

PATENT SPECIFICATION

(11)

1 336 067 (12)

DRAWINGS ATTACHED



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- (21) Application No. 9876/71 (22) Filed 19 April 1971
(31) Convention Application No. 30 379 (32) Filed 21 April 1970 in
(33) United States of America (US)
(44) Complete Specification published 7 Nov. 1973
(51) International Classification G02B 21/18
(52) Index at acceptance
G2J 8C 8H 8X
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(54) IMPROVEMENTS IN OR RELATING TO THE INSPECTION OF SMALL OBJECTS

(71) We, WESTERN ELECTRIC COMPANY, INCORPORATED, of 195, Broadway, New York City, 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 a method of and apparatus for inspecting small objects, and is particularly suited though not of course limited to the inspection of small, fragile objects such as semiconductor devices or the like. An example of a small fragile semiconductor device is the so-called beam-lead integrated circuit. A beam-lead integrated circuit includes a semiconductor body with interconnected circuit elements inseparably associated on or within the body. Leads are bonded to the body as an integral part of the device and extend from the body like cantilever beams to form both electrical and mechanical connections to a header or a circuit pattern formed on a substrate. In the manufacture of such circuits, it is necessary to inspect both their sides with a microscope to separate the defective from the good ones.

In the past much difficulty has been experienced in positioning the circuits under a vacuum pickup needle located in the field of view of the microscope because they were supported on a platform slidably mounted on a base, and, when the operator attempted to move the circuits under the pickup needle, he would frequently undershoot or overshoot the needle the effect of which was exaggerated by the magnification of the microscope. As a result, much time was consumed in accurately positioning the circuits, and therefore in inspecting them.

Also, much time was consumed in inspecting the active as well as the inactive sides of the circuits. Either the circuits had to be

manually turned over to inspect the active sides or a mirror had to be arranged beneath the circuits and the microscope tilted about its axis to inspect such active sides. Such methods permitted the inspection of only one circuit at a time with separate handling steps between each inspection and moreover, they had the disadvantage of not being readily adaptable to the rapid inspection of an array of a large number of circuits.

According to one aspect of this invention apparatus for inspecting opposed surfaces of a small object includes a microscope, a transparent support member for supporting said object within the field of view of said microscope, means fixedly arranged to reflect to said microscope an image of the surface of said object adjacent the surface of said support member, and means for moving said microscope along its principal axis relative to said support member to focus it, at will, on the surface of said object facing said microscope, or on said image.

In one embodiment of the invention said microscope is mounted to a base member, said support member is mounted to a slide member, said slide member is so arranged with respect to said base member as to permit movement of said support member transverse to said principal axis, and there is provided means for supplying pressurised fluid, said slide member and said base member being so adapted and arranged as to substantially not contact each other when said pressurised fluid is supplied between them.

The said means for moving said microscope relative to said support member may be adapted to move said microscope, or alternatively it may be adapted to move said support member.

According to a further aspect of this invention there is provided a method of inspecting opposed surfaces of a small object wherein said object is supported with one

[Price 25p]

of said surfaces facing a microscope, and the other of said surfaces adjacent the surface of a transparent support member and spaced apart from means arranged to reflect to said microscope an image of said other surface, and said microscope is moved along its principal axis relative to said support member to focus it, at will, on said one surface, or on said image.

10 The microscope may be focused on said one surface or on said image either by moving it along its principal axis or by moving said support member along said principal axis.

15 The invention will now be described with reference to the accompanying drawings, in which:

FIG. 1 is a greatly enlarged, perspective view of a beam-lead integrated circuit;

20 FIG. 2 is a perspective view of an apparatus for individually inspecting with a microscope both the active and inactive sides of a plurality of beam-lead integrated circuits;

FIG. 3 is a cross-sectional view taken along line 3-3 of FIG. 2, illustrating the microscope in its upper position for individually inspecting the inactive sides of beam-lead integrated circuits;

FIG. 4 is an enlarged top view taken along line 4-4 of FIG. 3, showing the inactive sides of the circuits with identifying marks;

FIG. 5 is a cross-sectional view taken along line 5-5 of FIG. 2, illustrating the microscope in its lower position for individually inspecting the active sides of the beam-lead integrated circuits;

FIG. 6 is an enlarged top view taken along line 6-6 of FIG. 5, showing the active side of a circuit;

FIG. 7 is a cross-sectional view taken along line 7-7 of FIG. 2;

FIG. 8 is a cross-sectional view taken along line 8-8 of FIG. 2; and

FIG. 9 is a cross-sectional view taken along line 9-9 of FIG. 2.

