

Description

Title of Invention: DEFECT DETECTION DEVICE, DEFECT DETECTION METHOD, WAFER, SEMICONDUCTOR CHIP, SEMICONDUCTOR DEVICE, DIE BONDER, BONDING METHOD, 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 in 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, thereby being capable of causing 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, thereby being capable of visualizing 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 06-82377 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. 28, 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 disclosed in Patent Literature 1, for example. Further, according to the method disclosed 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, thereby being capable of visualizing 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 in 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 first defect detection device of the present invention is a defect detection device, which is configured to detect a defect formed in a coating layer in a workpiece, the workpiece comprising a variable density layer having a variable density pattern derived from a semiconductor manufacturing process and the coating layer, which covers the variable density pattern of the variable density layer, the defect detection device comprising an observation mechanism, the observation mechanism comprising: an illuminator configured to illuminate the workpiece; and an image pickup device configured to observe an observation site of the workpiece illuminated by the illuminator, wherein illumination light emitted from the illuminator 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. In this case, the "variable density pattern derived from a semiconductor manufacturing process" refers to a pattern formed by the semiconductor manufacturing process, and there are given, for example, a pattern generated based on a wiring pattern and a pattern generated due

to the presence of oxidized Si, nitrided Si, and Si different from the oxidized Si and the nitrided Si. Further, 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, with the light to be used in the defect detection device, a luminance contrast caused by the variable density pattern is lowered as compared to that in the case of using light other than the light to be used in the defect detection device.

[0010] In the first defect detection device of the present invention, the illumination light emitted from the illuminator 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. Therefore, the light reflected or scattered from the coating layer can be projected, and the luminance contrast caused by the variable density pattern is lowered, thereby being capable of reducing (decreasing) the influence of the variable density layer.

[0011] A second 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.

[0012] In the second 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.

[0013] 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.

[0014] 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.

[0015] 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 $\theta_1 + \theta_2$, where θ_1 (clockwise direction) represents an inclination angle of one surface, and θ_2 (counterclockwise direction) represents an inclination angle of the other surface) is small.

[0016] 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.

[0017] 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.

[0018] 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.

[0019] 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.

[0020] 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 $\varepsilon_{\min}$ represents a minimum detection width of the image pickup device, θ_1 represents an angle formed by a line orthogonal to an optical axis and one of the pair of surface portions, θ_2 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.

[0021] In the above-mentioned configuration, when the θ_1 and the θ_2 of the workpiece to be inspected are limited by the numerical aperture NA of the observation optical system, the θ_1 and the θ_2 may satisfy the following expressions: $-\sin^{-1}(NA) \leq \theta_1 \leq \sin^{-1}(NA)$ and $-\sin^{-1}(NA) \leq \theta_2 \leq \sin^{-1}(NA)$.

[0022] 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.

[0023] The illuminator 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.

[0024] 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.

[0025] 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 enlargement of the defect, or both the change in shading of the defect and the change in enlargement 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).

[0026] 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 larger than an intensity of light from another layer.

[0027] 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 illuminator

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, thereby being capable of reducing (decreasing) the influence of the variable density layer.

[0028] 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 single layer or a plurality of layers comprising two or more layers. When the coating layer is formed of a plurality of layers, the plurality of 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.

[0029] It is preferred that, of the illumination light from the illuminator, 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.

[0030] The image pickup device may be configured to perform dark-field observation of observing the observation site of the workpiece illuminated by the illuminator from above, the defect of the workpiece may have at least any one of an opening or an inclined surface portion, and the image pickup device may be configured to perform observation of enlarging the defect on an observation image of the defect formed in the workpiece.

[0031] Through setting as described above, the influence of the variable density pattern can be reduced. Further, a defect formed in the workpiece can be observed in an enlarged state, and a defect that cannot be seen with an existing device becomes visible.

[0032] In the dark-field observation, a plurality of illuminators may be arranged at a predetermined pitch along a circumferential direction, or ring illumination using a plurality of light-emitting portions arranged in at least one row in a ring shape surrounding a photographing axis of the image pickup device

maybe used. As described above, through use of the ring illumination, a defect (crack) can be observed in an enlarged state irrespective of the direction (rotation angle) of the inclined surface portion of the defect.

[0033] The illumination direction of the illuminator may be set so that the workpiece and an illumination axis form an angle of from 50° to 85° when the photographing axis and the workpiece are arranged so as to be orthogonal to each other. In this manner, through setting of the angle formed by the workpiece and the illumination axis to an angle of from 50° to 85° , most of the generated defects (cracks) can be observed in an enlarged state.

[0034] 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).

[0035] A first defect detection method of the present invention is a defect detection method for detecting a defect formed in a coating layer in a workpiece, the workpiece comprising a variable density layer having a variable density pattern and the coating layer, which covers the variable density pattern of the variable

density layer, the method comprising irradiating the workpiece with illumination light having a wavelength at which an intensity of light that is reflected or scattered from the coating layer to enter an 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. Thus, the workpiece can be observed by reducing influence of the variable density pattern of the variable density layer by the image pickup device. That is, with the light to be used in the detection method, the 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, and the workpiece can be observed with the influence being reduced.

[0036] In the first defect detection method of the present invention, the illumination light 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. Therefore, the light reflected or scattered from the coating layer can be projected, thereby being capable of reducing (decreasing) the influence of the variable density layer.

[0037] 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, 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.

[0038] In the second 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.

[0039] 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.

[0040] 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 (that is, based on at least any one of a change in shading of the defect or a change in size of the defect).

[0041] 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.

[0042] 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.

[0043] According to one embodiment of the present invention, there is provided a die bonder, which is 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, the die bonder comprising the defect detection device, which is arranged at any position from the pickup position to the bonding position.

[0044] With the die bonder of one embodiment of the present invention, a defect, for example, a crack in the workpiece to be bonded can be detected at any position from the pickup position to the bonding position. That is, during a bonding operation and the like, 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.

[0045] 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.

[0046] 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 any one of claims 1 to 30 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.

[0047] A first bonding method of the present invention is a bonding method comprising: a bonding step of 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.

[0048] A second bonding method of the present invention is a bonding method comprising: a bonding step of 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.

[0049] A third bonding method of the present invention is a bonding method comprising: a bonding step of 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.

[0050] A fourth bonding method of the present invention is a

bonding method comprising: a bonding step of 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.

[0051] 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.

[0052] There is provided a semiconductor device manufacturing method for manufacturing a semiconductor device comprising subjecting an individual piece assembly formed of a plurality of individual pieces, the semiconductor device manufacturing method comprising 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

[0053] In the first defect detection device, the light reflected or scattered from the coating layer can be projected (and the luminance

contrast caused by the variable density pattern is lowered), thereby being capable of reducing (decreasing) the influence of the variable density pattern. Therefore, a defect (crack) can be stably detected. Further, a defect (crack) can be detected merely through setting of the illumination light, and an existing detection device can be used as the device, with the result that reduction in cost can be achieved.

[0054] Further, in the second defect detection device, 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

[0055] FIG. 1 is a schematic view of a first defect detection device according to the present invention.

FIG. 2 is a schematic view for illustrating a relationship between a workpiece and an illuminator.

FIG. 3 is a schematic view of ring illumination to be used in the first defect detection device according to the present invention.

FIG. 4A is a schematic view for illustrating a bonding step using a die bonder of the present invention.

FIG. 4B is a schematic perspective view of the die bonder of the present invention.

FIG. 4C is an entire schematic perspective view of the die bonder of the present invention.

FIG. 5 is a schematic perspective view for illustrating a wafer.

FIG. 6A is an enlarged sectional view of a main portion of a workpiece in which a coating layer is formed of a single layer.

FIG. 6B is an enlarged sectional view of a main portion of a workpiece in which a coating layer is formed of two layers.

