Multi-Chip Module With Stacked Dice

Background

This invention relates generally to packaging integrated circuit dice in multi-chip modules.

In a variety of applications it is desirable to package more than one die in a single integrated circuit package. This may be the result of limits on the integratability of the components on the two dice into a single semiconductor die. These limitations may arise from the limits on the ability to integrate components into a single package. They may also arise from the fact that the components on the packages are incompatible with one another. For example, components on the two different dice may be subject to different voltage requirements. Alternatively, the two dice may require processing techniques which are incompatible.

In a number of cases, it may be desirable to package two dice into one package and to couple both dice through a common set of contacts to the outside world. Generally a die has a top side which contains contacts for making an electrical connection to the outside world and a bottom or backside. A challenge that arises is to put together a plurality of dice into a single package when each die can be only contacted on one side.

Thus, there is a continuing need for better ways to package multiple dice in a single package.

Summary

In accordance with one aspect, a method of making multi-chip modules includes wire bonding a first die to contact in a first cavity of a structure. A second die is bump bonded through a contact on the structure over the first die. A solder ball is attached to the structure so that the solder ball is electrically coupled to the first and second dice.

Other aspects are set forth in the accompanying detailed description and claims.

Brief Description of the Drawings

Fig. 1 is a process flow for one embodiment of the present invention;

Fig. 2 is an enlarged cross-sectional view through one embodiment of the present invention;

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Fig. 3 is an enlarged cross-sectional view through another embodiment of the present invention;

Fig. 4 is an enlarged cross-sectional view through still another embodiment of the present invention;

Fig. 5 is an enlarged cross-sectional view through yet another embodiment of the present invention; and

Fig. 6 is an enlarged cross-sectional view through another embodiment of the present invention.

Detailed Description

A process for attaching more than one die to a carrier for making a multi-chip module is illustrated in Fig. 1. Initially, a peripheral bond chip is attached to a multi-cavity structure, as indicated at block 100. A peripheral bond chip includes a plurality of bond pads around its peripheral edges which are available for wire bonding. A multi-cavity structure is a chip carrier which includes more than one receiving area for integrated circuit dice or chips. In some cases, the multi-cavity structure includes die-receiving cavities which are vertically spaced with respect to one another. The die may be stacked one on top of the other with spacing between the dice.

After the peripheral bond chip has been attached by wire bonding, the resulting structure is tested in strip form for device functionality (block 102). Bad units are marked for subsequent flow identification and elimination from the assembly flow. In this way, the module may be tested prior to putting two dice into the module. This saves the cost of recovering the second die where either the module or the first inserted die is bad.

After the functionality test, the next step is to attach a bumped chip over the peripheral bond chip (block 104). The bumped chip is one which has solder bumps or solder balls which may be heat softened for attachment to other electrical devices.

After attaching the bumped chip, usually in a stacked arrangement over the peripheral bond chip, the entire assembly may be overmolded and cured (block 106). Thereafter solder balls are used to attach the module to peripheral components such as a printed circuit board, as indicated in block 108.

Referring now to Fig. 2, a multi-chip module 10, made by the process illustrated in Fig. 1, includes a multi-cavity structure 12, a plurality of externally attached solder balls 14 and an overmolding 16. In this case, the structure 12 includes a set of three cavities including

a lowermost cavity 26, a vertically upwardly displaced cavity 28 and an uppermost cavity 30. Thus, the cavities 26, 28 and 30 which become progressively larger from bottom to top, define a plurality of steps in the sidewalls of the structure 12.

A peripheral bond chip 18 is attached to the lowermost cavity 16 by wire bonding peripheral wire bond pads 17 on the chip to corresponding wire bond pads 33 on the second cavity 28. At this point, the entire assembly is tested.

Next, a bumped chip 22 is secured to the uppermost cavity 30 using bump bonding by way of solder balls or bumps 24. Thereafter, the entire assembly is overmolded so that the overmolding 16 actually covers a portion of the upper surface 32 of the structure 12.

