

WIRE BONDING METHOD

This invention relates to a wire bonding method

As the integration of semiconductor integrated
5 circuits becomes higher, the number of their external leads
and pins also becomes greater, but the number of the
electrode pads (wire bonding regions) and electrically
conductive leads disposed around the chip, on which the
semiconductor devices are formed, is restricted by the size
10 and shape of the chip or those of the package. Consequently,
there is a certain limit to the increase of the number of
pins. Attempts have been made to increase the number of
pins by forming electrode pads with a parallelogramic planar
shape so as to reduce the pitch between adjacent pads but
15 such attempts are inevitably restricted by the working
properties and reliability of the wire bonding when the
wire is bonded to the pads. The number of pins is at most
about 208 pins at the present for a chip size of $12 \times 12 \text{ mm}^2$.
In accordance with another proposal, the electrode pads and
20 leads to be formed on the chip are arranged in a zigzag so
as to substantially decrease the pad pitch but if the pad
pitch is reduced, the adjacent wires come closer to each
other and eventually come into contact, resulting in short-
circuits. In particular, because the shape of the loop of
25 the bonding wire formed between the electrode pad (a first
bonding region) and the lead (a second bonding region) in
the wire bonding apparatus is primarily determined by the

control of the vertical movement of the wire connecting tool of the wire bonding apparatus, that is, by the Z axis control, and by the wire hardness, the wire bonding apparatus is less able to change the shape of the loop and
5 the stability of the loop shape itself is low. This results in the short-circuiting problem described above.

The present invention provides a method of connecting wires between a semiconductor element and a plurality of conductive leads spaced from but adjacent at least one
10 side of the element, a surface of the element having at least two lines of electrode pads on that surface adjacent the said at least one side, a first line being closer to the said at least one side than a second line; wherein a wire is bonded to each electrode pad and to a corresponding
15 conductive lead such that a wire loop is formed between each electrode pad and the corresponding conductive lead, the wire loops of the second line of electrode pads extending higher, in a direction perpendicular to the said surface of the element, than the loops of the first line.

20 The present invention will be described in connection with the embodiments thereof with reference to the accompanying drawings, wherein:

Figure 1 is a schematic front view of the wire bonding apparatus for carrying out a method in accordance
25 with one embodiment of the present invention;

Figure 2 is a perspective view showing the principal parts of the wire bonding apparatus shown in Figure 1;

Figures 3A to 3D are front views, each showing a wire

bonding step when using the wire bonding apparatus shown in Figure 1;

Figure 4 is a perspective view showing a semiconductor device to which wire-bonding is effected by the use of the present wire bonding apparatus;

Figure 5 is a sectional view taken along line V-V of Figure 4;

Figure 6 is a front view showing the wire bonding apparatus for carrying out a method in accordance with a modified embodiment of the present invention; and

Figure 7 is an enlarged perspective view showing the principal parts of the wire bonding apparatus shown in Figure 6.

The present invention will now be described with reference to embodiments thereof shown in the accompanying drawings.

Figures 1 and 2 show the overall construction of a wire bonding apparatus in which reference numeral 1 represents a bonding head which is mounted on an XY table 2 and can move in the horizontal X-Y directions. An ultrasonic oscillator 3, which is electrically connected to an ultrasonic oscillation source not shown, is disposed in front of this bonding head 1, and a transducer 4 acting as the oscillation body projects forward from the front part of the oscillator 3. A wedge 5 acting as a bonding tool is fitted to the tip of the transducer 4 so as to project downward. A clamp 6 is supported by a support

18

4

block 7 above the transducer 4 in such a manner that its jaws are positioned immediately behind the wedge 5. The transducer 4 and the clamp 6 can

be actuated by a cam mechanism 8 disposed in front of the bonding head 1 so that the transducer 4 moves its tip up and down while the clamp 6 opens and closes its jaws.

A support arm 9 extends forward from the upper part of the bonding head 1 and supports a wire coil 10 and an industrial television camera 11 fitted thereto. The wire coil 10 consists of an aluminum wire as the bonding wire 12 which is wound on a bobbin or the like. The end of the wire 12 is pulled out from the lower part of the coil, is hooked around a wire guide 13 fitted to the support block 7 and is passed through a hole 4a in the transducer 4, then between the jaws of the clamp 6 and further through a hole (not shown) defined at the tip of the wedge 5. The industrial television camera views the scene in the proximity of the wedge 5 and shows the electrode pads of a chip 23 and inner leads of a workpiece 14 to which wires are to be bonded, on a monitor (not shown).

