

DESCRIPTION

TITLE

BONDING APPARATUS, METHOD OF MEASURING AMPLITUDE OF BONDING TOOL, AND METHOD OF CALIBRATING AMPLITUDE OF BONDING TOOL

TECHNICAL FIELD

[0001]

The present invention relates to a structure of a bonding apparatus, a method of measuring amplitude of a bonding tool attached to the bonding apparatus, and a method of calibrating the amplitude.

BACKGROUND ART

[0002]

In manufacturing of electronic components, a wire bonding apparatus that connects an electrode of semiconductor attached to a substrate with an electrode of the substrate by a gold wire is typically used. Such a wire bonding apparatus presses a capillary as a bonding tool attached to a tip of an ultrasonic horn while vibrating the capillary by ultrasonic vibration to a semiconductor chip and an electrode of a substrate, thereby bonding a wire inserted through the capillary to each electrode.

[0003]

However, as amplitude at a tip of a capillary of a wire bonding apparatus is different with each apparatus depending on a natural frequency of an ultrasonic horn to which the capillary is attached or individual variability among ultrasonic vibrators, bonding characteristics often vary among

the wire bonding apparatuses, resulting in a problem with quality control.

[0004]

In order to address this problem, there is proposed a method of measuring a vibratory motion of a capillary using a laser Doppler vibrometer, and stopping bonding operation when the vibratory motion of the capillary does not match a predetermined condition (see Patent Literature 1, for example).

[0005]

Alternatively, there is proposed a method of acquiring images of a capillary while not in ultrasonic vibration and in ultrasonic vibration using a camera, measuring amplitude of the capillary by measuring an increase in the width of the capillary in the acquired images, and providing feedback of the measured amplitude to a control apparatus (see Patent Literature 2, for example).

Citation List

Patent Literature

[0006]

Patent Literature 1: Japanese Unexamined Patent Application
Publication No. 2007-142049

Patent Literature 2: Japanese Patent No. 3802403

SUMMARY OF INVENTION

Technical Problems

[0007]

Although the method described in Patent Literature 1 using the laser Doppler vibrometer is capable of measuring

amplitude of a capillary with high precision, it is necessary to attach a laser Doppler vibrometer for measuring amplitude of a capillary to a wire bonding apparatus. This poses a problem of increasing the size of the apparatus. In addition, according to the method described in Patent Literature 2 of processing images acquired using a camera, while it is possible to simplify a wire bonding apparatus as a camera provided for the apparatus can be used, it is difficult to clearly identify an outline of an acquired image, and thus posing a problem of low measurement precision.

[0008]

An object of the present invention is to provide a bonding apparatus capable of measuring amplitude of a bonding tool by a simple method with high precision.

Solution to Problems

[0009]

A bonding apparatus according to the present invention is provided with: a base section; an ultrasonic horn configured to longitudinally vibrate in a longitudinal direction in resonance with vibration of an ultrasonic vibrator; a bonding tool attached at an anti-node in the vibration of the ultrasonic horn, and configured to move toward and away from a target to be bonded; a flange attached at a node in the vibration of the ultrasonic horn, and configured to micro-vibrate in a direction in which the flange extends due to a load in the longitudinal direction applied at the node of the ultrasonic horn when the ultrasonic horn vibrates; a bonding arm having the ultrasonic horn fixed thereto by the flange; a load sensor provided at a

portion within the bonding arm, and configured to detect a load in the longitudinal direction of the ultrasonic horn applied to the bonding tool; and an amplitude measurement unit configured to convert a signal of the load detected by the load sensor when the ultrasonic horn is caused to vibrate by the ultrasonic vibrator where the bonding tool is placed under unloaded condition, and to measure amplitude of vibration of the bonding tool in the longitudinal direction of the ultrasonic horn.

[0010]

In the bonding apparatus according to the present invention, it is preferable that the flange is attached so as to extend along a direction perpendicular to the longitudinal direction of the ultrasonic horn and to a moving direction of the bonding tool, or that the bonding arm is monolithically molded with a metallic material, includes a first block having a flange attachment surface, a second block rotatably attached to the base section so as to cause a tip of the bonding tool to move toward and away from the target to be bonded, and a connecting plate connecting the first block with the second block, and is configured to deform due to the microvibration of the flange, thereby changing an interval between the first block and the second block in the longitudinal direction of the ultrasonic horn.

