DESCRIPTION

METHOD OF INSPECTING DEFECTS, AND METHOD OF MANUFACTURING MASK BLANK, TRANSFER MASK AND SEMICONDUCTOR DEVICE

TECHNICAL FIELD

[0001] The present invention relates to a method of inspecting defects and a method of manufacturing a mask blank, transfer mask and semiconductor device.

BACKGROUND ART

[0002] In general, the formation of a fine pattern is carried out in the manufacturing process of semiconductor devices such as LSI using photolithography. In addition, multiple transfer masks are normally used to form the fine pattern.

[0003] Transfer masks are manufactured by carrying out drawing with an electron beam and the like on a mask blank having one or multiple layers of a thin film for forming a pattern on a mask blank substrate followed by forming a desired fine pattern. Thus, if a defect comprised of indentations and/or protrusions is present on the main surface of a mask blank substrate or on the surface of a thin film for forming a pattern on a mask blank, a transfer mask having high exposure accuracy cannot be obtained. Therefore, when manufacturing a mask blank, inspections are carried out as to whether or not defects are present on the main surface of the mask blank substrate or on the surface of the thin film for forming a pattern.

[0004] Various types of defect inspection apparatuses have been proposed for use in this inspection. For example, defect inspection apparatuses using a phase-shift method are used that convert a light beam (inspection light) to two mutually interfering sub-beams with an interference optical system followed by irradiating the surface of the inspection target (such as a mask blank substrate or mask blank).

[0005] Patent Document 1 discloses a method of manufacturing a mask blank substrate and a method of manufacturing a mask blank that enables defect occurring in the mask blank manufacturing process to be detected easily and reliably. In the case a defect is present on the surface of the inspection target, a phase difference is generated between two sub-beams that is equivalent to the height of the defect. Namely, a phase difference equivalent to the height of the defect is contained in a combined beam if the light reflected from the surface of the inspection target is combined. Therefore, if the combined light is converted to an electrical signal by photoelectric conversion apparatus followed by processing this electrical signal, the inspection target can be inspected as to whether or not it has a defect of a size not less than a reference value.

[0006] Patent Document 2 discloses an invention relating to a visual inspection apparatus and visual inspection method that detect defects appearing on the outer surface of a sample, and more particularly, to a visual inspection apparatus and visual inspection method that detect defects in a pattern formed on the outer surface of a semiconductor wafer and a photomask substrate, a liquid crystal panel substrate, a liquid crystal device substrate and the like. A TDI camera or CCD camera is employed in the imaging unit of this visual inspection device, and defects appearing in a reflected optical image reflected from the outer surface of the sample and a transmitted optical image transmitted through the sample are respectively detected.

[0007] Patent Document 3 describes a defect inspection apparatus that is capable of switching between a confocal inspection mode, in which a sample surface is scanned with multiple (m) light beams focusing at a micro spot to detect defects present on the sample surface based on luminance information of the reflected light, and an interference inspection mode, in which a sample surface is scanned with two mutually interfering focused light beams followed by combining the light reflected from the sample surface to detect height information of the sample surface as phase information.

[Prior Art Document]

[Patent Document]

[0008] [Patent Document 1] JP 5214479 B

[Patent Document 2] JP 2007-294604 A

[Patent Document 3] JP 2001-27611 A

DISCLOSURE OF THE INVENTION

[Problems to be Solved by the Invention]

[0009] It is important to carry out defect inspections on the surface of mask blanks or mask blank substrates in order to obtain transfer masks for manufacturing semiconductor devices demonstrating superior performance. Furthermore, in the present description, mask blanks and mask blank substrates are collectively referred to as a mask blank and the like. FIG. 1 and FIG. 2 indicate schematic drawings of one example of a mask blank substrate. It is necessary to carry out a highly precise defect inspection on the region where the transfer pattern is formed (pattern formation region) of main surface 2 (one of the main surfaces 2a) of the surfaces of the mask blank and the like. For example, in the case the dimensions of a mask blank substrate are 152 mm × 152 mm, the size of the pattern formation region is normally 132 mm × 104 mm. A highly precise defect inspection is carried out on the region containing the pattern formation region, such as a region of a size measuring 142 mm × 142 mm. In the

present description, the region of a main surface subjected to this highly precise defect inspection is referred to as an inside region 12.

[0010] A defect inspection apparatus that uses a confocal illumination optical system, for example, is used for highly precise defect inspection to the inside region 12 containing the pattern formation region. More specifically, it is required to detect defects of a size on the order of several tens of nanometers in an overhead view in the inside region 12. In the present description, a defect inspection apparatus for carrying out a highly precise defect inspection to the inside region 12 is referred to as a high-precision defect inspection apparatus. The high-precision defect inspection apparatus is designed such that the depth of focus of the confocal illumination optical system is shallow since it is necessary to inspect defects at a high magnification factor. Thus, the working distance (WD) of this high-precision defect inspection apparatus is small on the order of about 0.2 mm to 0.3 mm. Working distance is the distance from the defect inspection apparatus to the inspected surface of the mask blank and the like, and more particularly, the distance from the leading edge of the defect inspection apparatus on the substrate side, including the object lens and illumination apparatus, to the inspected surface. In the present description, working distance may be abbreviated as "WD".

[0011] In the present description, the region outside the inside region 12 of one of the main surfaces 2a of the mask blank and the like is referred to as the peripheral region 14. Chamfered surfaces 1b are normally present in the vicinity of an edge face 1 of the main surfaces 2 of the mask blank and the like for carrying out chamfering processing. Thus, surface profile changes rapidly in the vicinity of the edge face 1 of the peripheral region 14 of the mask blank and the like. Measurement with a high-precision defect inspection apparatus is not possible at such portions where the surface profile changes rapidly. The reason for this is that the WD of the high-precision defect inspection apparatus is excessively short. Namely, in order to make it possible to inspect defects with high precision, the high-precision defect inspection apparatus controls WD so that WD has a prescribed small range. In addition, the high-precision defect inspection apparatus measures defects while an object lens and the like reciprocates at a high speed on the order of several tens of millimeters per second. In the case the surface profile of the mask blank and the like changes rapidly, control of WD by the high-precision defect inspection apparatus is unable to keep up with the change in surface profile, and depending on the case, the object lens and the like of the high-precision defect inspection apparatus collides with a surface such as the edge face 1 that includes the chamfered surfaces 1b of the mask blank and the like as well as a jig and the like for holding the mask blank and the like, thereby resulting in the risk of damaging the

high-precision defect inspection apparatus and the mask blank and the like. In addition, since the defect inspection is carried out at a high magnification factor, the physical size of the object lens increases considerably in comparison with the size of the imaging area of the object lens of the high-precision defect inspection apparatus. Consequently, in the case the surface profile of the mask blank and the like changes rapidly, even if control of WD by the high-precision defect inspection apparatus is able to keep up with that change, there is the risk of a portion of the object lens colliding with the mask blank and the like. Thus, it becomes difficult to measure defects in the peripheral region 14, including the vicinity of the edge face 1, with a high-precision defect inspection apparatus. Consequently, defect inspections of the peripheral region 14 are normally carried out visually.

[0012] Although a transfer pattern is not formed in the peripheral region 14, product numbers and positioning marks of a transfer mask may be formed using lithographic techniques in the same manner as during formation of a transfer pattern. Thus, although highly precise defect inspections in the manner of the inside region 12 are not required for the peripheral region 14, it is necessary to inspect the peripheral region 14 for detects with a certain degree of precision. More specifically, in the peripheral region 14, it is necessary to detect defects having dimensions of about 1 μm to 2 μm. In the case of visual inspections, even if it is possible to evaluate for the presence or absence of large defects, it is difficult to specify the presence or absence of defects of a size that cannot be confirmed visually as well as coordinates where defects are present. Visual inspections have the problems of defects being overlooked and the occurrence of erroneous selection.

[0013] In order to solve the aforementioned problems, an object of the present invention is to provide a method of inspecting defects, which together with being able to carry out highly precise defect inspections on an inside region, is able to automatically and accurately carry out defect inspections of a peripheral region without damaging a mask blank, mask blank substrate or defect inspection apparatus.

[0014] In addition, an object of the present invention is to provide a method of manufacturing a mask blank and transfer mask using the defect inspection method. More specifically, an object of the present invention is to provide a suitable mask blank and transfer mask having few defects that cause problems by not only being able to acquire highly precise defect information for an inside region, but also automatically and accurately carrying out defect inspections on a peripheral region, without damaging a mask blank, mask blank substrate or defect inspection apparatus.

[0015] In addition, an object of the present invention is to provide a method of manufacturing a semiconductor device having a fine and highly precise transfer pattern.

[Means for Solving the Problems]

[0016] The present invention has the following configurations in order to solve the aforementioned problems.

[0017] (Configuration 1)

Configuration 1 of the present invention is a method of inspecting defects in a mask blank or a mask blank substrate, wherein

the mask blank or the mask blank substrate has two opposing main surfaces and a side surface perpendicular to the two opposing main surfaces,

one of the main surfaces has an inside region and a peripheral region,

the boundary between the inside region and the peripheral region is located at a distance d from a plane containing the side surface,

the distance d is such that $d \geq 1$ mm, and

the method of inspecting defects includes:

carrying out a defect inspection to the inside region by an optical measurement method in which a working distance (WD) is such that $WD \leq 0.5$ mm, and

carrying out a defect inspection to the peripheral region by an optical measurement method in which the working distance (WD) is such that $WD > 0.5$ mm.

