MICROELECTRONIC DEVICES, STACKED MICROELECTRONIC DEVICES, AND METHODS FOR MANUFACTURING MICROELECTRONIC DEVICES

TECHNICAL FIELD

The present invention is related to microelectronic devices, stacked microelectronic devices, and methods for manufacturing microelectronic devices.

BACKGROUND

Microelectronic devices generally have a die (i.e., a chip) that includes integrated circuitry having a high density of very small components. In a typical process, a large number of dies are manufactured on a single wafer using many different processes that may be repeated at various stages (e.g., implanting, doping, photolithography, chemical vapor deposition, plasma vapor deposition, plating, planarizing, etching, etc.). The dies typically include an array of very small bond-pads electrically coupled to the integrated circuitry. The bond-pads are the external electrical contacts on the die through which the supply voltage, signals, etc., are transmitted to and from the integrated circuitry. The dies are then separated from one another (i.e., singulated) by dicing the wafer and backgrinding the individual dies. After the dies have been singulated, they are typically "packaged" to couple the bond-pads to a larger array of electrical terminals that can be more easily coupled to the various power supply lines, signal lines, and ground lines.

An individual die can be packaged by electrically coupling the bond-pads on the die to arrays of pins, ball-pads, or other types of electrical terminals, and then encapsulating the die to protect it from environmental factors (e.g., moisture, particulates, static electricity, and physical impact). In

one application, the bond-pads are electrically connected to contacts on an interposer substrate that has an array of ball-pads. FIG. 1A schematically illustrates a conventional packaged microelectronic device 10 including an interposer substrate 20 and a microelectronic die 40 attached to the interposer substrate 20. The microelectronic die 40 has been encapsulated with a casing 30 to protect the die 40 from environmental factors.

Electronic products require packaged microelectronic devices to have an extremely high density of components in a very limited space. For example, the space available for memory devices, processors, displays, and other microelectronic components is quite limited in cell phones, PDAs, portable computers, and many other products. As such, there is a strong drive to reduce the surface area or "footprint" of the microelectronic device 10 on a printed circuit board. Reducing the size of the microelectronic device 10 is difficult because high performance microelectronic devices 10 generally have more bond-pads, which result in larger ball-grid arrays and thus larger footprints. One technique used to increase the density of microelectronic devices 10 within a given footprint is to stack one microelectronic device 10 on top of another.

FIG. 1B schematically illustrates the packaged microelectronic device (identified as 10a) of FIG. 1A stacked on top of a second similar microelectronic device 10b. The interposer substrate 20 of the first microelectronic device 10a is coupled to the interposer substrate 20 of the second microelectronic device 10b by large solder balls 50. One drawback of the stacked devices 10a-b is that the large solder balls 50 required to span the distance between the two interposer substrates 20 use valuable space on the interposer substrates 20, which increases the footprint of the microelectronic devices 10a-b.

FIG. 2 schematically illustrates another packaged microelectronic device 60 in accordance with the prior art. The device 60 includes a first microelectronic die 70a attached to a substrate 80 and a second

microelectronic die 70b attached to the first die 70a. The first and second dies 70a-b are electrically coupled to the substrate 80 with a plurality of wire-bonds 90. The device further includes a casing 95 encapsulating the dies 70a-b and wire-bonds 90. One drawback of the packaged microelectronic device 60 illustrated in FIG. 2 is that if one of the dies 70a-b fails a post-encapsulation quality control test because it is not properly wire bonded to the substrate 80 or for some other reason, the packaged device 60, including the good die 70, is typically discarded. Accordingly, encapsulating multiple dies together reduces the yield of the resulting packages.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1A schematically illustrates a conventional packaged microelectronic device.

FIG. 1B schematically illustrates the packaged microelectronic device of FIG. 1A stacked on top of a second similar microelectronic device.

FIG. 2 schematically illustrates another packaged microelectronic device in accordance with the prior art.

FIGS. 3A-3D illustrate stages in one embodiment of a method for manufacturing a plurality of microelectronic devices.

FIG. 3A is a schematic side cross-sectional view of an assembly including a plurality of microelectronic dies arranged on a first interposer substrate.

FIG. 3B is a schematic side cross-sectional view of the assembly after attaching a plurality of second interposer substrates to corresponding microelectronic dies.

FIG. 3C is a schematic side cross-sectional view of the assembly after forming a casing and attaching a plurality of electrical couplers.

FIG. 3D is a schematic side cross-sectional view of an upper microelectronic device stacked on top of a lower microelectronic device.

FIG. 4 is a schematic side cross-sectional view of a microelectronic device in accordance with another embodiment of the invention.

FIGS. 5A-5C illustrate stages in another embodiment of a method for manufacturing a plurality of microelectronic devices.

FIG. 5A is a schematic side cross-sectional view of an assembly including a plurality of microelectronic dies arranged on a first interposer substrate.

FIG. 5B is a schematic side cross-sectional view of the assembly after attaching a plurality of second interposer substrates to corresponding microelectronic dies.

FIG. 5C is a schematic side cross-sectional view of the assembly after wire-bonding the second interposer substrates to the first interposer substrate and forming a casing.

FIGS. 6A-6D illustrate stages in another embodiment of a method for manufacturing a plurality of microelectronic devices.

FIG. 6A is a schematic side cross-sectional view of an assembly including a plurality of microelectronic dies arranged on a first interposer substrate.

FIG. 6B is a schematic side cross-sectional view of the assembly after attaching a plurality of second interposer substrates to the corresponding dies.

FIG. 6C is a schematic side cross-sectional view of the assembly after forming a casing.

FIG. 6D is a schematic side cross-sectional view of an upper microelectronic device stacked on top of a lower microelectronic device.

FIG. 7 is a schematic side cross-sectional view of a microelectronic device in accordance with another embodiment of the invention.