The connections between the external solder balls 14 and the die 22 and 18 may be accomplished in a variety of ways. Where the structure 12 is a laminate, conductive traces 34 may extend through the structure 12 in a generally horizontal configuration. The traces 34 may be electrically isolated by intervening insulating layers. Vertical connections may be made to overlying contact pads on the cavities 28 and 30 by way of vias 36. Contacts may then be made downwardly to bond pads 39 coupled to the solder balls 14 by way of vias 38. Of course, other techniques may be utilized as well.

Thereafter, the package 10 may be surface mounted on a suitable device such as a printed circuit board (not shown). This is accomplished by simply positioning the module 10 on the board and heat reflowing to cause the solder balls 14 to physically and electrically couple the module 10 to the underlying device.

The lower die 18 may be physically connected to the structure 12 by way of a suitable die attach. A suitable die attach includes conductive paste, an adhesive tape, or adhesive such as an epoxy.

Referring next to Fig. 3, a multi-chip module 10A includes a structure 12A. A die 18 is coupled to a cavity 42 using wire bond wires 20 as described previously in connection with the module 10 and the cavity 26. In this case, a die 22 is bump bonded to the upper surface 40 of the structure 12A. Again, bumps 24 are utilized to bump bond the die 22 to contacts in the upper surface 40 of the structure 12A. The connections from the bumps 24 and wire bonds 20 to the solder balls 14 may be made using any conventional technique, including the laminate technique illustrated in Fig. 2.

In effect, the overmolding 16 extends upwardly to accommodate the upper die 22. Overall, a lower profile may be attained. This is accomplished by eliminating in effect the

second cavity and coupling the wires 20 and the bumps 24 to the same surface 40. This is generally not a problem because the wire bonding is done first before the upper die 22 is positioned. Then, the bumps 24 are made sufficiently large to provide adequate spacing over the wire bond wires 20.

Turning next to Fig. 4, a multi-chip module 10B which receives three dice includes a structure 12A having an upper surface 40 as described previously in connection with Fig. 3. In addition, the structure 12A is electrically coupled (as described previously) to solder balls 14. In this case, a pair of dice 44 and 46 are secured to the cavity 42. The dice 44, 46 are wire bonded by way of wires 48 to contacts on the upper surface 40 and are bonded together by intervening wire bond wire 50. Thus, wire bonding may be completed while the dice 44 and 46 are exposed. The dice 44 and 46 may actually extend upwardly above the upper surface 40 of the cavity 42.

Thereafter, the die 22 is attached to the upper surface 40 as described previously. The entire assembly is overmolded again as described in connection with the embodiment of Fig. 3.

Another multi-chip module 10C which can contain multiple die, shown in Fig. 5, includes a structure 12 as previously illustrated in connection with Fig. 2. The attachment of each die 18, 68 is generally as described above in connection with Fig. 2 except that a composite die 68 may be attached to the uppermost cavity 30. The composite die 68 may be made up of a pair of dice 66, 70 attached back-to-back so that their top sides 69 extend in opposite directions. A lower die 66 may extend beyond the upper die 70. The two die 66, 70 may be connected to one another using adhesive techniques, tape techniques, or conductive paste as examples.

The lower die 66 may be secured to the uppermost cavity 30 using bump bonding by way of bumps 24. The upper die 70 is then wire bonded, using peripheral wire bond contacts and bond wires 64 to the upper surface 32 of the structure 12. As before, the entire assembly is overmolded as indicated at 16. Electrical connections may be made through the structure 12 in any of a variety of ways, including the technique illustrated in Fig. 2.

Although an offset 56 is created between the two dice 66 and 70, this is not essential. The wire bonding can proceed in the same way even if the two dice have substantially the same dimensions.