FIG. 6C is an enlarged sectional view of a main portion of a workpiece in which a coating layer is formed of three layers.

FIG. 7 is an explanatory view of a transmittance of light.

FIG. 8A is a schematic sectional view for illustrating a defect (crack) generated in a workpiece in a state in which the workpiece is cut.

FIG. 8B 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. 8C 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. 8D 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. 8E 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. 8F 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. 8G 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. 8H 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. 8I 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. 8J 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. 8K 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. 9A is a schematic perspective view for illustrating a relationship among an inclination angle of an inclined surface portion of a defect, a rotation angle of the inclined surface portion of the defect, and an illumination angle of an illuminator in a state in which the rotation angle of the inclined surface portion is 0° .

FIG. 9B is a schematic perspective view for illustrating a relationship among the inclination angle of the inclined surface portion of the defect, the rotation angle of the inclined surface portion of the defect, and the illumination angle of the illuminator in a state in which the rotation angle of the inclined surface portion is 20° .

FIG. 10 is a graph for showing a relationship between the rotation angle of the inclined surface portion of the defect and an apparent inclination angle thereof.

FIG. 11 is a graph for showing a relationship between a luminance in a bright field and a pixel size.

FIG. 12 is a graph for showing a relationship between a luminance in a dark field and the pixel size.

FIG. 13 is a schematic view of a second defect detection device according to the present invention.

FIG. 14A is an explanatory diagram for illustrating reflection of light in a case in which an NA on the illuminator side is smaller

than an NA on an observation optical system side.

FIG. 14B 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. 15 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. 16 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. 17 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. 18 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 an out-of-focus position Fa, and a luminance cross section of an out-of-focus position Fb.

FIG. 19A 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. 19B 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. 19C 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. 19D 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. 19E 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. 19F 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. 19G 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. 20 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. 21 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 the out-of-focus position Fa, and a luminance cross section of the out-of-focus position Fb.

FIG. 22 is a graph for showing a relationship between the inclination angle and the minimum defocus amount.

FIG. 23 is a schematic view of the defect detection device comprising another defocusing unit.

FIG. 24 is a schematic view of the defect detection device comprising another defocusing unit.

FIG. 25 is a schematic view of the defect detection device comprising another defocusing unit.

FIG. 26 is a schematic view of a defect detection device comprising another illumination unit.

FIG. 27 is a process chart of a semiconductor manufacturing method.

FIG. 28 is a schematic sectional view of a state in which a semiconductor chip that is a workpiece is irradiated with illumination light.

Description of Embodiments

[0056] Now, embodiments of the present invention are described with reference to FIG. 1 to FIG. 27.

[0057] FIG. 1 is a schematic view of a first defect detection device for a workpiece according to the present invention, and a defect detection device 100 (100A) (see FIG. 4B) is configured to detect the presence or absence and the position of a defect 40 (see FIGS. 8), for example, a crack formed in a workpiece such as a semiconductor wafer 29 (see FIG. 5), a semiconductor chip 21 (see FIGS. 4) obtained by cutting the semiconductor wafer 29 into an individual piece, and a die.

[0058] As illustrated in FIG. 6A, FIG. 6B, and FIG. 6C, the workpiece comprises a variable density layer 11, which has a variable density pattern, and a coating layer 12, which 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. 6A, and is formed of a plurality of layers in FIG. 6B and FIG. 6C. That is, in FIG. 6B, the coating layer 12 is formed of two layers: a first layer 13 (13a) on a variable density layer side and a second layer 13 (13b) formed on an upper side of the first layer 13 (13a). In FIG. 6C, the coating layer 12 is formed of the first layer 13 (13a) on the variable density layer side, the second layer 13 (13b) formed on the first layer 13 (13a), and a third layer 13 (13c) formed on the second layer 13 (13b). The variable density pattern can be formed of a wiring pattern. When the variable density pattern is formed of a wiring pattern, the variable density layer 11 can be referred to as "wiring pattern layer". Further, the coating layer 12 may comprise more than three layers, that is, four or more layers.

[0059] 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.

[0060] 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. 6B and FIG. 6C, those layers 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. 6A, the coating layer 12 can be made of a silicone resin, a polyimide resin, or the like. When the coating layer 12 comprises two layers as illustrated in FIG. 6B, for example, the first layer 13a can be made of a polyimide resin, and the second layer 13b can be made of a silicone resin. Alternatively, the first layer 13a can be made of a silicone resin, and the second layer 13b can be made of a polyimide resin. Alternatively, the first layer 13a and the second layer 13b can be made of a polyimide resin. Alternatively, the first layer 13a and the second layer 13b can be made of a silicone resin. When the coating layer 12 comprises three or more layers as illustrated in FIG. 6C, all the layers can be made of the same material such as a silicone resin or a polyimide resin. Alternatively, all the layers can be made of different materials. Alternatively, any plurality of layers can be made of the same material, and the other layers can be made of different

materials. Further, even when each layer 13 is made of the same kind of resin, resins having different characteristics and the like may be used.

[0061] 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. 6A or is formed of a plurality of layers as illustrated in FIG. 6B and FIG. 6C.

[0062] The defect detection device 100A is installed in a die bonder 150 as illustrated in FIG. 4A to FIG. 4C. The die bonder 150 is configured to pick up the chip 21 cut out from the wafer 29 (see FIG. 5) 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. As illustrated in FIG. 1, 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 as illustrated in FIG. 5. As described later, in the die bonder 150 illustrated in FIG. 4B, an intermediate stage 101 is arranged between the pickup position P and the bonding position Q. When the intermediate stage 101 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 101 and picked up again from the intermediate stage 101 to be bonded. Thus, the first defect detection device 100A 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

101.

[0063] As illustrated in FIG. 4A, the die bonder 150 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 Z1 and lowered in a direction indicated by an arrow Z2 at the pickup position P. Further, the collet 23 can be lifted in a direction indicated by an arrow Z3 and lowered in a direction indicated by an arrow Z4 at the bonding position Q. Further, the collect 23 can reciprocate in directions indicated by arrows X1 and X2 between the pickup position P and the bonding position Q. The movement of the moving mechanism in the directions indicated by the arrows Z1, Z2, Z3, Z4, X1, and X2 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.

[0064] 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.

[0065] Further, the wafer 29 separated (divided) into the large number of chips 21 is placed on, for example, an XYθ table 25 (see FIG. 5), 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.

[0066] Specifically, after the collet is positioned above the chip 21 to be picked up, the collect 23 is lowered as indicated by the arrow Z2, and the chip 21 is picked up. After that, the collet 23 is lifted as indicated by the arrow Z1.

[0067] Next, the collet is moved in the direction indicated by the arrow X1 to be positioned above an island portion. Then, the collet is moved downward as indicated by the arrow Z4, and the chip 21 is supplied to the island portion. Further, after the chip is supplied to the island portion, the collect is lifted as indicated by the arrow Z3, and then returned to a standby position above the pickup position as indicated by the arrow X2.

[0068] Specifically, the chip 21 is picked up by the collet 23 at the pickup position by moving the collet 23 successively as indicated by the arrows Z1, X1, Z4, Z3, X2, and Z2, to be mounted at the bonding position.

[0069] It is required to perform position checking (position detection) of the chip to be picked up at the pickup position and to perform position checking (position detection) of the island of the lead frame for bonding also at the bonding position. Therefore, in general, the chip to be picked up is observed with a camera for checking arranged at a position above the pickup position, and the collet 23 is positioned above the chip 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, and the collet 23 is positioned above the island.

