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APPARATUS FOR BONDING A BEAM-LEAD DEVICE TO A SUBSTRATE

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2 Sheets-Sheet 2

FIG. 2

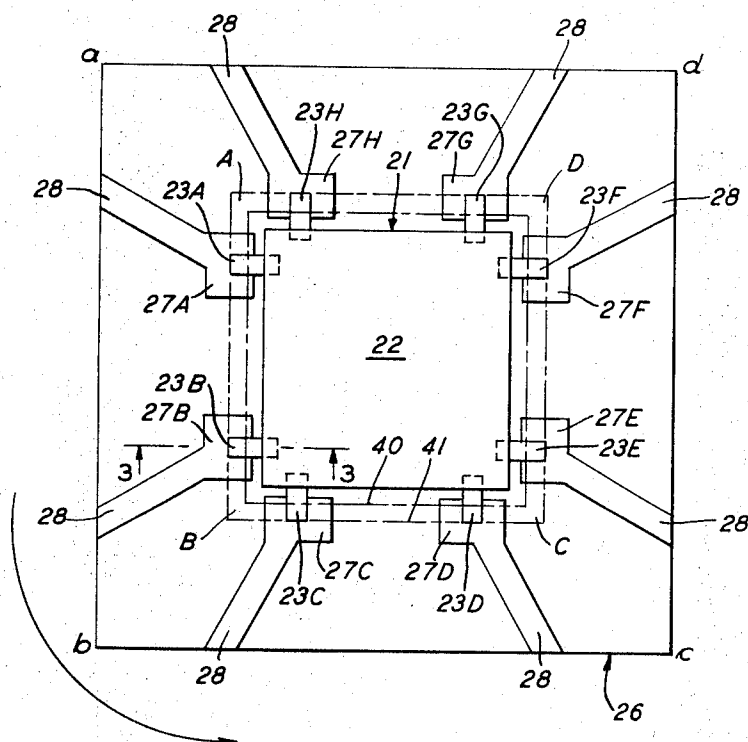
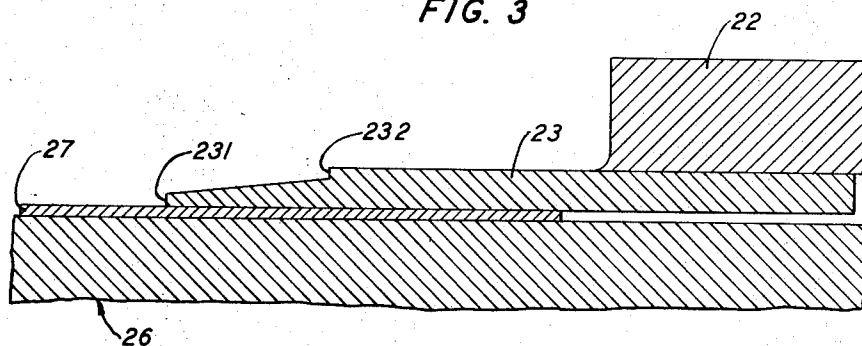


FIG. 3



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APPARATUS FOR BONDING A BEAM-LEAD DEVICE TO A SUBSTRATE

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8 Claims

ABSTRACT OF THE DISCLOSURE

A process and an apparatus are disclosed for the thermocompression bonding of beam-lead integrated circuits to a series of conductor patterns located on a substrate.

The flat tip of a hollow rectangular rod comprises the heating unit. The beam-lead device is positioned on a substrate; and, illustratively the substrate is mounted on a carrier; and, illustratively the carrier is located on a wobble table. When appropriate means undulate the wobble table, the beam leads are rocked into successive contact with the heating unit and thereby are bonded to the substrate.

