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DRAWINGS ATTACHED

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(19)

(54) HANDLING BEAM-LEADED DEVICES

(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 manufacture of beam-leaded integrated circuit devices.

Following their fabrication and etch-apart, beam-leaded devices are typically received at a testing station disposed in wax on a sapphire disc, with the beam leads arranged in an X-Z configuration and the devices having a fixed centre-to-centre spacing. Each device is electrically tested and thereafter forwarded to a further location for storage or preparatory to bonding; or discarded if found unsatisfactory.

Numerous systems for facilitating device handling at this stage have been proposed. The handling time and device yield rate for this stage have nevertheless remained unsatisfactory. One problem is that previous systems, insofar as is known, typically require a transfer of each device from its mounting wax to a carrier prior to testing and thereafter to a test pad. Device alignment is often disturbed; and to avoid incorrect test results, it is necessary to realign each device before testing. In other instances, electrical back-probing of the devices with needle probes is attempted while they are still disposed in the wax. Too frequently, however, the needles cause the beam leads to yield laterally and thus destroy the close tolerances needed for later bonding.

Another problem in many systems is that the pickup tools are not versatile enough to test and bond in one sequence with reliable, accurate positioning of the device at each step. Some present compliant pickup tools, for example, cannot bond a device to a substrate and can only tack-bond if the substrate is heated.

According to one aspect of the invention, there is provided a method of handling beam-leaded devices that are initially arrayed in mounting wax on a substrate with the leads of each device orientated in a particular way in a plane parallel with the face of the substrate, the method comprising the steps of successively moving the substrate to bring the devices successively to a first fixed position, aquiring each device from said wax at said first fixed position by pulse-heating a head of a pickup tool to effect a light tack bond to the beam leads and also lightly vacuum-holding that device to the head, and moving the pick-up head without disturbing said orientation of the device relative to planes parallel with said face of said substrate.

Preferably, a second fixed position to which the head is moved is at a test station and is constituted by a compliant pad having test leads orientated in a particular way relative to said planes, the method comprising the further step of moving the head and an acquired said device from the test station. An acquired device is easily disengaged by applying a gas blast via the head.

According to another aspect of the invention, there is provided apparatus for handling beam-leaded devices that are initially arrayed in mounting wax on a substrate with the leads of each device orientated in a particular way in a plane parallel with the face of the substrate, the apparatus comprising a pickup tool movable to place a head thereof at a first fixed position, substantially in contact with a said device to be picked up by pulse-heating the head to melt adjacent mounting wax and lightly vacuum holding said device to the head the pickup tool being movable without disturbing the orientation

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of a said device acquired by the head which has terminals for applying a heating electric pulse and a part for pressure reduction to effect said vacuum holding.

Preferably, the head comprises a block having bulk electrical conductivity and a chamber extending inwardly to said part from one surface of the block, the edges of the chamber being substantially rectilinear and electrically insulative. The block may comprise titanium carbide with a layer of titanium dioxide at said edges.

In one embodiment, the block is a thermal pulse-heated, four-sided block made of titanium carbide. The block contacts all beam leads; and defines an interior chamber to accept the silicon body of the device. The pickup-assisting vacuum is drawn on this chamber. Where device discard is indicated a pulse of air under pressure is applied to the chamber to release the device beam leads.

A mounting wax is used that is liquid in the range of 100-300°C. The heating pulse is alternating current of the order of 100 amperes applied for approximately a second, bringing the head of the tool to a peak temperature of about 950°C. The resulting device temperature peak is, however, only about 300°C.

In operation, the device-carrying sapphire disc is aligned, by optical methods for example, with respect to a particular, preselected head movement. Specifically, the disc is aligned to bring the beam leads into the same X-Z sense as the pickup edges of the head. The head then is indexed to a position over a selected one of the devices, and lowered to bring its edges into contact with the beam leads under a predetermined downward force. A current pulse is applied through the head, heating the head which melts the wax beneath and around the device being picked up, and also effects a tack bond of the leads to the edges of the head. A vacuum of about 10 inches of Hg also is drawn on the chamber to aid in pickup.

Thus acquired, the device is lifted from the wax, without any wax clinging to the body or leads and without altering the position of neighbouring devices. The head is indexed to a test pad with leads conforming in geometry to the device beam leads. The pad is compliant in the vertical direction to accommodate possible elevation differences among the beam leads. A full range of dynamic tests are then automatically made to guage the designed ac characteristics of the device.

