

DESCRIPTION

METHOD FOR PRODUCING PELLICLE, AND METHOD FOR PRODUCING PELLICLE-ATTACHED PHOTOMASK

5

TECHNICAL FIELD

[0001]

The present invention relates to a method for producing a pellicle.

10

BACKGROUND ART

[0002]

15

For producing a semiconductor device such as an LSI, a VLSI or the like, or a liquid crystal display panel or the like, patterning is performed by exposure through a photomask or a reticle. In the case where a foreign object is attached to a surface of the photomask or the reticle, the foreign object is transferred to a wafer each time the exposure to light is performed. In order to avoid this, a pellicle including a pellicle frame and a pellicle film is bonded such that the pellicle film is located several millimeters away from a surface of the photomask or the reticle. In the case where the pellicle is located on at least a patterned surface of the photomask or the reticle, the foreign object attached to a surface of the pellicle is not focused on. Therefore, an image of the foreign object is not formed on a photoresist formed on the semiconductor wafer, and thus the circuit pattern is prevented from being defective.

20

25

[0003]

Such a pellicle-attached photomask is conventionally produced as follows. A pellicle frame having a shape corresponding to the photomask or the reticle and a thickness of about several millimeters is prepared. A

pellicle film formed of a transparent polymer film of nitrocellulose or a cellulose derivative having a thickness of 10 μm or less is stretched on, and bonded to, one of two surfaces of the pellicle frame. Then, the other surface of the pellicle frame is bonded to the surface of the photomask or the reticle via an adhesive material.

[0004]

A wavelength of light usable for lithography has become shorter and shorter, and EUV lithography has been developed as a next generation lithography technology. The "EUV light" refers to light having a wavelength in a soft X-ray region or a vacuum ultraviolet region, more specifically, to light having a wavelength of approximately $13.5 \text{ nm} \pm 0.3 \text{ nm}$. In photolithography, the resolution limit of patterning is about $1/2$ of the wavelength of light used for exposure, and is considered to be about $1/4$ of the wavelength of light used for exposure even in the case where a liquid immersion method is used. The wavelength of light used for exposure is expected to be about 45 nm at the minimum even when a liquid immersion method with ArF laser (wavelength: 193 nm) is used. In such a situation, the EUV lithography is expected as a revolutionary technology realizing significant size reduction over the conventional lithography technology.

[0005]

EUV light is easily absorbed to any type of substance and thus, in EUV lithography, exposure to light needs to be performed in a vacuum exposure device. Therefore, attachment of a pellicle to a photomask has been considered as not being indispensable. However, the EUV lithography is a process of high precision that has not been provided conventionally, and the number of times of stacking is larger. For these reasons, it is concerned in the semiconductor industry that LSIs or the like may not be produced at high yield in the case where merely the inside of the device is cleaned. It

has been made clear that attachment of a pellicle to a photomask is indispensable. As described above, EUV light is easily absorbed to any type of substance. Therefore, in order to have a sufficiently high level of transmittance for EUV light, the pellicle film included in the pellicle needs to have a thickness of a nanometer order. For example, in the case where the wavelength of the EUV light is $13.5 \text{ nm} \pm 0.3 \text{ nm}$, the pellicle film needs to have a thickness of 10 nm or greater and 50 nm or less in order to have a transmittance of 90.0% or higher.

[0006]

For realizing this, it is conceivable that, for example, a pellicle film is formed on a substrate by vapor deposition and the substrate is back-etched to have a frame shape, so that the pellicle film is exposed. In this manner, a pellicle including a pellicle film is provided. However, with this method, the substrate needs to be trimmed (cut) to provide a part thereof that is required to form the pellicle, in order to match the shape of the pellicle to the shape of the photomask or the reticle. Since the pellicle film is very thin, it is preferable that the trimming is performed such that the part of the substrate that is required to form the pellicle is kept on an outer peripheral portion of the pellicle film, in consideration of the ease of handling. The part of the substrate left on the outer peripheral portion of the pellicle film as a result of the trimming is used as a part of the pellicle frame. The back-etching is described in Patent Document 1 mentioned below. Patent Document 1 describes the following. A silicon substrate of an SOI structure is thinned to have a thickness of 50 μm , and a honey-comb structure is formed by DRIE (Deep Reactive Ion Etching) to form a pellicle film. Then, the pellicle film is cut have the same size as that of the pellicle frame. As described in this publication, the substrate needs to be trimmed (cut) to provide a part thereof that is required to form the pellicle, in order to match the shape of the pellicle

to the shape of the photomask or the reticle.

