Description

Title of Invention: DEFECT DETECTION DEVICE, DEFECT DETECTION METHOD, WAFER, SEMICONDUCTOR CHIP, DIE BONDER, SEMICONDUCTOR MANUFACTURING METHOD, AND SEMICONDUCTOR DEVICE MANUFACTURING METHOD

Technical Field

[0001] The present invention relates to a wafer, a defect detection device configured to detect a crack formed on a surface of a workpiece, for example, a chip obtained by cutting the wafer into an individual piece, a defect detection method, a die bonder, and a bonding method, and further relates to a wafer, a semiconductor chip, a semiconductor manufacturing method, and a semiconductor device manufacturing method.

Background Art

[0002] As a detection device configured to detect cracks generated in a chip (semiconductor chip), there have hitherto been proposed various devices (Patent Literature 1 to Patent Literature 3). In Patent Literature 1, an image of a semiconductor surface is picked up by an image pickup unit, correlation coefficients of a plurality of color signals output from the image pickup unit are determined by a detector, and defects of the semiconductor surface are detected based on the correlation coefficients. Therefore, defects such as discoloration and contamination can be detected.

[0003] In Patent Literature 2, a rear surface side of a wafer

having formed thereon a resin layer for sealing a principal surface side is irradiated with an infrared light beam with an optical axis crossing the principal surface of the wafer, and an image is picked up by receiving reflected light, to thereby detect cracks generated in the wafer. That is, the rear surface side of the wafer, which is formed into an individual piece by dicing, is irradiated with the infrared light beam, to thereby allow the infrared light beam to be transmitted through the wafer, and the reflected light of the infrared light beam, which is diffusely reflected from an interface of cracks generated in the wafer, is received and formed into an image, to thereby enable visualization of the cracks generated in the wafer.

[0004] In Patent Literature 3, through detection of an elastic wave from a semiconductor chip, the deformation of the semiconductor chip and the generation of cracks are detected.

Citation List

[0005] Patent Literature 1: JP 6-82377 A

Patent Literature 2: JP 2008-45965 A

Patent Literature 3: JP 2015-170746 A

Summary of Invention

Technical Problem

[0006] As a workpiece, as illustrated in FIG. 23, there may be given a semiconductor chip 3 including a wiring pattern layer

1 and a coating layer 2 formed on the wiring pattern layer. In this case, when illumination light enters the surface of the workpiece, the illumination light is reflected from the surface of the coating layer 2, transmitted through the coating layer 2, absorbed by the coating layer 2, scattered from the coating layer 2, or reflected from the wiring pattern layer 1.

[0007] Therefore, cracks such as fracture formed on an upper surface of the coating layer 2 cannot be easily detected by the detection device described in Patent Literature 1, for example. Further, according to the method described in Patent Literature 2, the rear surface side of the wafer is irradiated with the infrared light beam to cause the infrared light beam to be transmitted through the wafer, to thereby enable visualization of the cracks generated in the wafer, and hence the cracks on the surface of the wafer cannot be detected. In Patent Literature 3, the elastic wave from the semiconductor chip is detected, to thereby detect whether or not cracks have been generated. Therefore, the positions of the cracks cannot be detected.

[0008] The present invention has been made in view of the above-mentioned problems, and an object of the present invention is to provide a defect detection device and a detection method, which are capable of stably detecting the presence or absence of a defect, for example, a crack formed on a surface of a workpiece. Another object of the present invention is to provide a die bonder and a bonding method, which are capable of stably detecting the

presence or absence of a defect, for example, a crack.

Solution to Problem

[0009] A defect detection device of the present invention is a defect detection device, which is configured to detect a defect having at least an inclined surface portion in a semiconductor product or a workpiece, which is a part of the semiconductor product, the defect detection device comprising an inspection mechanism, the inspection mechanism comprising: an illuminator configured to irradiate the workpiece with bright-field illumination light; and an image pickup device, which forms an observation optical system, and is configured to observe an observation site of the workpiece irradiated with the bright-field illumination light by the illuminator, wherein the inspection mechanism is configured to observe reflected light from the workpiece, which is output from an out-of-focus position defocused from an in-focus position in an optical axis direction, and emphasize a defect on an observation image formed by reflected light from the out-of-focus position as compared to a defect on an observation image formed by reflected light from the in-focus position. In this case, the semiconductor product encompasses an unfinished product in the middle of manufacturing as well as a finished product. In this case, the term "in-focus position" refers to any position on an in-focus plane (plane having a conjugate relationship with an image plane (sensor plane)), and the term "out-of-focus position" refers to a position

other than a position on the in-focus plane. The case in which an object plane is not matched with the in-focus position corresponds to defocusing.

[0010] In the defect detection device of the present invention, when the workpiece is irradiated with the bright-field illumination light, and the reflected light therefrom is observed, so-called defocusing is performed, in which the reflected light from the workpiece is caused to be output apparently from the out-of-focus position displaced from the in-focus position in the optical axis direction. In this case, the term "bright-field illumination light" refers to light (substantially parallel light) that illuminates the workpiece in an extending direction of a principal ray of the observation optical system. With this, a defect on an observation image formed by the reflected light from the out-of-focus position can be emphasized, with the result that a defect that is hard to see becomes visible, and a defect that cannot be seen with an existing device becomes visible. In this case, the term "emphasize" refers to enlarging a defect on the image as compared to a defect on the observation image formed by the reflected light from the in-focus position and increasing the contrast between the defect on the observation image and the other portions. That is, the term "emphasize" in the present invention refers to a situation in which at least any one of enlargement or an increase in contrast occurs.

[0011] In the above-mentioned configuration, the reflected light may be output from two different positions comprising at least

the out-of-focus position among the in-focus position and the out-of-focus position. Those positions comprise the in-focus position. That is, the expression "at least two different positions" encompasses the case of the in-focus position and one or more out-of-focus positions, and the case of two or more out-of-focus positions. Further, inspection or positioning of detecting a position of the workpiece on an image may be performed based on the reflected light from at least one of the above-mentioned positions. With this, the observation optical system has a positioning function in addition to an inspection function, and is effective for a device (in particular, a die bonder and the like) required to be positioned in the vicinity of the in-focus position (range of a depth of field).

[0012] The inspection mechanism may be configured to perform the inspection based on reflected light output from an out-of-focus position on a side close to the image pickup device and reflected light output from an out-of-focus position on a side away from the image pickup device, with the in-focus position being a boundary between the out-of-focus positions. With this, the color of the defect on the observation image at the out-of-focus position on the side close to the image pickup device becomes different from the color of the defect on the observation image at the out-of-focus position on the side away from the image pickup device with the in-focus position being the boundary.

[0013] A numerical aperture (NA) on the illuminator side may be smaller than an NA on the observation optical system side. With

this, the inspection can be performed even when, in a defect having a pair of opposed inclined surfaces, a relative angle between the inclined surfaces of the opposed surfaces (in this Description, a crack angle θ1+θ2, where θ1 (clockwise direction) represents an inclination angle of one surface, and θ2 (counterclockwise direction) represents an inclination angle of the other surface) is small.

[0014] The workpiece may be arranged at the out-of-focus position to cause the reflected light from the workpiece to be output from the out-of-focus position displaced from the in-focus position in the optical axis direction. Further, the inspection mechanism may comprise a defocusing unit configured to cause the reflected light from the workpiece to be output from the out-of-focus position displaced from the in-focus position in the optical axis direction, and the defocusing unit may be any one of a unit configured to cause the workpiece and an optical system to relatively move in the optical axis direction, a unit configured to change the optical system, a unit that uses a plurality of optical systems and a plurality of light-receiving elements having different in-focus positions, and a unit configured to change an illumination wavelength or an observation wavelength.

[0015] The defect detection device may further comprise a varying unit capable of varying at least one of an NA on the illumination unit side or an NA on an observation optical system side.

[0016] The defect detection device may further comprise an NA control portion configured to set at least an NA on the observation optical system side or an NA on the illuminator side in accordance with a tilt of the workpiece or a defocus amount.

[0017] The defect detection device may be configured to perform inspection at a position defocused by 100 μm or more from the in-focus position in the observation optical system.

[0018] When a defect in a workpiece to be inspected has a pair of surface portions having different directions, a defocus amount from a position of the workpiece to the out-of-focus position may be larger than a value calculated by the following expression: $\varepsilon_{min}-w/(\tan 2\theta 1+\tan 2\theta 2)$, where ε_{min} represents a minimum detection width of the image pickup device, θ1 represents an angle formed by a line orthogonal to an optical axis and one of the pair of surface portions, θ2 represents an angle formed by the line orthogonal to the optical axis and another of the pair of surface portions, and w represents a separation width between the pair of surface portions. With this, the certainty of being able to enlarge the defect on the observation image can be enhanced.

[0019] In the above-mentioned configuration, when the θ1 and the θ2 of the workpiece to be inspected are limited by the numerical aperture NA of the observation optical system, the θ1 and the θ2 may satisfy the following expressions: $-\sin^{-1}(NA)\leq\theta 1\leq\sin^{-1}(NA)$ and $-\sin^{-1}(NA)\leq\theta 2\leq\sin^{-1}(NA)$.

[0020] The defect detection device may further comprise a

control portion configured to control the defocusing unit so as to achieve a predetermined defocus amount. With this, the defect detection device automatically performs defocusing. In this case, the control portion may comprise a calculating portion configured to calculate a defocus amount based on a predetermined parameter. With this, merely through setting of the parameter by a user, the defect detection device automatically determines a defocus amount.

[0021] The illumination unit comprises a light source for inspection, a light source for positioning, and an NA switching portion configured to switch the light source to electrically switch an NA on the illumination side.

[0022] The defect detection device may further comprise a detection portion configured to detect an inclination angle and a defect width of a surface portion based on a defocus amount and a separation width. With this, angle measurement of the surface portion of the defect can be performed.

[0023] The defect detection device may further comprise a discriminating part configured to discriminate defects based on a change in shading of the defect and/or a change in size of the defect when inspection is performed from two different positions comprising at least the out-of-focus position among the in-focus position and the out-of-focus position. That is, through discrimination of any one of a change in shading of the defect and a change in size of the defect, or both the change in shading of the defect and the change in size of the defect, for example, the

defect can be classified (into a so-called crack having an inclined surface, a foreign matter, or the like). The term "change in size of the defect" refers to enlargement and reduction of the defect.