DETAILED DESCRIPTION

A. Overview

The following disclosure describes several embodiments of microelectronic devices, stacked microelectronic devices, and methods for manufacturing microelectronic devices. An embodiment of one such set of stacked microelectronic devices includes (a) a first microelectronic die having a first side and a second side opposite the first side, (b) a first substrate attached to the first side of the first microelectronic die and electrically coupled to the first microelectronic die, (c) a second substrate attached to the second side of the first microelectronic die, (d) a plurality of electrical couplers attached to the second substrate, (e) a third substrate coupled to the electrical couplers, and (f) a second microelectronic die attached to the third substrate. The electrical couplers are positioned such that at least some of the electrical couplers are inboard the first microelectronic die.

Another aspect of the invention is directed to microelectronic devices. In one embodiment, a microelectronic device includes (a) a microelectronic die having a first side, a second side opposite the first side, an integrated circuit, and a plurality of terminals electrically coupled to the integrated circuit, (b) a first interposer substrate coupled to the first side of the microelectronic die, and (c) a second interposer substrate coupled to the second side of the microelectronic die. The first interposer substrate has a plurality of first contacts and a plurality of second contacts. The first contacts are electrically coupled to corresponding terminals. The second interposer substrate has a plurality of contacts electrically coupled to corresponding second contacts of the first interposer substrate.

Another aspect of the invention is directed to methods for manufacturing a plurality of microelectronic devices. In one embodiment, a method includes mounting a plurality of microelectronic dies to a first interposer substrate with the dies arranged in an array, attaching a plurality of second interposer substrates to corresponding microelectronic dies with the microelectronic dies positioned between the first interposer substrate and the associated second interposer substrate, and electrically coupling the second interposer substrates to the first interposer substrate.

Another aspect of the invention is directed to methods for stacking microelectronic devices. In one embodiment, a method includes (a) providing a first microelectronic device having a microelectronic die, a first interposer substrate coupled to the microelectronic die, and a second interposer substrate coupled to the microelectronic die such that the die is positioned between the first and second interposer substrates, (b) providing a second microelectronic device having a microelectronic die and an interposer substrate coupled to the microelectronic die, and (c) stacking the second microelectronic device on top of the first microelectronic device with a plurality of electrical couplers positioned between the first and second microelectronic devices and inboard the die of the first microelectronic device. For example, the electrical couplers can be superimposed relative to the microelectronic die of the first microelectronic device and positioned in a zone within the perimeter of the die.

Many specific details of several embodiments of the invention are described below with reference to forming a plurality of microelectronic devices together in a single assembly, but in other embodiments each device can be formed separately. Several embodiments in accordance with the invention are set forth in FIGS. 3A-7 and the following text to provide a thorough understanding of particular embodiments of the invention. A person skilled in the art will understand, however, that the invention may

have additional embodiments, or that the invention may be practiced without several of the details of the embodiments shown in FIGS. 3A-7.

B. Embodiments of Methods for Manufacturing Microelectronic Devices

FIGS. 3A-3D illustrate stages in one embodiment of a method for manufacturing a plurality of microelectronic devices. For example, FIG. 3A is a schematic side cross-sectional view of an assembly 100 including a plurality of microelectronic dies 110 (only three are shown) arranged in an array on a first interposer substrate 120. The individual dies 110 include an integrated circuit 112 (shown schematically), an active side 114, a plurality of terminals 116 (e.g., bond pads) arranged in an array on the active side 114, and a backside 118 opposite the active side 114. The backsides 118 of the dies 110 are attached to the first interposer substrate 120 with an adhesive 130, such as an adhesive film, epoxy, tape, paste, or other suitable material. Although the illustrated dies 110 have the same structure, in other embodiments, the dies 110 may have different features to perform different functions.

The first interposer substrate 120 can be a printed circuit board or other member for carrying the dies 110. In the illustrated embodiment, the first interposer substrate 120 includes (a) a first side 122 having a plurality of first contacts 126 and a plurality of second contacts 127, and (b) a second side 124 having a plurality of pads 128. The first contacts 126 can be arranged in arrays for electrical connection to corresponding terminals 116 on the dies 110; the second contacts 127 can be arranged in arrays for electrical connection to corresponding contacts on a second interposer substrate (shown in FIG. 3B); and the pads 128 can be arranged in arrays to receive a plurality of electrical couplers (e.g., solder balls). The first interposer substrate 120 further includes a plurality of conductive traces 129 electrically coupling the first and second contacts 126 and 127 to corresponding pads 128.

FIG. 3B is a schematic side cross-sectional view of the assembly 100 after attaching a plurality of second interposer substrates 140 to corresponding microelectronic dies 110. The individual second interposer substrates 140 include a first side 142 and a second side 144 attached to one of the dies 110 with an adhesive 132. The first side 142 includes (a) a plurality of contacts 146 arranged in an array for electrical connection to a corresponding array of second contacts 127 on the first interposer substrate 120, and (b) a plurality of pads 148 arranged in an array for attachment to a plurality of electrical couplers (e.g., solder balls). In several embodiments, the pads 148 are generally aligned with corresponding pads 128 on the first interposer substrate 120 such that the microelectronic device can be stacked on a similar device and a plurality of electrical couplers can electrically connect corresponding sets of pads 128 and 148, as described below with reference to FIG. 3D. The individual second interposer substrates 140 further include a plurality of conductive traces 149 electrically connecting the pads 148 to corresponding contacts 146. Although the footprint of the illustrated second interposer substrates 140 is smaller than the footprint of the individual dies 110, in other embodiments, such as the embodiment described below with reference to FIG. 4, the footprint of the second interposer substrates 140 can be the same as or larger than the footprint of the dies 110.

