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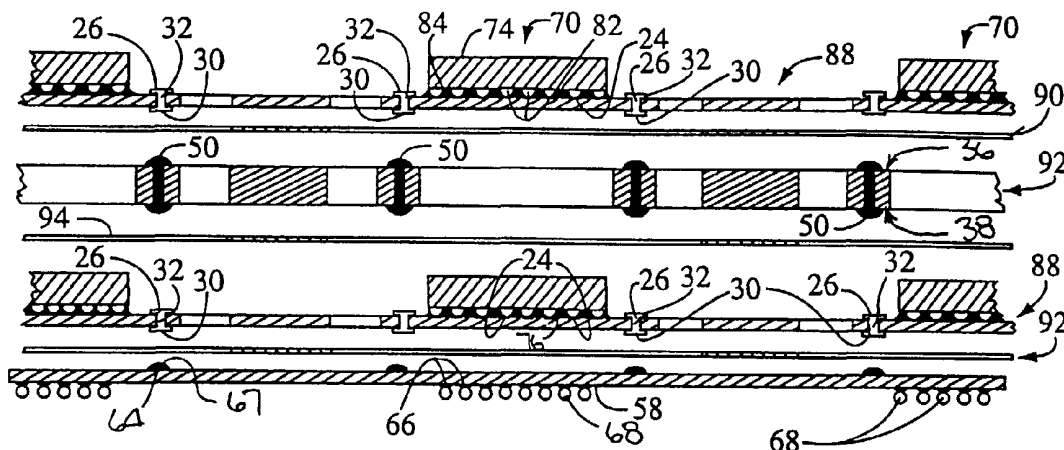
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(54) Title: PANEL STACKING OF BGA DEVICES TO FORM THREE-DIMENSIONAL MODULES



(57) Abstract: A chip stack (10) comprising at least two base layers (12), each of which includes a base substrate (14) and a first conductive pattern disposed on the base substrate (14). The chip stack (10) further comprises at least one interconnect frame (34) having a second conductive pattern disposed thereon. The interconnect frame (34) is disposed between the base layers (12), with the second conductive pattern being electrically connected to the first conductive pattern of each of the base layers (12). Also included in the chip stack (10) are at least two integrated circuit chips (70) which are electrically connected to respective ones of the first conductive patterns. One of the integrated circuit chips (70) is at least partially circumvented by the interconnect frame (34) and at least partially covered by one of the base layers (12). The chip stack (10) further comprises a transposer layer (52) comprising a transposer substrate having a third conductive pattern disposed thereon. The first conductive pattern of one of the base layers (12) is electrically connected to the third conductive pattern of the transposer layer (52).



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**PANEL STACKING OF BGA DEVICES  
TO FORM THREE-DIMENSIONAL MODULES**

5                   CROSS-REFERENCE TO RELATED APPLICATIONS  
                    (Not Applicable)

                    STATEMENT RE: FEDERALLY SPONSORED RESEARCH/DEVELOPMENT  
                    (Not Applicable)

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BACKGROUND OF THE INVENTION

                    The present invention relates generally to chip  
                    stacks, and more particularly to a chip stack having  
15                   connections routed from the bottom to the perimeter thereof  
                    to allow multiple integrated circuit chips such as BGA  
                    devices to be quickly, easily and inexpensively vertically  
                    interconnected in a volumetrically efficient manner.

                    Multiple techniques are currently employed in the  
20                   prior art to increase memory capacity on a printed circuit  
                    board. Such techniques include the use of larger memory  
                    chips, if available, and increasing the size of the circuit  
                    board for purposes of allowing the same to accommodate more  
                    memory devices or chips. In another technique, vertical  
25                   plug-in boards are used to increase the height of the  
                    circuit board to allow the same to accommodate additional  
                    memory devices or chips.

                    Perhaps one of the most commonly used techniques to  
                    increase memory capacity is the stacking of memory devices  
30                   into a vertical chip stack, sometimes referred to as 3D  
                    packaging or Z-Stacking. In the Z-Stacking process, from  
                    two (2) to as many as eight (8) memory devices or other  
                    integrated circuit (IC) chips are interconnected in a  
                    single component (i.e., chip stack) which is mountable to  
35                   the "footprint" typically used for a single package device  
                    such as a packaged chip. The Z-Stacking process has been  
                    found to be volumetrically efficient, with packaged chips  
                    in TSOP (thin small outline package) or LCC (leadless chip

carrier) form generally being considered to be the easiest to use in relation thereto. Though bare dies or chips may also be used in the Z-Stacking process, such use tends to make the stacking process more complex and not well suited to automation.

In the Z-Stacking process, the IC chips or packaged chips must, in addition to being formed into a stack, be electrically interconnected to each other in a desired manner. There is known in the prior art various different arrangements and techniques for electrically interconnecting the IC chips or packaged chips within a stack. Examples of such arrangements and techniques are disclosed in Applicant's U.S. Patent Nos. 4,956,694 entitled INTEGRATED CIRCUIT CHIP STACKING issued September 11, 1990, 5,612,570 entitled CHIP STACK AND METHOD OF MAKING SAME issued March 18, 1997, and 5,869,353 entitled MODULAR PANEL STACKING PROCESS issued February 9, 1999.

The various arrangements and techniques described in these issued patents and other currently pending patent applications of Applicant have been found to provide chip stacks which are relatively easy and inexpensive to manufacture, and are well suited for use in a multitude of differing applications. The present invention provides yet a further alternative arrangement and technique for forming a volumetrically efficient chip stack. In the chip stack of the present invention, connections are routed from the bottom of the chip stack to the perimeter thereof so that interconnections can be made vertically which allows multiple integrated circuit chips such as BGA, CSP, fine pitch BGA, or flip chip devices to be stacked in a manner providing the potential for significant increases in the production rate of the chip stack and resultant reductions in the cost thereof.

#### BRIEF SUMMARY OF THE INVENTION

In accordance with the present invention, there is provided a chip stack comprising at least two base layers (i.e., an upper base layer and a lower base layer). Each

of the base layers includes a base substrate having a first  
conductive pattern disposed thereon. The chip stack  
further comprises at least one interconnect frame having a  
second conductive pattern disposed thereon. The  
5 interconnect frame is disposed between the upper and lower  
base layers, with the second conductive pattern being  
electrically connected to the first conductive pattern of  
each of the base layers. In addition to the base layers  
and interconnect frame, the chip stack comprises at least  
10 two integrated circuit chips which are electrically  
connected to respective ones of the first conductive  
patterns. The integrated circuit chip electrically  
connected to the first conductive pattern of the lower base  
layer is at least partially circumvented by the  
15 interconnect frame and at least partially covered by the  
upper base layer. The chip stack further preferably  
comprises a transposer layer which includes a transposer  
substrate having a third conductive pattern disposed  
thereon. The first conductive pattern of the lower base  
20 layer is electrically connected to the third conductive  
pattern of the transposer layer.

