semiconductor device 13 that is an inspection target on a holding surface 10a on the upper side. The semiconductor device 13, for example, may be formed by a substrate 11 and a semiconductor die 12 installed onto the substrate 11 by using an adhesive, may be a device in which the semiconductor die 12 is mounted, by flip-chip bonding, onto the substrate 11, and may also be a device in which multiple semiconductor dies 12 are laminated onto the substrate 11 through direct bonding.

**[0050]** In the example shown in FIG. 1, the semiconductor device 13 is formed by bonding the semiconductor die 12 onto the substrate 11 by using an adhesive. Therefore, a gap 90 (see FIG. 4) due to a bonding defect intervenes between the upper surface of the substrate 11 and the lower surface of the semiconductor die 12. In the following description, a portion on the gap 90 of the semiconductor die 12 is referred to as a defective part 14.

**[0051]** The acoustic head 20 is disposed to be spaced apart from the stage 10 above the side of the holding surface 10a of the stage 10. The acoustic head 20 is formed by the casing 22 and the ultrasonic speakers 21 installed to the casing 22. The casing 22 of the acoustic head 20 is suspended by a rod 29a from a slider 29 movable in Y-direction and installed to a guide rail 28 provided on the stage 10.

**[0052]** The casing 22 of the acoustic head 20 is spherical, dome-shaped and open to the lower stage side 25. A spherical center 26 of a spherical surface formed by the casing 22 is located on a surface 15 of the semiconductor device 13 held on the holding surface 10a of the stage 10. The ultrasonic speaker 21 is a directive ultrasonic wave generator, and generates an ultrasonic wave 24 so that the ultrasonic wave 24 propagates within a range of a directive angle $\theta$ with an axis 21a as the center in the direction of the axis 21a. A frequency f of the ultrasonic wave 24 ranges from tens of kHz to hundreds of kHz. The ultrasonic speakers 21 are installed to the casing 22, so that the respective axes 21a intersect with each other at the spherical center 26 of the spherical surface of the casing 22. Therefore, the ultrasonic waves 24 respectively generated from the ultrasonic

the substrate 11.

**[0065]** When the defective part 14 of the semiconductor die 12 is vibrated through ultrasonic vibration, the surface 15 of the semiconductor die 12 vibrates as indicated by an arrow 96 shown in FIG. 5. Accordingly, the light path of the reflected laser light 33 reflected by the surface 15 of the defective part 14 of the semiconductor die 12 is shaken, as indicated by an arrow 97, between a light path 34a and a light path 34b shown in FIG. 5. The shaking of ~~the~~ a light path 34 including the light paths 34a and 34b occurs at a vibration period same as the ultrasonic vibration of the semiconductor die 12.

**[0066]** With the shaking of the light paths 34a and 34b, the image 14a of the defective part 14 of the semiconductor die 12 with the spotted pattern on the imaging element 42 described with reference to FIG. 3, becomes an image 14b shaken as indicated by an arrow 98 shown in FIG. 6. Here, if the image of the semiconductor die 12 is captured with an exposure time of the camera 40 longer than the vibration period of the ultrasonic vibration of the semiconductor die 12, the camera 40 obtains the image 14b with the shaken spotted pattern as shown in FIG. 6 as the image of the interference pattern of the defective part 14.

**[0067]** Meanwhile, portions other than the defective part 14 of the semiconductor die 12 and favorably bonded to the semiconductor die 12 of the substrate 11 are hardly vibrated with respect to the substrate 11. Therefore, the image 12a of the portions other than the defective part 14 of the semiconductor die 12 with the spotted pattern on the imaging element 42 is not shaken. Therefore, the camera 40 obtains the image 12a of the spotted pattern that is not shaken as described with reference to FIG. 3 as the image of the interference pattern of the portions other than the defective part 14.

**[0068]** In the defective part 14 where the image 14b of the interference pattern is shaken during exposure, the brightness intensity of the pixels 46 of the imaging element 42 changes as compared to the brightness intensity of the image 14a of the interference pattern in the static state without ultrasonic vibration or a non-vibrating state. As an example, the brightness intensity of the pixels

interference pattern of the portions other than the defective part 14 (ultrasonically vibrated image obtaining step).