After attaching the second interposer substrates 140, the microelectronic dies 110 and the second interposer substrates 140 are wire-bonded to the first interposer substrate 120. Specifically, a plurality of first wire-bonds 134 are formed between the terminals 116 of the dies 110 and corresponding first contacts 126 on the first interposer substrate 120, and a plurality of second wire-bonds 136 are formed between the contacts 146 on the second interposer substrates 140 and corresponding second contacts 127 on the first interposer substrate 120. In additional embodiments, the microelectronic dies 110 can be wire-bonded to the first interposer substrate

120 before the second interposer substrates 140 are attached to the dies 110. In other embodiments, the second interposer substrates 140 can be attached to the dies 110 before the dies 110 are attached to the first interposer substrate 120.

FIG. 3C is a schematic side cross-sectional view of the assembly 100 after forming a casing 150 and attaching a plurality of electrical couplers 160. The casing 150 encapsulates the microelectronic dies 110, the first and second wire-bonds 134 and 136, and a portion of the first and second interposer substrates 120 and 140. Specifically, the illustrated casing 150 encapsulates a perimeter portion of the first side 142 of the second interposer substrate 140 such that the contacts 146 are covered, and defines an opening 152 over a central portion of the first side 142 of the second interposer substrate 140 such that the pads 148 are exposed. The casing 150 can be formed by conventional injection molding, film molding, or other suitable processes. After forming the casing 150, the electrical couplers 160 can be attached to corresponding pads 128 on the first interposer substrate 120, and the assembly 100 can be cut along lines A-A to singulate a plurality of individual microelectronic devices 102.

FIG. 3D is a schematic side cross-sectional view of an upper microelectronic device 102a stacked on top of a lower microelectronic device 102b. The upper and lower devices 102a-b can be generally similar to the microelectronic devices 102 described above with reference to FIGS. 3A-3C. The upper device 102a is coupled to the lower device 102b by inserting the electrical couplers 160 of the upper device 102a into the opening 152 in the casing 150 of the lower device 102b and attaching the electrical couplers 160 to corresponding pads 148 on the second interposer substrate 140 of the lower device 102b. In other embodiments, the upper and lower devices 102a-b can be different devices. For example, the upper device 102a may not include the second interposer substrate 140 and the second wire-bonds 136. Moreover, the microelectronic dies 110 in the upper and lower

microelectronic devices 102a-b can be the same or different types of dies. In other embodiments, additional microelectronic devices can be stacked on top of the upper device 102a and/or below the lower device 102b. In additional embodiments, the microelectronic devices 102 can be stacked before the assemblies are cut and the devices 102 are singulated. For example, a plurality of singulated devices 102 can be attached to corresponding devices 102 in the assembly 100 illustrated in FIG. 3C. Alternatively, the devices 102 in two or more assemblies can be attached and singulated together.

One advantage of the microelectronic devices 102 described above with reference to FIGS. 3A-3D is that the devices 102 can be stacked on top of each other. Stacking microelectronic devices increases the capacity and/or performance within a given surface area or footprint of a circuit board. For example, when the upper microelectronic device 102a is stacked on top of the lower microelectronic device 102b and the lower device 102b is attached to a circuit board, the upper microelectronic device 102a is electrically and operably coupled to the circuit board without using significantly more surface area on the circuit board.

Another feature of the microelectronic devices 102 illustrated in FIGS. 3A-3D is that the individual devices can be tested after packaging and before stacking. An advantage of this feature is that defective packaged devices can be detected and excluded from a stack of devices. Therefore, stacks of microelectronic devices can include only known good devices, which increases the yield of the device stacks and reduces the number of devices that are discarded.

Another feature of the stacked microelectronic devices 102 illustrated in FIG. 3D is that the lower microelectronic device 102b includes a second interposer substrate 140 with a plurality of exposed pads 148 inboard the die 110. An advantage of this feature is that the upper microelectronic device 102a can include a fully populated ball grid array, which increases the

number of signals that can be passed from the upper device 102a to a circuit board without increasing the footprint on the circuit board.

C. Additional Embodiments of Microelectronic Devices and Methods for Manufacturing Microelectronic Devices

FIG. 4 is a schematic side cross-sectional view of a microelectronic device 202 in accordance with another embodiment of the invention. The microelectronic device 202 is generally similar to the microelectronic devices 102 described above with reference to FIGS. 3A-3D. For example, the microelectronic device 202 includes a microelectronic die 110 attached to a first interposer substrate 120. The illustrated microelectronic device 202, however, further includes a second interposer substrate 240 spaced apart from the die 110 by a stand-off 270. The second interposer substrate 240 includes (a) a first side 242 having a plurality of contacts 246 and a plurality of pads 248, and (b) a second side 244 opposite the first side 242. The contacts 246 are arranged in an array and electrically connected to corresponding second contacts 127 on the first interposer substrate 120 with a plurality of second wire-bonds 136. The pads 248 are arranged in an array and can be aligned with corresponding pads 128 on the first interposer substrate 120. Although the footprint of the illustrated second interposer substrate 240 is approximately the same as the footprint of the die 110, in other embodiments, the footprint of the second interposer substrate 240 can be larger or smaller than the footprint of the die 110.

The stand-off 270 is attached to the second side 244 of the second interposer substrate 240 with a first adhesive 232a and the active side 114 of the die 110 with a second adhesive 232b. The stand-off 270 is sized to space the second interposer substrate 240 apart from the die 110 so that the first wire-bonds 134 can extend between the terminals 116 and corresponding first contacts 126 on the first interposer substrate 120. The stand-off 270 can be a mirror wafer, tape, paste, or other suitable device. A

casing 250 can fill the void between the second interposer substrate 240 and the microelectronic die 110.

One feature of the microelectronic device 202 illustrated in FIG. 4 is that the second interposer substrate 240 has a larger footprint than the second interposer substrate 140 discussed above with reference to FIGS. 3A-3D. An advantage of this feature is that the illustrated second interposer substrate 240 can include more pads 248 and accommodate a larger ball grid array, which increases the number of signals that can be passed from an upper microelectronic device to a lower microelectronic device in a device stack.

