining first (exposed) and second (unexposed) portions of the under bump metallurgy layer. This continuous under bump

metallurgy layer may be used as an electrode for electroplating.

In addition, the structure may include a solder dam on the first (exposed) portions of the under bump metallurgy layer. This solder dam may be used to contain the solder during a solder flow step as discussed above.

Accordingly, an under bump metallurgy layer can be formed on a microelectronic substrate and used as an electrode to electroplate a solder structure including an elongate portion and an enlarged width portion. The solder structure is then used as a mask to selectively remove the portions of the under bump metallurgy layer not covered by the solder structure. A single photolithography step can therefore be used to pattern both the solder structure and the under bump metallurgy layer. In addition, the solder can be caused to flow from the elongate portion of the solder structure to the enlarged width portion thereby forming a raised solder bump. This is preferably achieved by heating the solder above its liquidus temperature allowing surface tension induced internal pressures to affect the flow. Accordingly, a stable multi-level solder structure is produced.

Brief Description of the Drawings

Figures 1-5 are cross sectional side views of a microelectronic substrate at various stages during the manufacture of a redistribution routing conductor according to the present invention.

Figures 6-10 are top views of a microelectronic substrate at various stages during the manufacture of a redistribution routing conductor corresponding respectively to Figures 1-5.

Detailed Description of Preferred Embodiments

The present invention will now be described more fully hereinafter with reference to the accompanying drawings, in which preferred embodiments of the invention are shown. This invention may, however, be embodied in many different forms and should not be construed as limited to the embodiments set forth herein; rather, these embodiments are provided so that this disclosure will be thorough and complete, and will fully convey the scope of the invention to those skilled in the art. In the drawings, the thickness of layers and regions are exaggerated for clarity. Like numbers refer to like elements throughout.

The invention relates to a microelectronic structure **11** including a redistribution routing conductor and a raised solder bump, as shown from the side in Figure 5 and as shown from the top in corresponding Figure 10. The microelectronic structure includes a contact pad **14** and passivation layer **12** on a substrate **15**. The redistribution routing conductor **17** and solder bump **21** each include respective portions of under bump metallurgy layer **16A-B** and solder layer **22A-B**.

The redistribution routing conductor **17** includes a relatively elongate solder portion **22B** on a respective elongate under bump metallurgy portion **16B**. The solder bump **21** includes an enlarged width solder portion **22A** on a respective enlarged width under bump metallurgy portion **16A**. Preferably the elongate solder portion **22B** is relatively thin while the enlarged width solder portion **22A** is raised, as shown in Figure 5.

Accordingly, the solder bump **21** can be located at a point on the substrate relatively distant from the contact pad **14** with the redistribution routing conductor **17** providing an electrical connection therebetween. This arrangement provides the advantage that a substrate having a layout with a contact pad **14**

at one predetermined location can have an associated solder bump at a second location. This can be particularly useful, for example, when a substrate has a layout with contact pads arranged for wire bonding, and it is desired to use the substrate in a flip-chip application. This solder bump and redistribution routing conductor can be fabricated simultaneously, as described below with regard to Figures 1-10.

While the redistribution routing conductor **17** can be straight as shown, it may also include bends and curves. Furthermore, the solder bump **21** may be circular as shown or it can have other shapes such as rectangular.

The solder bump **21** and the redistribution routing conductor **17** are preferably formed simultaneously. Figures 1-5 are cross-sectional side views of microelectronic structures at various stages of fabrication, while Figures 6-10 are corresponding top views of the same microelectronic structures. The microelectronic structure **11** initially includes a passivation layer **12** and an exposed contact pad **14** on a substrate **15**, as shown in Figures 1 and 6.

The substrate **15** can include a layer of a semiconducting material such as silicon, gallium arsenide, silicon carbide, diamond, or other substrate materials known to those having skill in the art. This layer of semiconducting material can in turn include one or more electronic devices such as transistors, resistors, capacitors, and/or inductors. The contact pad **14** may comprise aluminum, copper, titanium, an intermetallic including combinations of the aforementioned metals such as AlCu and $AlTi_3$, or other materials known to those having skill in the art. This contact is preferably connected to an electronic device in the substrate.

The passivation layer **12** can include polyimide, silicon dioxide, silicon nitride, or other

passivation materials known to those having skill in the art. As shown, the passivation layer **12** may cover top edge portions of the contact pad **14** opposite the substrate **15**, leaving the central portion of the contact pad **14** exposed. As will be understood by those having skill in the art, the term substrate may be defined so as to include the passivation layer **12** and contact pad **14** of Figures 1 and 6.

An under bump metallurgy layer **16** is formed on the passivation layer to provide a connection between the solder bump and the contact pad **14** and to provide a plating electrode, as shown in Figures 2 and 7. The under bump metallurgy layer **16** also protects the contact pad **14** and passivation layer **12** during subsequent processing steps, and provides a surface to which the solder will adhere. The under bump metallurgy layer preferably includes a chromium layer on the passivation layer **12** and contact pad **14**; a phased chromium/copper layer on the chromium layer; and a copper layer on the phased layer. This structure adheres to and protects the passivation layer **12** and contact pad **14**, and also provides a base for the plated solder which follows.