BACKGROUND OF THE INVENTION

From the beginnings of semiconductor technology, connecting a semiconductor element to the rest of the circuit has been a difficult task. The technique that evolved comprised several steps. On the surface of a semiconductor, several contact areas were formed. The semiconductor was then mounted on a platform through the base of which several insulated leads had been passed. Skilled technicians then connected the leads to the appropriate contact area by bonding, one at a time, a fine wire to each lead and to its related contact area. Since each bond was formed separately, the operation was quite expensive, requiring costly machinery and a highly skilled operator.

To reduce the cost of connecting the semiconductor to the rest of the circuit and to improve the connection itself, the beam-lead method was developed. In brief, this technique forms on the semiconductor the necessary connectors, called beam leads, as the final stage of the semiconductor fabrication process. The connectors are then bonded to the rest of the circuit. With the increasing commercial importance of integrated circuit devices that perform the function of many semiconductor elements in the volume once occupied by one, the beam-lead method is especially advantageous because it provides a good contact between the beam lead and the integrated circuit device and makes more efficient use of the area available on the surface of the device.

Nevertheless, problems still remain in connecting the beam leads to the rest of the circuit. Typically, the circuit pattern, a portion of which is designed for connection to the beam leads, is formed in a two-dimensional array on the surface of an insulating material. The beam-lead integrated circuit device is appropriately positioned on top of the pattern, and a bonding tool is then applied simultaneously to the beam leads. This technique, however, is subject to two problems. First, the connection areas of the circuit pattern frequently do not lie in a plane that is parallel to the bonding surface of the bonding tool. Moreover, the beam leads may not lie in a plane that is parallel to both the connection areas and the bonding surface. Hence it may be difficult for the bonding tool to make uniform contact to the beam leads. Secondly, if uniform simultaneous contact is made, severe stresses may be created in the beam leads and in the connections between the beam leads and the integrated circuit device. More specifically, the pressure of the bonding tool tends to push some of the material in the leads out of the region of

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the bond. Because the beam leads that are located on opposite sides of the semiconductor are bonded simultaneously, this develops an inward stress on the beam-lead device. And this manifests itself as a shear force that tends to buckle the beam leads or separate them from the integrated circuit device or lift the device off the surface of the substrate that bears the circuit pattern. The shear force is of course undesirable since it can break the connection to the integrated circuit device. The lifting that can result is also undesirable because this increases the thermal impedance between the device and the substrate when a silicon resin or similar filler is inserted between the two.

SUMMARY OF THE INVENTION

Accordingly it is an object of this invention to facilitate uniform thermocompression bonding of multi-lead semiconductor devices.

It is a further object of this invention to minimize the deleterious effects on the beam leads caused by the shear forces set up when the beam leads of an integrated circuit device are thermocompression bonded.

These and other objects of the invention are achieved by a process of rocking the beam leads into successive contact with the bonding tool, thereby bonding the leads to the substrate. In practicing this invention, the bonding tool used has a flat tip at the end of a hollow rectangular rod. The beam-lead device is positioned on a substrate in proper register with a circuit pattern on the substrate surface. The substrate is mounted on a carrier, and the carrier is mounted on a wobble table located under the bonding tool. When appropriate means undulate the wobble table, the beam leads are rocked into successive contact with the bonding tool and thereby are thermocompression bonded to the circuit pattern.

Because the bonding tool against which the beam leads are rocked is gravity- or spring-loaded, each beam lead is certain to be contacted and bonded. Hence it does not matter if the beam leads do not lie in a plane that is parallel to both the circuit pattern and the bonding surface. Because diametrically opposed leads are never bonded at the same time, an inward force on the beam-lead device is not created on opposite sides at any one time; and even if one of two diametrically opposed leads is already bonded when the second lead is bonded, the inward force is only about half of that created by simultaneously bonding diametrically opposed leads. Moreover, because the flat tip of the bonding tool is rocked onto a beam lead in a direction that is perpendicular to the axis of the lead, a substantial portion of the material that is compressed is pushed in a direction perpendicular to the axis of the lead. By bonding the leads at different times and by pushing some of the material compressed in a perpendicular direction rather than along the axis of a lead, the shear forces that are created during the bonding are minimized. Thus there is less likelihood that the beam lead will be severed from its connection to the semiconductor surface or that the beam-lead device will be lifted off the surface of the substrate that bears the circuit pattern.

