WIRE BONDING APPARATUS

[Technical Field]

[0001]

The present invention relates to a constitution of a bonding apparatus for bonding a wire to a bonding target.

[Background Art]

[0002]

A wire bonding apparatus for connecting an electrode of a semiconductor die and a lead of a lead frame to each other using a wire is often used. A wire bonding apparatus causes a capillary to perform ultrasonic vibration in a state in which a wire is pressed onto an electrode by the capillary, joins the wire and the electrode to each other, then lays the wire onto a lead, causes the capillary to perform ultrasonic vibration in a state in which the laid wire is pressed on the lead, and connects the wire and the lead to each other (for example, refer to Patent Literature 1).

[0003]

In a wire bonding apparatus, a direction of ultrasonic vibration of a capillary corresponds to an extending direction of an ultrasonic horn (which will hereinafter be referred to as a Y direction). For this reason, a shape of a joint portion between a wire and an electrode or a joint portion between a wire and a lead exhibits a shape extending in the Y direction that is the direction of ultrasonic vibration of a capillary, which may lead to poor joining.

[0004]

Hence, a structure in which a part between an ultrasonic horn and an actuator of the ultrasonic horn is constituted of a flexible coupling frame that is elastically deformable and a capillary is caused to vibrate in a Y direction that is a vibration direction of the actuator and in an X direction orthogonal to the Y direction has been proposed (for example, refer to Patent

clamping arms 31 open in the X direction that is an opening/closing direction, and the open dimension G becomes a fully-open dimension G0. Since the fully-open dimension G0 is larger than a diameter d of the wire 45, the clamping arms 31 release the wire 45.

[0029]

As indicated by a solid line a in Fig. 3, the applied voltage V with respect to the actuator 34 and the open dimension G at the tips of the clamping arms 31 substantially have a proportional relationship. If the applied voltage V is increased, the open dimension G at the tips of the clamping arms 31 also increases in accordance therewith. As illustrated in Fig. 3, when the applied voltage V is set to an applied voltage VB1 that is slightly lower than the open voltage V0, the open dimension G at the tips of the clamping arms 31 becomes a large open dimension G1 that is slightly smaller than the fully-open dimension G0 as in the clamping arms 31 indicated by the dashed line in Fig. 4. In addition, if the applied voltage V is set to an applied voltage VB2 that is lower than an applied voltage VB1, the open dimension G at the tips of the clamping arms 31 becomes a small open dimension G2 that is smaller than the large open dimension G1 as in the clamping arms 31 indicated by the one-dot dashed line in Fig. 4. Since the small open dimension G2 is larger than the diameter d of the wire 45, even when the open dimension G at the tips of the clamping arms 31 becomes the small open dimension G2, the clamping arms 31 do not touch the wire 45, and the wire clamper 30 maintains an open state. Therefore, if the applied voltage V is caused to fluctuate between the applied voltages VB1 and VB2, while the open state of the wire clamper 30 is maintained, the open dimension G at the tips of the clamping arms 31 can fluctuate in a dimension fluctuate range ΔG between the large open dimension G1 and the small open dimension G2. Here, in order to make the applied voltage V be a fluctuation voltage between the applied voltage VB1 and the applied voltage VB2, a median value between the applied voltage VB1 and the applied voltage VB2 may be set to a base

voltage VB, and the applied voltage V may be increased or decreased by a voltage range ΔV centering on the base voltage VB. The base voltage VB and the voltage range ΔV can be freely selected. For example, the base voltage VB may be a voltage within a range of 80% to 100% of the open voltage V0, and the voltage range ΔV may be a voltage within a range of 8% to 30% of the open voltage V0.

[0030]

The control unit 60 includes a clamper control unit 61 and a bonding control unit 62. The clamper control unit 61 adjusts the applied voltage V of the actuator 34 of the wire clamper 30 and causes the clamping arms 31 to perform an opening/closing operation. The bonding control unit 62 adjusts the Z-direction motor 27 upon an input of a signal from the piezoelectric element 17 and drives a tip of the capillary 41 in a contact/separation direction with respect to the substrate 52 or the semiconductor element 53. In addition, the bonding control unit 62 controls the XY driving mechanism 29 such that the position of the capillary 41 in the XY direction is adjusted. In addition, the bonding control unit 62 causes the horn main body 11 to perform ultrasonic vibration in the Y direction by driving the ultrasonic vibrator 16 of the ultrasonic horn 10.

[0031]

Next, with reference to Figs. 5A to 5C, 6A, and 6B, bonding operation of the wire bonding apparatus 100 having the foregoing constitution will be described.

[0032]

As illustrated in Fig. 5A, the clamper control unit 61 sets the applied voltage V of the actuator 34 of the wire clamper 30 to zero and causes the wire clamper 30 to be in a closed state such that the wire clamper 30 clamps the wire 45. The bonding control unit 62 generates sparks between a torch electrode (not illustrated) and the wire 45 extending from the tip of the capillary 41 and molds a lower end of the wire 45 into a free air ball 50.

[0033]

As illustrated in Fig. 5B, the clamper control unit 61 performs vibrations at a frequency f0 having the applied voltage V with respect to the actuator 34 of the wire clamper 30 within a range of the voltage range ΔV centering on the base voltage VB illustrated in Fig. 3.