[0018] According to Configuration 1 of the present invention, a method of inspecting defects can be obtained, which together with being able to carry out highly precise defect inspections on an inside region, is also capable of automatically and accurately carrying out defect inspections on a peripheral region, without damaging a mask blank, mask blank substrate or defect inspection apparatus.

[0019] (Configuration 2)

Configuration 2 of the present invention is the method of inspecting defects of Configuration 1, wherein the defect inspection to the peripheral region is carried out by an optical measurement method that uses a dark field optical system.

[0020] According to Configuration 2 of the present invention, defects can be detected with relatively high precision even if a defect inspection is carried out on a peripheral region at a relatively low magnification factor by using a dark field optical system to inspect defects in the peripheral region. Thus, defect inspections of the peripheral region can be carried out at a relatively long working distance.

[0021] (Configuration 3)

Configuration 3 of the present invention is the method of inspecting defects of Configuration 1 or Configuration 2, wherein the optical measurement method for the defect inspection to the inside region uses a bright field optical system.

[0022] According to Configuration 3 of the present invention, highly precise defect

inspections can be carried out on a pattern formation region by using a bright field optical system to inspect defects in the inside region.

[0023] (Configuration 4)

Configuration 4 of the present invention is the method of inspecting defects of any of Configurations 1 to 3, wherein the defect inspection to the inside region inspects the inside region with an optical system having an optical magnification factor of not less than 10X.

[0024] According to Configuration 4 of the present invention, highly precise defect inspections can be carried out on a pattern formation region by using a prescribed optical magnification factor in order to inspect defects in the pattern formation region.

[0025] (Configuration 5)

Configuration 5 of the present invention is the method of inspecting defects of any of Configurations 1 to 4, wherein the defect inspection to the peripheral region inspects the peripheral region with an optical system having an optical magnification factor of not more than 5X.

[0026] According to Configuration 5, defect inspections can be carried out on a peripheral region at a comparatively long working distance by using a prescribed low optical magnification factor in order to inspect defects in the peripheral region.

[0027] (Configuration 6)

Configuration 6 of the present invention is the method of inspecting defects of any of Configurations 1 to 5, wherein the mask blank or the mask blank substrate further has a chamfered surface between the main surface and the side surface, and a height difference h between a ridgeline of the side surface and the chamfered surface and a ridgeline of the main surface and a chamfered surface in a direction perpendicular to the main surfaces is such that $h \leq 0.5$ mm.

[0028] According to Configuration 6 of the present invention, even in the case a mask blank or a mask blank substrate has a chamfered surface of a prescribed shape, together with highly precise defect inspections being able to be carried out on the inside region, defect inspections can be carried out automatically on the peripheral region without damaging the mask blank, the mask blank substrate or the defect inspection apparatus.

[0029] (Configuration 7)

Configuration 7 of the present invention is the method of inspecting defects of any of Configurations 1 to 6, wherein the method of inspecting defects further includes carrying out a defect inspection to at least one of the side surface and the other main surface by an optical measurement method in which the working distance (WD) is such that $WD > 0.5$ mm.

[0030] According to Configuration 7 of the present invention, defect inspections can

be carried out on the side surface and/or the other main surface by a measurement method that is the same as the optical measurement method for inspecting defects in a peripheral region.

[0031] (Configuration 8)

Configuration 8 of the present invention is the method of inspecting defects of any of Configurations 1 to 7, wherein carrying out the defect inspection by an optical measurement method in which the working distance (WD) is such that WD > 0.5 mm is a final inspection.

[0032] There are cases in which unexpected adhesion of contaminant particles may occur resulting in defects in a process present prior to the final inspection after a highly precise defect inspection. According to Configuration 8 of the present invention, as a result of carrying out a defect inspection by an optical measurement method in which the working distance is comparatively long, the entire main surfaces, including the inside region and peripheral region, of a mask blank or a mask blank substrate can be inspected for defects by a single final inspection.

[0033] Configuration 9 of the present invention is a method of manufacturing a mask blank, including:

preparing a mask blank substrate having two opposing main surfaces and a side surface perpendicular to the two opposing main surfaces,

forming a thin film for forming a pattern on one of the main surfaces of the mask blank substrate, and

carrying out a defect inspection to a surface of the substrate with the thin film having the thin film formed thereon and selecting a mask blank from the substrate with the thin film using the results of the defect inspection; wherein,

one of the main surfaces of the substrate with the thin film has an inside region and a peripheral region,

the boundary between the inside region and the peripheral region is located at a distance d from a plane containing the side surface,

the distance d is such that $d \geq 1$ mm, and

carrying out a defect inspection to the surface of the substrate with the thin film includes:

carrying out a defect inspection to the inside region by an optical measurement method in which working distance (WD) is such that WD ≤ 0.5 mm, and

carrying out a defect inspection to the peripheral region by an optical measurement method in which working distance (WD) is such that WD > 0.5 mm.

[0034] According to Configuration 9 of the present invention, a prescribed defect inspection can be carried out when manufacturing a mask blank. Consequently,

together with being able to acquire highly precise defect information for the inside region, since defect information of the peripheral region can be acquired automatically and accurately, without damaging the mask blank or defect inspection apparatus, a suitable mask blank having few defects that cause problems can be selected and obtained.

[0035] (Configuration 10)

Configuration 10 of the present invention is the method of manufacturing a mask blank of Configuration 9, wherein the defect inspection to the peripheral region is carried out by an optical measurement method that uses a dark field optical system.

[0036] According to Configuration 10 of the present invention, even if a defect inspection is carried out on the peripheral region at a relatively low magnification factor, detects can be detected with comparatively high sensitivity by using as a dark field optical system in order to inspect the peripheral region for defects. Thus, defect inspections of the peripheral region can be carried out at a comparatively long working distance.

[0037] (Configuration 11)

Configuration 11 of the present invention is the method of manufacturing a mask blank of Configuration 9 or 10, wherein the defect inspection to the inside region is carried out by an optical measurement method that uses a bright field optical system.

[0038] According to Configuration 11 of the present invention, a highly precise defect inspection can be carried out on a pattern formation region by using a bright field optical system in order to inspect the inside region for defects.

[0039] (Configuration 12)

Configuration 12 of the present invention is the method of manufacturing a mask blank of any of Configurations 9 to 11, wherein the defect inspection to the inside region inspects the inside region with an optical system having an optical magnification factor of not less than 10X.

[0040] According to Configuration 12 of the present invention, a highly precise defect inspection can be reliably carried out on a pattern formation region by using a prescribed magnification factor in order to inspect the inside region for defects.

[0041] (Configuration 13)

Configuration 13 of the present invention is the method of manufacturing a mask blank of any of Configurations 9 to 12, wherein the defect inspection to the peripheral region inspects the peripheral region with an optical measurement system having a magnification factor of not more than 5X.

[0042] According to Configuration 13 of the present invention, a defect inspection to the peripheral region can be carried out at a comparatively long working distance by

using a prescribed low optical magnification factor in order to inspect the peripheral region for defects.

[0043] (Configuration 14)

Configuration 14 of the present invention is the method of manufacturing a mask blank of any of Configurations 9 to 13, wherein the mask blank or the mask blank substrate further has a chamfered surface between the main surface and the side surface, and a height difference h between a ridgeline of the side surface and the chamfered surface and a ridgeline of the main surface and the chamfered surface in a direction perpendicular to the main surfaces is such that $h \leq 0.5$ mm.

[0044] According to Configuration 14 of the present invention, even in the case the mask blank or the mask blank substrate has chamfered surfaces of a prescribed shape, together with being able to carry out highly precise defect inspections on the inside region, defect inspections can be carried out automatically on the peripheral region without damaging the mask blank, the mask blank substrate or the defect inspection apparatus.

[0045] (Configuration 15)

Configuration 15 of the present invention is the method of manufacturing a mask blank of any of Configurations 9 to 14, wherein the method of manufacturing mask blank further includes carrying out a defect inspection to at least one of the side surface and the other main surface by an optical measurement method in which the working distance (WD) is such that $WD > 0.5$ mm.

[0046] According to Configuration 15 of the present invention, defect inspections can be carried out on the side surface and/or the other main surface by a measurement method that is the same as the optical measurement method for inspecting defects in a peripheral region.

[0047] (Configuration 16)

Configuration 16 of the present invention is the method of manufacturing a mask blank of any of Configurations 9 to 15, wherein carrying out the defect inspection by the optical measurement method in which the working distance (WD) is such that $WD > 0.5$ mm is a final inspection.

[0048] According to Configuration 16 of the present invention, as a result of carrying out a defect inspection by an optical measurement method in which the working distance is comparatively long, the entire main surfaces, including the inside region and peripheral region, of a mask blank or a mask blank substrate can be inspected for defects by a single final inspection.

[0049] (Configuration 17)

Configuration 17 of the present invention is a method of manufacturing a

transfer mask in which a transfer pattern is formed on the thin film of a mask blank using the mask blank that has been manufactured by the method of manufacturing a mask blank of any of Configurations 9 to 16.

[0050] According to Configuration 17 of the present invention, a suitable transfer mask having few defects can be provided since a suitable mask blank can be used that has few defects that cause problems.

[0051] (Configuration 18)

Configuration 18 of the present invention is a method of manufacturing a semiconductor device in which the transfer pattern is exposed and transferred to a resist film on a semiconductor substrate using the transfer mask manufactured by the method of manufacturing a transfer mask of Configuration 17.

[0052] According to Configuration 18 of the present invention, a semiconductor device can be manufactured that has a fine and highly precise transfer pattern.