Turning finally to Fig. 6, a module 10D with three dice includes a structure 12A of the type previously described in connection with Fig. 3. Again, solder balls 14 are provided on the lower external surface of the structure 12A. As before, a die 18 is secured in the cavity 26 using peripheral wire bond wire 20.

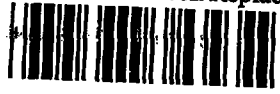
A composite die 68 is formed as described previously in connection with Fig. 5. A lower die 66 is bump bonded using bumps 24 to the upper surface 40 of the structure 12A. The upper die 68 is wire bonded, using wire bonds 64, to the upper surface 40. By extending the wire bonds 64 outwardly with respect to the bumps 24, both dice 66, 70 may be coupled to the same surface.

Separation or isolation of the signals may be possible by having vias which extend through the structure 12A to different depths. For example, as shown in Fig. 6, each of the wire bond wires 64 and bumps 24 may be coupled by a contact 72 through a via 73 to a trace 74, 76. The traces 74 and 76 may be formed at the same level within the carrier 12A but may be separated by an insulating gap. The gap may be defined during the photolithographic techniques used to form the trace layer. Vias 78 and 80 then extend downwardly to isolated traces 82 and 84. The traces 82 and 84 then contact by way of vias 86 and 88 to pads 90 which in turn are coupled to solder balls 14. While one technique has been described for coupling the signals independently to the solder balls 14, those skilled in the art will appreciate a number of other techniques for doing the same thing.

While the present invention has been described with respect to a limited number of embodiments, those skilled in the art will appreciate numerous modifications and variations therefrom. It is intended that the appended claims cover all such modifications and variations as fall within the true spirit and scope of this present invention.

What is claimed is:

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1. A method for making multi-chip modules comprising:

positioning a first die with its backside in a first cavity formed in a surface of a structure;

wire bonding the top side of a first die in said first cavity of said structure;

bump bonding a second die to said surface of said structure over said first die; and

attaching a solder ball to said structure such that said solder ball is electrically coupled to said first and second dice.

2. The method of claim 1 further including securing a first die in a lower cavity of a structure having two spaced cavities and securing said second die to an upper cavity.

3. The method of claim 1 wherein said structure includes one cavity, said method further including securing said first die in said cavity and securing said second die on top of said structure.

4. The method of claim 1 including securing a third die to said first cavity alongside said first die.

5. The method of claim 4 including wire bonding said first and third dies directly together.

6. The method of claim 4 further including securing said second die to said surface of said structure.

7. The method of claim 1 further including securing a pair of dice in back-to-back relationship to form said second die.

8. The method of claim 7 including attaching one die of said combined second die using bump bonding and attaching the other die of said combined second die using wire bonding.

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9. The method of claim 8 including attaching said first die to a first cavity below a second and third cavities, wire bonding said first die to said second cavity, wirebonding the surface of said structure to said second die and securing said second die to said third cavity.

10. The method of claim 7 including bump bonding said second die to said surface of said structure and wirebonding said second die to said surface of said structure.

11. A multi-chip module comprising:

a structure having a cavity for receiving a die;

a first die having a top side and a backside, said backside mounted in said cavity and said top side wirebonded to said structure;

a second die mounted in said structure over said first die, said second die being bump bonded to said structure; and

solder balls secured on said structure, said solder balls electrically coupled to said first and second dice.

12. The module of claim 11 wherein said structure is a multi-cavity structure including three cavities of progressively larger size as they extend upwardly through said structure.

13. The module of claim 12 wherein said first die is mounted in a first cavity and is wire bonded to said second cavity, said second die being bump bonded to said third cavity.

14. The module of claim 11 wherein said structure includes a single cavity and an upper surface.

15. The module of claim 14 wherein said first die is mounted in said cavity and is wire bonded to said upper surface, said second die being bump bonded to said upper surface at a point spaced outwardly from the location at which said first die is wire bonded to said upper surface.

16. The module of claim 15 including a third die mounted in said cavity alongside said first die, said first die being wire bonded to said upper surface and to said third die and said third die being wire bonded to said first die and said upper surface.