The under bump metallurgy layer may also include a titanium barrier layer between the substrate and the chromium layer as disclosed in U. S. Patent Application entitled "Solder Bump Fabrication Methods and Structures Including a Titanium Barrier Layer" filed March 20, 1995 and assigned to the assignee of the present invention. This titanium barrier layer protects the passivation layer from etchants used to remove the other components of the under bump metallurgy layer and also prevents the formation of residues on the passivation layer which may lead to shorts between solder bumps and redistribution routing conductors. The titanium layer can be easily removed

from the passivation layer without leaving significant residues.

Various under bump metallurgy layers are disclosed, for example, in U.S. Patent No. 4,950,623 to Dishon entitled "Method of Building Solder Bumps", U.S. Patent No. 5,162,257 to Yung entitled "Solder Bump Fabrication Method", and U.S. Patent Application to Mis et al. entitled "Solder Bump Fabrication Methods and Structures Including a Titanium Barrier Layer" filed on March 20, 1995. Each of these references is assigned to the assignee of the present invention, and the disclosure of each is hereby incorporated in its entirety herein by reference.

A solder dam **18** can be formed on the under bump metallurgy layer **16**. This solder dam **18** preferably includes a layer of a solder non-wettable material such as titanium or chromium on the under bump metallurgy layer **16**. The solder dam **18** will be used to contain the solder if a reflow step is performed prior to removing the first (exposed) portion of the under bump metallurgy layer **16** not covered by solder, as discussed below. A mask layer **20** is then formed on the solder dam **18**. The mask layer may comprise a photoresist mask or other mask known to those having skill in the art.

The mask layer **20** is patterned to cover the solder dam over the first portion of the under bump metallurgy layer and to uncover areas of the solder dam **18** over a second portion of the under bump metallurgy layer **16** on which the solder bump and redistribution routing conductor will be formed. The uncovered portion of the solder dam is then removed thereby uncovering the second portion of under bump metallurgy layer **16**, as shown in Figures 3 and 8. More particularly, the second portion of the under bump metallurgy layer **16**, which is not covered by the solder

dam and patterned mask layer, includes an enlarged width portion **16A** and an elongate portion **16B**.

A solder layer **22** is preferably electroplated on the second portion of the under bump metallurgy layer **16**, as shown in Figures 4 and 9. The solder can be electroplated by applying an electrical bias to the continuous under bump metallurgy layer **16** and immersing the microelectronic structure in a solution including lead and tin, as will be understood by those having skill in the art. This electroplating process allows solder layers to be formed simultaneously on a plurality of second portions of the under bump metallurgy layer **16**. The solder will not plate on the mask layer **20**. Alternatively, the solder can be applied by screen printing as a paste, by evaporation, by e-beam deposition, by electroless deposition or by other methods known to those having skill in the art. In addition, while lead-tin solder is used for purposes of illustration throughout the specification, other solders such as gold solder, lead-indium solder, or tin solder can be used as will be understood by those having skill in the art.

The solder layer **22** includes an elongate portion **22B** and an enlarged width portion **22A**. After removing the mask layer **20**, the microelectronic structure **11** can be heated causing the solder to flow from the elongate solder portion **22B** to the enlarged width solder portion **22A** thereby forming a raised solder bump at the enlarged width solder portion **22A**. The solder dam **18** prevents the solder from spreading beyond the elongate **16B** and enlarged width **16A** portions of the under bump metallurgy layer **16**, as shown in Figures 5 and 10.

The solder will flow when heated above its liquidus temperature (approximately 299°C for solder having 90% lead and 10% tin), and this process is commonly referred to as solder reflow. During reflow,

the surface tension of the solder creates a relatively low internal pressure in the enlarged width solder portion **22A** over the relatively wide geometry provided for the solder bump, and a relatively high internal pressure in the elongate solder portion **22B** over the relatively narrow geometry provided for the redistribution routing conductor.

In order to equalize this internal pressure differential, solder flows from the elongate solder portion **22B** to the enlarged width solder portion **22A**. Accordingly, the solder forms a raised solder bump at the enlarged width solder portion **22A** and a relatively thin layer of solder at the elongate solder portion **22B** over the redistribution routing conductor. When the solder is cooled below its liquidus temperature, it solidifies maintaining its shape including the raised solder bump and the thin layer of solder over the redistribution routing conductor.

It is known in the art of printed circuit board manufacture to apply solder at a uniform level on PCB lands by screen printing, and that the level of solder can be increased locally by enlarging a part of the land. *See*, Swanson, "PCB Assembly: Assembly Technology in China," *Electronic Packaging & Production*, pp. 40, 42, January 1995. To their knowledge, however, Applicants are the first to realize that solder can be electroplated on a microelectronic substrate at a uniform level and then heated to produce a raised solder bump together with a redistribution routing conductor on the substrate.