**[0082]** When obtaining the images 12a, 14b including the interference pattern by using the camera 40, the CPU 56 of the detection unit 55 proceeds to Step S106 of FIG. 9 and stores the images 12a, 14b in the storage unit 57.

**[0083]** <2. Defect detection step>

<a. Specification of vibration occurrence pixel>

In Step S107 of FIG. 9, the CPU 56 of the detection unit 55 reads the images 12a, 14a including the interference pattern when the semiconductor die 12 is static and the images 12a, 14b including the interference pattern when the semiconductor die 12 is ultrasonically vibrated from the storage unit 57, and executes Step S201 to ~~S201~~ S210 of FIG. 10 to specify the vibration occurrence pixel 47 based on the deviation between the images 12a, 14a including the interference pattern at the time of being static and the images 12a, 14b including the interference pattern at the time of ultrasonic vibration.

**[0084]** In the following, details of the operation for specifying the vibration occurrence pixel 47 are described with reference to FIGs. 7 and 10. The CPU 56 of the detection unit 55 specifies a pixel 46 in which the brightness intensity during ultrasonic vibration changes from the brightness intensity at the time of being static without ultrasonic vibration or at the time of non-vibration as the vibration occurrence pixel 47.

**[0085]** As shown in FIG. 7, the CPU 56 of the detection unit 55 performs a process as described below for each pixel 46 of an image frame 45 which is a region of a two-dimensional image of the visual field 43 on which an image process is performed once, and specifies the vibration occurrence pixel 47. In the following description, the coordinates (x, y) following a reference symbol indicate the coordinates (x, y) of the two-dimensional image frame 45. For example, the pixel 46 (x, y) indicates the pixel 46 whose coordinates are (x, y).

die 12.

**[0102]** Although the visualized image 12e can be presented in various forms, FIG. 8, as an example, illustrates an image in which portions corresponding to the vibration occurrence pixels 47 are superimposed with red dots as the expressions 18 in the image of a general semiconductor die 12 obtained by irradiating the semiconductor die 12 with non-interfering light such as a lamp. According to the image, in a region in the vicinity of the defective part 14 that vibrates through ultrasonic vibration, a large number of red dots that are the expressions 18 are displayed, whereas there is hardly any red dot that is the expression 18 in portions which do not vibrate and which is other than the defective part 14. In the example shown in FIG. 8, in the central portion of the semiconductor die 12 where a large number of red dots that are the expressions 18 are displayed, it is known that the gap 90 forming the defective part 14 that ultrasonically vibrates due to application of ultrasonic vibration is present, and the gap 90 is not present elsewhere. Accordingly, by visually confirming the visualized image 12e displayed on the display 58, whether the gap 90 that is a defect is present in the semiconductor device 13 can be detected. It is noted that the red dots representing the expressions 18 are shown as black dots in FIG. 8.

**[0103]** In addition, the CPU 56 of the detection unit 55 may also superimpose and display the defective region 91 set in Step S108 of FIG. 9 on the visualized image 12e. Accordingly, the defective region 91 and the expression 18 are superimposed and displayed on the image of the general semiconductor die 12, and whether a defect is detected can be checked visually.

**[0104]** <Function/effect of defect detection device 100>

As described above, the defect detection device 100 of the embodiment irradiates the semiconductor device 13 with the collimated laser light 32 and ultrasonically vibrates the semiconductor device 13, and performs defect detection based on the deviation between the images 12a, 14a including the interference pattern at the time of being static and the images 12a, 14b including the interference pattern at the time of ultrasonic vibration. Therefore, the defect detection device 100 can detect the defect of the semiconductor device 13 within a short time by

using an acoustic head 60 in which the ultrasonic speakers 21 are installed to an annular casing 62.

**[0114]** As shown in FIG. 11, the casing 62 is an annular member in a spherical stage shape with an open surface 64 having a small diameter on the upper side and an open surface 65 having a large diameter on the lower side. The ultrasonic speakers 21 are installed to a spherical band surface 63. A spherical center 66 of the spherical band surface 63 is located on the surface 15 of the semiconductor device 13 held on the holding surface 10a of the stage 10. The ultrasonic speakers 21 are installed to the casing 62, so that the respective axes 21a intersect with each other at the spherical center 66 of the spherical surface of the casing 62. Like the defect detection device 100 described with reference to FIG. 1, the ultrasonic waves 24 generated from the respective ultrasonic speakers 21 intersect with each other and are concentrated and superimposed at the spherical center 66. By superimposing the ultrasonic waves 24, the detection region 27 in which the amplitude of ultrasonic vibration is large is formed in the vicinity of the spherical center 66.

