

DESCRIPTION

Title of Invention

RESIN FILM-FORMING SHEET, RESIN FILM-FORMING COMPOSITE SHEET, AND SILICON WAFER REGENERATION METHOD

Technical Field

[0001]

The present invention relates to a resin film-forming sheet, and a resin film-forming composite sheet having a configuration of the resin film-forming sheet laminated on a supporting sheet, and to a method of regenerating a silicon wafer.

Background Art

[0002]

These days, the fabricating of a semiconductor device using a mounting method of what is called the face-down system is performed. In the face-down system, a semiconductor chip (hereinafter, occasionally simply referred to as a "chip") having electrodes such as bumps is mounted on a circuit surface of a substrate, and the electrodes of the chip are joined to the substrate. Hence, there is a case where the surface of a chip on the side opposite to the side bonded to the substrate (hereinafter, occasionally simply referred to as "the back surface of the chip") is exposed.

[0003]

On the exposed back surface of the chip, a resin film of an organic material may be formed, and may be incorporated into a semiconductor device as a resin film-having chip. The resin film may exhibit a function as a protective film for preventing cracking in a singulation step or after packaging, or a function as an adhesive film for adhering the resultant chip onto any other member such as a die pad member or any other different semiconductor chip or the like.

In general, the resin film-having chip may be produced according to a spin coating method or the like where a solution of a resin-containing composition is applied onto the back surface of a wafer to form a coating film thereon and then the coating film is dried and cured to give a resin film, and thereafter the resultant resin film-having wafer is singulated.

[0004]

Another method is also employable where a curable resin film-forming sheet is stuck onto the back surface of a wafer and, before and after wafer singulation, the resin film-forming sheet is cured through energy ray irradiation or heating to form a resin film, thereby producing a resin film-having wafer or a resin film-having chip.

As such a material for forming, on the back surface of a chip or on the back surface of a wafer, a resin film that exhibits a function as a protective film or an adhesive film, various resin film-forming sheets have been proposed.

For example, PTL 1 discloses a chip-protective film having such a configuration that an energy ray-curable protective film-forming layer containing a polymer component of an acrylic copolymer, an energy ray-curable component, a dye or a pigment, an inorganic filler and a photopolymerization initiator is sandwiched between two release sheets.

The description in PTL 1 says that the chip-protective film can form a protective film having good laser marking recognition performance, hardness and adhesiveness to wafer through irradiation with energy rays, and that the process for the film can be simplified as compared with that for conventional chip-protective films.

[0005]

PTL 2 discloses a singulation tape-integrated wafer back surface-protective film, which has a singulation tape having a substrate and a pressure sensitive adhesive layer, and which has, on the pressure sensitive adhesive layer of the singulation tape, a wafer back surface-protective film colored and having a given elastic modulus.

The description in PTL 2 says that the wafer back surface-protective film exhibits a good holding power to a semiconductor wafer in a step of singulation of semiconductor wafers.

Citation List

Patent Literature

[0006]

PTL 1: JP-A 2009-138026

PTL-2: JP-A 2010-199543

Summary of Invention

Technical Problem

[0007]

In a step of sticking the protective film described in PTLs 1 and 2 to a wafer, there may occur some problems that the position of the protective film to be stuck to the wafer may misalign, or some foreign substances may stick to a wafer and a protective film may be stuck to the wafer along with the foreign substances kept existing therebetween. In such cases, the protective film that has been once stuck to a wafer is difficult to rework (remove for resticking) from the wafer.

In particular, the protective films disclosed in PTLs 1 and 2 are for improving the adhesiveness thereof to wafer in sticking, and for improving the holding power thereof to wafer after sticking, and therefore once stuck onto a wafer, the protective film is extremely difficult to rework from the wafer since the adhesiveness to wafer is high.

In other words, wafer may be broken by the power applied thereto for forcibly peeling the protective film once stuck to the wafer, or even when the protective film could be peeled without breaking the wafer, a part of the protective film may remain on the wafer.

In PTLs 1 and 2, the protective films described therein are investigated in point of the adhesiveness thereof to wafer in sticking and in point of the holding power to wafer after sticking, but nothing is investigated therein in point of the reworking possibility of the protective film once stuck to a wafer.

[0008]

Not only one may become aware of a need of reworking a protective film for resticking immediately after the protective film has been stuck to a wafer, but also one may often become aware of a need of reworking the protective film after a laminate of a protective film stuck onto a wafer has been left as such for 24 hours or so after sticking in many cases.

With a lapse of a longer time after a protective film has been stuck to a wafer, the adhesiveness between the protective film and the wafer increases more, and therefore, in general, reworking the protective film becomes more difficult.

[0009]

Emphasizing the reworkability thereof after stuck to a silicon wafer, the use of a protective film designed to have a rough surface on the side thereof to be stuck to a wafer may be taken into consideration, but such a protective film may

have other problems in that, after stuck to a wafer, the edge thereof may swell or peel easily and the edge adhesiveness thereof is poor.

[0010]

The present invention has been made in consideration of the above-mentioned problems, and its object is to provide a resin film-forming sheet excellent in reworkability and edge adhesiveness, and a resin film-forming composite sheet having a configuration of the resin film-forming sheet laminated on a supporting sheet, and to provide a silicon wafer regeneration method.

Solution to Problem

[0011]

The present inventors have found that a resin film-forming sheet prepared by adjusting the surface roughness and the adhesive strength to a silicon wafer of the surface thereof on the side that is to be stuck to a silicon wafer, and also the adhesive strength to the pressure sensitive adhesive layer of an ordinary pressure sensitive adhesive sheet of the other surface thereof on the side opposite to the former surface can solve the above-mentioned problems, and have completed the present invention.

[0012]

Specifically, the present invention provides the following [1] to [10].

[1] A resin film-forming sheet which is to be stuck to a silicon wafer to form a resin film on the silicon wafer and which satisfies the following requirements (I) to (III):

Requirement (I): the surface roughness (R_a) of the surface (α) of the resin film-forming sheet on the side thereof to be stuck to a silicon wafer is 50 nm or less:

Requirement (II): the adhesive strength (α_1) of the surface (α) of the resin film-forming sheet to a silicon wafer is 1.0 to 7.0 N/25 mm; and

Requirement (III): the adhesive strength (β_1) of the surface (β) of the resin film-forming sheet on the side opposite to the side thereof to be stuck to a silicon wafer, to the pressure sensitive adhesive layer of a pressure sensitive adhesive sheet having a pressure sensitive adhesive layer formed of a pressure sensitive adhesive that contains 100 parts by mass of an acrylic resin having structural units derived from butyl acrylate and acrylic acid and having a mass-average molecular weight of 600,000 to 1,000,000, and 0.01 to 10 parts by mass of a crosslinking agent, and having a thickness of 10 to 50 μm , is 4.0 N/25 mm or more.

[2] The resin film-forming sheet according to the above [1], which has a storage elastic modulus at 23°C of 0.10 to 20 GPa.

[3] The resin film-forming sheet according to the above [1] or [2], wherein the contact angle with water on the surface (β) of the resin film-forming sheet is 70 to 110°.

[4] The resin film-forming sheet according to any one of the above [1] to [3], which contains a polymer component (A) and a curable component (B).

[5] The resin film-forming sheet according to the above [4], wherein the polymer component (A) contains an acrylic polymer (A1).

[6] The resin film-forming sheet according to the above [5], wherein the acrylic polymer (A1) is an acrylic copolymer having a structural unit (a1) derived from an alkyl (meth)acrylate and a structural unit (a2) derived from a nitrile monomer.

[7] The resin film-forming sheet according to any one of the above [1] to [6], which is a protective film-forming sheet for forming a protective film on a silicon wafer.

[8] A resin film-forming composite sheet, which has a configuration in which the resin film-forming sheet of any one of the above [1] to [7] is laminated on a supporting sheet.

[9] The resin film-forming composite sheet according to the above [8], which has a configuration in which the resin film-forming sheet is sandwiched between two supporting sheets.

[10] A method for regenerating a silicon wafer by reworking a resin film-forming sheet from a laminate where the surface (α) of the resin film-forming sheet of any one of the above [1] to [7] is directly stuck to a silicon wafer,

which includes the following steps (1) and (2):

Step (1): a step of sticking the pressure sensitive adhesive layer of a pressure sensitive adhesive sheet having a substrate and a pressure sensitive adhesive layer, to the surface (β) of the resin film-forming sheet of the laminate; and

Step (2): a step of pulling the pressure sensitive adhesive sheet stuck to the surface (β) of the resin film-forming sheet in the step (1) to rework the resin film-forming sheet stuck to the silicon wafer.

Advantageous Effects of Invention

[0013]

The resin film-forming sheet of the present invention is excellent in

reworkability and edge adhesiveness.

Accordingly, in the case where a necessity of resticking the sheet has occurred after the resin film-forming sheet of the present invention has been stuck to a silicon wafer, the resin film-forming sheet can be reworked from the silicon wafer not breaking the silicon wafer while the stuck resin film-forming sheet is prevented from partly adhering to and remaining on the silicon wafer. As a result, the silicon wafer after reworking the resin film-forming sheet therefrom can be reused.

In this description, "reworking a resin film-forming sheet" means that the resin film-forming sheet that has been once stuck onto a silicon wafer is peeled.

"Reworkability of a resin film-forming sheet" means a property that, when a resin film-forming sheet is once stuck to a silicon wafer and then reworked, the sheet can be peeled without breaking the silicon wafer and without leaving a part of the resin film-forming sheet on the silicon wafer.

Brief Description of the Drawing

[0014]

Fig. 1 is a cross-sectional view of a resin film-forming composite sheet of one aspect of the present invention.

Description of Embodiments

[0015]

In this description, values of a mass-average molecular weight (M_w) and a number-average molecular weight (M_n) of each component are standard polystyrene-equivalent values measured according to a gel permeation chromatography (GPC) method, and specifically, they are values measured according to the method described in the section of Examples.

In this description, for example, "(meth)acrylate" is used as a term indicating both "acrylate" and "methacrylate", and the same shall apply to the other terms similar thereto.

Also in this description, "energy ray" indicates, for example, ultraviolet ray, electron beam and the like, and is preferably ultraviolet ray.

[0016]

[Resin Film-Forming Sheet]

The resin film-forming sheet of the present invention is a sheet to be stuck

to a silicon wafer to form a resin film on the silicon wafer and satisfies the following requirements (I) to (III):

Requirement (I): The surface roughness (Ra) of the surface (α) of the resin film-forming sheet on the side thereof to be stuck to a silicon wafer (hereinafter this may be simply referred to as "the surface roughness (Ra) of the surface (α)") is 50 nm or less.

Requirement (II): The adhesive strength ($\alpha 1$) of the surface (α) of the resin film-forming sheet to a silicon wafer (hereinafter this may be simply referred to as "the adhesive strength ($\alpha 1$) of the surface (α)") is 1.0 to 7.0 N/25 mm.

Requirement (III): The adhesive strength ($\beta 1$) of the surface (β) of the resin film-forming sheet on the side opposite to the side thereof to be stuck to a silicon wafer, to the pressure sensitive adhesive layer of a pressure sensitive adhesive sheet having a pressure sensitive adhesive layer formed of a pressure sensitive adhesive that contains 100 parts by mass of an acrylic resin having structural units derived from butyl acrylate and acrylic acid and having a mass-average molecular weight of 600,000 to 1,000,000, and 0.01 to 10 parts by mass of a crosslinking agent, and having a thickness of 10 to 50 μm (hereinafter this may be simply referred to as "the adhesive strength ($\beta 1$) of the surface (β)"), is 4.0 N/25 mm or more.

[0017]

The surface (α) of the resin film-forming sheet of the present invention is a surface on the side thereof to be stuck to a silicon wafer, and the surface (β) is a sticking surface to the pressure sensitive adhesive layer of an ordinary pressure sensitive adhesive sheet to be stuck for reworking the resin film-forming sheet from a silicon wafer after stuck to a silicon wafer.

The form of the resin film-forming sheet of the present invention is not specifically limited and includes, for example, a long tape-like form, a single-leaf label-like form, etc.

[0018]

The resin film-forming sheet of one aspect of the present invention may be a single-layered sheet of one layer formed of one kind of a composition, or may also be a composite sheet of two or more layers formed of two or more kinds of compositions.

In the case where the resin film-forming sheet of one aspect of the present invention is a composite sheet of two or more layers, the kinds of the components

as well as the blending amount thereof to be contained in the composition (α') of a forming material for the layer on the side of the surface (α) and in the composition (β') of a forming material for the layer on the side of the surface (β) are preferably so controlled as to satisfy the above-mentioned requirements (I) to (III). Consequently, it is preferable that the composition (α') and the composition (β') differ from each other.