In the present chip stack, the base substrate of each  
of the base layers defines opposed, generally planar top  
and bottom surfaces. The first conductive pattern itself  
25 comprises first and second sets of base pads which are  
disposed on the top surface of the base substrate, with the  
base pads of the second set being electrically connected to  
respective ones of the base pads of the first set via  
conductive traces. In addition to the first and second  
30 sets of base pads, the first conductive pattern includes a  
third set of base pads disposed on the bottom surface of  
the base substrate and electrically connected to respective  
ones of the base pads of the second set. More  
particularly, each of the base pads of the second set is  
35 preferably electrically connected to a respective one of  
the base pads of the third set via a base feed-through  
hole. The base feed-through hole is preferably plugged  
with a conductive material selected from the group

consisting of nickel, gold, tin, and combinations thereof. The integrated circuit chips are disposed upon respective ones of the top surfaces of the base substrates and electrically connected to at least some of the base pads of  
5        respective ones of the first sets. Additionally, the base pads of the second set of the lower base layer are electrically connected to the second conductive pattern of the interconnect frame, as are the base pads of the third set of the upper base layer.

10        The interconnect frame of the chip stack itself defines opposed, generally planar top and bottom surfaces, with the second conductive pattern comprising first and second sets of frame pads disposed on respective ones of the top and bottom surfaces. Each of the frame pads of the  
15        first set is electrically connected to a respective one of the frame pads of the second set via a frame feed-through hole which is also plugged with a conductive material preferably selected from the group consisting of nickel, gold, tin, and combinations thereof. The interconnect  
20        frame is preferably disposed between the upper and lower base layers such that the frame pads of the second set are electrically connected to respective ones of the base pads of the second set of the lower base layer, with the frame pads of the first set being electrically connected to  
25        respective ones of the base pads of the third set of the upper base layer.

30        The transposer substrate of the present chip stack also defines opposed, generally planar top and bottom surfaces, with the third conductive pattern comprising first and second sets of transposer pads disposed on  
35        respective ones of the top and bottom surface of the transposer substrate. The transposer pads of the first set are electrically connected to respective ones of the transposer pads of the second set. Additionally, the base pads of the third set of the lower base layer are electrically connected to respective ones of the transposer pads of the first set.

In the present chip stack, the transposer pads of the first set, the frame pads of the first and second sets, and the base pads of the second and third sets are preferably arranged identical patterns. Additionally, the transposer and base substrates each preferably have a generally rectangular configuration defining opposed pairs of longitudinal and lateral peripheral edge segments. The interconnect frame itself preferably has a generally rectangular configuration defining opposed pairs of longitudinal and lateral side sections. The transposer pads of the first set extend along the longitudinal and lateral peripheral edge segments of the transposer substrate. Similarly, the first and second sets of frame pads extend along the longitudinal and lateral side sections of the interconnect frame, with the second and third sets of base pads extending along the longitudinal and lateral peripheral edge segments of the base substrate. Each of the transposer pads of the second set preferably has a generally spherical configuration, with each of the transposer pads of the first set and each of the frame pads of the first and second sets preferably having a generally semi-spherical configuration.

Each of the integrated circuit chips of the present chip stack preferably comprises a body having opposed, generally planar top and bottom surfaces, and a plurality of conductive contacts disposed on the bottom surface of the body. The conductive contacts of each of the integrated circuit chips are electrically connected to respective ones of the base pads of the first set of a respective one of the first conductive patterns. The transposer pads of the second set, the base pads of the first set, and the conductive contacts are themselves preferably arranged in identical patterns. The chip stack further preferably comprises a layer of flux underfill disposed between the bottom surface of the body of each of the integrated circuit chips and respective ones of the top surfaces of the base substrates. Each layer of flux underfill is preferably spread over the base pads of the

first set of a respective one of the first conductive patterns. The body of each of the integrated circuit chips and the interconnect frame are preferably sized relative to each other such that the top surface of the body of the integrated circuit chip electrically connected to the lower base panel and at least partially circumvented by the interconnect frame does not protrude beyond the top surface thereof. The integrated circuit chips are preferably selected from the group consisting of a BGA device, a fine pitch BGA device, a CSP device, and a flip chip device. Further, the transposer and base substrates are each preferably fabricated from a polyamide which may be as thin as about 0.010 inches.

Those of ordinary skill in the art will recognize that a chip stack of the present invention may be assembled to include more than two base layers, more than one interconnect frame, and more than two integrated circuit chips. In this respect, a multiplicity of additional interconnect frames, base layers, and integrated circuit chips may be included in the chip stack, with the second conductive pattern of each of the interconnect frames being electrically connected to the first conductive patterns of any adjacent pair of base layers, and each of the integrated circuit chips being electrically connected to the first conductive pattern of a respective one of the base layers.

Further in accordance with the present invention, there is provided a method of assembling a chip stack. The method comprises the initial step of electrically connecting an integrated circuit chip to a first conductive pattern of a base layer. Thereafter, a second conductive pattern of an interconnect frame is electrically connected to the first conductive pattern such that the interconnect frame at least partially circumvents the integrated circuit chip. Another integrated circuit chip is then electrically connected to the first conductive pattern of another base layer. The first conductive pattern of one of the base layers is then electrically connected to the second

conductive pattern of the interconnect frame such that one of the integrated circuit chips is disposed between the base layers. The method may further comprise the step of electrically connecting the first conductive pattern of one of the base layers to a third conductive pattern of a transposer layer. In the present assembly method, a layer of flux underfill is preferably applied to (i.e., spread over) each of the base layers over portions of the first conductive patterns prior to the electrical connection of respective ones of the integrated circuit chips thereto. All of the electrical connections in the present assembly method are preferably accomplished via soldering.

Still further in accordance with the present invention, there is provided a method of assembling a chip stack which comprises the initial steps of providing a transposer panel, at least two base panels, and at least one frame panel which each have opposed surfaces and a plurality of conductive pads disposed on the opposed surfaces thereof. A plurality of integrated circuit chips are also provided which each have opposed sides and include conductive contacts disposed on one of the sides thereof. In this assembly method, integrated circuit chips are placed upon each of the base panels such that the conductive contacts of each of the integrated circuit chips are disposed on at least some of the conductive pads of respective ones of the base panels. Thereafter, one of the base panels is stacked upon the transposer panel such that at least some of the conductive pads of the base panel are disposed on at least some of the conductive pads of the transposer panel. The frame panel is then stacked upon the base panel such that at least some of the conductive pads of the frame panel are disposed on at least some of the conductive pads of the base panel. Another base panel is then stacked upon the frame panel such that at least some of the conductive pads of the base panel are disposed on at least some of the conductive of the frame panel.

The assembly method further comprises bonding the conductive contacts of the integrated circuit chips to at



least some of the conductive pads of the base panel upon which the integrated circuit chips are positioned, bonding at least some of the conductive pads of one of the base panels to at least some of the conductive pads of the transposer panel, and bonding at least some of the conductive pads of the frame panel to at least some of the conductive pads of each of the base panels. The assembly method may further comprise the steps of stacking spacer sheets between one of the base panels and the transposer panel, and between the frame panel and each of the base panels. The spacer sheets each have opposed surfaces and a plurality of openings disposed therein. When stacked between the base and transposer panels and between the frame and base panels, the openings of the spacer sheets are aligned with the conductive pads of such panels.