CITATION LIST

PATENT LITERATURE

5 [0007]

Patent Literature 1: Japanese Laid-Open Patent Publication No.
2013-004893

SUMMARY OF INVENTION

10 TECHNICAL PROBLEM

[0008]

According to a method for trimming to provide a portion that is
required to form a pellicle, the substrate is cut by a mechanical force to
provide a pellicle frame. However, this method has a problem that after the
15 substrate is cut to provide the pellicle frame, foreign object particles are
generated at the cut surface and attached to the pellicle film, which results in
contaminating the pellicle film.

[0009]

Embodiments of the present invention suppress foreign object particles
20 generated at the timing of trimming from being attached to a pellicle film.

SOLUTION TO PROBLEM

[0010]

According to a first aspect of the present invention, there is provided a
25 method for producing a pellicle including a pellicle film and a pellicle frame
supporting an outer peripheral portion of the pellicle film, the method
including: forming the pellicle film on a substrate, and bonding a
pressure-sensitive adhesive sheet to each of two surfaces of the substrate,
the pressure-sensitive adhesive sheet being elastic and having a
30 pressure-sensitive adhesive force thereof decreased upon receipt of external

stimulation; making a notch inside a part of the substrate, the part having the pressure-sensitive adhesive sheets bonded thereto; separating a substrate outer peripheral portion outer to the notch of the substrate, in a state where the pressure-sensitive adhesive sheets are bonded to the substrate, to form a pellicle frame; and stimulating the pressure-sensitive adhesive sheets to peel off the pressure-sensitive adhesive sheets.

[0011]

The method for producing a pellicle may further comprise etching the substrate, from a surface opposite to a surface on which the pellicle film is formed, to expose the pellicle film.

[0012]

After the substrate is etched, from a surface opposite to a surface on which the pellicle film is formed, to expose the pellicle film, the pressure-sensitive adhesive sheet may be bonded to each of the two surfaces of a portion of the substrate that is around the exposed portion of the pellicle film.

[0013]

The substrate may have openings provided between a portion of the substrate to be the pellicle frame and the substrate outer peripheral portion may include a bridge portion coupling the portion of the substrate to be the pellicle frame and the substrate outer peripheral portion to each other; and making the notch inside the substrate may be making a notch inside the bridge portion.

[0014]

The pressure-sensitive adhesive sheets may be bonded to cover both of two surfaces and both of two side surfaces of the bridge portion.

[0015]

The bridge portion may be connected to each of four corners of the pellicle frame.

30

[0016]

The notch may be made inside the substrate by stealth dicing.

[0017]

The pressure-sensitive adhesive sheets may be antistatic.

5 [0018]

For separating the substrate outer peripheral portion to form the pellicle frame, gas in a portion along which the substrate is separated may be absorbed by an absorption device.

[0018a]

10

The pellicle film may have a thickness of 10 nm or greater and 50 nm or less.

[0019]

15

According to a second aspect of the present invention, there is provided a method for producing a pellicle-attached photomask, including joining the pellicle produced by the method for producing a pellicle according to the first aspect, and a photomask, to each other via a frame body attached to the pellicle frame.

ADVANTAGEOUS EFFECTS OF INVENTION

20

[0020]

A method for producing a pellicle according to embodiments of the present invention suppresses foreign object particles generated at the time of trimming from being attached to a pellicle film.

25

BRIEF DESCRIPTION OF DRAWINGS

[0021]

[FIG. 1A] FIG. 1A is a schematic view (plan view) of a

pellicle-attached photomask produced in embodiment 1.

[FIG. 1B] FIG. 1B is a cross-sectional view of the pellicle-attached photomask in embodiment 1, taken along line A-A in FIG. 1A.

5 [FIG. 2A] FIG. 2A is a schematic view showing a step of a method for producing the pellicle-attached photomask in embodiment 1.

[FIG. 2B] FIG. 2B is a schematic view showing a step of the method for producing the pellicle-attached photomask in embodiment 1.

[FIG. 2C] FIG. 2C is a schematic view showing a step of the method for producing the pellicle-attached photomask in embodiment 1.

10 [FIG. 2D] FIG. 2D is a schematic view showing a step of the method for producing the pellicle-attached photomask in embodiment 1.

[FIG. 2E] FIG. 2E is a schematic view showing a step of the method for producing the pellicle-attached photomask in embodiment 1.

