

SPECIFICATION

Method of Forming a Wire Bond

The invention relates to a method of forming a wire bond between a contact place on an electric microcircuit and a connection conductor, in which method a wire of aluminium or an aluminium alloy is passed through a capillary and a ball is formed at the end of the wire by means of a spark discharge between the wire and an electrode, which spark discharge takes place in a protective gas atmosphere, after which the wire is bonded by means of the capillary to the contact place on the electronic microcircuit and thereafter the wire is bonded to the connection conductor.

For making a wire bond between a contact place on, for example, a semiconductor body and an electric conductor it has proved favourable to use a ball bond in adhering the wire to the semiconductor body. The ball can be connected to the contact place by means of an ultrasonic welding tool and/or by means of a thermocompression bond. In the case of a gold wire the ball can preferably be formed by means of an electric spark discharge. The formation of a ball at a wire made of aluminium or an aluminium alloy, however, presents difficulties.

It has already been suggested to form a ball at the end of an aluminium wire by means of an electric spark discharge by contacting the wire and the electrode with each other for a short period of time at a voltage difference between the wire and the electrode of less than 200 V and in a protective gas atmosphere. The end of the wire melts and the contact is interrupted, as a result of which a spark discharge takes place and the ball is formed. The protective gas serves to prevent oxidation while forming the ball. This method of providing the ball, in which contact between the wire and the electrode is necessary, is complicated for mass production. Furthermore excessive wear of the electrode occurs which therefore has often to be replaced.

It has also been suggested to arrange that the end of the wire and the electrode have a small separation and a voltage difference of 350 to 10,000 Volts, so as to obtain a spark discharge. The ohmic resistance in the discharge current circuit is chosen to be so that the peak value of the current density in the wire cross-section is $1.2 \times 10^9 \text{ A/m}^2$ to $13.5 \times 10^9 \text{ A/m}^2$. However, it is to be preferred to cause the spark discharge to take place at a lower voltage. In addition, in this known method a very small distance, approximately 0.125 mm, must be adjusted rather accurately between the wire end and the electrode. However, in mass production it is undesirable to depend on an accurate adjustment and the distance between the wire end and the electrode is furthermore preferably chosen to be considerably larger than in the known method.

It is the object of the invention to provide a method in which a spark discharge is obtained with the use of a comparatively small voltage difference between the wire end and the

electrode, and in which the mutual distance between these two may be comparatively large and need not be accurately adjusted.

According to the invention a method having the steps mentioned in the opening paragraph is characterized in that an electric spark discharge is produced between two auxiliary electrodes such that a plasma is formed by ionisation of the protective gas, and in that the ball is formed at the end of the wire by an electric spark discharge which is produced between the electrode and the wire at a voltage between 25 and 200 V due to the low resistance in the plasma.

The discharge between the auxiliary electrodes between which a rather large voltage difference may be formed produces a plasma in the protective gas. The resistance of the plasma is very low as compared with the resistance of the unionised gas. As a result of this, with a comparatively small voltage difference between the electrode and the wire, a spark discharge is produced which forms the ball at the wire. The spacing between the electrode and wire end is not critical; when the resistance of the gas becomes sufficiently low the ball-forming spark discharge will take place automatically.

Using this method, which is suitable for mass production, a ball of a readily reproducible size is formed at a wire made of aluminium or an aluminium alloy. This size depends on the voltage difference between the electrode and the wire and on the electric charge; it has been found that in order to obtain a good shape of the ball the voltage difference should preferably be smaller than 200 V.

In a favourable embodiment of a method in accordance with the invention the plasma is formed by a spark discharge by means of an ignition coil, the voltage between the auxiliary electrodes being the range of 10,000 to 20,000 Volts. In that case only simple means are necessary to form the plasma in the protective gas.

It is recommendable for the spark discharge between the electrode and the wire to be obtained at a voltage difference from 50 to 100 v by discharge of an electric capacitor.

In a preferred embodiment of the method in accordance with the invention the spacing between the electrode and the end of the wire is kept at approximately 2 mm during the formation of the ball. Although the spacing can be chosen to be larger or smaller, the spacing of approximately 2 mm has proved to be suitable both for mass production and to obtain a favourable ball shape.

The invention will now be exemplified by an embodiment with reference to the accompanying drawings, in which:

Fig. 1 shows diagrammatically a device for providing a wire bond,

Figs. 2 to 4 are a longitudinal sectional view, a plan view and a front elevation, respectively, of an apparatus in which the ball is formed at the wire,

Fig. 5 shows an electric circuit to obtain the spark discharge,

Figs. 6 to 8 show schematically the bonding of the wire to the electronic microcircuit and to a current conductor respectively.

Fig. 1 shows an ultrasonic generator 1 pivoted about an axis 2 which is incorporated in a support 3. The welding arm 4 of the generator 1 has a capillary 5 through which a wire 6 of aluminium or an aluminium alloy is passed. A ball is to be formed at the end of the wire 6. For that purpose, the wire is guided into a slot 7 of a spark unit 8 (see also Figs. 2, 3 and 4). The body of the spark unit consists of an insulating material, for example a synthetic resin. A bore 9 opens into the slot 7 through which a protective gas, for example argon, can be passed via a hose 10. An electrode 11, as well as two auxiliary electrodes 12 and 13, are incorporated in the spark unit 8. The spacing between the ends of the auxiliary electrodes is preferably approximately 2 mm. The spacing between the electrode 11 and the end of the wire 6 is also approximately 2 mm. The spark unit can be rotated about a shaft 19 and can thus be moved towards and also away from the capillary 5.