[0019]

<Requirement (I)>

The resin film-forming sheet of the present invention satisfies the above-mentioned requirement (I), and therefore after stuck to a wafer, the wafer edges can be prevented from swelling or peeling and can have excellent edge adhesiveness.

In other words, when the surface roughness (Ra) of the surface (α) is more than 50 nm and when the resultant resin film-forming sheet is stuck to a silicon wafer, the adhesiveness of the sheet to the silicon wafer is insufficient and especially the silicon wafer edges may readily swell or peel to cause edge adhesion failure. In such adhesion failure, especially edge adhesion failure, washing water may penetrate into the interface between the resin film-forming sheet and the silicon wafer in singulation so that the surface of the silicon wafer may be contaminated or chipping may occur during singulation.

[0020]

From the above-mentioned viewpoint, the surface roughness (Ra) of the surface (α) of the resin film-forming sheet of one aspect of the present invention is preferably 40 nm or less, more preferably 35 nm or less, even more preferably 30 nm or less, still more preferably 25 nm or less.

In addition, from the viewpoint of providing a resin film-forming sheet having more improved reworkability, the surface roughness (Ra) of the surface (α) is preferably 5 nm or more, more preferably 10 nm or more, even more preferably 15 nm or more.

[0021]

In this description, the surface roughness (Ra) of the surface (α) is a value measured according to JIS B0601:2001, and more specifically, it means a value measured according to the method described in the section of Examples.

The surface roughness (Ra) of the surface (α) may be controlled, for example, by suitably defining the kind, the mean particle size and the content of

the fine particle components of the inorganic filler, the colorant and the like to be contained in the resin film-forming sheet. It may also be controlled according to a method of sticking the rough surface of a release film having a rough surface, onto the surface (α) of the resin film-forming sheet to transfer the rough shape.

[0022]

<Requirement (II)>

The resin film-forming sheet of the present invention satisfies the requirement (II), and is therefore reworkable even after lapse of time of 24 hours or so while keeping the adhesiveness thereof to a silicon wafer, especially the edge adhesiveness thereto good.

For example, conventional resin film-forming sheets such as those described in PTLs 1 and 2 are in many cases for the purpose of improving the adhesiveness to silicon wafer and the retentiveness thereof, and material planning for increasing the value of the adhesive strength of the surface (α) as defined in the requirement (II) has been made.

However, when the adhesive strength (α_1) of the surface (α) is more than 7.0 N/25 mm, it becomes often difficult to rework the resultant resin film-forming sheet from a silicon wafer after having been stuck thereto. In particular, with lapse of a longer time after sticking to a silicon wafer, the adhesiveness between the silicon wafer and the resin film-forming sheet increases more, and therefore when the resin film-forming sheet is forcedly reworked from the silicon wafer, the silicon wafer may often be broken by the reworking force.

On the other hand, when the adhesive strength (α_1) of the surface (α) is less than 1.0 N/25 mm, the adhesiveness thereof to a silicon wafer is insufficient and in particular, when the resultant resin film-forming sheet is stuck to a silicon wafer, the edges of the silicon wafer may swell or peel and the edge adhesiveness is therefore poor.

Given the situation, in the resin film-forming sheet of the present invention, the adhesive strength (α_1) of the surface (α) is controlled to fall within the range defined by the requirement (II).

[0023]

The adhesive strength (α_1) of the surface (α) of the resin film-forming sheet of one aspect of the present invention is, from the viewpoint of providing a resin film-forming sheet having improved adhesiveness to a silicon wafer, especially having improved edge adhesiveness after stuck to a silicon wafer,

preferably 1.3 N/25 mm or more, more preferably 1.5 N/25 mm or more, even more preferably 1.8 N/25 mm or more, still more preferably 2.0 N/25 mm or more, and is, from the viewpoint of providing a resin film-forming sheet having improved reworkability, preferably 6.8 N/25 mm or less, more preferably 6.5 N/25 mm or less, even more preferably 6.0 N/25 mm or less, still more preferably 5.5 N/25 mm or less.

[0024]

In this description, the adhesive strength (α_1) of the surface (α) means a value measured according to the method described in the section of Examples.

The adhesive strength (α_1) of the surface (α) can be controlled to fall within the above-mentioned range by suitably selecting the kind and the content of the polymer component, the curable component, the inorganic filler, the additive and others to be contained in the composition of a forming material for the layer on the side of the surface (α) of the resin film-forming sheet. Specifically, it can be readily controlled in consideration of suitable combination of the matters in the item of each component to be contained in the resin film-forming sheet.

[0025]

<Requirement (III)>

The resin film-forming sheet of the present invention satisfies the requirement (III) and is therefore still reworkable even after lapse of time of 24 hours or so.

After the resin film-forming sheet of the present invention has been stuck to a silicon wafer and when there has occurred a necessity of repeeling the resin film-forming sheet, the pressure sensitive adhesive layer of an ordinary pressure sensitive adhesive sheet is stuck to the surface (β) of the resin film-forming sheet and the pressure sensitive adhesive sheet is pulled whereby the resin film-forming sheet can be reworked from the silicon wafer.

In this case where the adhesive strength (β_1) of the surface (β) is less than 4.0 N/25 mm, when the surface (β) is stuck to the pressure sensitive adhesive layer of the pressure sensitive adhesive sheet and even when the resin film-forming sheet is tried to peel along with the pressure sensitive adhesive sheet, a part of the resin film-forming sheet may tend to remain on the silicon wafer and therefore the silicon wafer after reworking could no more be reused.

[0026]

From the above-mentioned viewpoint, the adhesive strength (β_1) of the surface (β) of the resin film-forming sheet of one aspect of the present invention is preferably 4.5 N/25 mm or more, more preferably 5.0 N/25 mm or more.

The upper limit of the adhesive strength of the surface (β) is not specifically limited, but the adhesive strength (β_1) of the surface (β) is generally 20 N/25 mm or less.

[0027]

The adhesive strength (β_1) of the surface (β) of the resin film-forming sheet defined by the requirement (III) is a adhesive strength to the pressure sensitive adhesive layer of a pressure sensitive adhesive sheet having a pressure sensitive adhesive layer formed of a pressure sensitive adhesive that contains 100 parts by mass of an acrylic resin having structural units derived from butyl acrylate and acrylic acid and having a mass-average molecular weight of 600,000 to 1,000,000, and 0.01 to 10 parts by mass of a crosslinking agent, and having a thickness of 10 to 50 μm .

The composition of the pressure sensitive adhesive is one defined for a commercially-available ordinary acrylic pressure sensitive adhesive, and the requirement (III) is to define the adhesive strength of the surface (β) to a pressure sensitive adhesive layer formed of an ordinary acrylic pressure sensitive adhesive.

The pressure sensitive adhesive to satisfy the requirement (III) is an extremely ordinary acrylic pressure sensitive adhesive that is widely distributed on the market.

Consequently, the selectivity of the pressure sensitive adhesive sheet to be used in reworking the resin film-forming sheet of the present invention from a silicon wafer is extremely broad, and it is possible to rework the sheet by using a pressure sensitive adhesive sheet having a pressure sensitive adhesive layer formed of an ordinary acrylic pressure sensitive adhesive.

[0028]

More specifically, the adhesive strength (β_1) of the surface (β) means a value measured according to the method described in the section of Examples.

The adhesive strength (β_1) of the surface (β) can be controlled to fall within the above-mentioned range by suitably selecting the kind and the content of the polymer component, the curable component, the inorganic filler, the additive and others to be contained in the composition of a forming material for the layer on the side of the surface (β) of the resin film-forming sheet.

Specifically, it can be readily controlled in consideration of suitable combination of the matters in the item of each component to be contained in the resin film-forming sheet.

[0029]

In the resin film-forming sheet of one aspect of the present invention, the adhesive strength (β 1) of the surface (β) is, from the viewpoint of providing a resin film-forming sheet having further improved reworkability, preferably a higher value than the adhesive strength (α 1) of the surface (α).

From the above-mentioned viewpoint, the difference between the adhesive strength (β 1) and the adhesive strength (α 1) [$(\beta$ 1) - (α 1)] is preferably 0 to 8.0 N/25 mm, more preferably 0.1 to 7.0 N/25 mm, even more preferably 0.5 to 6.0 N/25 mm, still more preferably 1.5 to 5.5 N/25 mm.

[0030]

The storage elastic modulus at 23°C of the resin film-forming sheet of one aspect of the present invention is preferably 0.10 to 20 GPa, more preferably 0.15 to 15 GPa, even more preferably 0.20 to 10 GPa, still more preferably 0.30 to 5.0 GPa.

When the storage elastic modulus is 0.10 GPa or more and when the resin film-forming sheet is stuck to a silicon wafer and is again peeled, a phenomenon of cobwebbing-like deformation of the resin film-forming sheet can be prevented and the resin film-forming sheet can be peeled without leaving the resin film-forming sheet partly on the silicon wafer.

On the other hand, when the storage elastic modulus is 20 GPa or less, the adhesiveness to a silicon wafer can be bettered.

In this description, the storage elastic modulus of the resin film-forming sheet means a value measured according to the method described in the section of Examples.

[0031]

The contact angle with water on the surface (β) of the resin film-forming sheet of one aspect of the present invention is, from the viewpoint of providing a resin film-forming sheet having further improved reworkability, preferably 70 to 110°, more preferably 75 to 100°, even more preferably 80 to 95°, still more preferably 83 to 93°.

In this description, the contact angle with water on the surface (β) of the resin film-forming sheet means a value measured according to the method

described in the section of Examples.

[0032]

<Constituent Components of Resin Film-Forming Sheet>

The resin film-forming sheet of one aspect of the present invention is not specifically limited so far as it has the surface (α) and the surface (β) satisfying the requirements (I) to (III), but preferably contains a polymer component (A) and a curable component (B).

Further, the resin film-forming sheet of one aspect of the present invention may contain, from the viewpoint of forming the surface (α) and the surface (β) satisfying the requirements (I) to (III), one or more selected from an inorganic filler (C), a colorant (D), a coupling agent (E), a leveling agent (F) and an ordinary additive (G) along with the above-mentioned components (A) and (B) within a range not detracting from the advantageous effects of the present invention.

The above-mentioned components (A) to (G) that may be the constituent components of the resin film-forming sheet of one aspect of the present invention are described below.

[0033]

[Polymer Component (A)]

In this description, the "polymer component" means a compound having a mass-average molecular weight (Mw) of 20,000 or more and having at least one kind of repeating units.

The resin film-forming sheet for use in one aspect of the present invention contains a polymer component (A) and therefore can be given flexibility and film formability and can better sheet property retentiveness. As a result, the storage elastic modulus at 23°C of the resin film-forming sheet can be controlled to fall within the above-mentioned range.

The mass-average molecular weight (Mw) of the polymer component (A) is, from the viewpoint of controlling the storage elastic modulus at 23°C of the resultant resin film-forming sheet to fall within the above-mentioned range, preferably 20,000 or more, more preferably 20,000 to 3,000,000, even more preferably 50,000 to 2,000,000, still more preferably 100,000 to 1,500,000.

[0034]

The content of the polymer component (A) in the resin film-forming sheet of one aspect of the present invention is preferably 5 to 50% by mass relative to

the total mass (100% by mass) of the resin film-forming sheet, more preferably 8 to 40% by mass, even more preferably 10 to 35% by mass, still more preferably 15 to 30% by mass.

[0035]

In this description, the "content of the component (A) relative to the total mass of the resin film-forming sheet" has the same meaning as that of the "content of the component (A) relative to the total mass of the active ingredient in the composition that is a forming material for the resin film-forming sheet", and the same shall apply to the content of the other components to be described hereinunder.

In other words, regarding the definition of the content of each component, the wording "relative to the total mass (100% by mass) of the resin film-forming sheet" may be replaced by the wording "relative to the total mass (100% by mass) of the active ingredient in the composition that is a forming material for the resin film-forming sheet".

Further, the above-mentioned "active ingredient" means an ingredient excluding substances that would not have any direct or indirect influence on the reaction and on the physical properties of the sheet to be formed, such as solvent or the like in the composition. Specifically, it means an ingredient other than solvent such as water and organic solvent or the like.

[0036]

The polymer component (A) preferably contains an acrylic polymer (A1), but may contain a non-acrylic polymer (A2) except an acrylic polymer (A1), such as polyester, phenoxy resin, polycarbonate, polyether, polyurethane, polysiloxane, rubber-type polymer, etc.