[0011]

In the bonding apparatus according to the present invention, it is preferable that the load sensor is offset in a moving direction of the bonding tool from a central axis of

the ultrasonic horn along the longitudinal direction, sandwiched between the first block and the second block, and configured to detect a load in the longitudinal direction of the ultrasonic horn applied between the first block and the second block, or that the amplitude measurement unit includes an analog-digital converter and a signal converting unit.

[0012]

A method of measuring amplitude of a bonding tool according to the present invention is provided with: preparing a bonding apparatus including: a base section; an ultrasonic horn configured to longitudinally vibrate in a longitudinal direction in resonance with vibration of an ultrasonic vibrator; a bonding tool attached at an anti-node in the vibration of the ultrasonic horn, and configured to move toward and away from a target to be bonded; a flange attached at a node in the vibration of the ultrasonic horn, and configured to micro-vibrate in a direction in which the flange extends due to a load in the longitudinal direction applied at the node of the ultrasonic horn when the ultrasonic horn vibrates; a bonding arm having the ultrasonic horn fixed thereto by the flange; a load sensor attached to a portion within the bonding arm, and configured to detect a load in the longitudinal direction of the ultrasonic horn applied to the bonding tool; and an amplitude measurement unit configured to convert a signal of the load detected by the load sensor and to measure amplitude of vibration of the bonding tool; causing the ultrasonic horn to vibrate using the ultrasonic vibrator while placing the bonding tool under unloaded condition; and causing the

amplitude measurement unit to convert the signal of the load detected by the load sensor, and to measure the amplitude of the vibration of the bonding tool in the longitudinal direction of the ultrasonic horn.

[0013]

In the method of measuring amplitude of a bonding tool according to the present invention, it is preferable that the flange is attached so as to extend along a direction perpendicular to the longitudinal direction of the ultrasonic horn and to a moving direction of the bonding tool, or that the bonding arm is monolithically molded with a metallic material, includes a first block having a flange attachment surface, a second block rotatably attached to the base section so as to cause a tip of the bonding tool to move toward and away from the target to be bonded, and a connecting plate connecting the first block with the second block, and is configured to deform due to the microvibration of the flange, thereby changing an interval between the first block and the second block in the longitudinal direction of the ultrasonic horn.

[0014]

In the method of measuring amplitude of a bonding tool according to the present invention, it is preferable that the load sensor is offset in a moving direction of the bonding tool from a central axis of the ultrasonic horn along the longitudinal direction, sandwiched between the first block and the second block, and configured to detect a load in the longitudinal direction of the ultrasonic horn applied between the first block and the second block, or that the amplitude

measurement unit includes an analog-digital converter and a signal converting unit.

[0015]

A method of calibrating amplitude of a bonding tool according to the present invention is provided with: preparing a bonding apparatus including: a base section; an ultrasonic horn configured to longitudinally vibrate in a longitudinal direction in resonance with vibration of an ultrasonic vibrator; a bonding tool attached at an anti-node in the vibration of the ultrasonic horn, and configured to move toward and away from a target to be bonded; a flange attached at a node in the vibration of the ultrasonic horn, and configured to micro-vibrate in a direction in which the flange extends due to a load in the longitudinal direction applied at the node of the ultrasonic horn when the ultrasonic horn vibrates; a bonding arm having the ultrasonic horn fixed thereto by the flange; a load sensor attached to a portion within the bonding arm, and configured to detect a load in the longitudinal direction of the ultrasonic horn applied to the bonding tool; a control unit configured to process a signal of the load detected by the load sensor; and an amplitude measurement unit configured to convert the signal of the load detected by the load sensor and to measure amplitude of vibration of the bonding tool; causing the ultrasonic horn to vibrate based on a reference applied voltage using the ultrasonic vibrator while placing the bonding tool under unloaded condition; causing the amplitude measurement unit to convert the signal of the load detected by the load sensor, and to measure the amplitude of the vibration of the bonding

tool in the longitudinal direction of the ultrasonic horn; and causing the control unit to compare the measured amplitude with target amplitude, and to change a voltage applied to the ultrasonic vibrator based on a result of the comparison such that amplitude of the vibration of the ultrasonic vibrator corresponds to the target amplitude.