[0024] The workpiece may have a multilayer structure, and light that is reflected or scattered from a layer to be inspected to enter the image pickup device may have a wavelength at which an intensity of the light is higher than an intensity of light from another layer.

[0025] In the above-mentioned configuration, the workpiece may comprise a variable density layer having a variable density pattern derived from a semiconductor manufacturing process and a coating layer, which covers the variable density pattern of the variable density layer, and illumination light emitted from the illumination unit may have a wavelength at which an intensity of light that is reflected or scattered from the coating layer to enter the image pickup device is higher than an intensity of light that is reflected from at least the variable density layer to enter the image pickup device, to thereby reduce influence of the variable density pattern of the variable density layer. The expression "reducing influence of the variable density pattern" refers to the case in which, when a defect is observed, the variable density pattern is eliminated or weakly reflected so as not to impair the observation of the defect. That is, the above-mentioned expression refers to the case in which a luminance contrast caused by the variable density pattern is lowered as compared to that in the case of using light other than the above-mentioned light. With this, the light reflected or scattered

from the surface of the coating layer can be projected, and the luminance contrast caused by the variable density pattern is lowered, so that the influence of the variable density layer can be reduced (decreased).

[0026] The coating layer may be an organic substance layer, and the organic substance layer may be made of a polyimide resin. The coating layer may be set to have a film thickness of from 1 μm to 100 μm. The coating layer may be formed of a plurality of layers comprising two or more layers, and the layers may be made of the same material or different materials, or predetermined layers of the plurality of layers may be made of the same material.

[0027] It is preferred that, of the illumination light from the illumination unit, illumination light to be observed have a wavelength of 450 nm or less, or a wavelength of 1,000 nm or more. As described above, when the wavelength of the illumination light to be observed is 450 nm or less or 1,000 nm or more, the coating layer can be made of a polyimide resin, and the influence of the wiring pattern of the variable density layer, which is the variable density pattern, can be stably reduced.

[0028] In the above-mentioned configuration, the defect detection device of the present invention may comprise a table on which the workpiece is placed, and a workpiece placement portion of the table may be formed of a porous material configured to attract the workpiece through suction to hold the workpiece. In addition, the defect detection device of the present invention may comprise

a table on which the workpiece is placed, and a workpiece placement portion of the table may be formed of an electrostatic chuck structure configured to attract the workpiece through static electricity to hold the workpiece. When the workpiece placement portion of the table is formed of the porous material or the electrostatic chuck structure, the workpiece is held by the table uniformly as a whole. Therefore, even when the workpiece is warped, the workpiece can be formed into a planar shape. With this, a warped portion can be prevented from being darkly observed at a time of observation.

[0029] As the workpiece, there are given, for example, a wafer in which the wiring pattern forms the variable density pattern and an individual piece (semiconductor chip) cut out from a wafer. That is, as the workpiece, there may be used an individual piece (unpackaged individual piece, that is, uncovered individual piece) to be mounted on a lead frame or a substrate, and a workpiece formed of a plurality of individual pieces (a laminate of single individual pieces, or an assembly of a plurality of individual pieces). There is given, for example, a laminated memory chip and a system in package (SiP).

[0030] A defect detection method of the present invention is a defect detection method for detecting a defect having at least an inclined surface portion, which is a semiconductor product or a part of the semiconductor product, the method comprising: irradiating the workpiece with bright-field illumination light to cause reflected light from the workpiece to be output from an out-of-focus position defocused from an in-focus position in an

optical axis direction; and emphasizing a defect on an observation image formed by reflected light from the out-of-focus position as compared to a defect on an observation image formed by reflected light from the in-focus position.

[0031] In the defect detection method of the present invention, when the workpiece is irradiated with the bright-field illumination light, and the reflected light therefrom is observed, so-called defocusing is performed, in which the reflected light from the workpiece is caused to be output apparently from the out-of-focus position displaced from the in-focus position in the optical axis direction. In this case, the term "bright-field illumination light" refers to light (substantially parallel light) that illuminates the workpiece in an extending direction of a principal ray of the observation optical system. With this, a defect on an observation image formed by the reflected light from the out-of-focus position can be emphasized, with the result that a defect that is hard to see becomes visible, and a defect that cannot be seen with an existing device becomes visible.

[0032] A second defect detection method of the present invention is a defect detection method for detecting a defect having at least an inclined surface portion in a semiconductor product or a workpiece, which is a part of the semiconductor product. The method comprises: placing the workpiece on a table having a workpiece placement portion formed of a porous material; sucking the workpiece through a pore of the porous material to cause the workpiece to be adsorbed to

the table; irradiating the workpiece with bright-field illumination light to cause reflected light from the workpiece to be output from an out-of-focus position defocused from an in-focus position in an optical axis direction; and emphasizing a defect on an observation image formed by reflected light from the out-of-focus position as compared to a defect on an observation image formed by reflected light from the in-focus position.

[0033] A third defect detection method is a defect detection method for detecting a defect having at least an inclined surface portion in a semiconductor product or a workpiece, which is a part of the semiconductor product. The method comprises: placing the workpiece on a table having a workpiece placement portion formed of an electrostatic chuck structure; attracting the workpiece through static electricity to cause the table to hold the workpiece; irradiating the workpiece with bright-field illumination light to cause reflected light from the workpiece to be output from an out-of-focus position defocused from an in-focus position in an optical axis direction; and emphasizing a defect on an observation image formed by reflected light from the out-of-focus position as compared to a defect on an observation image formed by reflected light from the in-focus position.

[0034] The defect detection method may be a defect detection method comprising using the defect detection device. The defect detection method may be a defect detection method including: setting in advance a determination criterion regarding whether a product

having a defect detected by the defect detection method is a defective product; and determining, through use of a defective image, whether the product is a defective product or a non-defective product based on the determination criterion.

[0035] When inspection is performed from two different positions comprising at least the out-of-focus position among the in-focus position and the out-of-focus position, defects may be discriminated based on a change in shading of the defect and/or a change in size of the defect. The term "change in size of the defect" refers to enlargement and reduction of the defect.

[0036] Further, there may be provided a wafer and a semiconductor chip, each of which is detected by the defect detection method to have no defect, or each of which is detected by the defect detection method to have a defect, and is determined by the defect detection method as a non-defective product.

[0037] There may be provided a semiconductor device comprising an individual piece, which is detected by the defect detection method to have no defect, or which is detected by the defect detection method to have a defect, and is determined by the defect detection method as a non-defective product.

[0038] According to the present invention, there is provided a die bonder comprising: a bonding portion configured to pick up a workpiece at a pickup position, convey the workpiece that has been picked up to a bonding position, and subject the workpiece to bonding at the bonding position; and the defect detection device.

[0039] In the die bonder of the present invention, a defect, for example, a crack on a surface of the workpiece to be bonded can be detected in a bonding portion or at a position other than the bonding portion, that is, at any portion of the die bonder. That is, in a period before bonding operation, during the bonding operation, and in a period after the bonding operation, the defect (crack) in the workpiece (semiconductor chip and the like) can be detected to prevent a defective product from being shipped. Further, in the case of a product in which semiconductor chips (dies) are laminated (stacked), the yield can be significantly improved. For example, when a chip is bonded onto a defective chip, and a defective chip is laminated on a laminated non-defective chip, the laminate becomes defective, and the rank of the product may be degraded.

[0040] The die bonder may be configured to perform positioning detection at the pickup position, and may be configured to perform positioning detection at the bonding position.

[0041] There may be provided a die bonder comprising an intermediate stage to which a workpiece is to be conveyed between a pickup position and a bonding position, wherein the defect detection device of the present invention is arranged also at the intermediate stage. Further, positioning detection may be performed at at least one of the pickup position, the bonding position, or the intermediate stage between the pickup position and the bonding position.

[0042] A first bonding method of the present invention is a bonding method comprising: a bonding step comprising picking up

a workpiece at a pickup position, conveying the workpiece that has been picked up to a bonding position, and subjecting the workpiece to bonding at the bonding position; and detecting a defect in the workpiece by the defect detection device during at least any one of a period before the pickup or a period after the pickup.

[0043] A second bonding method of the present invention is a bonding method comprising: a bonding step comprising picking up a workpiece at a pickup position, conveying the workpiece that has been picked up to a bonding position, and subjecting the workpiece to bonding at the bonding position; and detecting a defect in the workpiece by the defect detection device during at least any one of a period before the workpiece is supplied to an intermediate stage, which is arranged between the pickup position and the bonding position, or a period after the workpiece is discharged from the intermediate stage.

[0044] A third bonding method of the present invention is a bonding method comprising: a bonding step comprising picking up a workpiece at a pickup position, conveying the workpiece that has been picked up to a bonding position, and subjecting the workpiece to bonding at the bonding position; and detecting a defect in the workpiece by the defect detection device during at least any one of a period before the bonding or a period after the bonding.

[0045] A fourth bonding method of the present invention is a bonding method comprising: a bonding step comprising picking up a workpiece at a pickup position, conveying the workpiece that has

been picked up to a bonding position, and subjecting the workpiece to bonding at the bonding position; and performing an inspection step using the defect detection method during at least any one of a period before the workpiece is supplied to the bonding step or a period after the workpiece is discharged from the bonding step.

[0046] There is provided a semiconductor manufacturing method comprising an inspection step using the defect detection method, and further comprising at least any one of a dicing step of cutting a wafer into an individual piece or a mold sealing step of sealing a semiconductor chip formed into an individual piece with resin.

[0047] There is provided a semiconductor device manufacturing method for manufacturing a semiconductor device comprising an individual piece assembly formed of a plurality of individual pieces, the semiconductor device manufacturing method comprising subjecting at least any one of a target object comprising one individual piece or an assembly of a predetermined number of individual pieces or another individual piece to be assembled to the target object, to inspection through use of the defect detection method.