One alone or two or more of these polymer components may be used either singly or as combined.

[0037]

The content of the acrylic polymer (A1) relative to the total mass (100% by mass) of the polymer component (A) contained in the resin film-forming sheet of one aspect of the present invention is preferably 50 to 100% by mass, more preferably 60 to 100% by mass, even more preferably 70 to 100% by mass, still more preferably 80 to 100% by mass.

[0038]

(Acrylic Polymer (A1))

The mass-average molecular weight (Mw) of the acrylic polymer (A1) is, from the viewpoint of imparting flexibility and film formability to the resin film-forming sheet and from the viewpoint of controlling the storage elastic modulus at 23°C of the resin film-forming sheet to fall within the above-mentioned range, preferably 20,000 to 3,000,000, more preferably 100,000 to 1,500,000, even more preferably 150,000 to 1,200,000, still more preferably 250,000 to 1,000,000.

[0039]

The acrylic polymer (A1) is, from the viewpoint of controlling the adhesive strength (α 1) and (β 1) of the resin film-forming sheet to fall within the above-mentioned range, preferably an acrylic polymer having a structural unit (a1) derived from an alkyl (meth)acrylate, and is, especially from the viewpoint of controlling the adhesive strength (α 1) of the resin film-forming sheet to fall within the range, more preferably an acrylic copolymer having the structural unit (a1) and a structural unit (a2) derived from a nitrile monomer.

The acrylic polymer (A1) for use in one aspect of the present invention may contain, in addition to the structural units (a1) and (a2), a structural unit (a3) derived from any other monomer not corresponding to an alkyl (meth)acrylate and a nitrile monomer.

[0040]

One alone or two or more kinds of acrylic polymers (A1) may be used either singly or as combined.

In the case where the acrylic polymer (A1) is a copolymer, the morphology of the copolymer may be any of a block copolymer, a random copolymer, an alternate copolymer or a graft copolymer.

[0041]

(Structural Unit (a1))

The carbon number of the alkyl group of the alkyl (meth)acrylate that constitutes the structural unit (a1) is, from the viewpoint of imparting flexibility and film formability to the resin film-forming sheet, preferably 1 to 18, more preferably 1 to 12, even more preferably 1 to 8.

[0042]

Examples of the alkyl (meth)acrylate include methyl (meth)acrylate, ethyl (meth)acrylate, propyl (meth)acrylate, butyl (meth)acrylate, pentyl (meth)acrylate, 2-ethylhexyl (meth)acrylate, isooctyl (meth)acrylate, n-octyl

(meth)acrylate, n-nonyl (meth)acrylate, isononyl (meth)acrylate, decyl (meth)acrylate, lauryl (meth)acrylate, stearyl (meth)acrylate, etc.

One alone or two or more of these alkyl (meth)acrylates may be used either singly or as combined.

[0043]

Among these, an alkyl (meth)acrylate with an alkyl group having 1 to 3 carbon atoms is preferred, and methyl (meth)acrylate is more preferred.

The content of the structural unit (a1-1) derived from an alkyl (meth)acrylate with an alkyl group having 1 to 3 carbon atoms in the acrylic polymer (A1) is preferably 5 to 99% by mass relative to the total structural units (100% by mass) of the acrylic polymer (A1), more preferably 10 to 98% by mass, even more preferably 20 to 97% by mass, and still more preferably 25 to 97% by mass.

[0044]

The content of the structural unit (a1) in the acrylic polymer (A1) is preferably 50% by mass or more relative to the total structural units (100% by mass) of the acrylic polymer (A1), more preferably 50 to 99% by mass, even more preferably 55 to 98% by mass, still more preferably 60 to 97% by mass.

[0045]

(Structural Unit (a2))

Examples of the nitrile monomer that constitutes the structural unit (a2) include (meth)acrylonitrile, α -chloro(meth)acrylonitrile, α -ethoxy(meth)acrylonitrile, fumaronitrile, etc.

One alone or two or more of these nitrile monomers may be used either singly or as combined.

Among these, (meth)acrylonitrile is preferred.

[0046]

The content of the structural unit (a2) derived from a nitrile monomer in the acrylic polymer (A1) is, relative to the total structural units (100% by mass) of the acrylic polymer (A1), preferably 1 to 50% by mass, more preferably 5 to 45% by mass, even more preferably 10 to 42% by mass, still more preferably 15 to 40% by mass, further more preferably 20 to 35% by mass.

When the content of the structural unit (a2) is 1% by mass or more, the adhesive strength (α_1) of the surface (α) of the resultant resin film-forming sheet can be readily controlled to fall within the above-mentioned range. On the other

hand, when the content of the structural unit (a2) is 50% by mass or less, the adhesive strength (β 1) of the surface (β) of the resultant resin film-forming sheet can be readily controlled to fall within the above-mentioned range.

[0047]

(Structural Unit (a3))

The acrylic polymer (A1) may contain a structural unit (a3) derived from any other monomer not corresponding to an alkyl (meth)acrylate and a nitrile monomer in addition to the above-mentioned structural units (a1) and (a2), within a range not detracting from the advantageous effects of the present invention.

Examples of the other monomer to constitute the structural unit (a3) include a functional group-containing monomer having a functional group, such as a hydroxy group-containing monomer, a carboxy group-containing monomer, an epoxy group-containing monomer, etc.; a vinyl ester monomer such as vinyl acetate, vinyl propionate, etc.; an olefin monomer such as ethylene, propylene, isobutylene, etc.; an aromatic vinyl monomer such as styrene, methylstyrene, vinyltoluene, etc.; and a dienic monomer such as butadiene, isoprene, etc.

[0048]

From the viewpoint of controlling the adhesive strength (α 1) and (β 1) of the resin film-forming sheet to fall within the above-mentioned range, the acrylic polymer (A1) for use in one aspect of the present invention preferably contains a structural unit (a3-1) derived from a hydroxy group-containing monomer.

Examples of the hydroxy group-containing monomer include a hydroxyalkyl (meth)acrylate such as 2-hydroxyethyl (meth)acrylate, 2-hydroxypropyl (meth)acrylate, 3-hydroxypropyl (meth)acrylate, 2-hydroxybutyl (meth)acrylate, 3-hydroxybutyl (meth)acrylate, 4-hydroxybutyl (meth)acrylate, etc.; and an unsaturated alcohol such as vinyl alcohol, allyl alcohol, etc.

Among these, 2-hydroxyethyl (meth)acrylate is preferred.

[0049]

The content of the structural unit (a3-1) derived from a hydroxy group-containing monomer in the acrylic polymer (A1) is, from the viewpoint of controlling the adhesive strength (α 1) and (β 1) of the resin film-forming sheet to fall within the above-mentioned range, preferably 0.5 to 30% by mass relative to the total structural units (100% by mass) of the acrylic polymer (A1), more preferably 1 to 25% by mass, even more preferably 2 to 20% by mass, still more preferably 3 to 15% by mass, further more preferably 3.5 to 12% by mass.

[0050]

Further, when the content of the structural unit derived from an epoxy group-containing monomer in the acrylic polymer (A1) increases, the adhesiveness of the resultant resin film-forming sheet to a silicon wafer tends to increase and the value of the adhesive strength ($\alpha 1$) tends to increase. Consequently, the content of the structural unit derived from an epoxy group-containing monomer in the acrylic polymer (A1) is preferably smaller.

The content of the structural unit (a3-2) derived from an epoxy group-containing monomer in the acrylic polymer (A1) for use in one aspect of the present invention is, from the above-mentioned viewpoints, preferably 0 to 15% by mass relative to the total structural units (100% by mass) of the acrylic polymer (A1), more preferably 0 to 10% by mass, even more preferably 0 to 5% by mass, still more preferably 0 to 3.5% by mass.

[0051]

Examples of the epoxy group-containing monomer include an epoxy group-containing (meth)acrylate such as glycidyl (meth)acrylate, β -methylglycidyl (meth)acrylate, (3,4-epoxycyclohexyl)methyl (meth)acrylate, 3-epoxycyclo-2-hydroxypropyl (meth)acrylate, etc.; and a non-acrylic epoxy group-containing monomer such as glycidyl crotonate, allyl glycidyl ether, etc.

[0052]

In the case where an epoxy-type heat-curable component is used as the curable component (B) to be mentioned below, a carboxyl group may react with the epoxy group in the epoxy-type heat-curable component, and therefore, the content of the structural unit derived from a carboxyl group-containing monomer in the acrylic polymer (A1) is preferably smaller.

In the case where an epoxy-type heat-curable component is used as the curable component (B), the content of the structural unit (a3-3) derived from a carboxy group-containing monomer for use in one aspect of the present invention is preferably 0 to 10% by mass relative to the total structural units (100% by mass) of the acrylic polymer (A1), more preferably 0 to 5% by mass, even more preferably 0 to 2% by mass, still more preferably 0% by mass (not containing the structural unit (a3-3)).

In this description, the acrylic polymer having a structural unit derived from an epoxy group-containing monomer and having a mass-average molecular weight of 20,000 or more is heat-curable; however, this is not a curable component

(B) but is included in the concept of the polymer component (A).

[0053]

Examples of the carboxy group-containing monomer include (meth)acrylic acid, maleic acid, fumaric acid, itaconic acid, etc.

[0054]

The content of the structural unit (a3) in the acrylic polymer (A1) for use in one aspect of the present invention is preferably 0 to 30% by mass relative to the total structural units (100% by mass) of the acrylic polymer (A1), more preferably 1 to 20% by mass, even more preferably 2 to 10% by mass.

[0055]

(Non-acrylic Resin (A2))

As needed, the resin film-forming sheet of one aspect of the present invention may contain a non-acrylic polymer (A2) as the other polymer component than the above-mentioned acrylic polymer (A1).

Examples of the non-acrylic polymer (A2) include polyester, phenoxy resin, polycarbonate, polyether, polyurethane, polysiloxane, rubber polymer, etc.

One alone or two or more kinds of these non-acrylic polymers (A2) may be used either singly or as combined.

[0056]

The mass-average molecular weight (M_w) of the non-acrylic polymer (A2) is preferably 20,000 or more, more preferably 20,000 to 100,000, even more preferably 20,000 to 80,000.

[0057]

[Curable Component (B)]

The curable component (B) plays a role of curing the resin film-forming sheet to form a hard resin film, and is a compound having a mass-average molecular weight (M_w) of less than 20,000.

The resin film-forming sheet for use in the present invention preferably contains at least one of a heat-curable component (B1) and an energy ray-curable component (B2) as the curable component (B), and from the viewpoint of preventing the resin film to be formed of the resin film-forming sheet from being colored, from the viewpoint of making the curing reaction progressing sufficiently and from the viewpoint of cost reduction, the film more preferably contains a heat-curable component (B1).

The heat-curable component (B1) preferably contains a compound having

at least a functional group capable of reacting by heat, more preferably contains an epoxy group-having compound (B11).

The energy ray-curable component (B2) preferably contains a compound (B21) having a functional group that reacts through irradiation with energy rays.

The functional groups that these curable components have react with each other to form a three-dimensional network structure, thereby realizing curing.

The mass-average molecular weight (Mw) of the curable component (B) is, from the viewpoint of controlling the viscosity of the composition of a forming material for the resin film-forming sheet to thereby enhance the handleability of the composition by combined use with the component (A), preferably less than 20,000, more preferably 10,000 or less, even more preferably 100 to 10,000.

[0058]

(Heat-Curable Component (B1))

The heat-curable component (B1) is preferably an epoxy-type heat-curable component.

The epoxy-type heat-curable component is preferably a combination of an epoxy group-having component (B11) and a heat-curing agent (B12).

[0059]

Examples of the epoxy group-having compound (B11) (hereinafter also referred to as "epoxy compound (B11)") include epoxy compounds having 2 or more functional groups in the molecule, such as a polyfunctional epoxy resin, a bisphenol A diglycidyl ether and a hydrogenate thereof, a novolak-type epoxy resin such as a cresol/novolak epoxy resin, etc., a dicyclopentadiene-type epoxy resin, a biphenyl-type epoxy resin, a bisphenol A-type epoxy resin, a bisphenol F-type epoxy resin, a phenylene skeleton-having epoxy resin, etc.

One alone or two or more kinds of these epoxy compounds (B11) may be used either singly or as combined.

Among these, one or more selected from a novolak-type epoxy resin and a biphenyl-type epoxy resin is preferably contained from the viewpoint of controlling the adhesive strength ($\alpha 1$) and ($\beta 1$) of the resin film-forming sheet to fall within the above-mentioned range, and especially from the viewpoint of controlling the adhesive strength ($\alpha 1$) of the resin film-forming sheet to fall within the range, more preferably a biphenyl-type epoxy resin is contained, and even more preferably a biphenylaralkyl-type epoxy resin is contained.

