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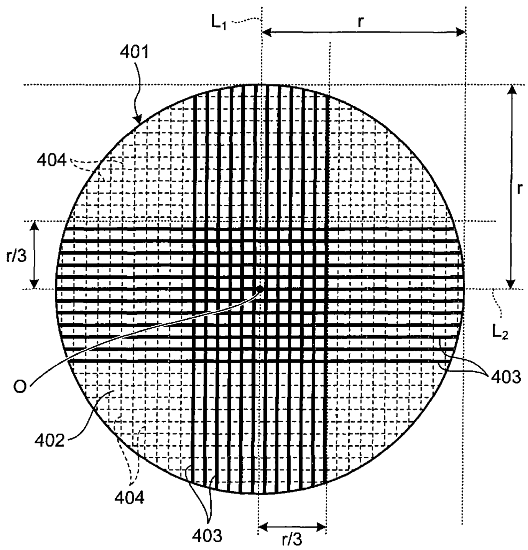
(54) **POLISHING PAD**

(57) A polishing pad for chemical mechanical polishing includes at least a polishing layer whose polishing surface includes a first groove and a second groove, the first and second grooves have side surfaces, which are continuous with the polishing surface, on each edge in a groove width direction, the first groove has an angle of larger than 105 degrees and 150 degrees or smaller, which is formed between the polishing surface and the side surface continuous with the polishing surface, on at least one edge in the groove width direction, and the second groove has an angle of 60 degrees or larger and 105 degrees or smaller, which is formed between the polishing surface and the side surface continuous with the polishing surface, on both of two edges in the groove width direction.

FIG.4



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Description

Field

[0001] The present invention relates to a polishing pad. More specifically, the invention relates to a polishing pad which is preferably used to form a planar surface on semiconductors, dielectric material/metal composites, integrated circuits, and the like.

Background

[0002] As the density of semiconductor devices increases, the importance of technologies for forming multilayer wires, interlayer insulating films in association therewith, and electrodes, such as plugs and damascene electrodes, has been increasing. Together with this, the importance of a planarization process for these interlayer insulating films and metal films of the electrodes has been also increasing. As an efficient technology for this planarization process, a polishing technology, which is referred to as chemical mechanical polishing (CMP), has been widely used.

[0003] In general, a CMP apparatus is configured to include a polishing head which holds a semiconductor wafer that is a material to be treated, a polishing pad for carrying out a polishing treatment of the material to be treated, and a polishing platen which holds the polishing pad. Further, the polishing technology, which is referred to as CMP, is a technology in which polishing is performed on a material to be polished using a polishing pad having a polishing layer while supplying slurry. Specifically, the CMP technology of the semiconductor wafer is to planarize a surface layer of the wafer in such a manner that projecting portions on the surface layer of the wafer are removed by causing the semiconductor wafer (hereinafter, simply referred to as the wafer) and the polishing pad to perform relative motion using slurry.

[0004] There are required properties for the CMP technology, such as securement of local planarity and global planarity of a wafer, prevention of defects, and securement of a high polishing rate. Therefore, in order to attain these required properties, the configuration of grooves of the polishing pad (pattern of grooves, cross-section of grooves, and the like), which is one of major factors affecting polishing characteristics, is devised in various ways.

[0005] For example, a technology for stabilizing polishing characteristics has been known in which a cross-section of grooves formed on a surface of a polishing layer is V-shaped or U-shaped, and the grooves are formed in a spiral pattern or a stitch pattern (see Patent Literature 1).

[0006] In such a technology, there is a case where scratches are generated on the surface of the wafer due to a corner portion of the cross-section of grooves or a case where a burr-like object is formed on the corner portion of the cross-section due to dressing or the like performed before and after polishing or during polishing and thus scratches are generated. As a technology to solve these problems, a technology has been also known in which an inclined face is provided on a boundary portion between the polishing surface and the groove (see Patent Literatures 2 and 3).

Citation List

Patent Literature

[0007]

Patent Literature 1: Japanese Laid-open Patent Publication No. 2001-212752
Patent Literature 2: Japanese Laid-open Patent Publication No. 2010-45306
Patent Literature 3: Japanese Laid-open Patent Publication No. 2004-186392

Summary

Technical Problem

[0008] To address this circumstance, the present inventors found that when an inclined face with a specific angle is provided on the boundary portion between the polishing surface and the groove, a suction force acts between the wafer and the polishing pad and thus a polishing rate becomes high and in-plane uniformity becomes excellent. Since it is important to provide the inclined face on the boundary portion between the polishing surface and the groove, for example, a case where the cross-section of the groove is V-shaped is also applicable. Incidentally, in consideration of a manufacturing process, it is preferable in that the cross-section of the groove has a simple shape.

[0009] However, in a case where the cross-section of the groove is V-shaped, the inventors found that there is a problem in that polishing defects are increased caused by a fact that functions of supplying and discharging slurry are not performed sufficiently at a final period of lifetime of the polishing pad when the polishing pad is worn in accordance with the use of the polishing pad and a cross-sectional area of the groove is decreased.

[0010] The invention is contrived in view of such problems of the related art, and an object thereof is to provide a polishing pad without increase in polishing defects caused by deterioration of the functions of supplying and discharging slurry even when the polishing pad is worn in accordance with the use of the polishing pad, while having a high polishing rate and an excellent in-plane uniformity.

Solution to Problem

[0011] The inventors considered that the above-described problems may be solved by combining a groove (for example, a V-shaped groove) for a high polishing rate and an excellent in-plane uniformity which has an inclined face with a specific angle formed on the boundary portion between the polishing surface and the groove, and a groove (for example, an I-shaped groove or a trapezoid (substantially I-shaped) groove) for maintaining the functions of supplying and discharging of slurry even when the polishing pad is worn in accordance with the use of the polishing pad.

[0012] In order to solve the problems described above, the invention employs a means such as follows.

[0013] That is, a polishing pad for chemical mechanical polishing includes at least a polishing layer, wherein a polishing surface of the polishing layer includes a first groove and a second groove, the first and second grooves have side surfaces, which are continuous with the polishing surface, on each edge in a groove width direction, the first groove has an angle of larger than 105 degrees and 150 degrees or smaller, which is formed between the polishing surface and the side surface continuous with the polishing surface, on at least one edge in the groove width direction, and the second groove has an angle of 60 degrees or larger and 105 degrees or smaller, which is formed between the polishing surface and the side surface continuous with the polishing surface, on both of two edges in the groove width direction.

Advantageous Effects of Invention

[0014] According to the invention, it is possible to provide a polishing pad without increase in polishing defects even when the polishing pad is worn in accordance with the use of the polishing pad and functions of supplying and discharging slurry are deteriorated, while having a high polishing rate and an excellent in-plane uniformity.

Brief Description of Drawings

[0015]

FIG. 1A is a diagram illustrating a cross-section of a first groove (first example) which a polishing pad according to an embodiment of the invention has.

FIG. 1B is a diagram illustrating a cross-section of the first groove (second example) which the polishing pad according to the embodiment of the invention has.

FIG. 1C is a diagram illustrating a cross-section of the first groove (third example) which the polishing pad according to the embodiment of the invention has.

FIG. 1D is a diagram illustrating a cross-section of the first groove (fourth example) which the polishing pad according to the embodiment of the invention has.

FIG. 2A is a diagram illustrating a cross-section of a second groove (first example) which the polishing pad according to the embodiment of the invention has.

FIG. 2B is a diagram illustrating a cross-section of the second groove (second example) which the polishing pad according to the embodiment of the invention has.