#### BRIEF DESCRIPTION OF THE DRAWINGS

These, as well as other features of the present invention, will become more apparent upon reference to the drawings wherein:

Figure 1 is a top perspective view of a chip stack constructed in accordance with the present invention;

Figure 2 is an exploded view of the chip stack shown in Figure 1;

Figure 3 is an exploded view of the various components which are stacked upon each other in accordance with a preferred method of assembling the chip stack of the present invention;

Figure 4 is a partial cross-sectional view of the components shown in Figure 3 as stacked upon each other prior to a solder reflow step of the present assembly method;

Figure 4a is an enlargement of the encircled region 4a shown in Figure 4;

Figure 5 is partial cross-sectional view similar to Figure 4 illustrating the components shown in Figure 3 as stacked upon each other subsequent to the

completion of the solder reflow step of the present assembly method; and

Figure 5a is an enlargement of the encircled region 5a shown in Figure 5.

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#### DETAILED DESCRIPTION OF THE INVENTION

Referring now to the drawings wherein the showings are for purposes of illustrating a preferred embodiment of the present invention only, and not for purposes of limiting the same, Figure 1 perspectively illustrates a chip stack 10 assembled in accordance with the present invention. The chip stack 10 comprises at least two identically configured base layers 12. Each of the base layers 12 itself comprises a rectangularly configured base substrate 14 which defines a generally planar top surface 16, a generally planar bottom surface 18, an opposed pair of longitudinal peripheral edge segments 20, and an opposed pair of lateral peripheral edge segments 22.

Disposed on the base substrate 14 of each base layer 12 is a first conductive pattern which itself preferably comprises a first set of base pads 24 and a second set of base pads 26 which are each disposed on the top surface 16 of the base substrate 14. The base pads 24 of the first set are preferably arranged in a generally rectangular pattern or array in the central portion of the base substrate 14, with the base pads 26 of the second set extending linearly along the longitudinal and lateral peripheral edge segments 20, 22 of the base substrate 14. The base pads 24 of the first set are electrically connected to respective ones of the base pads 26 of the second set via conductive traces 28. In addition to the base pads 24, 26 of the first and second sets, the first conductive pattern of each base layer 12 comprises a third set of base pads 30 which is disposed on the bottom surface 18 of the base substrate 14. The base pads 30 of the third set are preferably arranged in an identical pattern to the base pads 26 of the second set, and extend linearly along the longitudinal and lateral peripheral edge segments 20,

22 of the base substrate 14 such that each of the base pads 30 of the third set is aligned with and electrically connected to a respective one of the base pads 26 of the second set.

5           As is best seen in Figures 3-5, each of the base pads 26 of the second set is electrically connected to a respective one of the base pads 30 of the third set via a base feed-through hole 32. Each base feed-through hole 32 is preferably plugged with a conductive material. The  
10           conductive material is preferably selected from the group consisting of nickel, gold, tin, silver epoxy, and combinations thereof. The base pads 26, 30 of the second and third sets, as well as the base pads 24 of the first set, each preferably have a generally circular  
15           configuration. In this respect, each base feed-through hole 32 preferably extends axially between each corresponding, coaxially aligned pair of the base pads 26, 30 of the second and third sets. The base pads 26, 30 of the second and third sets are preferably formed upon (i.e.,  
20           surface plated to) the base substrate 14 subsequent to the plugging of the base feed-through holes 32 and are used to cover the opposed, open ends thereof. If the base feed-through holes 32 were left unplugged, solder coming into contact with the base pads 26, 30 of the second and third  
25           sets would tend to wick into the base feed-through holes 32 upon the reflow of the solder (which will be discussed below), thus robbing the base pads 26, 30 of solder needed to facilitate various electrical connections in the chip stack 10.

30           In addition to the base layers 12, the chip stack 10 of the present invention comprises at least one rectangularly configured interconnect frame 34 which defines a generally planar top surface 36, a generally planar bottom surface 38, an opposed pair of longitudinal  
35           side sections 40, and an opposed pair of lateral side sections 42. Disposed on the interconnect frame 34 is a second conductive pattern which itself preferably comprises a first set of frame pads 44 disposed on the top surface

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36, and a second set of frame pads 46 disposed on the bottom surface 38. The frame pads 44, 46 of the first and second sets are preferably arranged in patterns which are identical to each other, and to the patterns of the second and third sets of base pads 26, 30 of each of the base layers 12. In this respect, the frame pads 44, 46 of the first and second sets each extend linearly along the longitudinal and lateral side sections 40, 42 of the interconnect frame 34, with each of the frame pads 44 of the first set being aligned with and electrically connected to a respective one of the frame pads 46 of the second set.

As best seen in Figures 4(a) and 5(a), similar to the electrical connection of the base pads 26, 30 of the second and third sets to each other, the electrical connection of each of the frame pads 44 of the first set to a respective one of the frame pads 46 of the second set is preferably accomplished via a frame feed-through hole 48 which is also preferably plugged with a conductive material. The conductive material is preferably selected from the same group used as the conductive material to plug the base feed-through holes 32, i.e., nickel, gold, tin, silver epoxy, and combinations thereof. Each of the frame feed-through holes 48 preferably extends axially between a corresponding, coaxially aligned pair of the frame pads 44, 46 of the first and second sets, with the plugging of the frame feed-through holes 48 preferably occurring prior to the surface plating of the frame pads 44, 46 of the first and second sets to respective ones of the top and bottom surfaces 36, 38 of the interconnect frame 34.

In the preferred embodiment, the interconnect frame 34 is preferably prepared for use in the chip stack 10 by forming generally semi-spherically shaped solder bumps 50 on each of the frame pads 44, 46 of the first and second sets. These solder bumps 50 are preferably formed by first stenciling solder paste onto the frame pads 44, 46 of the first and second sets, and thereafter reflowing the solder paste to form the solder bumps 50. The use of a six mil thick stencil with an aperture approximately the same size

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as each of the frame pads 44, 46 will facilitate the formation of a solder bump 50 approximately six mils high. As indicated above, the frame pads 44, 46 of the first and second sets are formed (i.e., surface plated) subsequent to the frame feed-through holes 48 being plugged with the conductive material. If the frame feed-through holes 48 were left unplugged, each frame feed-through hole 48 could trap flux or air which would blow out the solder during the reflow cycle used to form the solder bumps 50 on each corresponding, coaxially aligned pair of frame pads 44, 46 of the first and second sets.

In the chip stack 10, the interconnect frame 34 is disposed between the base layers 12, with the second conductive pattern of the interconnect frame 34 being electrically connected to the first conductive pattern of each of the base layers 12. More particularly, the frame pads 46 of the second set are electrically connected to respective ones of the base pads 26 of the second set of one of the base layers 12 (i.e., the base layer 12 immediately below the interconnect frame 34 in the chip stack 10), with the frame pads 44 of the first set being electrically connected to respective ones of the base pads 30 of the third set of one of the base layers 12 (i.e., the base layer 12 immediately above the interconnect frame 34 in the chip stack 10). Due to the base pads 26, 30 of the second and third sets and the frame pads 44, 46 of the first and second sets all being arranged in identical patterns, each coaxially aligned pair of frame pads 44, 46 of the first and second sets is itself coaxially aligned with a coaxially aligned set of base pads 26, 30 of the second and third sets of each of the adjacent base layers 12. The electrical connection of the second conductive pattern of the interconnect frame 34 to the first conductive pattern of each of the adjacent base layers 12 is preferably facilitated via a soldering process which will be described in more detail below.