15 [FIG. 3A] FIG. 3A is a plan view showing a position at which a pressure-sensitive adhesive sheet is bonded in embodiment 1.

[FIG. 3B] FIG. 3B is an enlarged view of FIG. 3A, showing a portion to be subjected to trimming.

20 [FIG. 4A] FIG. 4A is a schematic view showing, in detail, a step of trimming in the method for producing the pellicle-attached photomask in embodiment 1.

[FIG. 4B] FIG. 4B is a schematic view showing, in detail, the step of trimming in the method for producing the pellicle-attached photomask in embodiment 1.

25 [FIG. 4C] FIG. 4C is a schematic view showing, in detail, the step of trimming in the method for producing the pellicle-attached photomask in embodiment 1.

[FIG. 4D] FIG. 4D is a schematic view showing, in detail, the step of trimming in the method for producing the pellicle-attached photomask in

embodiment 1.

[FIG. 5A] FIG. 5A is a schematic view showing positions at which pressure-sensitive adhesive sheets are bonded in embodiment 2.

5 [FIG. 5B] FIG. 5B is a schematic view showing the positions at which the pressure-sensitive adhesive sheets are bonded in embodiment 2.

[FIG. 5C] FIG. 5C is a cross-sectional view taken along line C-C in FIG. 5B.

[FIG. 5D] FIG. 5D shows a state where an opening shown in FIG. 5C is filled with the pressure-sensitive adhesive sheet.

10 [FIG. 6A] FIG. 6A is a schematic view showing positions at which pressure-sensitive adhesive sheets are bonded in embodiment 3.

[FIG. 6B] FIG. 6B is a cross-sectional view taken along line D-D in FIG. 6A.

15 [FIG. 6C] FIG. 6C shows a state where an opening shown in FIG. 6B is filled with the pressure-sensitive adhesive sheet.

[FIG. 7A] FIG. 7A is a schematic view showing a method of performing trimming by mechanically breaking a substrate.

[FIG. 7B] FIG. 7B is a schematic view showing the method of performing trimming by mechanically breaking the substrate.

20 [FIG. 7C] FIG. 7C is a schematic view showing the method of performing trimming by mechanically breaking the substrate.

[FIG. 8A] FIG. 8A is a schematic view showing a method of performing trimming by blade dicing or laser ablation.

25 [FIG. 8B] FIG. 8B is a schematic view showing the method of performing trimming by blade dicing or laser ablation.

[FIG. 8C] FIG. 8C is a schematic view showing the method of performing trimming by blade dicing or laser ablation.

[FIG. 9A] FIG. 9A is a schematic view showing a method of performing

trimming by stealth dicing.

[FIG. 9B] FIG. 9B is a schematic view showing the method of performing trimming by stealth dicing.

5 [FIG. 9C] FIG. 9C is a schematic view showing the method of performing trimming by stealth dicing.

[FIG. 9D] FIG. 9D is a schematic view showing the method of performing trimming by stealth dicing.

DESCRIPTION OF EMBODIMENTS

10 [0022]

Hereinafter, a method for producing a pellicle-attached photomask according to the present invention will be described with reference to the drawings. The method for producing a pellicle-attached photomask according to the present invention may be carried out in many different forms,
15 and is not construed as being limited to the embodiments described below. In the drawings referred to in the following embodiments, same portions or portions having substantially the same functions bear the identical reference signs, and detailed descriptions thereof will be omitted. For the sake of illustration, the ratio of sizes (ratio of sizes of different components, ratio of sizes in the length direction, the width direction and the height direction, etc.)
20 in the drawings may be different from the actual ratio of sizes, or a part of the components may be omitted from the drawings.

[0023]

<EMBODIMENT 1>

25 [Structure of the pellicle-attached photomask]

FIG. 1A is a schematic view (plan view) of a pellicle-attached photomask produced in embodiment 1. FIG. 1B is a cross-sectional view of the pellicle-attached photomask in embodiment 1, taken along line A-A in FIG.

1A. The pellicle-attached photomask 1 includes a pellicle 10 and a photomask 104. The pellicle 10 is attached to a patterned surface of the photomask 104. The pellicle 10 includes a pellicle film 101, a pellicle frame 102 and a frame body 103.

5 [0024]

Specific examples of compound usable to form the pellicle film 101 include polymer compounds such as fluorine-based polymers, polyolefin, polyimide and the like; metal materials such as ruthenium, nickel, zirconium, titanium, molybdenum, niobium and the like; crystalline silicon (e.g., single
10 crystalline silicon, polycrystalline silicon, etc.); amorphous silicon; diamond-like carbon (DLC); graphite; amorphous carbon; graphene; silicon carbide; silicon nitride; and the like.