[0060]

The total content of one or more selected from a novolak-type epoxy resin and a biphenyl-type epoxy resin is, relative to the total amount (100% by mass) of the epoxy compound (B11), preferably 70 to 100% by mass, more preferably 80 to 100% by mass, even more preferably 90 to 100% by mass, still more preferably 95 to 100% by mass.

From the viewpoint of controlling the adhesive strength (α_1) of the resin film-forming sheet to fall within the above-mentioned range, the content of the biphenyl-type epoxy resin is preferably 70 to 100% by mass relative to the total amount (100% by mass) of the epoxy compound (B11), more preferably 80 to 100% by mass, even more preferably 90 to 100% by mass, still more preferably 95 to 100% by mass.

[0061]

The content of the epoxy compound (B11) is preferably 1 to 500 parts by mass relative to 100 parts by mass of the component (A), more preferably 3 to 300 parts by mass, even more preferably 5 to 150 parts by mass, still more preferably 10 to 100 parts by mass.

[0062]

(Heat-Curing Agent (B12))

The heat-curing agent (B12) functions as a curing agent for the epoxy compound (B11).

The heat-curing agent is preferably a compound having 2 or more functional groups capable of reacting with an epoxy group, in one molecule.

The functional group includes a phenolic hydroxyl group, an alcoholic hydroxyl group, an amino group, a carboxyl group, an acid anhydride, etc. Among these, a phenolic hydroxyl group, an amino group and an acid anhydride are preferred, a phenolic hydroxyl group and an amino group are more preferred, and an amino group is even more preferred.

[0063]

Examples of the phenolic heat-curing agent having a phenol group include a polyfunctional phenol resin, a biphenol resin, a novolak-type phenol resin, a dicyclopentadiene-type phenol resin, a xyloc phenol resin, an aralkyl phenol resin, etc.

Examples of the amino group-having heat-curing agent include dicyandiamide (DICY), etc.

One alone or two or more kinds of these heat-curing agent (B12) may be

used either singly or as combined.

Among these, preferably a phenolic heat-curing agent is contained from the viewpoint of controlling the adhesive strength ($\alpha 1$) and ($\beta 1$) of the resin film-forming sheet to fall within the above-mentioned range.

The content of the phenolic heat-curing agent is preferably 50 to 100% by mass relative to the total amount (100% by mass) of the heat-curing agent (B12), more preferably 70 to 100% by mass, even more preferably 80 to 100% by mass, still more preferably 90 to 100% by mass.

[0064]

The content of the heat-curing agent (B12) is preferably 0.1 to 500 parts by mass relative to 100 parts by mass of the epoxy compound (B11), more preferably 1 to 200 parts by mass.

[0065]

The resin film-forming sheet of one aspect of the present invention preferably contains, from the viewpoint of controlling the adhesive strength ($\alpha 1$) and ($\beta 1$) of the resin film-forming sheet to fall within the above-mentioned range, a biphenyl-type epoxy resin as the epoxy compound (B1) and a phenolic heat-curing agent as the heat-curing agent (B12), and thus preferably contains both the components as combined.

In this case, more preferably, the sheet contains an acrylic polymer (A1) having a structural unit (a2-1) derived from a nitrile monomer, as the polymer component (A).

[0066]

(Curing Accelerator (B13))

The resin film-forming sheet of one aspect of the present invention may contain, from the viewpoint of controlling the curing rate of the sheet by heating, a curing accelerator (B13).

Preferably, the curing accelerator (B13) is used along with an epoxy compound (B11) as the heat-curable component (B1).

[0067]

Examples of the curing accelerator (B13) include tertiary amines such as triethylenediamine, benzyldimethylamine, triethanolamine, dimethylaminoethanol, tris(dimethylaminomethyl)phenol, etc.; imidazoles such as 2-methylimidazole, 2-phenylimidazole, 2-phenyl-4-methylimidazole, 2-phenyl-4,5-dihydroxymethylimidazole,

2-phenyl-4-methyl-5-hydroxymethylimidazole, etc.; organic phosphines such as tributyl phosphine, diphenyl phosphine, triphenyl phosphine, etc.; and tetraphenylboron salts such as tetraphenylphosphonium tetraphenylborate, triphenylphosphine tetraphenylborate, etc.

One alone or two or more kinds of these curing accelerators (B13) can be used either singly or as combined.

[0068]

The content of the curing accelerator (B13) is, from the viewpoint of improving the adhesiveness of the resin film formed of the resin film-forming sheet, preferably 0.01 to 10 parts by mass relative to 100 parts by mass of the total of the epoxy compound (B11) and the heat-curing agent (B12), more preferably 0.1 to 6 parts by mass, even more preferably 0.3 to 4 parts by mass.

[0069]

(Energy Ray-Curable Component (B2))

As the energy ray-curable component (B2), a compound (B21) having a functional group that reacts through irradiation with energy rays may be used singly, or the compound (B21) may be used as combined with a photopolymerization initiator (B22).

[0070]

(Compound (B21) having a functional group that reacts through irradiation with energy rays)

Examples of the compound (B21) having a functional group that reacts through irradiation with energy rays (hereinafter also referred to as "energy ray-reactive compound (B21)") include trimethylolpropane triacrylate, pentaerythritol triacrylate, pentaerythritol tetraacrylate, dipentaerythritol monohydroxy-pentaacrylate, dipentaerythritol hexaacrylate, 1,4-butyleneglycol diacrylate, 1,6-hexanediol diacrylate, oligoester acrylate, urethane acrylate oligomer, epoxy acrylate, polyether acrylate, itaconic acid oligomer, etc.

One alone or two or more kinds of these energy ray-reactive compounds (B21) may be used either singly or as combined.

The mass-average molecular weight (Mw) of the energy ray-reactive compound (B21) is preferably 100 to 30,000, more preferably 300 to 10,000.

[0071]

The content of the energy ray-reactive compound (B21) is preferably 1 to 1500 parts by mass relative to 100 parts by mass of the component (A), more

preferably 3 to 1200 parts by mass.

[0072]

(Photopolymerization Initiator (B22))

As combined with the above-mentioned energy ray-reactive compound (B21), a photopolymerization initiator (B22) may be used to shorten the polymerization curing time, thereby prosecuting the curing of the resin film-forming sheet even though the photoirradiation dose is small.

[0073]

Examples of the photopolymerization initiator (B22) include benzoin compounds, acetophenone compounds, acylphosphine oxide compounds, titanocene compounds, thioxanthone compounds, peroxide compounds, etc.

More specifically, examples of the photopolymerization initiator include 1-hydroxycyclohexyl phenyl ketone, benzoin, benzoin methyl ether, benzoin ethyl ether, benzoin isopropyl ether, benzyldiphenyl sulfide, tetramethylthiuram monosulfide, azobisisobutyronitrile, dibenzyl, diacetyl, β -chloroanthraquinone, 2,4,6-trimethylbenzoyldiphenyl phosphine oxide, etc.

One alone or two or more kinds of these photopolymerization initiators may be used either singly or as combined.

[0074]

The content of the photopolymerization initiator (B22) is, from the viewpoint of sufficiently prosecuting the curing reaction of the resin film-forming sheet and of preventing the formation of residues, preferably 0.1 to 10 parts by mass relative to 100 parts by mass of the energy ray-reactive compound (B21), more preferably 1 to 5 parts by mass.

[0075]

The content of the curable component (B) in the resin film-forming sheet of one aspect of the present invention is preferably 5 to 50% by mass relative to the total amount (100% by mass) of the resin film-forming sheet, more preferably 8 to 40% by mass, even more preferably 10 to 30% by mass, still more preferably 12 to 25% by mass.

The "content of the curable component (B)" indicates a total content of the heat-curable component (B1) including the above-mentioned epoxy compound (B11), the heat-curing agent (B12) and the curing accelerator (B13), as well as the energy ray-curable component (B2) including the energy ray-reactive compound (B21) and the photopolymerization initiator (B22).

[0076]

The total content of the polymer component (A) and the curable component (B) in the resin film-forming sheet of one aspect of the present invention is preferably 40% by mass or more relative to the total amount (100% by mass) of the resin film-forming sheet, more preferably 50% by mass or more, even more preferably 60 % by mass or more, still more preferably 70% by mass or more.

[0077]

[Inorganic Filler (C)]

Preferably, the resin film-forming sheet of one aspect of the present invention further contains an inorganic filler (C).

Containing an inorganic filler (C), the thermal expansion coefficient of the resin film to be formed of the resin film-forming sheet can be controlled to fall within a suitable range, and therefore the thermal expansion coefficient of a chip having the resin film can be optimized and the reliability of the semiconductor device with the chip incorporated therein can be thereby increased. In addition, the moisture absorption of the resin film to be formed of the resin film-forming sheet can be reduced.

[0078]

Examples of the inorganic filler (C) include powders of silica, alumina, talc, calcium carbonate, titanium oxide, iron oxide, silicon carbide, boron nitride, etc., beads produced by shaping them into spherical forms, single crystal fibers, glass fibers, etc.

One alone or two or more kinds of these inorganic fillers (C) may be used either singly or as combined.

Among these, silica and alumina are preferred.

[0079]

The mean particle size of the inorganic filler (C) is, from the viewpoint of controlling the surface roughness (Ra) of the surface (α) of the resin film-forming sheet to fall within the above-mentioned range, preferably 400 nm or less, more preferably 300 nm or less, even more preferably 200 nm or less, still more preferably 100 nm or less, and on the other hand, from the viewpoint of bettering the reliability of the resin film-attached chip to be produced using the resin film-forming sheet, preferably 10 nm or more, more preferably 20 nm or more.

In this description, the mean particle size of the inorganic filler (C) is a value measured using a laser diffraction scattering particle sizer, and means a

volume medium particle diameter (D_{50}).

[0080]

The content of the inorganic filler (C) in the resin film-forming sheet of one aspect of the present invention is, from the viewpoint of controlling the surface roughness (Ra) of the surface (α) of the resin film-forming sheet to fall within the above-mentioned range, preferably 0 to 50 % by mass relative to the total mass (100% by mass) of the resin film-forming sheet, more preferably 0 to 45% by mass, even more preferably 0 to 40% by mass, still more preferably 0 to 30% by mass.

[0081]

In the case where the resin film-forming sheet of one aspect of the present invention is a multi-layered sheet of two or more layers formed of two or more kinds of compositions, the inorganic filler (C) contained in the composition of a forming material for the layer on the side of the surface (α) of the resin film-forming sheet preferably has a small average particle size and the content thereof is preferably reduced to thereby control the surface roughness (Ra) of the surface (α).

On the other hand, in the composition of a forming material for the layer on the side of the surface (β), an inorganic filler (C') having a mean particle size of 0.01 μm or more may be incorporated within a range not having any influence on the surface roughness (Ra) of the surface (α).

The mean particle size of the inorganic filler (C') is generally 0.01 to 5 μm , preferably 0.02 to 3 μm .

[0082]

[Colorant (D)]

The resin film-forming sheet of one aspect of the present invention may further contain a colorant (D).

When the resin film-forming sheet contains a colorant (D) and when a semiconductor chip having a resin film formed of the resin film-forming sheet is incorporated in a device, the device can be shielded from IR rays and others to be generated by other surrounding devices and can be thereby protected from malfunction.

[0083]

As the colorant (D), organic or inorganic pigments and dyes can be used.

The dye may be any dye and examples thereof include acidic dyes, reactive dyes, direct dyes, disperse dyes, cationic dyes, etc.

The pigment is not specifically limited, and may be suitably selected from any known pigments.

Among these, black pigment is preferred as exhibiting good shielding performance from electromagnetic waves and IR rays and from the viewpoint of more improving the distinguishability according to a laser marking method.

Examples of the black pigment include carbon black, iron oxide, manganese dioxide, aniline black, activated carbon, etc. From the viewpoint of increasing the reliability of semiconductor chips, carbon black is preferred.

One alone or two or more kinds of these colorants (D) may be used either singly or as combined.

[0084]

The mean particle size of the colorant (D) is, from the viewpoint of controlling the surface roughness (Ra) of the surface (α) of the resin film-forming sheet to fall within the above-mentioned range, preferably 400 nm or less, more preferably 300 nm or less, even more preferably 200 nm or less, still more preferably 100 nm or less, and is preferably 10 nm or more, more preferably 20 nm or more.

In this description, the mean particle size of the colorant (D) is a value measured using a laser diffraction scattering particle sizer, and means a volume medium particle diameter (D_{50}).