[0016]

In the method of calibrating amplitude of a bonding tool according to the present invention, it is preferable that the flange is attached so as to extend along a direction perpendicular to the longitudinal direction of the ultrasonic horn and to a moving direction of the bonding tool, or that the bonding arm is monolithically molded with a metallic material, includes a first block having a flange attachment surface, a second block rotatably attached to the base section so as to cause a tip of the bonding tool to move toward and away from the target to be bonded, and a connecting plate connecting the first block with the second block, and is configured to deform due to the microvibration of the flange, thereby changing an interval between the first block and the second block in the longitudinal direction of the ultrasonic horn.

[0017]

In the method of calibrating amplitude of a bonding tool according to the present invention, it is preferable that the load sensor is offset in a moving direction of the bonding tool from a central axis of the ultrasonic horn along the longitudinal direction, sandwiched between the first block and the second block, and configured to detect a load in the

longitudinal direction of the ultrasonic horn applied between the first block and the second block, or that the amplitude measurement unit includes an analog-digital converter and a signal converting unit.

Advantageous Effects of Invention

[0018]

The present invention advantageously provides a bonding apparatus capable of measuring amplitude of a bonding tool by a simple method with high precision.

BRIEF DESCRIPTION OF DRAWINGS

[0019]

FIG. 1 is a diagram illustrating a structure of a wire bonding apparatus of an embodiment according to the present invention.

FIG. 2 is a plan view showing a lower surface of a bonding arm of the wire bonding apparatus of the embodiment according to the present invention.

FIG. 3 is a plan view showing an upper surface of the bonding arm of the wire bonding apparatus of the embodiment according to the present invention.

FIG. 4(a) and FIG. 4(b) are a diagram and a chart illustrating deformation of components when an ultrasonic horn of the wire bonding apparatus of the embodiment according to the present invention is caused to vibrate.

FIG. 5(a) is a chart showing amplitude measurement of a capillary of the wire bonding apparatus of the embodiment according to the present invention, and FIG. 5(a) is a chart

showing amplitude calibration of the capillary of the wire bonding apparatus of the embodiment according to the present invention.

FIG. 6 is a diagram illustrating a signal processing system of an amplitude measurement unit of the wire bonding apparatus of the embodiment according to the present invention, and charts showing a signal change.

DESCRIPTION OF EMBODIMENTS

[0020]

In the following, a preferred embodiment according to the present invention is described with reference to drawings. Referring to FIG. 1, a wire bonding apparatus 10 according to this embodiment includes a bonding head 11 as a base section, an ultrasonic vibrator 13, an ultrasonic horn 12, a capillary 17 as a bonding tool, a flange 14 provided for the ultrasonic horn 12, a bonding arm 21, a load sensor 31, a driving motor 45, an amplitude measurement unit 50, a control unit 60, and a bonding stage 33 to which a semiconductor chip 34 and a substrate 35 as targets to be bonded are suctioned and fixed. In FIG. 1, a longitudinal direction of the ultrasonic horn 12 corresponds to a Y-direction, a direction in which the capillary 17 moves toward and away from a surface of the substrate 35 or the semiconductor chip 34 corresponds to a Z-direction which is a height direction, and a direction perpendicular to the longitudinal direction of the ultrasonic horn 12 within a transversal plane along which the flange 14 extends corresponds to an X-direction.

[0021]

The bonding head 11 is provided with the driving motor 45 that rotationally drives the bonding arm 21. The ultrasonic vibrator 13 is configured as a layer of a plurality of piezoelectric devices, and attached to the ultrasonic horn 12 on a back end side. Further, the capillary 17 is attached to a tip of the ultrasonic horn 12. The flange 14 is provided at a position corresponding to a node in vibration of the ultrasonic horn 12 that will be later described, and the flange 14 is fixed to a flange attachment surface 22 of a tip of the bonding arm 21 using a fixing bolt 16.

[0022]

The bonding arm 21 is attached rotatably about a rotary shaft 30 provided for the bonding head 11. A rotational center 43 of the bonding arm 21 is positioned at the same level as a surface of the substrate 35 suctioned to the bonding stage 33 or as a surface of the semiconductor chip 34 attached to the substrate 35.