Furthermore, U. S. Patent No. 5,327,013 to Moore et al. states that a microsphere of a solder alloy can be pressed onto a pad, and that a stop formed of a polymeric solder resist material can be applied to the runner to confine the solder to the bond pad. While this patent states that the spread of solder along the runner during reflow can be limited by

constricting the width of the runner section relative to the bond pad, there is no suggestion that the relative dimensions of the runner section and the bond pad can be used to cause solder to flow from the runner to the bond pad thereby forming a multilevel solder structure. In addition, neither of these references suggest that a solder structure having an elongate portion and an enlarged width portion can be used to mask the under bump metallurgy layer in order to form a redistribution routing conductor together with a raised solder bump using only a single masking step.

The method of the present invention relies on differences in the surface-tension induced internal pressure of the reflowed (liquid) solder to form a thin layer of solder at the elongate solder portion **22B** and a raised solder bump at the enlarged width solder portion **22A**. The internal pressure P of a liquid drop of solder can be determined according to the formula:

$$P=2T/r,$$

where T is the surface tension of the liquid solder, and r is the radius of the drop.

Where liquid solder is on a flat wettable surface such as the under bump metallurgy layer, the formula becomes:

$$P=2T/r'.$$

In this formula, r' is the apparent radius of the liquid solder, and the apparent radius is the radius of the of the arc (radius of curvature) defined by the exposed surface of the solder. The apparent radius is dependent on the width of the underlying solder wettable layer such as the second portion of the under bump metallurgy layer which is in contact with the solder. Accordingly, the internal pressure of a reflowed solder structure is inversely proportional to the width of the second portion of the under bump metallurgy in contact with the solder. Stated in other words, a solder portion having on a relatively wide

under bump metallurgy portion will have a relatively low internal pressure while a solder portion on an elongate (relative narrow) under bump metallurgy portion will have a relatively high internal pressure. The internal pressures will equalize when the apparent radii of the elongate solder portion **22B** and the enlarged width solder portion **22A** are approximately equal.

Accordingly, when the solder layer **22** with a uniform level illustrated in Figures 4 and 9 is heated above its liquidus temperature, solder flows from the elongate solder portion **22B** to the enlarged width solder portion **22A** until each portion has approximately the same apparent radius thereby forming a raised solder bump. If the solder flow step is performed prior to removing the first portion of the under bump metallurgy layer **16** not covered by the solder structure, an intermetallic can be formed between the solder portions **22A-B** and under bump metallurgy portions **16A-B** adjacent the solder wherein the intermetallic is resistant to etchants commonly used to remove the under bump metallurgy. Accordingly, this intermetallic reduces undercutting of the solder during the following step of removing the first portion of the under bump metallurgy not covered by solder, as discussed in U. S. Patent No. 5,162,257 to Yung entitled "Solder Bump Fabrication Method" and assigned to the assignee of the present invention.

Preferably, the under bump metallurgy layer **16** includes a copper layer adjacent the solder structure and the solder is a lead-tin solder. Accordingly, the step of causing the solder to flow will cause the solder to react with the copper to form an intermetallic region adjacent the solder structure, and this intermetallic will comprise Cu_3Sn. This intermetallic does not readily react with etchants

commonly used to remove under bump metallurgy layers thereby reducing undercutting of the solder structure.

The solder layer **22** is then preferably used as a mask to selectively etch the first portions of the solder dam **18** and under bump metallurgy **16** not covered by solder. A chemical etchant can be used which etches the under bump metallurgy layer **16** preferentially with respect to the solder portions **22A-B**. Accordingly, no additional masking step is required to pattern the under bump metallurgy layer. Stated in other words, the formation of mask layer **20** is the only masking step required to pattern the solder dam **18** (Figures 3 and 8), selectively expose the second portion of the under bump metallurgy layer **16** during the plating step (Figures 3 and 8), and remove the first portions of the under bump metallurgy layer not covered by solder after the plating step (Figures 5 and 10).

Alternately, the first portions of the under bump metallurgy layer **16** not covered by solder portions **22A** and **22B** can be selectively removed prior to causing the solder to flow. In this case, the elongate **22B** and enlarged width **22A** solder portions are respectively supported on only the elongate **16B** and enlarged width **16A** under bump metallurgy portions, and while the liquid solder is wettable to the under bump metallurgy, it is not wettable to the passivation layer **12**. Accordingly, the passivation layer can contain the solder during the solder flow step, and the solder dam **18** can be eliminated.

In another alternative, the solder dam can include a solder non-wettable layer on the under bump metallurgy layer **16** and a solder wettable layer, such as copper, on the solder non-wettable layer opposite the under bump metallurgy layer, as disclosed in U. S. Patent Application to Mis et al. entitled "Solder Bump Fabrication Methods and Structures Including a Titanium Barrier Layer" filed March 20, 1995, and assigned to

the assignee of the present invention. The solder wettable layer allows solder to be plated on portions of the solder dam as well as the second portion of the under bump metallurgy layer not covered by the solder dam or mask.