Advantageous Effects of Invention

[0048] According to the present invention, a defect on the observation image formed by the reflected light from the out-of-focus position can be observed in an enlarged state as compared to a defect on the observation image formed by the reflected light from the in-focus position, and a defect that cannot be seen with an existing

device becomes visible. Therefore, a defect (crack) can be stably detected.

Brief Description of Drawings

[0049] FIG. 1 is a schematic view of a defect detection device according to the present invention.

FIG. 2A is a schematic view for illustrating a bonding step using a die bonder of the present invention.

FIG. 2B is a schematic perspective view of the die bonder.

FIG. 3 is a schematic view of the die bonder of the present invention comprising a defect detection device at a pickup position.

FIG. 4 is a schematic perspective view for illustrating a wafer.

FIG. 5A is an enlarged sectional view of a main portion of a workpiece in which a coating layer is formed of a single layer.

FIG. 5B is an enlarged sectional view of a main portion of a workpiece in which a coating layer is formed of a plurality of layers.

FIG. 6A is an explanatory diagram for illustrating reflection of light in a case in which an NA on an illuminator side is smaller than an NA on an observation optical system side.

FIG. 6B is an explanatory diagram for illustrating reflection of light in a case in which the NA on the illuminator side is larger than the NA on the observation optical system side.

FIG. 7A is a schematic sectional view for illustrating a defect (crack) generated in the workpiece in a state in which inclined

surface portions are formed on upper surfaces of a pair of cut end surfaces.

FIG. 7B is a schematic sectional view for illustrating a defect (crack) generated in the workpiece in a state in which the inclined surface portion is formed on the upper surface of one of the pair of cut end surfaces.

FIG. 7C is a schematic sectional view for illustrating a defect (crack) generated in the workpiece in a state in which the defect (crack) has a V-shape in cross section.

FIG. 7D is a schematic sectional view for illustrating a defect (crack) generated in the workpiece in a state in which the defect (crack) has a right-angled triangle shape in cross section.

FIG. 7E is a schematic sectional view for illustrating a defect (crack) generated in the workpiece in a state in which the workpiece is cut into a valley-folded shape, and the inclined surface portions are formed on the upper surfaces of the pair of cut end surfaces.

FIG. 7F is a schematic sectional view for illustrating a defect (crack) generated in the workpiece in a state in which the workpiece is cut into a mountain-folded shape, and the inclined surface portion is formed on the upper surface of one of the pair of cut end surfaces.

FIG. 7G is a schematic sectional view for illustrating a defect (crack) generated in the workpiece in a state in which the workpiece is bent into a valley-folded shape.

FIG. 7H is a schematic sectional view for illustrating a defect (crack) generated in the workpiece in a state in which the workpiece

is bent into a mountain-folded shape.

FIG. 7I is a schematic sectional view for illustrating a defect (crack) generated in the workpiece in a state in which the workpiece is cut into a valley-folded shape and the inclined surface portions that flatly extend from upper ends of the cut end surfaces are formed.

FIG. 7J is a schematic sectional view for illustrating a defect (crack) generated in the workpiece in a state in which the workpiece is cut into a mountain-folded shape and the inclined surface portions that flatly extend from the upper ends of the cut end surfaces are formed.

FIG. 8 is an explanatory diagram for illustrating a relationship between an in-focus position and an out-of-focus position of a workpiece having a defect cut into a valley-folded shape.

FIG. 9 is an explanatory view for illustrating a relationship between the illumination light and the reflected light on an object plane having a tilt θ.

FIG. 10 is an explanatory diagram for illustrating displacement between an image formed by the reflected light from the in-focus position and an image formed by the reflected light from the out-of-focus position.

FIG. 11 is a diagram for illustrating a reflected light flux from the workpiece having the defect cut into a valley-folded shape, a luminance cross section of a plane comprising an out-of-focus position Fa, and a luminance cross section of a plane comprising

an out-of-focus position Fb.

FIG. 12A is an observation image of the workpiece having the defect cut into a valley-folded shape at the out-of-focus position on an upper side.

FIG. 12B is an observation image of the workpiece having the defect cut into a valley-folded shape at the out-of-focus position on the upper side.

FIG. 12C is an observation image of the workpiece having the defect cut into a valley-folded shape at the out-of-focus position on the upper side.

FIG. 12D is an observation image of the workpiece having the defect cut into a valley-folded shape at the out-of-focus position on the upper side.

FIG. 12E is an observation image of the workpiece having the defect cut into a valley-folded shape at the out-of-focus position on a lower side.

FIG. 12F is an observation image of the workpiece having the defect cut into a valley-folded shape at the out-of-focus position on the lower side.

FIG. 12G is an observation image of the workpiece having the defect cut into a valley-folded shape at the out-of-focus position on the lower side.

FIG. 13 is an explanatory diagram for illustrating a relationship between the in-focus position and the out-of-focus position of the workpiece having the defect cut into a mountain-folded

shape.

FIG. 14 is a diagram for illustrating a reflected light flux from the workpiece having the defect cut into a mountain-folded shape, a luminance cross section of a plane comprising the out-of-focus position Fa, and a luminance cross section of a plane comprising the out-of-focus position Fb.

FIG. 15 is a graph for showing a relationship between the inclination angle and the minimum defocus amount.

FIG. 16 is an explanatory view of a transmittance of light.

FIG. 17A is a schematic view for illustrating a method of causing a semiconductor chip to adsorb to a pickup stage of the die bonder of the present invention before adsorption.

FIG. 17B is a schematic view for illustrating the method of causing the semiconductor chip to adsorb to the pickup stage of the die bonder of the present invention during adsorption.

FIG. 17C is a schematic view for illustrating the method of causing the semiconductor chip to adsorb to the pickup stage of the die bonder of the present invention after adsorption.

FIG. 18 is a schematic view of the defect detection device comprising another defocusing unit.

FIG. 19 is a schematic view of the defect detection device comprising another defocusing unit.

FIG. 20 is a schematic view of a defect detection device comprising another defocusing unit.

FIG. 21 is a schematic view of a defect detection device

comprising another illumination unit.

FIG. 22 is a schematic perspective view of the die bonder.

FIG. 23 is a schematic sectional view of a state in which a semiconductor chip that is a workpiece is irradiated with illumination light.

FIG. 24 is a block diagram for illustrating a semiconductor manufacturing process diagram.

Description of Embodiments

[0050] Now, embodiments of the present invention are described with reference to FIG. 1 to FIG. 24.

[0051] FIG. 1 is a schematic view of a defect detection device for a workpiece according to the present invention, and the defect detection device is configured to detect the presence or absence and the position of a defect 50 (see FIGS. 7), for example, a crack formed in a workpiece such as a semiconductor wafer 29 (see FIG. 4), a semiconductor chip 21 (see FIG. 2A and FIG. 2B) obtained by cutting the semiconductor wafer 29 into an individual piece, and a die.

[0052] As illustrated in FIG. 5A and FIG. 5B, the workpiece comprises a variable density layer 11 that is a variable density pattern and a coating layer 12 that covers the variable density pattern of the variable density layer 11. In this case, the coating layer 12 is formed of one layer in FIG. 5A, and is formed of a plurality of layers (in the illustrated example, two layers comprising a first

layer 13 on the variable density layer side and a second layer 14 that is an upper layer of the first layer 13) in FIG. 5B. The variable density pattern can be formed of a wiring pattern. When the variable density pattern is formed of the wiring pattern, the variable density layer 11 can be called a wiring pattern layer.

[0053] Specifically, in the invention of the present application, the variable density pattern is derived from a semiconductor manufacturing process and is formed by the semiconductor manufacturing process. As the variable density pattern, there are given, for example, a pattern generated based on a wiring pattern and a pattern generated due to the presence of oxidized Si and nitrided Si and Si different from the oxidized Si and the nitrided Si. Thus, it is only required that the variable density pattern of the workpiece be formed by the semiconductor manufacturing process, and a base material thereof may be a semiconductor, glass, or a polymer material. As a semiconductor manufacturing front-end process, there are given lithography (including ion implantation, etching, and the like), a film forming step, and the like.

[0054] The coating layer 12 can be made of, for example, a silicone resin or a polyimide resin. Further, when the coating layer 12 comprises a plurality of layers as illustrated in FIG. 5B, the first layer 13 and the second layer 14 may be made of the same material or different materials. That is, when the coating layer 12 is formed of one layer as illustrated in FIG. 5A, the coating layer 12 can

be made of a silicone resin, a polyimide resin, or the like. When the coating layer 12 comprises a plurality of layers as illustrated in FIG. 5B, for example, the first layer 13 can be made of a polyimide resin, and the second layer can be made of a silicone resin. Alternatively, the first layer 13 can be made of a silicone resin, and the second layer can be made of a polyimide resin. Alternatively, the first layer 13 and the second layer 14 can be made of a polyimide resin. Alternatively, the first layer 13 and the second layer 14 can be made of a silicone resin. Further, even when the first layer 13 and the second layer 14 are made of the same kind of resin, resins having different characteristics and the like may be used.

[0055] The thickness dimension of the coating layer 12 can be set to, for example, from 1 μm to 100 μm, more preferably, from about 1 μm to about 20 μm irrespective of whether the coating layer 12 is formed of a single layer as illustrated in FIG. 5A or is formed of a plurality of layers as illustrated in FIG. 5B. In addition, the coating layer may be formed of three or more layers. In this case, the layers may be made of the same material or different materials, or predetermined layers of the plurality of layers may be made of the same material.

[0056] In this embodiment, the defect detection device 100 is arranged at any position of a die bonder as illustrated in FIG. 2B and FIG. 22. The die bonder comprises a bonding portion configured to pick up a chip 21 cut out from a wafer 29 (see FIG. 4) at a pickup position P and transfer (mount) the chip 21 to a bonding position

Q of a substrate 22, for example, a lead frame. The wafer 29 is separated (divided) into a large number of chips 21 in a dicing step. Therefore, the chips 21 are arrayed in matrix on a table (pickup table) as illustrated in FIG. 4. As described later, in the die bonder illustrated in FIG. 2B, a table (intermediate stage) is arranged between the pickup position P and the bonding position Q. When the intermediate stage is arranged as described above, in a bonding step, the workpiece picked up from the wafer 29 can be temporarily placed on the intermediate stage and picked up again from the intermediate stage to be bonded. Thus, the defect detection device 100 according to the present invention is arranged on at least any one of the pickup position P, the bonding position Q, or the intermediate stage, at any position from the pickup position P to the bonding position Q, or at a position other than the bonding portion.