[0023]

The bonding arm 21 is a substantial rectangular cuboid that extends along a direction of a central axis 15 of the ultrasonic horn 12, and includes a front-end block 21a as a first block having the flange attachment surface 22 and a back-end block 21b as a second block having the rotational center 43. The front-end block 21a and the back-end block 21b are connected by a connecting plate 24 provided at a position corresponding to the central axis 15 of the ultrasonic horn 12 in the height direction (Z-direction). The front-end block 21a, the

back-end block 21b, and the connecting plate 24 are monolithically configured by a metallic material such as magnesium. In surfaces of the bonding arm 21 facing toward a bonding surface 41 and away from the bonding surface 41, narrow grooves 23 and 25 that separate the front-end block 21a from the back-end block 21b of the bonding arm 21 are respectively provided. In the upper surface of the bonding arm 21 in the Z-direction, which is the surface facing away from the bonding surface 41, a groove 26 for attaching the load sensor 31 is provided between the front-end block 21a and the back-end block 21b of the bonding arm 21. The connecting plate 24 is a section in a thin plate form between the groove 25 and the groove 23. [0024]

Referring to FIG. 1 and FIG. 2, in the surface of the bonding arm 21 facing toward the bonding surface 41, a depression 29 having a depth allowing the ultrasonic horn 12 and the ultrasonic vibrator 13 to be contained therein is provided. A depression 29a in the front-end block 21a is in a trapezoidal shape that spreads from the flange attachment surface 22 toward the back-end block 21b. A width of the depression on a side of the flange attachment surface 22 is slightly wider than that of the ultrasonic horn 12 so as not to be in contact with the ultrasonic horn 12, and a width of the depression on a side of the back-end block 21b is such that the ultrasonic vibrator 13 can be contained within the depression. An upper section of the front-end block 21a without the depression 29a constitutes a solid block in a substantial rectangular cuboid. A depression 29b in the back-end block 21b

is a rectangular depression having the same width as the depression of the front-end block 21a on a back end side. An upper section of the back-end block 21b without the depression 29b constitutes a solid block in a substantial rectangular cuboid.

[0025]

Referring to FIG. 1 and FIG. 3, the load sensor 31 attached to the groove 26 is configured to be sandwiched and pressurized between the front-end block 21a and the back-end block 21b using a screw 27 screwed from the front-end block 21a toward the back-end block 21b of the bonding arm 21. The load sensor 31 is attached such that a central axis 28 of the load sensor 31 is offset by a distance L from the central axis 15 of the ultrasonic horn 12 in the Z-direction in which the bonding surface 41 and a tip 17a of the capillary 17 approach and separate from each other. Further, referring to FIG. 3, the load sensor 31 is attached to a central portion of the bonding arm 21 in the across-the-width direction, and the screw 27 is provided on either side of the load sensor 31.

[0026]

Referring to FIG. 1, the load sensor 31 is connected to the amplitude measurement unit 50 and the control unit 60, and the ultrasonic vibrator 13, the driving motor 45, and the amplitude measurement unit 50 are connected to the control unit 60. Based on commands from the control unit 60, an output of the ultrasonic vibrator 13 and a rotational direction and an output of the driving motor 45 are controlled, and amplitude detected by the amplitude measurement unit 50 is inputted to

the control unit 60. The amplitude measurement unit 50 and the control unit 60 can be configured as a computer having such as a CPU and a memory included therein, or can be a detection and a control system configured by an electric circuit.

[0027]

When the driving motor 45 is driven by the control unit 60, the bonding arm 21 rotates, and when the tip 17a of the capillary 17 is pressed against a surface of the semiconductor chip 34 or a surface of the substrate 35 as a target to be bonded, the load sensor 31 is compressed to detect a pressure applied in the axial direction of the capillary 17 (Z-direction) and outputs the detected pressure to the control unit 60. The control unit 60 controls the driving motor 45 such that a load to the capillary 17 in the Z-direction obtained by the load sensor 31 is kept within a predetermined range.

[0028]

A vibratory condition of each component is described with reference to FIG. 4(a) and FIG. 4(b), when a voltage is applied to the ultrasonic vibrator 13 to cause the ultrasonic vibrator 13, and in turn the ultrasonic horn 12, to vibrate under unloaded condition, in which the tip 17a of the capillary 17 of the wire bonding apparatus 10 configured as described above is away from the substrate 35 or the semiconductor chip 34 shown in FIG. 1 and in which no pressure is applied to the capillary 17 in the axial direction.