FIGS. 5A-5C illustrate stages in another embodiment of a method for manufacturing a plurality of microelectronic devices. For example, FIG. 5A is a schematic side cross-sectional view of an assembly 300 including a plurality of microelectronic dies 310 (only three are shown) arranged in an array on a first interposer substrate 120. The individual microelectronic dies 310 include an integrated circuit 112 (shown schematically), an active side 314, a plurality of terminals 316 arranged in an array on the active side 314, and a backside 318 opposite the active side 314. The backsides 318 of the microelectronic dies 310 are attached to the first interposer substrate 120 with an adhesive 130. The first interposer substrate 120 is generally similar to the first interposer substrate 120 described above with reference to FIGS. 3A-3D.

FIG. 5B is a schematic side cross-sectional view of the assembly 300 after attaching a plurality of second interposer substrates 340 to corresponding microelectronic dies 310 with interconnect elements 370. The individual second interposer substrates 340 include a first side 342, a second side 344 opposite the first side 342, a plurality of first contacts 345 on the first side 342, a plurality of second contacts 346 on the first side 342, a plurality of third contacts 347 on the second side 344, and a plurality of pads 348 on the first side 342. The first contacts 345 are arranged in an

array for electrical connection to corresponding first contacts 126 on the first interposer substrate 120; the second contacts 346 are arranged in an array for electrical connection to corresponding second contacts 127 on the first interposer substrate 120; the third contacts 347 are arranged in an array and attached to corresponding interconnect elements 370; and the pads 348 are arranged in an array for attachment to a plurality of electrical couplers. The second interposer substrate 340 can further include a plurality of first conductive traces 349a electrically coupling the first contacts 345 to corresponding third contacts 347, and a plurality of second conductive traces 349b electrically coupling the second contacts 346 to corresponding pads 348. The interconnect elements 370 can be solder balls or other conductive members to electrically couple the terminals 316 of the microelectronic die 310 to corresponding third contacts 347 on the second interposer substrate 340. The assembly 300 may further include an underfill material 372 between the microelectronic dies 310 and the corresponding second interposer substrates 340 to bear some of the stress placed on the components and protect the components from moisture, chemicals, and other contaminants.

FIG. 5C is a schematic side cross-sectional view of the assembly 300 after wire-bonding the second interposer substrates 340 to the first interposer substrate 120 and forming a casing 350. A plurality of first wire-bonds 334 extend between the first contacts 345 of the second interposer substrates 340 and corresponding first contacts 126 on the first interposer substrate 120, and a plurality of second wire-bonds 335 extend between the second contacts 346 of the second interposer substrate 340 and corresponding second contacts 127 on the first interposer substrate 120. The first and second wire-bonds 334 and 335 accordingly electrically couple the terminals 316 of the microelectronic die 310 and the pads 348 of the second interposer substrate 340, respectively, to the pads 128 of the first interposer substrate 120.

The casing 350 encapsulates the microelectronic die 310 and a portion of the first and second interposer substrates 120 and 340. Specifically, the casing 350 encapsulates a perimeter portion of the second interposer substrate 340 such that the first and second contacts 345 and 346 are encapsulated and the pads 348 are exposed. After forming the casing 350, the assembly 300 can be cut along lines B-B to singulate a plurality of individual microelectronic devices 302.

FIGS. 6A-6E illustrate stages in another embodiment of a method for manufacturing a plurality of microelectronic devices. For example, FIG. 6A is a schematic side cross-sectional view of an assembly 400 including a plurality of microelectronic dies 410 (only three are shown) arranged in an array on a first interposer substrate 420. The individual microelectronic dies 410 include an integrated circuit 112, an active side 414 attached to the first interposer substrate 420, a plurality of terminals 416 on the active side 414, and a backside 418 opposite the active side 414.

The illustrated first interposer substrate 420 includes a first side 422, a second side 424 opposite the first side 422, a plurality of first contacts 426 on the first side 422, a plurality of second contacts 427 on the second side 424, a plurality of first pads 428a on the second side 424, a plurality of second pads 428b on the second side 424, and a plurality of slots 425 extending between the first and second sides 422 and 424. The first contacts 426 are arranged in arrays for electrical connection to corresponding contacts on a second interposer substrate (described below with reference to FIG. 6B); the second contacts 427 are arranged in arrays for electrical connection to corresponding terminals 416 on the dies 410; and the first and second pads 428a-b are arranged in arrays to receive a plurality of electrical couplers. The first interposer substrate 420 further includes a plurality of first conductive traces 429a electrically coupling the first contacts 426 to corresponding first pads 428a and a plurality of second conductive

traces 429b electrically coupling the second contacts 427 to corresponding second pads 428b.

FIG. 6B is a schematic side cross-sectional view of the assembly 400 after attaching a plurality of second interposer substrates 440 to corresponding dies 410 with an adhesive 432. The second interposer substrates 440 include a first side 442, a second side 444 attached to one of the dies 410, a plurality of contacts 446 on the first side 442, a plurality of pads 448 on the first side 442, and a plurality of conductive traces 449 electrically coupling the contacts 446 to corresponding pads 448. The pads 448 are arranged in an array for attachment to electrical couplers and can be generally aligned with corresponding pads 428 on the first interposer substrate 420. Although the illustrated second interposer substrates 440 have a footprint generally similar to the footprint of the die 410, in other embodiments, the second interposer substrates can have a larger or smaller footprint than the die 410.

After attaching the second interposer substrates 440 to the dies 410, the dies 410 are wire-bonded to the first interposer substrate 420, and the first interposer substrate 420 is wire-bonded to the second interposer substrates 440. Specifically, a plurality of first wire-bonds 434 electrically connect the terminals 416 of the dies 410 to corresponding second contacts 427 on the first interposer substrate 420, and a plurality of second wire-bonds 436 electrically connect the contacts 446 on the second interposer substrates 440 to corresponding first contacts 426 on the first interposer substrate 420.