[Effects of the Invention]

[0053] According to the present invention, a method of inspecting defects can be provided, which together with being able to carry out a highly precise defect inspection on an inside region, is capable of automatically and accurately carrying out a defect inspection to a peripheral region without damaging a mask blank, a mask blank substrate or a defect inspection apparatus.

[0054] In addition, according to the present invention, a method of manufacturing a mask blank and a method of manufacturing a transfer mask can be provided that use the defect inspection method. More specifically, according to the present invention, together with being able to acquire highly precise defect information for an inside region, since a defect inspection to a peripheral region can be carried out automatically and accurately without damaging a mask blank, a mask blank substrate or a defect inspection apparatus, a suitable mask blank and transfer mask can be provided that have few defects that cause problems.

[0055] In addition, according to the present invention, a method of manufacturing a semiconductor device that has a fine and highly precise transfer pattern can be provided.

BRIEF DESCRIPTION OF THE DRAWINGS

[0056] FIG. 1 is a cross-section schematic diagram showing one example of the vicinity of a side surface of a mask blank substrate for explaining the method of inspecting defects of the present invention.

FIG. 2 is an overhead schematic diagram of one example of a mask blank substrate for explaining the method of inspecting defects of the present invention.

FIG. 3(a) is a perspective view showing a mask blank substrate of one embodiment of the present invention. FIG. 3(b) is a cross-sectional schematic diagram showing the mask blank substrate of the present embodiment.

FIG. 4 is a schematic diagram for explaining the major components of one example of a defect inspection apparatus that uses a dark field optical system.

FIG. 5 is a schematic diagram for explaining an illumination ring used in the defect inspection apparatus shown in FIG. 4.

FIG. 6 is a cross-sectional schematic diagram for explaining a housing of the illumination ring shown in FIG. 5.

FIG. 7 is a cross-sectional schematic diagram showing one example of the mask blank of the present invention.

FIG. 8 is a cross-sectional schematic diagram showing one example of the transfer mask of the present invention.

MEANS FOR CARRYING OUT THE INVENTION

[0057] The following provides a detailed explanation of embodiments of the present invention with reference to the drawings. Furthermore, the following embodiments are forms used when embodying the present invention and do not limit the present invention to the scope thereof.

[0058] [Mask Blank Substrate 10]

An explanation is first provided of a mask blank substrate 10 that can be used in the method of inspecting defects of the present embodiment.

[0059] (Shape of Mask Blank Substrate 10)

FIG. 3(a) is a perspective view showing one example of the mask blank substrate 10 that can be used in the method of inspecting defects of the present embodiment. FIG. 3(b) is a cross-section schematic diagram of the mask blank substrate 10 shown in FIG. 3(a).

[0060] The mask blank substrate 10 able to be used in the present embodiment (which may also be simply referred to as the "substrate 10") is a rectangular plate-like body and has two opposing main surfaces 2 and an edge face 1. The two opposing main surfaces 2 constitute an upper surface and a lower surface of this plate-like body, and are formed so as to be mutually opposing. In addition, at least one of the two opposing main surfaces 2 is a main surface 2 on which a transfer pattern is to be formed.

[0061] The edge face 1 is adjacent to the outer edges of the opposing main surfaces 2. The edge face 1 has a flat edge face portion 1d and a curved edge face portion 1f. The flat edge face portion 1d is a surface that connects a side of one of the opposing main surfaces 2 and a side of the other opposing main surface 2, and includes a side surface

1a and a chamfered surface 1b. The side surface 1a is a portion (T surface) that is nearly perpendicular to the opposing main surfaces 2 in the flat edge face portion 1. The chamfered surface 1b is a portion (C surface) that is chamfered between the lateral surface portion 1a and the opposing main surfaces 2, and is formed between the side surface 1a and the opposing main surfaces 2.

[0062] The curved edge face portion 1f is a portion (R portion) that is adjacent to the vicinity of a corner portion 10a of the substrate 10 when the substrate 10 is viewed from overhead, and includes a side surface 1c and a chamfered surface 1e. Here, when the substrate 10 is viewed from overhead, the substrate 10 appears in, for example, a direction perpendicular to the opposing main surfaces 2. In addition, the corner portion 10a of the substrate 10 refers to, for example, the vicinity of the intersection of two sides along the outer edge of the opposing main surfaces 2. An intersection of two sides may be the intersection of lines respectively extending from two sides. In the present example, the curved edge face portion 1f is formed into a curved shape by rounding the corner portion 10a of the substrate 10.

[0063] The following further provides an explanation of the mask blank substrate 10 that is able to be used in the method of inspecting defects of the present embodiment. As shown in FIGS. 1 and 2, the substrate 10 has two opposing main surfaces 2 (of which one is a main surface 2a (or a front side main surface 2a) and the other is a main surface 2b (or a back side main surface 2b)). One of the main surfaces 2a is a surface for forming a transfer pattern and is also referred to as the front side surface. The other main surface 2b is a surface on the opposite side from the surface for forming a transfer pattern and is also referred to as the back side surface. One of the main surfaces 2a has an inside region 12 and a peripheral region 14. The inside region 12 contains a pattern formation region which is the region where the transfer pattern is formed. The peripheral region 14 is a region outside the inside region 12 of one of the main surfaces 2a.

[0064] As shown in FIGS. 1 and 2, the substrate 10 has the side surface 1a perpendicular to the two opposing main surfaces 2. In addition, as shown in FIGS. 1 and 2, the boundary between the inside region 12 and the peripheral region 14 is located at a distance d from a plane 18 containing the side surface 1a.

[0065] As shown in FIG. 1, the substrate 10 can have the chamfered surface 1b between the main surface 2 and the side surface 1a. As shown in FIG. 1, a height difference between a ridgeline 16a of the side surface 1a and the chamfered surface 1b and a ridgeline 16b of the main surfaces 2a,2b and a chamfered surface in a direction perpendicular to the main surfaces 2 is indicated with the symbol h in the present description.

[0066] In the present description, when referring to the upward and downward directions of the mask blank substrate 10, one of the main surfaces 2a (a front side surface) is facing in the upward direction while the other main surface 2b (a back side surface) is facing in the downward direction.

[0067] Furthermore, the explanation of the aforementioned mask substrate 10 is the same as that of a mask blank 30 to be subsequently described. Namely, the mask blank 30 able to be used in the present embodiment also has the two opposing main surfaces 2, the side surface 1a, the inside region 12, the peripheral region 14 and the prescribed distance d in the same manner as the mask blank substrate 10. In addition, the mask blank 30 can have the chamfered surface 1b and the prescribed height difference h.

[0068] The following provides a more detailed explanation of the mask blank substrate 10 of the embodiments of the present invention.

[0069] (Material of Mask Blank Substrate 10)

Synthetic quartz glass and various other types of glass materials (such as soda lime glass or aluminosilicate glass) can be used for the material used to manufacture the mask blank substrate 10. Among these, since synthetic quartz glass has the highest transmittance with respect to ultraviolet light having a short wavelength in the manner of an ArF excimer laser (wavelength: 193 nm), it is preferable as a binary mask blank substrate or a phase shift mask blank substrate used to form a high-definition transfer pattern.

[0070] In addition, low thermal expansion glass used in reflective masks using extreme ultraviolet (EUV) light for the exposure light can be used for the substrate used to manufacture the mask blank substrate 10. Examples of low thermal expansion glass that can be used in reflective masks include so-called multi-component-based glass such as SiO_2-TiO_2-based glass (such as a binary system (SiO_2-TiO_2) or tertiary system (such as SiO_2-TiO_2-SnO_2)) and SiO_2-Al_2O_3-LiO_2-based crystallized glass.

[0071] (Polishing Step and Pre-cleaning Step)

In the manufacturing process of the mask blank substrate 10, a pre-cleaning step is carried out for removing particles present on the main surfaces 2 (such as abrasive particles and other foreign matter adhered to the surface of the substrate) after the substrate polishing step. The mask blank substrate 10 at the stage prior to the defect inspection step is manufactured by going through these steps.

[0072] (Defect Inspection)

A defect inspection step for inspecting defects such as the adhesion of foreign matter to the surface of the mask blank substrate 10 can be included after the pre-cleaning step. The method of inspecting defects of the present invention can be

used for this defect inspection step. The following provides an explanation of the case of applying the method of inspecting defects of embodiments of the present invention to inspection of the mask blank substrate 10. As will be subsequently described, the method of inspecting defects of the embodiments of the present invention can also be applied for defect inspections of the mask blank 30.

[0073] In the method of inspecting defects of the present embodiment, a defect inspection to the inside region 12 of the substrate 10 is carried out by an optical measurement method in which the working distance (WD) is such that WD $\leq$ 0.5 mm, and a defect inspection to the peripheral region 14 of the substrate 10 is carried out by optical measurement method in which the working distance (WD) is such that WD > 0.5 mm. Furthermore, the boundary between the inside region 12 and the peripheral region 14 is located at a distance d from the plane 18 containing the side surface 1a. The distance d is such that d $\geq$ 1 mm, preferably such that d $\geq$ 2 mm and more preferably such that d $\geq$ 4 mm. In addition, in the case dimensions of the substrate 10 are 152 mm $\times$ 152 mm, the distance d is preferably such that d $\leq$ 10 mm, more preferably such that d $\leq$ 8 mm and even more preferably such that d $\leq$ 6 mm. More specifically, in the case dimensions of the substrate 10 are 152 mm $\times$ 152 mm, the size of the inside region 12 can be 142 mm $\times$ 142 mm. The shape of the inside region 12 and the peripheral region 14 is preferably that of a rectangle having the center of gravity thereof at the same location.