[0070] Therefore, in the die bonder 150, such a positioning device as illustrated in FIG. 1 is arranged at the pickup position. The positioning device comprises the first defect detection device 100 according to the present invention. The positioning device comprises an illumination mechanism 30. The illumination mechanism 30 comprises an image pickup device 32 configured to observe the chip 21 and an illumination unit 33 configured to illuminate the chip 21. Further, the image pickup device 32 and the illumination unit 33 are controlled by a control portion 34. The image pickup device 32 comprises a camera and a lens. The camera in this case comprises a CCD image sensor, a CMOS image sensor, and the like. That is, it is only required that the camera be able to image light having an illumination wavelength. Therefore, a camera having sensitivity to visible light, ultraviolet light, and infrared light may also be used. Further, the lens can be formed of a telecentric lens, a non-telecentric lens, or the like.

[0071] As illustrated in FIG. 1, the illumination unit 33 comprises a bright-field illuminator 35 and a dark-field illuminator 36. Bright-field illumination refers to illuminating an object to be measured with a light beam perpendicularly along an optical axis center. Dark-field illumination refers to irradiating the object to be measured with a light beam obliquely instead of irradiating

the object to be measured with a light beam along the optical axis center. That is, in general, the bright field is used for observing direct 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 (for example, a semiconductor chip surface or a chip surface) is brightly observed, and a defect portion is darkly observed. Further, the dark field is used for observing scattered light, and an illumination method in this case is called a scattered light illumination method. In this embodiment, a normal portion of a chip surface is darkly observed, and a defect portion is brightly observed. However, in this embodiment, reflected light (direct light) from a crack opening is observed, and hence the definition of the dark field in this case is different from the strict definition of the dark field. It is a correct expression that this embodiment has a dark-field observation configuration. Thus, a method involving observing mainly direct light reflected from a large portion (normal portion) of a chip surface is defined as a bright field, and a method involving observing light scattered or reflected from a defect portion (abnormal portion) without observing direct light reflected from the large portion (normal portion) of the chip surface is defined as a dark field. Therefore, in the dark-field illumination, defects such as a fine structure or a flaw, which are blurred and cannot be seen in the bright-field illumination, can be observed.

[0072] Specifically, in the present invention, the

bright-field illumination is illumination of the type of observing direct light of reflected or transmitted illumination light, in which a change in shading with respect to a background is observed, and in general, the state of a bright background portion and the state of a dark portion of a sample (workpiece) are observed. In contrast, the dark-field illumination is illumination of the type of observing scattered or reflected light, in which a change in shading with respect to a background is observed, and the state of a dark background portion and the state of a bright portion of a sample (workpiece) are observed.

[0073] As illustrated in FIG. 2, it is only required that the dark-field illuminator 36 comprise a light-emitting portion 38 configured to emit parallel light and comprise at least one light-emitting portion 38. However, the dark-field illuminator 36 may comprise a plurality of light-emitting portions 38 arranged at a predetermined pitch (equal pitch or indefinite pitch) in a circumferential direction. As described above, in this embodiment, description has been given of the use of parallel light (light beam parallel to an optical axis). However, the illumination light is not limited to parallel light. The illumination light may be substantially parallel light within a range that can be called parallel light and further light having an emission angle of about 30° within a range that cannot be called parallel light.

[0074] The control portion 34 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 disk 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.

[0075] The defect 40 of the workpiece has such various shapes as illustrated in FIG. 8A to FIG. 8K, for example. In FIG. 8A, the coating layer 12 of the workpiece is cut. In FIG. 8B, inclined surface portions S and S are formed at upper ends of a pair of cut end surfaces 41 and 42. In FIG. 8C, the inclined surface portion S is formed at the upper end of one of the cut end surfaces. Further, in FIG. 8D, a groove 43 having a V-shape in cross section is formed, and the pair of inclined surface portions S are formed. In FIG. 8E, a groove 44 having a right-angled triangle shape in cross section is formed, and the inclined surface portion S is formed. In FIG. 8F, 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 41 and 42. In FIG. 8G, 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 41. In FIG. 8H, the coating layer 12 of the workpiece is bent into a valley-folded shape, and the inclined surface portions S and S are formed through intermediation of a bent line. In FIG. 8I, the coating layer 12 of the workpiece is bent into a mountain-folded shape, and the inclined surface portions S and S are formed through intermediation of a bent line. In FIG. 8J, 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 41 and 42 are formed. In FIG. 8K, 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 41 and 42 are formed. In the present invention, such defects 40 (cracking, bending, cutting, and the like) of the coating layer 12 as illustrated in FIGS. 8 are detected as defects of a workpiece (wafer, individual piece, or the like).

[0076] The defect 40 is described above in the case where the coating layer 12 is formed of a single layer. In the case where the coating layer 12 is formed of a plurality of layers, the defect 40 may be present only in any one of the plurality of layers. Alternatively, the defect 40 may be present in all the plurality of layers. Alternatively, the defect may be present in any of the plurality of layers (for example, when the coating layer 12 comprises three layers, the defect may be present in any two of the three layers). In each of the layers, the defect 40 is formed in any one

of a variable density layer corresponding surface (rear surface), a variable density layer anti-corresponding surface (front surface), and an inner portion. The defect 40 may extend from the variable density layer corresponding surface (rear surface) to the variable density layer anti-corresponding surface (front surface). Alternatively, the defect 40 may extend from the variable density layer corresponding surface (rear surface) to the inner portion (site that does not reach the variable density layer anti-corresponding surface (front surface)). Alternatively, the defect 40 may extend from the variable density layer anti-corresponding surface (front surface) to the inner portion (site that does not reach the variable density layer corresponding surface (rear surface)).

[0077] The first defect detection device 100 (100A) according to the present invention adopts the dark-field illumination, and is configured to detect a defect having at least the inclined surface portion S as illustrated in FIG. 8B to FIG. 8K. Further, in the dark-field illumination, as illustrated in FIG. 2, the illumination direction of the illuminator 36 can be set, for example, so that, when a photographing axis L and the workpiece are arranged so as to be orthogonal to each other, an angle (elevation angle) formed by the workpiece and an illumination axis L1 becomes a predetermined angle. In the illustrated example, the cases of the elevation angles of 60°, 70°, and 80° are illustrated. However, the elevation angle is not limited thereto, and can be set within a range of from 50°

to 85°.

[0078] In this case, the defect detection device 100A illustrated in FIG. 1 is arranged, for example, at the pickup position P. Therefore, in this case, the wafer 29 serves as the workpiece. The workpiece is placed on a rotary table 25, and in this state, the workpiece is rotated about an axial center of the rotary table 25 as illustrated in FIG. 2. Further, the position checking (position detection) of a chip to be picked up can be performed through the bright-field illumination.

[0079] When the workpiece is irradiated with illumination light, the illumination light is reflected by, transmitted through, absorbed by, or scattered from each of the layers 13 (13a, 13b, 13c) of the coating layer 12 as illustrated in FIG. 6A, FIG. 6B, and FIG. 6C. Further, the illumination light is reflected from the variable density pattern (wiring pattern).

[0080] However, in order to detect the defect 40 of the coating layer 12, it is only required that the reflected light from the layer having the defect 40 of the coating layer 12 enter the image pickup device 32. Therefore, it is preferred that the illumination light have a wavelength at which an intensity of light that is reflected or scattered from the layer having the defect 40 of 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 32, 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.

[0081] 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. 7, 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 1.

[0082] [Expression 1]

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

T: Transmittance

It is only required that the light for reducing the influence of the variable density pattern 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 illuminator be set to 450 nm or less or 1,000 nm or more.

[0083] 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) 40 can be stably detected. Further, the defect (crack) 40 can be detected merely through setting of the illumination light, and an existing detection device can be used as the device, with the result that reduction in cost can be achieved.

[0084] Therefore, in order to decrease the influence of the variable density pattern, the influence of the variable density pattern can be decreased through the bright-field illumination, and the defect formed in the coating layer 12 (on the surface of the coating layer 12 in this embodiment) can be detected. Therefore, even the defect 40 that does not have the inclined surface portion S can be detected.

