

PATENT SPECIFICATION

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(54) IMPROVEMENTS IN OR RELATING TO BONDING A SMALL OBJECT TO A SUBSTRATE

(71) We, HITACHI LTD., of 1-5-1 Marunouchi, Chiyoda-ku, Tokyo, Japan, a Japanese Company, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The present invention relates to a method and apparatus for use in bonding a small object to a substrate, and more particularly relates to bonding a semiconductor pellet onto a substrate. Usually such pellets are square.

Among known apparatus for bonding a semiconductor pellet to a substrate, there is one which carries out the bonding by picking up and holding the pellet by suction on the pyramidal oblique planes of a recess formed by a four-sided pyramid at the lower end of suction holding means, termed a collet. The lower surface of the pellet is then brought into contact with a tab, a lead frame or other substrate, and a solder material between the pellet and the substrate is melted. With such equipment, unless the pellet is picked up when the collet has completely stopped its movement, the position of the pellet when held by the collet can vary if the pellet is inclined within the recess. This reduces the precision of the subsequent pellet bonding. Accordingly, additional time, such as time for the collet to become stationary, is required, so that the pellet bonding time is lengthened.

Apparatus has been devised which employs a collet having flat holding planes so as to prevent the pellet from being held askant. This apparatus can pick up and hold the pellet without inclining it even when the positional precision of the pellet on a jig from which it is picked up is poor and even when the collet has not stopped completely when it picks the pellet up, and can reduce the pellet bonding time. With this apparatus, however, due to inferior precision of the holding position of the pellet and to sliding between the collet and

the pellet during scrubbing (i.e. moving the collet back and forth when the pellet is supported on the substrate to center the pellet in the collet), the precision of bonding of the pellet is low and the shift of the pellet relative to a desired predetermined point of the substrate may be comparatively large and may amount to, for example, approximately ± 40 to $\pm 60\mu$.

For this reason, when subsequently a semi-automatic or automatic bonder is used in wire bonding, potentially at high wire bonding speed, it is necessary for every component to align the relative positions of a bonding electrode on the pellet and a wire-holding capillary of the wire bonder. Such an aligning operation for every component is expensive in labour costs. On the other hand, if for example, the possible shift of the pellet can be confined to within $\pm 30\mu$ while the size of the bonding electrode on the pellet is $50\mu \times 50\mu$, reliable wire bonding is possible without the foregoing aligning operation for every component, or the manual aligning operation may be simplified or omitted.

There has also been developed a method of bonding a semiconductor pellet to a substrate in which the pellet bonding step and the step of correcting the bonding position are performed separately. An apparatus for performing this known method is illustrated in Figures 1(a) and (b) of the accompanying drawings, which show part of a semiconductor pellet bonding equipment provided with a mechanism for correcting the position of a pellet, Figure 1(a) being a plan view while Figure 1(b) is a partial sectional view taken along the line 1b—1b of Figure 1(a). In Figure 1(a) and also in Figure 2(a) described below, the collets are for convenience shown out of their true position in plan view and turned through 90° so that they are seen in side view.

At the first station 2 on a heater block 1 (see Figure 1(b)) which is heated, a silicon pellet 4 is scrubbed on a substrate 5, e.g. a lead frame, by means of a collet 3, and gold

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foil 6 previously placed on the substrate 5 becomes molten in the formation of a eutectic alloy of gold and silicon from the foil 6 and pellet 4. A pin (not shown) is inserted into one of guide holes 7 in the substrate 5 and performs a rectangular motion (being lifted vertically into the holes 7 and the moved horizontally) so that the pellet 4 bonded on the substrate is transferred to the right as viewed in Figure 1(a). When the pellet 4 stops at a second station 8 adjacent the first station 2, a pair of position correcting arms 9 and 10, which are arranged on the desired diagonal line of the pellet 4 and which are generally symmetrical with respect to the pellet 4, advance towards the pellet 4, and correct the position of the pellet 4 to the predetermined desired position on the substrate 5 by means of 90° notches 11 and 12 provided at their respective ends. Since the second station 8 for carrying out the correcting operation is also situated on the heater block 1 which is heated to approximately 400°C, the eutectic alloy between the pellet 4 and the substrate 5 is in a molten or softened condition and the position correction of the pellet can be made very easily.