[0085]

The content of the colorant (D) in the resin film-forming sheet of one aspect of the present invention is preferably 0.01 to 30% by mass relative to the total amount (100% by mass) of the resin film-forming sheet, more preferably 0.05 to 25% by mass, even more preferably 0.1 to 15% by mass, still more preferably 0.15 to 5% by mass.

[0086]

[Coupling Agent (E)]

The resin film-forming sheet of one aspect of the present invention may further contain a coupling agent (E).

Containing a coupling agent (E), the resin film formed of the resultant resin film-forming sheet can have improved waterproofness without interfering with heat resistance. In addition, the agent may contribute toward improving the edge adhesiveness of the sheet after stuck to a silicon wafer.

[0087]

The coupling agent (E) is preferably a compound to react with the functional group that the component (A) and the component (B) have, and is more preferably a silane coupling agent.

Examples of the silane coupling agent include γ -glycidoxypolytrimethoxysilane, γ -glycidoxypolydimethoxysilane, β -(3,4-epoxycyclohexyl)ethyltrimethoxysilane, γ -(methacryloxypropyl)trimethoxysilane, γ -aminopropyltrimethoxysilane, N-6-(aminoethyl)- γ -aminopropyltrimethoxysilane, N-6-(aminoethyl)- γ -aminopropylmethyldiethoxysilane, N-phenyl- γ -aminopropyltrimethoxysilane, γ -ureidopropyltriethoxysilane, γ -mercaptopropyltrimethoxysilane, γ -mercaptopropylmethyldimethoxysilane, bis(3-triethoxysilylpropyl)tetrasulfane, methyltrimethoxysilane, methyltriethoxysilane, vinyltrimethoxysilane, vinyltriacetoxysilane, imidazolesilane, etc.

One alone or two or more kinds of these coupling agents (E) may be used either singly or as combined.

[0088]

The coupling agent (E) is preferably an oligomer-type coupling agent.

The molecular weight of the coupling agent (E) including an oligomer-type coupling agent is preferably 100 to 15000, more preferably 150 to 10000, even more preferably 200 to 5000, still more preferably 250 to 3000, further more preferably 350 to 2000.

[0089]

Containing a coupling agent (E), it is considered that the agent may be bonded to an adherend, silicon wafer or to the surface of the inorganic filler (C) that is optionally contained in the resin film-forming sheet, thereby improving the adhesiveness and the aggregability to increase the adhesive strength ($\alpha 1$) of the resin film-forming sheet.

Consequently, from the viewpoint of obtaining a resin film-forming sheet having excellent reworkability, the content of the coupling agent (E) in the resin film-forming sheet of one aspect of the present invention is preferably smaller.

From the above-mentioned viewpoint, the content of the coupling agent (E) in the resin film-forming sheet of one aspect of the present invention is 3.0% by mass or less relative to the total amount (100% by mass) of the resin film-forming sheet, more preferably 1.5% by mass or less, even more preferably

0.8% by mass or less, still more preferably 0.3% by mass or less, and is, on the other hand, from the viewpoint of bettering the edge adhesiveness after sticking the resin film-forming sheet to a silicon wafer, and from the viewpoint of controlling the adhesive strength ($\beta 1$) of the surface (β) of the resin film-forming sheet to fall within the above-mentioned range, preferably 0.01% by mass or more, more preferably 0.05% by mass or more, even more preferably 0.10% by mass or more.

[0090]

[Leveling Agent (F)]

The resin film-forming sheet of one aspect of the present invention may further contain a leveling agent (F).

Containing a leveling agent (F), the adhesive strength ($\alpha 1$) of the surface (α) of the resultant resin film-forming sheet can be readily controlled to fall within the above-mentioned range.

Examples of the leveling agent (F) include a silicone-type leveling agent, a fluorine-containing leveling agent, an acrylic leveling agent, a vinylic leveling agent, a compounded leveling agent of a fluorine-containing leveling agent and an acrylic leveling agent, etc.

One alone or two or more kinds of these leveling agents (F) may be used either singly or as combined.

Among these, a silicone-type leveling agent is preferably contained from the viewpoint that the adhesive strength ($\alpha 1$) of the surface (α) of the resin film-forming sheet can be readily controlled to fall within the above-mentioned range.

[0091]

When a leveling agent (F) is contained in the resin film-forming sheet, it becomes easy to control the adhesive strength ($\alpha 1$) of the surface (α) to fall within the above-mentioned range, but the adhesive strength ($\beta 1$) of the surface (β) may lower and the reworkability of the resin film-forming sheet may therefore worsen. Consequently, the content of the leveling agent on the side of the surface (β) of the resin film-forming sheet is preferably smaller.

[0092]

From the viewpoint of controlling the adhesive strength ($\alpha 1$) of the surface (α) of the resultant resin film-forming sheet to fall within the above-mentioned range, the content of the leveling agent (F) is preferably 0.010% by mass or more

relative to the total amount (100% by mass) of the resin film-forming sheet, more preferably 0.050% by mass or more, even more preferably 0.100% by mass or more.

On the other hand, from viewpoint of controlling the adhesive strength (β_1) of the surface (β) of the resin film-forming sheet to fall within the above-mentioned range, the content of the leveling agent (F) is preferably 0.500% by mass or less relative to the total amount (100% by mass) of the resin film-forming sheet, more preferably 0.300% by mass or more, even more preferably 0.200% by mass or more.

[0093]

Further, from the viewpoint of controlling the adhesive strength (α_1) and (β_1) of the resin film-forming sheet in a well-balanced manner, one embodiment of the resin film-forming sheet of the present invention containing a leveling agent is preferably a multilayered sheet having a layer formed of a composition (α') containing a leveling agent and a layer formed of a composition (β') not substantially containing a leveling agent.

The composition (α') is to be a forming material for the layer on the side of the surface (α) of the resin film-forming sheet, and the composition (β') is to be a forming material for the layer on the side of the surface (β) of the resin film-forming sheet.

[0094]

The content of the leveling agent (F) in the composition (α') is, from the viewpoint of controlling the adhesive strength (α_1) of the surface (α) to fall within the above-mentioned range, preferably 0.010 to 10% by mass relative to the total amount (100% by mass) of the active ingredients contained in the composition (α'), more preferably 0.050 to 7% by mass, even more preferably 0.100 to 5% by mass, still more preferably 0.150 to 2% by mass.

On the other hand, the content of the leveling agent (F) in the composition (β') is, from the viewpoint of controlling the adhesive strength (β_1) of the surface (β) to fall within the above-mentioned range, preferably 0 to 0.500% by mass relative to the total amount (100% by mass) of the active ingredients contained in the composition (β'), more preferably 0 to 0.100% by mass, even more preferably 0 to 0.010% by mass, still more preferably 0 to 0.001% by mass.

[0095]

[Wide-Use Additive (G)]

Within a range not detracting from the advantageous effects of the present invention, the resin film-forming sheet for use in one aspect of the present invention may contain, as needed, a wide-use additive (G) in addition to the above-mentioned components.

Examples of the wide-use additive (G) include a crosslinking agent, a plasticizer, an antistatic agent, an antioxidant, an ion scavenger, a gettering agent, a chain transfer agent, etc.

Among these, a crosslinking agent is preferably contained.

Examples of the crosslinking agent include an isocyanate-type crosslinking agent, an epoxy-type crosslinking agent, an aziridine-type crosslinking agent, a metal chelate-type crosslinking agent, an amine-type crosslinking agent, an amino resin-type crosslinking agent, etc. One alone or two or more kinds of these crosslinking agents may be used either singly or as combined.

[0096]

The content of each of such wide-use additives (G) in the resin film-forming sheet of one aspect of the present invention is preferably 0 to 10% by mass relative to the total amount (100% by mass) of the resin film-forming sheet, more preferably 0 to 5% by mass, even more preferably 0 to 2% by mass.

[0097]

<Method for Producing Resin Film-Forming Sheet>

The method for producing a resin film-forming sheet of one aspect of the present invention is not specifically limited, and the sheet can be produced according to a known method.

For example, a resin film-forming composition containing the above-mentioned components, which is to be a forming material for the resin film-forming sheet, is prepared, and then properly diluted with an organic solvent added thereto to give a solution of the resin film-forming composition. With that, the solution of the resin film-forming composition is applied onto a supporting sheet according to a known coating method to form a coating film, and the coating film is dried to produce a resin film-forming sheet.

[0098]

In the case where the resin film-forming sheet of one aspect of the present invention is a multilayered sheet formed of two layers or more, a method for producing the resin film-forming sheet includes, for example, applying a solution

of a resin film-forming composition for each layer individually onto each of two or more supporting sheets to form a coating film thereon, sticking the coating films to give a layered coating film, and then drying the layered coating film.

[0099]

Examples of the organic solvent for use in preparing the solution of a resin film-forming composition include toluene, ethyl acetate, methyl ethyl ketone, etc.

The solid concentration of the solution of a resin film-forming composition containing an organic solvent added thereto is preferably 10 to 80% by mass, more preferably 20 to 70% by mass, even more preferably 30 to 65% by mass.

Examples of the coating method include a spin coating method, a spray coating method, a bar coating method, a knife coating method, a roll coating method, a roll knife coating method, a blade coating method, a die coating method, a gravure coating method, etc.

[0100]

The thickness of the resin film-forming sheet of one aspect of the present invention may be suitably defined depending on the use thereof, but is preferably 3 to 300 μm , more preferably 5 to 250 μm , even more preferably 7 to 200 μm .

Also in the case where the resin film-forming sheet has a multilayered sheet formed of two layers or more, the total thickness of the multilayered sheet is preferably within the above-mentioned range.

[0101]

[Use of Resin Film-Forming Sheet]

The resin film-forming sheet of one aspect of the present invention may be stuck to the back surface of a workpiece such as a semiconductor wafer for chips or such as a silicon wafer, a semiconductor chip or the like of a face-down system to form a resin film on the workpiece. The resin film has a function as a protective film for protecting the back surface of a workpiece such as a semiconductor wafer, a semiconductor chip or the like. For example, in the case where the sheet is stuck to a semiconductor wafer, the resin film has a function of reinforcing the wafer and therefore the wafer can be prevented from being broken.

In other words, the resin film-forming sheet of one aspect of the present invention is preferably a protective film-forming sheet for forming a protective film on a silicon wafer.

[0102]

The resin film formed of the resin film-forming sheet of one aspect of the

present invention can be given a function as an adhesive film. In other words, in the case where the resin film formed using the resin film-forming sheet of one aspect of the present invention has a function as an adhesive film, the chip having the resin film may be adhered onto a die pad part or to any other member of a different semiconductor chip or the like (onto a chip-moulding part), and can therefore contribute toward improving the productivity for producing semiconductor devices.

In other words, the resin film-forming sheet of one aspect of the present invention can be an adhesive film-forming sheet for forming an adhesive film on a silicon wafer.

[0103]

[Configuration of Resin Film-forming Composite Sheet]

The resin film-forming composite sheet of the present invention (hereinafter simply referred to as "composite sheet") has a configuration in which the above-mentioned resin film-forming sheet capable of forming a resin layer of the present invention is laminated on a supporting sheet.

The form of the composite sheet of one aspect of the present invention is not specifically limited and includes, for example, a long tape-like form, a single-leaf label-like form, etc.

Fig. 1 is a cross-sectional view of a resin film-forming composite sheet of one aspect of the present invention.

The composite sheet of one aspect of the present invention includes a composite sheet 1a having a configuration in which a resin film-forming sheet 10 is directly laminated on a supporting sheet 11, as shown in Fig. 1(a).

The form of the resin film-forming sheet 10 of the composite sheet of one aspect of the present invention may be nearly the same form as that of a silicon wafer of an adherend, or may be a form capable of including the form of a silicon wafer.

[0104]

In the composite sheet 1a of Fig. 1(a), the supporting sheet 11 and the resin film-forming sheet 10 have nearly the same form, but as shown in Fig. 1(b), the form of the resin film-forming sheet 10 may be a composite sheet 1b smaller than the form of the supporting sheet 11.

[0105]

The composite sheet of one aspect of the present invention also includes a

composite sheet 1c having a ring-like jig-adhering layer 12, as shown in Fig. 1(c).

The ring-like jig-adhering layer 12 is provided for the purpose of improving the adhesion power to a jig in adhering the sheet to a jig such as a ring flame or the like, and may be formed of a double-face pressure sensitive adhesive sheet having a substrate (core material) or of a pressure sensitive adhesive.