Referring now to FIG. 1 beam-lead integrated circuit 11 to be inspected includes a semiconductor body 12 having a bottom or active side 13 and a top or inactive side 14, and a plurality of beam leads 16 extending from the active side 13. Usually the integrated circuit 11 is very small, e.g. it has a square shape, about 15 to 90 mils wide and about only 2 mils thick, while the leads 16 are about 9 mils long and 3 mils wide. The body 12 is frequently made of silicon and the leads 16 of gold. Extremely minute interconnected circuit elements (not shown), usually in the form of gold plated patterns, are formed on the active side 13 of the integrated circuits 11. These patterns, the leads 16, the bodies 12 and the active and inactive sides 13 and 14 have to be visually inspected for defects.

65 Referring now to FIGS. 2 and 3, the inte-

grated circuits 11 are removably supported on a carrier member or disc 17 of a first platform 18 with the inactive sides 14 facing up. The disc 17 may be either transparent or opaque, but for convenience is formed from a flat sheet of glass; its top surface may be covered with a layer of pressure sensitive, vacuum holding material, such as a silicone resin of the general type sold by the Dow Corning Corporation under the trade designation "Sylgard 182".

The carrier disc 17 is fixed to a first retainer 19 which is threaded into a second retainer 21 so that the distance of the integrated circuits 11 to a vacuum pickup needle 24 is adjustable simply by rotating the retainer 19 relative to the retainer 21. The vacuum pickup needle 24 is located under an objective lens 22 of a microscope 23.

The second retainer 21 is rotably mounted on a slide plate 25 so that an operator can angularly move the integrated circuits 11 relative to the objective lens 22. The slide plate 25 is movably mounted on a base 26 spaced from the microscope 23 and perpendicular to its principal axis 27.

The microscope 23 may be any standard commercial microscope of the type having an objective lens with a diameter substantially larger than the integrated circuits to be inspected. Preferably it has an adjustable magnification and is movable along its principal axis 27 to an upper and a lower aligned position. As an alternative to being movable to such upper and lower positions, the microscope 23 may be fixed on its axis 27 and means may be provided for moving the integrated circuits 11 to an upper and a lower aligned position under the microscope 23. The microscope 23 may be of the type which has a working distance (object to objective lens) of about four inches and an adjustable magnification of 10X to 40X.

The microscope 23 is mounted to the base 26 by conventional attaching means and has a first knob 28 for controlling its magnification and a second knob 29 for moving it along its principal axis 27 to its upper position as shown in FIG. 3 and to its lower position as shown in FIG. 5. The knob 29 is also used to focus the microscope 23 in these positions.

Referring now to FIG. 2 and 5, a second platform 30 is also mounted to the slide plate 25. The platform 30 includes a transparent carrier member or disc 31 for removably supporting the integrated circuits 11 in a spaced relationship with their inactive sides 14 facing up. Preferably, the disc 31 is formed from a flat sheet of glass, has its top surface is covered with a transparent layer of the aforementioned pressure sensitive, vacuum holding material, and has a grid 32 formed thereon to aid the operator in positioning the integrated circuits 11 in a spaced

relationship.

The carrier disc 31 is fixed to a third retainer 33 which is threaded into a fourth retainer 34 so that the distance of the integrated circuits 11 to the vacuum pickup needle 24 is adjustable simply by rotating the retainer 33 relative to the retainer 34. The retainer 34 is rotatably mounted to the slide plate 25 so that the operator can angularly adjust the circuits 11 relative to the objective lens 22.

A mirror 35 is located within the retainer 34 beneath and parallel to the carrier disc 31. In use the mirror 35 reflects images of the active sides 13 of the integrated circuits 11 to the microscope 23. Preferably the mirror 35 is formed from a flat, highly polished silicon slice which has the appearance of a black mirror and provides excellent contrast for viewing the gold leads 16.