[0057] As illustrated in FIG. 3, the table (pickup table 101 in this embodiment) comprises a rectangular porous material 102 and a support portion 103 configured to support the porous material 102 from the periphery, and is connected to a suction mechanism, for example, a vacuum pump (not shown). The porous material is a material in which an indefinite number of small pores are formed. As the porous material, there are given various materials such as a metal and ceramics. For example, it is preferred that the porous material 102 have a mesh particle diameter of about 240 μm and an average pore diameter of about 55 μm. An upper surface of the porous

material 102 serves as a placement portion on which the workpiece is placed. When the suction mechanism is driven under a state in which the workpiece is placed on the porous material 102, the workpiece is sucked through a closed space formed below the porous material 102 and the support portion 103, and the infinite number of pores of the porous material 102, and the workpiece adsorbs to the porous material 102 as a whole.

[0058] The porous material 102 is slightly larger than the outer diameter size of the workpiece (chip). For example, when the chip size is 10×15 mm, it is preferred that the outer periphery length of the porous material 102 be set to a size obtained by adding about 0.1 mm to the chip size. With this, the chip adsorbs to the porous material 102 up to the outer peripheral portion.

[0059] There is provided a vacuum pressure sensor 104 (or a flow rate sensor) configured to measure a vacuum pressure in a flow passage between the pickup table 101 and the suction mechanism. When a sensor value is read, it can be determined whether or not the workpiece has been sucked on the pickup table 101.

[0060] In the related art, when the workpiece is sucked through a suction port formed in a table, for example, the pickup table 101, the diameter of the suction port is as large as about 300 μm. Therefore, the workpiece is sucked into the suction port when the workpiece is fixed to the table, for example, the pickup table 101. With this, the surface of the workpiece is inclined and darkly observed in some cases. In addition, a residual stress occurs in a forming

process of the workpiece to cause a warp in the workpiece, and the warped portion is darkly observed in some cases. In this embodiment, the workpiece placement portion of the pickup table 101 is formed of the porous material 102, and thus, the workpiece is held by the stage uniformly as a whole. Therefore, even when there is a warp in the workpiece, the workpiece can be formed into a planar shape, and the warped portion can be prevented from being darkly observed at a time of observation. In addition, a large suction portion as in the related art is not formed in the pickup table 101, and hence the workpiece can be prevented from being sucked into the suction port to be inclined and darkly observed.

[0061] As illustrated in FIG. 2A, the die bonder comprises a collet (adsorption collet) 23. Through use of a moving mechanism (not shown), the collet 23 can be lifted in a direction indicated by an arrow "a" and lowered in a direction indicated by an arrow "b" at the pickup position P. Further, the collet 23 can be lifted in a direction indicated by an arrow "c" and lowered in a direction indicated by an arrow "d" at the bonding position Q. Further, the collect 23 can reciprocate in directions indicated by arrows e and f between the pickup position P and the bonding position Q. The movement of the moving mechanism in the directions indicated by the arrows a, b, c, d, e, and f is controlled by a controller of, for example, a microcomputer. The moving mechanism can comprise various mechanisms, such as a cylinder mechanism, a ball screw mechanism, and a linear motor mechanism.

[0062] The adsorption collet 23 comprises a head (adsorption nozzle) 24 having an adsorption hole 28 opened on a lower surface thereof. The chip 21 is sucked by vacuum through the adsorption hole 28 to adsorb to a lower end surface (distal end surface) of the head 24. When this vacuum suction (vacuuming) is released, the chip 21 is removed from the head 24.

[0063] Further, the wafer 29 separated (divided) into the large number of chips 21 is placed on, for example, an XYθ table 25 (see FIG. 4), and the XYθ table 25 is provided with a push-up part comprising a push-up pin. That is, the chip 21 to be picked up is pushed up from below by the push-up part so that the chip 21 is easily peeled from a pressure-sensitive adhesive sheet. In this state, the chip 21 adsorbs to the adsorption collet 23 that is lowered.

[0064] Specifically, after the collet is positioned above the chip 21 to be picked up, the collect 23 is lowered as indicated by the arrow "b", and the chip 21 is picked up. After that, the collet 23 is lifted as indicated by the arrow "a".

[0065] Next, the collet is moved in the direction indicated by the arrow "e" to be positioned above an island portion. Then, the collet is moved downward as indicated by the arrow "d", and the chip 21 is supplied to the island portion. Further, after the chip 21 is supplied to the island portion, the collect is lifted as indicated by the arrow "c", and then returned to a standby position above the pickup position P as indicated by the arrow "f".

[0066] Specifically, the chip 21 is picked up by the collet

23 at the pickup position P by moving the collet 23 successively as indicated by the arrows "b", "a", "e", "d", "c", and "f", to be mounted at the bonding position Q.

[0067] It is required to perform position checking (position detection) of the chip 21 to be picked up at the pickup position P and to perform position checking (position detection) of the island of the lead frame for bonding also at the bonding position Q. Therefore, in general, the chip 21 to be picked up is observed with a camera for checking arranged at a position above the pickup position P, and the collet 23 is positioned above the chip 21 to be picked up. Further, the island of the lead frame is observed with a camera for checking arranged at a position above the bonding position Q, and the collet 23 is positioned above the island.

[0068] Therefore, in the die bonder, such a positioning device is arranged at the pickup position P. The positioning device comprises the defect detection device 100 according to the present invention. That is, the defect detection device comprises an inspection mechanism 30 as illustrated in FIG. 1. The inspection mechanism 30 comprises an image pickup device 31 configured to observe the chip 21, an illumination unit 32 configured to illuminate the chip 21, a half mirror 33 configured to reflect light emitted from the illumination unit 32, and a defocusing unit 39 configured to cause the reflected light from the chip 21 to be output from an out-of-focus position displaced (defocused) from an in-focus position in the optical axis direction. In this case, the term

"in-focus position" refers to a position which a light beam crosses on an optical axis when a parallel light flux is input to a lens. The term "out-of-focus position" refers to a position other than the in-focus position, which is defocused from the in-focus position.

[0069] The image pickup device 31 forming an observation optical system comprises a camera 34 and a lens 35. The camera 34 in this case can comprise a CCD image sensor, a CMOS image sensor, and the like. That is, it is only required that the camera 34 be able to image light having an illumination wavelength. Therefore, a camera having sensitivity to visible light, ultraviolet light, and infrared light may be used. Further, the lens 35 can be formed of a telecentric lens, a non-telecentric lens, or the like. The image pickup device 31 is controlled by a controller 43. The controller 43 comprises an inspection processor 44 configured to inspect a defect and a positioning processor 45 configured to detect the position of a workpiece on an image (for example, image matching).

[0070] As illustrated in FIG. 1, the illumination unit 32 comprises a bright-field illuminator including a light source 36 and a lens 37. The term "bright-field illumination" refers to illuminating the workpiece in an extending direction of a principal ray of the observation optical system 31 (parallel light). That is, in general, the bright field is used for observing direct light of reflected or transmitted illumination light, and an illumination method in this case is called a direct light illumination method. In this embodiment, a normal portion of a workpiece surface (surface

of the chip 21) is brightly observed, and direct light reflected from a large portion (normal portion) of the surface of the chip 21 is mainly observed. The expression "illuminating the workpiece in an extending direction of a principal ray of the observation optical system 31" includes the case involving refracting output light from a light-emitting unit by a lens to form light having a converging direction close to a parallel direction, reflecting the light refracted by the lens by a half mirror to irradiate a substantially entire surface to be inspected with the light, and guiding the light reflected from the surface to be inspected to an image pickup unit provided in a site in which the light is converged as in, for example, JP 2002-39956 A.

[0071] In this embodiment, the numerical aperture (NA) on the illumination unit side is set to be smaller than that on the observation optical system side. That is, a light beam is tilted due to reflection (transmission) on an inclined surface of the workpiece (chip 21) as illustrated in FIG. 6A and FIG. 6B. In this case, when the NA on the illumination unit side is larger than that on the observation optical system side as illustrated in FIG. 6B, a light beam other than a principal ray does not form an image by being blocked by a diaphragm of the observation optical system. Therefore, the position of an image is not changed (enlarged) even when defocusing is performed. Meanwhile, when the NA on the illumination unit side is smaller than that on the observation optical system side as illustrated in FIG. 6A, a light beam is not blocked

by the diaphragm of the observation optical system, and the position of an image is changed (enlarged) when defocusing is performed. Therefore, even when the workpiece is tilted or when the crack angle is small, an image can be enlarged.

[0072] A varying unit (not shown) capable of varying at least one of the NA on the illumination unit side or the NA on the observation optical system side is provided. As the varying unit, for example, an aperture stop mechanism can be used. The aperture stop mechanism is provided in any one or both of the image pickup device 31 and the illumination unit 32. The aperture stop mechanism is controlled so as to provide a predetermined NA in accordance with the tilt of the workpiece or the defocus amount. For example, in this embodiment, the aperture stop mechanism is provided in each of the image pickup device 31 and the illumination unit 32. When the defocus amount is determined by a calculating portion 41 described later, an NA control portion 47 determines an NA based on the defocus amount by calculation to control the aperture stop mechanism.

[0073] The defocusing unit 39 in this embodiment is provided below the image pickup device 31 and comprises a table 38, on which the chip 21 is to be placed, and a drive unit (not shown) configured to reciprocate the table 38 upward and downward. The drive unit can comprise various well-known and publicly used mechanisms (preferably having high precision), such as a cylinder mechanism, a ball screw mechanism, and a linear motor mechanism. With this, the chip 21 can move upward and downward as indicated by the arrow

of FIG. 1, and is brought close to and separated from the image pickup device 31. That is, the defocusing unit 39 is configured to perform so-called defocusing involving moving the chip 21 upward and downward, positioning the chip 21 at the in-focus position, positioning the chip 21 at the out-of-focus position, and causing the reflected light from the surface of the chip 21 to be output from the out-of-focus position displaced from the in-focus position in the optical axis direction.

