

PATENT SPECIFICATION

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DRAWINGS ATTACHED

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(54) IMPROVEMENTS IN OR RELATING TO BONDING

(71) We, WESTERN ELECTRIC COMPANY, INCORPORATED, of 195 Broadway, New York City, New York State, United States of America, a Corporation organised and existing under the laws of the State of New York, United States of America, 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:—

This invention relates to methods of and apparatus for bonding workpieces together.

In apparatus used for bonding electronic devices, such as integrated-circuit chips to substates, one of the principal problems is aligning the integrated-circuit chips as desired, e.g. to bonding tips, prior to engaging the chips with the tips, and aligning the chips with a pattern on a substrate. Various optical systems have been used to facilitate such alignment, but these suffer from various limitations and are thus not entirely satisfactory.

One of the most common systems employs a half-silvered mirror suspended between a bonding tip and a plane on which either chips or a substrate lie. An optical axis of a microscope is obliquely directed to the half-silvered mirror and an image of both the tip and a chip or substrate on the plane over the mirror appear simultaneously in the microscope eyepiece. However, the oblique viewing causes perspective distortions which make accurate alignment difficult. Additionally, because the mirror is suspended between the tip and the workpiece with which the tip must be engaged, the mirror must be mounted on a swing-away mechanism which adds complexity to the bonding apparatus.

Problems associated with half-silvered mirrors may be reduced to a certain extent by the use of beam-splitter prism combinations which are suspended similarly to the mirror but which direct an image of both a tip and a workpiece perpendicularly to a

bonding axis on which it is suspended. These combinations however require very accurate alignment to the bonding axis and thus the supporting mechanism, in addition to being capable of swinging away from the bonding axis, must have adjustments provided thereon to achieve precise planar alignment of the prism. "Bonding axis" is defined herein as an axis passing through the bonding tip and along which relative movement of the bonding tip towards a workpiece is caused to occur in order to effect bonding.

Systems employing reference reticles have also been used to accomplish the desired alignments. Such systems are described in United States Patent No. 3,477,630. These systems, while performing admirably when properly adjusted, do suffer from the limitation that accurate alignment of a mechanism which positions a movable head requires very precise adjustment with respect to the reference reticle in order to achieve the necessary degree of accuracy.

Even more complex systems have been utilised employing rapidly oscillated mirrors to project images of workpieces and bonding tips simultaneously to an operator while an operator tries to achieve alignment therebetween. Obviously, systems that use oscillating mirrors suffer from problems associated with their inherent complexity.

Except for the reference reticle system, the above described systems have the common shortcoming that some optical element of the apparatus must be temporarily suspended between the bonding tip and the workpiece. In order to provide space for these elements, the bonding tip must travel extensive distances in accomplishing either engagement with the workpiece for pickup purposes or for bonding purposes. Extensive travel of the bonding tip results in difficulty in providing precise positioning of the bonding tip throughout its range of operation.

According to one aspect of this invention apparatus for bonding first and second

workpieces together includes means for aligning said workpieces in desired relation to each other, a bonding head for applying bonding energy to said workpieces to bond them together, said bonding head including a transparent bonding tip, and said apparatus further including means for inspecting at least one of said workpieces via said transparent tip along a bonding axis (as hereinbefore defined) to inspect alignment of said one workpiece.

According to another aspect of this invention there is provided a method of bonding two workpieces together utilising bonding apparatus including a bonding head having a transparent bonding tip for applying bonding energy to said workpieces to bond them together, the method including aligning said workpieces in desired relation to each other, inspecting alignment of at least one of said workpieces with means adapted to inspect it via said transparent tip along a bonding axis (as hereinbefore defined), and applying bonding energy to said workpieces to bond them together.

The bonding energy may be applied to said workpieces via a transparent compliant bonding medium.

A compliant bonding medium is a medium which serves to distribute bonding energy more uniformly to the workpieces. Reference is directed to the description and claims of our U.K. Patent No. 1239631 which relates to the bonding of workpieces using a compliant bonding medium.

Preferably said one workpiece is held adjacent said tip portion after alignment by a reduction in air pressure transmitted through the tip portion to said workpiece.

The invention will now be described by way of example with reference to the accompanying drawings, in which:

FIG. 1 is a perspective view of an apparatus in accordance with the invention;

FIG. 2 is a partially sectioned elevation view on a larger scale of the bonding head of the apparatus of FIG. 1;

FIGS. 3 to 6 are views showing the various stages of alignment of first and second workpieces;

FIG. 7 is a partially sectioned elevation view of a bonding head in another apparatus in accordance with the invention; and

FIGS. 8 to 11 are views showing the various stages of alignment of first and second workpieces.