[0025]

The pellicle film 101 may include an anti-oxidant film or a heat
15 dissipation film. The anti-oxidant film is formed of, for example, SiO_x ($x \leq 2$), Si_xN_y ($x/y = 0.7$ to 1.5), SiON , SiC , Y_2O_3 , YN , Mo , Ru , Rh , or the like.

[0026]

The heat dissipation film is preferably formed of a material having a high heat radiation ratio or a material having a high heat conductivity.
20 Specifically, the heat dissipation film may be formed of, for example, substantially the same material as that of the anti-oxidant film, Rb , Sr , Y , Zr , Nb , graphite, graphene, or the like. The anti-oxidant film and the heat dissipation film may be formed on one surface, or both of two surfaces, of the pellicle film 101. The pellicle film 101 may contain one of, or two or more of,
25 the above-listed elements and compounds.

[0027]

The pellicle-attached photomask 1 includes the pellicle 10 and the photomask 104. The pellicle 10 includes the pellicle film 101, the pellicle

frame 102 and the frame body 103. The pellicle frame 102 is formed of silicon and has a thickness of about 0.7 mm, and supports an outer peripheral portion of the pellicle film 101.

[0028]

5 The frame body 103 is located between the photomask 104 and the pellicle frame 102. In this example, the thickness of the frame body 103 is determined such that the pellicle film 101 and the photomask 104 are away from each other by an interval of about 2 mm. The frame body 103 is joined to the photomask 104 and the pellicle frame 102 with an adhesive layer. An
10 air hole communicating a space formed between the photomask 104 and the pellicle film 101, and the external space, to each other may be provided in the pellicle frame 102 or the frame body 103.

[0029]

[Method for producing the pellicle-attached photomask]

15 A pellicle-attached photomask in this embodiment may be produced, for example, as described below with reference to FIG. 2A through FIG. 2E. The production method described below is an example. FIG. 2A through FIG. 2E are schematic views each showing a step of the method for producing the pellicle-attached photomask in an embodiment. A substrate
20 105 is prepared, and the pellicle film 101 is formed on the substrate 105 (FIG. 2A). The substrate 105 is to become the pellicle frame 102 in a state where the production of the pellicle 10 is finished. The substrate 105 may be, for example, a silicon substrate, a sapphire substrate, a silicon carbide substrate or the like, but is not limited to any of these.

25 [0030]

There is no specific limitation on the thickness of the substrate. In the case where, for example, the substrate is a silicon substrate, an 8-inch wafer having a thickness of 725 μm conformed to the SEMI standards is

preferably usable. In order to perform back-etching described below efficiently, a thinner substrate may be used. A substrate having a thickness of 50 μm or greater may be preferably used without being broken when the pellicle film is formed.

5 [0031]

The pellicle film 101 is formed on the substrate 105 by vapor deposition so as to have a thickness of 10 nm or greater and 50 nm or less. EUV light is easily absorbed to any type of substance. Therefore, the pellicle film 101 has, for example, a transmittance of 90% or higher for light
10 having a wavelength of 13.5 ± 0.3 nm.

[0032]

The substrate 105 having the pellicle film 101 formed thereon is etched from a surface opposite to the surface on which the pellicle film 101 is formed (back-etched), and the pellicle film 101 is exposed such that the
15 substrate 105 is frame-shaped (FIG. 2B). The back-etching may be dry etching or wet etching.

[0033]

The back-etched substrate 105 is trimmed to separate a substrate outer peripheral portion 111 thereof to provide the pellicle frame 102, which
20 needs to be joined with the frame body 103 (FIG. 2C). The method for the trimming will be described below in detail with reference to FIG. 3A, FIG. 3B, and FIG. 4A through FIG. 4D. In FIG. 2A through FIG. 2E, the trimming is performed to provide the pellicle frame 102 after the back-etching. Alternatively, the back-etching may be performed after the trimming.

25 [0034]

The frame body 103 is joined with a surface of the pixel frame 102 opposite to a surface on which the pellicle film 101 is located (FIG. 2D).

[0035]

It is preferable that the frame body 103 is formed of a material that is tolerable against EUV light, is made flat easily and has a low rate of ion elution. It is also preferable that the frame body 103 is formed of a material tolerable against hydrogen radical because hydrogen gas is supplied to the
5 inside of the exposure device in order to remove contaminants derived from carbon.