Accordingly, the mask layer **20** can uncover portions of the solder dam as well as portions of the under bump metallurgy layer **16** thereby allowing a greater volume of solder to be plated. The mask layer **20** and underlying portions of the solder wettable layer are then removed. When heat is applied to cause the solder to flow, the remaining portion of the solder wettable layer under the solder will be dissolved into the solder exposing the solder to the solder non-wettable layer. Accordingly, the solder will retreat to the second portion of the under bump metallurgy layer which is wettable.

As an example, a first portion of the under bump metallurgy layer **16** is covered by a solder dam **18** and a mask layer **20**. A second portion of the under bump metallurgy layer **16** is uncovered and has an elongate portion **16B** that is 150 μm wide and 500 μm long, and a circular enlarged width portion **16A** with a 500 μm diameter (or width), as shown in Figures 3 and 8. A uniform 35 μm high solder layer **22** is then electroplated on the second portion of the under bump metallurgy layer **16** including elongate portion **16A** and enlarged width portion **16B**, as shown in Figure 4. This solder is 90% lead and 10% tin. After removing the mask layer **20**, the solder is heated above its liquidus temperature (approximately 299°C) allowing it to flow.

The liquid solder is contained on the second portion **16A-B** of the solder wettable under bump metallurgy layer by the solder dam **18** to which the solder will not wet. Because the solder structure has varying widths, the internal pressure of the solder structure is not consistent when the height is uniform.

In particular, the internal pressure of the elongate solder portion **22B** is relatively high (approximately 1.283×10^4 Pa or 1.86 psi) and the internal pressure of the enlarged width solder portion **22A** is relatively low (approximately 3.848×10^3 Pa or .558 psi) at the original solder height.

Accordingly, solder flows from the elongate solder portion **22B** to the enlarged width solder portion **22A** until the internal pressures equalize, thereby forming a raised solder bump at the enlarged width solder portion **22A**, as shown in Figures 5 and 10. In Figures 5 and 10, the solder dam **18** and the first portion of the under bump metallurgy layer **16** not covered by the solder structure have also been removed.

In this example, equilibrium is obtained at an internal pressure of approximately 3.4×10^3 Pa (.493 psi). At equilibrium, the elongate solder portion **22B** is approximately 10 μm high and the enlarged width solder portion is approximately 130 μm high, and both portions have a radius of curvature of approximately 281 μm. Accordingly, a two level solder structure can be provided with a single masking step. When cooled, this structure solidifies while maintaining its form. In addition, the elongate solder portion **22B** with a solder height of 10 μm is sufficient to mask the respective elongate under bump metallurgy layer portion **16B** when removing the first portion of the under bump metallurgy layer not covered by solder. The enlarged width portion of the solder structure may have a width (or diameter if the enlarged width portion is circular) of at least 2 times a width of the elongate portion of the solder structure in order to ensure that the solder bump formed by the method described above is sufficiently raised relative to the elongate solder portion to provide an adequate connection to a printed circuit board.

In the drawings and specification, there have been disclosed typical preferred embodiments of the invention and, although specific terms are employed, they are used in a generic and descriptive sense only and not for purposes of limitation, the scope of the invention being set forth in the following claims.

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* C L M S *

THAT WHICH IS CLAIMED:

1. A solder bump structure for a microelectronic substrate including an electrical contact having an exposed portion, said structure comprising:

an under bump metallurgy layer on said microelectronic substrate and electrically contacting said exposed portion of said electrical contact; and

a solder structure on said under bump metallurgy layer opposite said microelectronic substrate, said solder structure including an elongate portion and an enlarged width portion.

2. A solder bump structure according to Claim 1 wherein said under bump metallurgy layer extends across said microelectronic substrate, said solder structure defining first and second portions of said under bump metallurgy layer, said second portion of said under bump metallurgy layer including an elongate portion and an enlarged width portion respectively corresponding to said elongate and enlarged width portions of said solder structure.

3. A solder bump structure according to Claim 2 further comprising a solder dam on said first portion of said under bump metallurgy layer.

4. A solder bump structure according to Claim 1 wherein said elongate portion of said solder structure has a first predetermined thickness and said enlarged width portion of said solder structure has a second predetermined thickness.

5. A solder bump structure according to Claim 4 wherein said first predetermined thickness is thin relative to said second predetermined thickness.

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6. A solder bump structure according to Claim 1 wherein said elongate portion of said solder structure has a first end adjacent said exposed portion of said electrical contact and a second end connected to said enlarged width portion of said solder structure.

7. A solder bump structure according to Claim 1 wherein said elongate portion of said solder structure and said enlarged width portion of said solder structure have a common predetermined thickness.

8. A solder bump structure according to Claim 1 wherein said enlarged width portion of said solder structure has a width of at least 2 times a width of said elongate portion of said solder structure.

9. A solder bump structure according to Claim 1 wherein said under bump metallurgy layer comprises a chromium layer on said microelectronic substrate, a phased layer of chromium and copper on said chromium layer opposite said microelectronic substrate, and a copper layer on said phased layer opposite said chromium layer.

10. A solder bump structure according to Claim 9 wherein said under bump metallurgy layer comprises a titanium layer between said chromium layer and said microelectronic substrate.