In the composite sheet 1c shown in Fig. 1(c), the jig-adhering layer 12 is arranged on the composite sheet 1a of Fig. 1(a), but the composite sheet of one aspect of the present invention may also include such a configuration in which the jig-adhering layer 12 is arranged on the surface of the supporting sheet 11 of the composite sheet 1b shown in Fig. 1(b).

[0106]

The composite sheet of one aspect of the present invention may be a composite sheet 1d where a resin film-forming sheet 10 is sandwiched between two supporting sheets 11 and 11' as shown in Fig. 1(d).

Like in the configuration of the composite sheet 1d, any other supporting sheet than the supporting sheet 11 may be arranged on the exposed surface of the resin film-forming sheet 10 of the composite sheet 1b of Fig. 1(b).

Also similarly, any other supporting sheet than the supporting sheet 11 may be arranged on the surface of the resin film-forming sheet 10 and on the surface of the jig-adhering layer 12 of the composite sheet 1c shown in Fig. 1(c).

[0107]

<Supporting Sheet>

The supporting sheet that the composite sheet of one aspect of the present invention has is a release sheet for preventing adhesion of dust and others to the surface of the resin film-forming sheet, or a sheet that plays a role of a singulation sheet or the like for protecting the surface of the resin film-forming sheet in the singulation step or the like.

[0108]

The supporting sheet for use in the present invention preferably has a configuration having a resin film.

Examples of the resin film include a polyethylene film such as a low-density polyethylene (LDPE) film, a linear low-density polyethylene (LLDPE) film, etc., and an ethylene-propylene copolymer film, a polypropylene film, a polybutene film, a polybutadiene film, a polymethylpentene film, a polyvinyl chloride film, a vinyl chloride copolymer film, a polyethylene terephthalate film, a

polyethylene naphthalate film, a polybutylene terephthalate film, a polyurethane film, an ethylene-vinyl acetate copolymer film, an ionomer resin film, an ethylene-(meth)acrylic acid copolymer film, an ethylene-(meth)acrylate copolymer film, a polystyrene film, a polycarbonate film, a polyimide film, a fluororesin film, etc.

The supporting sheet for use in one aspect of the present invention may be a single-layer film formed of one kind of a resin film, or may be a laminate film produced by laminating two or more kinds of resin films.

[0109]

The resin film may be a crosslinked film.

Also, a sheet produced by coloring the resin film or by printing on the resin film may be used.

Further, the resin film may be formed as a sheet through extrusion of a thermoplastic resin, or may also be a stretched one. A curable resin may be formed into a film and cured to be a sheet according to a predetermined method, and the sheet may be used.

[0110]

Among these resin films, a resin film containing a polypropylene film is preferred from the viewpoint that it is excellent in heat resistance and is expandable as having suitable flexibility and that it can readily maintain a good pickup aptitude.

Regarding the configuration of the supporting sheet having the resin film that contains a polypropylene film, it may have a single-layer structure of a polypropylene film alone, or a multilayered sheet formed of a polypropylene film and any other resin film.

In the case where the resin film-forming sheet is thermally curable, the resin film to constitute the supporting sheet has heat resistance and can prevent the supporting sheet from being damaged by heat to prevent occurrence of defects in a production process for semiconductor devices.

[0111]

In the case where the supporting sheet is used as release sheet for preventing adhesion of dust and others to the surface of the resin film-forming sheet, the supporting sheet is preferably a resin film that can be readily peeled from the resin film-forming sheet when stuck to a silicon wafer or in a singulation step.

[0112]

As the supporting sheet, a resin film that has been processed for lubrication on the surface of the above-mentioned resin film may also be used.

As the method for lubrication treatment, a method of arranging a release film formed of a release agent on the surface of the resin film is preferred.

Examples of the release agent include a release agent containing a resin selected from an acrylic resin, an alkyd resin, a silicone resin, a fluororesin, an unsaturated polyester resin, a polyolefin resin, a wax resin, etc.

[0113]

In the case where the supporting sheet is used as a singulation sheet for protecting the surface of the resin film-forming sheet in a singulation step or the like, the supporting sheet is preferably a pressure sensitive adhesive sheet having a pressure sensitive adhesive layer formed of a pressure sensitive adhesive on the above-mentioned resin film.

Examples of the pressure sensitive adhesive resin that is contained in the pressure sensitive adhesive include, when the structure of the pressure sensitive adhesive resin is specifically noted, an acrylic resin, an urethane resin, a rubber resin, a silicone resin, a vinyl ether resin, etc.; but when the function thereof is specifically noted, examples of the pressure sensitive adhesive resin include an energy ray-curable resin, etc.

In one aspect of the present invention, a pressure sensitive adhesive containing an energy ray-curable resin is preferred from the viewpoint of bettering the aptitude.

In the case where a pressure sensitive adhesive layer formed of a pressure sensitive adhesive that contains an energy ray-curable resin is arranged on the resin film, the pressure sensitive adhesive layer may be a pressure sensitive adhesive layer that has been cured through exposure to energy rays, or may be an uncured pressure sensitive adhesive layer before irradiation with energy rays. In the case where a supporting sheet that has an uncured pressure sensitive adhesive layer before irradiation with energy rays is used, the pressure sensitive adhesive layer may be cured by exposure to energy rays before the pickup step.

[0114]

The thickness of the supporting sheet may be suitably selected depending on the use thereof, but is preferably 10 to 500 μm , more preferably 20 to 350 μm , even more preferably 30 to 200 μm .

The thickness of the supporting sheet includes not only the thickness of the resin film that constitutes the supporting sheet but also in the case where the sheet has a pressure sensitive adhesive layer or a release film, the thickness thereof includes the thickness of the pressure sensitive adhesive layer or the release film.

[0115]

<Jig-Adhering Layer>

The jig-adhering layer may be formed of a double-face pressure sensitive adhesive sheet having a substrate (core material) or of a pressure sensitive adhesive composition containing a pressure sensitive adhesive.

The substrate (core material) includes a resin film that can be used as the above-mentioned supporting sheet, and is preferably a polypropylene film.

Examples of the pressure sensitive adhesive include an acrylic resin, a urethane resin, a rubber resin, a silicone resin, a vinyl ether resin, etc.

The thickness of the jig-adhering layer is preferably 1 to 80 μm , more preferably 5 to 60 μm , even more preferably 10 to 40 μm .

[0116]

[Silicon Wafer Regeneration Method]

The present invention also provides a method for regenerating a silicon wafer by reworking a resin film-forming sheet from a laminate where the surface (α) of the resin film-forming sheet of the present invention is directly stuck to a silicon wafer.

The silicon wafer regeneration method of the present invention includes the following steps (1) and (2).

Step (1): A step of sticking the pressure sensitive adhesive layer of a pressure sensitive adhesive sheet having a substrate and a pressure sensitive adhesive layer, to the surface (β) of the resin film-forming sheet of the laminate.

Step (2): A step of pulling the pressure sensitive adhesive sheet stuck to the surface (β) of the resin film-forming sheet in the step (1) to rework the resin film-forming sheet stuck to the silicon wafer.

[0117]

The silicon wafer regeneration method of the present invention utilizes the property of the resin film-forming sheet of the present invention that, after the resin film-forming sheet has been stuck onto a silicon wafer and when the necessity of reworking the sheet has occurred, the sheet can be reworked without

breaking the silicon wafer and without leaving a part of the resin film-forming sheet to remain on the silicon wafer.

The silicon wafer regeneration method of one aspect of the present invention is applicable not only to a laminate just after the surface (α) of the resin film-forming sheet of the present invention has been directly stuck onto a silicon wafer, but also to a laminate in such a state where after a lapse of 24 hours after the sticking, the adhesiveness between the silicon wafer and the resin film-forming sheet has increased.

The steps (1) and (2) of the silicon wafer regeneration method of the present invention are described below.

[0118]

<Step (1)>

The step (1) is a step of sticking the pressure sensitive adhesive layer of a pressure sensitive adhesive sheet that has a substrate and a pressure sensitive adhesive layer onto the surface (β) of the resin film-forming sheet of the laminate.

The pressure sensitive adhesive sheet for use in this step has a substrate and a pressure sensitive adhesive layer.

The substrate is preferably a resin film, and includes the resin film as exemplified in the section of the above-mentioned supporting sheet.

The pressure sensitive adhesive layer is preferably a pressure sensitive adhesive layer formed of a pressure sensitive adhesive that contains 100 parts by mass of an acrylic resin having structural units derived from butyl acrylate and acrylic acid and having a mass-average molecular weight of 600,000 to 1,000,000, and 0.01 to 10 parts by mass of a crosslinking agent, and having a thickness of 10 to 50 μm , as defined in the requirement (III).

However, in one aspect of the present invention, any other pressure sensitive adhesive capable of forming a pressure sensitive adhesive layer for which the adhesive strength (β_1) of the surface (β) can fall within the above-mentioned range is also usable, than the above-mentioned pressure sensitive adhesive.

[0119]

The form of the pressure sensitive adhesive sheet is not specifically limited, but from the viewpoint of the handleability in the next step (2), a pressure sensitive adhesive sheet having the same form as the resin film-forming sheet or having a larger form than the resin film-forming sheet is preferred.

[0120]

Regarding the sticking method for the surface (β) to the pressure sensitive adhesive layer of the pressure sensitive adhesive sheet in this step, the sticking may be carried out by machine or by hand.

[0121]

In the case where the surface (α) of the resin film-forming sheet that the composite sheet of one embodiment of the present invention has is stuck to a silicon wafer and where a singulation sheet serving as a supporting sheet has already been laminated on the side of the surface (β) thereof, the singulation sheet may also be used as the pressure sensitive adhesive sheet in this step.

[0122]

<Step (2)>

The step (2) is a step of pulling the pressure sensitive adhesive sheet stuck to the surface (β) of the resin film-forming sheet in the step (1) to rework the resin film-forming sheet stuck to the silicon wafer.

In this step, the resin film-forming sheet of the present invention is used and the adhesive strength ($\alpha 1$) and ($\beta 1$) of the resin film-forming sheet falls within the above-mentioned range, and accordingly, by pulling the pressure sensitive adhesive sheet stuck to the surface (β) in the step (1), the resin film-forming sheet can be peeled together and therefore the resin film-forming sheet can be reworked from the silicon wafer.

[0123]

The speed and the angle in pulling the pressure sensitive adhesive sheet are not specifically limited and can be suitably defined.

In this step, the pressure sensitive adhesive sheet may be pulled by machine, but from the viewpoint of operability, it is preferable that the pressure sensitive adhesive sheet is pulled by hand to rework the resin film-forming sheet from a silicon wafer.

[0124]

In this step, after the resin film-forming sheet has been removed, if desired, the surface of the silicon wafer may be washed with an organic solvent such as ethanol, etc.

After the above-mentioned steps, the silicon wafer to which a resin film-forming sheet has been once stuck can be regenerated.

Examples

[0125]

The measurement method for the mass-average molecular weight (Mw) or the number-average molecular weight (Mn) of each component used in Production Examples 1 to 8 is as mentioned below.

<Mass-Average Molecular Weight (Mw), Number-Average Molecular Weight (Mn)>

Using a gel permeation chromatography apparatus (trade name "HLC-8220GPC" manufactured by Tosoh Corporation), the measurement was carried out under the condition mentioned below, and a standard polystyrene-equivalent value of the found data was used.

(Measurement Condition)

Column: "TSK Guard Column HXL-H", "TSK Gel GMHXL ($\times 2$)", "TSK Gel G2000HXL" (all manufactured by Tosoh Corporation).

Column temperature: 40°C

Developing solvent: tetrahydrofuran

Flow rate: 1.0 mL/min

[0126]

Production Examples 1 to 8

(Preparation of Solution of Resin Film-Forming Composition)

The components of the type and the blending amount shown in Table 1 were blended to prepare each of resin-film forming compositions (1) to (8) (in Table 1, abbreviated as "Compositions (1) to (8)"). Each composition was diluted with methyl ethyl ketone to prepare a solution of the composition having a solid concentration of 61% by mass.

In Table 1, the blending amount of each component is a ratio to the total amount, 100% by mass of the composition (total blending amounts of the components (A) to (G)) (unit: % by mass (as the ratio of the active ingredient)). The details of each component shown in Table 1 are as follows.

[0127]

<Polymer Component (A)>

(A-1): Acrylic copolymer prepared by copolymerization of methyl acrylate (MA) and 2-hydroxyethyl acrylate (HEA) (component ratio: MA/HEA = 95/5 (% by mass), Mw = 800,000.