The chip stack 10 of the present invention further preferably comprises a transposer layer 52. The transposer

layer 52 itself comprises a rectangularly configured transposer substrate 54 which defines a generally planar top surface 56, a generally planar bottom surface 58, an opposed pair of longitudinal peripheral edge segments 60, and an opposed pair of lateral peripheral edge segments 62. Disposed on the transposer substrate 54 is a third conductive pattern. The third conductive pattern comprises a first set of transposer pads 64 which are disposed on the top surface 56 of the transposer substrate 54, and a second set of transposer pads 66 which are disposed on the bottom surface 58 thereof. The transposer pads 64 of the first set are electrically connected to respective ones of the transposer pads 66 of the second set via conductive traces. The transposer pads 64 of the first set are preferably arranged in a pattern which is identical to the patterns of the second and third sets of base pads 26, 30 and the first and second sets of frame pads 44, 46. In this respect, the transposer pads 64 of the first set extend linearly along the longitudinal and lateral peripheral edge segments 60, 62 of the transposer substrate 54. The transposer pads 66 of the second set are themselves preferably arranged in a generally rectangular pattern or array in the central portion of the bottom surface 58 of the transposer substrate 54, with the pattern of the transposer pads 66 of the second set preferably being identical to the pattern of the base pads 24 of the first set of each of the base layers 12.

In the preferred embodiment, the transposer layer 52 is prepared for use in the chip stack 10 by forming generally spherically shaped solder balls 68 on each of the transposer pads 66 of the second set. These solder balls 68 are preferably formed by stencil printing solder paste onto each of the transposer pads 66 of the second set, and thereafter reflowing the solder paste to form the solder balls 68. The aperture in the stencil used to form the solder balls 68 is typically larger than each of the transposer pads 66 and thick enough to deposit sufficient solder to form the solder balls 68. As seen in Figure 3,

the transposer layer 52 is also prepared for use in the chip stack 10 by forming generally semi-spherically shaped solder bumps 67 on each of the transposer pads 64 of the first set. These solder bumps 67 are preferably formed in the same manner previously described in relation to the formation of the solder bumps 50 on the frame pads 44, 46 of the first and second sets.

In the chip stack 10, the first conductive pattern of one of the base layers 12 (i.e., the lowermost base layer 12 in the chip stack 10) is electrically connected to the third conductive pattern of the transposer layer 52. More particularly, each of the base pads 30 of the third set of the lowermost base layer 12 is electrically connected to a respective one of the transposer pads 64 of the first set. Due to the base pads 30 of the third set and the transposer pads 64 of the first set being arranged in identical patterns, each of the base pads 30 of third set is coaxially alignable with a respective one of the transposer pads 64 of the first set, with the electrical connection therebetween preferably being facilitated via soldering as will be discussed in more detail below.

In the present chip stack 10, the base pads 24, 26, 30 of the first, second and third sets, the conductive traces 28, the frame pads 44, 46 of the first and second sets, and the transposer pads 64, 66 of the first and second sets are each preferably fabricated from very thin copper having a thickness in the range of from about five microns to about twenty-five microns through the use of conventional etching techniques. Advantageously, the use of thin copper for the various pads and traces 28 allows for etching line widths and spacings down to a pitch of about 4 mils which substantially increases the routing density on each of the base layers 12, as well as the transposer layer 52. Additionally, the base substrate 14, the interconnect frame 34, and the transposer substrate 54 are each preferably fabricated from either FR-4, polyamide, or some other suitable material which can easily be routed. As indicated above, all of the base feed-through holes 32 and frame

feed-through holes 48 are plugged with a conductive material prior to the surface plating procedure used to form the base pads 24, 26, 30 of the first, second and third sets, and the frame pads 44, 46 of the first and second sets. The material used to form each base substrate 14 and/or the transposer substrate 54 may be as thin as about 0.010 inches or may be a thicker multiple layer structure.

The chip stack 10 of the present invention further comprises at least two identically configured integrated circuit chips 70 which are electrically connected to respective ones of the first conductive patterns of the base layers 12. Each of the integrated circuit chips 70 preferably comprises a rectangularly configured body 72 defining a generally planar top surface 74, a generally planar bottom surface 76, an opposed pair of longitudinal sides 78, and an opposed pair of lateral sides 80. Disposed on the bottom surface 76 of the body 72 are a plurality of generally spherically shaped conductive contacts 82 which are preferably arranged in a pattern identical to the patterns of the base pads 24 of the first set and the transposer pads 66 of the second set. The conductive contacts 82 of each of the integrated circuit chips 70 are electrically connected to respective ones of the base pads 24 of the first set of a respective one of the first conductive patterns of the base layers 12. Due to the conductive contacts 82 and base pads 24 of each of the first sets being arranged in identical patterns, the conductive contacts 82 of each of the integrated circuit chips 70 are coaxially alignable with respective ones of the base pads 24 of the corresponding first set. In each of the integrated circuit chips 70, solder is preferably pre-applied to each of the conductive contacts 82 thereof. The electrical connection of the conductive contacts 82 of each integrated circuit chip 70 to respective ones of the base pads 24 of the first set of a respective one of the first conductive patterns is preferably accomplished via soldering in a manner which will be discussed in more



detail below. Additionally, each of the integrated circuit chips 70 is preferably a BGA (ball grid array) device, though the same may alternatively comprise either a CSP device or a flip chip device.

5           In the present chip stack 10, a layer 84 of flux underfill is preferably disposed between the bottom surface 76 of the body 72 of each of the integrated circuit chips 70 and respective ones of the top surfaces 16 of the base substrates 14. Each layer 84 of the flux underfill is  
10           preferably spread over the base pads 24 of the first set of a respective one of the first conductive patterns of the base layers 12. Each layer 84 substantially encapsulates the conductive contacts 82 of the corresponding integrated circuit chip 70 when the same is electrically connected to  
15           the first conductive pattern of a respective one of the base layers 12.

          Prior to the attachment of the integrated circuit chip 70 to a respective base layer 12, a bakeout cycle is required to drive out the moisture in the base layer 12 and  
20           the corresponding integrated circuit chip 70. A cycle of approximately eight hours at about 125°Celsius is desirable, which is followed by storage in a dry nitrogen atmosphere until use. The first step in the attachment of the integrated circuit chip 70 to the corresponding base  
25           layer 12 is the precise deposition of the layer 84 of an appropriate flux underfill material over the base pads 24 of the corresponding first set. The integrated circuit chip 70 is then placed over the pad area, squeezing out the flux underfill material of the layer 84 to the longitudinal  
30           and lateral sides 78, 80 of the body 72 and seating the conductive contacts 82 onto respective ones of the base pads 24 of the corresponding first set. If done properly, the layer 84 of the flux underfill material, when cured, will have no voids or minimum voids. The base layer 12  
35           having the integrated circuit chip 70 positioned thereupon in the above-described manner is then run through a solder reflow cycle with no dwelling time at an intermediate temperature of approximately 150°Celsius. A post cure

cycle to complete the polymerization of the layer 84 of the flux underfill material may be required depending on the particular flux underfill material used in the layer 84. At this juncture, the base layer 12 having the integrated circuit chip 70 electrically connected thereto may be electrically tested.

In the prior art, the standard approach for the attachment or electrical connection of the conductive contacts of a BGA device to an attachment or pad site is to first flux the pad site or conductive contacts of the BGA device, place the BGA device on the pad site in the proper orientation, reflow the solder pre-applied to the conductive contacts of the BGA device to facilitate the electrical connection to the pad site, clean, then underfill and cure. The cleaning step typically requires considerable time since the gap under the bottom surface of the body of the BGA device is very small and very difficult to penetrate with standard cleaning methods. Also, the removal of the cleaning fluid (which is generally water) requires long bakeout times.