The invention will be described in connection with the bonding of beam-lead integrated-circuit chips to conductive elements on ceramic substrates. However, it is to be understood that the invention will find application in the bonding of many types of small articles where accurate alignment between parts is important.

Referring now to FIG. 1, a bonding

machine 20 includes a movable head assembly 22, a base 24, a conventional positioner assembly 26, and an electronic-optical system including a television camera 27 and a monitor 28. Even though the machine 20 is illustrated with an electronic-optical system, a conventional microscope could be used with equal effectiveness.

Operation of the machine 20 can best be understood by a description of one complete bonding cycle. A beam-lead integrated-circuit 30 is illustrated on a screen 32 of the monitor 28. The image on the screen illustrates leads 36 of the chip 30 being well aligned with conductive elements 38 on a ceramic substrate 40.

The monitor 28 shows an image of chip 30 bounded by an aperture 42 in a compliant member 44. The compliant member 44 is transparent and for this reason the substrate 40 below the compliant member is visible through the system 27.

One example of a material suitable for use as the compliant member 44 is polyimide film and one example of such a film is marketed by E. I. DuPont DeNemours and Company of Wilmington, Delaware under the trade mark "Kapton". By way of example, a film thickness of 0.005 inch has been found to be suitable for chips which are approximately 0.002 inch thick.

For increased visibility, the compliant member 44 may be coloured. Sensing the colour is done readily with a microscope but an electronic-optical system must have colour sensing capability to take advantage of the additional visibility which colour imparts to the compliant member 44.

The chip 30 is held in engagement with the compliant member 44 by vacuum developed within a bonding head 46 carried on the head assembly 22. The inner structure of the head 46 is more clearly illustrated in FIG. 2. A vacuum chamber 48 is formed in the head 46 and is connected to a vacuum source 49 through a port 50 and tubing 52 (see FIG. 1).

In order that the system 27 can receive images of the chip 30, the substrate 40 and the compliant member 44, the vacuum chamber 48 is constructed so that the walls through which an optical axis 54 passes are transparent. It will be noted that the optical axis 54 is also the bonding axis of the machine 20. The uppermost wall is a clear glass or quartz disc 56. Directly below the disc 56 is a clear glass or quartz engagement portion or bonding tip 58. The tip 58 is provided with an aperture or vacuum port 60 through which the force of vacuum within the chamber 48 can be transmitted to the chip 30.

The chip 30 is shown in "engagement" with the tip 58 under the influence of the forces of the vacuum source 49. Although

the chip 30 is being held compressively against the tip 58, there is no actual contact therewith because the thickness of the compliant member 44 is greater than the thickness of a body portion 61 of the chip 30.

The tip 58 is advantageously provided with a projection 62 to localise bonding forces to a small region of substrate 40. This localisation is often desirable when a number of the chips 30 are bonded on the substrate 40. The projection 62 will fit into a small space on the substrate 40 during bonding and the likelihood is reduced of disturbing another one of the chips which has previously been bonded nearby on the substrate.

Conventional cartridge heaters 63 are also provided in the head 46 in order to provide for heating of the chip 30 prior to and during bonding.

Bonding is accomplished by lowering the movable head assembly 22 along conventional slide assemblies 64. After the assembly 22 is lowered, a bond is produced between the leads 36 and the conductive elements 38. A detailed description of the use of polyimide as a compliant bonding member is included in the specification of copending British application No. 47394/70 (Serial No. 1315510).

A substantial amount of heat is required to produce an effective thermocompression bond and it is found desirable to supplement the heating produced by the heater 63 in the head 46 by heating the substrate 40. This is best accomplished by putting conventional heaters 65 in a substrate support 66.

After the bond is complete, the head assembly 22 is raised again to the position shown in FIG. 1. The positioner assembly is moved to the right along conventional slide members 68 until a chip tray 70 is positioned on the optical axis 54. The compliant member 44 is also indexed so that a subsequent one of the bonding apertures 42 is aligned with the axis 54.

It can be seen from FIG. 1 that the compliant member 44 is a continuous strip which is wound from a supply reel 72 to a takeup reel 74. The takeup reel 74 has torque continuously applied to it by a conventional torque motor 76. Control of the movement of the takeup reel 74 is provided through an indexing sprocket 78.

The indexing sprocket 78 is moved in accurately controlled 45° increments. Movement of the member 44 is initiated when a cylinder-actuated pin 80 is withdrawn from one of eight holes 82 in a plate 84. The pin 80 is controlled by a spring-biased cylinder 86 and the cylinder acts only momentarily to pull the pin out of the hole 82 with which it is engaged. As soon as the pin 80 is free from the hole 82, the plate 84,

which is on the same shaft as the sprocket 78, begins to rotate because of the force exerted on the sprocket by the member 44. After 45° of rotation the pin 80 snaps into the next one of the holes 82 and motion of the compliant member 44 stops. Spacing between bonding aperture 42 is such that 45° rotation of the sprocket 78 results in accurate location of the subsequent one of the apertures 42 on the optical axis 54.