After testing, the head is indexed to any one of several possible subsequent stations. The device can, for example, be directly bonded by bringing the head into position with respect to a circuit substrate, where a suitable further electrical pulse reheats the tool thus to effect a full bond. Alternatively, the tool can be heated to effect a tack bond which later is augmented by compliant or other bonding techniques in a separate fixture. Or, if desired, the devices can be sequentially spaced by the head into wax on a carrier for storage.

A device may be reinserted into the wax and disengaged from the tool by reheating the tool and then allowing the carrier wax to solidify around the device before vertically indexing the head. Devices may be placed in regular patterns on either hard carriers or on carriers covered with a layer of soft, tacky material by pressing against the surface and removing the vacuum. This deposition is facilitated by introducing low gas pressure into the chamber of the tool. Devices may be discarded by application of a gas pressure burst to the chamber.

Details of preferred practical implementation of the invention will now be given, by way of example, with reference to the drawings, in which:

Fig. 1 is an isometric view showing an overall system embodying the invention;

Fig. 2 is a side perspective diagram illustrating features of the pickup tool;

Figs. 3, 4 and 5 are perspective schematic diagrams illustrating operating sequences for the tool;

Fig. 6 is a frontal perspective view of a test fixture; and

Fig. 7 is a schematic perspective diagram of a development of the embodiment of Fig. 1.

In Fig. 1, at a pickup station 10, a large number of beam-leaded devices 11 are arrayed in a wax. Their alignment is established in the wax during the previous etch-apart step. The wax rests on a sapphire disc 12. A pickup tool 13 is mounted for precision movement to and from fixed, preselected points of the X-Y plane of the fixed coordinate system denoted 9. Said movement is denoted by the paths 13*a*. The pickup station 10 is mounted on a step-and-repeat table 8, whose position is controllable in the X-Z plane. Thus, suitable indexing of the table 8 brings successive one of the devices 11 into coincidence with the fixed pickup point defined for the tool 13.

A test fixture 15, also positionable in the X-Z plane by means (not shown) similar to table 8, for example, is normally fixedly located with its test pad in coincidence with the fixed test point defined for the tool 13. Further, station 16 represents a substrate bonding station or, alternatively, a storage carrier; and is also positionable in the X-Z plane to enable the tool 13 to coincide with bonding points or to array the devices on a carrier in a desired X-Z array. Devices rejected by fixture 15 are segregated, as by placement in reject bin 7.

The positioning of devices 11 in the wax on disc 12 typically follows a centre-to-centre spacing of about 0.070 inch, the exact spacing depending upon the size of the device and the spacing between devices. Hence, an initial orientation of the entire disc 12 within the X-Z plane followed by a step-and-repeat indexing of table 8 enables the tool to pick up successive devices for their individual testing and later disposition. In all instances, only one pickup of a device is necessary; and given proper positioning of the sapphire disc 12 at the outset, no individual device alignment thereafter is necessary.

The tool 13, as depicted in Fig. 2, comprises a block-shaped head 14 having an interior chamber 14*a* defined by exterior edges 14*b*. A typical width of an edge 14*b* is 5 mils; and each edge typically is 0.067 inch on a side, these dimensions being dictated by the beam-leaded device size. An orifice 17 opening into the chamber 14*a* connects to a pneumatic line 27*a* (Fig. 1).

The head 14 is supported by welding to platinum strips 18, 19. The strips 18, 19 in turn are welded to mounting ears 20, 21 which advantageously are of nickel and make ohmic contact with said strips. A fastening hole 22 in each mounting ear 20, 21 serves to affix the tool 13 to a precision movement system denoted by indexer 25a in Fig. 1. Blocks 24 respectively flanking strips 18 and 19 are heat-insulating pads through which mechanical pressure is applied by clamp 23 (Fig. 3) to press strips 18 and 19 against head 14. Electrical current is passed to head 14 via platinum strips 18 and 19, wires 23*a* and pulser 26.

The head 14 is an electrical insulator at its exterior surfaces such as edges 14*b*, in order not to interfere with electrical testing of devices supported by the tool. At the same time, the head 14 must be a bulk conductor capable of heating rapidly on the application of current pulses.

