

APPARATUS FOR DETECTING SEMICONDUCTOR BONDING DEFECTS

BACKGROUND OF THE INVENTION1. Field of the Invention

The present invention relates to an apparatus for detecting the bonding defects of a semiconductor element such as an IC by monitoring the output waveform of an ultrasonic oscillator of a bonder.

2. Description of the Related Art

In the case of a semiconductor element having as many as several hundreds of pins, it is usual to determine the quality of the products by bonding the pins using ultrasonic waves and then measuring the characteristic of the product with a semiconductor tester. However, with this method, even when the bonding strength does not satisfy its rated value, if the pins are only electrically connected, no bonding defect will be detected, and there is a high possibility that several bonding defects may appear after the product has been shipped.

Further, although there has conventionally been a bonding defect detecting apparatus aiming at the variations of voltage waveform and current waveform of an ultrasonic oscillator of the bonder, the measuring method is based on the measurement of absolute values. That is, the apparatus is used to measure the effective values of the voltage and current during the bonding operation, setting a reference value based on the average value thereof, and determining whether or not the product is qualified by setting this reference value to be a fixed value.

However, in the case of an actual bonding for an IC, there

are differences in reference values resulting from the different types of apparatuses or semiconductor elements, or there are differences in average value due to the positions of the pins on the frame. Therefore, using the reference value as a fixed value is not practical because of the gross errors produced when determination is made.

Further, even in the case of the same semiconductor element, the effective values of the voltage and current fluctuate with time due to the wear, and a rise in temperature, of the tool at the top end of the bonder, and the conventional apparatus using the average values has had the problem of being unable to cope with the fluctuation, with the result that the criterion of determination of the quality of the product is not kept constant.

SUMMARY OF THE INVENTION

The present invention has been made to solve the above-mentioned problems, and its object is to provide a bonding defect detecting apparatus that enables bonding defects to be detected irrespective of the difference in type and the position of the pin, without being influenced by the operation state of the bonder.

To attain the above-described object, according to the present invention, there is provided a semiconductor bonding defect detecting apparatus which is connected to a wire bonder for performing bonding of the pins by use of ultrasonic waves generated from an ultrasonic oscillator and which comprises means for performing an analog-digital conversion of a voltage waveform and current waveform of

the ultrasonic oscillator that are input thereto by being sampled on a real time basis from the ultrasonic oscillator during a bonding process, digital signal processing means for calculating specific data such as frequency, phase difference between the voltage waveform and the current waveform and impedance from the sampled data of the voltage waveform and current waveform that are digitally converted, data accumulating means for accumulating the digital data that has been calculated by the digital signal processing means for each pin, and determining means for comparing a previous average value of a plurality of digital data items that are accumulated in the data accumulating means with a present digital data item that has been obtained by the operation of the digital signal processing means to thereby determine a bonding defect.

The previous average value of the plurality of digital data items in the determining means is calculated using a plurality of the most recent data items.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a block diagram illustrating the structure of a bonding defects detecting apparatus according to the present invention;

Fig. 2 is a flow chart illustrating a method of averaging data according to the present invention;

Fig. 3(a) through 3(d) are illustrations of numbers of pins IC1 to ICm, respectively;

Figs. 4(a) and 4(b) are an output voltage waveform diagram and an output current waveform diagram, respectively, of an ultrasonic

oscillator during a bonding operation;

Fig. 5 is an illustration of how to obtain an average voltage value;

Fig. 6 is an illustration of how to obtain an average current value;

Fig. 7 is an illustration of how to obtain a voltage frequency;

Fig. 8 is an illustration of how to obtain a current frequency;

Fig. 9 is an illustration of how to obtain a phase difference when the voltage waveform is advanced relative to the current waveform; and

Fig. 10 is an illustration of how to obtain a phase difference when the current waveform is advanced relative to the voltage waveform.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Fig. 1 is a block diagram illustrating the structure of a bonding defect detecting apparatus according to the present invention. This bonding defect detecting apparatus 1 is connected to a wire bonder 2 when it is in use. The wire bonder 2 is composed of an ultrasonic oscillator 21 and a wire bonder control device 22. The bonding defect detecting apparatus is equipped with A/D converters 11, 12 which receive a voltage waveform and a current waveform generated from the ultrasonic oscillator 21 to thereby perform a digital conversion, digital signal processing means 13 for calculating the frequency, the phase difference

between the voltage waveform and the current waveform and impedance from the sampled data of the voltage waveform and current waveform that are digitally converted, data accumulating means 14 for accumulating the digital data calculated by being calculated by the digital signal processing means for each pin, and determining means 15 for comparing a previous average value of a plurality of digital data items accumulated in the data accumulating means 14 with a present digital data item calculated by the digital signal processing means 13 to thereby determine a bonding defect. It is to be noted that the operation of the digital signal processing means 13 is performed through software processing that is executed by a high speed DSP (Digital Signal Processor).