The Fig. 1 device also comprises a support 14 on which a slide 15 is present. A conductor grid may be placed on the slide 15. An electronic microcircuit in the form of a semiconductor device 17 is present on a supporting part 16 of the conductor grid. The device 17 has contact places to provide an electrically conductive wire. The wire is guided from a contact place of the semiconductor device 17 to a conductor 18 of the conductor grid.

The formation of a ball at the wire 6 of aluminium or an aluminium alloy will be explained with reference to Figs. 2 to 5. The end of the wire 6 is provided in the slot 7 of the spark unit 8. A protective gas, for example argon, is passed into the slot via a bore 9; the gas flow preferably takes place for a short period of time, namely only during the formation of the ball. Between the auxiliary electrodes 12 and 13 a voltage difference is generated, preferably of 10,000 to 20,000 Volts by means of an ignition coil so that a spark discharge takes place. Said spark discharge causes a plasma in the protective argon gas. As a result of this the electric resistance in said gas drops to a very low value. A voltage difference of 200 V or less, preferably approximately 70 V, is maintained between the electrode 11 and the end of the wire 6.

As a result of the low value of the electric resistance in the plasma a spark discharge may take place between the electrode 11 and the end of the wire 6, in spite of the fact that the spacing between the two may be comparatively large; for example it may be 2 mm. As a result of the spark discharge a ball is formed at the end of the wire, the size of said ball being readily reproducible.

Fig. 5 shows diagrammatically a circuit arrangement to generate a spark to form a ball at the aluminium wire. A pulse 20 originating from a monostable multivibrator (not shown) brings the base of a transistor 21 to a sufficiently high

voltage to cause current to flow through the transistor. As a result of said current the base of a transistor 22 is brought to such a voltage that current also flows through transistor 22. The current through transistor 22 is sufficiently large to control a high-voltage transistor 23; current flows through the primary 24 of an ignition coil 26. At the end of the short pulse 20, the transistors 21, 22 and 23 successively switch off and the current in the primary 24 of the ignition coil suddenly drops to zero. By induction, a high voltage, for example 20,000 V, is generated in the secondary 25 of the ignition coil. As a result of this the electric spark discharge is formed between the electrodes 12 and 13 and a plasma is formed in the protective argon gas.

An electric capacitor 27 is connected between the wire 6 and the electrode 11. The capacitor is connected to a voltage source and is hence charged. As a result of the low resistance in the plasma the capacitor 27 will discharge while forming a spark between the electrode 11 and the end of the wire 6. The ball is thus formed at the end of the wire.

The voltage across and the capacitance of the capacitor 27 can be chosen depending on the diameter of the wire at which the ball is formed. For example, it has proved to be advantageous with a wire having a diameter of 200 μm to use a capacitor of 500 μF with a voltage difference of 70 V. With a wire having a diameter of 40 μm a favourable ball shape was obtained by discharge of a capacitor of 15 μF with a voltage difference of 70 V.

Figs. 6 to 8 show the bonding of the wire at one end of the semiconductor device 17 and at the other end to a current conductor 18.

On the slide 15 also shown in Fig. 1 a conductor grid is placed having a supporting part 16 on which a semiconductor device 17 is connected. The current conductor is referenced 18. The capillary 5 having therein the wire 6 at which a ball has been formed is present above a contact place on the semiconductor device 17.

The capillary is moved towards the semiconductor device, for example by pivoting the ultrasonic generator 1 about shaft 2 (Fig. 1). When the ball pressed against the contact place on the semiconductor element the bond is produced by means of ultrasonic vibrations (Fig. 7), the ball being formed into a flat head. The capillary is then raised and moved towards a flat head. The capillary is then raised and moved towards the current conductor 18. The wire is clamped there between the conductor 18 and the lower side of the capillary and bonded to conductor 18 by means of ultrasonic energy. Fig. 8 shows the finished wire bond. The bond with the connection conductor has not necessarily to be made with the capillary, but can be done in any desired manner.

Claims

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connection conductor, in which method a wire made of aluminium or an aluminium alloy is passed through a capillary and a ball is formed at the end of the wire by means of a spark discharge

5 between the wire and an electrode, which spark discharge takes place in a protective gas atmosphere, after which the wire is bonded by means of the capillary to the contact place on the electronic microcircuit and thereafter the wire is

10 bonded to the connection conductor, characterized in that an electric spark discharge is produced between two auxiliary electrodes such that a plasma is formed by ionisation of the protective gas, and in that the ball is formed at the

15 end of the wire by an electric spark discharge which is produced between the electrode and the wire at a voltage between 25 V and 200 V due to the low resistance in the plasma.

2. A method as claimed in Claim 1,

20 characterized in that the plasma is formed by a

spark discharge by means of an ignition coil, the voltage between the auxiliary electrodes being in the range of 10,000 to 20,000 V.

3. A method as claimed in Claim 1 or 2,

25 characterized in that the spark discharge between the electrode and the wire is obtained at a voltage difference of 50 to 100 V by discharge of an electric capacitor.

4. A method as claimed in any of the preceding

30 Claims, characterized in that the spacing between the electrode and the end of the wire and the spacing between the auxiliary electrodes during formation of the ball is kept at approximately 2 mm.

5. A method as claimed in any of the preceding

35 Claims, characterized in that the protective gas is supplied only during the formation of the ball.

6. A method of forming a wire bond substantially as herein described with reference to

40 the accompanying drawings.

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