[0074] The defocusing unit 39 (drive unit) is driven based on the control of the control portion 40. The control portion 40 can be formed of, for example, a microcomputer in which a read only memory (ROM), a random access memory (RAM), and the like are connected to each other through buses with a central processing unit (CPU) being the center. The control portion 40 comprises the calculating portion 41. For example, merely through setting of parameters by a user through use of a method described later, the calculating portion 41 automatically determines a defocus amount.

[0075] The defect detection device illustrated in FIG. 1 is arranged, for example, at the pickup position P. In this case, the wafer 29 serves as the workpiece. First, the workpiece is placed on the pickup table 101, and the workpiece is sucked through the pores of the porous material 102 to adsorb to the pickup table 101. The defect detection device further comprises another bright-field illumination unit 42 below the image pickup device 31, and is configured to detect the position on the image of the chip 21 to

be picked up through use of the bright-field illumination unit 42 and perform image matching processing and the like through use of the positioning processor 45, to thereby enable positioning of the workpiece. After that, a defect of the workpiece is detected.

[0076] The defect 50 on the surface of the workpiece has various shapes, for example, as illustrated in FIGS. 7. In FIG. 7A, inclined surface portions S and S are formed at upper ends of a pair of cut end surfaces 51 and 52. In FIG. 7B, the inclined surface portion S is formed at the upper end of the cut end surface 51. In addition, in FIG. 7C, a groove 53 having a V-shape in cross section is formed, and the pair of inclined surface portions S are formed. In FIG. 7D, a groove 54 having a right-angled triangle shape in cross section is formed, and the inclined surface portion S is formed. In FIG. 7E, the coating layer 12 of the workpiece is cut into a valley-folded shape, and the inclined surface portions S and S are formed at the upper ends of the pair of cut end surfaces 51 and 52. In FIG. 7F, the coating layer 12 of the workpiece is cut into a mountain-folded shape, and the inclined surface portion S is formed at the upper end of the cut end surface 51 out of the cut end surfaces. In FIG. 7G, the coating layer 12 of the workpiece is bent into a valley-folded shape, and the inclined surface portions S and S are formed across a bending line. In FIG. 7H, the coating layer 12 of the workpiece is bent into a mountain-folded shape, and the inclined surface portions S and S are formed across a bending line. In FIG. 7I, the coating layer 12 of the workpiece is cut into a valley-folded shape,

and the inclined surface portions S and S that flatly extend from the upper ends of the cut end surfaces 51 and 52 are formed. In FIG. 7J, the coating layer 12 of the workpiece is cut into a mountain-folded shape, and the inclined surface portions S and S that flatly extend from the upper ends of the cut end surfaces 51 and 52 are formed. In the present invention, such defects 50 (defects having the inclined surface portions S at any position, such as cracking, bending, and cutting) of the coating layer 12 as illustrated in FIGS. 7 are detected as defects of a workpiece (wafer, individual piece, or the like).

[0077] Through use of the defect detection device 100 according to this embodiment, a defect image on the observation image of the defect 50 formed in the workpiece can be observed in an emphasized state. The term "emphasizing" refers to enlarging a defect on an image as compared to a defect on an observation image formed by reflected light from the in-focus position, or increasing the contrast between the defect on the observation image and the other portion. That is, "emphasizing" in the present invention refers to at least any one of the occurrence of enlargement or the occurrence of an increase in contrast. The reason for this is described regarding, for example, the case of detecting a defect (having a cut portion in a valley-folded shape) as illustrated in FIG. 7I and FIG. 8. In FIG. 8, a separation width (crack width) between one inclined surface portion S1 (on the right side of FIG. 8) and the other inclined surface portion S2 (on the left side of FIG.

8) is represented by w, an angle (inclination angle) formed by a line orthogonal to an optical axis and the one inclined surface portion S1 is represented by θ1, an angle (inclination angle) formed by the line orthogonal to the optical axis and the other inclined surface portion S2 is represented by θ2, and a crack angle θ is represented by θ1+θ2. In FIG. 8, the dotted line represents illumination light, and the solid line represents reflected light.

[0078] As illustrated in FIG. 9, it is assumed that parallel light is output from a workpiece surface (inclined surface portion S) having inclination with an inclination angle θ. In this case, a light beam of reflected light L2 is tilted by 2θ from an optical axis of irradiation light L1. When the workpiece is placed at an in-focus position F illustrated in FIG. 10, reflected light, which passes through an intersection of a focus plane and a principal ray of the irradiation light L1 and falls within a range of ±NA (illumination side numerical aperture), forms an image IA. With this, a focused image (image at a time when the object plane and the in-focus position F are matched with each other) (see FIGS. 12) can be obtained.

[0079] As illustrated in FIG. 10, when the workpiece is moved to be defocused from the in-focus position F to an out-of-focus position Fb below the in-focus position F, the output position of the reflected light is moved (displaced downward) on the optical axis. When the reflected light is observed from an observation side lens, the reflected light appears to have been output from a point

P moved toward the left side on the drawing sheet by a positional displacement amount on the in-focus position F. With this, on an image plane, an image IB is observed as displacement in a parallel direction from the image IA. In this case, the positional displacement amount of the image can be calculated as "focus movement amount×tan(2θ)". The illumination side numerical aperture (NA) may be decreased to increase a depth of field (range allowing blurring) before the defect is inspected. With this, an image can be prevented from being blurred even when defocusing is performed.

[0080] As described above, in the case of a valley-folded shape, when the workpiece is defocused from the object plane (in-focus position F) to the out-of-focus position Fb below the in-focus position F, apparent positions of a reflected light flux A and a reflected light flux B are displaced to spread as illustrated in FIG. 11. With this, in the luminance cross section in a plane including the out-of-focus position Fb, the interval between images of the reflected light flux A and the reflected light flux B is increased, and the defect 50 is enlarged (thickened) blackly (darkly). That is, as defocusing is performed downward from the object plane, the defect on the image is blackly enlarged as shown in FIG. 12E to FIG. 12G. In FIG. 12G, an image at an out-of-focus position that is separated most downward from the object plane is taken, and the defect 50 is most enlarged (thickened). FIG. 12E is an image close to the object plane.

[0081] Further, in the case of a valley-folded shape, when the

workpiece is defocused from the object plane (in-focus position F) to the out-of-focus position Fa above the in-focus position F, apparent positions of the reflected light flux A and the reflected light flux B are displaced to approach each other as illustrated in FIG. 11. In this case, the reflected light flux A and the reflected light flux B do not overlap with each other in a region from the object plane to the out-of-focus position Fc. Therefore, the contrast is not increased, and the defect on the image become smaller as defocusing is performed upward. When defocusing is performed upward from the out-of-focus position Fc, the reflected light flux A and the reflected light flux B overlap with each other. Therefore, the overlapping portion is enlarged as the defect on the image becomes more whitish (brighter), with the result that the defect on the image is enlarged as defocusing is performed upward. In the luminance cross section in a plane including the out-of-focus position Fa, the reflected light flux A and the reflected light flux B overlap with each other. Therefore, the defect on the image becomes white, and the contrast is increased, with the result that the size of the defect reaches the crack width w. Further, as defocusing is performed upward from the out-of-focus position Fa, the defect on the image is whitely enlarged as shown in FIG. 12A to FIG. 12D. In FIG. 12A, an image at an out-of-focus position that is separated most upward from the object plane is taken, and the defect 50 is most enlarged (thickened). FIG. 12D is an image close to the out-of-focus position Fc.

[0082] In the case of a defect having no crack width w as illustrated in FIG. 7G, there is no region (region in which the contrast is not increased and the defect on the image becomes smaller than w) from the object plane to the out-of-focus position Fc. Therefore, as defocusing is performed downward from the object plane, the defect on the image is blackly enlarged. As defocusing is performed upward from the object plane, the defect on the image is whitely enlarged.

[0083] In the case of such a defect (having a cut portion in a mountain-folded shape) as illustrated in FIG. 7J, when the workpiece is defocused from the object plane (in-focus position F) to the out-of-focus position Fb below the in-focus position F, apparent positions of the reflected light flux A and the reflected light flux B are displaced to approach each other as illustrated in FIG. 13. In this case, the reflected light flux A and the reflected light flux B do not overlap with each other in a region from the object plane to the out-of-focus position Fc. Therefore, the contrast is not increased, and the defect on the image become smaller as defocusing is performed downward. When defocusing is performed downward from the out-of-focus position Fc, the reflected light flux A and the reflected light flux B overlap with each other. Therefore, the overlapping portion is enlarged as the defect on the image becomes brighter, with the result that the defect on the image is enlarged as defocusing is performed downward. In the luminance cross section in a plane including the out-of-focus position Fb, the reflected

light flux A and the reflected light flux B overlap with each other. Therefore, the defect on the image becomes white, and the contrast is increased, with the result that the size of the defect reaches the crack width w. Further, as defocusing is performed downward from the out-of-focus position Fb, the defect on the image is whitely enlarged.

[0084] Further, in the case of a mountain-folded shape, when the workpiece is defocused from the object plane (in-focus position F) to the out-of-focus position Fa above the in-focus position F, apparent positions of the reflected light flux A and the reflected light flux B are displaced to spread as illustrated in FIG. 14. With this, in the luminance cross-section in a plane including the out-of-focus position Fa, the interval between the images of the reflected light flux A and the reflected light flux B is increased, and the defect 50 is blackly enlarged (thickened). That is, as defocusing is performed upward from the object plane, the defect on the image is blackly enlarged.

[0085] In the case of a defect having no crack width w as illustrated in FIG. 7H, there is no region (region in which the contrast is not increased and the defect on the image becomes smaller than w) from the object plane to the out-of-focus position Fc. Therefore, as defocusing is performed upward from the object plane, the defect on the image is blackly enlarged. As defocusing is performed downward from the object plane, the defect on the image is whitely enlarged.