The mirror 35 permits the active sides 13 of the integrated circuits 11 to be individually inspected by the operator with the microscope 23 simply by rotating the knob 29. This moves the microscope 23 to its lower position along its principal axis 27, as shown in FIG. 5, and permits the focusing of it on the mirror images of such active sides 13. With the microscope 23 in this position, its magnification is preferably greatly increased to provide a larger image of the active sides 13 and thereby facilitate their inspection. This increased magnification also decreases the depth of field of the microscope 23 so that the inactive sides 14 are far out of focus and therefore not visible. This improves the clarity of the image of the active sides 13. In effect, the sides 14 merely decrease some of the light entering the objective lens 22. For a microscope having a four-inch working distance the circuits 11 may be located about three inches from the lens 22 in its lower position, and the mirror 35 located about one-half inch from the disc 31.

In this way both the active and inactive sides 13 and 14 of the circuits 11 can be inspected without manually turning the circuits 11 over and without tilting the microscope 23. Thus, the operator can rapidly and accurately inspect a large array of the circuits 11.

Air bearing means are provided to minimize the difference between the static and sliding friction of the slide plate 25 on the base 26 and thus enable the operator, taking hold of the left end of the plate 25, to overcome the problem of undershooting or overshooting the vacuum pickup needle 24 in the process of positioning the integrated circuits 11 under such needle 24. Unwanted rotational movement of the plate 25 is also reduced. By overcoming these problems the operator can accurately move the slide plate

25 very small distances, e.g. about one mil.

Referring now to FIGS. 7 and 8, the air bearing means are adapted to operate from a source of air 36 under pressure connected by a flexible tube 37 to a longitudinally extending passageway 38 in the slide plate 25. The passageway 38 communicates with a laterally extending passageway 39 which in turn communicates with a vertical passageway 40, one end of which forms an aperture 41 in the bottom of the plate 25.

A housing 42, (FIGS. 2 and 8), is fixed to the left end of the slide plate 25 and has a passageway 43 formed therein, one end of which communicates with the other end of the longitudinal passageway 38 and the other end of which forms a port 44 in the housing 42. The port 44 is selectively blockable by the operator to force the air from the source 36 out of the aperture 40 in the bottom of the plate 25 to thereby float the plate 25 out of contact with the base 26 on a substantially frictionless air film. With the plate 25 so floating, the operator can controllably move it very minute distances to rapidly and accurately position the integrated circuits 11 under the vacuum pickup needle 24. Also, the operator can control the amount of friction between the slide plate 25 and the base 26 by partially blocking the port 44 to provide greater control over the movement.

The vacuum pickup needle 24 is mounted to the base 26 for movement substantially perpendicular to the integrated circuits 11 on carrier discs 17 and 30 so that it can be used to pick up the circuits 11. Such mounting of the needle 24 is accomplished with a standard commercial micropositioner, designated generally by the numeral 47. The micropositioner 47 includes a chuck 48 for removably holding the needle 24 and for providing a passageway 49 communicating with that of the needle 24. The needle 24 is preferably coated with a flat black paint to render it unobtrusive and to prevent glare when viewed simultaneously with the integrated circuits 11 through the microscope 23. When the circuits 11 are viewed, the needle 24 is out of focus and therefore does not interfere with their inspection.

The chuck 48 is fixed to a housing 51 which also has a passageway 52 communicating with the passageway 49. One end of a tube 53 for providing a vacuum from a source 54 to the needle 24 is fixed to the housing 51 in communication with the passageway 52 therein. The other end of the tube 53 is fixed to a handle 56 pivotally mounted to a base plate 57 for moving the needle 24 substantially perpendicular to the integrated circuits 11 on the platforms 18 and 30. The base plate 57 is fixed to the base 26.

The handle 56 has a first passageway 58,

one end of which communicates with that of the tube 53 and the other end of which communicates with that of another tube 59 connected to the vacuum source 54.

- 5 Intersecting the passageway 58 is a second passageway 61 in the handle 56. The second passageway 61 has a port 62 on the top surface of the handle 56, over which the operator can place his finger to control the vacuum at the free end of the needle 24 to pick up the integrated circuits 11. If the operator quickly uncovers the port 62, the rushing in of air to the needle 24 produces a puff of air at the free end of the needle 24, to assist release of a circuit 11 that may stick to the needle 24.

- Referring now to FIGS. 2 and 9, the housing 51 is fixed to a slide 63 of the micro-positioner 47 which is mounted on linear side bearings for vertical movement in a retaining plate 64 fixed to the base plate 57. A stop 65 is mounted to the retaining plate 64 for limiting the upper movement of the slide 63. The vertical position of the stop 65 is adjustable by a micrometer head 66. A tension spring 67 connected to the slide 63 and the retaining plate 64 normally holds the slide 63 up against the stop 65 and the handle 56 in its upper position, as shown in FIG. 2.

