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(54) WIRE BONDING APPARATUS

(71) We, HITACHI LTD., a Japanese Company, of 1-5-1 Marunouchi, Chiyoda-ku, Tokyo, Japan, 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 wire bonding apparatus, especially such apparatus for use in semiconductor manufacturing processes.

Generally, in wire bonding processes in semiconductor manufacture, it is required to stretch the wire while preventing "pellet short" resulting from contact of wire with the pellet, "tab short" caused by contact of wire with the tab supporting the pellet and "lead short" resulting from contact of wire with a lead. For this purpose, when the wire which has been bonded at its one end to a first bonding spot is stretched from the first bonding spot to a second bonding spot, it is necessary first to draw out the wire from the feed capillary by a length of $l_0 + \alpha$ (l_0 being the length necessary for stretching from the first to the second bonding spot, and α being an additional extra length) and then draw in said extra length (α) of wire into the capillary immediately before the wire reaches the second bonding spot. If the necessary length (l_0) of wire alone is drawn out from the capillary and passed to the second bonding spot after completion of bonding at the first bonding spot, the wire extending out from the first bonding spot does not form a sufficiently large curve, that is, it describes only a small curve, so that the wire portion lying between the two bonding spots hangs down to cause the various "short" troubles mentioned above. In the case of nailhead bonding, it is necessary to draw the wires into the capillary such that the ball at the wire end contacts the bottom surface of the capillary.

In order to meet these requirements, a leaf spring has been provided in contact with the wire portion between the spool and the capillary so as to give tension to the wire. This method however is still unsatisfactory for

providing sufficient wire tension in a wire bonder. Because vibration is likely to be produced owing to use of a leaf spring, this method is undesirable in high-speed operation. It is also difficult in known means to give a desired curved configuration to the wire.

According to this invention there is provided wire bonding apparatus having means to receive a supply of wire, a capillary for holding the wire length extending in use from the wire supply at a region spaced therefrom, and wire tensioning means to act upon the wire between the wire supply and the capillary, the wire tensioning means having an orifice through which in use a gas jet is blown against the wire and two guide members arranged respectively on opposite sides of the gas jet and providing between them a space through which the wire passes. The guide members may be arranged so as to keep constant the flow rate of the gas between them. They are designed to regulate the flow of gas on both sides thereof.

One embodiment of the present invention will now be described by way of example with reference to the accompanying drawing, in which:—

Fig. 1 is a schematic illustration of the principal components of a wire bonder embodying the present invention; and

Fig. 2 is a partially cut away perspective view showing detail of the wire tensioning means.

Referring to Fig. 1, in the illustrated wire bonder a wire supply in the form of a spool 2 carrying a wire 1 wound thereon is loosely and rotatably fitted on a shaft 3 which is so arranged that air is ejected against the contacting inner surface of the spool 2. The air is ejected in a direction oblique to the radial direction of the shaft 3 so that the spool 2 is always urged in rotation in the direction of the arrow 4, thus continuously applying a back-tension to the wire.

The lower end portion of the length of wire 1 drawn out from the spool 2 passes

through a ring-shaped guide 5 and is held by a cylindrical feed capillary 6. By feed capillary, we means any suitable narrow tube through which the wire can pass. Provided between the guide 5 and the capillary 6 is a clamp 7 which, when required, is operated to clamp the wire 1 securely. There is also provided a wire tensioning means 8 acting upon the wire 1 between the capillary 6 and the spool 2. This wire tensioning means 8, as shown in Fig. 2, has a nozzle 10 having at its end an aperture or orifice 9 from which a gas jet is ejected, and a pair of flat guide plates 11, 12 mounted at the end of the nozzle 10. The guide plates 11 and 12 are suitably spaced apart from each other to form a space 13 along which the gas jet from orifice 9 passes and through which the wire 1 is fed.

This apparatus may be operated as follows. First, a hydrogen flame 14 is applied to the end of the wire 1 projecting from the lower end of the capillary 6 to fuse the wire end into a ball-like mass 15. Then the clamp 7 is opened to release the wire 1 and the wire is pulled back into the capillary until the ball-like mass 15 contacts the bottom surface of the capillary. The capillary 6 is then lowered down onto the electrode portion, or the first bonding point 18, of the pellet 17 on the tab 16 to perform bonding. After bonding the capillary 6 is raised, then moved horizontally to a point above the lead 19. By this movement the wire is drawn out by the length $l_0 + \alpha$ (as above described). When the capillary 6 is again lowered to press against the second bonding point 20, the wire is pulled back into the capillary by the length α by the back tension. The second bonding is then performed. The wire 1 is secured by the clamp 7 and both the clamp 7 and capillary 6 are raised after the wire 1 is cut at a point close to the second bonding point 20. As a result, a wire loop 21, such as shown by the chain line in Fig. 1 is formed and wire bonding is completed.