11. A solder bump structure according to Claim 1 further comprising an intermetallic region between said under bump metallurgy layer and said solder structure, said intermetallic region comprising a constituent of said metallurgy layer and a constituent of said solder structure.

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12. A method of forming a redistribution routing conductor on a microelectronic substrate including an electrical contact pad at a surface of said microelectronic substrate, said method comprising the steps of:

forming an under bump metallurgy layer on said surface, and electrically contacting said electrical contact pad; and

forming a solder structure on said under bump metallurgy layer opposite said microelectronic substrate, said solder structure including an elongate portion and an enlarged width portion.

13. A method according to Claim 12 further comprising the step of causing solder in said solder structure to flow from said elongate portion to said enlarged width portion to thereby form a raised solder bump in said enlarged width portion of said solder structure and a thin solder layer in said elongate portion of said solder structure.

14. A method according to Claim 12 wherein said elongate portion extends over said electrical contact pad.

15. A method according to Claim 12 wherein said solder structure defines a first portion of said under bump metallurgy layer not covered by said solder structure and a second portion of said under bump metallurgy layer covered by said solder structure, and wherein said step of forming a solder structure is followed by the step of selectively removing said first portion of said under bump metallurgy layer.

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16. A method according to Claim 12 wherein said solder structure defines a first portion of said under bump metallurgy layer not covered by said solder structure and a second portion of said under bump metallurgy layer covered by said solder structure, said method further comprising the steps of:

forming a solder dam layer on said first portion of said under bump metallurgy layer; and

causing said solder structure to flow so that solder flows from said elongate portion of said solder structure to said enlarged width portion of said solder structure thereby forming a raised solder bump on said enlarged width portion of said under bump metallurgy layer and a thin solder layer on said elongate portion of said under bump metallurgy layer.

17. A method according to Claim 16 wherein said step of causing said solder structure to flow forms an intermetallic region between said under bump metallurgy layer and said solder structure, said intermetallic region comprising a constituent of said metallurgy layer and a constituent of said solder structure.

18. A method according to Claim 12 wherein said step of forming said under bump metallurgy layer comprises the steps of:

forming a chromium layer on said microelectronic substrate;

forming a phased layer of chromium and copper on said chromium layer opposite said microelectronic substrate; and

forming a copper layer on said phased layer opposite said chromium layer.

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19. A method according to Claim 18 wherein said step of forming said under bump metallurgy layer further comprises the step of forming a titanium layer between said microelectronic substrate and said chromium layer.

20. A method according to Claim 12 wherein said solder structure defines a first portion of said under bump metallurgy layer not covered by said solder structure and a second portion of said under bump metallurgy layer covered by said solder structure, and wherein said step of forming said solder structure comprises the steps of:

forming a patterned mask layer on said under bump metallurgy layer, said patterned mask layer covering said first portion of said under bump metallurgy layer and defining said second portion of said under bump metallurgy layer;

forming said solder structure on said second portion of said under bump metallurgy layer; and

selectively removing said patterned mask layer.