- A ball plunger 68 mounted in a housing 69 threaded into the slide 63 is normally urged downward, as shown in FIG. 2, by a compression spring 71. The extension of the plunger 68 is adjustable by a set screw 72 threaded in the slide 63. The ball plunger 68 limits the downward motion of the handle 56 so that when the needle 24 is positioned over the integrated circuits 11, the end of the needle 24 does not strike and, as a result, does not damage the circuit 11. This limiting action on the handle 56 is particularly important, because the feel of the ball plunger 68 striking the base 26 is an indication to the operator that the end of the needle 24 is very close to the circuit 11 and that any additional movement of the needle 24 must be slight so as not to damage the circuit.

- As shown in FIGS. 3 and 5 a spot illuminator 76 is mounted adjacent the microscope 23 and its light beam is reflected off the mirror 35 and onto the active sides 13 of the integrated circuits 11. The illuminator 76 aids in providing a bright, clear and easily inspected image of the active sides 13 of the circuits 11 by eliminating a hazy image of the opposite inactive sides 14, apparently caused by incident light reflections off sides 14 which are face up on the carrier disc 31. The incident angle of the light beam is relatively shallow (less than about 45°) so that the light beam reflected off the mirror 35 does not enter the objective lens 22 of the microscope.

In operation air from the source 36 passes through the tube 37, the passageways 38 and 43 and out of the port 44. To inspect the integrated circuits 11 the operator takes hold of the slide plate 25 and places his finger over and blocks the port 44 to force the air from the passageway 38 through passageways 39 and 40 and out of the aperture 41 in the bottom of the slide plate 25. As a result, the slide plate 25 floats out of contact with the base 26 on a substantially frictionless air film. The operator then moves the slide plate 25 to position the integrated circuits 11 supported on the disc 17 of the first platform 18 under the vacuum pickup needle 24 and in the field of view the objective lens 22 of the microscope 23. It is assumed that the microscope 23 is in its upper position along its principal axis 27, as shown in FIG. 3, and that its magnification is 10X to provide a large field of view. The operator then looks through the microscope 23 and individually inspects the inactive sides 14 of the integrated circuits 11 some of which have, as shown in FIG. 4, ink dots 77 thereon. The ink dots 77 indicate that the circuits 11 are defective as a result of previous tests.

The inactive sides 14 of the circuits 11 not having the ink dots 77 thereon are further inspected through the microscope 23 for any mechanical defects, such as cracks in the silicon body 12, under or over etching, and leads 16 that are bent. Having performed this inspection the operator takes hold of the handle 56 and places his finger over the port 62 to produce a vacuum from the source 54 at the free end of the needle 24. He then depresses the handle 56 moving the needle 24 toward the circuit 11, until the ball plunger 68 strikes the base 26 and the consequent increased pressure on the handle indicates to the operator that the needle 24 is very close to the circuits 11. The vacuum from the needle 24 should draw up the circuit 11 but, if this does not happen, the operator places a slightly increased pressure on the handle 56 pushing the ball plunger 68 against its compression spring 71 thereby moving the needle 24 even closer to, but still not in contact with, the circuit 11 to draw it up to the needle 24. Next, the operator moves the slide plate 25 to position the transparent carrier disc 31 of the second platform 30 in the field of view of the microscope 23 such that the circuit 11 held by the needle 24 is precisely centered inside a square of the grid 32.

The operator then uncovers the port 62, permitting air to rush into the needle 24 to release the circuit 11 onto the carrier disc 31. He then releases the handle 56 allowing it to return to its upward position as shown in FIG. 2.

Then, the operator rotates the knob to 130

increase the magnification of the microscope 23 to 40X and performs a second more detailed inspection of the same inactive side 14 of the deposited circuit 11 for the aforementioned mechanical defects. He then rotates the knob 29 to move the microscope 23 to its lower position along its axis 27, as shown in FIG. 5, and focuses the microscope 23 on the image reflected by the mirror 35 of the active side 13 of the circuit 11 being inspected. This places the inactive side 14 outside the now decreased depth of field of the microscope 23 and renders the side 14 invisible.