[0074] There are no particular limitations on the optical measurement method for inspecting defects of the inside region 12 provided the working distance (WD) is of a prescribed value. More specifically, an example of the optical measurement method for inspecting defects of the inside region 12 is an optical measurement method that uses a bright field optical system (such as a measurement method employing a differential interference optical system or confocal optical system). In addition, an optical measurement system using a dark field optical system can be used for inspecting defects of the inside region 12, if it is possible to detect defects with a prescribed degree of precision.

[0075] In the case of a typical defect inspection apparatus, a step for scanning in a first direction of the main surfaces 2 of the inspection target (substrate 10) is repeated towards a second direction orthogonal to the first direction, and the presence or absence of defects of a size not less than a reference value is inspected based on an electrical signal obtained from the first scan in the first direction. In a defect inspection to a pattern formation region of a mask blank substrate and a mask blank, the presence or absence of defects of a size on the nanometer order (less than 1 μm) is typically required in that pattern formation region. This is because, when manufacturing a

transfer mask 40 from the mask blank 30, if defects are present in the pattern formation region of the main surfaces 2, even if the size thereof is on the nanometer order, these defects have an effect on the precision of the transfer pattern.

[0076] In the case of a defect inspection apparatus that satisfies such requirements, it is difficult to scan the vicinity of the peripheral edges of the main surfaces of a mask blank substrate and a mask blank. Therefore, in the case the dimensions of the substrate 10 are 152 mm × 152 mm, there are many cases in which a region on the substrate 10 within 142 mm × 142 mm is scanned. This is because, in order to detect defects of a size of the nanometer order, it is necessary to considerably narrow the imaging area, which inevitably shortens the working distance (WD). Namely, in the case of a defect inspection apparatus as described above, the working distance (WD) is such that WD ≤ 0.5 mm. In the case of this defect inspection apparatus, the working distance (WD) is preferably such that WD ≤ 0.4 mm and more preferably such that WD is ≤ 0.3 mm.

[0077] On the other hand, in a defect inspection to a region outside the pattern formation region on the main surfaces of a mask blank substrate and a mask blank, it is typically considered to be satisfactory to be able to detect the presence or absence of defects of size on the micrometer order (not less than 1 μm) within that region. A defect inspection apparatus used in this case enables the working distance (WD) to be lengthened since the required level of detectable defect size is relatively lenient. The imaging area becomes broader and depth of focus also increases as a result of lengthening the working distance (WD). In the case of this defect inspection apparatus, although the size of defects able to be detected is on the micrometer order, a wider image formation area of the main surface 2 can be obtained in a wide range of the broad imaging area. Consequently, even if the working distance of the defect inspection apparatus between the object lens and the main surface 2 in the vicinity of the peripheral edges of the main surface 2 is controlled to keep up with rapid changes in the surface profile of a mask blank substrate 10 and a mask blank 30, there is no risk of the object lens colliding with the mask blank 30 and the like. Furthermore, the working distance (WD) of such a defect inspection apparatus is such that WD > 0.5 mm. In the case of this defect inspection apparatus, the working distance (WD) is preferably such that WD ≥ 1 mm and more preferably such that WD is ≥ 5 mm.

[0078] Therefore, in the method of inspecting defects of the present invention, by combining a defect inspection method in which the aforementioned WD for the inside region 12 that includes a pattern formation region is such that WD ≤ 0.5 mm and a defect inspection method in which WD for the peripheral region 14 is such that WD > 0.5 mm, a defect inspection can be carried out on a region near the edge face of the

substrate 10 (peripheral region 14) while maintaining a defect inspection to the area requiring a strict defect guarantee (inside region 12), and the entirety of one of the main surfaces 2a of the substrate 10 can be guaranteed by guaranteeing with respect to defects in both regions.

[0079] Namely, by carrying out a defect inspection by an optical measurement method in which the boundary between the inside region 12 and the peripheral region 14 is at a prescribed distance d and the inside region 12 and the peripheral region 14 each have different working distances (WD), together with being able to carry out a highly precise defect inspection on the inside region 12, a defect inspection to the peripheral region 14 can be carried out automatically and accurately without damaging the mask blank 30, the mask blank substrate 10 or the defect inspection apparatus.

[0080] In the method of inspecting defects of the present embodiment, a defect inspection to the peripheral region 14 is preferably carried out by an optical measurement method that uses a dark field optical system.

[0081] An optical measurement method that uses a dark field optical system refers to a measurement system in which an observation target is illuminated while inclining the target so that reflected light does not enter the object lens from the normal portion of the sample followed by observing light scattered by the sample. In the case of capturing an image of a defect with a bright field optical system, relatively small-sized defects are difficult to detect with background light since the defect appears dark on a bright background in the captured image. In contrast, in the case of capturing an image of a defect with a dark field optical system, even defects of a relatively small size are detected easily since captured images are such that defects appear bright on a dark background. Consequently, by using a dark field optical system for inspecting defects in the peripheral region 14, a defect inspection can be carried out on the peripheral region 14 at a relatively low magnification factor (such as about 0.7X to 1.0X). Thus, a defect inspection to the peripheral region 14 can be carried out at a relatively long working distance. Furthermore, in the case of using a dark field optical system, it is difficult to determine concavity and convexity of defects. However, the presence or absence of foreign matter and the like as well as the coordinates thereof can be determined automatically and accurately with a defect inspection apparatus that uses a dark field optical system.

[0082] In the method of inspecting defects of the present embodiment, a defect inspection to the peripheral region 14 is preferably carried out with an optical system having an optical magnification factor of not more than 5X. In order to inspect the peripheral region 14 for defects, a defect inspection to the peripheral region 14 can be carried out by using a prescribed low optical magnification factor at a relatively long

working distance and at a relatively deep depth of focus.

[0083] The mask blank substrate 10 can contain chamfered surfaces 1b having a height difference h. Since excessively large chamfered surfaces 1b may cause difficulties, the height difference h is preferably such that $h \leq 0.5$ mm. Even in the case the mask blank substrate 10 has chamfered surfaces 1b of a prescribed shape, together with being able to carry out a defect inspection on the inside region 12, a defect inspection to the peripheral region 14 can be carried out automatically and accurately without damaging the mask blank 30, mask blank substrate 10 or defect inspection apparatus. On the other hand, height difference h is preferably such that $h \geq 0.3$ mm.

[0084] Next, an explanation is provided of one example of a defect inspection apparatus using a dark field optical system that can be used in a defect inspection to the peripheral region 14.

[0085] FIG. 4 is a schematic diagram for explaining the major components of a defect inspection apparatus able to be used in the present embodiment. In FIG. 4, the direction perpendicular to the page represents the X axis, the direction extending in the vertical direction on the page represents the Y axis, and the direction extending in the horizontal direction on the page represents the Z axis.

[0086] An imaging optical system 100 is disposed on the surface side (right side in the drawing) of the substrate 10. The imaging optical system 100 is composed to be able to be driven in the directions of the X, Y and Z axes by an XYZ driving means (not shown). The imaging optical system 100 has an imaging camera 110 (such as a TDI camera) provided with an object lens 111, an imaging lens 112 and an imaging element 113, an autofocus module (coaxial AF module) 120 disposed between the object lens 111 and the imaging lens 112, and an illumination means 131. The illumination means 131 is attached to the object lens 111.

[0087] As shown in FIGS. 5 and 6, the illumination means 13 is an illumination ring. The illumination ring has multiple LEDS 136 and 137 mounted on an annular member with adjusting the directivity and optical axes of the multiple LEDs 136 and 137, so that the multiple LEDs 136 and 137 are disposed in the shape of rings, and each spotlight generated by the multiple LEDS 136 and 137 focuses on a region having the focal position of the imaging camera 110 at the center thereof. The illumination ring, which is the illumination means 131, is made to be coaxial by aligning the central axis of the rings in the aforementioned illumination ring with the optical axis O of the aforementioned imaging optical system 100.

[0088] The illumination ring, which is the illumination means 131, has a configuration in which three sets (rows) of LEDs are arranged in the form of rings along each of three concentric circles (see FIG. 5). Blue LEDs are used in the outside and inside rows of

LED rings and yellow LEDs or orange LEDs are used in the middle row of LED rings.

[0089] Furthermore, the working distance d (working distance: WD) of the illumination ring, which is the illumination means 131, can be adjusted corresponding to the thickness of the inspection target. The working distance is the distance at which the ring illumination is installed with respect to the surface of the inspection target, and more specifically, is the distance from the leading edge of the ring illumination on the side of the substrate 10 to the surface of the substrate 10. In an inspection to the substrate 10, optical defects such as scratches, foreign matter, foreign matter within the glass and striae are detected. In an inspection of the mask blank 30 (a substrate 10 with a thin film 32), pinholes, half pinholes, foreign matter and the like are detected.

[0090] A light shielding mask 140 is inserted in the optical system as a countermeasure against stray light. The light shielding mask 140 cuts out light that does not contribute to defect imaging (stray light). The light shielding mask 140 is installed at a suitable size at a location suitable for demonstrating countermeasures against stray light while changing size. The light shielding mask 140 may use a douser or an aperture.

[0091] In the present embodiment, typical examples of the imaging element 113 include a solid-state imaging apparatus such as a CCD, TDI, CMOS or VMIS (Voltage Modulation Image Sensor). The stand 200 is a vibration isolation table.

[0092] A housing 134 of the illumination means 131 (illumination ring) is designed to have an inner diameter R1, an outer diameter R2, a thickness t and the like (see FIG. 6). These values are determined from the viewpoint of improving defect detection ability. The housing 134 of the illumination ring is of an annular shape and inclined portions 135 are formed on the inner periphery of the rings for attaching the LEDs 136 and 137. The housing dimension R3 (thickness of the body portion) is designed in consideration of strength (see FIG. 6).