(A-2): Acrylic copolymer prepared by copolymerization of n-butyl acrylate

(BA), ethyl acrylate (EA), acrylonitrile (AN) and glycidyl methacrylate (GMA) (component ratio: BA/EA/AN/GMA = 39/29/29/3 (% by mass), Mw = 800,000.

(A-3): Acrylic copolymer prepared by copolymerization of n-butyl acrylate (BA), methyl acrylate (MA), glycidyl methacrylate (GMA) and 2-hydroxyethyl acrylate (HEA) (component ratio: BA/MA/GMA/HEA = 55/10/20/15 (% by mass), Mw = 800,000.

(A-4): Acrylic copolymer prepared by copolymerization of n-butyl acrylate (BA), ethyl acrylate (EA) and glycidyl methacrylate (GMA) (component ratio: BA/EA/GMA = 53/44/3 (% by mass), Mw = 800,000.

[0128]

<Curable Component (B)>

(B-1): Acryloyl group-added cresol-novolak-type epoxy resin (trade name "CNA-147" manufactured by Nippon Kayaku Co., Ltd., epoxy compound corresponding to the component (B11)).

(B-2): Biphenyl aralkyl-type epoxy resin (trade name "NC-3000H" manufactured by Nippon Kayaku Co., Ltd., epoxy compound corresponding to the component (B11)).

(B-3): Bisphenol A-type epoxy resin (trade name "jER828" manufactured by Mitsubishi Chemical Corporation, epoxy compound corresponding to the component (B11)).

(B-4): Bisphenol A-type epoxy resin (trade name "jER1055" manufactured by Mitsubishi Chemical Corporation, epoxy compound corresponding to the component (B11)).

(B-5): Dicyclopentadiene-type epoxy resin (trade name "Epiclon HP-7200HH" manufactured by DIC Corporation, epoxy compound corresponding to the component (B11)).

(B-6): Biphenylene aralkyl-type phenolic resin (trade name "MEH-7851-H" manufactured by Meiwa Plastic Industries, Ltd., heat-curing agent corresponding to the component (B12)).

(B-7): Dicyandiamide (trade name "Adeka Hardener 3636AS" manufactured by ADEKA Corporation, heat-curing agent corresponding to the component (B12)).

(B-8): Imidazole-type curing accelerator (trade name "Curesol 2PHZ" manufactured by Shikoku Chemicals Corporation, curing accelerator corresponding to the component (B13)).

[0129]

<Inorganic Filler (C)>

(C-1): Silica filler (mean particle size = 50 nm).

(C-2): Silica filler (mean particle size = 500 nm).

[0130]

<Colorant (D)>

(D-1): Carbon black (mean particle size = 28 nm).

<Silane Coupling Agent (E)>

(E-1): Silane coupling agent (trade name "KBM-403" manufactured by Shin-Etsu Chemical Co., Ltd.).

<Leveling Agent (F)>

(F-1): Silicone-type leveling agent (trade name "XF42-334" manufactured by Momentive Performance Materials Japan Inc.).

<Wide-Use Additive (G)>

(G-1): Isocyanate-type crosslinking agent (trade name "BHS 8515" manufactured by Toyo-Chem Co., Ltd.)

[0131]
Table 1

		Production Example 1	Production Example 2	Production Example 3	Production Example 4	Production Example 5	Production Example 6	Production Example 7	Production Example 8
		Composition (1)	Composition (2)	Composition (3)	Composition (4)	Composition (5)	Composition (6)	Composition (7)	Composition (8)
Polymer Component (A)	A-1 (acrylic copolymer)	57.52	57.34	57.00	56.66	57.46	-	-	-
	A-2 (acrylic copolymer)	-	-	-	-	-	79.00	-	-
	A-3 (acrylic copolymer)	-	-	-	-	-	-	19.90	-
	A-4 (acrylic copolymer)	-	-	-	-	-	-	-	79.00
Curable Component (B)	B-1 (epoxy compound)	18.16	18.11	18.00	17.89	18.15	-	-	-
	B-2 (epoxy compound)	-	-	-	-	-	11.00	-	11.00
	B-3 (epoxy compound)	-	-	-	-	-	-	10.95	-
	B-4 (epoxy compound)	-	-	-	-	-	-	1.99	-
	B-5 (epoxy compound)	-	-	-	-	-	-	5.97	-
	B-6 (heat-curing agent)	3.03	3.02	3.00	2.98	3.02	8.90	-	8.90
	B-7 (heat-curing agent)	-	-	-	-	-	-	0.40	-
	B-8 (curing accelerator)	-	-	-	-	-	0.20	0.40	0.20
Inorganic Filler (C)	C-1 (silica filler)	20.18	20.12	20.00	19.88	20.16	-	-	-
	C-2 (silica filler)	-	-	-	-	-	-	59.70	-
Colorant (D)	D-1 (carbon black)	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Silane Coupling Agent (E)	E-1 (silane coupling agent)	0.20	0.20	0.20	0.20	0.20	0.40	0.20	0.40
Leveling Agent (F)	F-1 (silicone-type leveling agent)	-	0.30	0.90	1.49	0.10	-	-	-
Wide-Use Additive (G)	G-1 (isocyanate-type crosslinking agent)	0.40	0.40	0.40	0.40	0.40	-	-	-
Total Blending Amount (part by mass)		100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

*The values in the above table each indicates the blending amount of each component relative to the total amount (the total blending amount of the components (A) to (G)). 100% by mass of each composition (unit: % by mass (ratio of active ingredients)).

[0132]

Example 1

A solution of the resin film-forming composition (2) prepared in Production Example 2 was applied onto the lubricated surface of a first supporting sheet formed of a lubricated resin film (trade name "SP-PET3811" manufactured by Lintec Corporation, thickness: 38 μm), and dried to form a coating film (α').

On the other hand, a solution of the resin film-forming composition (1) prepared in Production Example 1 was applied onto the lubricated surface of a second supporting sheet that is the same as the first supporting sheet, and dried to form a coating film (β').

The coating films (α') and (β') formed on the two supporting sheets were stuck together, and dried at 120°C for 2 minutes to form a resin film-forming sheet having a total thickness of the two layers of 25 μm , thereby preparing a resin film-forming composite sheet having a configuration of first supporting sheet/resin film-forming sheet/second supporting sheet.

In the composite sheet, the surface of the resin film-forming sheet that is exposed out after the first supporting sheet is removed is the "surface (α)" on the side to be stuck to a silicon wafer, and the surface of the resin film-forming sheet that is exposed out after the second supporting sheet is removed is the "surface (β)".

[0133]

Example 2

A resin film-forming composite sheet was produced in the same manner as in Example 1, except that "a solution of the resin film-forming composition (3) prepared in Production Example 3" was used in place of the "solution of the resin film-forming composition (2) prepared in Production Example 2".

[0134]

Example 3

A resin film-forming composite sheet was produced in the same manner as in Example 1, except that "a solution of the resin film-forming composition (4) prepared in Production Example 4" was used in place of the "solution of the resin film-forming composition (2) prepared in Production Example 2".

[0135]

Example 4

A resin film-forming composite sheet was produced in the same manner as

in Example 1, except that "a solution of the resin film-forming composition (5) prepared in Production Example 5" was used in place of the "solution of the resin film-forming composition (2) prepared in Production Example 2".

[0136]

Example 5

A solution of the resin film-forming composition (6) prepared in Production Example 6 was applied onto the lubricated surface of a first supporting sheet formed of a lubricated resin film (trade name "SP-PET3811" manufactured by Lintec Corporation, thickness: 38 μm), and dried at 120°C for 2 minutes to produce a resin film-forming sheet having a thickness of 25 μm .

The surface of the produced resin film-forming sheet was stuck to the lubricated surface of a second supporting sheet that is the same as the first supporting sheet, thereby producing a resin film-forming composite sheet having a configuration of first supporting sheet/resin film-forming sheet/second supporting sheet.

[0137]

Comparative Example 1

A resin film-forming composite sheet was produced in the same manner as in Example 5, except that "a solution of the resin film-forming composition (3) prepared in Production Example 3" was used in place of the "solution of the resin film-forming composition (6) prepared in Production Example 6".

[0138]

Comparative Example 2

A resin film-forming composite sheet was produced in the same manner as in Example 5, except that "a solution of the resin film-forming composition (7) prepared in Production Example 7" was used in place of the "solution of the resin film-forming composition (6) prepared in Production Example 6".

[0139]

Comparative Example 3

A resin film-forming composite sheet was produced in the same manner as in Example 5, except that "a solution of the resin film-forming composition (8) prepared in Production Example 8" was used in place of the "solution of the resin film-forming composition (6) prepared in Production Example 6".

[0140]

The composite sheets produced in Examples and Comparative Examples

were analyzed for the physical data mentioned below, and evaluated in the manner mentioned below. The results are shown in Table 2.

[0141]

<Requirement (I): Measurement of surface roughness (Ra) of surface (α) of resin film-forming sheet>

The first supporting sheet was removed from the composite sheet produced in Examples and Comparative Examples, and the exposed surface (α) of the resin film-forming sheet was analyzed using a contact-type surface roughness meter (trade name "SURFTEST SV-3000" manufactured by Mitutoyo Corporation) at a cutoff value λ_c of 0.8 mm and an evaluation length L_n of 4 mm, according to JIS B0601:2001.

[0142]

<Requirement (II): Measurement of adhesive strength to silicon wafer of surface (α) of resin film-forming sheet>

The first supporting sheet was removed from the composite sheet produced in Examples and Comparative Examples, and the exposed surface (α) of the resin film-forming sheet was stuck to the polished surface of a #2000-polished silicon wafer (diameter: 200 mm, thickness: 600 μ m), using a tape mounter (trade name "Adwill RAD-3600 F/12" manufactured by Lintec Corporation), with heating at 70°C.

Next, the second supporting sheet was removed from the composite sheet, and the exposed surface (β) of the resin film-forming sheet was stuck to the pressure sensitive adhesive layer of a pressure sensitive adhesive sheet that is a commercial product for use as a lining tape (trade name "PET50(A) PAT1" manufactured by Lintec Corporation, width: 25 mm) on a hot plate heated at 70°C, using a 2-kg roller, and then left in an environment at 23°C and 50% RH (relative humidity) for 24 hours.

After thus left, this was tested in a tensile test using a universal tester (trade name "Autograph AG-IS" manufactured by Shimadzu Corporation), at a peel angle of 180° and a peel rate of 0.3 m/min, in which the load in peeling the protective film-forming sheet and the lining tape from the surface of the silicon wafer was measured. The value of the load is referred to as the adhesive strength of the surface (α) of the resin film-forming sheet to the silicon wafer.

The above-mentioned pressure sensitive adhesive sheet that is a commercial product for use as a lining tape did not peel at the interface between

the protective film-forming sheet and the pressure sensitive adhesive layer of the pressure sensitive adhesive sheet in a tensile test, and had an adhesive strength on a level that the protective film-forming sheet could be stably peeled at the interface to the silicon wafer.

[0143]

<Requirement (III): Measurement of adhesive strength of surface (β) of resin film-forming sheet to pressure sensitive adhesive layer of pressure sensitive adhesive sheet>

A double-sided pressure sensitive adhesive tape for fixing a resin film-forming sheet (trade name "TL-4100S-50" manufactured by Lintec Corporation) was stuck to a silicon wafer at room temperature (25°C) using a rubber roll. The double-sided pressure sensitive adhesive tape was so selected that it could sufficiently fix a protective film-forming sheet in a tensile test.

Next, the adhesive surface of the double-sided pressure sensitive adhesive tape was stuck to the exposed surface (α) of the resin film-forming sheet of the composite sheet produced in Examples and Comparative Examples, from which the first supporting sheet had been removed, using a tape mounter (trade name "Adwill RAD-3600 F/12" manufactured by Lintec Corporation) at room temperature.

Next, the second supporting sheet was removed from the composite sheet, and the exposed surface (β) of the resin film-forming sheet was stuck to the pressure sensitive adhesive layer of a pressure sensitive adhesive sheet to be mentioned below, using a 2-kg roller at 23°C, and then left in an environment at 23°C and 50% RH (relative humidity) for 20 minutes.

After thus left, this was tested in a tensile test under the condition of a peel angle of 180° and a peel rate of 0.3 m/min, using a universal tester (trade name "Autograph AG-IS" manufactured by Shimadzu Corporation), in which the load in peeling the pressure sensitive adhesive sheet from the surface (β) of the protective film-forming sheet was measured. The value of the load is referred to as the adhesive strength of the surface (β) of the resin film-forming sheet to the pressure sensitive adhesive layer of the pressure sensitive adhesive sheet.