Conveniently, head 14 is of titanium carbide, the exterior of which has been oxidised to a depth in the angstrom unit range. The titanium dioxide film provides the desired insulation layer, exhibiting a working breakdown voltage of 100 volts. Additionally, dc resistance between the tool and the beam leads is at least 30 megohms, and capacitance between the tool and a 2-mil wide beam lead is about 0.17 pF at 100 MHz.

The bulk titanium carbide is directly contacted by the strips 18, 19 which conduct the current pulses for heating. The oxide layer at edges 14*b* readily effects a tack bond to the device beam leads. The choice of titanium carbide thus is advantageous because of its resistance to high temperatures; its readiness to accept a tenacious surface oxide layer which tack bonds to gold, and its bulk conductivity enabling it to be quickly heated.

Returning to Fig. 1, the system advantageously comprises in addition to indexer 25*a*, indexer 25*b*, pulser 26, a pneumatic source 27, a test circuit 41, and a master control 29. The indexer 25*a* on instruction from control 29 sequentially moves the tool 13 to several specified X-Y coordinates in the course of a testing cycle. Indexer 25*b* also sequentially positions table 8 as earlier described. The pulser 26, pneumatic source 27 and test circuit 28 are also connected to, and are under the control of, master control 29.

Figs. 3, 4 and 5 depict the picking up by the head 14 of a beam-leaded device. In Fig. 3, table 8 is indexed to the pickup position of head 14, and the head then is lowered until its edges 14*b* contact the beam leads 30 of a particular device 11*a*. The force of the tool against the leads is approximately 500 grams, for example. At this stage, the wax 31 in which the device 11*a* is embedded is in its solid state. With the head edges 14*b* in contact as in Fig. 4, an electrical pulse of approximately 100 amperes is applied by pulser 26 through the head for a duration of about one second to heat the head. The wax beneath and around the head melts, while concurrently a tack bond is effected between the edges 14b and some or all of the beam leads 30. During this period, a vacuum from source 27 is applied to chamber 14*a* through line 27*a*, the vacuum amounting to approximately 10 inches of Hg.

After the bonds to the leads are made and while the wax is still molten, the pickup head is indexed vertically, as in Fig. 5, drawing with it the beam-leaded device 11*a*. The electrical heating pulse may be removed before the wax is molten as the hot tool will supply the heat necessary to melt the wax.

Since the head is only intermittently heated, less thermal energy is generated than in systems using continuously heated heads. In consequence, device temperatures stay well below levels as, for example, the gold-silicon eutectic point of 380°C., where damage could occur. For example, peak head temperatures at the level of 1000°C. have been measured, but concurrent device temperatures not in excess of about 300°C. were recorded.

The test fixture 15 is detailed in Fig. 6 and consists of a pressure plate 35 on top of which is located resilient pad 36. On top of the resilient pad is a material layer 37 which serves the purpose of supporting gold-plated copper conductors 39 in precise alignment so as to contact the leads of the device 11 when it is lowered by tool 14. An alumina substrate 38 above the layer 37 incorporates gold conductors 42, which extend to the test orifice 40 in the substrate 38 and connect ultimately to test circuit 41. The conductors 42 on substrate 38 make ohmic contact with conductors 39 on the layer 37 by the pressure

supplied by resilient pad 36.

A device to be tested is lowered through the orifice 40 and into contact with the conductors 39 where upon the tests are performed and the results sent to control 29.

Device pickup and testing can be accomplished within about five seconds per device; less in many instances. One hundred percent testing of all devices can thus be substituted for the back probing widely used heretofore. A device not passing electrical tests is readily blown off the handling tool by indexing the tool 13 to the reject bin 7 and applying a pneumatic pulse of approximately 20 psi through the head orifice 17. Devices passing the electrical test are attached in their final position on a substrate such as 50 at the mounting station 16. Alternatively, the passed devices are deposited onto a carrier such as a glass covered with an appropriate soft material, one example of which is "Sylgard" (Registered Trade Mark), a product of the Dow Corning Company.

When the device is brought into contact with a substrate such as 50 for bonding, the head 14 is pulse-heated to form either a tack bond or a final bond. In either case, advantageously, the substrate remains at ambient temperature. If the handling tool is to achieve final bond, a suitable form of force compensation must be provided, such as rocking the tool to contact the beam leads essentially one at a time.