[0093] A first mechanical requirement (dimensional limitation) is the working distance d (working distance: WD) of the illumination ring, this is the distance at which the illumination ring is installed with respect to the surface of the substrate 10, and more particularly, is the distance from the leading edge of the illumination ring on the side of the substrate 10 to the surface of the substrate 10. Although working distance d is such that $d > 0.5$ mm, the working distance of the illumination ring is preferably such that $d \geq 5$ mm and more preferably such that $d \geq 15$ mm in order to adequately ensure clearance with the substrate holder.

[0094] The dark field requirement (optical requirement) is the illumination angle α of the illumination ring. The illumination angle α of the illumination ring is the angle formed by a light beam and the surface of the substrate 10 when a light beam of the

LEDs 136 and 137 enter the substrate 10. In the case of dark field illumination, illumination light is prevented from entering the object lens 111.

[0095] An illumination design that includes an imaging lens system is required to realize dark field illumination. Since a high numerical aperture (NA) lens is used in the imaging lens 112, illumination at an acute angle to the surface of the substrate 10 is required. Consequently, it is necessary to increase the ring outer diameter in order to secure working distance. The upper limit of the illumination angle α is determined by the magnification factor and NA of the object lens 111 in the imaging optical system 100. For example, when the magnification factor of the object lens 111 is 1X and NA is 0.5, the upper limit of the illumination angle α becomes 50°. In addition, the upper limit of the illumination angle α is preferably not more than 30° from the viewpoint of setting the illumination angle to a safer angle in order to reduce stray light.

[0096] In the present defect inspection apparatus, the imaging element 113 preferably uses a TDI sensor and the aforementioned imaging optical system 100 preferably uses a TDI camera.

[0097] The present defect inspection apparatus preferably has a means for relatively moving the substrate 10 and TDI camera in a given direction and at a constant speed, and a means for repeatedly exposing and imaging an imaging region (imaging target) for a number of times equal to the number of vertical stages of the CCDs by aligning the direction of movement and speed of the imaging region (imaging target) on the substrate 10 with the direction and speed of the charge transfer of the CCDs in the TDI sensor. Here, as a result of aligning the direction of movement and speed of the imaging region on the substrate 10 with the direction and speed of the charge transfer of the CCDs in the TDI sensor, the means for repeatedly exposing and imaging the imaging region for a number of times equal to the number of vertical stages of the CCDs is able to carry this out with, for example, a control device (such as a control circuit, CPU or software) incorporated within the TDI camera.

[0098] Ordinary line sensors have CCDs arranged in a row. In a time delay integration (TDI) sensor (element), the CCDs arranged in a row (single row) on the line are also arranged in plurality in the direction perpendicular to the direction along the aforementioned line. Images having high sensitivity can be obtained by integrally exposing images obtained with the multiple rows of CCDs.

[0099] If the imaging target moves at a constant speed and in a given direction, the target (same region on the target corresponding to one row of CCDs) is repeatedly exposed and imaged by aligning the direction of movement and speed of the imaging target with the direction and speed of charge transfer of the CCDs.

[0100] In the method of inspecting defects of the present embodiment, a defect

inspection to the inside region 12 is preferably carried out by an optical measurement method that uses a bright field optical system.

[0101] An optical measurement method that uses a bright field optical system refers to an optical measurement method in which light reflected from an illuminated sample is enlarged directly with an object lens to observe the sample, and samples can be observed using differences in reflectance in contrast to optical measurement methods using a dark field optical system. By using a bright field optical system to inspect the inside region 12 for defects, a highly precise defect inspection can be carried out on a pattern formation region.

[0102] An example of a defect inspection method of an optical measurement system using a bright field optical system is a defect inspection method that uses an optical system having a differential interference prism (Nomarski prism) as described in Patent Document 1 (JP 5214479 B). In addition, an example of a defect inspection method of an optical measurement system using a bright field optical system is a defect inspection method that uses a confocal inspection mode (confocal optical system) as described in Patent Document 3 (JP 2001-27611 A). Furthermore, Patent Document 3 also describes a defect inspection method that uses an interference inspection mode, which is a kind of bright field optical system.

[0103] Since a confocal optical system has high resolution with respect to the direction of height of a sample, in the case the focal point of the object lens is at a sample surface, a large amount of light enters the light receiving element. In addition, in the case the focal point has shifted from the sample surface, the amount of light entering the light receiving element decreases considerably. Thus, by scanning with a beam while changing the relative distance between the focal point of the object lens and the sample surface and determining the relationship between the relative amount of displacement of the object lens focal point and sample surface and brightness, which is the output of the light receiving element, defect height information can be obtained. Or in other words, it can be discriminated as to whether the defect is convex or concave. Similarly, the size of a defect can be measured with a defect inspection apparatus that uses a confocal optical system.

[0104] More specifically, in the case of a defect inspection that uses a confocal optical system, the sample stage is moved and a detected defect is positioned at the position where it is scanned with a beam using the address of the detected defect. Next, the defect is scanned with the beam multiple times while changing the relative distance between the focal point of the object lens and the sample surface. At this time, the relative displacement between the focal point and sample can be controlled by moving the object lens along the direction of the optical axis. In addition, the relative

displacement can also be controlled by moving the sample stage in the direction of the optical axis. As a result of measuring in this manner, minute defects of a size on order of several tens of nanometers can be accurately detected.

[0105] In the method of inspecting defects of the present embodiment, inspection of defects in the inside region 12 is preferably carried out with an optical system having an optical magnification factor of not less than 10X. A highly precise defect inspection can be reliably carried out on a pattern formation region by using a prescribed optical magnification factor in order to inspect the inside region 12 for defects.

[0106] As was previously described, a defect inspection apparatus having a dark field illumination optical system has a mechanism for detecting scattered light by dark field illumination provided with a reflective dark field illumination ring. As was previously described, use of a dark field illumination optical system makes it possible to relatively easily detect defects up to a size at the level of 1 μm even if the working distance (WD) is long (defects of a size at the level of 1 μm are not easily detected in the case of a bright field optical system). In the present embodiment, defect inspection information (such as image data and defect information) can be acquired by adopting a TDI camera in the imaging optical system 100 of the defect inspection apparatus. Defects can be guaranteed to be inspected in both the region conventionally guaranteed to be inspected for defects (inside region 12) and the region not guaranteed to be inspected for defects (peripheral region 14) by combining defect inspection information of the peripheral region 14 obtained from this defect inspection apparatus and defect inspection information of the inside region 12 as previously described.

[0107] In the method of inspecting defects of the present embodiment, in addition to an inspection of defects of the inside region 12 and the peripheral region 14 on one of the main surfaces 2a, defects can be inspected for at least one of the side surface 1a and the other main surface 2b. A defect inspection to at least one of the side surface 1a and the other main surface 2b is preferably carried out by the same method as a defect inspection to the peripheral region 14, or in other words, an optical inspection method in which the working distance (WD) is such that $WD > 0.5$ mm. Since a transfer pattern is not required to be formed on the side surface 1a and other main surface 2b, defects can be inspected by a defect inspection method having a relatively low magnification factor. Furthermore, when the side surface 1a is inspected using an optical measurement method in which the working distance (WD) is such that $WD \geq 5$ mm, the depth of focus becomes greater than the chamfer width of the chamfered surfaces 1b. As a result, both the side surface 1a and the chamfered surfaces 1b can be inspected for defects all at once since the chamfered surfaces 1b enter the imaging range when an image of the side surface 1a is captured.

[0108] In the method of inspecting defects of the present embodiment, a final inspection of the mask blank substrate 10 can be carried out by an optical measurement method in which the working distance (WD) is such that WD > 0.5 mm. This final inspection can be carried out on one of the main surfaces of the mask blank substrate 10, namely on the inside region 12 and the peripheral region 14. After a highly precise defect inspection on the inside region 12, unexpected adhesion of contaminant particles and so forth may occur resulting in defects in a process present prior to the final inspection. Unexpected adhesion of contaminant particles and so forth can be detected by a single final inspection by carrying out a final inspection on the mask blank substrate 10. In the case of this final inspection, the working distance (WD) of the defect inspection apparatus is preferably such that WD ≥ 1 mm and more preferably such that WD ≥ 5 mm.

[0109] [Mask Blank 30]

Next, an explanation is provided of an embodiment of the method of manufacturing the mask blank 30 of the present invention.

[0110] In the method of manufacturing the mask blank 30 of the present embodiment, the mask blank substrate is first prepared that has two opposing main surfaces 2 and an edge face perpendicular to the two opposing main surfaces 2. Next, as shown in FIG. 7, a thin film 32 for forming a pattern is formed on one of the main surfaces 2a of the mask blank substrate 10. Next, the surface of the substrate 10 having the thin film 32 formed thereon is inspected for defects and the mask blank 30 is selected from the substrate 10 with the thin film 32 using the results of this defect inspection. The aforementioned method of inspecting defects of the present invention is used for this defect inspection. Furthermore, a defect inspection using the aforementioned method of inspecting defects of the present invention can be carried out on the mask blank substrate 10 when preparing the mask blank substrate 10.

[0111] In addition to an aspect in which the mask blank 30 is inspected in the state of a single layer film, a defect inspection of the mask blank 30 in a state of a laminated film having two layers or more is included in the defect inspection of the mask blank 30. In addition, in the case of a film having two layers or more, a defect inspection carried out each time a layer is deposited is included in the defect inspection of the mask blank 30.