[0086] As described above, when reflected light is output from at least two different positions, defect inspection can be performed by emphasizing the defect on the observation image (enlarging the defect, increasing the contrast with another portion, or enlarging the defect and increasing the contrast). Further, inspection or positioning of detecting the position of a workpiece on an image can be performed based on reflected light from at least one of the above-mentioned positions. In this case, it is preferred that inspection be performed at a position defocused by 100 μm or more from the in-focus position in the observation optical system. Further, when defocusing is performed at each of the out-of-focus position Fa on a side (upper side) close to the image pickup device 31 and the out-of-focus position Fb on a side (lower side) separated from the image pickup device 31 with the in-focus position F being a boundary between the out-of-focus positions, the defect 50 can be inspected with different colors.

[0087] When the defect becomes black (dark) as illustrated in FIG. 11, a minimum defocus amount z is calculated through use of the angle θ1 formed by a line L orthogonal to an optical axis and one surface portion, the angle θ2 formed by the line L orthogonal to the optical axis and the other surface portion, the crack width w, and a minimum detection width ε_{min} as in Expression 1, Expression 2, and Expression 3. In Expressions, Δx1 represents an enlargement amount on one surface portion side, Δx2 represents an enlargement amount on the other surface portion side, and ΔXd represents a

dimension of an enlarged defect. Further, when the defect becomes white (bright), the minimum defocus amount z is calculated through use of θ1, θ2, w, and ε_{min} as in Expression 4, Expression 5, and Expression 6. In Expressions, Δx1'(=Δx1) represents an enlargement amount on one surface portion side, Δx2'(=Δx2) represents an enlargement amount on the other surface portion side, and ΔX1 represents a dimension of an enlarged defect.

[Expression 1]

$$\Delta x_1 = z \cdot \tan 2\theta_1$$
$$\Delta x_2 = z \cdot \tan 2\theta_2$$
$$\Delta X_d = \Delta x_1 + \Delta x_2 + w$$

Detection condition $\Delta X_d \geqq \varepsilon_{min}$

[Expression 2]

$$\Delta X_d \geqq \varepsilon_{min}$$
$$\Delta x_1 + \Delta x_2 + w \geqq \varepsilon_{min}$$
$$z \cdot \tan 2\theta_1 + z \cdot \tan 2\theta_2 \geqq \varepsilon_{min} - w$$
$$z(\tan 2\theta_1 + \tan 2\theta_2) \geqq \varepsilon_{min} - w$$

[Expression 3]

$$z \geqq \frac{\varepsilon_{min} - w}{\tan 2\theta_1 + \tan 2\theta_2}$$

where $\varepsilon_{min} - w > 0$

[Expression 4]

$$\Delta x_1' = z \cdot \tan 2\theta_1$$
$$\Delta x_2' = z \cdot \tan 2\theta_2$$
$$\Delta X_1 = \Delta x_1' + \Delta x_2' - 2w$$

Detection condition $\Delta X_1 \geqq \varepsilon_{min}$

[Expression 5]

$$\Delta X_1 \geqq \varepsilon_{min}$$
$$\Delta x_1' + \Delta x_2' - 2w \geqq \varepsilon_{min}$$
$$z \cdot \tan 2\theta_1 + z \cdot \tan 2\theta_2 - 2w \geqq \varepsilon_{min}$$
$$z(\tan 2\theta_1 + \tan 2\theta_2) \geqq \varepsilon_{min} + 2w$$

[Expression 6]

$$z \geqq \frac{\varepsilon_{min} + 2w}{\tan 2\theta_1 + \tan 2\theta_2}$$

where $\varepsilon_{min} - w > 0$

[0088] FIG. 15 is a graph for showing a relationship between the crack angle θ and the minimum defocus amount z when the minimum detection width ε_{min} is 10 μm, and the crack width w is 0 μm. Further, when the numerical aperture of the observation optical system is represented by NA, it is preferred that $-\sin^{-1}(NA) \leq \theta 1 \leq \sin^{-1}(NA)$, and $-\sin^{-1}(NA) \leq \theta 2 \leq \sin^{-1}(NA)$ be satisfied. In this case, ε_{min} is set to, for example, about 1/5 of the resolution of the image pickup device. This is the case of satisfying the following conditions: cracks are usually generated continuously in a linear shape; the luminance fluctuation of about 10% of a dynamic range (DR) can be stably detected in image processing; when the surrounding luminance is set to a

median of the DR, due to defocusing, the luminance is changed to 0 on a dark side and to the DR on a bright side, and the luminance fluctuation is equal to the median; and median×1/5=DR×10%.

[0089] The control portion 40 comprises the calculating portion 41, and the calculating portion 41 is configured to calculate a defocus amount based on predetermined parameters. For example, in the case where the calculating portion 41 calculates a defocus amount by the above-mentioned Expression 1, when the parameters ε_{min}, θ1, θ2, and w are set, the calculating portion 41 calculates the minimum defocus amount z by Expression 1. When a user sets the parameters, θ1 and θ2 may be independently set as two parameters or one parameter may be set as the crack angle θ (θ1+θ2). When one parameter θ is set, the calculating portion 41 performs calculation by distributing θ into θ1 and θ2, for example, by setting θ1=θ/2 and θ2=θ/2 or setting θ1=0 and θ2=θ. The control portion 40 is configured to control the drive of the defocusing unit 39 (drive mechanism) based on the defocus amount calculated by the calculating portion 41.

[0090] When the workpiece is irradiated with illumination light, the illumination light is reflected by the surface of the coating layer 12, transmitted through the coating layer 12, absorbed by the coating layer 12, or scattered from the coating layer 12 as illustrated in FIG. 5A and FIG. 5B. Further, the illumination light is reflected from the variable density pattern (wiring pattern).

[0091] However, in order to detect the defect 50 of the coating layer 12, it is only required that the reflected light from the

surface of the coating layer 12 enter the image pickup device 31. Therefore, it is preferred that the illumination light have a wavelength at which an intensity of light that is reflected or scattered from the coating layer 12 to enter the image pickup device is higher than an intensity of light that is reflected from at least the variable density layer to enter the image pickup device 31, to thereby reduce the influence of the variable density pattern of the variable density layer 11. In this case, the expression "reducing the influence of the variable density pattern" refers to the case in which, when a defect is observed, the variable density pattern is eliminated or weakly reflected so as not to impair the observation of the defect. That is, the above-mentioned expression refers to the case in which a luminance contrast caused by the variable density pattern is lowered as compared to that in the case of using light other than the above-mentioned light.

[0092] In this case, the wavelength of the illumination light can be set based on the transmittance of light in the coating layer 12. The transmittance is represented by a ratio of incident light having a particular wavelength, which is transmitted through a sample, in an optical method and spectroscopy. As illustrated in FIG. 16, when a radiant exitance of the incident light is represented by I_0, and a radiant exitance of light transmitted through the sample (coating layer 12) is represented by I, a transmittance T is presented by the following Expression 7.

[0093] [Expression 7]

$$T = \frac{I}{I_0}$$

T: Transmittance

It is only required that, as the light that has decreased influence of the variable density pattern, the light have a light transmittance of 50% or less in the coating layer 12. Specifically, when the coating layer 12 is made of a polyimide resin, it is preferred that the wavelength to be observed in the illumination light of the illumination unit be 450 nm or less or 1,000 nm or more.

[0094] Therefore, as described above, the illumination light can reduce (decrease) the influence of the variable density pattern, and the light reflected or scattered from the coating layer 12 can be projected. Therefore, the defect (crack) 50 can be stably detected.

[0095] In the embodiment, the defect at the pickup position P is detected, but the defect detection device 100 illustrated in FIG. 1 may also be arranged at the bonding position Q. Thus, the defect detection device 100 can detect the defect 50 on the surface of the chip 21 and can also be used for performing position checking (positioning) for observing the position of the island of the lead frame at the bonding position Q

[0096] The die bonder illustrated in FIG. 2A and FIG. 2B, and the like comprises the bonding portion configured to convey the workpiece, for example, the semiconductor chip 21, from the pickup position P to the bonding position Q. In such a bonding step, there

is also a case in which the workpiece picked up from the wafer 29 is temporarily placed on the intermediate stage and picked up again from the intermediate stage to be bonded.

[0097] Therefore, the defect detection device 100 illustrated in FIG. 1 can be arranged on the intermediate stage. Thus, when the defect detection device 100 is arranged on the intermediate stage 101, a defect image on the observation image of the defect 50 formed in the workpiece (semiconductor chip 21, die, or the like) on the intermediate stage can be observed in an enlarged state with respect to the workpiece. Further, the influence of the variable density pattern (wiring pattern) can be reduced, and the defect (crack) can be stably detected. Through use of the defect detection device 100, positioning can be performed also on the intermediate stage.

[0098] It is preferred that, in the table to be provided at a position (at the pickup position P, on the intermediate stage, or at the bonding position Q) at which the defect detection device 100 is arranged, the workpiece placement portion be formed of the porous material. In this case, through provision of the step of sucking the semiconductor chip 21 from below as illustrated in FIG. 17A, and further pressing the semiconductor chip 21 against the porous material 102 from above with the collet 23 as illustrated in FIG. 17B, the semiconductor chip 21 is held by the table uniformly as a whole as illustrated in FIG. 17C. Therefore, even when there is a warp in the workpiece, the warp can be regulated to be formed

into a planar shape through cooperation of the porous material 102 and the collet 23, and the warped portion can be prevented from being darkly observed at a time of observation.

[0099] In the die bonder, a defect is detected at the pickup position, the bonding position, the intermediate stage, and the like. A defect can be detected in at least any one of the period before pickup or the period after pickup, that is, in any one of the period before pickup and the period after pickup or both the periods before and after pickup.

[0100] Further, a defect can be detected in at least any one of the period before bonding or the period after bonding, that is, in any one of the period before bonding and the period after bonding or both the periods before and after bonding.

[0101] Further, a defect can be detected in any one of the period before the workpiece is supplied to the intermediate stage and the period after the workpiece is discharged from the intermediate stage, that is, in any one of the period before the workpiece is supplied to the intermediate stage and the period after the workpiece is discharged from the intermediate stage or both the period before the workpiece is supplied to the intermediate stage and the period after the workpiece is discharged from the intermediate stage. In addition, a defect can be detected also at a position other than the bonding portion. Specifically, the defect detection device is arranged at any position on the die bonder, and the defect can be detected at any position on the die bonder.

