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HIGH DENSITY, THREE-DIMENSIONAL INTEGRATED CIRCUIT MODULE AND ELEMENTS FOR MAKING SAME

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BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to an integrated circuit module and elements for making same, and more particularly, to a high density, three-dimensional integrated circuit module in which a plurality of individual integrated circuits are electrically and mechanically associated in a space and volume conservative manner. The present invention also relates to the elements for making the foregoing module.

Prior Work

It is often desirable to electrically and physically associate together plural integrated circuits, such as DRAMs, SRAMs, EPROMs, logic packages and other semiconductor packages. Electrical association relates primarily to properly interconnecting the circuits with electrical conductors, such as wires or conductive paths deposited on appropriate substrates. Space constraints may limit or affect the manner of physically and electrically associating the circuits.

A desiderata of the present invention is achieving the physical and electrical association together of plural integrated circuits in a module which module occupies substantisally the least possible amount of space or volume while properly electrically interconnecting the integrated circuits.

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SUMMARY OF THE INVENTION

The present invention contemplates elements for producing a modular integrated circuit assembly. The assembly first includes at least two integrated circuits; typical assemblies include more than two integrated circuits. Each integrated circuit generally comprises a chip, which has been appropriately processed so as to be able to perform selected electrical functions, and a body, often an ambient-excluding, insulative package surrounding and enclosing the chip. Leads which are electrically continuous with the circuit project beyond the periphery of the body or package for connection to or association with other conductors or components.

The assembly also includes intermediate circuit-supporting facilities. Each intermediate facility includes a torroidal --open or closed-- electrically insulative member or substrate. The member surrounds or defines a void or generally central opening which is adapted to surround the peripheries of the bodies of adjacent integrated circuits. There are electrically conductive pads on the member. The pads are adapted to be respectively engaged by and bonded to the leads when the bodies are inserted into, and surrounded by, the void.

Preferably , the thickness of the member is selected so that the adjacent integrated circuits abut just as they would absent the supporting facilities. In this fashion, a stack of alternating integrated circuits and supporting facilities --whether the stack include two or ten or more integrated circuits-- occupies no more vertical space or volume than would a stack of the same number of integrated circuits alone, that is, without the supporting facilities being present.

Also, preferably, mounted on the ends of the stack are cap-like end pieces which are similar in

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structure to the supporting facilities, but which do not include voids or central openings. The top end-piece may include conductive pads which are adapted to be engaged by and bonded to the leads of the uppermost integrated circuit in the stack. Electrically conductive paths may be present on the top end-piece to selectively electrically interconnect the pads thereof. The bottom end-piece may include the same or similar elements as the top end-piece in addition to facilities for mounting and electrically connecting the stack to a mother board or the like. These latter facilities may, for example, include conductive balls, such as solder balls, relatively stiff board-mountable leads or conductive lands.

BRIEF DESCRIPTION OF THE DRAWING

Figure 1 is a perspective view of an integrated circuit package;

Figure 2 is a perspective view of a mounting facility which permits two integrated circuit packages of the type shown in Figure 1 to be mounted in a stack according to the principles of the present invention;

Figure 3 is a side elevation of the mounting facility of Figure 2 taken along line 3-3;

Figure 4 is an exploded perspective view of two circuit packages of Figure 1 and two mounting facilities of Figure 2 adapted to form a stack thereof;

Figure 5 is a magnified view of a circuit package and a mounting facility associated together in an unexploded form of the invention depicted in Figure 4;

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Figure 6 is a perspective view of a stack of ten circuit packages and nine mounting facilities, along with a bottom end-piece; and

Figure 7 is a side elevation of the stack depicted in Figure 6 showing the bottom end-piece in greater detail and a top end-piece for the stack.

DETAILED DESCRIPTION

Referring first to Figure 1, there is shown a perspective view of a generalized integrated circuit package 10, a first element adapted for the construction of an integrated circuit module. According to the present invention, a plurality of such circuit packages 10 are cost effectively associated together in a stack or three dimensional array thereof 12 (see Figures 5 and 7) in a space- and volume-conserving manner by the use of elements or facilities shown in Figures 2 and 3.

Referring to Figures 1 and 5, the integrated circuit package 10 is, in general, of standard construction and includes a body 14, which may comprise a plastic, ceramic or similar material, surrounding and enclosing one or more chips or the like which contain integrated circuits, not specifically shown, but generally indicated by the reference numeral 16. The body 14 preferably has a rectangular or square configuration and periphery 17 and is quite thin or low in height compared to its length and width, although other configurations and shapes are contemplated. Conductive leads 18 protrude from the periphery 17 of the body 14. The leads 18 are electrically continuous with leads or conductive paths (not shown) on the chip or chips 16 and, in turn, with the various circuits and circuit components in and on the chip or chips 16. The leads 18 permit

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the chips 16 to be electrically connected to external circuitry, including other circuit packages 10. When the body 14 assumes its preferred configuration and shape, the leads 18 protruding from the periphery 17 of the body 14 are generally coplanar in a flat plane, although such coplanarity is not required by the present invention.