FIG. 6C is a schematic side cross-sectional view of the assembly 400 after forming a casing 450. The casing 450 encapsulates the microelectronic dies 410, the first and second wire-bonds 434 and 436, and a portion of the first and second interposer substrates 420 and 440. Specifically, the casing 450 encapsulates a perimeter portion of the individual second interposer substrates 440 such that the contacts 446 are

covered by the casing 450, but the pads 448 are exposed. As such, the casing 450 defines an opening 452 for receiving electrical couplers from another microelectronic device. The casing 450 also covers the second contacts 427 and the slot 425 in the first interposer substrate 420. After forming the casing 450, a plurality of electrical couplers 460 can be placed on corresponding pads 428 of the first interposer substrate 420, and the assembly 400 can be cut along lines C-C to singulate a plurality of individual devices 402.

FIG. 6D is a schematic side cross-sectional view of an upper microelectronic device 402a stacked on top of a lower microelectronic device 402b. The upper device 402a is coupled to the lower device 402b by inserting the electrical couplers 460 of the upper device 402a into the opening 452 in the casing 450 of the lower device 402b and attaching the electrical couplers 460 to corresponding pads 448 on the second interposer substrates 440 of the lower device 402b.

One feature of the microelectronic devices 402 illustrated in FIGS. 6A-6D is that the electrical couplers 460 are positioned inboard the microelectronic dies 410. An advantage of this feature is that the footprint of the devices 402 is reduced. In contrast, in prior art devices, such as the devices 10a-b illustrated in FIGS. 1A and 1B, the solder balls 50 are positioned outboard the dies 40, and consequently, the devices 10a-b have a larger footprint than the microelectronic devices 402 illustrated in FIGS. 6A-6D. Devices with larger footprints use more space on printed circuit boards and other substrates in cell phones, PDAs, computers, and other products.

FIG. 7 is a schematic side cross-sectional view of a microelectronic device 502 in accordance with another embodiment of the invention. The microelectronic device 502 is generally similar to the microelectronic devices 402 described above with reference to FIGS. 6A-6D. For example, the illustrated microelectronic device 502 includes a microelectronic die 410

attached between a first interposer substrate 520 and a second interposer substrate 540. In the illustrated embodiment, however, the first interposer substrate 520 includes a plurality of first contacts on the second side 424, and the second interposer substrate 540 includes a plurality of contacts 546 on the second side 444. Moreover, the illustrated second interposer substrate 540 has a larger footprint than the die 410 and the first interposer substrate 520. The illustrated microelectronic device 502 further includes (a) a plurality of second wire-bonds 536 extending between the contacts 546 on the second interposer substrate 540 and corresponding first contacts 526 on the first interposer substrate 520, and (b) a casing 550 encapsulating the first and second wire-bonds 434 and 536.

One feature of the microelectronic device 502 illustrated in FIG. 7 is that the first and second wire-bonds 434 and 536 are formed on a single side of the device 502. An advantage of this feature is that the microelectronic device 502 can be wire-bonded in a single-pass process that is faster and easier than processes which require flipping a device over to form wire-bonds on both sides. Another feature of the microelectronic device 502 illustrated in FIG. 7 is that the casing 550 is formed on only a single side of the second interposer substrate 540. An advantage of this feature is that the casing 550 can be formed with a one-sided mold cavity, which is less complex and expensive than a two-sided mold cavity.

From the foregoing, it will be appreciated that specific embodiments of the invention have been described herein for purposes of illustration, but that various modifications may be made without deviating from the spirit and scope of the invention. For example, many of the elements of one embodiment can be combined with other embodiments in addition to or in lieu of the elements of the other embodiments. Accordingly, the invention is not limited except as by the appended claims.

CLAIMS

We claim:

1. A set of stacked microelectronic devices, comprising:

a first microelectronic die including a first side and a second side opposite the first side;

a first substrate attached to the first side of the first microelectronic die and electrically coupled to the first microelectronic die;

a second substrate attached to the second side of the first microelectronic die;

a plurality of electrical couplers attached to the second substrate and positioned such that at least some of the electrical couplers are inboard the first microelectronic die;

a third substrate coupled to the electrical couplers; and

a second microelectronic die attached to the third substrate, wherein a microelectronic die is not positioned between the second and third substrates.

2. The microelectronic devices of claim 1 wherein:

the first side of the first microelectronic die comprises a back side and the second side of the first microelectronic die comprises an active side;

the first microelectronic die further comprises a plurality of terminals on the active side;

the first substrate comprises a first side attached to the back side of the first microelectronic die, a plurality of first contacts on the first side, and a plurality of second contacts on the first side;

the second substrate comprises a plurality of pads attached to corresponding electrical couplers and a plurality of contacts electrically coupled to corresponding pads; and

the microelectronic devices further comprise (a) a plurality of first wire-bonds electrically coupling the terminals on the first microelectronic die to corresponding first contacts on the first substrate, (b) a plurality of second wire-bonds electrically coupling the contacts on the second substrate to corresponding second contacts on the first substrate, and (c) a stand-off between the second substrate and the first microelectronic die.

3. The microelectronic devices of claim 1 wherein:

the first side of the first microelectronic die comprises an active side;

the first microelectronic die further comprises a plurality of terminals on the active side;

the first substrate comprises a first side attached to the active side of the first microelectronic die, a second side opposite the first side, an opening extending between the first and second sides, and a plurality of contacts on the second side; and

the microelectronic devices further comprise a plurality of wire-bonds electrically coupling the terminals to corresponding contacts.