[0029]

Referring to FIG. 4(a), when a voltage is applied to the ultrasonic vibrator 13 to cause the ultrasonic vibrator 13 to

vibrate, the ultrasonic vibrator 13 causes the ultrasonic horn 12 to longitudinally vibrate by resonating in the longitudinal direction along the central axis 15. As used herein, the longitudinal vibration refers to vibration in which a direction of vibratory transmission is identical with a direction of amplitude. As schematically shown in FIG. 4(b), the ultrasonic horn 12 is caused to vibrate by the vibration of the ultrasonic vibrator 13 attached to the back end of the ultrasonic horn 12 in a resonant mode between the back end to which the ultrasonic vibrator 13 is attached and the tip to which the capillary 17 is attached, where the back end and the tip are anti-nodes in the vibration. Further, the flange 14 that fixes the ultrasonic horn 12 to the bonding arm 21 is provided at a node in the vibration between the back end and the tip, that is, a point that does not vibrate in the longitudinal direction of the ultrasonic horn 12 in a resonant condition. The flange 14 is fixed to the flange attachment surface 22 of the bonding arm 21 using the fixing bolt 16. Here, the amplitude of FIG. 4(b) shows the amplitude in the longitudinal direction of the ultrasonic horn in a cross direction for the sake of understandability.

[0030]

At an anti-node in vibration, amplitude is large but a pressure in the longitudinal direction due to longitudinal vibration is minimum, and at a node in vibration, by contrast, amplitude is minimum but a pressure in the longitudinal direction due to longitudinal vibration increases.

Accordingly, while the node of the ultrasonic horn 12 to which

the flange 14 is attached does not vibrate in the longitudinal direction of the ultrasonic horn 12 (Y-direction), a large compressive force and a large tensile force are applied to this portion when the ultrasonic horn 12 longitudinally vibrates in the longitudinal direction. Further, the ultrasonic horn 12 is made of a metallic material and has a predetermined elastic coefficient and a Poisson's ratio. Consequently, when a compressive load is applied to the ultrasonic horn 12 in one direction, the ultrasonic horn 12 is compressed in this direction, and expands in a direction perpendicular to the compressed direction by an amount defined by the Poisson's ratio. Therefore, when a compressive load is applied to a portion corresponding to the node of the ultrasonic horn 12 to which the flange 14 is attached as indicated by arrows in the Y-direction as shown in FIG. 4(a), for example, the portion corresponding to the node is compressed in the Y-direction and expands in the X-direction, thereby causing positions for the fixing bolts 16 in the flange 14 to move outwardly in the X-direction. As a result, positions of the fixing bolts 16 that fix the flange 14 move outwardly in the X-direction, and this imparts an outward force toward either side in the X-direction as indicated by arrows to the front-end block 21a of the bonding arm 21, which is in turn expanded in the X-direction as indicated by arrows. The front-end block 21a is also made of a metallic material and has a predetermined elastic coefficient and a Poisson's ratio. Consequently, when the front-end block 21a expands in the X-direction due to the loads toward both sides in the X-direction, the front-end block 21a is compressed in

the Y-direction perpendicular to the X-direction, as shown by arrows, by an amount defined by the Poisson's ratio. The compression of the front-end block 21a in the Y-direction increases the width of the groove 26 in which the load sensor 31 is sandwiched between the front-end block 21a and the back-end block 21b by a very small amount, and this decreases the load in the Y-direction applied to the load sensor 31. By contrast, when a tensile load is applied to the node of the ultrasonic horn 12, the portion corresponding to the node of the ultrasonic horn 12 is compressed in the X-direction, an interval between the fixing bolts 16 in the X-direction becomes narrower, and the front-end block 21a is compressed in the X-direction and expands in the Y-direction. This in turn decreases the width of the groove 26 in the Y-direction by a very small amount, and increases the load in the Y-direction applied to the load sensor 31.

[0031]

As described above, the front-end block 21a to which the ultrasonic horn 12 is attached is configured such that the load in the Y-direction applied to the load sensor 31 due to the vibration changes by a very small amount when the ultrasonic horn 12 is caused to vibrate by the ultrasonic vibrator 13, and whereby the load sensor 31 outputs fluctuation of the load.

[0032]

According to what the inventors have confirmed from the experimentation, when a voltage is applied to the ultrasonic vibrator 13 to cause the ultrasonic horn 12 to vibrate where the capillary 17 is placed under unloaded condition, a certain

relation is found between the output of the load sensor 31 and the amplitude of the capillary 17 in the Y-direction as shown in FIG. 5(a). Accordingly, it is possible to measure the amplitude of the capillary 17 in the Y-direction by obtaining the output of the load sensor 31, and applying the obtained output to the chart shown in FIG. 5(a).