Next, the data averaging method in the data accumulating means 14 will be explained with reference to an illustrative view of the pin numbers of IC1 to ICm shown in Fig. 3 as well as a flow chart shown in Fig. 2.

Assuming that the number of pins to be averaged is represented by n and the pin number is represented by P, the total (n, P) of an n-number of pins P measured values that run from the measured value X (n, P) to the measured value X (n, P) regarding an n-number of pins will be expressed by the following equation [1].

[Equation 1]

$$T(n, P) = \sum_{P=1}^n P(N, P)$$

In this case, the average value A (n, P) will be expressed as follows.

$$A(n, P) = T(n, P) / n \text{ (Fig. 2, step 100).}$$

From the $(n + 1)$ th pin, the data is processed at a high speed in the following way.

Assume that measurement has been performed of the m th ($m > n$) order pin (step 110).

Assume that the measured value of the pin P be $X(m, P)$ (step 120).

Confirm whether or not this measured value satisfies the following formula (step 130).

$$A(m-1, P) - \alpha < X(m, P) < A(m-1, P) + \alpha$$

If the measured value satisfies, it is determined that the pin is normal (qualified) (step 140).

When the pin is normal, the average value of an n number of the most recent measured values is calculated as follows.

The total $T(m, P)$ of an n number of pins P measured values of $(m-n+1)$ number that cover from the measured value $X(m-n+1, P)$ to the measured value $X(m, P)$ is expressed as follows.

$$T(m, P) = T(m-1, P) - A(m-1, P) + X(m, P)$$

In this case, the average value $A(m, P)$ is expressed as follows.

$$A(m, P) = T(m, P) / n \text{ (step 150).}$$

Unless the requirement of step 150 is satisfied, it will be determined that the product is abnormal (unqualified) (step 160).

It is then determined whether or not the IC to be measured next will be a new IC (step 170).

If this IC is new, +1 is added to the IC number, whereby the pin number is set to be 1 (step 180).

If it is not a new IC, +1 is added to the pin number (step

190).

The averaging operation is repeated from step 120.

(Embodiment)

Figs. 4(a) and 4(b) illustrate typical examples of the output waveform from the ultrasonic oscillator at the time of bonding a single pin. Fig. 4(a) illustrates a voltage waveform and Fig. 4(b) illustrates a current waveform. The envelope curve of the waveform exhibits a specific curvilinear configuration as illustrated. The fact that the amplitude of the waveform becomes small midway in the contour thereof is considered to indicate that at a point in time when the bonding processes complete the welding of the pin, the voltage drop between the contact points lessens. When the welding is defective, the envelope curve of the waveform does not become a typical pattern as shown in Fig. 4 but becomes a distorted pattern. This waveform is thus divided into, for example, 10 blocks and the data is measured for each block.

Fig. 5 illustrates a method of determining an average voltage value within the region of a measuring block. The measuring block is divided into an n-number of parts, thereby performing sampling of the voltage waveform. And, the average voltage value V_{AVE} is determined using the respective sampled values V_i .

[Equation 2]

$$V_{AVE} = \left\{ \sum_{i=1}^n |V_i| \right\} / n$$

Also, the maximum value of the voltage is determined from the maximum value among $|V_1|$ to $|V_n|$.

Fig. 6 illustrates a method of determining an average current value within the region of a measuring block. The measuring block is divided into an n number of parts, thereby performing sampling of the current waveform. And, the average current value I_{AVE} is determined using the respective sampled values I_i .

[Equation 3]

$$I_{AVE} = \left\{ \sum_{i=1}^n |I_i| \right\} / n$$

Also, the maximum value of the current is determined from the maximum value among $|I_1|$ to $|I_n|$.