**[0115]** The operation of the defect detection device 200 is the same as the defect detection 100 described with reference to FIG. 1.

**[0116]** In the defect detection device 200, since the casing 62 is formed with an annular member in a spherical stage shape and a top plate 67, the thickness in Z-direction can be reduced, and the defect detection device 200 can be installed to a small-sized bonding apparatus, etc.

**[0117]** <Other Embodiment 2>

In the following, a defect detection device 300 of another embodiment is described with reference to FIGs. 12 to 17. In the defect detection device 300, in place of the acoustic head 20 of the defect detection device 100 described with reference to FIG. 1, an ultrasonic vibrator 70 connected with the semiconductor device 13 is used to ultrasonically vibrate the semiconductor device 13. The ultrasonic vibrator 70 forms an ultrasonic vibration device. The configuration of the laser

**[0133]** After the ultrasonic vibration on the semiconductor device 13 by using the ultrasonic vibrator 70 starts, the CPU 51 of the control unit 50 outputs the signal that ultrasonic vibration is being carried out and the starting frequency f0 of ultrasonic vibration to the detection unit 55. When the signal is input, at Step S105 of FIG. 15, the CPU 56 of the detection unit 55 sets the exposure time of the camera 40 to be longer than the period of ultrasonic vibration at the time of the starting frequency f0, obtains the images 12a, 14b including the interference pattern at the time of ultrasonic vibration by using the camera 40 as described with reference to FIG. 6, and stores the images 14a, 14b in the storage unit 57 at Step S106 of FIG. 15. The camera 40 may capture the images 12a, 14a, 14b as motion images and store motion image data in the storage unit 57, and may also capture the images 12a, 14a, 14b as static images every time when the frequency f of ultrasonic vibration changes by a predetermined frequency $\Delta f$ and store a data set of multiple static images in the storage unit 57.

**[0134]** The CPU 56 of the detection unit 55, like the defect detection device 100 described above, specifies the vibration occurrence pixel 47 at Step S107 of FIG. 15, and sets, as the defective region 91, a region in which the vibration occurrence pixel 47 is densely arranged in the predetermined number of more at Step S108 of FIG. 15. Then, in the case of YES in Step S109 of FIG. 15, the defect detection signal is output at Step S110 of FIG. 15, and in the case of NO in Step S109 of FIG. 15, the good product detection signal is output at Step S111 of FIG. 15. Then, the visualized image 12e is displayed on the display 58 at Step S112 of FIG. 15.

**[0135]** As described above, when the frequency of the high frequency power is changed to ultrasonically vibrate the semiconductor device 13, the defect detection device 300 of the embodiment sets the amplitude of the ultrasonic vibrator 70 within the predetermined range, and can suppress the substrate 11 and the semiconductor die 12 from vibrating significantly at a specific frequency. Accordingly, that the vibration of the defective part 14 is hidden in the vibration of the substrate 11 and the semiconductor die 12 and not detectable at a specific

WHAT IS CLAIMED IS:

1. A defect detection device, detecting a defect of an inspection target, the defect detection device comprising:

an ultrasonic vibration device, ultrasonically vibrating the inspection target;

a coherent light source, irradiating the inspection target with coherent light;

a camera, having an imaging element imaging the inspection target irradiated with the coherent light to obtain an image; and

a detection unit, detecting the defect of the inspection target based on the image imaged by the camera,

wherein an exposure time when the camera images is longer than a period of ultrasonic vibration of the inspection target, and the camera obtains an image comprising an interference pattern generated due to interference of the coherent light reflected by a surface of the inspection target,

the detection unit specifies a vibration occurrence pixel based on a deviation between an image comprising an interference pattern when the inspection target is static and an image comprising an interference pattern when the inspection target is ultrasonically vibrated that are obtained by the camera, and sets a region in which the vibration occurrence pixel that is specified is densely arranged in a predetermined number or more as a defective region, and detects the defect.