FIG. 2C is a diagram illustrating a cross-section of the second groove (third example) which the polishing pad according to the embodiment of the invention has.

FIG. 2D is a diagram illustrating a cross-section of the second groove (fourth example) which the polishing pad according to the embodiment of the invention has.

FIG. 2E is a diagram illustrating a cross-section of the second groove (fifth example) which the polishing pad according to the embodiment of the invention has.

FIG. 2F is a diagram illustrating a cross-section of the second groove (sixth example) which the polishing pad according to the embodiment of the invention has.

FIG. 3A is a cross-sectional view illustrating a configuration example (first example) of a unitary unit including the first and second grooves.

FIG. 3B is a cross-sectional view illustrating a configuration example (second example) of a unitary unit including the first and second grooves.

FIG. 3C is a cross-sectional view illustrating a configuration example (third example) of a unitary unit including the

first and second grooves.
FIG. 3D is a cross-sectional view illustrating a configuration example (fourth example) of a unitary unit including the first and second grooves.
FIG. 3E is a cross-sectional view illustrating a configuration example (fifth example) of a unitary unit including the first and second grooves.
FIG. 3F is a cross-sectional view illustrating a configuration example (sixth example) of a unitary unit including the first and second grooves.
FIG. 3G is a cross-sectional view illustrating a configuration example (seventh example) of a unitary unit including the first and second grooves.
FIG. 3H is a cross-sectional view illustrating a configuration example (eighth example) of a unitary unit including the first and second grooves.
FIG. 3I is a cross-sectional view illustrating a configuration example (ninth example) of a unitary unit including the first and second grooves.
FIG. 4 is a diagram schematically illustrating an arrangement example of the first grooves on the polishing surface of the polishing pad according to the embodiment of the invention.

Description of Embodiments

[0016] Hereinafter, embodiments for carrying out the invention will be described.
[0017] A polishing pad of the invention has at least a polishing layer and includes a groove A (first groove) and a groove B (second groove) formed on the polishing surface of the polishing layer. The groove A and the groove B have side surfaces, which are continuous with the polishing surface, on each edge in a groove width direction. The groove A has an angle of larger than 105 degrees and 150 degrees or smaller, which is formed between the polishing surface and the side surface continuous with the polishing surface, on at least one edge in the groove width direction. The groove B has an angle of 60 degrees or larger and 105 degrees or smaller, which is formed between the polishing surface and the side surface continuous with the polishing surface, on both of two edges in the groove width direction.
[0018] When the groove A has an angle of larger than 105 degrees and 150 degrees or smaller, which is formed between the polishing surface and the side surface continuous with the polishing surface, on at least one edge in the groove width direction, a suction force acts between a wafer and the polishing pad and thus it can be considered that a polishing rate is increased. In addition, by the action of the suction force, together with an effect of bringing the polishing pad into uniform contact within the wafer surface, it can be considered that a high in-plane uniformity is provided to the polishing rate of the wafer.
[0019] When the angle formed between the polishing surface and the side surface continuous with the polishing surface is too large, the surface area of the polishing pad is decreased. In addition, since the cross-sectional area of the groove becomes too large, slurry is excessively discharged and thus the polishing rate is decreased. On the other hand, when the angle is too small, the suction effect which the inclined side surfaces of the groove have is not exhibited. Therefore, the angle formed between the polishing surface and the side surface continuous with the polishing surface needs to be larger than 105 degrees and 150 degrees or smaller, and is preferably 110 degrees or larger, more preferably 115 degrees or larger, and even more preferably 120 degrees or larger.
[0020] The groove A may have a bottom face. The bottom face is a face continuous with a side opposite to the polishing surface with respect to the side surface continuous with the polishing surface, and a face connecting to the other side surface facing the side surface continuous with the polishing surface. Incidentally, the shape of the bottom face is not particularly limited.
[0021] FIGS. 1A to 1D are diagrams illustrating specific examples of the cross-section of the groove A.
[0022] A groove A 101 illustrated in FIG. 1A has a V-shaped cross-section. The groove A 101 has two side surfaces 2, each of which is continuous with a polishing surface 1, on edges thereof in the groove width direction. In the case illustrated in FIG. 1A, angles θ_A formed between the polishing surface and the side surfaces continuous with the polishing surface on the two edges in the groove width direction are equal to each other. As described above, the value of the angle is larger than 105 degrees and 150 degrees or smaller.
[0023] A groove A 102 illustrated in FIG. 1B has a substantially U-shaped bottom face 3 formed between the two side surfaces 2.
[0024] A groove A 103 illustrated in FIG. 1C has a trapezoidal cross-section and has a bottom face 4 which is formed between the two side surfaces 2 and is parallel to the polishing surface 1.
[0025] A groove A 104 illustrated in FIG. 1D has a concave portion 5 which is formed by making a hole between the two side surfaces 2 in a direction perpendicular to the polishing surface 1. The bottom face of the concave portion is parallel to the polishing surface 1.
[0026] Further, the side surface continuous with the polishing surface in the groove A may be a curved line, a polygonal line, a wavy line, or a combination thereof in addition to a straight line, as long as the angle formed with respect to the

polishing surface on the edge can be maintained to be larger than 105 degrees and 150 degrees or smaller even when the polishing pad is worn.

[0027] Herein, it is not necessary to form the polishing pad by using one kind of the groove A. For example, the polishing pad may be formed by a combination of grooves having a plurality of different cross-sections in which an angle, which is formed between the polishing surface and the side surface continuous with the polishing surface, on at least one edge in the groove width direction is larger than 105 degrees and 150 degrees or smaller. Incidentally, from the viewpoint of the in-plane uniformity, it is preferable to form the polishing pad by using one kind of the groove A.

[0028] At the time of polishing the polishing pad, conditioning for dressing the pad surface by using a conditioner having diamond arranged to a metal or ceramic pedestal is necessary. By performing the conditioning, the surface of the polishing pad can have a concavo-convex shape suitable for polishing and stable polishing can be realized. However, the polishing layer is ground by the conditioning, and the grooves thereof decrease as the polishing is further carried out. When the cross-sectional area of the groove is decreased, the balance between supplying and discharging of slurry is deteriorated and thus, in some cases, there is an adverse effect such as decrease in a polishing rate or increase in defects.

[0029] For example, in a case where the cross-section of the groove is only V-shaped, the supplying and discharging of slurry is sufficient at the initial period of polishing. However, in the case of the final period in the lifetime of the polishing pad when the polishing is further carried out and thus the cross-sectional area of the groove is decreased, the supplying and discharging of slurry is not performed sufficiently. Therefore, in some cases, there is a problem that defects increase or the wafer is adsorbed on the polishing pad.

[0030] In a case where only the groove A having the side surfaces is arranged on the entire surface of the pad, the cross-sectional area of the groove is decreased at the final period in the lifetime of the polishing pad and thus, in some cases, there is a problem of decrease in a polishing rate or increase in defects. However, by providing the groove B in charge of the supplying and discharging of slurry, it can be considered that a high polishing rate and in-plane uniformity can be maintained and stable polishing can be performed until the final period in the lifetime of the polishing pad.

[0031] Therefore, in order to stabilize the shape of the groove B, all angles formed between the polishing surface and "the side surfaces of the groove B which are continuous with the polishing surface" need to be 60 degrees or larger and 105 degrees or smaller, and are more preferably 80 degrees or larger and even more preferably 85 degrees or larger. In addition, the angles are more preferably 100 degrees or smaller and even more preferably 95 degrees or smaller.