A bonding stage 15 is disposed in front of the bonding head 1 and a feeder unit 17 is disposed on the bonding stage 15. The feeder unit 17 is able to sequentially convey a carrier jig 16, which supports a plurality of workpieces 14 thereon, arranged in a line in the direction perpendicular to the plane of Fig. 1. Reference numeral 18 represents a feed pawl of the sequential conveyor mechanism. A compact XYZ table 19 is disposed above and in front of the bonding stage 15 and a wire guide unit 20 having an end bent substantially into an L-shape, as shown in Figure 2,

is fitted to the top of the XYZ table 19. This end of the wire guide unit 20 is normally positioned immediately behind the wedge 5 and the clamp 6 and an upwardly recessed hook 21 is formed at the end. The XY table 2, the cam mechanism 8, the compact XYZ table 19, etc., are controlled by a computer in a control unit (not shown).

Next, the wire bonding method using the wire bonding apparatus of the construction described above will be described with reference to Figures 3A to 3D. In the drawings, reference numeral 22 represents an outer lead formed on the surface of the base 100 of a package, 26 is an inner lead and 23 is a chip fixed to the base 100 of the package. They form the workpiece 14 described above. In particular, in this embodiment the electrode pads 24, 25 formed on the chip 23 are arranged in two lines.

Referring initially to Figure 3A, the wedge 5 is first moved over a first bonding region on an electrode pad 24 in the outermost line, and is then pressed into contact with the electrode pad 24 as shown in Figure 3B so as to bond the wire 12 ultrasonically. Meanwhile, the wire guide unit 20 is kept back behind the wedge 5. Next, the wedge 5 is moved some distance upward and is then moved towards the inner lead 26, that is, to the right in the drawing. When it reaches the position of a second bonding region over the inner lead 26, the wedge 5 is moved down so as to connect the other end of the wire to the inner lead 26. At this time, the hook 21 of the wire guide unit 20 is moved some

(21)

distance to the left so that it is positioned between the electrode pad 24 and the inner lead 26, and an intermediate part of the wire 12 being connected between the electrode pad 24 and the inner lead 26 is hooked as shown by the broken lines in Figures 3C and 3D. Accordingly, the shape of the loop in the wire 12 is determined by the position of the hook 21 at this time, and any variation of the loop resulting from differences of wire hardness or winding properties can be eliminated.

5
10 In this case, the height and transverse position of the hook 21 are naturally controlled by the XYZ table 19. After the wire bonding to the inner lead 26 is completed, the wire 12 is cut by the clamping action of the clamp 6 and by the upward movement of the wedge 5 as shown in Figure 3D, thus completing the wire bonding operation.

15 In this embodiment, the steps shown in Figures 3A and 3B are carried out once again, this time to connect the wire to the inner electrode pad 25, and thereafter the other end of this wire 12A is connected to the outer position of the inner lead 26, as shown by the broken lines in Figure 3D. In this case, the hook 21 of the wire guide unit 20 is held at a position higher than the previous position so as to hook an intermediate part of the wire 12A. Hence, the wire 12A is shaped in a loop over the previous wire 12 so as to bridge it.

25 As shown in Figure 4 and Figure 5 (which is a sectional view taken along the line V-V of Figure 4), in the

chip thus wire-bonded, the inner and outer electrode pads 24,25 and the inner lead 26 can be connected to one another by wires 12,12A that do not cross one another in substantially the same vertical plane. In this instance, the loop of each wire 12,12A is formed by hooking an intermediate part of the wire by the hook 21 of the wire holding unit 20 and hence, can be stabilized without coming into contact with the other loops. As a result, it is no longer necessary to reduce the size of the electrode pad and thus reduce the pad pitch, and a higher density of wire bonding as well as an increase in the number of pins and an improvement in the reliability of the semiconductor device can be accomplished. Incidentally, reference numeral 101 in Figure 5 represents the package cap.

15 The XYZ table 19 supporting the wire holding unit 20 operates in an interconnected sequence with the XY table 2 and with the cam mechanism 8 and controls the wire holding unit 20 and in particular, the height and transverse position of the hook 21. It is preferred in this case that data on the positions to be moved to and the timing are input in advance in accordance with the specifications of the article being bonded, and control is effected on the basis of the data thus stored.

25 Figures 6 and 7 show another arrangement in which the wire guide unit in particular is modified. An XYZ moving mechanism 27 such as an XYZ table or the like is disposed in front of the bonding head 1 at

the position at which the transducer 4 slants downward, and the wire holding unit 28 projects forward from the front end of this XYZ moving mechanism 27. A rocking link 30 is turnably supported by a pivot 31 on the upper part of a main arm 29 of the wire guide unit 28 and can be made to rock by an electromagnetic solenoid 32. A clamping unit 35 comprises a movable clamp arm 34 disposed in such a manner as to co-operate with a fixed clamp arm 33 which is disposed substantially in an L-shape at the end of the main arm 29.