[0085] However, in a case where a defect is small or other case, it is difficult to detect the defect even when the influence of the variable density pattern is decreased. Therefore, the dark-field illumination of irradiating an object to be measured (workpiece) with a light beam obliquely instead of irradiating the object to be measured with a light beam along the optical axis center is used.

[0086] As illustrated in FIG. 9A and FIG. 9B, in the dark-field

illumination, when the illumination light is set so as to be radiated to the inclined surface portion on a lower inclined side from the photographing axis L of the image pickup device 32, a defect image on the observation image of the defect 40 formed in the workpiece can be observed in an enlarged state as compared to the case in which the illumination light is radiated in parallel to the photographing axis L.

[0087] In this case, the illumination angle of the illumination light can be determined by a tilt (inclination angle) of the inclined surface portion S. That is, when the plane of the inclination angle of the inclined surface portion S is the same as the plane of the elevation angle (when the rotation angle of the inclined surface portion S is 0° as illustrated in FIG. 9A), it is required that the illumination be radiated so that the illumination light reflected from the inclined surface portion S falls within a range of an observation side NA. When the inclined surface portion S is rotated, the angle of the reflected light changes in accordance with an apparent inclination angle. The inclination angle and the reflected light have a relationship in which the reflected light is tilted by 2θ when the inclination is tilted by θ .

[0088] When the inclination angle is represented by α , and the rotation angle is represented by β , an apparent inclination angle γ can be represented by the following Expression 2.

[0089] [Expression 2]

$$\gamma = \text{atan}(\tan \alpha \times \cos \beta)$$

Therefore, for example, when $\alpha=10^\circ$ and $\beta=0^\circ$ as illustrated in FIG. 9A, γ becomes 10° , which is the same as α . Further, when $\alpha=10^\circ$ and $\beta=20^\circ$ as illustrated in FIG. 9B, γ becomes 9.4° as represented by Expression 3. In FIG. 10, there is shown a relationship between the rotation angle and the apparent inclination angle observed when the inclination angle of the inclined surface portion is set to 10° .

[0090] [Expression 3]

$$\text{atan}(\tan 10^\circ \times \cos 20^\circ) = 9.4^\circ$$

As described above, in the case where the defect 40 having the inclined surface portion S is formed, when the dark-field illumination is performed, and a workpiece is rotated, a defect image on the observation image of the defect 40 formed in the workpiece can be observed in an enlarged state even at any rotation angle of the inclined surface portion S.

[0091] Description is given of the reason for being capable of observing a defect in an enlarged state (thickened state) by performing the dark-field illumination. In the bright field, it is required to set the brightness of a normal portion (chip surface) so that the brightness falls within a dynamic range of a sensor. Further, a part of scattered light and direct light reflected depending on the shape of a defect portion enters a camera. Therefore,

the contrast with respect to the defect portion becomes small. However, in the case of the dark field, even when the brightness of an abnormal portion (defect portion) is set so as to exceed the dynamic range, the direct light from the normal portion (chip surface) does not enter the camera, and hence the normal portion does not become bright (as compared to the defect portion, the normal portion is flat, and hence scattering therefrom is small). Thus, the brightness of the abnormal portion is observed as a dynamic range upper limit (or observed to be sufficiently large), and the brightness of the normal portion is observed as a dynamic range lower limit (or observed to be sufficiently small), with the result that the defect can be detected with a high contrast. Now, the case in which a defect is smaller than the resolution (pixel size) of an object is considered. When the defect is smaller than a pixel size, the luminance of the pixel is determined by an area ratio between the defect portion and the normal portion and each luminance value thereof.

[0092] Further, in the bright field, as shown in FIG. 11, it is required to set the luminance difference between the normal portion and the abnormal portion so that the luminance difference falls within a dynamic range, and hence the luminance of the normal portion becomes dominant. Thus, the contrast with respect to the surrounding normal portion becomes small. However, in the dark field, as shown in FIG. 12, the luminance of the defect portion can be set so as to significantly exceed the dynamic range. Therefore, the luminance

of the defect portion can be set to be large. Thus, the contrast with respect to the surrounding normal portion becomes large. Further, when there is blurring in the case where images of shading are adjacent to each other, blurring in the bright image is observed in a more spreading state as compared to blurring in the dark image. Therefore, in the bright field, the defect becomes small. That is, the contrast (which is buried because the bright image in the surrounding normal portion spreads) becomes low. Meanwhile, in the dark field, the defect portion becomes large. Although the contrast is decreased due to blurring (spreading defect portion), the brightness of the defect portion can be set so as to exceed the dynamic range as described above, and hence the defect is thickened while the contrast remains constant.

[0093] When the resolution of an observation device (illumination mechanism 30) is larger than a defect size, the defect cannot be seen with the observation device (illumination mechanism 30). In contrast, when the resolution of the observation device (illumination mechanism 30) is smaller than the defect size, the defect can be seen with the observation device (illumination mechanism 30). Therefore, in the present invention, the defect is thickened, and hence the defect, which cannot be seen (observed) in the related art, can be seen by thickening the defect even through use of the observation device (illumination mechanism 30) having a resolution larger than the defect size. Further, when the observation device (illumination mechanism 30) having a resolution

smaller than the defect size is used, the observation performance can be improved by thickening the defect.

[0094] A defect may have such an opening as illustrated in FIG. 8A. Also in this case, the defect can be observed through scattering of light. The reason for this is described below. The opening has a fine structure, and scattering of light occurs therein. The scattered light diffuses in an entire circumferential direction, and hence a part of the light enters a lens. In contrast, the normal portion has a flat surface regarded as a mirror surface, and the substantially entire light caused by the dark-field illumination travels in a direction in which the light does not enter the lens due to reflection. Therefore, even when the defect has the opening as illustrated in FIG. 8A, the defect formed of the opening can be observed.

[0095] Next, a second defect detection device 100 (100B) according to the present invention is described. The second defect detection device 100 (100B) comprises an inspection mechanism 55 as illustrated in FIG. 13. The inspection mechanism 55 comprises an image pickup device 61 configured to observe the chip 21, an illumination unit 62 configured to illuminate the chip 21, a half mirror 63 configured to reflect light emitted from the illumination unit 62, and a defocusing unit 69 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 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 out-of-focus position refers to a position other than the in-focus position, which is defocused from the in-focus position.

[0096] The image pickup device 61 forming an observation optical system comprises a camera 64 and a lens 65. The camera 64 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 64 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 65 can be formed of a telecentric lens, a non-telecentric lens, or the like. The image pickup device 61 is controlled by a controller 73. The controller 73 comprises an inspection processor 74 configured to inspect a defect and a positioning processor 75 configured to detect the position of a workpiece on an image (for example, image matching).

[0097] As illustrated in FIG. 13, the illumination unit 62 comprises a bright-field illuminator including a light source 66 and a lens 67. Bright-field illumination refers to illuminating the workpiece in an extending direction of a principal ray of the observation optical system (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" 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.

[0098] 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. 14A and FIG. 14B. 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. 14B, 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. 14A, 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.

[0099] 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 61 and the illumination unit 62. 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 61 and the illumination unit 62. When the defocus amount is determined by a calculating portion 71 described later, an NA control portion 77 determines an NA based on the defocus amount by calculation to control the aperture stop mechanism.

[0100] The defocusing unit 69 in this embodiment is provided below the image pickup device 61 and comprises a table 68, on which the chip 21 is to be placed, and a drive unit (not shown) configured to reciprocate the table 68 upward and downward. The drive unit can comprise various 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. 13, and is brought close to and

separated from the image pickup device 61. That is, the defocusing unit 69 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.