[0032] It is preferable that the groove B have a bottom face. Incidentally, even in the case of the groove B, the shape of the bottom face is not particularly limited.

[0033] FIGS. 2A to 2F are diagrams illustrating specific examples of the cross-section of the groove B.

[0034] A groove B 201 illustrated in FIG. 2A has a rectangular cross-section. The groove B 201 has two side surfaces 2, each of which is continuous with the polishing surface 1, on edges thereof in the groove width direction. In the case illustrated in FIG. 2A, angles θ_B formed between the polishing surface and the side surfaces continuous with the polishing surface on the two edges in the groove width direction are equal to each other and the values thereof are 90 degrees. In this case, the groove B 201 has a rectangular cross-section and a bottom face 6 thereof is parallel to the polishing surface 1.

[0035] A groove B 202 illustrated in FIG. 2B has a substantially U-shaped bottom face 7 formed between the two side surfaces 2.

[0036] A groove B 203 illustrated in FIG. 2C has a concave portion 8 which is formed by making a hole between the two side surfaces 2 to be narrow-width. The bottom surface of the concave portion is parallel to the polishing surface 1.

[0037] A groove B 204 illustrated in FIG. 2D has tapered inclined faces 9, which are respectively continuous with the two side surfaces 2 and are inclined to the inner periphery, and a substantially U-shaped bottom face 10 formed between the two inclined faces 9.

[0038] A groove B 205 illustrated in FIG. 2E has tapered inclined faces 11, which are respectively continuous with the two side surfaces 2 and are inclined to the inner periphery, and a V-shaped bottom face 12 formed between the two inclined faces 11.

[0039] A groove B 206 illustrated in FIG. 2F has a bottom face 14 which is formed between two side surfaces 13 and is parallel to the polishing surface 1. In the groove B 206, angles θ_B' formed between the polishing surface 1 and the side surfaces 2 continuous with the polishing surface 1 are an acute angle.

[0040] Further, the side surface continuous with the polishing surface in the groove B may be a curved line, a polygonal line, a straight line having a plurality of folding points, a wavy line, or a combination thereof in addition to a straight line, as long as the angle formed with respect to the polishing surface on the edge can be maintained to be 60 degrees or larger and 105 degrees or smaller even when the polishing pad is worn.

[0041] Herein, it is not necessary to form the polishing pad by using one kind of the groove B, but the polishing pad may be formed by a combination of grooves having a plurality of different cross-sections. Incidentally, from the viewpoint of the in-plane uniformity, it is preferable to form the polishing pad by using one kind of the groove.

[0042] The groove formed on the polishing surface is defined by the area ratio of the groove formed per area of the polishing surface. The groove-area ratio of the groove, which is formed on the polishing surface, per unitary unit is preferably 5% or higher and 50% or lower. In particular, the lower limit of the groove-area ratio per unitary unit is preferably 10% or higher, and more preferably 15% or higher. In addition, the upper limit of the groove-area ratio per unitary unit is more preferably 45% or lower, and even more preferably 40% or lower.

[0043] The "unitary unit" is a unit formed by a combination of the groove A and the groove B which are arranged in parallel to each other, and grooves are formed on the entire surface of the polishing surface by repeatedly forming the unitary unit on the polishing surface.

[0044] FIGS. 3A to 3I are diagrams illustrating representative examples of the configuration of a unitary unit including the groove A and the groove B.

[0045] A unitary unit 301 illustrated in FIG. 3A includes a combination of one groove A and three adjacent grooves B (arrangement pattern: ABBB).

[0046] A unitary unit 302 illustrated in FIG. 3B includes a combination of one groove A and two adjacent grooves B (arrangement pattern: ABB).

[0047] A unitary unit 303 illustrated in FIG. 3C includes a combination of two adjacent grooves A and three adjacent grooves B (arrangement pattern: AABBB).

[0048] A unitary unit 304 illustrated in FIG. 3D includes a combination of one groove A and one groove B which are adjacent to each other (arrangement pattern: AB).

[0049] A unitary unit 305 illustrated in FIG. 3E includes a combination of two adjacent grooves A and two adjacent grooves B (arrangement pattern: AABB).

[0050] A unitary unit 306 illustrated in FIG. 3F includes a combination of three adjacent grooves A and three adjacent grooves B (arrangement pattern: AAABBB).

[0051] A unitary unit 307 illustrated in FIG. 3G includes a combination of three adjacent grooves A and two adjacent grooves B (arrangement pattern: AAABB).

[0052] A unitary unit 308 illustrated in FIG. 3H includes a combination of two adjacent grooves A and one groove B (arrangement pattern: AAB).

[0053] A unitary unit 309 illustrated in FIG. 3I includes a combination of three adjacent grooves A and one groove B (arrangement pattern: AAAB).

[0054] Meanwhile, an area occupying ratio of the groove A per groove area is an area ratio of the groove A per area of groove which is formed on the polishing surface. The area occupying ratio of the groove A per area of groove which is formed on the polishing surface is preferably 30% or higher and 90% or lower, more preferably 40% or higher, and even more preferably 50% or higher. Moreover, the area occupying ratio of the groove A per groove area is more preferably 80% or lower, and even more preferably 70% or lower.

[0055] A groove, which a general polishing pad may have, may be provided on the surface of the polishing layer of the polishing pad in a lattice form, a dimple form, a spiral form, a concentric circle form, or the like, in order to suppress a hydroplane phenomenon or to prevent the wafer and the pad from being sucked with each other. A combination of these forms is preferably used, but in particular, a lattice form is preferable. The lattice form is a form by combining lines on a grid at a right angle. In the lattice form, there are a plurality of cases where grooves in a vertical direction and a horizontal direction have equal intervals, the intervals of grooves in the vertical direction are narrower than the intervals of grooves in the horizontal direction, and the intervals of grooves in the horizontal direction are narrower than the intervals of grooves in the vertical direction.

[0056] The groove A formed on the polishing surface of the polishing pad contributes to a high polishing rate and an excellent in-plane uniformity as described above. However, the balance between the supplying and discharging of slurry is deteriorated in accordance with decrease in the cross-sectional area at the final period of lifetime of the polishing pad. According to this, defects are increased. Therefore, for grooves formed on the polishing surface, the sum total of groove lengths of the grooves A formed on the entire polishing surface is preferably 10% or higher and 90% or lower, more preferably 20% or higher, even more preferably 25% or higher, even more preferably 30% or higher, and particularly preferably 35% or higher of the sum total of groove lengths of the grooves formed on the polishing surface. Moreover, the sum total of groove lengths of the grooves A formed on the entire polishing surface is more preferably 80% or lower, even more preferably 70% or lower, even more preferably 60% or lower, and particularly preferably 55% or lower.

[0057] When a ratio of the sum total of groove lengths of the grooves A formed on the entire polishing surface to the sum total of groove lengths of all grooves is within the above-described range, the suction force acts between the wafer and the polishing pad and an effect of increasing a polishing rate is exhibited. Moreover, as a forming method of grooves formed on the polishing surface of the polishing pad, a method may be employed in which the groove A is formed to be concentrated on the center of the polishing pad and the groove B is formed on the remaining portion. When the polishing surface of the polishing pad is circular, the groove A is formed in an area where two straight lines passing through the center of the polishing surface and intersected with each other are included and a distance from at least one of two straight lines is preferably 70% or lower, more preferably 60% or lower, even more preferably 50% or lower, and particularly preferably 40% or lower of the radius of the polishing surface.