The impedance Imp is determined using the average voltage value V_{AVE} and the average value current I_{AVE} .

$$Imp = V_{AVE} / I_{AVE}$$

Fig. 7 illustrates a method of determining a voltage frequency. The voltage frequency V_f is expressed by the equation:

$$V_f = f_s / N$$

Wherein, f_s represents the sampling frequency. N represents the number of data items that corresponds to one cyclic period and, in this case, the number of data items that corresponds to one cyclic period is determined from the number of samplings that falls within one cyclic period from a zero-cross point A to a zero-cross point B.

Fig. 8 illustrates a method of determining a current frequency. The current frequency I_f is expressed by the equation:

$$I_f = f_s / N$$

Wherein, f_s represents the sampling frequency. N represents the number

of data items that corresponds to one cyclic period and, in this case, the number of data items that corresponds to one cyclic period is determined from the number of samplings that falls within one cyclic period from a zero-cross point A to a zero-cross point B.

Figs. 9 and 10 are diagrams illustrating a method of determining a phase difference, with Fig. 9 illustrating a case where the voltage waveform is advanced relative to the current waveform and Fig. 10 illustrating a case where the current waveform is advanced relative to the voltage waveform. In Fig. 9, determination is performed on the zero-cross points A1 and A2 of the voltage waveform and the zero-cross points B1 and B2 of the current waveform and then an operation is performed on the phase difference of the (B1 - A1) by using the following equation.

$$\text{Phase Difference} = \{(B1 - A1) \times 360^\circ\} / (B2 - B1)$$

It is to be noted that when the phase difference is more than 360° , a value that has been obtained by subtracting 360° therefrom is set to be the phase difference.

Also, Fig. 10 illustrates a case where the current waveform is advanced relative to the voltage waveform, and determination is performed of the zero-cross points A1 and A2 of the voltage waveform and the zero-cross points B1 and B2 of the current waveform. An operation is then performed on the phase difference of the (B2 - A1) by using the following equation.

$$\text{Phase Difference} = \{(B2 - A1) \times 360^\circ\} / (B2 - B1)$$

It is to be noted that when the phase difference is more than

360° , a value that has been obtained by subtracting 360° therefrom is set to be the phase difference.

If there exists an abnormality in the voltage waveform or current waveform, and as a result, the voltage or current waveform does not become a sine wave such as that illustrated in Fig. 5 or 6, the abnormality apparatus in at least one of the average voltage value, average current value, impedance, frequency, phase difference, etc., can be expressed in the form of a numeric value, and can be distinguished from a normal value.

Further, by obtaining the average value from an n number of the most recent normal values, even when the effective values of the voltage and the current have fluctuated with over time as a result of wear, and a rise in temperature, of the tool at the top end of the bonder, this average value becomes a determination criterion for determining whether or not the product is qualified to cope with such fluctuations.

The present invention has the following advantages.

(1) By high speed sampling of the data being performed using the DSP (Digital Signal Processor) and the data being digitized, it has become possible to perform a post-processing of the data.

(2) Since the oscillation waveform data of the current and voltage is sampled, even past data regarding the frequency, phase difference, impedance and etc. is stored for each pin. By comparing this past data with an average value of a prescribed number of the most recent data, it is possible to detect bonding defects irrespective of differences in system types or the positions of the pins.

(3) Since of the oscillation waveforms are measured, it is possible to perform estimates on even a delicate bonding.

CLAIMS

What is claimed is:

1. A semiconductor bonding defect detecting apparatus connected to a wire bonder for bonding pins by using ultrasonic waves generated from an ultrasonic oscillator, comprising:

means for digitally converting a voltage waveform and a current waveform of said ultrasonic oscillator by real-time sampling and receiving them as inputs during a bonding process;

digital signal processing means for calculating specific data such as frequency, phase difference between the voltage waveform and the current waveform and impedance from the sampled data of the digital converted voltage waveform and current waveform;

data accumulating means for accumulating the digital data that has been calculated by the digital signal processing means for each pin; and

determining means for comparing a previous average value of a plurality of digital data accumulated in the data accumulating means with a present digital datum calculated by the digital signal processing means to thereby determine a bonding defect.

2. A semiconductor bonding defect detecting apparatus as set forth in claim 1, wherein the previous average value of the plurality of digital data in the determining means is calculated using a plurality of most recent data.