[0033]

The amplitude measurement unit 50 according to this embodiment is described in detail with reference to FIG. 6. Referring to FIG. 6, the amplitude measurement unit 50 includes a filter 51, a full-wave rectifier circuit 52, a smoothing circuit 53, an analog-digital converter 54, and a signal converting unit 55. The filter 51 can be configured as a combination of a low-pass filter and a band-pass filter through which an operating frequency of the driving motor 45 can be cut, the two filters connected continuously, or one of the two filters as long as it is possible to filter out the noise. The full-wave rectifier circuit 52 is configured by a combination of a plurality of rectifying devices, and to convert alternating-current power into direct-current power. The smoothing circuit 53 is configured by a combination of a resistance and a capacitor, and to reduce fluctuation of the signal by smoothing. The signal converting unit 55 includes a function for converting the signal outputted from the load sensor 31 shown in FIG. 5(a) into the amplitude of the capillary 17 in the Y-direction.

[0034]

The following describes signal processing by the

amplitude measurement unit 50. A signal of fluctuation of the load detected by the load sensor 31 exhibits a waveform vibrating in both positive and negative directions as shown in FIG. 6(a). Through the filter 51, noise of a high-frequency component in the signal and the noise of the operating frequency of the driving motor 45 are removed. The signal after the noises are removed is inputted into the full-wave rectifier circuit 52. The signal is converted into a direct-current signal showing a voltage fluctuation in the positive direction by the full-wave rectifier circuit 52 as shown in FIG. 6(b). Then, a fluctuating direct-current component in the signal that has passed through the full-wave rectifier circuit 52 is smoothed by the smoothing circuit 53 as shown in FIG. 6(c). At this time, an intensity of the signal takes an effective value substantially as large as $\sqrt{2}$ of the amplitude after the full-wave rectification shown in FIG. 6(b). As shown in FIG. 6(a), immediately after the ultrasonic vibrator 13 starts vibrating, the amplitude of the signal outputted from the load sensor 31 is small. The amplitude gradually increases as the vibration becomes more stationary, and then becomes substantially constant. After passing through the full-wave rectifier circuit 52 and the smoothing circuit 53, the signal shows amplitude with fluctuation as shown in FIG. 6(c), where the intensity is zero when the ultrasonic vibrator 13 starts vibrating, gradually increases over time, and then becomes substantially constant. As the fluctuation in the intensity per unit time of the signal after passing through the smoothing circuit 53 is reduced as shown in FIG. 6(c), it is possible to

more efficiently convert an analog signal into a digital signal. The amplitude of the signal that has been converted into a digital signal by the analog-digital converter 54 is converted into the amplitude of the capillary 17 in the Y-direction by the signal converting unit, and the amplitude of the capillary 17 is transmitted to the control unit 60 at a predetermined interval. Alternatively, the amplitude can be displayed in an indicator.

[0035]

As described above, according to this embodiment, as amplitude of the capillary 17 under unloaded condition can be measured using the load sensor 31 for detecting a load to the capillary 17 in the Z-direction, it is possible to measure the amplitude of the capillary 17 in the Y-direction with a simple structure without adding a separate device. In addition, according to this embodiment, as a signal from the load sensor 31 is converted from analog to digital after smoothing, it is possible to more efficiently perform the conversion into a digital signal with a smaller memory and to obtain the amplitude of the capillary 17 in the Y-direction.

[0036]

Further, as shown in FIG. 5(b), there is a certain relation between the voltage applied to the ultrasonic vibrator 13 and the amplitude of the capillary 17 in the Y-direction. Thus, the control unit 60 obtains data, from the amplitude measurement unit 50, for the amplitude of the capillary 17 in the Y-direction when a reference voltage is applied to the ultrasonic vibrator 13 to cause the ultrasonic horn 12 to vibrate where the capillary

17 is placed under unloaded condition, compares the obtained amplitude with target amplitude, increases or decreases the voltage to be applied to the ultrasonic vibrator 13 by a voltage E in the figure according to the result of the comparison, and thereby calibrates the amplitude of the capillary 17 by amplitude D in the figure such that the amplitude of the capillary 17 under unloaded condition corresponds to the target amplitude. With this, it is possible to suppress variation of the amplitude of the capillary 17 in the Y-direction due to errors in characteristics of the ultrasonic horn 12, as well as to stabilize bonding quality.

[0037]

According to the embodiment described above, the amplitude measurement unit 50 and the control unit 60 are separately provided. However, it is possible to include the chart shown in FIG. 5(a) within the control unit 60, and process the operation of the amplitude measurement unit 50 using the CPU incorporated in the control unit 60.