4. The microelectronic devices of claim 1 wherein:

the first side of the first microelectronic die comprises an active side and the second side of the first microelectronic die comprises a back side;

the first microelectronic die further comprises a plurality of terminals on the active side;

the first substrate comprises a first side attached to the active side of the first microelectronic die, a second side opposite the first side, an opening extending between the first and second sides, a plurality of first contacts on the first side, and a plurality of second contacts on the second side;

the second substrate comprises a plurality of pads attached to corresponding electrical couplers and a plurality of contacts electrically coupled to corresponding pads; and

the microelectronic devices further comprise (a) a plurality of first wire-bonds electrically coupling the terminals on the first microelectronic die to corresponding second contacts on the first substrate, and (b) a plurality of second wire-bonds electrically coupling the contacts on the second substrate to corresponding first contacts on the first substrate.

5. The microelectronic devices of claim 1 wherein:

the first side of the first microelectronic die comprises a back side and the second side of the first microelectronic die comprises an active side;

the first microelectronic die further comprises a plurality of terminals on the active side;

the first substrate comprises a first side attached to the back side of the first microelectronic die and a plurality of contacts on the first side; and

the microelectronic devices further comprise a plurality of wire-bonds electrically coupling the terminals to corresponding contacts.

6. The microelectronic devices of claim 1 wherein:

the first side of the first microelectronic die comprises a back side and the second side of the first microelectronic die comprises an active side;

the first microelectronic die further comprises a plurality of terminals on the active side;

the first substrate comprises a first side attached to the back side of the first microelectronic die, a plurality of first contacts on the first side, and a plurality of second contacts on the first side;

the second substrate comprises a plurality of pads attached to corresponding electrical couplers and a plurality of contacts electrically coupled to corresponding pads; and

the microelectronic devices further comprise (a) a plurality of first wire-bonds electrically coupling the terminals on the first microelectronic die to corresponding first contacts on the first substrate, and (b) a plurality of second wire-bonds electrically coupling the contacts on the second substrate to corresponding second contacts on the first substrate.

7. The microelectronic devices of claim 1 wherein:

the first side of the first microelectronic die comprises a back side and the second side of the first microelectronic die comprises an active side;

the first microelectronic die further comprises a plurality of terminals on the active side;

the first substrate comprises a first side attached to the back side of the first microelectronic die and a plurality of contacts on the first side;

the second substrate comprises a first side facing toward the active side of the first microelectronic die, a plurality of first contacts

on the first side, and a plurality of second contacts electrically coupled to corresponding first contacts; and

the microelectronic devices further comprise (a) a plurality of electrical couplers positioned between the first microelectronic die and the second substrate and electrically coupling the terminals to corresponding first contacts, and (b) a plurality of wire-bonds electrically coupling the second contacts on the second substrate to corresponding contacts on the first substrate.

8. The microelectronic devices of claim 1 wherein:

the first side of the first microelectronic die comprises a back side and the second side of the first microelectronic die comprises an active side;

the first microelectronic die further comprises a plurality of terminals on the active side;

the first substrate comprises a first side attached to the back side of the first microelectronic die and a plurality of contacts on the first side;

the second substrate comprises a first side facing toward the active side of the first microelectronic die, a second side opposite the first side, a plurality of first contacts on the first side, a plurality of second contacts on the second side attached to corresponding electrical couplers, and a plurality of third contacts; and

the microelectronic devices further comprise (a) a plurality of interconnect elements positioned between the first microelectronic die and the second substrate and electrically coupling the terminals to corresponding first contacts, and (b) a plurality of wire-bonds electrically coupling the third contacts on

the second substrate to corresponding contacts on the first substrate.

9. The microelectronic devices of claim 1 wherein:

the second substrate comprises a plurality of contacts;

the third substrate comprises a plurality of contacts; and

the electrical couplers comprise conductive balls electrically connecting the contacts of the second substrate to corresponding contacts of the third substrate.

10. The microelectronic devices of claim 1 wherein:

the second microelectronic die comprises a first side attached to the third substrate and a second side opposite the first side; and

the microelectronic devices further comprise a fourth substrate attached to the second side of the second microelectronic die.

11. The microelectronic devices of claim 1, further comprising a casing covering at least a portion of the first microelectronic die, the first substrate, and the second substrate.

12. The microelectronic devices of claim 1 wherein:

the second substrate comprises a first side attached to the second side of the first microelectronic die and a second side opposite the first side;

the microelectronic devices further comprise a casing covering at least a portion of the first microelectronic die, the first substrate, and the second substrate; and

the casing defines an opening exposing a section of the second side of the second substrate.

13. The microelectronic devices of claim 1 wherein:

the first microelectronic die further comprises an integrated circuit and a plurality of terminals electrically coupled to the integrated circuit;

the first substrate further comprises a first side attached to the first side of the first microelectronic die, a second side opposite the first side, a plurality of pads on the second side, and a plurality of contacts electrically connected to corresponding pads;

the electrical couplers comprise a plurality of first electrical couplers; and

the microelectronic devices further comprise a plurality of second electrical couplers on corresponding pads.

14. The microelectronic devices of claim 1 wherein:

the first microelectronic die further comprises an integrated circuit and a plurality of terminals electrically coupled to the integrated circuit;

the first substrate further comprises a plurality of contacts; and

the microelectronic devices further comprise a plurality of wire-bonds electrically coupling the terminals to corresponding contacts.

15. The microelectronic devices of claim 1 wherein:

the first substrate comprises a plurality of contacts;

the second substrate comprises a plurality of contacts; and

the microelectronic devices further comprise a plurality of wire-bonds electrically coupling the contacts on the first substrate to corresponding contacts on the second substrate.

16. The microelectronic devices of claim 1 wherein:

the first side of the first microelectronic die comprises an active side and the second side of the first microelectronic die comprises a back side;

the first microelectronic die further comprises a plurality of terminals on the active side;

the first substrate comprises a first side attached to the active side of the first microelectronic die, a second side opposite the first side, an opening extending between the first and second sides, a plurality of first contacts on the second side, and a plurality of second contacts on the second side;

the second substrate comprises a plurality of pads attached to corresponding electrical couplers and a plurality of contacts electrically coupled to corresponding pads; and

the microelectronic devices further comprise (a) a plurality of first wire-bonds electrically coupling the terminals on the first microelectronic die to corresponding second contacts on the first substrate, and (b) a plurality of second wire-bonds electrically coupling the contacts on the second substrate to corresponding first contacts on the first substrate.