After a new one of the bonding apertures is aligned with the optical axis 54, an image, such as that shown in FIG. 3, appears on the screen 32 of the monitor 28. An operator can see the aperture 42 and the projection 62 of the tip 58 as well as any one of the chips 30 which is within the field of the camera 27. The chips 30 are not necessarily in an ordered array on the chip tray 70 and because of this, it is quite likely that the chip 30 may not be aligned with the aperture 42.

To achieve alignment, an operator moves a handle 88 of the positioner assembly 26 and rotates the chip tray 70 while viewing the screen 32 until the image shown on FIG. 4 is achieved. FIG. 4, of course, illustrates the chip 30 being properly aligned with the aperture 42.

After the image of FIG. 4 is achieved, the head assembly is lowered and the force of vacuum within the chamber 48 brings the chip 30 into engagement with the head 46 by being drawn against the compliant member 44. After this engagement, the head assembly 22 is raised to the position shown in FIG. 1.

The positioner assembly 26 is then moved to the left so that a substrate 40 is roughly aligned with the optical axis 54. At this time, the operator sees an image similar to that shown in FIG. 5 on the screen 32.

The operator then moves the positioner handle 88 to manipulate the substrate 40 while viewing the screen 32 to achieve alignment of the conductive elements 38 with the leads 36. After an image like that shown in FIG. 6 is achieved, bonding of the leads 36 to the elements 38 can take place and a full cycle of operation is thus completed.

It is important to note that the vertical movement of the head assembly 22 can be quite small because there is no need to place complex optical system components between the tip 58 and the workpieces. It is desirable to take advantage of the fact that the movement can be small so that great precision can be provided in machine 20. Keeping the movement of the assembly 22 small also ensures that the image of the aperture 42 and the image of the chip 30 supported on the tray 70 as well as the image of the conductive elements 38 supported on the substrate holder 66 are simultaneously within the depth of field of the system 27. It

is also important to construct the machine 20 so that the chips 30 and the conductive elements 38 are supported at substantially the same elevation so that each of the
 5 respective images will be in focus when they are placed on the optical axis 54 by movement of the positioner assembly 26.

Another embodiment of the apparatus is illustrated in FIG. 7 and includes a bonding
 10 head 146. The bonding head includes a vacuum chamber 148, a vacuum port 150, a transparent disc 156 and a transparent bonding tip 158. The head 146 can be used on a bonding machine similar to that shown in
 15 FIG. 1 with the exception that it is not necessary to use a compliant member. The head 146 is designed to be used in a so-called "hard tip" mode of operation. Provision must be made for compensating for different
 20 thicknesses of leads 36, to thereby equalize bonding forces simultaneously applied to all of leads 36.

The tip 158 includes a projection 162 and an aperture 160. The aperture 160 is large
 25 enough so that the body portion 61 of one of the chips 30 will fit into the aperture with some clearance around all sides of the body portion. The relative size of the aperture 160 to the body portion 61 is shown in FIG. 9.
 30 The projection 162 serves substantially the same purpose as the projection 62 (FIG. 2).

Some heat is transmitted through the tip 158 from cartridge heaters 163. Of course, it is still desirable to provide heating from
 35 sources other than the lead 146.

In using the lead 146, an operator usually first encounters a situation in which the
 40 aperture 160 is misaligned with respect to one of the chips 30 such as that shown in FIG. 8. This is somewhat analogous to the situation shown in FIG. 3. The chip 30 is moved into proper alignment with the
 45 aperture 160 while being viewed along an optical-bonding axis 164 through a system which takes advantage of the transparency of the disc 156 and the tip 158. FIG. 9 represents an image that an operator sees after proper alignment of the chip 30 and
 50 the aperture 160 is achieved.

FIG. 10 illustrates the conductive elements 38 of a substrate 40 as they appear
 55 to an operator prior to final alignment of the substrate and the chip 30. The substrate 40 is carefully moved until the conductive elements 38 are properly aligned with the leads 36.

FIG. 11 illustrates an image that an operator sees during bonding of the leads 36
 60 to the elements 38. One of the very significant advantages of the apparatus according to the invention is that it may

permit an operator to visually determine the extent of "squash out" of the leads 36 while bonding is proceeding and to respond to
 65 excessive or insufficient "squash-out" — the likelihood of getting good quality bonds is greatly enhanced.