[0058] FIG. 4 is a diagram schematically illustrating an arrangement example of the grooves A on the polishing surface of the polishing pad. In a circular polishing surface 402 of a polishing pad 401 illustrated in FIG. 4, grooves A 403 (indicated by heavy lines) are formed in an area where two straight lines L_1 and L_2 passing through the center O of the polishing surface 402 are included and a minimum distance from at least one of two straight lines is 1/3 (approximately 33%) or less of the radius r. Incidentally, dashed lines illustrated in FIG. 4 indicate grooves B 404. In this case, when an XY lattice shape is applied to the shape of grooves, it is more preferable that the grooves A 403 be distributed in two directions perpendicular to each other (X direction and Y direction), as compared to a case where the grooves A 403 are concentrated in only one direction.

[0059] In a case where the groove A and the groove B are formed by regularly arranging the grooves, the polishing pad may be formed, for example, on the basis of any one of unitary units illustrated in FIGS. 3A to 3H. However, a ratio of the number of the grooves A to the number of all grooves as a combination of grooves is not limited to exemplary combinations of grooves.

[0060] The groove widths of the groove A and the groove B are preferably 0.1 mm or more and 10 mm or less, more preferably 0.3 mm or more, and even more preferably 0.5 mm or more, because it is necessary to have a cross-sectional area where slurry can be supplied and discharged. Moreover, the groove widths of the groove A and the groove B are more preferably 8 mm or less, and even more preferably 5 mm or less.

[0061] The groove depths of the groove A and the groove B are preferably 0.2 mm or more and 4 mm or less, more preferably 0.3 mm or more, and even more preferably 0.4 mm or more, because it is necessary to secure supplying and discharging of slurry and sufficient lifetime. Moreover, the groove depths of the groove A and the groove B are more preferably 3 mm or less, and even more preferably 2 mm or less.

[0062] It is sufficient that the thickness of the polishing layer is smaller than a distance from the upper surface of the platen of the polishing apparatus to the lower surface of the polishing head. Therefore, the thickness of the polishing layer is preferably 4.0 mm or less, more preferably 3.5 mm or less, even more preferably 3.0 mm or less, and particularly preferably 2.5 mm or less.

[0063] In the invention, as the polishing layer that forms the polishing pad, a structure having the micro-rubber A hardness of 70 degrees or higher and isolated bubbles forms a planar surface on semiconductors, dielectric material/metal composites, integrated circuits and the like. Therefore, the structure is preferable. Although there are no particular limitations in terms of a material for forming the structure, examples of the material include polyethylene, polypropylene, polyester, polyurethane, polyurea, polyamide, polyvinyl chloride, polyacetal, polycarbonate, polymethyl methacrylate, polytetrafluoroethylene, epoxy resin, ABS resin, AS resin, phenol resin, melamine resin, "Neoprene (registered trademark)" rubber, butadiene rubber, styrene butadiene rubber, ethylene propylene rubber, silicon rubber, fluorine rubber, and resin having one of these as a main component. Among these, two or more materials may be used. Among these resins, a material having polyurethane as a main component is more preferable in terms of the fact that a diameter of isolated bubbles can be controlled relatively easily.

[0064] Polyurethane means a polymer synthesized by inducing addition polymerization reaction or a polymerization reaction using polyisocyanate. Examples of polyisocyanate may include tolylene diisocyanate, diphenylmethane diisocyanate, naphthalene diisocyanate, hexamethylene diisocyanate, and isophorone diisocyanate. However, polyisocyanate is not limited to these and two or more of these may be used. The compound to be used as a reactant with polyisocyanate is a compound containing active hydrogen, that is, a compound that contains two or more polyhydroxy groups or an amino group. Polyol is typically used as a compound containing a polyhydroxy group, and examples thereof include polyether polyol, polytetramethylene ether glycol, epoxy resin modified polyol, polyester polyol, acryl polyol, polybutadiene polyol, and silicone polyol. Two or more of these may be used. It is preferable to determine a combination of polyisocyanate and polyol, and a catalyst, a foaming agent and a foam stabilizer and optimal amounts thereof on the basis of hardness, a diameter of bubbles and an expansion ratio.

[0065] As a method for forming isolated bubbles in the polyurethane, a chemical foaming method for mixing various types of foaming agents with the resin at the time of manufacturing polyurethane is generally used, but a method for foaming a resin by mechanically stirring and then curing the resin can be also appropriate for use.

[0066] An average diameter of isolated bubbles is preferably 20 μm or greater and more preferably 30 μm or greater, from the viewpoint of holding slurry on the surface of the pad. Meanwhile, the average diameter of isolated bubbles is preferably 150 μm or less, more preferably 140 μm or less, and even more preferably 130 μm or less, from the viewpoint of securing the local planarity of unevenness on a semiconductor substrate. Incidentally, the average diameter of bubbles is a value obtained by observing the cross-section of a sample through an ultra-depth profile measuring microscope VK-8500 manufactured by Keyence Corporation at a magnification of 400 times, measuring an equivalent circle diameter of circular bubbles, which are obtained by excluding circularly-deficient bubbles observed outside of the field of view from bubbles observed in one field of view, from a cross-sectional area by using an image processing apparatus, and calculating an average value.

[0067] As an embodiment of the polishing pad according to the invention, a pad, which contains polyurethane and a polymer obtained by polymerizing a vinyl compound and has isolated bubbles, is preferable. By containing only the polymer obtained by polymerizing a vinyl compound, toughness and hardness can be increased, but it is difficult to obtain a uniform polishing pad having isolated bubbles. Moreover, polyurethane becomes fragile as the hardness increases. By impregnating polyurethane with the vinyl compound, it is possible to obtain a polishing pad containing isolated bubbles and having a high toughness and hardness.

[0068] The vinyl compound is a compound having a polymeric carbon-carbon double bond. Specific examples thereof include methyl acrylate, methyl methacrylate, ethyl acrylate, ethyl methacrylate, n-butyl acrylate, n-butyl methacrylate, 2-ethylhexyl methacrylate, isodecyl methacrylate, isobutyl methacrylate, n-lauryl methacrylate, 2-hydroxyethyl methacrylate, 2-hydroxypropyl methacrylate, 2-hydroxybutyl methacrylate, dimethylaminoethyl methacrylate, diethylaminoethyl methacrylate, glycidyl methacrylate, ethylene glycol dimethacrylate, acrylic acid, methacrylic acid, fumaric acid, dimethyl fumarate, diethyl fumarate, dipropyl fumarate, maleate, dimethyl maleate, diethyl maleate, dipropyl maleate, phenylmaleimide, cyclohexylmaleimide, isopropylmaleimide, acrylonitrile, acrylamide, vinyl chloride, vinylidene chloride, styrene, α-methyl styrene, divinylbenzene, ethylene glycol dimethacrylate, and diethylene glycol dimethacrylate. Moreover, two or more of these may be used as the vinyl compound.

[0069] Among the above-described vinyl compounds, $CH_2=CR^1COOR^2$ (R^1: a methyl group or an ethyl group, R^2: a methyl group, an ethyl group, a propyl group or a butyl group) is preferable. Among these, methyl methacrylate, ethyl methacrylate, n-butyl methacrylate, and isobutyl methacrylate are preferable, from the viewpoints that isolated bubbles are easily formed in polyurethane, the impregnating ability of monomers is preferable, polymerization curing is easy, and a foaming structure containing polyurethane and a polymer obtained by polymerizing a polymerization cured vinyl compound has a high hardness and planarization characteristics.