DESCRIPTION OF THE DRAWING

These and other objects and features of the invention will be better understood from a consideration of the following detailed description taken in conjunction with the accompanying drawing in which:

FIG. 1 is a schematic view of the bonding apparatus, partially in section and partially in perspective, showing the relative positioning of the tool, the parts to be bonded and the wobble table;

FIG. 2 is a plan view of the beam-lead integrated circuit device, mounted on a substrate, showing the rela-

tion between the integrated circuit device, the substrate and the tip of the bonding tool; and

FIG. 3 is a cross-section view through line 3—3 of FIG. 2 of the bond that is formed by the apparatus of FIG. 1.

DETAILED DESCRIPTION

Referring now to FIG. 1, there is shown one embodiment of the invention comprising a heated bonding tool 11, a beam-lead integrated circuit device 21 mounted on a ceramic substrate 26, and a wobble table 31 for wobbling the beam-lead device 21 and the substrate 26 into contact with bonding tool 11.

Bonding tool 11 comprises a rectangular rod 12 at one end of which is a recess 13 that accommodates integrated circuit device 21. The remaining portion of this end of rod 12 constitutes tip 14 of bonding tool 11. The bonding face 15 of tip 14 comprises a rectangular border area of uniform width lying in a plane perpendicular to axis OX which is collinear with the longitudinal axis of rod 12. Rod 12 includes an internal tube 16 for applying a suction to hold the integrated circuit device in the bonding tool. Bonding tool 11 is mounted on a conventional mechanical structure that affords the tool substantial vertical and horizontal displacement. During the bonding operation, the bonding tool is forced against the beam leads on the substrate by either gravity or springs.

Beam-lead integrated circuit device 21 comprises a body 22 of semiconductor material and a series of electrically-conductive beam leads 23A to 23H extending beyond the edge of one surface of body 22. These beam leads 23A-H are mounted in register with bonding pads 27A to 27H that are elements of electrically-conductive circuit pattern 28 mounted on the upper surface of substrate 26.

The substrate is positioned on nonrotating plate 32, which is an element of wobble table 31. Plate 32 rests on bearings 33 which are contained and supported by rotating plate 34. Plate 34, in turn, is supported by tilting and supporting means 35 and is rotated about central axis OX by rotating means 36.

Further understanding of the relationship of the elements is provided by the plan view of FIG. 2. Here again element 21 is the beam-lead integrated circuit device; 22 the semiconductor body; 23A-H the beam leads; 26 the ceramic substrate; 27A-H the bonding pads; and 28 the circuit pattern. The dotted lines 40 and 41 show the inside and outside edges of bonding face 15 of bonding tool 11, shown in FIG. 1, in position for bonding the beam leads.

Prior to the bonding operation, the substrate is so positioned on nonrotating plate 32 that bonding pads 27A-H are substantially centered about axis OX. Integrated circuit device 21 is then positioned on substrate 26 so that beam leads 23A-H are in proper alignment with bonding pads 27A-H. This may conveniently be done by loading device 21 into a suitably designed nest, beam leads facing down, picking the device out of the nest with the vacuum pickup incorporated in recess 13 and tube 16 of bonding tool 11, and positioning the device on substrate 26. Inasmuch as the extremities of beam leads 23 are precisely determined, in contrast to the less well defined boundaries of semiconductor body 22, it is possible to fix precisely the position of device 21 in the nest by making an accurately machined nest, the dimensions of which just accommodate the beam leads. Because bonding tool 11 can be precisely located with respect to both the nest and bonding pads 27 on substrate 26, leads 23 can be accurately positioned on bonding pads 27.