With this equipment, although the position can be corrected comparatively accurately (the positional precision is $\pm 30\mu$ or so) during the initial period of use, it becomes impossible continuously to attain high positional precision because for example gold, silicon, silicon oxide etc. adhere gradually to the surfaces of the notches 11 and 12 and also the position correcting arms 9 and 10 become warped by the heat as illustrated in Figure 1(b). It has been shown that, for example, the precision of the position of fixing of the pellet in the X- and Y-directions relative to the substrate may become ± 40 to 60μ .

Since this equipment operates so as to hold the end faces of the pellet 4 at both sides thereof, a further problem which may appear is failure of the pellet.

On the other hand, it has been experimentally found that when the aforementioned collet having the pyramidal hollow is used with a scrubbing time of approximately 4 seconds, it can give a good pellet bonding precision. This is believed to be so because the pellet held by suction shifts into a stable state within the pyramid, turning as a result of the scrubbing action, and most of the pellets fall into the stable state in 4 seconds or so.

It has also be found that the pellet is stabilized in a shorter time in the scrub by making the vertical angle of the pyramid sharper i.e. making the oblique planes steeper. Such a measure, however, has been found in practice to be unsuitable for

picking up the pellet by suction because, when picking up a pellet from the jig by means of a collet with sharply inclined planes, the range in which the pellet is reliably picked up becomes narrow and on the other hand the positional precision of the pellet on the jig cannot be expected to be high.

According to the present invention, there is provided apparatus for use in bonding a small object having two pairs of opposite straight sides to a substrate, including a first work station having a first collet having a recess to which suction can be applied in order to hold the object, the first collet being movable to pick up the object and place it on the substrate, and a second work station having a second collet having a recess for engaging the object to adjust its position on the substrate if necessary before the bonding becomes firm, each said recess having two pairs of opposed inwardly converging planar walls, the rate of convergence inwardly being less in the second collet than in the first collet, the apparatus further including means for causing relative movement between the substrate and the collets to bring an object placed by the first collet to the second work station.

According to the invention in another aspect there is provided a method of bonding a small object having two pairs of opposite straight sides to a substrate, comprising the steps of placing the object on the substrate by means of a first collet having a recess in which the object is held by suction and thereafter, following removal of the first collet, applying to the object a second collet also having a recess which receives the object and scrubbing the object on the substrate in order to correct its positioning by means of the second collet, the recess of each collet having pairs of opposed inwardly converging planar walls corresponding to said sides of the object, the rate of convergence inwardly of the walls being less in the second collet than in the first collet, firm bonding being achieved after said scrubbing.

An embodiment of the present invention will now be described by way of example with reference to Figures 2(a) and (b) of the accompanying drawings, in which Figure 2(a) is a plan view thereof and (b) is a sectional view showing the placing and correction steps.

A substrate 21, e.g. a lead frame, is placed on a heater block 20 which is heated. The substrate 21 is provided with guide holes 22 along its side edge at fixed intervals, and the lower end of a pin (not shown) which reciprocates right and left is inserted into these guide holes 22, so as

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intermittently to transfer the substrate 21 to the right as viewed in the Figures.

5 A first collet 24 is disposed at a first station 23 on the heater block 20 and is adapted to move between the heater block 20 and a jig 26 juxtaposed to the heater block 20 and having silicon pellets 25 arranged thereon. A second station 27 is provided towards the right hand side of the heater block 20 and a second correction collet 28 for correcting the bonding position is arranged at the second station 27. Both collets in this embodiment have bores for applying vacuum to recesses at their lower ends, but the second collet 28 need not have provision for suction.

10 Both collets 24 and 28 have their recesses shaped so that the peripheral edges of the pellet are held by the oblique planar faces of a four-sided pyramid (see Figure 2(b)), the shape as illustrated actually being frusto-pyramidal by reason of the bores in the collets. Alternatively, it may be pyramidal. The vertical included angle of opposite sides of the pyramid of the first collet 24 is 120 degrees, while the same angle of the second collet 28 is sharper being 90 degrees. Thus the opposite sides of the recess of the first collet converge upwardly more quickly than those of the second collet.