[0101] The defocusing unit 69 (drive unit) is driven based on the control of the control portion 70. The control portion 70 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 70 comprises the calculating portion 71. For example, merely through setting of parameters by a user through use of a method described later, the calculating portion 71 automatically determines a defocus amount.

[0102] The defect detection device 100B illustrated in FIG. 13 is arranged, for example, at the pickup position P. In this case, the wafer 29 serves as the workpiece. The defect detection device 100B further comprises another bright-field illumination unit 72 below the image pickup device 61, 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 72 and perform image matching processing and the like through use of the positioning processor 75, thereby being capable of performing positioning of the workpiece.

[0103] As described above, the defect 40 on the surface of the workpiece has various shapes, for example, as illustrated in FIGS. 8. In the second defect detection device according to the embodiment, the defects 40 (defects having the inclined surface portions S at any position, such as cracking, bending, and cutting) of the coating layer 12 are detected as defects of a workpiece (wafer, individual piece, or the like). Therefore, it is difficult to detect such a defect having the inclined surface portion S as illustrated in FIG. 8A.

[0104] Through use of the defect detection device 100B according to this embodiment, a defect image on the observation image of the defect 40 formed in the workpiece can be observed in an emphasized state. "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. 8J and FIG. 15. In FIG. 15, a separation width (crack width) between one inclined surface portion S1 (on the right side of FIG. 15) and the other inclined surface portion S2 (on the left side of FIG. 15) 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 θ_1 , an angle (inclination angle) formed by the line orthogonal to the optical axis and the other inclined surface portion S2 is represented by θ_2 , and a crack angle θ is represented by $\theta_1 + \theta_2$. In FIG. 15, the dotted line represents illumination light, and the solid line represents reflected light.

[0105] As illustrated in FIG. 16, 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 L2b is tilted by 2θ from an optical axis of irradiation light L1a. When the workpiece is placed at an in-focus position F illustrated in FIG. 17, reflected light, which passes through an intersection of a focus plane and a principal ray of the irradiation light L1a and falls within a range of $\pm NA$ (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 FIG. 11) can be obtained.

[0106] As illustrated in FIG. 17, 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 P1 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 surface, 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 $\times$ tan(2 θ)". It is preferred that the illumination side numerical aperture (NA) be decreased to increase a depth of field (range allowing blurring) before the defect 40 is inspected. With this, an image can be prevented from being blurred even when defocusing is performed.

[0107] 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. 18. 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 40 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. 19E to FIG. 19G. In FIG. 19G, an image at an out-of-focus position that is separated most downward from the object plane, and the defect 40 is most enlarged (thickened). FIG. 19E is an image close to the object plane.

[0108] 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. 18. 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 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. 19A to FIG. 19D. In FIG. 19A, an image at an out-of-focus position that is separated most upward from the object plane, and the defect 40 is most enlarged (thickened). FIG. 19D is an image close to the out-of-focus position Fc.

[0109] In the case of a defect having no crack width w as

illustrated in FIG. 8H, 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 F_c . 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.

[0110] In the case of such a defect (having a cut portion in a mountain-folded shape) as illustrated in FIG. 8K, when the workpiece is defocused from the object plane (in-focus position F) to the out-of-focus position F_b 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. 20. 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 F_c . Therefore, the contrast is not increased, and the defect on the image becomes smaller as defocusing is performed downward. When defocusing is performed downward from the out-of-focus position F_c , 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 F_b , 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 F_b , the defect on the image is whitely enlarged.

[0111] 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 F_a 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. 21. With this, in the luminance cross-section in a plane including the out-of-focus position F_a , the interval between the images of the reflected light flux A and the reflected light flux B is increased, and the defect 40 is blackly enlarged (thickened). That is, as defocusing is performed upward from the object plane, the defect on the image is blackly enlarged.

[0112] In the case of a defect having no crack width w as illustrated in FIG. 8I, 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 F_c . 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.

[0113] 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 51 and the out-of-focus position Fb on a side (lower side) separated from the image pickup device 51 with the in-focus position F being a boundary between the out-of-focus positions, the defect 40 can be inspected with different colors.

[0114] When the defect becomes black (dark) as illustrated in FIG. 18, a minimum defocus amount z is calculated through use of the angle θ_1 formed by a line L5 orthogonal to an optical axis and one surface portion, the angle θ_2 formed by the line L5 orthogonal to the optical axis and the other surface portion, the crack width w , and a minimum detection width $\varepsilon_{\min}$ as in Expression 4, Expression 5, and Expression 6. Δx_1 represents an enlargement amount on one surface portion side, Δx_2 represents an enlargement amount on the other surface portion side, and ΔX_d represents a dimension of an enlarged defect. Further, when the defect becomes white (bright),

the minimum defocus amount z is calculated through use of θ_1 , θ_2 , w , and $\varepsilon_{\min}$ as in Expression 7, Expression 8, and Expression 9. $\Delta x_1'$ ($=\Delta x_1$) represents an enlargement amount on one surface portion side, $\Delta x_2'$ (Δx_2) represents an enlargement amount on the other surface portion side, and ΔX_l represents a dimension of an enlarged defect.

[Expression 4]

$$\begin{aligned}\Delta x_1 &= z \cdot \tan 2\theta_1 \\ \Delta x_2 &= z \cdot \tan 2\theta_2 \\ \Delta X_d &= \Delta x_1 + \Delta x_2 + w\end{aligned}$$

Detection condition

$$\Delta X_d \geq \varepsilon_{\min}$$

[Expression 5]

$$\begin{aligned}\Delta X_d &\geq \varepsilon_{\min} \\ \Delta x_1 + \Delta x_2 + w &\geq \varepsilon_{\min} \\ z \cdot \tan 2\theta_1 + z \cdot \tan 2\theta_2 &\geq \varepsilon_{\min} - w \\ z (\tan 2\theta_1 + \tan 2\theta_2) &\geq \varepsilon_{\min} - w\end{aligned}$$

[Expression 6]

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

where

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

[Expression 7]

$$\begin{aligned}\Delta x_1' &= z \cdot \tan 2\theta_1 \\ \Delta x_2' &= z \cdot \tan 2\theta_2 \\ \Delta X_l &= \Delta x_1' + \Delta x_2' - 2w\end{aligned}$$

Detection condition

$$\Delta X_l \geq \varepsilon_{\min}$$

[Expression 8]

$$\begin{aligned}\Delta X_l &\geq \varepsilon_{\min} \\ \Delta x_1' + \Delta x_2' - 2w &\geq \varepsilon_{\min} \\ z \cdot \tan 2\theta_1 + z \cdot \tan 2\theta_2 - 2w &\geq \varepsilon_{\min} \\ z (\tan 2\theta_1 + \tan 2\theta_2) &\geq \varepsilon_{\min} + 2w\end{aligned}$$

[Expression 9]

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

where

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

[0115] FIG. 22 is a graph for showing a relationship between the crack angle θ and the minimum defocus amount z when the minimum detection width $\varepsilon_{\min}$ 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 $-\sin^{-1}(\text{NA}) \leq \theta_1 \leq \sin^{-1}(\text{NA})$, and $-\sin^{-1}(\text{NA}) \leq \theta_2 \leq \sin^{-1}(\text{NA})$ be satisfied. In this case, $\varepsilon_{\min}$ 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 $\text{median} \times 1/5 = \text{DR} \times 10\%$.