The leads 18 of the package 10 are specifically different from those of the prior art. In particular, and referring to Figures 1 and 5-7 each lead 18 comprises a conductive, metallic body 20 protruding from the periphery 17 of the body 14 and ending at a terminus 22. Intermediate the terminus 22 and the periphery 17 is a hole or passageway 24 formed through the body 20 in a direction generally perpendicular to both the direction in which the lead 18 extends and the plane containing the leads 18.

The second element adapted to construct the module 12 comprises stacking facilities 30. The stacking facilities 30 permit a number of the circuit packages 10 to be contained in a stack or three dimensional module such as that 12 shown in Figures 5 and 7. The facilities 30 include an electrically insulative, generally torroidal or generally ring-shaped member 32 defining a generally central void or opening 34. The void or opening 34 is adapted to conform to the periphery 17 of the body 14 when the body 14 of the circuit package 10 is inserted threreinto. The member 32 has an upper surface 36 and a lower surface 38. In preferred embodiments, where the leads 18 are coplanar in a flat plane, the surfaces 36,38 are also flat. If the leads 18 are coplanar in a curved plane or are otherwise not coplanar, the surfaces 36,38 are shaped so as to conform to the plane or path defined by the leads 18. In any event, when a circuit package 10 is inserted into the opening 34, its leads 18 and one surface 36 of the member 32 are generally parallel. Preferably, the member 32 and its void 34 are rectangular, as most circuit packages 10

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are also rectangular. Obviously, other shapes may be used, depending on the configuration of the associated circuit packages 10. Further, while it is preferable that the torroid of the member 32 be closed, it is intended that the word "torroidal" connote both closed, or O-like, and open, or C-like, torroids.

The thickness 50 of the member 32 is preferably selected so that with the body 14 of one circuit package 10 inserted into the opening 34 with its leads 18 parallel to the surface 36, the body 14 of a second circuit package 10 may be inserted into the opening 34 so that its leads 18 are parallel to the surface 38. Also, preferably, when the bodies 14 of the two circuit packages 10 are inserted into the opening 34, the bodies 14 abut within the opening 34. Those skilled in the art will appreciate that the thickness 50 may be adjusted to achieve the foregoing following a consideration of the thickness of the bodies 14 and the locations, relative to the "top" and "bottom" of the circuit packages 10, at which the leads 18 protrude. According to the foregoing preferred construction, a stack 12 of circuit packages 10 comprising two packages 10 and one stacking facility 30 has a total thickness equal to the thickness of one package 10 stacked on top of the other without the intervening mounting facility 30.

Formed on both surfaces 36,38 of the member 32 are separated conductive areas 52, which may comprise solder pads 54 resident on a conductive layer therebeneath (not shown). The formation of the solder pads may accord with any prior art technique. The mounting facility 30, including its member 32 and the solder pads 54 may comprise a printed circuit board produced in any convenient manner. Each solder pad 54 respectively corresponds to a lead 18 of a circuit package 10. That is, when a circuit package 10 is inserted into the opening 34, each lead 18 corresponds to, and overlies, one of the solder pads 54. Preferably, each lead 18 engages its corresponding

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solder pad 54, although it is contemplated that for particular applications of the circuit packages 10 selected leads 18 may not engage solder pads 54.

As best seen in Figure 3, the solder pads 54 are preferably formed on both surfaces 36,38 of the member 32 with corresponding solder pads 54 on each side of the member 32 being electrically continuous. Electrical continuity is preferably achieved by forming pairs of pads 54 on either surface 36,38 of the member 32 in alignment with a conductor 56 which electrically interconnects the pad pair. The conductors 56 may comprise vias or apertures 58 formed through the member 32 the walls of which have deposited thereon a conductive coating. Thus, the apertures constitute conductive vias through the member 32. It is also contemplated that only some of the pads 54 on one surface 36 are electrically continuous with pads 54 on the other surface 38. Such electrical continuity may be chosen so that the module 12 performs desired functions.

The correspondence or lack of correspondence between selected leads 22 and pads 54, the presence of absence of leads 22 and pads 54 at selected locations, the electrical continuity or lack thereof between selected pads 54 on the surfaces 36,38 may all be chosen so that, giving due consideration to the type and function of each circuit package 10 the module or stack 12 will perform a desired function. As should be obvious, the circuit packages 10 may be the same in a module 12 or may be partially or completely different.

Various methods may be used to mechanically affix the leads 18 to their respective solder pads 54. These methods include laser soldering and hot air reflow soldering. In the latter case, the leads 18 are preferably solder plated prior to being soldered to the pads 54.