[0112] Examples of the thin film 32 for forming a pattern formed with the method of manufacturing the mask blank 30 of the present embodiment include a light shielding film used in a binary mask blank, a light-semi-transmitting film of a half-tone type phase shift mask, and a multilayer reflective film of a reflective mask. In addition to these three types of thin films 32, additional thin films can be formed corresponding to

the type of mask blank substrate 10 and the application of the transfer mask 40. The following provides explanations of a binary mask blank, phase shift mask blank and reflective mask blank.

[0113] (Binary Mask Blank)

A binary mask blank is manufactured by forming the thin film 32 containing a light shielding film on a glass substrate processed through the aforementioned wet etching step. For example, the light shielding film (thin film 32 for forming a transfer pattern) can be formed with a material containing a transition metal alone selected from chromium, tantalum, ruthenium, tungsten, titanium, hafnium, molybdenum, nickel, vanadium, zirconium, niobium, palladium and rhodium and the like or a compound thereof. In addition, the light shielding film can be formed with a tantalum compound containing not less than one type of element selected from oxygen, nitrogen, boron and the like in addition to tantalum.

[0114] On the other hand, the light shielding film can be formed with a material containing a transition metal and silicon. For example, the light shielding film can be formed with a transition metal silicide compound containing not less than one type of element selected from oxygen and nitrogen in addition to the transition metal and silicon.

[0115] (Phase Shift Mask Blank)

A phase shift mask blank is that of an aspect having a light-semi-transmitting film (a thin film 32 for forming a transfer pattern) on a glass substrate processed through the aforementioned wet etching, and a half-tone type phase shift mask is a type provided with a shifter portion by patterning the light-semi-transmitting film.

[0116] An example of this phase shift mask is a form having a light-semi-transmitting film on a glass substrate and a light shielding film (light shielding band) thereon in order to prevent pattern defects in the transferred glass substrate attributable to the light-semi-transmitting film pattern formed in the transfer region based on light that has passed through the light-semi-transmitting film.

[0117] Examples of this light-semi-transmitting film include a material containing a transition metal and silicon, and a material containing not less than one type of element selected from oxygen, nitrogen and carbon in addition to the transition metal and silicon.

[0118] In addition, in the case of a form that has a light shielding film on a light-semi-transmitting film, the material of the light shielding film preferably has etching selectivity for the aforementioned light-semi-transmitting film since the material of the light-semi-transmitting film contains a transition metal and silicon. The light shielding film is preferably composed with a chromium compound.

[0119] In addition, a configuration may also be employed in which the configuration has an etching mask on a light-shielding film in order to form a fine pattern by reducing the film thickness of a resist film.

[0120] In the case the light shielding film has been formed with a chromium compound as described above, the etching mask film is preferably composed with a material comprised of a silicon compound that is a material having etching selectivity for this light shielding film. In addition, in the case the light shielding film is formed with the aforementioned transition metal silicide compound, tantalum compound or silicon compound, the etching mask film is preferably composed with a material comprised of chromium or a chromium compound that is a material having etching selectivity for these light shielding films.

[0121] (Reflective Mask Blank)

In the case of a reflective mask blank, a low thermal expansion glass (such as SiO_2-TiO_2 glass) on which processing through the aforementioned wet etching has been completed is used for the mask blank substrate 10. The thin film 32 of the reflective mask has a structure in which a multilayer reflective film that reflects exposure light is formed on the glass substrate and an absorber film (thin film 32 for forming a transfer pattern) that absorbs exposure light is formed in a pattern shape on the multilayer reflective film.

[0122] The multilayer reflective film is formed by alternately laminating a high refractive index layer and a low refractive index layer.

[0123] An example of a multilayer reflective film is a Mo/Si cyclically laminated film obtained by alternately laminating a Mo film and Si film for about 40 cycles. In addition, the absorber film has a function that absorbs exposure light in the form of, for example, EUV light, and tantalum (Ta) alone or a material having Ta for the main component thereof, for example, can be used preferably.

[0124] (Defect Inspection of Mask Blank 30)

A defect inspection to the surface of the substrate 10 with the thin film 32 can be carried out in the same manner as the aforementioned defect inspection of the mask blank substrate 10. Namely, the defect inspection can be carried out by carrying out a defect inspection to the inside region 12 by an optical measurement method in which the working distance (WD) is such that $WD \leq 0.5$ mm (preferably such that $WD \leq 0.4$ mm and more preferably such that $WD \leq 0.3$ mm), and carrying out a defect inspection to the peripheral region 14 by an optical measurement method in which the working distance (WD) is such that $WD > 0.5$ mm (preferably such that $WD \geq 1$ mm and more preferably such that $WD \geq 5$ mm). The inside region 12 and peripheral region 14 of the mask blank 30 are the same as the inside region 12 and peripheral region 14 of the

aforementioned mask blank substrate 10.

[0125] In addition, a defect inspection to the peripheral region 14 of the surface of the substrate 10 with the thin film 32 is preferably carried out by an optical measurement method that uses a dark field optical system. The defect inspection to the peripheral region 14 at this time is preferably an inspection using an optical system having an optical magnification factor of not more than 5X.

[0126] In addition, a defect inspection to the inside region 12 of the surface of the substrate 10 with the thin film 32 is preferably carried out by an optical measurement method that uses a bright field optical system. The defect inspection to the inside region 12 at this time is preferably an inspection using an optical system having an optical magnification factor or not less than 10X.

[0127] The mask blank 30 of the present embodiment can further have chamfered surfaces having a height difference h ($h \leq 0.5$ mm) in the same manner as the aforementioned mask blank substrate 10. In addition, this height difference is preferably such that $h \geq 0.3$ mm.

[0128] In the method of inspecting defects of the present embodiment, a defect inspection can be carried out on at least one of the side surface 1a and the other main surface 2b in addition to a defect inspection to the inside region 12 and the peripheral region 14 of one of the main surfaces 2a. A defect inspection to at least one of the side surface 1a and the other main surface 2b is preferably an inspection according the same method as a defect inspection to the peripheral region 14, namely an inspection by an optical measurement method in which the working distance (WD) is such that $WD > 0.5$ mm. Since a transfer pattern is not required to be formed on the side surface 1a and the other main surface 2b, defects can be inspected by a defect inspection method having a relatively low magnification factor. Furthermore, if the side surface 1a is inspected using an optical measurement method in which the working distance (WD) is such that $WD \geq 5$ mm, the depth of focus becomes greater than the chamfer width of the chamfered surfaces 1b. As a result, both the side surface 1a and the chamfered surfaces 1b can be inspected for defects all at once since the chamfered surfaces 1b enter the imaging range when an image of the side surface 1a is captured.

[0129] In the method of inspecting defects of the present embodiment, a final inspection of the mask blank 30 can be carried out by an optical measurement method in which the working distance (WD) is such that $WD > 0.5$ mm (preferably such that $WD \geq 1$ mm and more preferably such that $WD \geq 5$ mm). This final inspection can be carried out on one of the main surfaces of the mask blank 30, namely on the inside region 12 and the peripheral region 14. After a highly precise defect inspection on the inside region 12, unexpected adhesion of contaminant particles and so forth may occur

resulting in defects in a process present prior to the final inspection. Unexpected adhesion of contaminant particles and so forth can be detected by a single final inspection by carrying out a final inspection on the mask blank substrate 10.

[0130] The mask blank 30 of the present invention can be manufactured in the manner described above.

[0131] (Manufacturing of Transfer Mask 40)

The mask blank 30 manufactured using the aforementioned method of manufacturing the mask blank 30 is used in an embodiment of the method of manufacturing the transfer mask 40 of the present invention. As shown in FIG. 8, the transfer mask 40 can be manufactured by forming a transfer pattern 32a in the thin film 32 of this mask blank 30. Since the aforementioned mask blank 30 is a suitable mask blank 30 having few defects that cause problems, a suitable transfer mask 40 can be obtained that has few defects that cause problems.

[0132] The method of manufacturing the transfer mask 40 of the present embodiment is provided with a step for forming a transfer pattern (thin film pattern 32a) in the thin film 32 of the mask blank 30 manufactured using the aforementioned method of manufacturing the mask blank 30. The following provides an explanation of the step for manufacturing the transfer mask 40 from the mask blank 30. Furthermore, the mask blank 30 used here is the half-tone type phase shift mask blank described above. This phase shift mask blank is provided with a structure in which a light-semi-transmitting film (thin film 32 for forming a pattern) and a light shielding film are laminated in that order on a transparent mask blank substrate 10. In addition, this method of manufacturing the transfer mask 40 (a phase shift mask) is merely one example thereof and the transfer mask 40 can still be manufactured even if a portion of the procedure is changed.

[0133] First, a resist film is formed on the light shielding film of the phase shift mask blank by a spin coating method. A chemically amplified resist for electron beam drawing is preferably used for this resist film. Next, a transfer pattern to be formed on the light-semi-transmitting film is exposed and drawn on the resist film with an electron beam followed by carrying out prescribed processing such as development to form a resist pattern having a transfer pattern. Continuing, dry etching is carried out on the light shielding film using the resist pattern as a mask to form a transfer pattern to be formed on the light-semi-transmitting film on the light shielding film. The resist pattern is removed after dry etching. Next, dry etching is carried out on the light-semi-transmitting film using the light shielding film having a transfer pattern as a mask to form a transfer pattern on the light-semi-transmitting film. Continuing, a resist film is formed again, the pattern to be formed on the light shielding film (pattern

of a light shielding band and the like) is exposed and drawn with an electron beam followed by carrying out prescribed processing such as development to form a resist pattern. Dry etching, in which the resist pattern having a pattern of a light shielding band and the like is masked, is then carried out to form the pattern of a light shielding band and the like on the light shielding film. Prescribed cleaning processing and the like is then carried out to obtain the transfer mask 40 (a phase shift mask).