~~2. (Cancelled)~~

~~3. (Cancelled)~~

~~4~~2. The defect detection device as claimed in claim 1,

wherein, in a case where a predetermined number of other vibration occurrence pixels are present within a predetermined range around the vibration occurrence pixel that is specified, the detection unit maintains specification of the pixel as the vibration occurrence pixel, and in a case

where the predetermined number of vibration occurrence pixels are not present within the predetermined range, the detection unit cancels the specification of the pixel as the vibration occurrence pixel.

~~5~~3. The defect detection device as claimed in claim 1 or ~~4~~2, comprising a display displaying an image of the inspection target,

wherein the detection unit displays a visualized image in which an expression corresponding to the vibration occurrence pixel that is specified is comprised in an image of the inspection target on the display.

~~6~~4. The defect detection device as claimed in any one of claims 1 ~~or 4 or 5~~to 3,

wherein the coherent light is laser light, and

the coherent light source irradiates the inspection target with collimated laser light of a single wavelength.

~~7~~5. The defect detection device as claimed in any one of claims 1 ~~and 4 to 6~~to 4, comprising:

a driving unit, supplying high frequency power to the ultrasonic vibration device; and

a control unit, adjusting a frequency of the high frequency power supplied from the driving unit to the ultrasonic vibration device,

wherein when the detection unit detects the defect of the inspection target, the control unit changes the frequency of the high frequency power supplied from the driving unit to the ultrasonic vibration device.

~~8~~6. The defect detection device as claimed in claim ~~7~~5, comprising a current sensor, detecting a current of the high frequency power supplied from the driving unit to the ultrasonic vibration device,

wherein when the frequency of the high frequency power supplied from the driving unit to the ultrasonic vibration device is changed, the control unit adjusts a voltage of the high frequency power supplied from the driving unit to the ultrasonic vibration device, so that the current detected

by the current sensor falls within a predetermined range.

~~9~~7. The defect detection device as claimed in claim ~~7~~5,

wherein the control unit comprises a map in which a change of a voltage of the high frequency power supplied from the driving unit to the ultrasonic vibration device with respect to the frequency of the high frequency power supplied from the driving unit to the ultrasonic vibration device is defined in advance, so that a current of the high frequency power supplied from the driving unit to the ultrasonic vibration device falls within a predetermined range, and

when the frequency of the high frequency power supplied from the driving unit to the ultrasonic vibration device is changed, the voltage of the high frequency power supplied from the driving unit to the ultrasonic vibration device is adjusted based on the map.

~~10~~8. The defect detection device as claimed in any one of claims 1 ~~and 4 to 9~~to 7,

wherein the ultrasonic vibration device is an ultrasonic speaker arranged on a periphery of the inspection target or an ultrasonic vibrator connected with the inspection target and ultrasonically vibrating the inspection target.

~~11~~9. The defect detection device as claimed in any one of claims 1 ~~and 4 to 6~~to 4,

wherein the ultrasonic vibration device is formed by a plurality of ultrasonic speakers that are directive and disposed on a periphery of the inspection target, the ultrasonic speakers are installed to a casing, so as to concentrate a plurality of ultrasonic waves generated by the respective ultrasonic speakers on the inspection target.

~~12~~10. The defect detection device as claimed in claim ~~11~~9, comprising:

a plurality of driving units, respectively supplying high frequency power to the ultrasonic speakers; and

a control unit, adjusting a frequency of the high frequency power supplied from each of the driving units to each of the ultrasonic speakers,

wherein when the detection unit detects the defect of the inspection target, the control unit

changes the frequency of the high frequency power supplied from each of the driving units to each of the ultrasonic speakers.

~~13~~11. The defect detection device as claimed in claim ~~12~~10, comprising a current sensor, each detecting a current of the high frequency power supplied from each of the driving units to each of the ultrasonic speakers,

wherein when the frequency of the high frequency power supplied from each of the driving units to each of the ultrasonic speakers is changed, the control unit adjusts a voltage of the high frequency power supplied from each of the driving units to each of the ultrasonic speakers, so that the current detected by each of the current sensors falls within a predetermined range.