The underfill of an epoxy between the bottom surface of the body of the BGA device and the top surface of the substrate having the pad site thereon is a relatively easy procedure, but is very slow. If a no-clean flux is used for attachment, the residue from the flux typically becomes entrapped within the epoxy underfill and may cause corrosion problems. A subsequent solder reflow process to facilitate the attachment of the chip stack to a main printed circuit board (PCB) often causes the residue flux to vaporize which exerts pressure on the solder joints and could delaminate the structure. Most underfill materials become very hard (i.e., greater than ninety shore D) and are cured at a temperature of less than about 180° Celsius. The solder is solid at this temperature and the underfill encases the solder with no room for expansion. The solder from the conductive contacts of the BGA device expands when molten again, thus exerting pressure which can delaminate the structure. If the chip stack is not subjected to

subsequent reflow temperatures when completed, there is no problem. However, the chip stack must be able to withstand the subsequent reflow temperature.

5 The flux underfill material used for the layer 84 provides both flux and underfill properties with one formulation. As the temperature rises during the solder reflow process which will be discussed below, the flux characteristics of the material aid in the solder process, with extended exposure to the peak solder reflow  
10 temperature beginning the polymerization process of the underfill portion of the material. The flux is incorporated into the underfill, thus becoming one compatible material which is cured above the melting point of solder. Thus, there is room within the encased solder for expansion at  
15 the reflow temperature. No cleaning steps are required, though careful dispensing of the correct volume and accurate placement of the integrated circuit chip 70 upon its corresponding base layer 12 is critical.

The complete chip stack 10 shown in Figure 1 includes  
20 a transposer layer 52, four base layers 12, three interconnect frames 34, and four integrated circuit chips 70. The first conductive pattern of the lowermost base layer 12 is electrically connected to the third conductive pattern of the transposer layer 52 in the above-described  
25 manner. Additionally, each of the interconnect frames 34 is disposed or positioned between an adjacent pair of base layers 12, with the second conductive pattern of each of the interconnect frames 34 being electrically connected to the first conductive pattern of such adjacent pair of base  
30 layers 12 in the above-described manner. Since the conductive contacts 82 of each of the integrated circuit chips 70 are electrically connected to respective ones of the base pads 24 of the first set of respective ones of the first conductive patterns, the integrated circuit chips 70  
35 other than for the uppermost integrated circuit chip 70 are disposed between adjacent pairs of the base layers 12 and are each circumvented by a respective one of the interconnect frames 34. Thus, the bodies 72 of the

integrated circuit chips 70 and the interconnect frames 34 are preferably sized relative to each other such that the top surface 74 of the body 72 of an integrated circuit chip 70 which is circumvented by an interconnect frame 34 does not protrude beyond the top surface 36 thereof.

As also indicated above, all the various electrical connections within the chip stack 10 are preferably facilitated via soldering. The transposer pads 66 of the second set, which are spherically shaped as indicated above, form a ball grid array on the bottom of the chip stack 10 which is specifically suited for facilitating the attachment of the chip stack 10 to a printed circuit board (PCB). Those of ordinary skill in the art will recognize that the chip stack 10 may be assembled to include fewer or greater than four base layers 12, three interconnect frames 34, and four integrated circuit chips 70.

Having thus described the structural attributes of the chip stack 10, the preferred method of assembling the same will now be described with specific reference to Figures 3, 4, 4(a), 5 and 5(a). In accordance with the present invention, multiple chip stacks 10 may be concurrently assembled through the use of a transposer panel 86, at least two base panels 88, at least one frame panel 90, at least three spacer sheets 92, and a plurality of integrated circuit chips 70. The transposer panel 86 is formed to include multiple groups of the first and second sets of transposer pads 64, 66 with such groups being formed on the transposer panel 86 in spaced relation to each other. Similarly, each of the base panels 88 is formed to include multiple groups of the first, second and third sets of base pads 24, 26, 30, with the frame panels 90 each being formed to include multiple groups of the first and second sets of frame pads 44, 46. As indicated above, the transposer panel 86 is prepared such that the transposer pads 64 of the first set of each group have the solder bumps 67 formed thereon, with the transposer pads 66 of the second set of each group having the solder balls 68 formed thereon. Similarly, each of the frame panels 90 is prepared such

that the first and second sets of frame pads 44, 46 of each group have the solder bumps 50 formed thereon. The spacer sheets 92 are each formed to define a plurality of rectangularly configured openings 94, the length and width dimensions of which exceed those of the base and transposer substrates 14, 54 and interconnect frames 34 which are substantially equal to each other.

In a preferred assembly process, the integrated circuit chips 70 are electrically connected to respective ones of each of the first sets of base pads 24 included on each of the base panels 88. Such electrical connection is accomplished in the above-described manner. Subsequent to the pre-attachment of the integrated circuit chips 70 to the base panels 88, flux underfill material is dispensed onto each of the solder bumps 67 of the transposer panel 86, with the flux underfill material also being dispensed onto all of the solder bumps 50 of each of the frame panels 90. The transposer panel is then cooperatively engaged to a stacking fixture such that the solder balls 68 face or are directed downwardly. A spacer sheet 92 is then stacked upon the transposer panel 86 such that the transposer pads 64 of the first set of each group are aligned with respective ones of the openings 94 within the spacer sheet 92. A base panel 88 is then stacked upon the spacer sheet 92 such that the base pads 30 of the third set of each group face or are directed downwardly and are aligned with respective ones of the openings 94 and respective ones of the transposer pads 64 of the first set of the corresponding group upon the transposer panel 86 immediately therebelow. Another spacer sheet 92 is then stacked upon the base panel 88 such that the base pads 24, 26 of the first and second sets of each group are aligned with respective ones of the openings 94.

In the next step of the assembly process, a frame panel 90 is stacked upon the uppermost spacer sheet 92 such that the bodies 72 of the integrated circuit chips 70 are each circumvented by the frame panel 90. Another spacer sheet 92 is then stacked upon the frame panel 90 such that

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the frame pads 44 of the first set of each group are aligned with respective ones of the openings 94. Another base panel 88 is then stacked upon the uppermost spacer sheet 92 in a manner wherein the base pads 30 of the third set of each group of such uppermost base panel 88 are aligned with respective ones of the openings 94 and respective ones of the frame pads 44 of the first set of the corresponding group upon the frame panel 90 immediately therebelow. As will be recognized, the above-described stacking process may be continued or repeated to form a chip stack having a greater number of electrically interconnected integrated circuit chips 70.

Upon the stacking of the various panels and sheets in the above-described manner, a pressure plate is applied to the top of the stack to maintain such panels and sheets in prescribed orientations relative to each other. The stacked panels and sheets are then subjected to heat at a level sufficient to facilitate the reflow of the solder bumps 50, 67. The solder reflow cycle is typically conducted in a temperature range of from about 215°Celsius to about 250°Celsius. Upon the completion of solder reflow process, the individual chip stacks are separated through the use of a router.