[0070] Examples of a polymerization initiator which can be preferably used to obtain the polymer obtained by polymerizing a vinyl compound may include radical initiators such as azobisisobutylonitrile, azobis(2,4-dimethylvaleronitrile), azobiscyclohexane carbonitrile, benzoyl peroxide, lauroyl peroxide, and isopropyl peroxydicarbonate. Two or more of these may be used. In addition, an oxidation-reduction based polymerization initiator, for example, a combination of peroxide and amines may be also used.

[0071] As a method for impregnating polyurethane with a vinyl compound, a method for immersing polyurethane in a container including a vinyl compound can be exemplified. Further, at this time, it is preferable to perform a process such as heat application, pressure application, pressure reduction, stirring, vibration, and ultrasonic vibration, for the purpose of increasing a rate of impregnation.

[0072] An impregnated amount of the vinyl compound in the polyurethane should be determined on the basis of types of a vinyl compound and polyurethane to be used, or properties of a polishing pad to be manufactured. Although it depends on circumstances, for example, a content ratio of a polymer obtained from a vinyl compound in the polymerization cured foaming structure and the polyurethane is preferably 30/70 to 80/20 in terms of a weight ratio. When the content ratio of the polymer obtained from a vinyl compound is 30/70 or more in terms of a weight ratio, the hardness of the polishing pad can be increased sufficiently. Moreover, when the content ratio thereof is 80/20 or less, the elasticity of the polishing layer can be increased sufficiently.

[0073] The contents of the polyurethane and the polymer obtained from the polymerization cured vinyl compound in the polyurethane can be measured by pyrolysis gas chromatography/mass spectrometry. As an apparatus used for this technique, a double shot pyrolizer "PY-2010D" (manufactured by Frontier Laboratories Ltd.) may be used as a pyrolytic equipment, and "TRIO-1" (manufactured by VG Co., Ltd.) may be used as a gas chromatography/mass spectrometry equipment.

[0074] In the invention, it is preferable that the phase of the polyurethane and the phase of the polymer obtained from a vinyl compound be contained in a non-separated state, form the viewpoint of the local planarity of unevenness on the semiconductor substrate. Quantitatively speaking, "an infrared spectrum obtained when the polishing pad is observed with a microscopic infrared spectrometer having a spot size of 50 μm has an infrared absorption peak of the polymer polymerized from a vinyl compound and an infrared absorption peak of the polyurethane, and the infrared spectrum is approximately the same in various places". As a microscopic infrared spectrometer used herein, IRμs manufactured by SPECTRA-TEC Inc., may be used.

[0075] The polishing pad may contain various types of additives, such as a polishing agent, a charge preventing agent, a lubricant, a stabilizer or a dye, for the purpose of improving properties of the polishing pad.

[0076] In the invention, a micro-rubber A hardness of the polishing layer is a value obtained by evaluation using a micro-rubber hardness meter MD-1 manufactured by KOBUNSHI KEIKI CO., LTD. The micro-rubber A hardness meter MD-1 makes measurement of the hardness of thin or small objects which are difficult to measure using a conventional hardness meter possible. Since the micro-rubber A hardness meter MD-1 is designed and manufactured as a scaled-down model of approximately 1/5 of a type A spring-type rubber hardness meter (durometer), it is possible to obtain a measurement value which coincides with the hardness measured using a type A spring-type hardness meter. A conventional polishing pad has a polishing layer or a hard layer of which a thickness is less than 5 mm, and thus cannot be evaluated using a type A spring-type rubber hardness meter. Accordingly, in the invention, the micro-rubber A hardness of the polishing layer is evaluated using the above-described micro-rubber MD-1.

[0077] In the invention, the hardness of the polishing layer is preferably 70 degrees or higher, and more preferably 80 degrees or higher in terms of the micro-rubber A hardness, from the viewpoint of the local planarity or unevenness on the semiconductor substrate.

[0078] In the invention, the density of the polishing layer is preferably 0.3 g/cm^3 or higher, more preferably 0.6 g/cm^3 or higher, and even more preferably 0.65 g/cm^3 or higher, from the viewpoint of reducing defects in the local planarity, or global level differences. Meanwhile, the density of the polishing layer is preferably 1.1 g/cm^3 or lower, more preferably 0.9 g/cm^3 or lower, and even more preferably 0.85 g/cm^3 or lower, from the viewpoint of reducing scratches. Incidentally, the density of the polishing layer according to the invention is a value which is measured with water as a medium, using a Harvard type pycnometer (JIS R-3503 standard).

[0079] It is preferable that the polishing pad according to the invention have a cushion layer of which a volume modulus of elasticity is 40 MPa or higher and a tensile modulus of elasticity is 1 MPa or higher and 20 MPa or lower, from the viewpoint of making the in-plane uniformity excellent. The volume modulus of elasticity is obtained in such a manner that the change in volume is measured by applying isotropic pressure to an object to be measured, of which the volume has been measured in advance, and calculation is carried out on the basis of the measurement result using the formula "volume modulus of elasticity = applied pressure/(change in volume/original volume). In the invention, the volume modulus of elasticity means a value measured when a sample is applied with a pressure of 0.04 to 0.14 MPa at 23°C.

[0080] In the invention, the volume modulus of elasticity is measured as follows. A test piece and water of 23°C are put in a measurement cell made of stainless steel having an internal volume of approximately 40 mL, and a measuring pipette made of borosilicate glass having a volume of 0.5 mL (minimum scale: 0.005 mL) is installed. A tube made of a polyvinyl chloride resin (inner diameter: 90 mmϕ x 2000 mm, thickness: 5 mm) is separately used as a pressure container, the measurement cell in which the above-described test piece has been put is put therein, and a pressure P is applied using nitrogen, so that a change in volume V1 is measured. Subsequently, the pressure P is applied using nitrogen without putting the test piece in the measurement cell so that a change in volume V0 is measured. A value obtained by dividing the pressure P by $\Delta V/Vi = (V1 - V0)/Vi$ is calculated as the volume modulus of elasticity of the sample.

[0081] In the invention, the volume modulus of elasticity of the cushion layer is preferably 40 MPa or higher. When the volume modulus of elasticity is 40 MPa or higher, the in-plane uniformity on the entire surface of the semiconductor substrate can be enhanced. Moreover, it is difficult that the cushion layer is impregnated with slurry or water which flows into a hole that penetrates through the polishing pad from the front surface to the rear surface and thus a cushioning property can be maintained.

[0082] In the invention, the tensile modulus of elasticity is obtained in such a manner that a tensile stress is applied to a test piece in a dumbbell form, and the tensile stress is measured for a tensile distortion (= change in the tensile length/original length) in a range from 0.01 to 0.03 and calculation is carried out on the basis of the measurement result using the formula "tensile modulus of elasticity = ((tensile stress when the tensile distortion is 0.03) - (tensile stress when the tensile distortion is 0.01))/0.02". As an apparatus for measuring the tensile stress, Tensilon Multi-Purpose Tester RTM-100 manufactured by Orientec Co., Ltd. or the like may be used. As for measuring conditions of the tensile stress, a rate of testing is 5 cm/min and the test piece is in a dumbbell form with a width of 5 mm, and a sample length of 50 mm.

[0083] In the invention, the tensile modulus of elasticity of the cushion layer is preferably 1 MPa or higher, and more preferably 1.2 MPa or higher, from the viewpoint of the in-plane uniformity on the entire surface of the semiconductor substrate. The tensile modulus of elasticity of the cushion layer is preferably 20 MPa or lower, and more preferably 10 MPa or lower.