17. The microelectronic devices of claim 1 wherein the electrical couplers are positioned in a zone within a perimeter of the first microelectronic die.

18. The microelectronic devices of claim 1 wherein the electrical couplers are superimposed relative to the first microelectronic die.

19. A set of stacked microelectronic devices, comprising:

a first microelectronic die;

a first interposer substrate attached to the first microelectronic die;

a second interposer substrate attached to the first microelectronic die such that the first microelectronic die is positioned between the first and second interposer substrates;

a third interposer substrate coupled to the second interposer substrate such that the second interposer substrate is positioned between the first microelectronic die and the third interposer substrate, wherein a microelectronic die is not positioned between the second and third interposer substrates; and

a second microelectronic die attached to the third interposer substrate such that the third interposer substrate is positioned between the second microelectronic die and the second interposer substrate.

20. The microelectronic devices of claim 19, further comprising a plurality of electrical couplers attached between the second and third interposer substrates and positioned such that at least some of the electrical couplers are inboard the first microelectronic die.

21. The microelectronic devices of claim 19 wherein:

the first microelectronic die comprises an active side and a plurality of terminals on the active side;

the first interposer substrate comprises a first side attached to the active side of the first microelectronic die, a second side opposite the first side, an opening extending between the first and second sides, and a plurality of contacts on the second side; and

the microelectronic devices further comprise a plurality of wire-bonds electrically coupling the terminals to corresponding contacts.

22. The microelectronic devices of claim 19 wherein:

the first microelectronic die comprises an active side, a back side opposite the active side, and a plurality of terminals on the active side;

the first interposer substrate comprises a first side attached to the back side of the first microelectronic die and a plurality of contacts on the first side; and

the microelectronic devices further comprise a plurality of wire-bonds electrically coupling the terminals to corresponding contacts.

23. The microelectronic devices of claim 19 wherein:

the first microelectronic die comprises an active side, a back side opposite the active side, and a plurality of terminals on the active side;

the first interposer substrate comprises a first side attached to the back side of the first microelectronic die and a plurality of contacts on the first side;

the second interposer substrate comprises a first side facing toward the active side of the first microelectronic die, a plurality of first contacts on the first side, and a plurality of second contacts electrically coupled to corresponding first contacts; and

the microelectronic devices further comprise (a) a plurality of interconnect elements positioned between the first microelectronic die and the second interposer substrate and electrically coupling the terminals to corresponding first contacts, and (b) a plurality of wire-bonds electrically coupling the second contacts on the second interposer substrate to corresponding contacts on the first interposer substrate.

24. The microelectronic devices of claim 19, further comprising a casing covering at least a portion of the first microelectronic die, the first interposer substrate, and the second interposer substrate.

25. The microelectronic devices of claim 19 wherein:

the first microelectronic die comprises an integrated circuit and a plurality of terminals electrically coupled to the integrated circuit;

the first interposer substrate comprises a plurality of contacts; and

the microelectronic devices further comprise a plurality of wire-bonds electrically coupling the terminals to corresponding contacts.

26. The microelectronic devices of claim 19 wherein:

the first interposer substrate comprises a plurality of contacts;

the second interposer substrate comprises a plurality of contacts; and

the microelectronic devices further comprise a plurality of wire-bonds electrically coupling the contacts on the first interposer substrate to corresponding contacts on the second interposer substrate.

27. A microelectronic device, comprising:

a microelectronic die including a first side, a second side opposite the first side, an integrated circuit, and a plurality of terminals electrically coupled to the integrated circuit;

a first interposer substrate coupled to the first side of the microelectronic die, the first interposer substrate having a plurality of first contacts electrically coupled to corresponding terminals and a plurality of second contacts;

a second interposer substrate coupled to the second side of the microelectronic die, the second interposer substrate having a

plurality of contacts electrically coupled to corresponding second contacts on the first interposer substrate; and

a third interposer substrate coupled to the second interposer substrate such that the second interposer substrate is positioned between the first microelectronic die and the third interposer substrate, wherein a microelectronic die is not positioned between the second and third interposer substrates.

28. The microelectronic device of claim 27 wherein:

the first side of the microelectronic die comprises an active side with the terminals;

the first interposer substrate further comprises a first side attached to the active side of the microelectronic die and having the second contacts, a second side opposite the first side and having the first contacts, and an opening extending between the first and second sides; and

the microelectronic device further comprises a plurality of wire-bonds electrically coupling the terminals to corresponding first contacts on the first interposer substrate.

29. The microelectronic device of claim 27 wherein:

the first side of the microelectronic die comprises an active side with the terminals and the second side of the microelectronic die comprises a back side;

the first interposer substrate further comprises a first side attached to the active side of the microelectronic die and having the second contacts, a second side opposite the first side and having the first contacts, an opening extending between the first and second sides; and

the microelectronic device further comprises (a) a plurality of first wire-bonds electrically coupling the terminals on the microelectronic die to corresponding first contacts on the first interposer substrate, and (b) a plurality of second wire-bonds electrically coupling the contacts on the second interposer substrate to corresponding second contacts on the first interposer substrate.

30. The microelectronic device of claim 27 wherein:

the first side of the microelectronic die comprises an active side with the terminals and the second side of the microelectronic die comprises a back side;

the first interposer substrate further comprises a first side attached to the back side of the microelectronic die; and

the microelectronic device further comprises a plurality of wire-bonds electrically coupling the terminals to corresponding first contacts on the first interposer substrate.