[0116] The control portion 70 comprises the calculating portion 71, and the calculating portion 71 is configured to calculate a defocus amount based on predetermined parameters. For example, in the case where the calculating portion 71 calculates a defocus amount by the above-mentioned Expression 4, when the parameters $\varepsilon_{\min}$, θ_1 , θ_2 , and w are set, the calculating portion 71 calculates the minimum defocus amount z by Expression 4. When a user sets the parameters, θ_1 and θ_2 may be independently set as two parameters or one parameter may be set as the crack angle θ ($\theta_1 + \theta_2$). When one parameter θ is set, the calculating portion 71 performs calculation by distributing θ into θ_1 and θ_2 , for example, by setting $\theta_1 = \theta/2$ and $\theta_2 = \theta/2$ or setting $\theta_1 = 0$ and $\theta_2 = \theta$. The control portion 70 is configured to control the drive of the defocusing unit 69 (drive mechanism) based on the defocus amount calculated by the calculating portion 71.

[0117] It is only required that the light to be used in the defect detection device 100 (100B) illustrated in FIG. 13 have decreased influence of the variable density pattern and 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.

[0118] 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) 40 can be stably detected.

[0119] The second defect detection device 100B according to the present invention can also be arranged on at least any one of the pickup position P, the bonding position Q, or the intermediate stage 101. That is, the defect 40 on the surface of the chip 21 can be detected on at least any one of the pickup position P, the bonding position Q, or the intermediate stage 101.

[0120] There is a case in which a rotation mechanism is not arranged on the workpiece (semiconductor chip or die) side at the bonding position Q. In this case, it is preferred that a ring illuminator 50 illustrated in FIG. 3 be used as the dark-field illuminator 36 of the first defect detection device 100A. The ring illuminator 50 is an illuminator comprising a plurality of light-emitting portions 51 arranged in at least one row in a ring shape surrounding the photographing axis L of the image pickup device 32.

[0121] Therefore, when the defect detection device 100 (100A) comprising such a ring illuminator 50 as illustrated in FIG. 3 is arranged at the bonding position Q, the influence of the variable density pattern (wiring pattern) can be reduced at the bonding

position. Further, even when the inclined surface portion of the defect 40 has any rotation angle, a defect image on the observation image of the defect 40 formed in the workpiece can be observed in an enlarged state, and the defect (crack) 40 can be stably detected. The defect detection device 100 (100A) illustrated in FIG. 1, which does not use the ring illuminator 50, may be arranged at the bonding position Q.

[0122] Further, when the first defect detection device 100A or the second defect detection device 100B is arranged at the bonding position Q, the first defect detection device 100A or the second defect detection device 100B can be used for position checking (positioning) of observing the position of the island of the lead frame through the bright-field illumination.

[0123] The die bonder 150 illustrated in FIGS. 4 and the like is 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 101 and picked up again from the intermediate stage 101 to be bonded.

[0124] Therefore, the defect detection device 100A illustrated in FIG. 1, the defect detection device 100A using the ring illuminator illustrated in FIG. 3, and further the defect detection device 100B illustrated in FIG. 13 can be arranged on the intermediate stage 101. Thus, when the defect detection device 100 (100A, 100B) is

arranged on the intermediate stage 101, the influence of the variable density pattern (wiring pattern) on the workpiece (semiconductor chip 21, die, or the like) on the intermediate stage can be reduced. Further, a defect image on the observation image of the defect 40 formed in the workpiece can be observed in an enlarged state, and the defect (crack) can be stably detected. Through use of the defect detection device 100 (100A, 100B), positioning can be performed also on the intermediate stage.

[0125] In the die bonder 150, a defect is detected at the pickup position, the bonding position, the intermediate stage 101, 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.

[0126] 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.

[0127] Further, a defect can be detected in any one of the period before the workpiece is supplied to the intermediate stage 101 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 101 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

101 and the period after the workpiece is discharged from the intermediate stage 101.

[0128] Thus, in the defect detection device 100A illustrated in FIG. 1 and the defect detection device 100A using the ring illuminator 50 illustrated in FIG. 3, a determination part configured to determine whether or not the detected defect 40 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 100A, 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. The determination part can comprise the control portions 34 and 70.

[0129] Therefore, in the present invention, 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).

[0130] As described above, in the first defect detection device 100 (100A), the influence of the variable density pattern can be reduced (decreased), and the light reflected or scattered from the coating layer 12 can be projected. Therefore, the defect (crack) 40 can be stably detected. Further, the defect (crack) 40 can be detected merely through setting of the illumination light, and an

existing detection device can be used as the device, with the result that reduction in cost can be achieved.

[0131] In the first defect detection device 100 (100A), when such a ring illuminator 50 as illustrated in FIG. 3 is used, the defect (crack) can be observed in an enlarged state irrespective of the direction of the inclined surface portion S of the defect 40. Through setting of the illumination direction of the illuminator 36 to an angle of from 50° to 85° , most of the generated defects (cracks) 40 can be observed in an enlarged state.

[0132] In the second defect detection device 100 (100B), the defect 40 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 40 on the observation image formed by the reflected light from the in-focus position F, and the defect 40 which cannot be seen with the existing device becomes visible. Therefore, the defect 40 can be stably detected.

[0133] Also in the second defect detection device 100 (100B), when the illumination light emitted from the illumination unit 62 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 61 is higher than an intensity of light that is reflected from at least the variable density layer 11 to enter the image pickup device 61, 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

40 can be stably detected.

[0134] In the die bonder 150 on which the first defect detection device 100A or the second defect detection device 100B is mounted, the defect 40, for example, a crack, on the surface of the workpiece to be subjected to bonding can be detected at any one of the pickup position to the bonding position.

[0135] 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 (first defect detection method) for detecting the defect 40 through use of the first defect detection device 100A corresponds to a failure as a product or whether a defect detection method (second defect detection method) for detecting the defect 40 through use of the second defect detection device 100B 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) 40 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 150, positioning detection can be performed, and a stable bonding step with high precision can be performed.

[0136] As illustrated in FIG. 27, 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. 27.

[0137] 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.

[0138] Further, the workpiece may be a semiconductor device comprising an individual piece in which a defect is not detected by the first defect detection method or the second defect detection method or in which a detected defect is determined to correspond to a non-defective product by the first defect detection method or the second defect detection method.

[0139] Further, the workpiece for the first defect detection device, the second defect detection device, the first defect detection method, and the second defect detection method 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 juxtaposed to each other in a horizontal direction, or further a combination of the laminated individual pieces and the juxtaposed

individual pieces. When the semiconductor device comprising such an individual assembly is manufactured, the semiconductor device is 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.

[0140] Further, the die bonder 150 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 150 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.

[0141] In the defect detection device 100 (100B) illustrated in FIG. 13 and the like, the defocusing unit is a mechanism configured to move only the workpiece upward and downward in the embodiment.

However, the defocusing unit may be configured to move only the image pickup device 61 upward and downward or move the workpiece and the image pickup device 61 upward and downward.

[0142] Further, the defocusing unit 69 may be configured to change an optical system. As one example thereof, for example, as illustrated in FIG. 23, an object (for example, plate glass) 76 having a refractive index different from that in the atmosphere is inserted between the image pickup device 61 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.

[0143] Further, as the defocusing unit 69, a plurality of optical systems and light-receiving elements having different in-focus positions may be used. For example, as illustrated in FIG. 24, a first image pickup device 61a and a second image pickup device 61b are provided. The first image pickup device 61a is set to a side on which defocusing is performed above the in-focus position, and the second image pickup device 61b is set to a side on which defocusing is performed below the in-focus position.

[0144] In this case, a pair of half mirrors 90 and 63 are arranged between the first image pickup device 61a and the defocusing unit 69. The second image pickup device 61b is arranged at a position corresponding to the half mirror 90 of the first image pickup device 61a.

[0145] Further, the defocusing unit 69 may be configured to change an illumination wavelength or an observation wavelength. For example, as illustrated in FIG. 25, the illumination unit 62 comprises a first light source 66a and a second light source 66b, and is configured to change the wavelength of light from the first light source 66a and the wavelength of light from the second light source 66b. In this case, a half mirror 91 is arranged between the first light source 66a and the illumination unit 62.