15 The operator now looks for the aforementioned mechanical defects on the side 13, and also for smeared elements (usually in the form of gold), foreign particles, and under and over etching of such elements.

20 The first inspection can of course be eliminated, the inspections of the integrated circuits 11 being performed on the second platform 30 only.

While the invention has been described 25 in connection with the inspection of a plurality of beam-lead integrated circuits 11, clearly it also finds application in the inspection of other small objects.

WHAT WE CLAIM IS:—

30 1. Apparatus for inspecting opposed surfaces of a small object, said apparatus including a microscope, a transparent support member for supporting said object within the field of view of said microscope, means fixedly arranged to reflect to said 35 microscope an image of the surface of said object adjacent the surface of said support member, and means for moving said microscope along its principal axis relative to said support member to focus it, at will, on the 40 surface of said object facing said microscope, or on said image.

2. Apparatus as claimed in claim 1 wherein said microscope is mounted to a 45 base member, said support member is mounted to a slide member, said slide member is so arranged with respect to said base member as to permit movement of said support member transverse to said 50 principal axis, and there is provided means

for supplying pressurised fluid, said slide member and said base member being so adapted and arranged as to substantially not contact each other when said pressurised fluid is supplied between them.

3. Apparatus as claimed in claim 1 or 2 wherein said means for moving said microscope relative to said support member is adapted to move said microscope.

4. Apparatus as claimed in claim 1 or 2 60 wherein said means for moving said microscope relative to said support member is adapted to move said support member.

5. Apparatus as claimed in any one preceding claim wherein said microscope is of 65 adjustable magnification.

6. A method of inspecting opposed surfaces of a small object wherein said object is supported with one of said surfaces facing a microscope, and the other of said surfaces adjacent the surface of a transparent support member and spaced apart from means arranged to reflect to said microscope an image of said other surface, and said microscope is moved along its 75 principal axis relative to said support member to focus it, at will, on said one surface, or on said image.

7. A method as claimed in claim 6 wherein said microscope is focused on said 80 one surface or on said image by moving it along its principal axis.

8. A method as claimed in claim 6 wherein said microscope is focused on said one surface or on said image by moving said 85 support member along said principal axis.

9. Apparatus for inspecting opposed surfaces of a small object substantially as herein described with reference to and as illustrated in the accompanying drawings. 90

10. A method of inspecting opposed surfaces of a small object substantially as herein described with reference to the accompanying drawings.

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increase the magnification of the microscope 23 to 40X and performs a second more detailed inspection of the same inactive side 14 of the deposited circuit 11 for the aforementioned mechanical defects. He then rotates the knob 29 to move the microscope 23 to its lower position along its axis 27, as shown in FIG. 5, and focuses the microscope 23 on the image reflected by the mirror 35 of the active side 13 of the circuit 11 being inspected. This places the inactive side 14 outside the now decreased depth of field of the microscope 23 and renders the side 14 invisible.

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45 2. Apparatus as claimed in claim 1 wherein said microscope is mounted to a base member, said support member is mounted to a slide member, said slide member is so arranged with respect to said base member as to permit movement of said support member transverse to said 50 principal axis, and there is provided means

for supplying pressurised fluid, said slide member and said base member being so adapted and arranged as to substantially not contact each other when said pressurised fluid is supplied between them.

3. Apparatus as claimed in claim 1 or 2 wherein said means for moving said microscope relative to said support member is adapted to move said microscope.

4. Apparatus as claimed in claim 1 or 2 wherein said means for moving said microscope relative to said support member is adapted to move said support member.

5. Apparatus as claimed in any one preceding claim wherein said microscope is of adjustable magnification.

6. A method of inspecting opposed surfaces of a small object wherein said object is supported with one of said surfaces facing a microscope, and the other of said surfaces adjacent the surface of a transparent support member and spaced apart from means arranged to reflect to said microscope an image of said other surface, and said microscope is moved along its principal axis relative to said support member to focus it, at will, on said one surface, or on said image.

7. A method as claimed in claim 6 wherein said microscope is focused on said one surface or on said image by moving it along its principal axis.

8. A method as claimed in claim 6 wherein said microscope is focused on said one surface or on said image by moving said support member along said principal axis.

9. Apparatus for inspecting opposed surfaces of a small object substantially as herein described with reference to and as illustrated in the accompanying drawings.

10. A method of inspecting opposed surfaces of a small object substantially as herein described with reference to the accompanying drawings.

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