15 A bonding operation will now be described. As illustrated in Figure 2(a), the first collet 24 at the first station 23 advances in the direction of an arrow 29 across the substrate 21 and picks up by suction a pellet 25 from the jig 26, whereupon it retreats and stops just above the substrate 21. Thereafter, it descends little by little, and as illustrated in Figure 2(b), it presses the lower surface of the pellet 25 lightly onto a gold foil 30 which has been previously fixed to the substrate 21. Subsequently as illustrated in Figure 2(a), the collet 24 is repeatedly swung (scrubbed) back and forth in the directions of arrows 31 and 32, vacuum no longer being applied. Since, in this case, the substrate 21 is placed on the heater block 20 heated to approximately 400°C, a gold-silicon eutectic alloy layer (junction layer) 33 is formed from the gold foil 30 at the lower surface of the pellet 25, and the pellet 25 is thus fixed to the substrate 21 but the bonding is provisional and not yet firm.

20 Subsequently, after the collet 24 is raised, owing to the movement of a pin in the hole 22, the substrate 21 is shifted to the right by one step, and the pellet 25 is transported to the second station 27. Then, the second collet 28 corrects the position of fixing by scrubbing the pellet 25 again in the directions of arrows 34 and 35.

25 Since, for this position-correcting scrub operation, the correcting collet 28 is so

constructed that each oblique plane of the quadrangular pyramid for holding the pellet 25 is relatively sharply inclined (oblique plane at 45°, vertical included angle of 90°) the speed at which the pellet is moved to the central part of the correcting collet 28 with the swing thereof is high, and the positional precision of the pellet can be confined to within $\pm 30\mu$.

30 In this embodiment, the substrate 21 is transferred one step every 2 seconds, and the provisional bonding and the position-correction are successively carried out at the two consecutive stations, so that the bonding speed can be high.

35 The collets are constructed so that even when the pyramidal part of the pellet guiding portion spreads due to heat from the heater block, the pellet moves towards the centre of the pyramidal portion, and hence there is no lowering in precision of the bonding due to the heat.

40 Since in this apparatus the pellet is lightly pressed from above to effect the bonding, the pellet is not damaged as it may be in the V-notch system described above with reference to Figure 1.

45 Furthermore, in this embodiment, the variation in position of the bonded pellet can be kept within $\pm 30\mu$, and hence, when employing a sequence bonder in subsequent wire bonding, once the wire-holding capillary is set by the first program operation so as to move accurately between the electrode of the pellet surface and the bonding part of the substrate, the bonding can thereafter be performed continuously without any check.

WHAT WE CLAIM IS:—

1. Apparatus for use in bonding a small object having two pairs of opposite straight sides to a substrate, including a first work station having a first collet having a recess to which suction can be applied in order to hold the object, the first collet being movable to pick up the object and place it on the substrate, and a second work station having a second collet having a recess for engaging the object to adjust its position on the substrate if necessary before the bonding becomes firm, each said recess having two pairs of opposed inwardly converging planar walls, the rate of convergence inwardly being less in the second collet than in the first collet, the apparatus further including means for causing relative movement between the substrate and the collets to bring an object placed by the first collet to the second work station.

2. Apparatus according to Claim 1 wherein each said recess is pyramidal or frusto-pyramidal.

3. Apparatus according to Claim 1 or



(10)

intermittently to transfer the substrate 21 to the right as viewed in the Figures.

5 A first collet 24 is disposed at a first station 23 on the heater block 20 and is adapted to move between the heater block 20 and a jig 26 juxtaposed to the heater block 20 and having silicon pellets 25 arranged thereon. A second station 27 is provided towards the right hand side of the heater block 20 and a second correction
10 collet 28 for correcting the bonding position is arranged at the second station 27. Both collets in this embodiment have bores for applying vacuum to recesses at their lower ends, but the second collet 28 need not have provision for suction.

Both collets 24 and 28 have their recesses shaped so that the peripheral edges of the pellet are held by the oblique planar faces of a four-sided pyramid (see Figure 2(b)), the shape as illustrated actually being frusto-pyramidal by reason of the bores in the collets. Alternatively, it may be pyramidal. The vertical included angle of
20 opposite sides of the pyramid of the first collet 24 is 120 degrees, while the same angle of the second collet 28 is sharper being 90 degrees. Thus the opposite sides of the recess of the first collet converge
25 upwardly more quickly than those of the second collet.