(Details of pressure sensitive adhesive sheet to be stuck to surface (β))

A pressure sensitive adhesive sheet having a 20- μ m thick pressure sensitive adhesive layer formed of a pressure sensitive adhesive composition mentioned blow, on the corona-treated surface of a corona-treated resin film

formed of an ethylene-methyl methacrylate copolymer (constitution ratio: ethylene/methyl methacrylate = 90/10 (ratio by mass)) was used.

Pressure sensitive adhesive Composition: Prepared by adding 5 parts by mass of a tolylene diisocyanate-type crosslinking agent (trade name "Coronate L" manufactured by Nippon Polyurethane Industry Co., Ltd.) to 100 parts by mass of an acrylic copolymer obtained through copolymerization of butyl acrylate (BA) and acrylic acid (AA) (BA/AA = 90/10 (ratio by mass), $M_w = 700,000$).

[0144]

<Measurement of storage elastic modulus at 23°C of resin film-forming sheet>

Plural resin film-forming sheets prepared by removing the two supporting sheets from the composite sheets produced in Examples and Comparative Examples were laminated to give a test sample having a thickness of 0.18 mm, a width of 4.5 mm and a length of 20.0 mm.

The test sample was tested for the storage elastic modulus (unit: GPa) at 23°C of the resin film-forming sheet, using a dynamic viscoelastometer (trade name "DMA Q800" manufactured by TA Instruments) in a tensile mode at a frequency of 11 Hz and in an air atmosphere at 23°C.

[0145]

<Measurement of contact angle with water of surface (β) of resin film-forming sheet>

The second supporting sheet was removed from the composite sheet produced in Examples and Comparative Examples, and 10 ml of distilled water was dropped onto the exposed surface (β) of the resin film-forming sheet, and left as such for 10 minutes.

After thus left, the angle between the surface (β) and the water droplet was measured using an automatic contact angle meter (trade name "DSA100S" manufactured by KRUSS GmbH), and the angle is referred to as the "contact angle with water of the surface (β)".

[0146]

<Evaluation (1): Reworkability of resin film-forming sheet>

The first supporting sheet was removed from the composite sheet produced in Examples and Comparative Examples, and the exposed surface (α) of the resin film-forming sheet was stuck to the polished surface of a #2000-polished silicon wafer (diameter: 200 mm, thickness: 600 μm), using a tape mounter (trade name "Adwill RAD-3600 F/12" manufactured by Lintec Corporation), with heating

at 70°C, and then left in an environment at 23°C and 50% RH (relative humidity) for 24 hours.

After thus left, the second supporting sheet was removed from the composite sheet, and the exposed surface (β) of the resin film-forming sheet was stuck to the surface of the pressure sensitive adhesive layer of a commercially-available general-purpose singulation tape (trade name "Adwill D-510T" manufactured by Lintec Corporation - pressure sensitive adhesive sheet having a pressure sensitive adhesive layer formed of a pressure sensitive adhesive defined in the above-mentioned requirement (III)), at room temperature (25°C), and left as such for 20 minutes.

Subsequently, the general-purpose singulation tape was pulled by hand to rework the resin film-forming sheet from the silicon wafer, and evaluated for the reworkability as to whether or not the sheet could be reworked from the silicon wafer and as to whether or not any residue remained on the surface of the reworked silicon wafer. According to the following criteria, the reworkability of the resin film-forming sheet was evaluated.

A: The protective film-forming sheet was completely removed from the silicon wafer. Any visible residue of the protective film-forming sheet was not detected on the reworked silicon wafer.

B: The protective film-forming sheet was removed from the silicon wafer. Some residue of the protective film-forming sheet was detected on the reworked silicon wafer, but was completely removed by wiping with ethanol.

C: The silicon wafer broke during reworking, or even though the silicon wafer could be reworked without breaking, a residue of the protective film-forming sheet remained on the reworked silicon wafer in such a degree that the residue could not be wiped off with ethanol.

[0147]

<Evaluation (2): Edge adhesiveness of resin film-forming sheet>

The first supporting sheet was removed from the composite sheet produced in Examples and Comparative Examples, and the exposed surface (α) of the resin film-forming sheet was stuck to the polished surface of a #2000-polished silicon wafer (diameter: 200 mm, thickness: 600 μ m), using a tape mounter (trade name "Adwill RAD-3600 F/12" manufactured by Lintec Corporation), with heating at 70°C. Subsequently, the second supporting sheet was removed to stick the silicon wafer and the resin film-forming sheet.

With that, the edges of the silicon wafer with the resin film-forming sheet stuck thereto was visually checked. Depending on the number of peelings and chippings of 0.5 mm or more, the edge adhesiveness of the resin film-forming sheet was evaluated according to the following criteria.

- A: The number of peelings or chippings of 0.5 mm or more is 0.
- B: The number of peelings or chippings of 0.5 mm or more is 1 to 4.
- C: The number of peelings or chippings of 0.5 mm or more is 5 or more.

[0148]
Table 2

Kind of Resin Film-Forming Composition	Surface (α) side Surface (β) side	Surface roughness Ra (nm) of surface (α)	Example 1		Example 2		Example 3		Example 4		Example 5		Comparative Example 1		Comparative Example 2		Comparative Example 3	
			Composition (2) Composition (1)	21	Composition (3) Composition (1)	21	Composition (4) Composition (1)	21	Composition (5) Composition (1)	23	Composition (6) Composition (1)	29	Composition (3) Composition (1)	21	Composition (7) Composition (1)	67	Composition (8) Composition (1)	29
Requirement (I)				21		21		21		23		29		21		67		29
Requirement (II)		Adhesive strength (α1) to silicon wafer of surface (α) (N/25mm)		4.6		3.4		2.1		6.5		1.5		3.4		2.1		7.2
Requirement (III)		Adhesive strength (β1) to pressure sensitive adhesive layer of pressure sensitive adhesive sheet of surface (β) (N/25mm)		7.1		7.1		7.1		7.1		5.1		3.9		8.5		8.1
-		Difference between adhesive strength (β1) and adhesive strength (α1) (N/25mm)		2.5		3.7		5.0		0.6		3.6		0.5		6.4		0.9
-		Storage elastic modulus at 23°C of resin film-forming sheet (GPa)		1.8		1.8		1.8		1.8		3.1		2.1		6.1		0.9
-		Contact angle of surface (β) (°)		84		84		84		84		87		99		81		82
Evaluation (1)		Reworkability of resin film-forming sheet		A		A		A		B		A		C		A		C
Evaluation (2)		Edge adhesiveness of resin film-forming sheet		A		A		A		A		B		A		C		A

[0149]

From Table 2, the results are that the resin film-forming sheets produced in Examples 1 to 5 as one aspect of the present invention were excellent both in reworkability and edge adhesiveness.

On the other hand, of the resin film-forming sheet of Comparative Example 1, the adhesive strength ($\beta 1$) of the surface (β) was low, and therefore in the reworking operation of the resin film-forming sheet using a pressure sensitive adhesive sheet, a part of the resin film-forming sheet remained on the silicon wafer, and the reworkability of the sheet was therefore poor.

Of the resin film-forming sheet of Comparative Example 3, the adhesive strength ($\alpha 1$) of the surface (α) was high, and therefore during the course of the reworking operation of the resin film-forming sheet using a pressure sensitive adhesive sheet, the silicon wafer broke, and the reworkability of the sheet was therefore poor.

The reworkability of the resin film-forming sheet of Comparative Example 2 was good, but after stuck to a silicon wafer, the edge adhesiveness thereof was poor.

Industrial Applicability

[0150]

The resin film-forming sheet of one aspect of the present invention is favorable as a forming material for a protective film for protecting the back surface of a semiconductor chip, or as a forming material for an adhesive film that can be adhered to a die pad part or to any other part.

Reference Signs List

[0151]

- 1a, 1b, 1c, 1d Resin Film-Forming Composite Sheet
- 10 Resin Film-Forming Sheet
- 11, 11' Supporting Sheet
- 12 Jig-Adhering Layer

CLAIMS

[Claim 1]

A resin film-forming sheet which is to be stuck to a silicon wafer to form a resin film-having wafer having a cured resin film on the silicon wafer and which satisfies the following requirements (I) to (III):

Requirement (I): the surface roughness (Ra) of the surface (α) of the resin film-forming sheet on the side thereof to be stuck to a silicon wafer is 50 nm or less;

Requirement (II): the adhesive strength (α_1) of the surface (α) of the resin film-forming sheet to a silicon wafer is 1.0 to 7.0 N/25 mm; and

Requirement (III): the adhesive strength (β_1) of the surface (β) of the resin film-forming sheet on the side opposite to the side thereof to be stuck to a silicon wafer, to the pressure sensitive adhesive layer of a pressure sensitive adhesive sheet having a pressure sensitive adhesive layer formed of a pressure sensitive adhesive that contains 100 parts by mass of an acrylic resin having structural units derived from butyl acrylate and acrylic acid and having a mass-average molecular weight of 600,000 to 1,000,000, and 0.01 to 10 parts by mass of a crosslinking agent, and having a thickness of 10 to 50 μm , is 4.0 N/25 mm or more.

[Claim 2]

The resin film-forming sheet according to claim 1, which has a storage elastic modulus at 23°C of 0.10 to 20 GPa.

[Claim 3]

The resin film-forming sheet according to claim 1 or 2, wherein the contact angle with water on the surface (β) of the resin film-forming sheet is 70 to 110°.

[Claim 4]

The resin film-forming sheet according to any one of claims 1 to 3, which comprises a polymer component (A) and a curable component (B).

[Claim 5]

The resin film-forming sheet according to claim 4, wherein the polymer component (A) contains an acrylic polymer (A1).

[Claim 6]

The resin film-forming sheet according to claim 5, wherein the acrylic polymer (A1) is an acrylic copolymer having a structural unit (a1) derived from an alkyl (meth)acrylate and a structural unit (a2) derived from a nitrile monomer.

[Claim 7]

The resin film-forming sheet according to any one of claims 1 to 6, which is a protective film-forming sheet for forming a protective film on a silicon wafer.

[Claim 8]

The resin film-forming sheet according to any one of claims 1 to 7, wherein the adhesive strength (β_1) of the surface (β) is a higher value than the adhesive strength (α_1) of the surface (α).

[Claim 9]

The resin film-forming sheet according to any one of claims 1 to 8, wherein the difference between the adhesive strength (β_1) and the adhesive strength (α_1) [$(\beta_1) - (\alpha_1)$] is 8.0 N/25 mm or smaller.

[Claim 10]

The resin film-forming sheet according to any one of claims 1 to 9, which contains fine particles having a mean particle size of 10 nm or greater and 400 nm or smaller.

[Claim 11]

The resin film-forming sheet according to any one of claims 1 to 10, which comprises a multi-layered sheet of two or more layers formed of two or more kinds of compositions.

[Claim 12]

The resin film-forming sheet according to claim 11, wherein the multi-layered sheet comprises a layer containing fine particles, and comprises at least two layers in which at least one of kinds, mean particle sizes and contents of the fine particles are different from each other.

[Claim 13]

The resin film-forming sheet according to claim 11, wherein the multi-layered sheet comprises a first layer containing fine particles and a second layer located on the side of the surface (α) with respect to the first layer, wherein at least one of mean particle size and content of the fine particles contained in the second layer is smaller than the one of the fine particles contained in the first layer.

[Claim 14]

The resin film-forming sheet according to claim 11, wherein the multi-layered sheet comprises a layer formed of a composition containing a leveling agent and a layer formed of a composition not substantially containing

the leveling agent, wherein the layer formed of a composition containing a leveling agent is located on the side of the surface (α) with respect to the layer formed of the composition not substantially containing the leveling agent.

[Claim 15]

A resin film-forming composite sheet, which has a configuration in which the resin film-forming sheet of any one of claims 1 to 14 is laminated on a supporting sheet.

[Claim 16]

The resin film-forming composite sheet according to claim 15, which has a configuration in which the resin film-forming sheet is sandwiched between two supporting sheets.

[Claim 17]

A method for regenerating a silicon wafer by reworking a resin film-forming sheet from a laminate where the surface (α) of the resin film-forming sheet of any one of claims 1 to 14 is directly stuck to a silicon wafer, which comprises the following steps (1) and (2):

Step (1): a step of sticking the pressure sensitive adhesive layer of a pressure sensitive adhesive sheet having a substrate and a pressure sensitive adhesive layer, to the surface (β) of the resin film-forming sheet of the laminate; and

Step (2): a step of pulling the pressure sensitive adhesive sheet stuck to the surface (β) of the resin film-forming sheet in the step (1) to rework the resin film-forming sheet stuck to the silicon wafer.