[0084] As such a cushion layer, unfoamed elastomers, such as natural rubber, nitrile rubber, "Neoprene (registered trademark)" rubber, polybutadiene rubber, thermosetting polyurethane rubber, thermoplastic polyurethane rubber or silicon rubber, may be used, but there are no limitations to these. A thickness of the cushion layer is preferably in a range from 0.1 to 2 mm. A thickness of the cushion layer is preferably 0.2 mm or more, and more preferably 0.3 mm or more, from the viewpoint of the in-plane uniformity on the entire surface of the semiconductor substrate. Moreover, a thickness of the cushion layer is preferably 2 mm or less, and more preferably 1.75 mm or less, from the viewpoint of the local planarity.

[0085] As means for pasting the polishing layer and the cushion layer, for example, a double-sided tape or an adhesive may be used.

[0086] The double-sided tape has a general configuration in which an adhesive layer is provided on the both surfaces of a base material such as non-woven fabric or a film. Moreover, the polishing pad of the invention may include a double-sided tape formed on a surface to which a platen of the cushion sheet is attached. As such a double-sided tape, a double-sided tape having a general configuration in which an adhesive layer is provided on the both surfaces of a base material in the same manner as described above may be used. As a base material, for example, non-woven fabric or a film may be used. In consideration of peeling the polishing pad from the platen after using the polishing pad, a film is preferably used as a base material.

[0087] Further, as a composition of the adhesive layer, for example, a rubber-based adhesive, an acrylic-based adhesive, or the like may be used. In consideration of a content of metal ions, an acrylic-based adhesive is preferable in terms of a small content of metal ions. Moreover, in many cases, the cushion sheet has a different composition from the platen. Thus, compositions of respective adhesive layers of the double-sided tape make different from each other and it is also possible to make an adhesive force to the cushion sheet and the platen proper.

[0088] In the invention, as a material to be polished, for example, the surface of an insulating layer and metal wires formed on a semiconductor wafer may be used. Examples of the insulating layer may include interlayer insulating films of metal wires, lower layer insulating films of metal wires, and shallow trench isolation used for element isolation. Examples of the metal wires include aluminum wires, tungsten wires, and copper wires having a damascene, dual damascene, or plug structure. In a case where metal wires are made of copper, a barrier metal made of silicon nitride or the like also becomes an object to be polished. Although insulating films made of silicon oxide are currently used as mainstream insulating films, low dielectric constant insulating films may also be used. The material to be polished can be used for polishing magnetic heads, hard discs, and sapphire, in addition to semiconductor wafers.

[0089] The polishing method of the invention is preferably used to form a planar surface on glass, semiconductors, dielectric material/metal composites, integrated circuits, and the like.

Examples

[0090] Hereinafter, the detail description of the invention will be made on the basis of Examples. However, it should be understood that the invention is not limited to Examples. Incidentally, measurement was carried out as follows.

<Inclination Angle Measurement>

[0091] An angle formed between the polishing surface and the side surface continuous with the polishing surface was measured in such a manner that the polishing pad including the groove formed on the surface of the polishing layer was sliced in the groove depth direction and the cross-section of the groove was observed through an ultra-depth profile measuring microscope VK-8500 manufactured by Keyence Corporation. In a case where the polishing pad is circular, the nearest grooves from positions at 50 mm, 150 mm, and 250 mm distant from the center of the polishing pad were measured and an average of these three points was set as an inclination angle. Meanwhile, in a case where the polishing pad is not circular, the nearest grooves from positions at 50 mm, 150 mm, and 250 mm distant from an intersection point of diagonal lines of the sheet toward one end thereof were measured and an average of these three points was set as an inclination angle.

<Average Polishing Rate Measurement and In-plane Uniformity>

[0092] The polishing was carried out using Mirra 3400 manufactured by Applied Material Co., Ltd. under a predetermined polishing condition while performing endpoint detection. An average polishing rate as polishing characteristics was obtained in such a manner that polishing rates (nm/min) were measured by excluding 10 mm of the outmost circumference of the 8-inch wafer. The in-plane uniformity was obtained by dividing the standard deviation of the polishing rate by a difference between the maximum value and the minimum value of the polishing rates.

<Defect Evaluation>

[0093] As an enhancement process, after the polished wafer was immersed for 10 minutes in 0.5% by weight of hydrofluoric acid and then washed with water, the wafer was washed with a mixture solution of 1.0% by weight of ammonia and 1.0% by weight of hydrogen peroxide and then washed with water to be dried. The number of defects of 0.155 μm or greater was counted on the washed wafer, using SP-1 manufactured by KLA-Tencor Co., Ltd.

<Pad Grinding Rate>

[0094] The depth of the groove before and after polishing was measured using a depth gauge (digimatic type) maunfactured by Mitutoyo Corporation, and a pad grinding rate was obtained by dividing a reduced value of the groove by a time of using a disk which was being evaluated.

<Ratio of the Number of Grooves A>

[0095] The polishing pad including the groove formed on the polishing surface was sliced in parallel to the groove so as to count the number of the grooves A and the grooves B. Further, the ratio of the number of the grooves A was obtained in such a manner that the sum of the number of the groove A and the groove B was obtained from the arrangement example of the groove A and the groove B (cross-sectional view: FIG. 3) and the arrangement example of the groove A and the groove B (pattern diagram: FIG. 4) and the number of the grooves A was divided by the sum of the number of the groove A and the groove B. The calculation formula is described below.

$$\text{Ratio of the number of the grooves A} = \text{the number of the grooves A}/(\text{the number of the grooves A} + \text{the number of the grooves B}) \times 100\ (\%)$$

[0096] Hereinafter, Examples 1 to 11 and Comparative Examples 1 to 3 will be described.

(Example 1)

[0097] 30 parts by weight of polypropylene glycol, 40 parts by weight of diphenylmethane diisocyanate, 0.5 part by weight of water, 0.3 part by weight of triethylamine, 1.7 parts by weight of a silicon foam stabilizer, and 0.09 part by weight of tin octylate were mixed in an RIM molding machine, and the mixture was discharged into a mold for pressure molding to manufacture a foam polyurethane sheet with isolated bubbles having a thickness of 2.6 mm (micro-rubber A hardness: 42 degrees, density: 0.76 g/cm^3, average diameter of isolated bubbles: 34 μm).

[0098] The above-described foam polyurethane sheet was immersed for 60 minutes in methyl methacrylate to which 0.2 part by weight of azobisisobutylonitrile was added. Next, the above-described foam polyurethane sheet was immersed in a solution of 15 parts by weight of polyvinyl alcohol "CP" (degree of polymerization: approximately 500, manufactured by Nacalai Tesque, Inc.), 35 parts by weight of ethyl alcohol (special class reagent produced by Katayama Chemical Industries Co., Ltd.) and 50 parts by weight of water, and after that dried, and thus, the surface layer of the above-described foam polyurethane sheet was coated with polyvinyl alcohol.

[0099] Next, the above-described foam polyurethane sheet was sandwiched between two glass plates via a gasket made of vinyl chloride, and heated for six hours at 65°C and for three hours at 120°C so as to be cured through polymerization. The sheet was removed from the glass plates and washed with water, and after that dried in a vacuum at 50°C. The hard foam sheet thus obtained was sliced to have a thickness of 2.00 mm, and thus a polishing layer was manufactured. The content of methyl methacrylate in the polishing layer was 66% by weight. In addition, the D hardness of the polishing layer was 54 degrees, the density thereof was 0.81 g/cm^3, and the average diameter of the isolated bubbles was 45 μm.