A bonding operation will now be described. As illustrated in Figure 2(a), the first collet 24 at the first station 23 advances
35 in the direction of an arrow 29 across the substrate 21 and picks up by suction a pellet 25 from the jig 26, whereupon it retreats and stops just above the substrate 21. Thereafter, it descends little by little, and as illustrated in Figure 2(b), it presses the
40 lower surface of the pellet 25 lightly onto a gold foil 30 which has been previously fixed to the substrate 21. Subsequently as illustrated in Figure 2(a), the collet 24 is repeatedly swung (scrubbed) back and forth in the directions of arrows 31 and 32,
45 vacuum no longer being applied. Since, in this case, the substrate 21 is placed on the heater block 20 heated to approximately 400°C, a gold-silicon eutectic alloy layer (junction layer) 33 is formed from the gold foil 30 at the lower surface of the pellet 25,
50 and the pellet 25 is thus fixed to the substrate 21 but the bonding is provisional and not yet firm.

Subsequently, after the collet 24 is raised, owing to the movement of a pin in the hole 22, the substrate 21 is shifted to the right by one step, and the pellet 25 is transported to the second station 27. Then, the second
60 collet 28 corrects the position of fixing by scrubbing the pellet 25 again in the directions of arrows 34 and 35.

Since, for this position-correcting scrub operation, the correcting collet 28 is so

constructed that each oblique plane of the quadrangular pyramid for holding the pellet 25 is relatively sharply inclined (oblique plane at 45°, vertical included angle of 90°) the speed at which the pellet is moved to the central part of the correcting collet 28 with the swing thereof is high, and the positional precision of the pellet can be confined to within $\pm 30\mu$.

In this embodiment, the substrate 21 is transferred one step every 2 seconds, and the provisional bonding and the position-correction are successively carried out at the two consecutive stations, so that the bonding speed can be high.

The collets are constructed so that even when the pyramidal part of the pellet guiding portion spreads due to heat from the heater block, the pellet moves towards the centre of the pyramidal portion, and hence there is no lowering in precision of the bonding due to the heat.

Since in this apparatus the pellet is lightly pressed from above to effect the bonding, the pellet is not damaged as it may be in the V-notch system described above with reference to Figure 1.

Furthermore, in this embodiment, the variation in position of the bonded pellet can be kept within $\pm 30\mu$, and hence, when employing a sequence bonder in subsequent wire bonding, once the wire-holding capillary is set by the first program operation so as to move accurately between the electrode of the pellet surface and the bonding part of the substrate, the bonding can thereafter be performed continuously without any check.

WHAT WE CLAIM IS:—

1. Apparatus for use in bonding a small object having two pairs of opposite straight sides to a substrate, including a first work station having a first collet having a recess to which suction can be applied in order to hold the object, the first collet being movable to pick up the object and place it on the substrate, and a second work station having a second collet having a recess for engaging the object to adjust its position on the substrate if necessary before the bonding becomes firm, each said recess having two pairs of opposed inwardly converging planar walls, the rate of convergence inwardly being less in the second collet than in the first collet, the apparatus further including means for causing relative movement between the substrate and the collets to bring an object placed by the first collet to the second work station.

2. Apparatus according to Claim 1 wherein each said recess is pyramidal or frusto-pyramidal.

3. Apparatus according to Claim 1 or

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- Claim 2 which includes means for heating the substrate to achieve bonding of the object to the substrate.
4. Apparatus according to any one of the preceding claims wherein the angle of inward convergence of said pairs of walls of the first collet is 120° and of the second collet is 90°.
5. Apparatus for bonding a small object to a substrate substantially as herein described with reference to and as illustrated in Figures 2(a) and 2(b) of the accompanying drawing.
6. A method of bonding a small object having two pairs of opposite straight sides to a substrate, comprising the steps of placing the object on the substrate by means of a first collet having a recess in which the object is held by suction and thereafter, following removal of the first collet, applying to the object a second collet also having a recess which receives the object and scrubbing the object on the substrate in order to correct its positioning by means of the second collet, the recess of each collet having pairs of opposed inwardly converging planar walls corresponding to said sides of the object, the rate of convergence inwardly of the walls being less in the second collet than in the first collet, firm bonding being achieved after said scrubbing.
7. A method according to Claim 6 wherein the object is scrubbed by the first collet for initial positioning.
8. A method according to Claim 6 or Claim 7 wherein the object is a semiconductor pellet.
9. A method according to Claim 8 wherein gold is used to alloy with the semiconductor material to bond it to the substrate, the alloy being formed when the pellet is applied to the substrate.
10. A method according to Claim 6 substantially as herein described with reference to Figures 2(a) and 2(b) of the accompanying drawings.
11. A substrate having a small object bonded thereto by a method as claimed in any one of Claims 6 to 10 or by means of an apparatus as claimed in any one of Claims 1 to 5.

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