[0034]

Accordingly, vibrations are performed at the frequency f0 having the applied voltage V with respect to the actuator 34 within a range of the applied voltage VB1 and an applied voltage VB2 illustrated in Fig. 3, and vibrations are performed at the frequency f0 having the open dimension G at the tips of the clamping arms 31 between the large open dimension G1 and the small open dimension G2 as illustrated in Fig. 4. In this manner, the clamper control unit 61 causes the clamping arms 31 to vibrate at the frequency f0 while the open state of the wire clamper 30 is maintained. Here, if the frequency f0 is set to a frequency close to a resonant frequency f1 at which the clamping arms 31 vibrate in the X direction, the clamping arms 31 laterally vibrate in the X direction centering on the elastic hinge 37 due to resonance as indicated by the arrow 96 in Fig. 6B. The frequency f0 need only be a frequency close to the resonant frequency f1 of vibrations of the clamping arms 31 in the X direction. When the resonant frequency of the clamping arms 31 is substantially 2 kHz, for example, the frequency f0 may be a frequency near 2 kHz, for example, a frequency within a range of approximately 1.9 kHz to 2.0 kHz. Since the clamping arms 31 are light, they can sufficiently vibrate in the X direction even at such a high frequency. Accordingly, even when bonding is performed within a short period of time, the number of vibrations at the tip of the capillary 41 in the X direction during bonding can be increased. The frequency f0 may be selected from a range such as $f1/\sqrt{2}<f0<f1\times\sqrt{2}$, for example, as long as it is a frequency at which the clamping arms 31 resonate in the X direction or may be selected from frequencies within a range of 80% to 120% of the resonant frequency f1

of the clamping arms 31 in the X direction.

[0035]

If the clamping arms 31 resonate, vibrations of the clamping arms 31 in the X direction are transferred from the bonding arm 20 to the ultrasonic horn 10. Here, the length Lc from the elastic hinge 37 of the wire clamper 30 to the tips of the clamping arms 31 corresponds to a length substantially similar to the length Lh from the flange 14 of the ultrasonic horn 10 fixed to the tip 21 of the bonding arm 20 to the positive side end of the horn main body 11 in the Y direction. For this reason, a resonant frequency f2 of the ultrasonic horn 10 in the X direction becomes a frequency close to the resonant frequency f1 of the clamping arms 31 in the X direction. For this reason, due to resonant vibration of the clamping arms 31 in the X direction transferred from the bonding arm 20, the ultrasonic horn 10 resonates in the X direction as indicated by the arrow 96 in Fig. 6A, and a tip of the horn main body 11 laterally vibrates in the X direction. Accordingly, the capillary 41 attached to the tip of the horn main body 11 vibrates in the X direction.

[0036]

On the other hand, the bonding control unit 62 applies a predetermined voltage to the ultrasonic vibrator 16 of the ultrasonic horn 10 and causes the ultrasonic vibrator 16 to perform ultrasonic vibration. Ultrasonic resonance in the Y direction is generated in the horn main body 11. Accordingly, as indicated by the arrow 92 in Fig. 5B, the tip of the capillary 41 vibrates in the Y direction.

[0037]

In this manner, the clamper control unit 61 causes the ultrasonic horn 10 and the tip of the capillary 41 to vibrate in the X direction by causing the clamping arms 31 to vibrate, and the bonding control unit 62 causes the tip of the capillary 41 to vibrate in the Y direction by driving

the ultrasonic vibrator 16. In this manner, in a state in which the tip of the capillary 41 has vibrated in the XY direction, the bonding control unit 62 operates the Z-direction motor 27 to press the capillary 41 to an electrode of the semiconductor element 53, thereby bonding the free air ball 50 to the electrode of the semiconductor element 53 as indicated by the arrow 91 in Fig. 5B.

[0038]

After bonding to the semiconductor element 53 ends, the bonding control unit 62 operates the Z-direction motor 27 to raise the capillary 41. In addition, the clamper control unit 61 sets the applied voltage V of the actuator 34 to zero and causes the clamping arms 31 to clamp the wire 45. Further, the bonding control unit 62 operates the Z-direction motor 27 and the XY driving mechanism 29 for looping of the tip of the capillary 41, thereby guiding it to a portion on the electrode of the substrate 52 as the arrow 93 illustrated in Fig. 5C.

[0039]

Here, similar to when bonding of the free air ball 50 is performed, the clamper control unit 61 performs vibrations having the applied voltage V of the actuator 34 of the wire clamper 30 at the frequency f0 close to the resonant frequency f1 of vibrations of the clamping arms 31 in the X direction. Accordingly, as indicated by the arrow 96 in Fig. 6B, the clamping arms 31 laterally vibrate in the X direction centering on the elastic hinge 37 due to resonance. In addition, as indicated by the arrow 96 in Fig. 6A, the tip of the horn main body 11 laterally vibrates in the X direction, and the tip of the capillary 41 vibrates in the X direction. In addition, the bonding control unit 62 causes the tip of the capillary 41 to vibrate in the Y direction by driving the ultrasonic vibrator 16 as indicated by the arrow 95 in Fig. 5C. Further, in a state in which the tip of the capillary 41 has vibrated in the XY direction, the bonding control unit 62 drives the Z-direction motor 27 to press the tip of the capillary 41 to the electrode