[0100] The both sides of the hard foam sheet thus obtained were ground to manufacture a polishing layer having a thickness of 2 mm.

[0101] The polishing layer obtained by the above-described method was layered with thermoplastic polyurethane produced by Nihon Matai Co., Ltd. having a micro-rubber A hardness of 90 degrees and a thickness of 0.3 mm (volume modulus of elasticity = 65 MPa, tensile modulus of elasticity = 4 MPa), which functioned as a cushion layer, via an adhesive layer MA-6203 manufactured by Mitsui Chemicals Polyurethanes, Inc. using a roll coater, and furthermore, a double-sided tape 5604TDM manufactured by Sekisui Chemical Co., Ltd., was pasted on the rear surface as a rear surface tape.

[0102] The groove A, which has a groove width of 3.0 mm, a groove pitch of 15 mm, a V-shaped cross-section with an inclination angle θ_A of 135 degrees, and a groove depth of 1.5 mm, and the groove B, which has a groove width of 1.5 mm, a groove pitch of 15 mm, and a rectangular cross-section with a groove depth of 1.5 mm (inclination angle θ_B = 90 degrees) were alternately repeated (hereinafter, referred to as a pattern A) to be formed in the XY lattice shape. Therefore, the polishing pad was obtained. A groove-area ratio of the groove A per unitary unit was 24.9% and an area occupying ratio of the groove A per groove area was 73.7%.

[0103] The polishing pad obtained by the above-described method was pasted on the platen of a polishing apparatus ("Mirra 3400" manufactured by Applied Materials, Inc.). 100 pieces of 8-inch wafer with an oxide film were polished under a retainer ring pressure of 41 kPa (6 psi), an inner tube pressure of 28 kPa (4 psi), a membrane pressure of 28 kPa (4 psi), the number of rotations of platen of 76 rpm and the number of rotations of the polishing head of 75 rpm, and with slurry (SS-25, produced by Cabot Corporation) flowing at a flowing rate of 150 mL/min, by using a dresser manufactured by Saesol Diamond ind. Co., Ltd. under a load of 17.6 N (4 lbf) and for a polishing time of one minute, and by performing in-situ dressing for 30 seconds after the start of polishing. The average polishing rate of the 100th oxide film was 202 nm/min and the in-plane uniformity was 11.8%.

[0104] When the number of defects of 0.155 μm or greater was counted on the polished wafer by the defect evaluation method, the number of defects was 331, which was very excellent. In addition, the pad grinding rate during polishing was 1.01 μm/min.

(Example 2)

[0105] The polishing was carried out in the same manner as Example 1, except that grooves of the polishing surface were configured to include the groove A, which has a groove width of 3.0 mm, a groove pitch of 15 mm, a V-shaped cross-section with an inclination angle θ_A of 135 degrees, and a groove depth of 1.5 mm, and the groove B, which has a groove width of 1.5 mm, a groove pitch of 15 mm, and a rectangular cross-section with a groove depth of 1.5 mm, and a combination of one groove A and two grooves B was repeated (hereinafter, referred to as a pattern B) to be formed in the XY lattice shape over the entire area in the radius of the pad from the center of the polishing surface of the polishing pad. The groove-area ratio of the groove A per unitary unit was 20.7%, and the area occupying ratio of the groove A per groove area was 60.9%. The average polishing rate was 197 nm/min, and the in-plane uniformity was 9.0%.
[0106] When the number of defects of 0.155 μm or greater was counted on the polished wafer by the defect evaluation method, the number of defects was 211, which was excellent. In addition, the pad grinding rate during polishing was 1.21 μm/min.

(Example 3)

[0107] The polishing was carried out in the same manner as Example 1, except that the polishing pad was configured in such a manner that, on the surface of the polishing layer, the groove A, which has a groove width of 3.0 mm, a groove pitch of 15 mm, a V-shaped cross-section with an inclination angle θ_A of 135 degrees, and a groove depth of 1.5 mm, was formed in the XY lattice shape in an area where two straight lines passing through the center of the polishing surface and intersected with each other are included and a distance from at least one straight line is 32% or lower of the radius of the polishing surface, and the groove B, which has a groove width of 1.5 mm, a groove pitch of 15 mm, and a rectangular cross-section with a groove depth of 1.5 mm, was formed in the XY lattice shape in an area where a distance from the diameter exceeds 32% of the radius (hereinafter, referred to as a pattern C). The groove-area ratio of the groove A per unitary unit was 23.1%, and the area occupying ratio of the groove A per groove area was 67.7%. The arrangement diagram of grooves is illustrated in FIG. 4. The average polishing rate was 196 nm/min, and the in-plane uniformity was 10.9%.
[0108] When the number of defects of 0.155 μm or greater was counted on the polished wafer by the defect evaluation method, the number of defects was 142, which was very excellent. In addition, the pad grinding rate during polishing was 1.34 μm/min.

(Example 4)

[0109] The polishing was carried out in the same manner as Example 1, except that the groove A was formed on the surface of the polishing layer to have a trapezoidal cross-section with an inclination angle θ_A of 120 degrees. The groove-area ratio of the groove A per unitary unit was 16.5%, and the area occupying ratio of the groove A per groove area was 54.8%. The average polishing rate was 199 nm/min, and the in-plane uniformity was 6.0%.
[0110] When the number of defects of 0.155 μm or greater was counted on the polished wafer by the defect evaluation method, the number of defects was 155, which was very excellent. In addition, the pad grinding rate during polishing was 1.14 μm/min.

(Example 5)

[0111] The polishing was carried out in the same manner as Example 4, except that the groove A was formed on the surface of the polishing layer to have a trapezoidal cross-section with an inclination angle θ_A of 123 degrees. The groove-area ratio of the groove A per unitary unit was 28.3%, and the area occupying ratio of the groove A per groove area was 73.6%. The average polishing rate was 203 nm/min, and the in-plane uniformity was 8.4%.
[0112] When the number of defects of 0.155 μm or greater was counted on the polished wafer by the defect evaluation method, the number of defects was 141, which was very excellent. In addition, the pad grinding rate during polishing was 1.32 μm/min.

(Example 6)

[0113] The polishing was carried out in the same manner as Example 4, except that the groove B was formed on the surface of the polishing layer to have a trapezoidal cross-section with an inclination angle θ_B of 85 degrees. The groove-area ratio of the groove A per unitary unit was 30.2%, and the area occupying ratio of the groove A per groove area was 68.9%. The average polishing rate was 201 nm/min, and the in-plane uniformity was 9.1%.
[0114] When the number of defects of 0.155 μm or greater was counted on the polished wafer by the defect evaluation

method, the number of defects was 139, which was very excellent. In addition, the pad grinding rate during polishing was 1.11 μm/min.

(Example 7)

[0115] The polishing was carried out in the same manner as Example 3, except that, on the surface of the polishing layer, the groove A was formed to have a V-shaped cross-section with an inclination angle θ_A of 120 degrees and the groove B was formed to have a trapezoidal cross-section with an inclination angle θ_B of 85 degrees. The groove-area ratio of the groove A per unitary unit was 16.5%, and the area occupying ratio of the groove A per groove area was 54.8%. The average polishing rate was 200 nm/min, and the in-plane uniformity was 9.8%.
[0116] When the number of defects of 0.155 μm or greater was counted on the polished wafer by the defect evaluation method, the number of defects was 211, which was very excellent. In addition, the pad grinding rate during polishing was 1.33 μm/min.