[0036]

There is no specific limitation on the material of the frame body 103. The frame body 103 may be formed of a material that is usually usable for a
10 pellicle frame. Specific examples of material usable for the frame body 103 include aluminum, aluminum alloys (5000-type, 6000-type, 7000-type, etc.), stainless steel, silicon, silicon alloys, iron, iron alloys, carbon steel, tool steel, ceramics, metal-ceramic composite materials, resins and the like. Among these materials, aluminum and aluminum alloys, which are lightweight and
15 rigid, are more preferable. The frame body 103 may have a protective film formed on a surface thereof.

[0037]

The protective film is preferably tolerable against hydrogen radical present in an exposure atmosphere and against EUV light. The protective
20 film is, for example, an oxide film. The oxide film may be formed by a known method such as anodization or the like.

[0038]

The pellicle 10 including the pellicle film 101, the pellicle frame 102 and the frame body 103 obtained as a result of the trimming is joined with the
25 photomask 104 (FIG. 2E). At this step, the pellicle-attached photomask 1 is produced.

[0039]

[Details of the trimming method]

FIG. 3A is a plan view showing a position at which a pressure-sensitive adhesive sheet is bonded in embodiment 1 according to the present invention. FIG. 3B is an enlarged view of FIG. 3A, and shows a portion to be subjected to the trimming. The one-dot chain line represents a region of the pellicle film 101 that is exposed by the etching performed on the substrate 105 from the opposite surface (by the back-etching performed on the substrate 105). FIG. 3A shows a position at which a frame-shaped pressure-sensitive adhesive sheet 106 is bonded. The pressure-sensitive adhesive sheet 106 is not limited to being frame-shaped and may cover a top surface of the pellicle film 101. The trimming shown in FIG. 2C is performed as follows. First, as shown in FIG. 3B, a pressure-sensitive adhesive sheet is bonded to each of two surfaces of the substrate 105 so as to cover a cut line L along which the substrate 105 and the pellicle film 101 are to be cut. Namely, the pressure-sensitive adhesive sheet 106 is bonded to the top surface of the pellicle film 101. Although not shown in FIG. 3A or FIG. 3B, a pressure-sensitive adhesive sheet 307 is bonded to a bottom surface of the substrate 105 (see FIG. 4A through FIG. 4C). The pressure-sensitive adhesive sheets 106 and 107 are elastic and have a pressure-sensitive adhesive force thereof decreased upon receipt of external stimulation. The term "elastic" refers to having a tensile strength of 10 MPa or greater when having a Young's modulus is 100 MPa to 600 MPa and an elasticity of 20 to 40%. The "external stimulation" refers to ultraviolet light. The external stimulation is not limited to ultraviolet light and may be heat or the like.

[0040]

There is no specific limitation on the material of the pressure-sensitive adhesive sheets 106 and 107. The pressure-sensitive adhesive sheet 106 and 107 may each be, for example, a sheet including a substrate film and a pressure-sensitive adhesive layer formed thereon. The substrate film may

be any of a wide range of conventionally known substrate films, and may be, for example, a general-purpose polymer film such as a polyolefin-based film, an elastomer-based film or the like. Specific examples of material usable for the general-purpose polymer film include ethylene-based copolymers such as polyethylene, ethylene-vinyl acetate copolymer and the like; and general-purpose polymers such as polypropylene, polybutylene, ionomer; polybutadiene, polyethyleneterephthalate, polybutyleneterephthalate, polymethylpentene, polyurethane, and the like.

[0041]

The pressure-sensitive adhesive layer may be formed of any of a wide range of conventionally known pressure-sensitive adhesives, and may be formed of, for example, an acrylic resin-based pressure-sensitive adhesive. Specific examples of usable acrylic resin-based pressure-sensitive adhesive include acrylic resin-based polymers such as polymers having an acrylic acid ester as a polymer structural unit, acrylic acid ester-based copolymers, and the like; copolymers with functional monomers; and mixtures of such polymers. It is preferable to use, for a pressure-sensitive adhesive layer, an ultraviolet-curable or thermally curable pressure-sensitive adhesive. In the case where the pressure-sensitive adhesive layer is ultraviolet-curable or thermally curable, the following occurs. For peeling off the pressure-sensitive adhesive sheet, the pressure-sensitive adhesive layer may be cured by being irradiated with ultraviolet or being heated. Thus, the pressure-sensitive adhesive force of the pressure-sensitive adhesive layer is decreased, and thus the pressure-sensitive adhesive sheet is peeled off with no influence on the pellicle film or the pellicle frame. In FIG. 4A through FIG. 4C, the pressure-sensitive adhesive sheet 107 is bonded to the entirety of the bottom surface of the substrate 105. Alternatively, the pressure-sensitive adhesive sheet 107 may be bonded in any manner as long

as being located to face the pressure-sensitive adhesive sheet 106.