[0134] (Manufacturing of Semiconductor Device)

In the method of manufacturing a semiconductor device of the present invention, a transfer pattern is exposed and transferred to a resist film on a semiconductor substrate using the transfer mask 40 manufactured using the aforementioned method of manufacturing the transfer mask 40. A semiconductor device having a fine and highly precise transfer pattern can be manufactured by using the transfer mask 40 of the present invention.

[Examples]

[0135] The following provides a more detailed explanation of embodiments of the present invention through examples thereof.

[0136] (Example 1)

The mask blank substrate 10 was manufactured in the following manner as Example 1. Furthermore, 100 of the mask blank substrates 10 were manufactured under the same conditions in Example 1. The measured number of defects is the average of 100 mask blank substrates 10.

[0137] (Preparation of Glass Substrate and Polishing Step)

The glass substrate used as the raw material of the mask blank substrate 10 was a synthetic quartz substrate (size: 152.4 mm × 152.4 mm, thickness: 6.35 mm, height difference of chamfered surfaces: h = 0.5 mm). The main surfaces 2 and edge face 1 of this synthetic quartz substrate were ground and subjected to coarse polishing processing and precision polishing with a polishing solution containing cerium oxide abrasive particles followed by placing the glass substrate in the carrier of a double-side polishing apparatus and carrying out polishing processing (ultra-precision polishing) under the conditions indicated below.

Polishing pad: Soft polisher (suede type)

Polishing solution: Colloidal silica abrasive particles (average particle diameter: 100 nm) + water

Processing pressure: 50 g/cm^2 to 100 g/cm^2

Processing time: 60 minutes

[0138] Following completion of ultra-precision polishing, the colloidal silica abrasive

particles were removed and the main surfaces 2 and the edge face 1 of the glass substrate were cleaned with a brush. Next, the main surfaces 2 and edge face 1 of the glass substrate were subjected to a prescribed cleaning.

[0139] After the aforementioned cleaning, defect inspections were carried out on the inside region 12 (dimensions: 142 mm × 142 mm, distance from plane 18 containing side surface to boundary: d = 5.2 mm) of one of the main surfaces 2a of each of the 100 glass substrates using a defect inspection apparatus having sensitivity of 60 nm employing a laser interference confocal optical system (a bright field optical system) (Lasertec Corp., M6640). The working distance (WD) during the defect inspection was made to be about 0.3 mm (a difference of about ±0.1 mm occurred depending on the measured location due to the use of auto-focus). As a result, there were no defects equivalent to a size of not less than 100 nm detected in the inside region 12 of any of the 100 glass substrates that underwent defect inspections. However, not less than 6 defects of a size equivalent to less than 100 nm were detected in the inside region 12 of two of the glass substrates. These two glass substrates were excluded as rejected products that did not satisfy the standard.

[0140] Next, defect inspections were carried out on the peripheral region 14 outside the aforementioned inside region 12 (dimensions: 142 mm × 142 mm) of one of the main surfaces 2a of each of the aforementioned 98 glass substrates that satisfied the standard using a defect inspection apparatus having a dark field optical system (applying a TDI camera) with the previously explained configuration of FIG. 4. More specifically, defect inspections were carried out using a defect inspection apparatus having a sensitivity of 1 μm employing a dark field optical system on the peripheral region 14 (region between side surface 1a and distance d = 5.2 mm from plane 18 containing side surface 1a) outside the aforementioned inside region 12 (dimensions: 142 mm × 142 mm) of one of the main surfaces 2 of the aforementioned glass substrates. The working distance (WD) during the defect inspections was made to be such that WD = 21 mm. As a result, defects (scratches) of size equivalent to not less than 1 μm were detected in the peripheral region 14 of two of the glass substrates among the 98 glass substrates subjected to defect inspections. These two glass substrates were excluded as rejected products that did not satisfy the standard.

[0141] Next, similar defect inspections were carried out on the back side main surface 2b of the aforementioned 96 glass substrates that satisfied the standard using the aforementioned defect inspection apparatus employing a dark field optical system. As a result, defects (scratches) of a size equivalent to not less than 1 μm were detected on the back side main surface 2b of one of the glass substrates among the 96 glass substrates that underwent defect inspections. This single glass substrate was excluded

as a rejected product that did not satisfy the standard.

[0142] Next, similar defect inspections were carried out on the four edge faces 1 (side surface 1a and chamfered surfaces 1b) of the aforementioned 95 glass substrates that satisfied the standard. As a result, defects (scratches) of a size equivalent to not less than 1 μm were detected in a side surface 1a of a single glass substrate among the 95 glass substrates that underwent defect inspections. This single glass substrate was excluded as a rejected product that did not satisfy the standard. As a result of going through the aforementioned steps, 94 glass substrates were determined to be acceptable as mask blank substrates 10.

[0143] Defect coordinates and other defect information was able to be recorded automatically and accurately by the defect inspection apparatus. Moreover, by carrying out these defect inspections, glass substrates in which defects were detected were able to be identified automatically as rejected products that cannot be used as mask blank substrates.

[0144] The mask blank substrate 10 of Example 1 was manufactured using a synthetic quartz glass substrate as raw material in the manner described above. As was previously described, defect information regarding the entirety of one of the main surfaces 2a of the mask blank substrate 10 of Example 1 was able to be recorded automatically and accurately. In addition, glass substrates in which defects equivalent to a size of not less than 1 μm were able to be identified automatically as rejected products. Furthermore, incidents such as the defect inspection apparatus colliding with a synthetic quartz glass substrate did not occur during the defect inspections.

[0145] (Comparative Example 1)

A visual defect inspection to the peripheral region 14 was carried out on 100 glass substrates that underwent a defect inspection to the peripheral region 14 using the defect inspection apparatus employing a dark field optical system used in Example 1. This visual inspection was carried out on the same glass substrates in duplicate by multiple inspectors. As a result, a portion of the inspectors were unable to find defects in visual inspections of glass substrates in which defects (scratches) of a size equivalent to not less than 1 μm were detected in the peripheral region 14 using the defect inspection apparatus employing a dark field optical system. It was therefore determined that there is the possibility of such defects being overlooked in visual inspections.

[0146] (Manufacturing of Mask Blank of Example 1)

Mask blanks 30 for the half-tone type phase shift mask of Example 1 were manufactured using the 94 mask blank substrates 10 determined to be acceptable in Example 1.

[0147] A light-semi-transmitting film comprised of nitrided molybdenum and silicon was first deposited on one of the main surfaces 2a of the aforementioned mask blank substrates 10. More specifically, a MoSiN film comprised of molybdenum, silicon and nitrogen was deposited at a film thickness of 69 nm by reactive sputtering (DC sputtering) using a mixed target of molybdenum (Mo) and silicon (Si) (Mo:Si = 10 mol%:90 mol%) in a mixed gas atmosphere of argon (Ar), nitrogen (N_2) and helium (He) (gas flow rate ratio Ar:N_2:He = 5:49:46) at a gas pressure of 0.3 Pa while setting the power of the DC power supply to 3.0 kW. Next, the aforementioned glass substrates having the MoSiN film formed thereon were subjected to heat treatment using a heating furnace at a heating temperature in air of 450°C and heating time of 1 hour. Furthermore, this MoSiN film had a transmittance of 6.16% and phase difference of 184.4 degrees in exposure light from an ArF excimer laser.

[0148] The light shielding film indicated below was then deposited on the aforementioned semi-light-transmitting film. More specifically, a CrOCN layer having a film thickness of 30 nm was deposited by reactive sputtering (DC sputtering) using a chromium (Cr) target for the sputtering target in a mixed gas atmosphere of argon (Ar), carbon dioxide (CO_2), nitrogen (N_2) and helium (He) (gas pressure: 0.2 Pa, gas flow rate ratio Ar:CO_2:N_2:He = 20:35:10:30) while setting the power of the DC power supply to 1.7 kW. Continuing, a CrN layer having a film thickness of 4 nm was deposited by reactive sputtering (DC sputtering) in a mixed gas atmosphere of argon (Ar) and nitrogen (N_2) (gas pressure: 0.1 Pa, gas flow rate ratio Ar:N_2 = 25:5) while setting the power of the DC power supply to 1.7 kW. Finally, a CrOCN layer having a film thickness of 14 nm was deposited by reactive sputtering (DC sputtering) in a mixed gas atmosphere of argon (Ar), carbon dioxide (CO_2), nitrogen (N_2) and helium (He) (gas pressure: 0.2 Pa, gas flow rate ratio Ar:CO_2:N_2:He = 20:35:5:30) while setting the power of the DC power supply to 1.7 kW, thereby forming a chromium-based light shielding film having a three-layer structure and total film thickness of 48 nm.

[0149] This light shielding film was adjusted so that the optical density (OD) in the laminated structure with the aforementioned light-semi-transmitting film was 3.0 at a wavelength of ArF excimer laser exposure light of 193 nm. In addition, surface reflectance of the light shielding film with respect to the wavelength of the aforementioned exposure light was 20%.

[0150] Defect inspections of the inside region 12 and peripheral region 14 were carried out on one of the main surfaces 2a (surface of light shielding film) of the 94 substrates with thin film obtained in the manner described above.