[0102] Thus, in the defect detection device 100 illustrated in FIG. 1, a determination part configured to determine whether or not the detected defect 50 corresponds to a failure as a product may be provided. That is, in a defect detection method to be performed by the defect detection device 100, determination criteria for determining whether or not a detected defect corresponds to a failure as a product are set in advance, and the determination criteria are compared to a defect image on the observation image to determine whether the product is a defective product or a non-defective product.

[0103] The determination part can be formed of a control portion (not shown) configured to control the image pickup device 31. The control portion can be formed of, for example, a microcomputer in which a read only memory (ROM), a random access memory (RAM), and the like are connected to each other through buses with a central processing unit (CPU) being the center. A storage device is connected to the microcomputer. The storage device is configured to store determination criteria and the like serving as determination criteria of the determination unit. The storage device can be formed of a hard disc drive (HDD), a digital versatile disk (DVD) drive, a compact disc-recordable (CD-R) drive, an electronically erasable and programmable read only memory (EEPROM), or the like. A program to be executed by the CPU and data are stored in the ROM.

[0104] Therefore, an object in which a defect is not detected by the defect detection method or in which a detected defect is determined to correspond to a non-defective product by the

determination part can be defined as a product (for example, wafer 29, semiconductor chip 21, or die).

[0105] As described above, in the present invention, the defect 50 on the observation image formed by the reflected light from the out-of-focus positions Fa and Fb can be observed in an enlarged state as compared to the defect 50 on the observation image formed by the reflected light from the in-focus position F, and the defect 50 which cannot be seen with the existing device becomes visible. Therefore, the defect 50 can be stably detected.

[0106] When the illumination light emitted from the illumination unit 32 has a wavelength at which an intensity of light that is reflected or scattered from the coating layer 12 to enter the image pickup device 31 is higher than an intensity of light that is reflected from at least the variable density layer 11 to enter the image pickup device 31, to thereby reduce influence of the variable density pattern of the variable density layer 11, the light reflected or scattered from the coating layer 12 can be projected, and hence the defect 50 can be stably detected.

[0107] In the die bonder, the defect 50, for example, a crack on the surface of the workpiece to be bonded can be detected at any position of the die bonder.

[0108] Further, when the determination criteria are set in advance, which is to be used for determining whether or not a defect detected by a defect detection method corresponds to a failure as a product, and it is determined whether the defect corresponds to

a defective product or a non-defective product, the defect (crack) 50 of the workpiece (semiconductor chip or the like) can be detected during bonding operation and the like, and the shipping of the defective product can be prevented. In the die bonder, positioning detection can be performed, and a stable bonding step with high precision can be performed.

[0109] As illustrated in FIG. 24, a semiconductor manufacturing method may comprise a dicing step 105 of cutting a wafer into an individual piece, a step (die bonding step 106) of bonding a semiconductor chip obtained by cutting the wafer into an individual piece in the dicing step, and a mold sealing step (molding step 108) of sealing the semiconductor chip that is the individual piece with resin, and further may comprise a wire bonding step 107 or the like of bonding a wire in FIG. 24.

[0110] Therefore, the semiconductor manufacturing method comprising the above-mentioned steps may comprise an inspection step using the defect detection method during bonding operation. The semiconductor manufacturing method may comprise the dicing step 105 and the inspection step, the inspection step and the mold sealing step 108, or the dicing step 105, the inspection step, and the mold sealing step 108.

[0111] Further, the workpiece may be a semiconductor device comprising an individual piece in which a defect is not detected by the defect detection method or in which a detected defect is determined to correspond to a non-defective product by the defect

detection method.

[0112] Further, the workpiece may be an individual piece assembly in which a plurality of individual pieces are assembled. The individual piece assembly may be individual pieces laminated in a vertical direction, individual pieces arranged side by side in a horizontal direction, or further a combination of the laminated individual pieces and the individual pieces arranged side by side. When the semiconductor device comprising such an individual assembly is manufactured, the semiconductor device can be formed so that at least any one of a target object comprising one individual piece or an assembly of a predetermined number of individual pieces or another individual piece to be assembled to the target object is inspected through use of the defect detection method. That is, only the target object side comprising one individual piece or the assembly of a predetermined number of individual pieces can be inspected by the inspection method. Alternatively, only another individual piece side to be assembled to the target object can be inspected by the inspection method. Alternatively, both the target object side and another individual piece side can be inspected.

[0113] Further, the die bonder and the like can be set so that, when a defect is found in the workpiece at any one of the detection positions, the conveyance of the workpiece is stopped at the detection position, and an operator is informed of the defect with at least any one of an alarm sound or lighting of an alarm light. Further, the die bonder and the like can be set so that a defective product

discharge mechanism is provided, and when a defect is found in the workpiece, a defective product is discharged from the detection position to an outside of the device.

[0114] The present invention can be variously modified without being limited to the embodiment. For example, in the embodiment, the defocusing unit is a mechanism configured to move only the workpiece upward and downward, but the defocusing unit may be configured to move only the image pickup device 31 upward and downward or move the workpiece and the image pickup device 31 upward and downward.

[0115] Further, the defocusing unit may be configured to change an optical system. As one example thereof, for example, as illustrated in FIG. 18, an object (for example, plate glass) 46 having a refractive index different from that in the atmosphere is inserted between the image pickup device 31 and the workpiece. Further, in order to change the optical system, a lens and a mirror (a variable-focal-length lens and a variable-focal-length mirror) capable of changing the in-focus position, or a window capable of changing the optical thickness may be used.

[0116] Further, as the defocusing unit, a plurality of optical systems and light-receiving elements having different in-focus positions may be used. For example, as illustrated in FIG. 19, a first image pickup device 31a and a second image pickup device 31b are provided, and a half mirror 45 is also provided, so that the first image pickup device 31a is set to a side on which defocusing

is performed above the in-focus position, and the second image pickup device 31b is set to a side on which defocusing is performed below the in-focus position.

[0117] Further, the defocusing unit may be configured to change an illumination wavelength or an observation wavelength. For example, as illustrated in FIG. 20, the illumination unit 32 comprises a first light source 36a and a second light source 36b, and is configured to change the wavelength of light from the first light source 36a and the wavelength of light from the second light source 36b.

[0118] Further, the defocusing unit may not be provided. That is, when the workpiece is arranged at the out-of-focus position in advance, the reflected light from the workpiece can be caused to be output from the out-of-focus position displaced from the in-focus position in the optical axis direction.

[0119] As illustrated in FIG. 21, the illumination unit 32 may comprise an inspection light source 50, a positioning light source 51, an NA switching portion 52 configured to electrically switch an NA on an illumination side by switching those light sources, and the half mirror 46.

[0120] Further, in the above-mentioned embodiment, a defect on the observation image with respect to the defect formed in the workpiece can be observed in an enlarged state, and further, the influence of the variable density pattern (wiring pattern) is reduced. However, the defect detection device may be configured merely to

enlarge the defect on the observation image with respect to the defect formed in the workpiece.

[0121] A detection portion configured to perform the following detection (not shown) can be provided, for example, in the controller 43. That is, when inspection is performed from two different positions including at least the out-of-focus position, in the case where a defect detection width observed when the defect becomes bright is represented by ΔXl, a defect detection width observed when the defect becomes dark is represented by ΔXd, and a relative angle (crack angle) between the opposed surface portions is represented by θ=θ1+θ2, θ and w are detected by detecting the defect detection widths ΔXl and ΔXd by Expression 8 under the condition of θ2=0 and θ1=θ. With this, angle measurement of the inclined surface portion can be performed.

[Expression 8]

$$\Delta X_l = z \cdot \tan 2\theta_1 - 2w$$
$$\Delta X_d = z \cdot \tan 2\theta_1 + w$$

[0122] When inspection is performed from two different positions including at least the out-of-focus position, a discriminating part (not shown) configured to discriminate defects changed to be dark and bright and defects changed to be dark or bright may be provided, for example, in the controller 43. That is, the discriminating part can determine that defects changed to be dark and bright are defects (cracks) each having inclination

and that defects changed to be dark or bright are defects (foreign matters and the like) having no inclination, to thereby classify the defects (cracks, foreign matters, and the like). With this, for example, only the workpiece having a defect changed in shading can be removed, with the result that the yield can be improved. Further, the discriminating part can also determine the kind of a defect based on a change in size of the defect (enlargement or reduction). Further, the discriminating part can also determine the kind of a defect based on both the change in shading and the change in size of the defect.

[0123] Image pickup conditions (exposure time, illumination light amount, and the like) can be appropriately set in accordance with a defocus state. Further, a plurality of images can be taken under a plurality of image pickup conditions also in the same defocus state. For example, when an average value of the surrounding (normal portion) is set to be bright for a workpiece in which a defect has been found to become black, a contrast can be easily provided.

[0124] The film thickness of the coating layer is not limited to a range of from 1 μm to 100 μm. Further, the material for the coating layer is not limited to a polyimide resin or a silicone resin. That is, it is only required that, when the surface of the coating layer is observed, the illumination light that reduces the influence of the variable density pattern (wiring pattern), which is suitable for the material for the coating layer and the film thickness of the coating layer, be able to be selected.

[0125] When observation is performed in the dark field using the illumination light of the light (visible light) having a wavelength out of the range of 450 nm or less or 1,000 nm or more, in the case where the illumination light reaches a wiring pattern layer, diffraction occurs, and the variable density pattern enters the image pickup device (camera), when the pattern pitch of the wiring pattern layer is at a wavelength level of the light. However, through use of light other than the visible light, the illumination light that causes diffraction is attenuated to reach the wiring pattern layer, and diffracted light itself can be attenuated.

[0126] As the table in which the workpiece placement portion is formed of the porous material, the pickup table is used in the embodiment. However, the table having the above-mentioned configuration is not limited to the pickup table, and another table, for example, an intermediate stage may be used. Specifically, it is preferred that, depending on a position at which the defect detection device of the present invention is arranged, the table at a position corresponding thereto be configured as described above.