[0042]

FIG. 4A through FIG. 4C are schematic views showing a step of trimming in detail in the method for producing the pellicle-attached photomask in embodiment 1. FIG. 4A corresponds to a cross-section taken along line B-B in FIG. 3B. As shown in FIG. 4A, the pressure-sensitive adhesive sheets 106 and 107 are bonded to both of the two surfaces of the substrate 105. As described above, the pressure-sensitive adhesive sheets 106 and 107 are bonded to cover both of two surfaces of the portion including the cut line along which the cutting is to be performed for the trimming. In FIG. 4A, the pressure-sensitive adhesive sheet 106 is bonded to a part of the top surface of the substrate 105. The pressure-sensitive adhesive sheet 106 may be bonded in any manner as long as covering the cut line.

[0043]

Next, a notch is made inside the substrate 105 on which the pressure-sensitive adhesive sheets 106 and 107 are bonded (FIG. 4B). Since merely the notch is made inside in the substrate 105, no dust is generated from the surface of the substrate 105. The notch may be made in the substrate 105 by, for example, stealth dicing. Any other method may be used as long as the notch is made inside the substrate 105. According to the "stealth dicing", laser light is focused and directed to the inside of a processing target to form a quality-modified region inside the processing target along a line along which the processing target is to be cut. Then, the processing target is cut using the quality-modified region as a start point.

[0044]

Next, the substrate 105 is expanded (pulled) together with the pressure-sensitive adhesive sheet 107 (FIG. 4C). When the substrate 105 and the pressure-sensitive adhesive sheet 107 are expanded, the substrate

outer peripheral portion 111 is separated and thus the pellicle frame 102 is formed. When the substrate outer peripheral portion 111 is separated, foreign object particles 109 located in the notch inside the substrate 105 scatter as dust. However, the foreign object particles 109 are captured by
5 the pressure-sensitive adhesive sheets 106 and 107. The expansion may be made by pushing the substrate 105 with a rod-like item from below the pressure-sensitive adhesive sheet 107. Alternatively, the pressure-sensitive adhesive sheet 107 may be expanded horizontally. Still alternatively, the pressure-sensitive adhesive sheet 106 may be expanded
10 together with the pressure-sensitive adhesive sheet 107. At the time of expansion, the foreign object particles 109 may be absorbed by a vacuum (absorption device) from above the pressure-sensitive adhesive sheet 106. In the case of being absorbed by the vacuum in this manner, the foreign object particles 109 are easily captured by the pressure-sensitive adhesive
15 sheet 106 or absorbed into the vacuum. In order to allow the generated foreign object particles 109 to be captured by the pressure-sensitive adhesive sheets efficiently, static electricity may be removed by an ionizer or the like at the time of, or after, the expansion. Alternatively, one of the pressure-sensitive adhesive sheets bonded to both of the two surfaces may
20 be first peeled off, so that the cut surface is seen, and then the foreign object particles 109 may be absorbed by the vacuum, or a gas current may be supplied to allow the pressure-sensitive adhesive sheets to capture the foreign object particles 109. For peeling off one of the pressure-sensitive adhesive sheets, external stimulation may be given to one of the
25 pressure-sensitive adhesive sheets, or two different types of pressure-sensitive adhesive sheets that are different in the release force (release temperature) may be used, for example.

[0045]

In a final step, the pressure-sensitive adhesive sheet 106 and the pressure-sensitive adhesive sheet 107 are irradiated with ultraviolet light to have the pressure-sensitive adhesive force thereof decreased. Then, the pressure-sensitive adhesive sheet 106 is peeled off from the pellicle film 101, and the pressure-sensitive adhesive sheet 107 is peeled off from the pellicle frame 102 (FIG. 4D). In FIG. 4A through FIG. 4D, the pellicle frame 102 is formed by trimming after the back-etching. In the case where the back-etching is performed after the trimming, the pressure-sensitive adhesive sheets 106 and 107 may be bonded to cover both of the two surfaces of the portion including a line along which the cut is to be performed at the time of trimming, and the pressure-sensitive adhesive sheets 106 and 107 may be peeled off as shown in FIG. 4A through FIG. 4D after the trimming and then the back-etching may be performed to expose the pixel film 101.