10 The movable clamp arm 34 is connected to the other end of the rocking link 30 so that it is actuated by the rocking of the rocking link 30 to clamp part of the wire between it and the fixed clamp arm 33.

According to the construction described above, after the wire is bonded by the wedge 5 in co-operation with the clamp 6 as shown in Figures 3A and 3B, the wire guide unit 28 causes the clamping unit 35 to project to an intermediate position of the wire 12B by the operation of the XYZ moving mechanism 27 so that the intermediate part of the wire 12B is clamped and fixed by the fixed and movable clamp arms 33 and 34. The wedge 5 then connects the other end of the wire to the inner lead, forming the wire loop. In this instance, the desired loop can be formed by restricting an intermediate part of the wire by the operation of the wire guide unit 28, in the same way as in the foregoing embodiment.

In this arrangement since the wire guide unit 28

partly clamps an intermediate part of the wire 12B, the wire tension is prevented from acting upon the electrode pad of the chip at the first bonding region when connecting the wire to the inner lead at the second bonding region so that breakages of the pad, etc., can be prevented. Since the wire guide unit 28 has an L shape, it does not interfere with the wedge 5, etc.

In this arrangement, too, the shape of the wire loop can be controlled as required. In other words, wire bonding of wire loops such as is shown in Figures 4 and 5 can be made and this is extremely effective for increasing the number of pins and the density of the semiconductor device.

Although the foregoing embodiments use an ultrasonic bonding by way of example, the present invention can of course be applied to a wire bonding method using thermo compression bonding using a capillary as the bonding tool.

As described in the foregoing, a wire guide unit capable of operating independently of the bonding tool is disposed in the proximity of the bonding tool, and wire bonding can be carried out while a loop of the bonding wire is being formed by temporarily hooking the wire on the wire guide unit. According to this construction, the desired shape of the loop of the bonding wire can be obtained easily, and the ease of changing the shape of the wire loop as well as its stability can be enhanced. As a result, the

apparatus described provides the advantage that a high integration of semiconductor devices can be made possible.

In the apparatus described, the fact that the wire guide unit can move independently of the bonding tool in the vertical direction and in both horizontal directions greatly increases the flexibility, enabling the apparatus to adapt to the relative positions of electrode pads and leads of a wide variety of semiconductor devices without fouling wires already bonded. However, it would be possible to use a wire guide unit which was movable independently of the bonding tool in the vertical direction Z (Figures 2 and 7) and which moved either with or independently of the bonding tool in the transverse horizontal direction, marked Y in Figures 2 and 7. In the longitudinal horizontal direction, marked X in Figures 2 and 7, such a wire guide unit could be fixed relative to the position of the workpiece 14, or more preferably, movable independently of the bonding tool. Furthermore, if it were desired to form loops other than in generally vertical planes as seen in Fig. 5, in order to avoid short-circuits, the wire guide unit could be constrained so as to be movable in some other direction other than vertical (though obviously full XYZ freedom of movement would be preferable).

This application has been divided out of U.K. Patent Application No. 8303459 (published under No. 2116101) and discloses matter also disclosed in that application.

Attention is therefore drawn to Application No. 8303459.



26

CLAIMS:

1. A method of connecting wires between a semiconductor element and a plurality of conductive leads spaced from but adjacent at least one side of the element, a surface
5 of the element having at least two lines of electrode pads on that surface adjacent the said at least one side, a first line being closer to the said at least one side than a second line; wherein a wire is bonded to each electrode pad and to a corresponding conductive lead such that a wire
10 loop is formed between each electrode pad and the corresponding conductive lead, the wire loops of the second line of electrode pads extending higher, in a direction perpendicular to the said surface of the element, than the loops of the first line.
2. A method according to claim 1, wherein an inter-
15 mediate point of each wire is supported by a hook of a wire holding unit above the surface of the element during bonding of the wire to the electrode pad and to the corresponding conductive lead, the wires bonded to the pads of the second line being supported at a greater
20 height than the wires bonded to the pads of the first line.
3. A method according to claim 1 or claim 2, wherein the bonding is ultrasonic bonding.
4. A method according to claim 1 or claim 2, wherein the bonding is thermo-compression bonding.
- 25 5. A method according to any one of the preceding claims, wherein there are two lines of electrode pads adjacent each side of the element on the said surface, and conductive leads adjacent each side of the element, the

21



13

said wire loops being formed between each pad and a corresponding conductive lead.