In the preferred assembly method as discussed above, the spacer sheets 92 are needed only for the solder reflow process, and do not become part of each resultant chip stack formed by the completion of the routing process. The solder bumps 50, 67 are slightly higher than each spacer sheet 92. Since light pressure is applied to the various panels and sheets during the solder reflow process, the solder bumps 50, 67 collapse, thus making the appropriate electrical connections to the corresponding pads (i.e., the base pads 26, 30 of either the second or third sets). Thus, the spacer sheets 92 keep the solder from being squeezed out and bridging to neighboring pads. A spacing of from about four mils to about six mils can be accomplished using spacer sheets 92 which are fabricated from paper. The paper can be easily punched to form the

openings 94, does not interfere with the routing process, can withstand the solder reflow temperature in the aforementioned range, and is inexpensive. The paper spacer sheets 92 would be sized the same as the transposer, base and frame panels 86, 88, 90, and punched to include openings 94 which are slightly larger than the finished, routed chip stack. With slight pressure being applied to the stacked panels and sheets, the space between the panels and sheets is easily maintained, thus eliminating the necessity to remove the spacer sheets 92 subsequent to the reflow of the solder. As indicated above, the paper spacer sheets 92 would not interfere with the routing process, and would be removed with the rest of the debris.

The present assembly method has high volume potential, with the use of the flux underfill material providing localized encapsulation of the conductive contacts 82 of the integrated circuit chips 70 and eliminating the need for a cleaning cycle as discussed above. Those of ordinary skill in the art will recognize that a transposer panel 86 need not necessarily be included in the assembly process, since the lowermost base layer 12 in any chip stack may be used as a transposer board to facilitate the mounting or electrical connection of the chip stack to a PCB. In the completed chip stack, the solder joints between each of the integrated circuit chips 70 and the corresponding base layer 12 are protected by the flux underfill material.

Additional modifications and improvements of the present invention may also be apparent to those of ordinary skill in the art. Thus, the particular combination of parts and steps described and illustrated herein is intended to represent only one embodiment of the present invention, and is not intended to serve as limitations of alternative devices and methods within the spirit and scope of the invention.

## CLAIMS:

1. A chip stack comprising:  
at least two base layers, each of the base layers  
5 comprising:  
a base substrate; and  
a first conductive pattern disposed on the  
base substrate;  
a least one interconnect frame having a second  
10 conductive pattern disposed thereon, the interconnect  
frame being disposed between the base layers, with the  
second conductive pattern being electrically connected  
to the first conductive pattern of each of the base  
layers; and  
15 at least two integrated circuit chips  
electrically connected to respective ones of the first  
conductive patterns, one of the integrated circuit  
chips being at least partially circumvented by the  
interconnect frame and at least partially covered by  
20 one of the base layers.
2. A chip stack of Claim 1 further comprising:  
a transposer layer comprising:  
a transposer substrate; and  
a third conductive pattern disposed on the  
25 transposer substrate;  
the first conductive pattern of one of the base  
layers being electrically connected to the third  
conductive pattern.
3. The chip stack of Claim 2 wherein:  
30 the base substrate defines opposed top and bottom  
surfaces; and  
the first conductive pattern comprises:  
a first set of base pads disposed on the top  
surface of the base substrate;  
35 a second set of base pads disposed on the  
top surface of the base substrate and  
electrically connected to respective ones of the  
base pads of the first set; and



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a third set of base pads disposed on the bottom surface of the base substrate and electrically connected to respective ones of the base pads of the second set;

5           the integrated circuit chips being disposed upon respective ones of the top surfaces of the base substrates and electrically connected to at least some of the base pads of respective ones of the first sets, with the base pads of the second set of one of the base layers being electrically connected to the second  
10           conductive pattern, and the base pads of the third set of one of the base layers being electrically connected to the second conductive pattern.

4.   The chip stack of Claim 3 wherein:

15           the interconnect frame defines opposed top and bottom surfaces; and

          the second conductive pattern comprises:

                  a first set of frame pads disposed on the top surface of the interconnect frame;  
20                   and

                  a second set of frame pads disposed on the bottom surface of the interconnect frame and electrically connected to respective ones of the frame pads of the first set;

25           the interconnect frame being disposed between the base layers such that the frame pads of the second set are electrically connected to respective ones of the base pads of the second set of one of the base layers, and the frame pads of the first set are electrically  
30           connected to respective ones of the base pads of the third set of one of the base layers.

5.   The chip stack of Claim 4 wherein:

          the transposer substrate defines opposed top and bottom surfaces; and

35           the third conductive pattern comprises:

                  a first set of transposer pads disposed on the top surface of the transposer substrate; and

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a second set of transposer pads disposed on the bottom surface of the transposer substrate and electrically connected to respective ones of the transposer pads of the first set;

5 the base pads of the third set of one of the base layers being electrically connected to respective ones of the transposer pads of the first set.

6. The chip stack of Claim 5 wherein the transposer pads of the first set, the frame pads of the first and  
10 second sets, and the base pads of the second and third sets are arranged in identical patterns.

7. The chip stack of Claim 6 wherein:

the transposer and base substrates each have a generally rectangular configuration defining opposed  
15 pairs of longitudinal and lateral peripheral edge segments;

the interconnect frame has a generally rectangular configuration defining opposed pairs of longitudinal and lateral side sections;

20 the transposer pads of the first set extend along the longitudinal and lateral peripheral edge segments of the transposer substrate;

the first and second sets of frame pads extend along the longitudinal and lateral side sections of  
25 the interconnect frame; and

the second and third sets of base pads extend along the longitudinal and lateral peripheral edge segments of the base substrate.

8. The chip stack of Claim 6 wherein each of the  
30 transposer pads of the second set has a generally spherical configuration.

9. The chip stack of Claim 6 wherein each of the transposer pads of the first set and each of the frame pads of the first and second sets has a generally semi-spherical  
35 configuration.

10. The chip stack of Claim 6 wherein:

each of the frame pads of the first set is electrically connected to a respective one of the

frame pads of the second set via a frame feed-through hole; and

5 each of the base pads of the second set is electrically connected to a respective one of the base pads of the third set via a base feed-through hole.

11. The chip stack of Claim 10 wherein each of the frame and base feed-through holes is plugged with a conductive material.

10 12. The chip stack of Claim 11 wherein the conductive material is selected from the group consisting of:

nickel;  
gold;  
tin;  
silver epoxy; and  
15 combinations thereof.

13. The chip stack of Claim 6 wherein the integrated circuit chips each comprise:

a body having opposed, generally planar top and bottom surfaces; and  
20 a plurality of conductive contacts disposed on the bottom surface of the body;

the conductive contacts of each of the integrated circuit chips being electrically connected to respective ones of the base pads of the first set  
25 of a respective one of the first conductive patterns.

14. The chip stack of Claim 13 wherein the transposer pads of the second set, the base pads of the first set, and the conductive contacts are arranged in identical patterns.

30 15. The chip stack of Claim 13 further comprising a layer of flux underfill disposed between the bottom surface of the body of each of the integrated circuit chips and respective ones of the top surfaces of the base substrates.

35 16. The chip stack of Claim 13 wherein the body of each of the integrated circuit chips and the interconnect frame are sized relative to each other such that the top surface of the body of the integrated circuit chip at least

partially circumvented by the interconnect frame does not protrude beyond the top surface thereof.