[0046]

In this embodiment, as compared with the conventional method of applying a mechanical force for the trimming, the foreign object particles, generated at the time of trimming to separate a portion of the substrate that is required to form the pellicle frame, are suppressed from being attached. This will be described in more detail. With the conventional method of applying a mechanical force for the trimming, as shown in FIG. 7A through FIG. 7C, foreign object particles 409 are generated when a substrate 405 is cut, and are attached to a pellicle film 401 or a pellicle frame 402. By contrast, in this embodiment, as described above with reference to FIG. 4C, the foreign object particles 109 are captured by the pressure-sensitive adhesive sheets 106 and 107, and thus are suppressed from being attached to the pellicle film 101.

[0047]

There are other methods for improving the trimming in addition to the method in this embodiment. For example, as shown in FIG. 8A through FIG. 8C, the substrate may be trimmed by blade dicing or laser ablation. However, these methods do not avoid generation of foreign object particles 509 while the substrate 505 is cut. As a result, the foreign object particles 509 are attached to a pellicle film 501 or a pellicle frame 502, and thus the pellicle is contaminated.

[0048]

According to another method, the above-described stealth dicing may be used. With this method, no notch is made in the surface of the pellicle, which is a processing target. Therefore, on the stage of forming a quality-modified region inside the substrate, no foreign object particle is generated. However, as shown in FIG. 9A through FIG. 9D, foreign object particles 609 scatter as dust on the stage of expanding (pulling) a substrate 605 and a pressure-sensitive adhesive sheet 607 using the quality-modified region as a start point. Therefore, even with the stealth dicing, the foreign object particles 609 are attached to a pellicle film 601 or a pellicle frame 602, and thus the pellicle is contaminated.

[0049]

In this embodiment, a path through which the foreign object particles scatter outside is blocked by the pressure-sensitive adhesive sheets 106 and 107 more than by the above-described other trimming methods. Therefore, the foreign object particles 109 are suppressed from being attached to the pellicle film 101 or the pellicle frame 102.

[0050]

<EMBODIMENT 2>

Described in embodiment 2 is a method for bonding pressure-sensitive adhesive sheets in the case where a portion of the

substrate that is to be a pellicle frame and the substrate outer peripheral portion have, therebetween, an opening formed in advance and are coupled with each other via a bridge portion. In this example, a notch for the trimming merely needs to be made in the bridge portion.

5 [0051]

FIG. 5A and FIG. 5B are plan views showing positions at which pressure-sensitive adhesive sheets are bonded in embodiment 2 according to the present invention. FIG. 5A shows a state with no pressure-sensitive adhesive sheet 206. FIG. 5B shows a state where the pressure-sensitive
10 adhesive sheets 206 are bonded. FIG. 5C is a cross-sectional view taken along line C-C in FIG. 5B. A bridge portions 210 is connected to each of four corners of a pellicle frame 202. Openings 212 are provided between the pellicle frame 202 and the substrate outer peripheral portion 211, and the pellicle frame 202 and a substrate outer peripheral portion 211 are coupled
15 with each other via the bridge portions 210. Pressure-sensitive adhesive sheets 206 and 207 are bonded to cover both of two surfaces and both two side surfaces of each of the bridge portions 210. The pressure-sensitive adhesive sheets may be bonded along the openings over the bridge portions, or as shown in FIG. 5D, a pressure-sensitive adhesive sheet 207A may be
20 bonded such that a pressure-sensitive adhesive thereof fills each opening. In this example, one pressure-sensitive adhesive sheet 206 covers two bridge portions 210.

[0052]

After the pressure-sensitive adhesive sheets 206 and 207 (or 207A)
25 are bonded, a notch is made inside each of the bridge portions at the four corners. The notch is made along a direction perpendicular to the direction in which the bridge portion 210 extends (e.g., the notch is made in the direction of line C-C). Then, the pressure-sensitive adhesive sheet 207 or

207A and the bridge portions 210 are expanded to separate the bridge portions, so that the pellicle frame is formed. After this, the pressure-sensitive adhesive sheets 206 and 207 (or 207A) are irradiated with ultraviolet light to be peeled off. Thus, the trimming is finished.