Once device 21 is accurately aligned on substrate 26, the bonding operation can begin. The nonrotating plate 32 is tilted about a point defined by the intersection of axis OX and the upper surface of the substrate. The amount of this tilt will, of course, vary with the thickness of the beam leads, the geometry of the integrated

device, and the location of the beam leads on the device. For most devices presently conceived, nonrotating plate 32 would be tilted approximately 0.5° to 3.0° from the plane perpendicular to axis OX. As a result substrate 26 comes in contact with face 15 of bonding tool 11 at one point, which can be assumed to be point A on FIG. 2. If tilting and supporting means 35 are now rotated about axis OX, plate 34 rotates about axis OX and nonrotating plate 32 wobbles, or undulates, about the point defined by the intersection of axis OX and the upper surface of the substrate. In mechanical engineering terms, a line that intersects axis OX and is situated in the plane of rotating plate 34 precesses about axis OX at a fixed nutation angle. At the same time, a line that intersects axis OX and is situated in the plane of nonrotating plate 32 does not precess, since it does not rotate; but it does nutate.

More specifically, as plate 34 rotates in a counter-clockwise direction as indicated by the arrow of FIG. 2, substrate 26 rises on sides *ab* and *bc* and falls on sides *cd* and *da*. As it rises on side *ab*, the substrate pushes the beam leads on side *ab* into contact with face 15 of the bonding tool. First, beam lead 23A, the beam lead closest to point A, is rocked into contact with the face; then beam lead 23B, the beam lead next in line, is pushed against the face of the bonding tool. Even if the plane in which the beam leads lie is not parallel with the planes in which the bonding surface and the bonding pads are situated, each lead on side *ab* will be bonded to its bonding pad because the bonding tool is gravity- or spring-loaded against the beam leads and only the leads on side *ab* are contacted. Finally tilting means 35 has been rotated 90° and the substrate is in contact with the bonding tool at point B.

Rotation of tilting means 35 continues in a counter-clockwise direction. Side *bc* of the substrate is now raised against face 15 of the bonding tool. Beam lead 23C, the beam lead closest to point B, is the next to be rocked into contact with the face, and then beam lead 23D. In similar fashion sides *cd* and *da* are pushed by the tilting means 35 against the face of the bonding tool. Because the bonding tool is forced against the beam leads and because the successive bonding operation proceeds on only one side of the tool and the integrated circuit device at a time, all of the beam leads of the device will be contacted and bonded once the complete rotation of 360° has been made.

As can be appreciated by those skilled in the art, the embodiment just described admits of many variations in its practice. As shown in FIG. 1, the bonding face 15 of bonding tool 11 is flat. Such a geometry allows for the easiest manufacture and the simplest maintenance of the bonding face; and the flat bonding face does make satisfactory bonds of the beam leads to the bonding pad. However, the flat bonding face causes greater deformation to the beam leads adjacent to the four corners of the beam-lead device than it does to any leads in between the corner leads. Furthermore, when the flat surface of the substrate is wobbled into contact with the flat bonding face of the bonding tool, there is one particular instant when all the beam leads on one side of the device are in contact with the bonding face. If elimination of these two effects is desired, the bonding face can be shaped as part of a conic section.

A cross section of the bond made with this invention is shown in FIG. 3, depicting semiconductor body 22, a beam lead 23, a bonding pad 27 and substrate 26. Because nonrotating plate 32 and therefore beam-lead device 21 and substrate 26 are tilted during the bonding operation, the greatest deformation in the beam lead occurs at its outer extremity 231 and the least at the inner edge 232 of the bond. For a lead of maximum strength, there should be no notch at edge 232 of the bond; and by suitable adjustment of the tilt of the wobble

table it is possible to provide a bond in which the deformation tapers off to zero.

In contrast to the wobble table technique, simultaneous bonding of all the beam leads tends to flatten each beam lead uniformly so that the deformation at the inner and the outer edges of the bond is substantially the same. This, however, results in an abrupt change in the cross-sectional area of the lead—an obvious point of weakness.