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FIG. 6

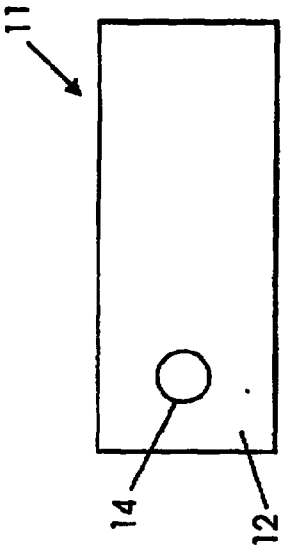


FIG. 7

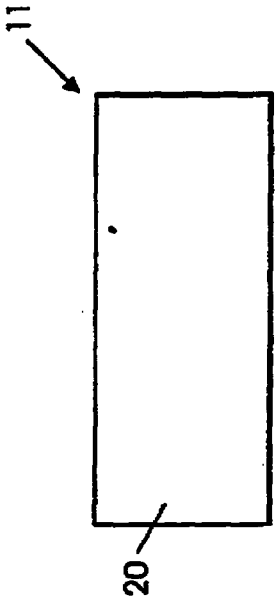


FIG. 8

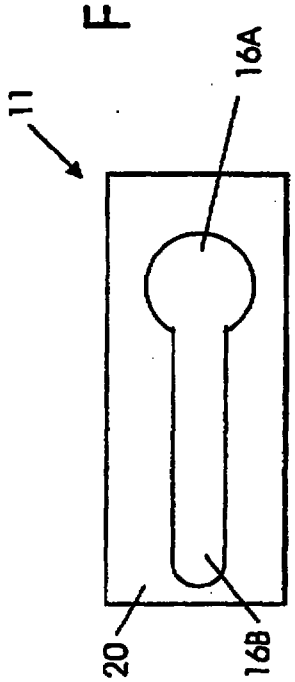


FIG. 1

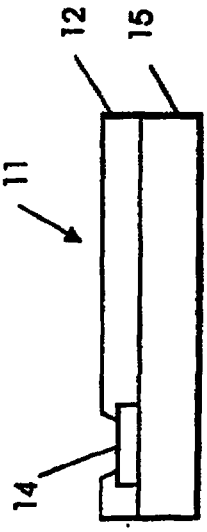


FIG. 2

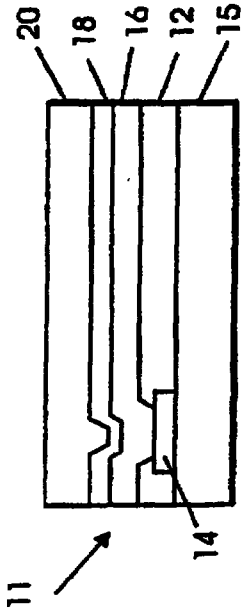


FIG. 3

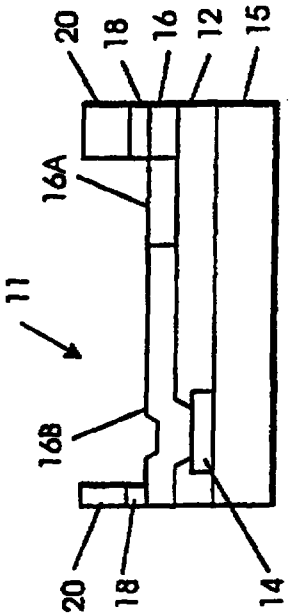


FIG. 9

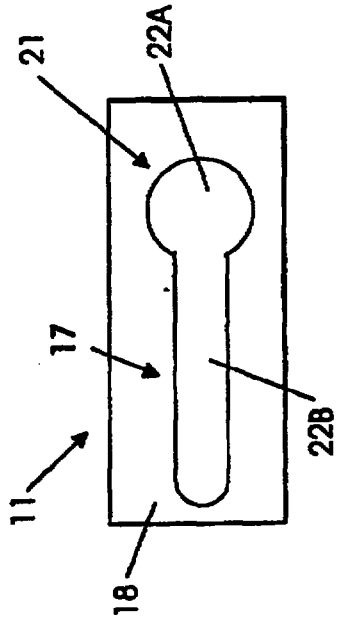


FIG. 10

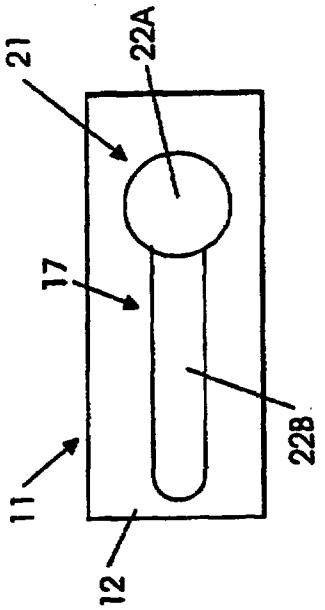


FIG. 4

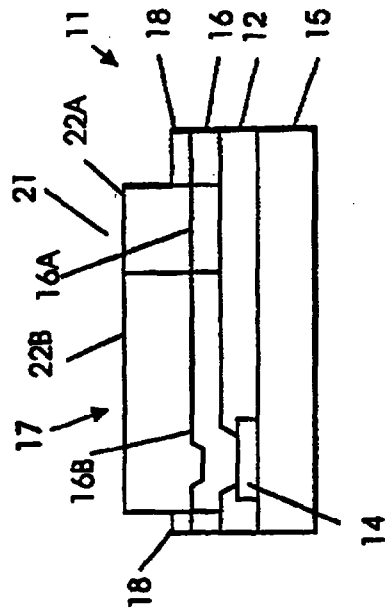
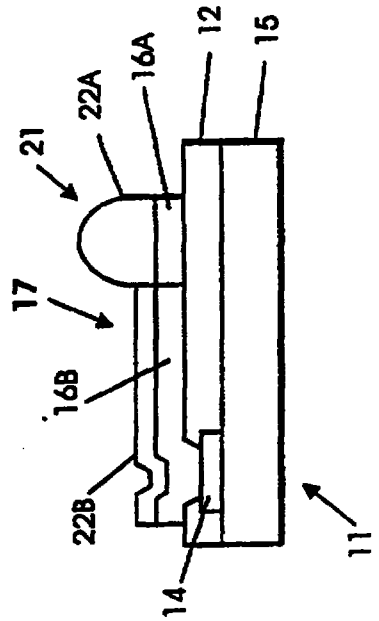


FIG. 5



Annex

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☐ Drawing(s) : paged ..... to paged .....
☐ Abstract : paged ..... to paged .....

THAT WHICH IS CLAIMED IS:

1. A flip-chip structure comprising a semiconductor substrate 15 including an electronic device formed thereon, and a contact pad 14 on said semiconductor substrate 15 electrically connected to said electronic device, said flip-chip characterized by:

a passivation layer 12 on said semiconductor substrate 15 and on said contact pad 14 wherein said passivation layer 12 defines a contact hole therein exposing a portion of said contact pad 14;

an under bump metallurgy layer 16 on said passivation layer 12 and electrically contacting said exposed portion of said contact pad 14; and

a solder layer 22 on said under bump metallurgy layer 16, said solder layer 22 including an elongate portion 22B opposite said contact pad 14 and an enlarged width portion 22A opposite said passivation layer 12 wherein said elongate portion 22B is narrow relative to said enlarged width portion 22A and wherein said enlarged width portion 22A is remote from said contact pad 14.