~~14~~12. The defect detection device as claimed in claim ~~12~~10,

wherein the control unit comprises a map in which a change of a voltage of the high frequency power supplied from each of the driving units to each of the ultrasonic speakers with respect to the frequency of the high frequency power supplied from each of the driving units to each of the ultrasonic speakers is defined in advance, so that a current of the high frequency power supplied from each of the driving units to each of the ultrasonic speakers each falls within a predetermined range, and

when the frequency of the high frequency power supplied from each of the driving units to each of the ultrasonic speakers is changed, the voltage of the high frequency power supplied from each of the driving units to each of the ultrasonic speakers is adjusted based on the map.

~~15~~13. The defect detection device as claimed in any one of claims ~~12~~ 10 to ~~14~~12,

wherein the control unit respectively adjusts each phase of each of the ultrasonic waves generated by each of the ultrasonic speakers by using each of the driving units.

~~16~~14. A defect detection method for detecting a defect of an inspection target, the defect detection method comprising:

a static image obtaining step, irradiating the inspection target with coherent light, imaging

the inspection target by using a camera, and obtaining an image when the inspection target is static;

an ultrasonically vibrated image obtaining step, ultrasonically vibrating the inspection target by using an ultrasonic vibration device while irradiating the inspection target with the coherent light, imaging the inspection target by using the camera, and obtaining an image when the inspection target is ultrasonically vibrated; and

a defect detection step, detecting the defect of the inspection target based on a deviation between the image when the inspection target is static and the image when the inspection target is ultrasonically vibrated that are obtained by the camera,

wherein in the static image obtaining step, an image comprising an interference pattern at a time of being static generated through interference of the coherent light reflected by a surface of the inspection target is obtained,

in the ultrasonically vibrated image obtaining step, an exposure time of the camera is set longer than a period of ultrasonic vibration of the inspection target, and an image comprising an interference pattern at a time of ultrasonic vibration generated through interference of the coherent light reflected by the surface of the inspection target is obtained by using the camera, and

in the defect detection step, a vibration occurrence pixel is specified based on a deviation between an image comprising an interference pattern when the inspection target is static and an image comprising an interference pattern when the inspection target is ultrasonically vibrated that are obtained by the camera, a region in which the vibration occurrence pixel that is specified is densely arranged in a predetermined number or more is set as a defective region, and the defect is detected.

~~17. (Cancelled)~~

~~18. (Cancelled)~~

~~19~~15. The defect detection method as claimed in claim ~~16~~14,

wherein in the defect detection step, in a case where a predetermined number of other

vibration occurrence pixels are present within a predetermined range around the vibration occurrence pixel that is specified, specification of the pixel as the vibration occurrence pixel is maintained, and in a case where the predetermined number of vibration occurrence pixels are not present within the predetermined range, the specification of the pixel as the vibration occurrence pixel is canceled.

~~20~~16. The defect detection method as claimed in claim ~~16~~14 or ~~19~~15, further comprising:

a display step, displaying a visualized image in which an expression corresponding to the vibration occurrence pixel that is specified is comprised in an image of the inspection target on a display.

~~21. (Cancelled)~~

~~22. (Cancelled)~~

~~23~~17. A defect detection device, detecting a defect of an inspection target, the defect detection device comprising:

an ultrasonic vibration device, ultrasonically vibrating the inspection target;

a driving unit, supplying high frequency power to the ultrasonically vibration device;

a current sensor, detecting a current of the high frequency power supplied from the driving unit to the ultrasonic vibration device;

a control unit, adjusting a frequency of the high frequency power supplied from the driving unit to the ultrasonic vibration device;

a coherent light source, irradiating the inspection target with coherent light;

a camera, having an imaging element imaging the inspection target irradiated with the coherent light to obtain an image; and

a detection unit, detecting the defect of the inspection target based on a deviation between an image at a time when the inspection target is static and an image at a time when the inspection target is ultrasonically vibrated that are obtained by using the camera,

wherein when the detection unit detects the defect of the inspection target, the control unit changes the frequency of the high frequency power supplied from the driving unit to the ultrasonic vibration device, and when the frequency of the high frequency power is changed, the control unit adjusts a voltage of the high frequency power supplied from the driving unit to the ultrasonic vibration device, so that the current detected by the current sensor falls within a predetermined range.