[0146] Further, the defocusing unit 69 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.

[0147] As illustrated in FIG. 26, the illumination unit 62 may comprise an inspection light source 80, a positioning light source 81, an NA switching portion 82 configured to electrically switch an NA on an illumination side by switching those light sources, and the half mirror 91.

[0148] 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.

[0149] In the second defect detection device illustrated in FIG. 13 and the like, an inclination angle of a surface portion and a defect width can be detected based on the defocus amount and the separation width. 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 ΔX_l , a defect detection width observed when the defect becomes dark is represented by ΔX_d , and a relative angle (crack angle) between the opposed surface portions is represented by $\theta = \theta_1 + \theta_2$, θ and w can be detected by detecting the defect detection widths ΔX_l and ΔX_d by Expression 10 under the condition of $\theta_2 = 0$ and $\theta_1 = \theta$. In this case, a detection portion configured to perform such calculation can be provided, for example, in the controller 73. With this, angle measurement of the inclined surface portion can be performed.

[Expression 10]

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

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

[0150] Further, in the defect detection device illustrated in FIG. 13 and the like, when inspection is performed from two different positions including at least the out-of-focus position, a discriminating part (not shown) configured to discriminate a defect changed in shading from other defects may be provided, for example, in the controller 73. That is, the discriminating part can determine

that defects (cracks) changed in shading are defects (cracks) each having inclination and that the other defects (which have not been changed in shading) 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 40, that is, whether or not the defect 40 has been enlarged. Further, the discriminating part can also determine the kind of a defect based on both the change in shading and the change in enlargement of the defect.

[0151] In the defect detection device illustrated in FIG. 13 and the like, 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 photographed 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.

[0152] The present invention can be variously modified without being limited to the above-mentioned embodiment. For example, in the embodiment, the influence of the variable density pattern (wiring pattern) can be reduced, and further, the defect on the observation

image with respect to the defect formed in the workpiece can be observed in an enlarged state. However, the defect detection device 100 may have only a configuration in which the influence of the variable density pattern (wiring pattern) can be reduced.

[0153] In the defect detection device 100A illustrated in FIG. 1, the bright-field illuminator is used mainly for positioning (alignment), and the dark-field illuminator is used for illumination for observing the defect on the observation image with respect to the defect formed in the workpiece in an enlarged state while reducing the influence of the variable density pattern (wiring pattern). However, the bright-field illuminator may be used for observation in which the influence of the variable density pattern (wiring pattern) is reduced, and the dark-field illuminator may be used only for observing the defect on the observation image of the defect formed in the workpiece in an enlarged state.

[0154] In the defect detection device 100A illustrated in FIG. 1, as a method of observing the defect on the observation image in an enlarged state, a method involving enlarging (thickening) the defect through use of an optical blurring part may be used. The optical blurring part can be formed through use of, for example, a low-pass filter. That is, when a low-pass filter is installed in front of a sensor surface, blurring, for example, image blurring occurs. Further, in order to cause blurring, it is only required that a signal be deteriorated. Therefore, a blurring part can be formed also by deteriorating the performance of a lens. Further,

blurring may be caused by performing defocusing through use of an aberration called an axial chromatic aberration, in which a focus position varies depending on the wavelength.

[0155] In the dark-field observation of the first defect detection device 100A, as the inclination angle (elevation angle) of the illumination light, the best angle is selected in accordance with the inclination angle of the inclined surface portion S of the defect 40 to be formed. Therefore, when the inclined surface portion S of the defect 40 to be formed is constant, an elevation angle corresponding thereto is set. However, when there are various inclination angles of the inclined surface portion S of the defect 40 to be formed, the elevation angle cannot be set to be constant. Therefore, it is preferred that a mechanism (angle displacement mechanism of an illuminator) capable of suitably changing the elevation angle of the illumination light be provided so as to set an elevation angle corresponding to the inclination angle of the inclined surface portion S.

[0156] The wavelength to be used for observation can be selected through use a wavelength selection filter or the like. In this case, the wavelength selection filter is an optical filter configured to allow only light having a particular wavelength to transmit therethrough, and there are given a filter in which an optical thin film (derivative or metal) is vapor-deposited on the surface of a base material (glass) and a filter using a base material that absorbs the particular wavelength, for example. Depending on the

design of a transmittance wavelength, there are various names of filters (short-pass filter, long-pass filter, band-pass filter, notch filter, hot mirror, cold mirror, and the like). That is, through limitation of the wavelength selection filter or the wavelength of the illumination light, observation can be performed at the particular wavelength.

[0157] When the light-emitting portions are arranged in a ring shape at a predetermined pitch along the circumferential direction as the illuminator, the pitch can be suitably set along the circumferential direction in accordance with the size, shape, inclination angle of an inclined surface, direction of a defect to be formed, and the like so that the defect formed in the workpiece can be observed from the entire circumference.

[0158] The term "ring shape" in the case where the light-emitting portions are arranged in a ring shape encompasses a ring without any defect, a ring having a defect, and the like. Further, the arrangement of the light-emitting portions is not limited to the ring shape, and the light-emitting portions may be arranged in a C-shape, a semicircular shape, or the like.

[0159] In the embodiment, description is given mainly of the case in which the defect 40 is formed on the surface of the coating layer 12. However, the defect 40 may be formed at positions other than the surface. That is, the defect 40 may be formed in the first layer 13a in FIG. 6B, and may be formed in the first layer 13a or the second layer 13b in FIG. 6C, for example. Therefore, the defect

40 may be formed in the coating layer 12. Even when the defect 40 is formed in the coating layer 12 as described above, the defect 40 can be detected by the defect detection device 100A and the defect detection method according to the present invention. Even when the coating layer 12 is formed of a single layer as illustrated in FIG. 6A, the defect 40 may be formed in the coating layer 12 or on a variable density layer corresponding surface. Even in this case, the defect 40 can be detected by the defect detection device 100A and the defect detection method according to the present invention.

[0160] The film thickness of the coating layer of a workpiece W 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.

[0161] 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.

[0162] In order to inspect a defect, according to the present invention, there are the first defect detection method for detecting the defect 40 through use of the first defect detection device 100A and the second defect detection method for detecting the defect 40 through use of the second defect detection device 100B. Therefore, in the present invention, it is only required that at least any one of the first defect detection method or the second defect detection method be performed. That is, any one of the methods may be first performed, and then the other method may be performed (irrespective of whether the defect 40 has been detected or has not been detected by the one method). Alternatively, any one of the methods may be performed, and then the other method may be performed only when the defect has not been detected by the one method. Further, the method to be performed first may be any one of the first defect detection method and the second defect detection method.

Industrial Applicability

[0163] The defect detection device according to the present invention can be used in a die bonder, which is a device configured to bond a die (chip of a silicon substrate in which an electronic circuit is built) to a lead frame, a substrate, or the like through use of solder, gold plate, or resin as a joining material.

Reference Signs List

[0164]	P	pickup position
Q		bonding position
S		inclined surface portion
θ_1, θ_2		minimum detection angle
w		crack width
$\varepsilon_{\min}$		minimum detection width (parameter)
11		variable density layer
12		coating layer
21		semiconductor chip
29		wafer
30		illumination mechanism
32		image pickup device
35		bright-field illuminator
36		dark-field illuminator
38		light-emitting portion
40		defect
50		ring illuminator
51		light-emitting portion
55		inspection mechanism
61		image pickup device (observation optical system)
62		illumination unit
69		defocusing unit
77		NA control portion

Claims

[Claim 1] A defect detection device, which is configured to detect a defect formed in a coating layer in a workpiece, the workpiece comprising a variable density layer having a variable density pattern derived from a semiconductor manufacturing process and the coating layer, which covers the variable density pattern of the variable density layer,

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

an illuminator configured to illuminate the workpiece;

and

an image pickup device configured to observe an observation site of the workpiece illuminated by the illuminator,

wherein illumination light emitted from the illuminator 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 2] The defect detection device according to claim 1,

wherein the image pickup device is configured to perform dark-field observation of observing the observation site of the workpiece illuminated by the illuminator from above,

wherein the defect of the workpiece has at least any one of an opening or an inclined surface portion, and

wherein the image pickup device is configured to perform observation of enlarging the defect on an observation image of the defect formed in the workpiece.