[0151] First, defect inspections were carried out on each of the 94 substrates with thin film using a defect inspection apparatus having sensitivity of 60 nm employing a laser

interference confocal optical system (bright field optical system) (Lasertec Corp., M6640) in the same manner as in the case of the defect inspections carried out on the glass substrates. As a result, defects of a size equivalent to not less than 100 nm were not detected in the inside region 12 in any of the 94 substrates 10 with the thin film 32 that underwent this defect inspection. However, not less than six defects of a size equivalent to less than 100 nm were detected in the inside region 12 of four of the substrates 10 with the thin film 32. These four substrates with thin film were excluded as rejected products that did not satisfy the standard. In addition, the sizes and locations (coordinates) of all defects detected in this defect inspection were recorded in association with the substrates 10 with the thin film 32 that underwent this defect inspection.

[0152] Next, defect inspections were carried out on the 90 substrates with thin film that were determined to be acceptable in the aforementioned defect inspection using a defect inspection apparatus employing a dark field optical system (applying a TDI camera) in the same manner as in the case of the defect inspections carried out on the glass substrates. Here, defect inspections were simultaneously carried out not only on the peripheral region 14 of the substrates 10 with the thin film 32, but also on the inside region 12, and defect inspections were further carried out on the back side main surface 2b and edge face 1. Namely, the defect inspection here was carried out as a final inspection of the mask blank 30. As a result, among the 90 glass substrates that underwent this defect inspection, defects (foreign matter) of a size equivalent to not less than 1 μm were detected in the peripheral region 14 of two of the substrates 10 with the thin film 32, and defects (scratches) of a size equivalent to not less than 1 μm were detected in the back side main surface of one of the substrates 10 with the thin film 32. These three substrates 10 with the thin film 32 were excluded as rejected products that did not satisfy the standard. As a result of these steps, 87 substrates 10 with the thin film 32 were determined to be acceptable as mask blanks 30 for half-tone type phase shift masks.

[0153] (Manufacturing of Half-Tone Type Phase Shift Mask of Example 1)

Mask blanks for a half-tone type phase shift mask (transfer mask) 40 of Example 1 were manufactured in the following manner using the mask blanks 30 for a half-tone type phase shift mask of Example 1 determined to be acceptable as described above.

[0154] First, a chemically amplified positive resist film for electron beam drawing (FujiFilm Electronic Materials Co., Ltd., PRL009) was formed on the mask blank 30 described above. The resist film was formed by spin coating using a spinner (spin coating apparatus). After coating the aforementioned resist film, the resist film was

subjected to prescribed heat drying treatment. The film thickness of the resist film was 150 nm.

[0155] Next, a desired pattern on the resist film formed on the aforementioned mask blank 30 was drawn using an electron beam drawing apparatus followed by developing with a prescribed developer to form a resist pattern.

[0156] Next, the light shielding film was etched by using the aforementioned resist pattern as a mask. A mixed gas of Cl_2 and O_2 was used for the dry etching gas. Continuing, the light-semi-transmitting film (MoSiN film) was etched to form a light-semi-transmitting film pattern. A mixed gas of SF_6 and He was used for the dry etching gas.

[0157] Next, the remaining resist pattern was stripped off, the same resist film as previously described was again formed over the entire surface, drawing was carried out to form a light shielding band around the periphery of the mask, and the resist film was developed following drawing to form a resist pattern. The light shielding film other than that in the region of the light shielding band was removed by etching using this resist pattern as a mask.

[0158] Next, the remaining resist pattern was stripped off to obtain the phase shift mask 40.

[0159] The phase shift mask (transfer mask) 40 of Example 1 obtained in the manner described above using the mask blank 30 of Example 1 was formed in which a fine pattern having a half pitch of 45 nm was formed with favorable precision.

[0160] (Manufacturing of Semiconductor Device)

When a semiconductor device was fabricated using the aforementioned phase shift mask 40 of Example 1 and transferring a pattern to a resist film on a transferred substrate in the form of a semiconductor substrate using an exposure apparatus followed by patterning an interconnection layer, a semiconductor device was able to be fabricated that had a fine and highly precise transfer pattern.

BRIEF DESCRIPTION OF THE REFERENCE SYMBOLS

[0161] 1 Edge face
1a Side surface
1b Chamfered surface
1c Side surface
1d Flat edge face portion
1e Chamfered surface
1f Curved edge face portion
2 Main surface

2a One of main surface (Front side main surface)
2b Other main surface (Back side main surface)
10 Substrate (mask blank substrate)
10a Corner portion
12 Inside region
14 Peripheral region
16a Ridgeline
16b Ridgeline
18 Plane containing side surface
30 Mask blank
32 Thin film
32a Thin film pattern
40 Phase shift mask (transfer mask)
100 Imaging optical system
110 Imaging camera (e.g. TDI camera)
111 Object lens
112 Imaging lens
113 Imaging element
120 Autofocus module
131 Illumination means
134 Housing
135 Inclined portion
136 Flexible printed board
137 LED
140 Light shielding mask
200 Stand

CLAIMS

1. A method of inspecting defects in a mask blank or a mask blank substrate, wherein

the mask blank or the mask blank substrate has two opposing main surfaces and a side surface perpendicular to the two opposing main surfaces,

one of the main surfaces has an inside region and a peripheral region,

the boundary between the inside region and the peripheral region is located at a distance d from a plane containing the side surface,

the distance d is such that $d \geq 1$ mm, and,

the method of inspecting defects comprises:

carrying out a defect inspection to the inside region by an optical measurement method in which a working distance (WD) is such that $WD \leq 0.5$ mm, and

carrying out a defect inspection to the peripheral region by an optical measurement method in which the working distance (WD) is such that $WD > 0.5$ mm,

the optical measurement method for the defect inspection to the peripheral region uses a dark field optical system, and

the optical measurement method for the defect inspection to the inside region uses a bright field optical system.

2. The method of inspecting defects according to claim 1, wherein the defect inspection to the inside region inspects the inside region with an optical system having an optical magnification factor of not less than 10X.

3. The method of inspecting defects according to claim 1 or 2, wherein the defect inspection to the peripheral region inspects the peripheral region with an optical system having an optical magnification factor of not more than 5X.

4. The method of inspecting defects according to any of claims 1 to 3, wherein the mask blank or the mask blank substrate further has a chamfered surface between the main surface and the side surface, and a height difference h between a ridgeline of the side surface and the chamfered surface and a ridgeline of the main surface and the chamfered surface in a direction perpendicular to the main surfaces is such that $h \leq 0.5$ mm.

5. The method of inspecting defects according to any of claims 1 to 4, wherein the method of inspecting defects further includes carrying out a defect inspection to at least one of the side surface and the other main surface by an optical measurement method in which the working distance (WD) is such that $WD > 0.5$ mm.

6. The method of inspecting defects according to any of claims 1 to 5, wherein carrying out the defect inspection by the optical measurement method in which the

working distance (WD) is such that WD > 0.5 mm is a final inspection.

7. A method of manufacturing a mask blank, comprising:

preparing a mask blank substrate having two opposing main surfaces and a side surface perpendicular to the two opposing main surfaces,

forming a thin film for forming a pattern on one of the main surfaces of the mask blank substrate, and

carrying out a defect inspection to a surface of the substrate with the thin film having the thin film formed thereon and selecting a mask blank from the substrate with the thin film using the results of the defect inspection; wherein,

one of the main surfaces of the substrate with the thin film has an inside region and a peripheral region,

the boundary between the inside region and the peripheral region is located at a distance d from a plane containing the side surface,

the distance d is such that $d \geq 1$ mm, and

carrying out the defect inspection to the surface of the substrate with the thin film comprises:

carrying out a defect inspection to the inside region by an optical measurement method in which working distance (WD) is such that WD ≤ 0.5 mm, and

carrying out a defect inspection to the peripheral region by an optical measurement method in which working distance (WD) is such that WD > 0.5 mm,

the optical measurement method for the defect inspection to the peripheral region uses a dark field optical system, and

the optical measurement method for the defect inspection to the inside region uses a bright field optical system.

8. The method of manufacturing a mask blank according to claim 7, wherein the defect inspection to the inside region inspects the inside region with an optical system having an optical magnification factor of not less than 10X.

9. The method of manufacturing a mask blank according to claim 7 or 8, wherein the defect inspection to the peripheral region inspects the peripheral region with an optical measurement system having a magnification factor of not more than 5X.

10. The method of manufacturing a mask blank according to any of claims 7 to 9, wherein the mask blank or the mask blank substrate further has a chamfered surface between the main surface and the side surface, and a height difference h between a ridgeline of the side surface and the chamfered surface and a ridgeline of the main surface and the chamfered surface in a direction perpendicular to the main surfaces is such that h ≤ 0.5 mm.

11. The method of manufacturing a mask blank according to any of claims 7 to

10, wherein the method of manufacturing mask blank further includes carrying out a defect inspection to at least one of the side surface and the other main surface by an optical measurement method in which the working distance (WD) is such that WD > 0.5 mm.

12. The method of manufacturing a mask blank according to any of claims 7 to 11, wherein carrying out the defect inspection by the optical measurement method in which the working distance (WD) is such that WD > 0.5 mm is a final inspection.

13. A method of manufacturing a transfer mask in which a transfer pattern is formed on the thin film of the mask blank using the mask blank that has been manufactured by the method of manufacturing a mask blank according to any of claims 7 to 12.

14. A method of manufacturing a semiconductor device in which the transfer pattern is exposed and transferred to a resist film on a semiconductor substrate using the transfer mask manufactured by the method of manufacturing a transfer mask according to claim 13.