~~24~~18. A defect detection device, detecting a defect of an inspection target, the defect detection device comprising:

an ultrasonic vibration device, ultrasonically vibrating the inspection target;

a driving unit, supplying high frequency power to the ultrasonically vibration device;

a control unit, adjusting a frequency of the high frequency power supplied from the driving unit to the ultrasonic vibration device;

a coherent light source, irradiating the inspection target with coherent light;

a camera, having an imaging element imaging the inspection target irradiated with the coherent light to obtain an image; and

a detection unit, detecting the defect of the inspection target based on a deviation between an image at a time when the inspection target is static and an image at a time when the inspection target is ultrasonically vibrated that are obtained by using the camera,

wherein the control unit comprises a map in which a change of a voltage of the high frequency power supplied from the driving unit to the ultrasonic vibration device with respect to the frequency of the high frequency power supplied from the driving unit to the ultrasonic vibration device is defined in advance, so that a current of the high frequency power supplied from the driving unit to the ultrasonic vibration device falls within a predetermined range, and

when the frequency of the high frequency power supplied from the driving unit to the ultrasonic vibration device is changed, the voltage of the high frequency power supplied from the

driving unit to the ultrasonic vibration device is adjusted based on the map.

~~25~~19. A defect detection device, detecting a defect of an inspection target, the defect detection device comprising:

an ultrasonic vibration device, formed by a plurality of ultrasonic speakers that are directive and disposed on a periphery of the inspection target, the ultrasonic speakers are installed to a casing, so as to concentrate a plurality of ultrasonic waves generated by the respective ultrasonic speakers on the inspection target, and ultrasonically vibrate the inspection target;

a plurality of driving units, respectively supplying high frequency power to the ultrasonic speakers;

a current sensor, each detecting a current of the high frequency power supplied from each of the driving units to each of the ultrasonic speakers;

a control unit, adjusting a frequency of the high frequency power supplied from each of the driving units to each of the ultrasonic speakers,

a coherent light source, irradiating the inspection target with coherent light;

a camera, having an imaging element imaging the inspection target irradiated with the coherent light to obtain an image; and

a detection unit, detecting the defect of the inspection target based on a deviation between an image at a time when the inspection target is static and an image at a time when the inspection target is ultrasonically vibrated that are imaged by using the camera,

wherein when the detection unit detects the defect of the inspection target, the control unit changes the frequency of the high frequency power supplied from each of the driving units to each of the ultrasonic speakers, and when the frequency of the high frequency power is changed, the control unit adjusts a voltage of the high frequency power supplied from each of the driving units to each of the ultrasonic speakers, so that the current detected by each of the current sensors falls within a predetermined range.

~~26~~20. A defect detection device, detecting a defect of an inspection target, the defect detection device comprising:

an ultrasonic vibration device, formed by a plurality of ultrasonic speakers that are directive and disposed on a periphery of the inspection target, the ultrasonic speakers are installed to a casing, so as to concentrate a plurality of ultrasonic waves generated by the respective ultrasonic speakers on the inspection target, and ultrasonically vibrate the inspection target;

a plurality of driving units, respectively supplying high frequency power to the ultrasonic speakers;

a control unit, adjusting a frequency of the high frequency power supplied from each of the driving units to each of the ultrasonic speakers,

a coherent light source, irradiating the inspection target with coherent light;

a camera, having an imaging element imaging the inspection target irradiated with the coherent light to obtain an image; and

a detection unit, detecting the defect of the inspection target based on a deviation between an image at a time when the inspection target is static and an image at a time when the inspection target is ultrasonically vibrated that are imaged by using the camera,

wherein the control unit comprises a map in which a change of a voltage of the high frequency power supplied from each of the driving units to each of the ultrasonic speakers with respect to the frequency of the high frequency power supplied from each of the driving units to each of the ultrasonic speakers is defined in advance, so that each current of the high frequency power supplied from each of the driving units to each of the ultrasonic speakers falls within a predetermined range, and

when the frequency of the high frequency power supplied from each of the driving units to each of the ultrasonic speakers is changed, the voltage of the high frequency power supplied from each of the driving units to each of the ultrasonic speakers is adjusted based on the map.