Fig. 7 depicts a possible production line arrangement consisting of four stations denoted A, B, C, and D, each coupled into a common test circuit 41*a*. Each of the stations A to D may be substantially identical to that depicted in Fig. 1. The stations time share the test circuit 41*a* in accordance with any suitable time-sharing technique.

WHAT WE CLAIM IS:—

1. Apparatus for handling beam-leaded devices that are initially arrayed in mounting wax on a substrate with the leads of each device orientated in a particular way in a plane parallel with the face of the substrate, the apparatus comprising a pickup tool movable to place a head thereof at a first fixed position, substantially in contact with a said device to be picked up by pulse-heating the head to melt adjacent mounting wax and lightly vacuum holding said device to the head, the pickup tool being movable without disturbing the orientation of a said device acquired by the head which has terminals for applying a heating electric pulse and a part for pressure reduction to effect said vacuum holding.

2. Apparatus according to claim 1, wherein the head comprises a block having bulk electrical conductivity and a chamber extending inwardly to said part from one surface of the block, the edges of the chamber being substantially rectilinear and electrically insulating.

3. Apparatus according to claim 2, wherein the block comprises titanium carbide with a layer of titanium dioxide on said edges.

4. Apparatus for handling beam-leaded devices substantially as herein described with reference to and as shown in Figs. 1 to 6, or Fig. 7 of the drawings.

5. Method of handling beam-leaded devices that are initially arrayed in mounting wax on a substrate with the leads of each device orientated in a particular way in a plane parallel with the face of the substrate, the method comprising the steps of successively moving the substrate to bring the devices successively to a first fixed position, acquiring each device from said wax at said first fixed position by pulse-heating a head of a pickup tool to effect a light tack bond to the beam leads and also lightly vacuum-holding that device to the head, and moving the pickup head without distributing said orientation of the device relative to planes parallel with said face of said substrate.

6. Method according to claim 5, wherein a second fixed position to which the head is moved is at a test station and is constituted by a compliant pad having test leads orientated in a particular way relative to said planes, the method comprising the further step of moving the head and an acquired said device from the test station.

7. Method according to claim 5 or 6, comprising the further step of applying a gas blast from the head to disengage a said device.

8. Method according to claim 7, wherein the further step is carried out when the head together with an acquired said device is adjacent a discard bin.

9. Method according to claim 7 or 8, wherein the further step is, or is alternatively, carried out when the head together with an acquired said device is at a third fixed position relative to which a storage carrier is indexable in a said plane to bring successive selected regions thereof to said third fixed position to receive a said device.

10. Method according to claim 7 with claim 6, or claim 6, wherein after testing the head together with an acquired said device is moved to a bonding station for affixing successive devices to circuit substrates.

11. Method of handling beam-leaded devices substantially as herein described with reference to the drawings.

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Fig. 7 depicts a possible production line arrangement consisting of four stations denoted A, B, C, and D, each coupled into a common test circuit 41*a*. Each of the stations A to D may be substantially identical to that depicted in Fig. 1. The stations time share the test circuit 41*a* in accordance with any suitable time-sharing technique.

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2. Apparatus according to claim 1, wherein the head comprises a block having bulk electrical conductivity and a chamber extending inwardly to said part from one surface of the block, the edges of the chamber being substantially rectilinear and electrically insulating.

3. Apparatus according to claim 2, wherein the block comprises titanium carbide with a layer of titanium dioxide on said edges.

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6. Method according to claim 5, wherein a second fixed position to which the head is moved is at a test station and is constituted by a compliant pad having test leads orientated in a particular way relative to said planes, the method comprising the further step of moving the head and an acquired said device from the test station.

7. Method according to claim 5 or 6, comprising the further step of applying a gas blast from the head to disengage a said device.

8. Method according to claim 7, wherein the further step is carried out when the head together with an acquired said device is adjacent a discard bin.

9. Method according to claim 7 or 8, wherein the further step is, or is alternatively, carried out when the head together with an acquired said device is at a third fixed position relative to which a storage carrier is indexable in a said plane to bring successive selected regions thereof to said third fixed position to receive a said device.

10. Method according to claim 7 with claim 6, or claim 6, wherein after testing the head together with an acquired said device is moved to a bonding station for affixing successive devices to circuit substrates.

11. Method of handling beam-leaded devices substantially as herein described with reference to the drawings.

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