[0038]

Further, according to the above description, the wire bonding apparatus 10 is taken as the embodiment. However, the present invention is not limited to an application for wire bonding apparatuses, and can be applied to measurement and calibration of amplitude of a bonding tool of other bonding apparatuses such as die bonding apparatuses, as long as such a bonding apparatus includes a bonding tool attached to an ultrasonic horn that is caused to vibrate using an ultrasonic vibrator.

[0039]

The present invention is not limited to the above described embodiment, and can include any alterations and modifications without departing from the technical scope and the spirit of the present invention defined by the appended claims.

REFERENCE SIGNS LIST

[0040]

- 10 Wire Bonding Apparatus
- 11 Bonding Head
- 12 Ultrasonic Horn
- 13 Ultrasonic Vibrator
- 14 Flange
- 15 Central Axis
- 16 Fixing Bolt
- 17 Capillary
- 17a Tip
- 21 Bonding Arm
- 21a Front-End Block
- 21b Back-End Block
- 22 Flange Attachment Surface
- 23, 25, 26 Groove
- 24 Connecting Plate
- 27 Screw
- 28 Central Axis
- 29, 29a, 29b Depression
- 30 Rotary Shaft

31	Load Sensor
33	Bonding Stage
34	Semiconductor Chip
35	Substrate
41	Bonding Surface
43	Rotational Center
45	Driving Motor
50	Amplitude Measurement Unit
51	Filter
52	Full-Wave Rectifier Circuit
53	Smoothing Circuit
54	Analog-Digital Converter
55	Signal Converting Unit
60	Control Unit

CLAIMS

1. A bonding apparatus comprising:

a base section;

an ultrasonic horn configured to longitudinally vibrate in a longitudinal direction in resonance with vibration of an ultrasonic vibrator;

a bonding tool attached at an anti-node in the vibration of the ultrasonic horn, and configured to move toward and away from a target to be bonded;

a flange attached at a node in the vibration of the ultrasonic horn, and configured to micro-vibrate in a direction in which the flange extends due to a load in the longitudinal direction applied at the node of the ultrasonic horn when the ultrasonic horn vibrates;

a bonding arm having the ultrasonic horn fixed thereto by the flange;

a load sensor provided at a portion within the bonding arm, and configured to detect a load in the longitudinal direction of the ultrasonic horn applied to the bonding tool; and

an amplitude measurement unit configured to convert a signal of the load detected by the load sensor when the ultrasonic horn is caused to vibrate by the ultrasonic vibrator where the bonding tool is placed under unloaded condition, and to measure amplitude of vibration of the bonding tool in the longitudinal direction of the ultrasonic horn.

2. The bonding apparatus according to claim 1, wherein the flange is attached so as to extend along a direction perpendicular to the longitudinal direction of the ultrasonic horn and to a moving direction of the bonding tool.

3. The bonding apparatus according to claim 1, wherein the bonding arm is monolithically molded with a metallic material, comprises a first block having a flange attachment surface, a second block rotatably attached to the base section so as to cause a tip of the bonding tool to move toward and away from the target to be bonded, and a connecting plate connecting the first block with the second block, and is configured to deform due to the microvibration of the flange, thereby changing an interval between the first block and the second block in the longitudinal direction of the ultrasonic horn.

4. The bonding apparatus according to claim 3, wherein the load sensor is offset in a moving direction of the bonding tool from a central axis of the ultrasonic horn along the longitudinal direction, sandwiched between the first block and the second block, and configured to detect a load in the longitudinal direction of the ultrasonic horn applied between the first block and the second block.

5. The bonding apparatus according to claim 1, wherein the amplitude measurement unit comprises an analog-digital converter and a signal converting unit.

6. A method of measuring amplitude of a bonding tool for a bonding apparatus, the method comprising:

preparing a bonding apparatus comprising:

a base section;

an ultrasonic horn configured to longitudinally vibrate in a longitudinal direction in resonance with vibration of an ultrasonic vibrator;

a bonding tool attached at an anti-node in the vibration of the ultrasonic horn, and configured to move toward and away from a target to be bonded;

a flange attached at a node in the vibration of the ultrasonic horn, and configured to micro-vibrate in a direction in which the flange extends due to a load in the longitudinal direction applied at the node of the ultrasonic horn when the ultrasonic horn vibrates;

a bonding arm having the ultrasonic horn fixed thereto by the flange;

a load sensor attached to a portion within the bonding arm, and configured to detect a load in the longitudinal direction of the ultrasonic horn applied to the bonding tool;
and

an amplitude measurement unit configured to convert a signal of the load detected by the load sensor and to measure amplitude of vibration of the bonding tool;

causing the ultrasonic horn to vibrate using the ultrasonic vibrator while placing the bonding tool under unloaded condition; and

causing the amplitude measurement unit to convert the

signal of the load detected by the load sensor, and to measure the amplitude of the vibration of the bonding tool in the longitudinal direction of the ultrasonic horn.