31. The microelectronic device of claim 27 wherein:

the first side of the microelectronic die comprises a back side and the second side of the microelectronic die comprises an active side with the terminals;

the first interposer substrate further comprises a first side attached to the back side of the microelectronic die and having the first and second contacts; and

the microelectronic device further comprises (a) a plurality of first wire-bonds electrically coupling the terminals on the microelectronic die to corresponding first contacts on the first interposer substrate, and (b) a plurality of second wire-bonds electrically coupling the contacts on the second interposer

substrate to corresponding second contacts on the first interposer substrate.

32. The microelectronic device of claim 27 wherein:

the first side of the microelectronic die comprises a back side and the second side of the microelectronic die comprises an active side with the terminals;

the first interposer substrate further comprises a first side attached to the back side of the microelectronic die and having the first and second contacts; and

the microelectronic device further comprises (a) a plurality of first wire-bonds electrically coupling the terminals on the microelectronic die to corresponding first contacts on the first interposer substrate, (b) a plurality of second wire-bonds electrically coupling the contacts on the second interposer substrate to corresponding second contacts on the first interposer substrate, and (c) a stand-off between the second interposer substrate and the microelectronic die.

33. The microelectronic device of claim 27 wherein:

the first side of the microelectronic die comprises a back side and the second side of the microelectronic die comprises an active side with the terminals;

the first interposer substrate further comprises a first side attached to the back side of the microelectronic die and having the first and second contacts;

the contacts on the second interposer substrate comprise a plurality of first contacts;

the second interposer substrate further comprises a first side facing toward the active side of the microelectronic die, a second side

opposite the first side and having the first contacts, and a plurality of second contacts on the first side; and

the microelectronic device further comprises (a) a plurality of interconnect elements positioned between the microelectronic die and the second interposer substrate and electrically coupling the terminals to corresponding second contacts on the second interposer substrate, and (b) a plurality of wire-bonds electrically coupling the first contacts on the second interposer substrate to corresponding first contacts on the first interposer substrate.

34. The microelectronic device of claim 27 wherein:

the first interposer substrate further comprises a first side attached to the first side of the microelectronic die, a second side opposite the first side, and a plurality of pads on the second side; and

the microelectronic device further comprises a plurality of electrical couplers on corresponding pads.

35. The microelectronic device of claim 27, further comprising a casing covering at least a portion of the microelectronic die, the first interposer substrate, and the second interposer substrate.

36. The microelectronic device of claim 27 wherein:

the second interposer substrate further comprises a first side attached to the second side of the microelectronic die and a second side opposite the first side;

the microelectronic device further comprises a casing covering at least a portion of the microelectronic die, the first interposer substrate, and the second interposer substrate; and

the casing defines an opening exposing a section of the second side of the second interposer substrate.

37. The microelectronic device of claim 27 wherein:

the first side of the microelectronic die comprises an active side with the terminals and the second side of the microelectronic die comprises a back side;

the first interposer substrate further comprises a first side attached to the active side of the microelectronic die, a second side opposite the first side and having the first and second contacts, and an opening extending between the first and second sides; and

the microelectronic device further comprises (a) a plurality of first wire-bonds electrically coupling the terminals on the microelectronic die to corresponding first contacts on the first interposer substrate, and (b) a plurality of second wire-bonds electrically coupling the contacts on the second interposer substrate to corresponding second contacts on the first interposer substrate.

38. A plurality of microelectronic devices, comprising:

a first interposer substrate having a plurality of first contact arrays and a plurality of second contact arrays;

a plurality of microelectronic dies attached to the first interposer substrate, the individual microelectronic dies including a plurality of terminals electrically coupled to corresponding first contacts and an integrated circuit electrically coupled to the terminals;

a plurality of second interposer substrates coupled to corresponding microelectronic dies such that the individual microelectronic

dies are positioned between the first interposer substrate and the associated second interposer substrate, the individual second interposer substrates having a plurality of contacts;

a plurality of wire-bonds electrically coupling the contacts on the second interposer substrates to corresponding second contacts on the first interposer substrate; and

a casing covering at least a portion of the microelectronic dies, the first interposer substrate, and the second interposer substrates.

39. The microelectronic devices of claim 38 wherein:

the individual microelectronic dies further comprise an active side with the terminals;

the first interposer substrate further comprises a first side attached to the active side of the microelectronic dies and having the second contacts, a second side opposite the first side and having the first contacts, and a plurality of openings extending between the first and second sides;

the wire-bonds comprise a plurality of first wire-bonds; and

the microelectronic devices further comprise a plurality of second wire-bonds extending through the openings and electrically coupling the terminals to corresponding first contacts on the first interposer substrate.

40. The microelectronic devices of claim 38 wherein:

the individual microelectronic dies further comprise an active side with the terminals and a back side opposite the active side;

the first interposer substrate further comprises a first side attached to the back side of the microelectronic dies and having the first and second contacts;

the wire-bonds comprise a plurality of first wire-bonds; and

the microelectronic devices further comprise a plurality of second wire-bonds electrically coupling the terminals to corresponding first contacts on the first interposer substrate.

41. The microelectronic devices of claim 38 wherein:

the individual microelectronic dies comprise an active side with the terminals and a back side opposite the active side;

the first interposer substrate further comprises a first side attached to the back side of the microelectronic dies, the first side having the first and second contacts;

the wire-bonds comprise a plurality of first wire-bonds; and

the microelectronic devices further comprise (a) a plurality of second wire-bonds electrically coupling the terminals of the microelectronic dies to corresponding first contacts on the first interposer substrate, and (b) a plurality of stand-offs between corresponding pairs of second interposer substrates and microelectronic dies.

42. The microelectronic devices of claim 38 wherein:

the first interposer substrate further comprises a first side attached to the first side of the microelectronic dies, a second side opposite the first side, and a plurality of pad arrays on the second side; and

the microelectronic devices further comprise a plurality of electrical couplers on corresponding pads.