WHAT WE CLAIM IS:—

1. Apparatus for bonding first and second workpieces together, said apparatus including means for aligning said workpieces
 70 in desired relation to each other, a bonding head for applying bonding energy to said workpieces to bond them together, said bonding head including a transparent
 75 bonding tip, and said apparatus further including means for inspecting at least one of said workpieces via said transparent tip along a bonding axis (as hereinbefore defined) to inspect alignment of said one
 80 workpiece.

2. A method of bonding two workpieces together utilizing bonding apparatus including a bonding head having a transparent
 85 bonding tip for applying bonding energy to said workpieces to bond them together, the method including aligning said workpieces in desired relation to each other, inspecting alignment of at least one of said workpieces with means adapted to inspect it via said
 90 transparent tip along a bonding axis (as hereinbefore defined), and applying bonding energy to said workpieces to bond them together.

3. A method as claimed in claim 2 wherein
 95 said workpieces are inspected with said means during application of bonding energy.

4. A method as claimed in claim 2 or 3 wherein said bonding energy is applied to
 100 said workpieces via a transparent compliant bonding medium.

5. A method as claimed in claim 2 or 3 wherein said tip directly contacts one of said
 105 workpieces during application of bonding energy.

6. A method as claimed in any one of claims 2 to 5 wherein said one workpiece is held adjacent said tip after alignment by a
 110 reduction in air pressure transmitted through said tip to said workpiece.

7. A method of bonding two workpieces together substantially as herein described with reference to the accompanying
 115 drawings.

8. Workpieces bonded together by a method as claimed in any one of claims 2 to
 7.

9. Apparatus for bonding workpieces together substantially as herein described
 120 with reference to the accompanying drawings.

is also important to construct the machine 20 so that the chips 30 and the conductive elements 38 are supported at substantially the same elevation so that each of the
5 respective images will be in focus when they are placed on the optical axis 54 by movement of the positioner assembly 26.

Another embodiment of the apparatus is illustrated in FIG. 7 and includes a bonding
10 head 146. The bonding head includes a vacuum chamber 148, a vacuum port 150, a transparent disc 156 and a transparent bonding tip 158. The head 146 can be used on a bonding machine similar to that shown
15 in FIG. 1 with the exception that it is not necessary to use a compliant member. The head 146 is designed to be used in a so-called "hard tip" mode of operation. Provision must be made for compensating for different
20 thicknesses of leads 36, to thereby equalize bonding forces simultaneously applied to all of leads 36.

The tip 158 includes a projection 162 and an aperture 160. The aperture 160 is large
25 enough so that the body portion 61 of one of the chips 30 will fit into the aperture with some clearance around all sides of the body portion. The relative size of the aperture 160 to the body portion 61 is shown in FIG. 9.
30 The projection 162 serves substantially the same purpose as the projection 62 (FIG. 2).

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In using the lead 146, an operator usually first encounters a situation in which the aperture 160 is misaligned with respect to
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45 which takes advantage of the transparency of the disc 156 and the tip 158. FIG. 9 represents an image that an operator sees after proper alignment of the chip 30 and the aperture 160 is achieved.

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50 to an operator prior to final alignment of the substrate and the chip 30. The substrate 40 is carefully moved until the conductive elements 38 are properly aligned with the leads 36.

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1. Apparatus for bonding first and second workpieces together, said apparatus including means for aligning said workpieces
70 in desired relation to each other, a bonding head for applying bonding energy to said workpieces to bond them together, said bonding head including a transparent
75 bonding tip, and said apparatus further including means for inspecting at least one of said workpieces via said transparent tip along a bonding axis (as hereinbefore defined) to inspect alignment of said one
80 workpiece.

2. A method of bonding two workpieces together utilizing bonding apparatus including a bonding head having a transparent
85 bonding tip for applying bonding energy to said workpieces to bond them together, the method including aligning said workpieces in desired relation to each other, inspecting alignment of at least one of said workpieces
90 with means adapted to inspect it via said transparent tip along a bonding axis (as hereinbefore defined), and applying bonding energy to said workpieces to bond them together.

3. A method as claimed in claim 2 wherein said workpieces are inspected with said
95 means during application of bonding energy.

4. A method as claimed in claim 2 or 3 wherein said bonding energy is applied to
100 said workpieces via a transparent compliant bonding medium.

5. A method as claimed in claim 2 or 3 wherein said tip directly contacts one of said
105 workpieces during application of bonding energy.

6. A method as claimed in any one of claims 2 to 5 wherein said one workpiece is held adjacent said tip after alignment by a
110 reduction in air pressure transmitted through said tip to said workpiece.

7. A method of bonding two workpieces together substantially as herein described with reference to the accompanying
115 drawings.

8. Workpieces bonded together by a method as claimed in any one of claims 2 to
7.

9. Apparatus for bonding workpieces together substantially as herein described
120 with reference to the accompanying drawings.



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