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As shown in Figures 5 and 7, the stack 12 may comprise any selected number of circuit packages 10 alternating with mounting facilities 30. In preferred embodiments the top or free surface of the uppermost circuit package 10 and the bottom or free surface of the lowermost circuit package are covered with end-pieces 60 and 62.

The upper end-piece 60 is similar to the mounting facility 30 but does not include the opening 34 and may have solder pads 54 on only one side thereof. The pads 54 may be selectively electrically interconnected by, or may be selectively connected to, conductive paths or circuit components, such as capacitors (not shown) on or in an electrically insulative body 64 of the end-piece 60. The free surface of the end-piece may contain indicia such as the manufacturer's identity, part number, or the like. The lower end-piece 62 is similar to the upper end-piece 60. It includes an electrically insulative body 68 with solder pads 54 on one side thereof. The pads may be selectively interrconnected by, or may be selectively connected to, conductive pads and/or circuit components (not shown) formed on or in the body 68. On the other side of the body 68 are formed plural solder balls 70 which are selectively connected to each other, to the solder pads 54 and to the conductors/components on or in the body 68. The solder balls 70 are used to surface- mount the stack 12 to a mother board, SIMM or other similar element (not shown). The solder balls 70 are abutted with appropriate conductive pads on the mother board and are then melted to mechanically and electrically interconnect the stack 12 thereto.

As noted above, the leads 18 contain holes or passageways 24. The presence of the holes 24 results in the mechanical bond of each lead 18 to its solder pad 54 (and/or the underlying conductive layer) being quite strong and robust. Specifically, when the leads 18 (solder coated or otherwise) and the solder pads 54 are heated, the solder melts and wets the main trunk of the

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leads 18 as well as the walls of the holes 24. Ultimately such wetting, possible aided by capillarity, results in the hole 24 becoming filled with solder. When the heat is removed, the solder within the holes 24 and the solder wetting and coating the lead18 are fused in a continuum, which renders the lead/pad 18/54 mechanically stronger than would be the case were the holes 24 absent. Thus, the stack 12 of circuit packages 10 is stable and robust. Further, the stack 12 occupies minimal space and volume while nevertheless providing for electrical interconnection of plural circuit packages 10.

Those skilled in the art will appreciate that the foregoing description sets forth various embodiments of the present invention, but that the invention in its broadest aspects is defined by the following claims and as disclosed may be modified by those skilled in the art to nevertheless fall within the scope of such claims. For example, the solder pads 54 may be replaced by equivalent elements, such as conductive polymers or other conductive substances.

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CLAIMS

WE CLAIM:

1. Elements usable to produce a modular integrated circuit assembly, which elements comprise:

(A) an integrated circuit package, which includes

(i) a body enclosing a circuit and

(ii) a plurality of leads which are electrically continuous with the circuit and which project from the periphery of the body; and

(B) a package-supporting facility, which includes

(i) a generally torroidal, electrically insulative member having a void adapted to surround the periphery of the body and

(ii) electrically conductive pads on the member which are adapted to be engaged by and bonded to selected leads when the body is inserted into and surrounded by the void.

2. A facility for forming a modular integrated circuit assembly, the assembly being of the type which includes an integrated circuit package having a body enclosing a circuit and a plurality of leads which are electrically continuous with the circuit and which project from the periphery of the body, wherein the facility comprises:

a generally torroidal, electrically insulative member having a void adapted to surround the periphery of the body when the body is inserted thereinto, and

electrically conductive pads on the member which are adapted to be engaged by and bonded to selected leads when the body is inserted into and surrounded by the void.

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3. A facility as set forth in Claim 2 and usable with two integrated circuit packages insertable into the void from opposite sides of the member, wherein:

the thickness of the member is such that the bodies are abuttable with each other within the void and the pads are simultaneously engageable with the selected leads so that the effective thickness of the abutting bodies inserted into the void is the same as the effective thickness of the abutting bodies without the facility.

4. A plurality of the facilities as set forth in Claim 3, wherein:

the plural facilities are adapted to be alternated with a plurality of the circuit packages to produce a modular assembly in the form of a stack.

5. A facility as set forth in Claim 3, wherein:

the member has two opposed surfaces each of which carries conductive pads.

6. A facility as set froth in Claim 5, wherein:

selected pads on one surface are electrically connected to selected pads on the other surface.

7. A facility as set forth in Claim 6, wherein:

the electrically connected pads are mutually connected to conductive vias formed through the member.

8. A modular assembly which comprises at least one of the facilities and at least two circuit packages, both as set forth in Claim 3, wherein:

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the facilities and the packages are alternated within a stack thereof.

9. A facility as set forth in Claim 2, wherein:

the leads are included in a first plane, and

the conductive pads are included in a second plane which is congruent with the first plane.

10. A facility as in Claim 2, wherein:

the conductive pads include solder or a conductive polymer.

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