[Claim 3] The defect detection device according to claim 2, wherein the illuminator comprises a plurality of light-emitting portions arranged at a predetermined pitch along a circumferential direction of the illuminator.

[Claim 4] The defect detection device according to claim 2, wherein the illuminator comprises a ring illuminator comprising a plurality of light-emitting portions arranged in at least one row in a ring shape surrounding a photographing axis of the image pickup device.

[Claim 5] The defect detection device according to any one of claims 2 to 4, wherein the illuminator has an illumination direction in which the workpiece and an illumination axis form an angle of from 50° to 85° when a photographing axis and the workpiece are arranged so as to be orthogonal to each other.

[Claim 6] 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; 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,

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 7] The defect detection device according to claim 6, 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 8] The defect detection device according to claim 7, wherein
the defect detection device is configured to perform inspection
or positioning of detecting a position of the workpiece on an image
based on the reflected light from at least one of the two different

positions.

[Claim 9] The defect detection device according to claim 7 or 8, 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 10] The defect detection device according to any one of claims 6 to 9, wherein a numerical aperture (NA) on the illumination unit side is smaller than an NA on the observation optical system side.

[Claim 11] The defect detection device according to any one of claims 6 to 10, 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 12] The defect detection device according to any one of claims 6 to 10,

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 13] The defect detection device according to any one of claims 6 to 12, further comprising a varying unit capable of varying at least one of an NA on the illumination unit side or an NA on the observation optical system side.

[Claim 14] The defect detection device according to any one of claims 6 to 13, further comprising an NA control portion configured to set at least an NA on the observation optical system side or an NA on the illumination unit side in accordance with a tilt of the workpiece or a defocus amount.

[Claim 15] The defect detection device according to any one of claims 6 to 14, 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 16] The defect detection device according to any one of claims 6 to 15,

wherein, when a defect in a workpiece to be inspected has a pair of surface portions having different directions, a defocus amount z from a position of the workpiece to the out-of-focus position is larger than a value calculated by the following expression: $\varepsilon_{\min} - w / (\tan 2\theta_1 + \tan 2\theta_2)$, where $\varepsilon_{\min}$ represents a minimum detection width of the image pickup device, θ_1 represents an angle formed by a line orthogonal to an optical axis and one of the pair of surface portions, θ_2 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.

[Claim 17] The defect detection device according to claim 16, wherein, when the θ_1 and the θ_2 of the workpiece to be inspected are limited by an numerical aperture NA of the observation optical system, the θ_1 and the θ_2 satisfy the following expressions: $-\sin^{-1}(NA) \leq \theta_1 \leq \sin^{-1}(NA)$ and $-\sin^{-1}(NA) \leq \theta_2 \leq \sin^{-1}(NA)$.

[Claim 18] The defect detection device according to any one of claims 12 to 17, further comprising a control portion configured to control the defocusing unit so as to achieve a predetermined defocus amount.

[Claim 19] The defect detection device according to claim 18, wherein the control portion comprises a calculating portion configured to

calculate a defocus amount based on a predetermined parameter.

[Claim 20] The defect detection device according to any one of claims 6 to 19, wherein 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.

[Claim 21] The defect detection device according to any one of claims 6 to 20, further comprising 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.

[Claim 22] The defect detection device according to any one of claims 6 to 21, further comprising 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.

[Claim 23] The defect detection device according to any one of claims 6 to 22,

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 larger than an intensity of light from another layer.

[Claim 24] The defect detection device according to any one of claims 6 to 23,

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 25] The defect detection device according to claim 1 or 6, wherein the coating layer comprises an organic substance layer.

[Claim 26] The defect detection device according to claim 25, wherein the organic substance layer is made of a polyimide resin.

[Claim 27] The defect detection device according to claim 1 or 6, wherein the coating layer has a film thickness of from 1 μm to 100

μm.

[Claim 28] The defect detection device according to claim 1, wherein the coating layer is formed of a single layer.

[Claim 29] The defect detection device according to claim 1 or 6, wherein the coating layer is formed of a plurality of layers comprising two or more layers, and

wherein the plurality of layers are made of the same material, the plurality of layers are made of different materials, or predetermined layers of the plurality of layers are made of the same material.

[Claim 30] The defect detection device according to claim 1 or 6, wherein, of the illumination light from the illuminator, illumination light to be observed has a wavelength of 450 nm or less, or a wavelength of 1,000 nm or more.

[Claim 31] A defect detection method for detecting a defect formed in a coating layer in a workpiece, the workpiece comprising a variable density layer having a variable density pattern and the coating layer, which covers the variable density pattern of the variable density layer,

the method comprising irradiating the workpiece with illumination light having a wavelength at which an intensity of

light that is reflected or scattered from the coating layer to enter an 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 observe the workpiece by reducing influence of the variable density pattern of the variable density layer.

[Claim 32] 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 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.

[Claim 33] A defect detection method, comprising using the defect detection device of any one of claims 1 to 30.

[Claim 34] A defect detection method, comprising:

setting in advance a determination criterion regarding whether

a product having a defect detected by the defect detection method of any one of claims 31 to 33 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.

[Claim 35] The defect detection method according to any one of claims 32 to 34, further comprising discriminating 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.

[Claim 36] A wafer, which is detected by the defect detection method of any one of claims 31 to 33 to have no defect, or which is detected by the defect detection method of any one of claims 31 to 33 to have a defect, and is determined by the defect detection method of claim 34 as a non-defective product.

[Claim 37] A semiconductor chip, which is detected by the defect detection method of any one of claims 31 to 33 to have no defect, or which is detected by the defect detection method of any one of claims 31 to 33 to have a defect, and is determined by the defect detection method of claim 34 as a non-defective product.

[Claim 38] A semiconductor device, comprising an individual piece, which is detected by the defect detection method of any one of claims 31 to 33 to have no defect, or which is detected by the defect detection method of any one of claims 31 to 33 to have a defect, and is determined by the defect detection method of claim 34 as a non-defective product.

[Claim 39] A die bonder, 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 subject the workpiece to bonding at the bonding position,

the die bonder comprising the defect detection device of any one of claims 1 to 30, which is arranged at any position from the pickup position to the bonding position.

[Claim 40] A die bonder, comprising an intermediate stage to which a workpiece is to be conveyed between a pickup position a bonding position,

wherein the defect detection device of any one of claims 1 to 30 is arranged at the intermediate stage.

[Claim 41] The die bonder according to claim 39 or 40, wherein the die bonder is configured to perform positioning detection at at least one of the pickup position, the bonding position, or an intermediate stage between the pickup position and the bonding position.

[Claim 42] A bonding method, comprising:

a bonding step of 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 of any one of claims 1 to 30 during at least any one of a period before the pickup or a period after the pickup.

[Claim 43] A bonding method, comprising:

a bonding step of 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 of any one of claims 1 to 30 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.

[Claim 44] A bonding method, comprising:

a bonding step of 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 of any one of claims 1 to 30 during at least any one of a period before the bonding or a period after the bonding.

[Claim 45] A bonding method, comprising:

a bonding step of 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 of any one of claims 31 to 35 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.

[Claim 46] A semiconductor manufacturing method, comprising an inspection step using the defect detection method of any one of claims 31 to 35, 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 47] 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 31 to 35.