2. A flip-chip structure according to Claim 1 wherein said under bump metallurgy layer 16 extends across said passivation layer, said solder layer 22 defining first and second portions of said under bump metallurgy layer, wherein said solder layer 22 covers said second portion and exposes said first portion, said second portion of said under bump metallurgy layer 16 including an elongate portion 16B and an enlarged width portion 16A respectively corresponding to said elongate 22B and enlarged width 22A portions of said solder layer 22.

3. A flip-chip structure according to Claim 2 further comprising a solder dam 18 on said first portion of said under bump metallurgy layer 16.

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4. A flip-chip structure according to Claim 1 wherein said elongate portion 22B of said solder layer 22 has a first predetermined thickness and said enlarged width portion 22A of said solder layer 22 has a second predetermined thickness.

5. A flip-chip structure according to Claim 4 wherein said first predetermined thickness is thin relative to said second predetermined thickness.

6. A flip-chip structure according to Claim 1 wherein said elongate portion 22B of said solder layer 22 has a first end adjacent said exposed portion of said contact pad 14 and a second end connected to said enlarged width portion 22A of said solder layer 22.

7. A flip-chip structure according to Claim 1 wherein said elongate portion 22B of said solder layer 22 and said enlarged width portion 22A of said solder layer 22 have a common predetermined thickness.

8. A flip-chip structure according to Claim 1 wherein said enlarged width portion 22A of said solder layer 22 has a width of at least 2 times a width of said elongate portion 22B of said solder layer 22.

9. A flip-chip structure according to Claim 1 wherein said under bump metallurgy layer 16 comprises a chromium layer on said passivation layer 12, a phased layer of chromium and copper on said chromium layer opposite said passivation layer 12, and a copper layer on said phased layer opposite said chromium layer.

10. A flip-chip structure according to Claim 9 wherein said under bump metallurgy layer 16 comprises a titanium layer between said chromium layer and said passivation layer 12.

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11. A flip-chip structure according to Claim 1 further comprising an intermetallic region between said under bump metallurgy layer 16 and said solder layer 22, said intermetallic region comprising a constituent of said metallurgy layer 16 and a constituent of said solder layer 22.

(4) 12. A method of forming a redistribution routing conductor on a semiconductor substrate 15 including an electronic device formed thereon and a contact pad 14 on said semiconductor substrate 15 electrically connected to said electronic device, said method characterized by the steps of:

forming a passivation layer 12 on said semiconductor substrate 15 and on said contact pad 14 wherein said passivation layer 12 defines a contact hole therein exposing a portion of said contact pad 14;

forming an under bump metallurgy layer 16 on said passivation layer 12, and electrically contacting said exposed portion of said contact pad 14; and

forming a solder layer 22 on said under bump metallurgy layer 16, said solder layer 22 including an elongate portion 22B opposite said contact pad 14 and an enlarged width portion 22A opposite said passivation layer 12 wherein said elongate portion 22B is narrow relative to said enlarged width portion 22A and wherein said enlarged width portion 22A is remote from said contact pad 14.

(5) 13. A method according to Claim 12 further comprising the step of causing solder in said solder layer 22 to flow from said elongate portion 22B to said enlarged width portion 22A to thereby form a raised solder bump in said enlarged width portion 22A of said solder layer 22 and a thin solder layer in said elongate portion 22B of said solder layer 22, wherein said step of causing said solder to flow comprises heating said solder above its liquidus temperature.

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14. A method according to Claim 12 wherein said elongate portion 22B extends over said contact pad 14.

15. A method according to Claim 12 wherein said solder layer 22 defines a first portion of said under bump metallurgy layer 16 not covered by said solder layer 22 and a second portion of said under bump metallurgy layer 16 covered by said solder layer 22, and wherein said step of forming a solder layer 16 is followed by the step of selectively removing said first portion of said under bump metallurgy layer 16.

16. A method according to Claim 12 wherein said solder layer 22 defines a first portion of said under bump metallurgy layer 16 not covered by said solder layer 22 and a second portion of said under bump metallurgy layer 16 covered by said solder layer 22, said method further comprising the steps of:

forming a solder dam layer 18 on said first portion of said under bump metallurgy layer 16; and

causing said solder layer 22 to flow so that solder flows from said elongate portion 22B of said solder layer 22 to said enlarged width portion 22A of said solder layer 22 thereby forming a raised solder bump on said enlarged width portion 16A of said under bump metallurgy layer 16 and a thin solder layer on said elongate portion 16B of said under bump metallurgy layer 16, wherein said step of causing said solder to flow comprises heating said solder above its liquidus temperature.