17. The chip stack of Claim 13 wherein the integrated circuit chips are each selected from the group consisting of:

- a BGA device;
- a fine pitch BGA device;
- a CSP device; and
- a flip chip device.

18. The chip stack of Claim 2 wherein the transposer and base substrates are each fabricated from a polyamide.

19. The chip stack of Claim 1 further comprising:

a second interconnect frame, the second conductive pattern of which is electrically connected to the first conductive pattern of one of the base layers such that the second interconnect frame at least partially circumvents one the integrated circuit chips;

a third base layer, the first conductive pattern of which is electrically connected to the second conductive pattern of the second interconnect frame such that the third base layer at least partially covers one of the integrated circuit chips; and

a third integrated circuit chip electrically connected to the first conductive pattern of the third base layer.

20. The chip stack of Claim 19 further comprising:

a multiplicity of additional interconnect frames, base layers, and integrated circuit chips;

the second conductive pattern of each of the interconnect frames being electrically connected to the first conductive patterns of any adjacent pair of base layers, with each of the integrated circuit chips being electrically connected to the first conductive pattern of a respective one of the base layers.

21. A method of assembling a chip stack, comprising the steps of:

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(a) electrically connecting an integrated circuit chip to a first conductive pattern of a base layer;

5 (b) electrically connecting a second conductive pattern of an interconnect frame to the first conductive pattern such the interconnect frame at least partially circumvents the integrated circuit chip;

10 (c) electrically connecting another integrated circuit chip to the first conductive pattern of another base layer; and

(d) electrically connecting the first conductive pattern of one of the base layers to the second conductive pattern of the interconnect frame such that  
15 one of the integrated circuit chips is disposed between the base layers.

22. The method of Claim 21 further comprising the step of:

20 (e) electrically connecting the first conductive pattern of one of the base layers to a third conductive pattern of a transposer layer.

23. The method of Claim 21 wherein steps (a) and (c) each comprise applying a layer of flux underfill to each of the base layers over portions of the first conductive  
25 patterns prior to the electrical connection of respective ones of the integrated circuit chips thereto.

24. The method of Claim 22 wherein steps (a)-(e) are accomplished via soldering.

30 25. A method of assembling a chip stack, comprising the steps of:

(a) providing a transposer panel which has opposed surfaces and a plurality of conductive pads disposed on the opposed surfaces thereof;

35 (b) providing at least two base panels which each have opposed surfaces and a plurality of conductive pads disposed on the opposed surfaces thereof;

(c) providing at least one frame panel which has opposed surfaces and a plurality of conductive pads disposed on the opposed surfaces thereof;

5 (d) providing a plurality of integrated circuit chips which each have opposed sides and a plurality of conductive contacts disposed on one of the sides thereof;

10 (e) placing integrated circuit chips upon each of the base panels such that the conductive contacts of each of the integrated circuit chips are disposed on at least some of the conductive pads of respective ones of the base panels;

15 (f) stacking one of the base panels upon the transposer panel such that at least some of the conductive pads of the base panel are disposed on at least some of the conductive pads of the transposer panel;

20 (g) stacking the frame panel upon the base panel such that at least some of the conductive pads of the frame panel are disposed on at least some of the conductive pads of the base panel; and

25 (h) stacking another base panel upon the frame panel such that at least some of the conductive pads of the base panel are disposed on at least some of the conductive pads of the frame panel.

26. The method of Claim 25 wherein steps (g) and (h) are repeated at least once subsequent to step (h).

27. The method of Claim 25 further comprising the step of:

30 (i) bonding the conductive contacts of the integrated circuit chips to at least some of the conductive pads of the base panel upon which the integrated circuit chips are positioned, bonding at least some of the conductive pads of one of the base  
35 panels to at least some of the conductive pads of the transposer panel, and bonding at least some of the conductive pads of the frame panel to at least some of the conductive pads of each of the base panels.

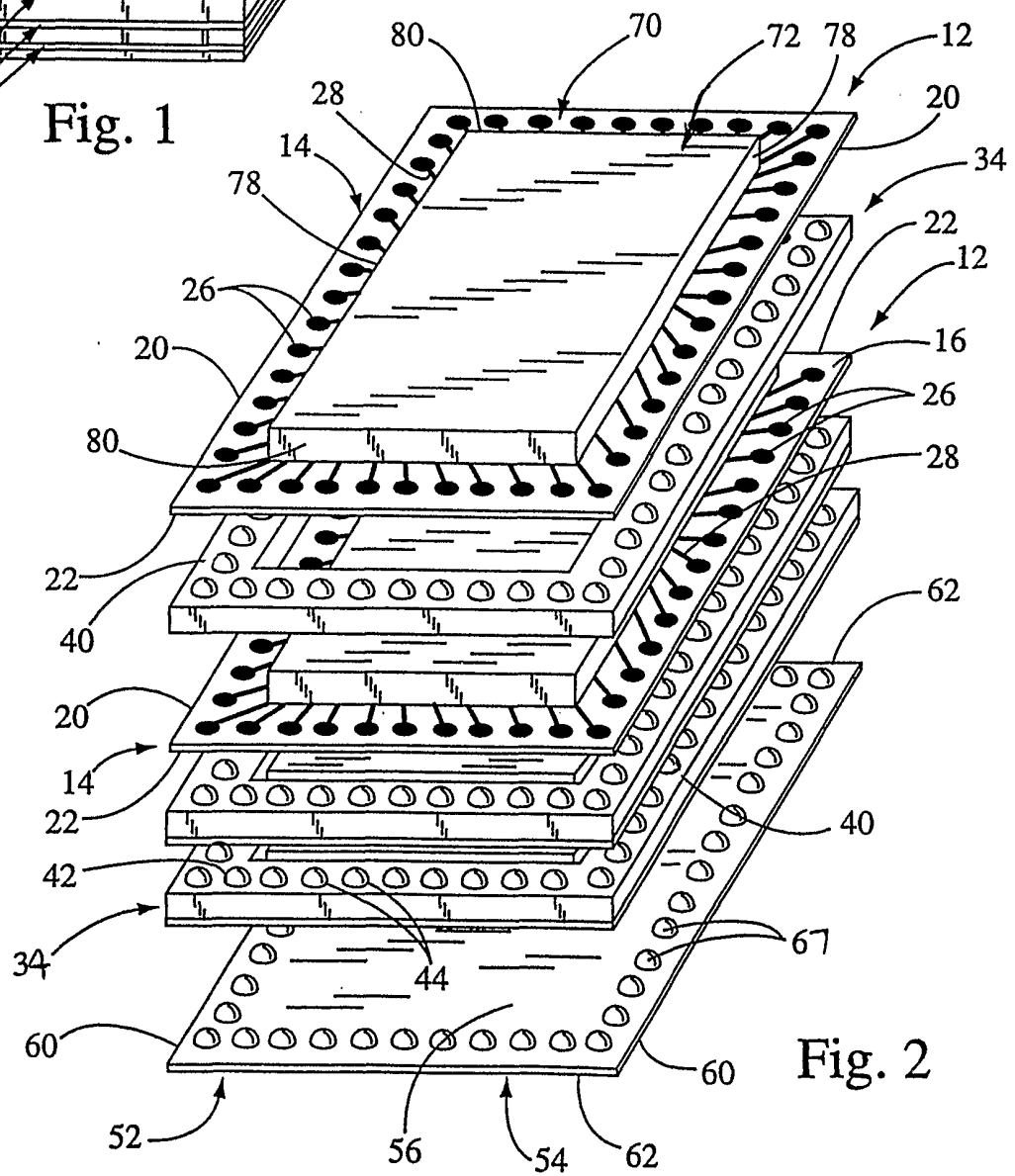
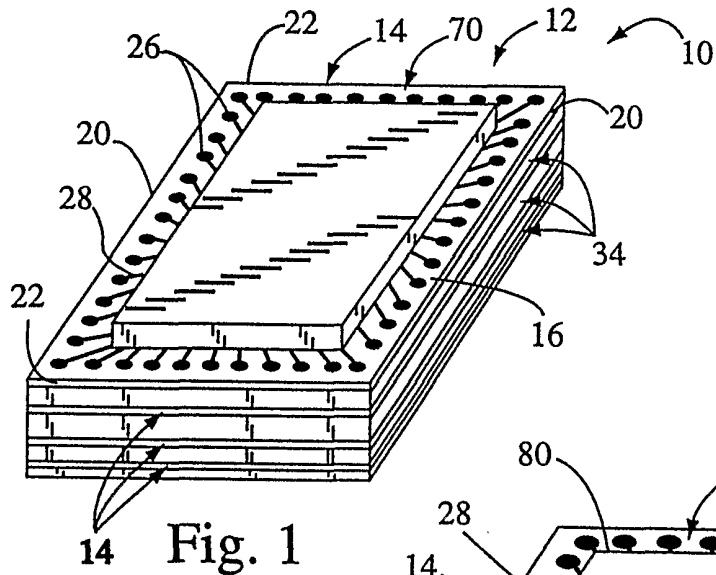
28. The method of Claim 25 wherein at least three spacer sheets are also provided which each have opposed surfaces and a plurality of openings disposed therein, and:

5           step (f) comprises stacking one of the spacer sheets upon the transposer panel and stacking the base panel upon the spacer sheet such that the conductive pads of the transposer and base panels are aligned with respective ones of the openings;

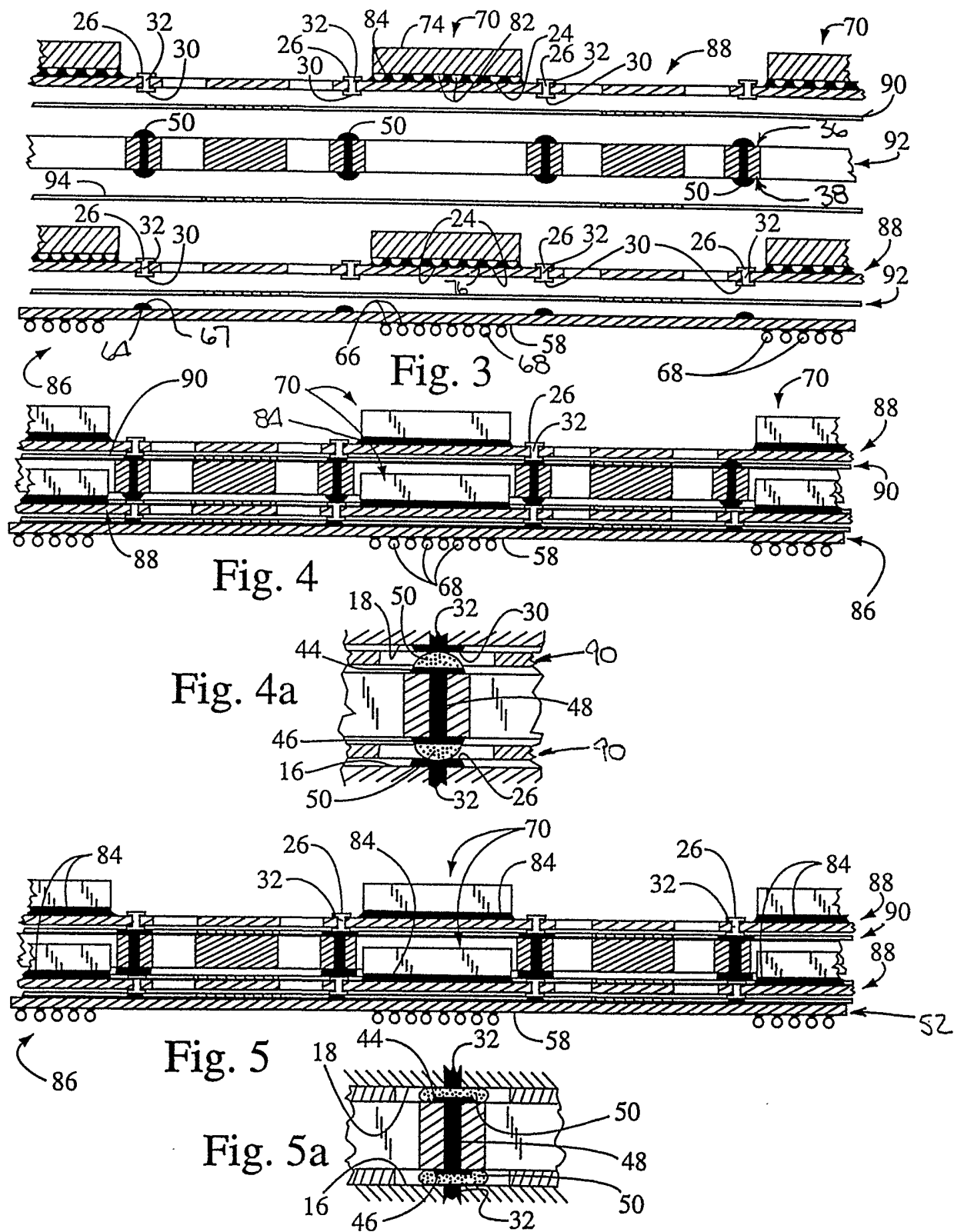
10           step (g) comprises stacking another spacer sheet upon the base panel and stacking the frame panel upon the spacer sheet such that the conductive pads of the base and frame panels are aligned with respective ones of the openings; and

15           step (h) comprises stacking another spacer sheet upon the frame panel and stacking the base panel upon the spacer sheet such that the conductive pads of the frame and base panels are aligned with respective ones of the openings.

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## INTERNATIONAL SEARCH REPORT

International application No.  
PCT/US01/10130

**A. CLASSIFICATION OF SUBJECT MATTER**

IPC(7) :H01L 23/02, 23/48, 23/52, 29/40

US CL :257/685, 686, 777, 778; 438/108, 109

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

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 257/685, 686, 777, 778; 438/108, 109

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched  
None

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)  
EAST SEARCH (No Text)

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5,612,570 A (Eide et al.) 18 March 1997 (18.03.1997), Figs. 1 and 5.	1, 2, 21
A	US 5,266,833 A (Capps) 30 November 1993 (30.11.1993), Fig. 6.	1, 21
A	WO 93/23873 A (Miyake) 25 November 1993 (25.11.1993), Figs. 1-6.	1-28
A	JP 6-61415 A (Tajika et al.) 04 March 1994 (04.03.1994), Figs. 25.	1-28

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A" document defining the general state of the art which is not considered to be of particular relevance	"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
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"O" document referring to an oral disclosure, use, exhibition or other means	
"P" document published prior to the international filing date but later than the priority date claimed	

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