5 [0053]

<EMBODIMENT 3>

In embodiment 3, the structure of the substrate is the same as that in embodiment 2. The pressure-sensitive adhesive sheets are bonded in a different manner.

10 [0054]

FIG. 6A is a plan view showing positions at which pressure-sensitive adhesive sheets are bonded in embodiment 3 according to the present invention. FIG. 6B is a cross-sectional view taken long line D-D in FIG. 6A. Like in embodiment 2, pressure-sensitive adhesive sheets 306 and 307 are bonded to cover both of two surfaces and both two side surfaces of each of the bridge portions 210. In this embodiment, one pressure-sensitive adhesive sheet 306 and one pressure-sensitive adhesive sheet 307 cover each of the bridge portions 210. The pressure-sensitive adhesive sheets may be bonded along openings 212 over the bridge portions 210, or as shown in FIG. 6C, a pressure-sensitive adhesive sheet 307A may be bonded such that a pressure-sensitive adhesive thereof fills each opening 212. The method for separation and the like are substantially the same as those in embodiment 2 and will not be described here.

25 **REFERENCE SIGNS LIST**

[0055]

1: Pellicle-attached photomask

10: Pellicle

	101, 201, 401, 501, 601: Pellicle film
	102, 402, 502, 602; Pellicle frame
	103: Frame body
	104: Photomask
5	105, 405, 505, 605: Substrate
	106, 206, 306: Pressure-sensitive adhesive sheet
	107, 207, 207A, 307, 307A, 607: Pressure-sensitive adhesive sheet
	108, 608: Notch
	109, 409, 509, 609: Foreign object particles
10	210: Bridge portion
	111, 211: Substrate outer peripheral portion
	212: Opening

CLAIMS

1. A method for producing a pellicle including a pellicle film and a pellicle frame supporting an outer peripheral portion of the pellicle film, the method
5 comprising:
forming the pellicle film on a substrate, and bonding a pressure-sensitive adhesive sheet to each of two surfaces of the substrate, the pressure-sensitive adhesive sheet being elastic and having a pressure-sensitive adhesive force thereof decreased upon receipt of external stimulation;
10 making a notch inside a part of the substrate, the part having the pressure-sensitive adhesive sheets bonded thereto;
separating a substrate outer peripheral portion outer to the notch of the substrate, in a state where the pressure-sensitive adhesive sheets are bonded to the substrate, to form the pellicle frame; and
15 stimulating the pressure-sensitive adhesive sheets to peel off the pressure-sensitive adhesive sheets.
2. The method for producing a pellicle according to claim 1, further comprising etching the substrate, from a surface opposite to a surface on which
20 the pellicle film is formed, to expose the pellicle film.
3. The method for producing a pellicle according to claim 1 or 2, wherein:
after the substrate is etched, from a surface opposite to a surface on which the pellicle film is formed, to expose the pellicle film, the pressure-sensitive
25 adhesive sheet is bonded to each of the two surfaces of a portion of the substrate that is around the exposed portion of the pellicle film.
4. The method for producing a pellicle according to any one of claims 1

through 3, wherein:

the substrate has openings provided between a portion of the substrate to be the pellicle frame and the substrate outer peripheral portion includes a bridge portion coupling the portion of the substrate to be the pellicle frame and the substrate outer peripheral portion to each other; and

making the notch inside the substrate is making the notch inside the bridge portion.

5. The method for producing a pellicle according to claim 4, wherein the pressure-sensitive adhesive sheets are bonded to cover both of two surfaces and both of two side surfaces of the bridge portion.

6. The method for producing a pellicle according to claim 4 or 5, wherein the bridge portion is connected to each of four corners of the pellicle frame.

7. The method for producing a pellicle according to any one of claims 1 through 6, wherein the notch is made inside the substrate by stealth dicing.

8. The method for producing a pellicle according to any one of claims 1 through 7, wherein the pressure-sensitive adhesive sheets are antistatic.

9. The method for producing a pellicle according to any one of claims 1 through 8, wherein for separating the substrate outer peripheral portion to form the pellicle frame, gas in a portion along which the substrate is separated is absorbed by an absorption device.

10. The method for producing a pellicle according to any one of claims 1 through 9, the pellicle film has a thickness of 10 nm or greater and 50 nm or less.

11. A method for producing a pellicle-attached photomask, comprising joining the pellicle produced by the method for producing a pellicle according to any one of claims 1 through 10, and a photomask, to each other via a frame body attached to the pellicle frame.