[0127] The workpiece placement portion may be formed of an electrostatic chuck structure configured to attract the workpiece through static electricity to hold the workpiece. Specifically, the placement portion may have a structure comprising electrodes in a dielectric layer in which the electrodes are connected to a control power supply, and the workpiece may be fixed to the placement portion through electrostatic attractive force caused by charge

generated in the electrodes. In this case, first, the workpiece is placed on the table, and the workpiece is attracted through static electricity to be held by the table. After that, a defect of the workpiece is detected by the above-mentioned method.

[0128] In the case where the workpiece placement portion of the table is formed of the porous material or the electrostatic chuck structure, even when the workpiece warps in a direction in which the workpiece protrudes upward, the warp can be regulated. The defect detection device and the defect detection method of the present invention can be applied to devices other than the die bonder in which it is required to detect a defect of a semiconductor product or a workpiece that is a part of the semiconductor product.

Reference Signs List

[0129] P pickup position

Q bonding position

S inclined surface portion

θ1, θ2 crack angle

w crack width

ε_{min} minimum detection width

11 variable density layer

12 coating layer

21 semiconductor chip

29 wafer

30 inspection mechanism

31 image pickup device

32 illumination unit

39 defocusing unit

47 NA control portion

50 defect

52 NA switching portion

Claims

[Claim 1] A defect detection device, which is configured to detect a defect having at least an inclined surface portion in a semiconductor product or a workpiece, which is a part of the semiconductor product,

the defect detection device comprising an inspection mechanism, the inspection mechanism comprising:

an illumination unit configured to irradiate the workpiece with bright-field illumination light having a numerical aperture smaller than a numerical aperture of an observation optical system; and

an image pickup device configured to observe an observation site of the workpiece irradiated with the bright-field illumination light by the illumination unit,

wherein a defect on an observation image formed by reflected light from the workpiece, which is obtained by the bright-field illumination light being emitted from the illumination unit having the numerical aperture smaller than the numerical aperture of the observation optical system, and being output from an out-of-focus position defocused from an in-focus position in an optical axis direction, is enlarged as compared to a defect on an observation image formed by reflected light from the in-focus position,and

wherein the image pick up device is configured to observe the reflected light from the workpiece, which is the output from the out-of-focus position to inspect the enlarged defect.

[Claim 2] The defect detection device according to claim 1, further comprising a positioning device configured to perform position detection of the workpiece, wherein the positioning device comprises the inspection mechanism.

[Claim 3] The defect detection device according to claim 1 or 2, further comprising a workpiece placement portion, which is configured to position the workpiece placed thereon, and to inspect a defect in the workpiece.

[Claim 4] The defect detection device according to any one of claims 1 to 3, further comprising a varying unit configured to vary the numerical aperture of the illumination unit.

[Claim 5] The defect detection device according to any one of claims 1 to 3, wherein the illumination unit comprises an inspection light source and a positioning light source, and is configured to switch between the inspection light source and the positioning light source to switch a numerical aperture on an illumination side.

[Claim 6] The defect detection device according to any one of claims 1 to 5, wherein the reflected light is output from two different positions comprising at least the out-of-focus position among the in-focus position and the out-of-focus position.

[Claim 7] The defect detection device according to claim 6, wherein the inspection mechanism is configured to perform the inspection based on reflected light output from an out-of-focus position on a side close to the image pickup device and reflected light output from an out-of-focus position on a side away from the image pickup device, with the in-focus position being a boundary between the out-of-focus positions.

[Claim 8] The defect detection device according to any one of claims 1 to 7, wherein the workpiece is arranged at the out-of-focus position to cause the reflected light from the workpiece to be output from the out-of-focus position displaced from the in-focus position in the optical axis direction.

[Claim 9] The defect detection device according to any one of claims 1 to 8,

wherein the inspection mechanism comprises a defocusing unit configured to cause the reflected light from the workpiece to be output from the out-of-focus position displaced from the in-focus position in the optical axis direction, and

wherein the defocusing unit comprises any one of a unit configured to cause the workpiece and an optical system to relatively move in the optical axis direction, a unit configured to change the optical system, a unit that uses a plurality of optical systems

and a plurality of light-receiving elements having different in-focus positions, and a unit configured to change an illumination wavelength or an observation wavelength.

[Claim 10] The defect detection device according to any one of claims 1 to 9, wherein the defect detection device is configured to perform inspection at a position defocused by 100 μm or more from the in-focus position in the observation optical system.

[Claim 11] The defect detection device, which is configured to detect a defect having at least an inclined surface portion in a semiconductor product or a workpiece, which is a part of the semiconductor product,

the defect detection device comprising:

an inspection mechanism comprising:

an illumination unit configured to irradiate the workpiece with bright-field illumination light; and

an image pickup device, which forms an observation optical system, and is configured to observe an observation site of the workpiece irradiated with the bright-field illumination light by the illumination unit; and

a detection portion configured to detect an inclination angle and a defect width of a surface portion based on a defocus amount and a separation width between one inclined surface portion and another inclined surface portion of the defect,

wherein the inspection mechanism is configured to observe

reflected light from the workpiece, which is output from an out-of-focus position defocused from an in-focus position in an optical axis direction, and emphasize a defect on an observation image formed by reflected light from the out-of-focus position as compared to a defect on an observation image formed by reflected light from the in-focus position.

[Claim 12] The defect detection device according to any one of claims 1 to 11,

wherein the workpiece has a multilayer structure, and

wherein light that is reflected or scattered from a layer to be inspected to enter the image pickup device has a wavelength at which an intensity of the light is higher than an intensity of light from another layer.

[Claim 13] The defect detection device according to claim 12,

wherein the workpiece comprises a variable density layer having a variable density pattern derived from a semiconductor manufacturing process and a coating layer, which covers the variable density pattern of the variable density layer, and

wherein illumination light emitted from the illumination unit has a wavelength at which an intensity of light that is reflected or scattered from the coating layer to enter the image pickup device is higher than an intensity of light that is reflected from at least the variable density layer to enter the image pickup device, to

thereby reduce influence of the variable density pattern of the variable density layer.

[Claim 14] The defect detection device according to claim 13, wherein the coating layer comprises an organic substance layer.

[Claim 15] The defect detection device according to any one of claims 1 to 14, wherein, of the illumination light from the illumination unit, illumination light to be observed has a wavelength of 450 nm or less, or a wavelength of 1,000 nm or more.

[Claim 16] The defect detection device according to any one of claims 1 to 15, further comprising a table on which the workpiece is placed,

wherein a workpiece placement portion of the table is formed of a porous material configured to attract the workpiece through suction to hold the workpiece.

[Claim 17] The defect detection device according to any one of claims 1 to 15, further comprising a table on which the workpiece is placed,

wherein a workpiece placement portion of the table is formed of an electrostatic chuck structure configured to attract the workpiece through static electricity to hold the workpiece.

[Claim 18] A defect detection method for detecting a defect having at least an inclined surface portion in a semiconductor product

or a workpiece, which is a part of the semiconductor product,

the method comprising:

irradiating the workpiece with bright-field illumination light having a numerical aperture smaller than a numerical aperture of an observation optical system to cause reflected light from the workpiece to be output from an out-of-focus position defocused from an in-focus position in an optical axis direction so as to enlarge a defect on an observation image formed by reflected light from the out-of-focus position as compared to a defect on an observation image formed by reflected light from the in-focus position;

observing the reflected light from the workpiece, which is output from the out-of-focus position to inspect the enlarged defect.

[Claim 19] A defect detection method for detecting a defect having at least an inclined surface portion in a semiconductor product or a workpiece, which is a part of the semiconductor product,

the method comprising:

placing the workpiece on a table having a workpiece placement portion formed of a porous material;

sucking the workpiece through a pore of the porous material to cause the workpiece to be adsorbed to the table;

irradiating the workpiece with bright-field illumination light having a numerical aperture smaller than a numerical aperture of an observation optical system to cause reflected light from the workpiece to be output from an out-of-focus position defocused from

an in-focus position in an optical axis direction so as to enlarge a defect on an observation image formed by reflected light from the out-of-focus position as compared to a defect on an observation image formed by reflected light from the in-focus position; and

observing the reflected light from the workpiece, which is output from the out-of-focus position to inspect the enlarged defect.

[Claim 20] A defect detection method for detecting a defect having at least an inclined surface portion in a semiconductor product or a workpiece, which is a part of the semiconductor product,

the method comprising:

placing the workpiece on a table having a workpiece placement portion formed of an electrostatic chuck structure;

attracting the workpiece through static electricity to cause the table to hold the workpiece;

irradiating the workpiece with bright-field illumination light having a numerical aperture smaller than a numerical aperture of an observation optical system to cause reflected light from the workpiece to be output from an out-of-focus position defocused from an in-focus position in an optical axis direction so as to enlarge a defect on an observation image formed by reflected light from the out-of-focus position as compared to a defect on an observation image formed by reflected light from the in-focus position; and

observing the reflected light from the workpiece, which is output from the out-of-focus position to inspect the enlarged defect.

[Claim 21] The defect detection method according to any one of claims 18 to 20, wherein the defect detection method allows a defect in the workpiece to be inspected at a position at which positioning of the workpiece is performed.

[Claim 22] The defect detection method according to any one of claims 18 to 20, wherein a light source is switched between an inspection light source and a positioning light source to switch a numerical aperture on an illumination side.

[Claim 23] The defect detection method according to claim 19 or 20, further comprising a step of pressing the workpiece against the table.

[Claim 24] A die bonder, comprising:

a bonding portion、which is configured to pick up an individual piece serving as a workpiece at a pickup position, convey the individual piece that has been picked up to a bonding position, and to subject the workpiece to bonding at the bonding position; and

the defect detection device of any one of claims 1 to 17.

[Claim 25] A semiconductor manufacturing method, comprising an inspection step using the defect detection method of any one of

claims 18 to 20, and further comprising at least any one of a dicing step of cutting a wafer into an individual piece or a mold sealing step of sealing a semiconductor chip formed into an individual piece with resin.

[Claim 26] A semiconductor device manufacturing method for manufacturing a semiconductor device comprising an individual piece assembly formed of a plurality of individual pieces,

the semiconductor device manufacturing method comprising subjecting at least any one of a target object comprising one individual piece or an assembly of a predetermined number of individual pieces or another individual piece to be assembled to the target object, to inspection through use of the defect detection method of any one of claims 18 to 20.