During this operation, the wire 1 is urged laterally under pressure of the gas jet from the orifice 9, but the lower end of wire is held for example by the clamp 7 or engagement of the ball-like mass 15 with the capillary while the upper end is pulled upwardly by the back tension applied by the spool 2. Consequently, the wire 1 forms a curve such as shown by the full line in Fig. 1 in a state of equilibrium between the back tension applied at its upper end and the gas pressure applied to the wire by the jet. It will therefore be understood that when the capillary 6 descends rapidly, wire 1 is a once deformed for example to curve 22 shown by the chain line in Fig. 1 but restores itself to its original shape by re-establishment of the above-mentioned equilibrium, i.e. wire 1 is drawn out against the back tension of the spool 2

since the gas pressure exerted on the wire 1 by the jet in the position of curve 22 is greater than in the equilibrium position shown by the full line of Fig. 1. Even if this drawing-out action cannot instantaneously follow a sharp descending motion of the capillary 6, an excessive tension is not developed in the metal wire since the rapid motion is accommodated by deformation, e.g. to the curve 22, of the portion of the wire 1. Therefore, the risk of break of the wire is minimized.

Also, since the gas flow from the orifice 9 is guided at both its sides by the pair of guide plates 11, 12, its flow rate does not fall or does not fall greatly with increasing distance from the orifice 9. Therefore, constant tension is always obtained in the wire 1. Thus, since the wire 1 is always under a desired constant tension, the extra wire portion (i.e. length α) extending out from the capillary end, that is, the wire portion drawn out in addition to the length l_0 required to provide the bonded wire loop, is drawn back into the capillary 6 by the tension at a point just before the second bonding is practiced. Therefore, the wire loop formed should not hang down undesirably and a desired tall loop is formed.

As described above, in this embodiment of the invention, the wire 1 is passed through the space 13 between the pair of guide plates 11, 12 while acted upon by the pressure of gas ejected from the orifice 9. Since the gas flow is guided uniformly to the terminal ends of the guide plates 11, 12 owing to presence of these plates, constant tension is always given to the wire 1 even if the curve of the wire 1 is changed during the bonding operation. As a result, the bonded wire can form a curve of the most desirable configuration to prevent "short" trouble such as "pellet short", "tab short" or "lead short" of the semiconductor device.

The present invention is not limited to the particular embodiment shown and described hereabove. For instance, the pair of guide plates may be arranged parallel to each other or in such a way that the space between them is narrowed down in the direction of gas flow so as to compensate for decrease of the gas flow rate.

With the illustrated wire bonder, wire feed can be performed smoothly and the risk of wire break, even if the wire bonding operation is carried out at high speed, is non-existent or low. Consequently, operating efficiency of the wire bonder is improved. Also, since constant tension can always be applied to the wire, wire bonding is performed always in a preferred manner. Therefore, the risk of "short" trouble is zero or minimized and the yield is improved.

Thus by the present invention it is possible to provide a wire bonder equipped with a

wire tensioning mechanism whereby resistance of the wire drawn out from a capillary as well as wire retracting force is kept constant independently of the feed speed, even with high-speed wire bonding.

WHAT WE CLAIM IS:—

1. Wire bonding apparatus having means to receive a supply of wire, a capillary for holding the wire length extending in use from the wire supply at a region spaced therefrom, and wire tensioning means to act upon the wire between the wire supply and the capillary, the wire tensioning means having an orifice through which in use a gas jet is blown against the wire and two guide members arranged respectively on opposite sides of the gas jet and providing between them a space through which the wire passes.
2. Wire bonding apparatus according to claim 1 wherein the said two guide members are a pair of spaced guide plates.
3. Wire bonding apparatus according to claim 1 or claim 2 wherein means for providing back tension in the said wire length are provided.
4. Wire bonding apparatus according to claim 3 wherein the means to receive a supply of wire is adapted to receive a spool, there being provided means to urge the spool in rotation so as to produce a back tension in the wire extending therefrom.
5. Wire bonding apparatus according to claim 4 wherein said urging means produces

said back tension by means of a gas blown against the spool.

6. Wire bonding apparatus according to claim 5 wherein the means to receive the spool has a shaft on which in use the spool is rotatably mounted by means of an air bearing in which air is blown against the spool with a non-radial component with respect to the shaft so as to produce said back tension.

7. Wire bonding apparatus according to any one of the preceding claims wherein the means to receive the wire supply, the wire tensioning means and the capillary are arranged so that the wire extending in use from the wire supply to the capillary presents a curved shape in the wire tensioning means, the wire tensioning means permitting shifting of the position of the curved shape, when wire is pulled out, so as to shorten the wire length between the capillary and the wire supply:

8. Wire bonding apparatus according to any one of the preceding claims having a clamp for the wire between the wire tensioning means and the capillary.

9. Wire bonding apparatus substantially as herein defined with reference to and as shown in the accompanying drawing.

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