17. A method according to Claim 16 wherein said step of causing said solder layer 22 to flow forms an intermetallic region between said under bump metallurgy layer 16 and said solder layer 22, said intermetallic region comprising a constituent of said metallurgy layer 16 and a constituent of said solder layer 22.

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18. A method according to Claim 12 wherein said step of forming said under bump metallurgy layer 16 comprises the steps of:

forming a chromium layer on said passivation layer 12;

forming a phased layer of chromium and copper on said chromium layer opposite said passivation layer 12; and

forming a copper layer on said phased layer opposite said chromium layer.

19. A method according to Claim 18 wherein said step of forming said under bump metallurgy layer 16 further comprises the step of forming a titanium layer between said passivation layer 12 and said chromium layer.

20. A method according to Claim 12 wherein said solder layer 22 defines a first portion of said under bump metallurgy layer 16 not covered by said solder layer 22 and a second portion of said under bump metallurgy layer 16 covered by said solder layer 22, and wherein said step of forming said solder layer 22 comprises the steps of:

forming a patterned mask layer 20 on said under bump metallurgy layer 16, said patterned mask layer 20 covering said first portion of said under bump metallurgy layer 16 and defining said second portion of said under bump metallurgy layer 16;

forming said solder layer 22 on said second portion of said under bump metallurgy layer 16; and

selectively removing said patterned mask layer 20.

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CLAIMS:

1. A solder bump structure for a microelectronic substrate including an electrical contact having an exposed portion, said structure comprising:

an under bump metallurgy layer on said microelectronic substrate and electrically contacting said exposed portion of said electrical contact; and

a solder structure on said under bump metallurgy layer opposite said microelectronic substrate, said solder structure including an elongate portion and an enlarged width portion.

2. A solder bump structure according to Claim 1 wherein said elongate portion of said solder structure has a first end adjacent said exposed portion of said electrical contact and a second end connected to said enlarged width portion of said solder structure.

3. A solder bump structure according to Claim 1 wherein said elongate portion of said solder structure and said enlarged width portion of said solder structure have a common predetermined thickness.

4. A method of forming a redistribution routing conductor on a microelectronic substrate including an electrical contact pad at a surface of said microelectronic substrate, said method comprising the steps of:

forming an under bump metallurgy layer on said surface, and electrically contacting said electrical contact pad; and

forming a solder structure on said under bump metallurgy layer opposite said microelectronic

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substrate, said solder structure including an elongate portion and an enlarged width portion.

5. A method according to Claim 4 further comprising the step of causing solder in said solder structure to flow from said elongate portion to said enlarged width portion to thereby form a raised solder bump in said enlarged width portion of said solder structure and a thin solder layer in said elongate portion of said solder structure.

6. A method according to Claim 4 wherein said elongate portion extends over said electrical contact pad.

7. A method according to Claim 4 wherein said solder structure defines a first portion of said under bump metallurgy layer not covered by said solder structure and a second portion of said under bump metallurgy layer covered by said solder structure, and wherein said step of forming a solder structure is followed by the step of selectively removing said first portion of said under bump metallurgy layer.

8. A method according to Claim 4 wherein said solder structure defines a first portion of said under bump metallurgy layer not covered by said solder structure and a second portion of said under bump metallurgy layer covered by said solder structure, said method further comprising the steps of:

forming a solder dam layer on said first portion of said under bump metallurgy layer; and

causing said solder structure to flow so that solder flows from said elongate portion of said solder structure to said enlarged width portion of said solder structure thereby forming a raised solder bump on said enlarged width portion of said under bump metallurgy

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layer and a thin solder layer on said elongate portion of said under bump metallurgy layer.

9. A method according to Claim 4 wherein said step of causing said solder structure to flow forms an intermetallic region between said under bump metallurgy layer and said solder structure, said intermetallic region comprising a constituent of said metallurgy layer and a constituent of said solder structure.

10. A method according to Claim 4 wherein said solder structure defines a first portion of said under bump metallurgy layer not covered by said solder structure and a second portion of said under bump metallurgy layer covered by said solder structure, and wherein said step of forming said solder structure comprises the steps of:

forming a patterned mask layer on said under bump metallurgy layer, said patterned mask layer covering said first portion of said under bump metallurgy layer and defining said second portion of said under bump metallurgy layer;

forming said solder structure on said second portion of said under bump metallurgy layer; and

selectively removing said patterned mask layer.

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(57) Abstract

A method for forming integrated redistribution routing conductors (17) and solder bumps (21) on a microelectronic substrate (15) comprises the steps of forming an under bump metallurgy layer (16) on the substrate and forming a solder structure on the under bump metallurgy layer wherein the solder structure includes an elongate portion (22B) and an enlarged width portion (22A). The portions of the under bump metallurgy layer not covered by the solder structure can be selectively removed using the solder structure as a mask. In addition, the solder is caused to flow from the elongate portion of the solder structure to the enlarged width solder portion thereby forming a raised solder bump. This step is preferably performed by heating the solder structure above its liquidus temperature allowing surface tension induced internal pressures to affect the flow. Various solder structures are also disclosed.