17. The module of claim 15 wherein said second die is formed of two dice secured in back-to-back relationship, the uppermost die of said composite second die being wire bonded to said upper surface and the lowermost die of said composite die being bump bonded to said upper surface, said first die being bonded to said upper surface, said lowermost die being bump bonded to said upper surface at a point spaced from the point where said first die is bonded to said upper surface.

18. The module of claim 11 wherein said second die is a composite die having contacts on two outwardly facing sides of said composite die, one of said outwardly facing sides being wire bonded to said structure and the other of said outwardly facing sides being bump bonded to said structure.

19. The module of claim 18 wherein said structure includes at least two cavities, said composite die having one side bump bonded to the uppermost of said cavities and the other side being wire bonded to said structure.

20. The module of 19 including a first cavity mounting said first die and a second cavity, said first die being wire bonded to said second cavity, said structure including an upper surface and a third cavity, said second die bump bonded to a third cavity and wire bonded to the upper surface of said structure.

21. A multi-chip module comprising:

a carrier having a first side and a second side and a cavity formed in said first side;

first and second chips mounted on said first side of said carrier with said second chip over said first chip, said first chip secured to said carrier in said cavity;

said first and second chips being electrically coupled to said first side, said second chip being bump bonded to said first side and said first chip being wire bonded to said first side.

22. The module of claim 21 wherein said second chip is electrically coupled to said first side outwardly with respect to the location where said first chip is coupled to the said first side.

23. The module of claim 22 including a third chip contained in said cavity with said first chip.

24. The module of claim 21 wherein said second chip is made up of a pair of dice coupled together in back to back relationship.

25. The module of claim 24 wherein one of said dice is bump bonded to said first side and the other of said dice is wire bonded to said first side.

26. A method of coupling a pair of chips to a carrier comprising:

positioning a first chip in a cavity on a first side of said carrier;

wire bonding said first chip to said first side of said carrier;

bump bonding a second chip to said first side outwardly with respect to said first chip.

27. The method of claim 26 including mounting said second chip over said first chip on said first side.

28. The method of claim 26 including mounting a third chip in said cavity with said first chip.

29. The method of claim 26 including forming said second chip by securing a pair of dice in back to back relationship.

30. The method of claim 29 including wire bonding one of said dice to said first side and bump bonding the other of said dice to said first side.

31. A multi-chip module comprising:

a carrier including a cavity;

a first chip secured to said carrier in said cavity; and

a second chip including a pair of dice secured to one another in back to back relationship, said second chip secured to said carrier over said first chip.

32. The module of claim 31 wherein said second chip is secured to a second cavity defined in said module.

33. The module of claim 31 wherein said second chip is secured on an upper surface of said carrier.

34. The module of claim 31 wherein one of said dice is wire bonded to said carrier and the other of said dice is bump bonded to said carrier.

35. The module of claim 34 wherein said dice are bonded to different surfaces of said carrier.

36. A method of forming a multi-chip module comprising:

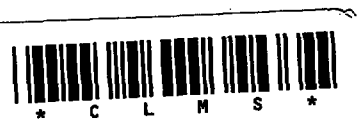
securing a first chip in a cavity in a carrier;

forming a second chip by securing a pair of dice together in back to back relationship; and

securing said second chip to said carrier over said first chip.

37. The method of claim 36 including securing said second chip to a second cavity in said carrier over said first chip.

38. The method of claim 37 including bump bonding one of said dice to said second cavity over said first cavity.



39. The method of claim 36 including wire bonding said first chip to said carrier at a first location, bump bonding one of said dice to said carrier at a second location and wire bonding the other of said dice to said carrier at a third location, said first location being inwardly on said carrier with respect to said second location and said second location being inwardly on said carrier with respect to said third location.

40. The method of claim 39 including bonding said dice and said first chip to the same surface of said carrier.