7. The method of measuring amplitude of a bonding tool according to claim 6, wherein

the flange is attached so as to extend along a direction perpendicular to the longitudinal direction of the ultrasonic horn and to a moving direction of the bonding tool.

8. The method of measuring amplitude of a bonding tool according to claim 6, wherein

the bonding arm is monolithically molded with a metallic material, comprises a first block having a flange attachment surface, a second block rotatably attached to the base section so as to cause a tip of the bonding tool to move toward and away from the target to be bonded, and a connecting plate connecting the first block with the second block, and is configured to deform due to the microvibration of the flange, thereby changing an interval between the first block and the second block in the longitudinal direction of the ultrasonic horn.

9. The method of measuring amplitude of a bonding tool according to claim 8, wherein

the load sensor is offset in a moving direction of the bonding tool from a central axis of the ultrasonic horn along the longitudinal direction, sandwiched between the first block and the second block, and configured to detect a load in the

longitudinal direction of the ultrasonic horn applied between the first block and the second block.

10. The method of measuring amplitude of a bonding tool according to claim 6, wherein

the amplitude measurement unit comprises an analog-digital converter and a signal converting unit.

11. A method of calibrating amplitude of a bonding tool of a bonding apparatus, the method comprising:

preparing a bonding apparatus comprising:

a base section;

an ultrasonic horn configured to longitudinally vibrate in a longitudinal direction in resonance with vibration of an ultrasonic vibrator;

a bonding tool attached at an anti-node in the vibration of the ultrasonic horn, and configured to move toward and away from a target to be bonded;

a flange attached at a node in the vibration of the ultrasonic horn, and configured to micro-vibrate in a direction in which the flange extends due to a load in the longitudinal direction applied at the node of the ultrasonic horn when the ultrasonic horn vibrates;

a bonding arm having the ultrasonic horn fixed thereto by the flange;

a load sensor attached to a portion within the bonding arm, and configured to detect a load in the longitudinal direction of the ultrasonic horn applied to the bonding tool;

a control unit configured to process a signal of the load detected by the load sensor; and

an amplitude measurement unit configured to convert the signal of the load detected by the load sensor and to measure amplitude of vibration of the bonding tool;

causing the ultrasonic horn to vibrate based on a reference applied voltage using the ultrasonic vibrator while placing the bonding tool under unloaded condition;

causing the amplitude measurement unit to convert the signal of the load detected by the load sensor, and to measure the amplitude of the vibration of the bonding tool in the longitudinal direction of the ultrasonic horn; and

causing the control unit to compare the measured amplitude with target amplitude, and to change a voltage applied to the ultrasonic vibrator based on a result of the comparison such that amplitude of the vibration of the ultrasonic vibrator corresponds to the target amplitude.

12. The method of calibrating amplitude of a bonding tool according to claim 11, wherein

the flange is attached so as to extend along a direction perpendicular to the longitudinal direction of the ultrasonic horn and to a moving direction of the bonding tool.

13. The method of calibrating amplitude of a bonding tool according to claim 11, wherein

the bonding arm is monolithically molded with a metallic material, comprises a first block having a flange attachment

surface, a second block rotatably attached to the base section so as to cause a tip of the bonding tool to move toward and away from the target to be bonded, and a connecting plate connecting the first block with the second block, and is configured to deform due to the microvibration of the flange, thereby changing an interval between the first block and the second block in the longitudinal direction of the ultrasonic horn.

14. The method of calibrating amplitude of a bonding tool according to claim 13, wherein

the load sensor is offset in a moving direction of the bonding tool from a central axis of the ultrasonic horn along the longitudinal direction, sandwiched between the first block and the second block, and configured to detect a load in the longitudinal direction of the ultrasonic horn applied between the first block and the second block.

15. The method of calibrating amplitude of a bonding tool according to claim 11, wherein

the amplitude measurement unit comprises an analog-digital converter and a signal converting unit.