The embodiment described has eight beam leads and the circuit pattern provides for one integrated circuit device. However, beam-lead devices with eighteen beam leads have been bonded in accordance with the invention and it is expected that devices with sixty or more leads may likewise be bonded. Regardless of the number of leads that are used on the device, the wobble technique that has been described is capable of producing satisfactory bonds.

Likewise the wobble technique can be adapted to bond more than one integrated circuit device to an appropriate circuit pattern. To do this, it is only necessary to provide a suitable mechanism, on which the substrate can be mounted, that can move the substrate and therefore the circuit pattern from one bonding location to another. Thus, with the aid of a computer control or an alignment pattern, it would be possible to center each bonding location at the center of the wobble table in an appropriate position for bonding.

The wobble method and apparatus shown is only illustrative of the method and the mechanism that can be used for bonding sequentially in accordance with this invention. It would also be possible to perform the bonding operation by wobbling the thermode instead of the substrate. Numerous other modifications can be made by those skilled in the art without departing from the spirit and scope of the invention.

What is claimed is:

1. In combination, apparatus comprising:

tool means adapted to position leads of a multilead semiconductor device in bonding relationship with an array of electrically conductive areas on a first surface of a substrate,

bonding means adapted to bond said leads to said array, said bonding means comprising a bonding face that faces the first surface of the substrate with leads of the semiconductor device being located between the bonding face and the substrate, and

means for rocking the bonding face toward the substrate or means for rocking the substrate toward the bonding face to establish bonding contact successively between the bonding face and at least some of the different leads of the semiconductor device that are located between the bonding face and the substrate.

2. The apparatus of claim 1 wherein the rocking means comprises:

means for reducing the distance between part of the bonding face and part of the substrate enough to establish a region where bonding contact can be made between the bonding face and leads located between the bonding face and the substrate, and

means for changing the region where bonding contact can be made to establish bonding contact successively between the bonding face and at least some of the different leads of the semiconductor.

3. The apparatus of claim 2 wherein:

the tool means further comprises a suction tube for holding the semiconductor device and means for displacing the device horizontally and vertically and

the means for reducing the distance between part of the bonding face and part of the substrate comprises means for tilting the bonding face or means for tilting the substrate.

4. The apparatus of claim 1 wherein bonding contact is made between only part of the bonding face and some of the leads at any one time, thereby defining a region where bonding contact can be made, and the rocking means comprises means for moving this region to establish bonding contact first between the bonding face and one or more leads and then between the bonding face and a different one or more leads.

5. The apparatus of claim 1 wherein the rocking means comprises means for undulating the substrate about a point located in or near its first surface.

6. The apparatus of claim 1 wherein:

the multi-lead semiconductor device has at least three sides,

leads of the semiconductor device are peripherally disposed,

the bonding face has a recess substantially conforming to the semiconductor device, and

the tilting and rotating means successively rock each side of the semiconductor device toward the bonding face to establish bonding contact between any leads on each side of the device and the bonding face.

7. The apparatus of claim 6 wherein the rocking means comprises:

a first nonrotating plate on which the substrate is mounted,

a second plate on which the first plate is mounted, tilting means for tilting the second plate and therefore the substrate to reduce the distance between part of the bonding face and part of the substrate enough to establish a region where bonding contact can be made between the bonding face and leads located between the bonding face and the substrate, and rotating means for rotating the second plate and therefore the region where bonding contact can be made to bring into bonding contact at different times the bonding face and different leads of the semiconductor device, whereby leads of the device are bonded to the electrically conductive areas on the substrate.

8. The apparatus of claim 7 wherein:

the tool means further comprises a suction tube for holding the semiconductor device and means for displacing the device horizontally and vertically, the semiconductor device is a rectangular beam-lead device,

the recess in the bonding face is rectangular, and the bonding means is a thermocompression bonding means.

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