(Example 8)

[0117] The polishing was carried out in the same manner as Example 3, except that, on the surface of the polishing layer, the groove A was formed to have a V-shaped cross-section with an inclination angle θ_A of 120 degrees and the groove B was formed to have a trapezoidal cross-section with an inclination angle θ_B of 95 degrees. The groove-area ratio of the groove A per unitary unit was 18.4%, and the area occupying ratio of the groove A per groove area was 49.0%. The average polishing rate was 209 nm/min, and the in-plane uniformity was 10.1%.
[0118] When the number of defects of 0.155 μm or greater was counted on the polished wafer by the defect evaluation method, the number of defects was 109, which was very excellent. In addition, the pad grinding rate during polishing was 1.30 μm/min.

(Example 9)

[0119] The polishing was carried out in the same manner as Example 3, except that the groove A was formed on the surface of the polishing layer to have a V-shaped cross-section with an inclination angle θ_A of 150 degrees. The groove-area ratio of the groove A per unitary unit was 34.6%, and the area occupying ratio of the groove A per groove area was 78.4%. The average polishing rate was 200 nm/min, and the in-plane uniformity was 9.9%.
[0120] When the number of defects of 0.155 μm or greater was counted on the polished wafer by the defect evaluation method, the number of defects was 111, which was very excellent. In addition, the pad grinding rate during polishing was 1.41 μm/min.

(Example 10)

[0121] The polishing was carried out in the same manner as Example 3, except that, on the surface of the polishing layer, the groove A was formed to have a V-shaped cross-section with an inclination angle θ_A of 150 degrees and the groove B was formed to have a trapezoidal cross-section with an inclination angle θ_B of 85 degrees. The groove-area ratio of the groove A per unitary unit was 34.6%, and the area occupying ratio of the groove A per groove area was 78.4%. The average polishing rate was 206 nm/min, and the in-plane uniformity was 10.0%.
[0122] When the number of defects of 0.155 μm or greater was counted on the polished wafer by the defect evaluation method, the number of defects was 153, which was very excellent. In addition, the pad grinding rate during polishing was 1.44 μm/min.

(Example 11)

[0123] The polishing was carried out in the same manner as Example 3, except that, on the surface of the polishing layer, the groove A was formed to have a V-shaped cross-section with an inclination angle θ_A of 150 degrees and the groove B was formed to have a trapezoidal cross-section with an inclination angle θ_B of 95 degrees. The groove-area ratio of the groove A per unitary unit was 36.5%, and the area occupying ratio of the groove A per groove area was 74.3%. The average polishing rate was 200 nm/min, and the in-plane uniformity was 10.1%.
[0124] When the number of defects of 0.155 μm or greater was counted on the polished wafer by the defect evaluation method, the number of defects was 134, which was very excellent. In addition, the pad grinding rate during polishing was 1.40 μm/min.

(Comparative Example 1)

[0125] The polishing was carried out in the same manner as Example 1, except that only grooves, which have a groove width of 1.5 mm, a groove pitch of 15 mm, and a rectangular cross-section with a groove depth of 1.5 mm, were formed on the surface of the polishing layer. The average polishing rate was 180 nm/min, and the in-plane uniformity was 12.2%.

[0126] When the number of defects of 0.155 μm or greater was counted on the polished wafer by the defect evaluation method, the number of defects was 583, which was excellent. In addition, the pad grinding rate during polishing was 1.13 μm/min.

(Comparative Example 2)

[0127] The polishing was carried out in the same manner as Example 1, except that only grooves, which have a groove width of 3.0 mm, a groove pitch of 15 mm, a groove depth of 1.5 mm, and a V-shaped cross-section with an inclination angle of 135 degrees, were formed on the surface of the polishing layer. The average polishing rate was 217 nm/min, and the in-plane uniformity was 21.1%.

[0128] When the number of defects of 0.155 μm or greater was counted on the polished wafer by the defect evaluation method, the number of defects was 297, which was very excellent. In addition, the pad grinding rate during polishing was 1.73 μm/min.

(Comparative Example 3)

[0129] The polishing was carried out in the same manner as Example 1, except that the polishing layer was formed to have a thickness of 1.0 mm, and only grooves, which have a groove width of 1.0 mm, a groove pitch of 15 mm, a groove depth of 0.5 mm, and a V-shaped cross-section with an inclination angle of 135 degrees, were formed on the surface of the polishing layer. The average polishing rate was 205 nm/min, and the in-plane uniformity was 18.3%.

[0130] When the number of defects of 0.155 μm or greater was counted on the polished wafer by the defect evaluation method, the number of defects was 1521, which was a large number of defects. In addition, the pad grinding rate during polishing was 1.68 μm/min.

[0131] The results obtained from Examples 1 to 11 and Comparative Examples 1 to 3 described above are listed in Table 1.

Table 1

	Example 1	Example 2	Example 3	Example 4	Example 5	Example 6	Example 7	Example 8	Example 9	Example 10	Example 11	Comparative Example 1	Comparative Example 2	Comparative Example 3
Cross-section of groove A	V	V	V	Trapezoidal	Trapezoidal	Trapezoidal	V	V	V	V	V	Rectangular	V	V
Inclination angle θ_A of groove A (degree)	135	135	135	120	123	120	120	120	150	150	150	90	135	135
Cross-section of groove B	Rectangular	Rectangular	Rectangular	Rectangular	Rectangular	Trapezoidal	Trapezoidal	Trapezoidal	Rectangular	Trapezoidal	Trapezoidal	-	-	-
Inclination angle θ_B of groove B (degree)	90	90	90	90	90	85	85	95	90	85	95	-	-	-
Groove arrangement pattern	A	B	C	A	A	A	C	C	C	C	C	-	-	-
Groove-area ratio of groove A per unitary unit (%)	24.9	20.7	23.1	16.5	28.3	30.2	16.5	18.4	34.6	34.6	36.5	-	-	-
Area occupying ratio of groove A per groove area (%)	73.7	60.9	67.7	54.8	73.6	68.9	54.8	49.0	78.4	78.4	74.3	-	-	-
Average polishing rate (nm/min)	202	197	196	199	203	201	200	209	200	206	200	180	217	205

(continued)

	Example 1	Example 2	Example 3	Example 4	Example 5	Example 6	Example 7	Example 8	Example 9	Example 10	Example 11	Comparative Example 1	Comparative Example 2	Comparative Example 3
In-plane uniformity (%)	11.8	9.0	10.9	6.0	8.4	9.1	9.8	10.1	9.9	10.0	10.1	12.2	21.1	18.3
Defect	331	211	142	155	141	139	211	109	111	153	134	583	297	1521
Pad grinding rate (μm/min)	1.01	1.21	1.34	1.14	1.32	1.11	1.33	1.30	1.41	1.44	1.40	1.13	1.73	1.68

Reference Signs List

[0132]

1, 402	POLISHING SURFACE
2, 13	SIDE SURFACE
3, 4, 6, 7, 8, 10, 12, 14	BOTTOM FACE
5	CONCAVE PORTION
9, 11, 13	INCLINED FACE
101, 102, 103, 104, 403	GROOVE A
201, 202, 203, 204, 205, 206, 404	GROOVE B
301, 302, 303, 304, 305, 306, 307, 308, 309	UNITARY UNIT
401	POLISHING PAD

Claims

1. A polishing pad for chemical mechanical polishing, the polishing pad comprising at least a polishing layer, wherein a polishing surface of the polishing layer includes a first groove and a second groove,
the first and second grooves have side surfaces, which are continuous with the polishing surface, on each edge in a groove width direction,
the first groove has an angle of larger than 105 degrees and 150 degrees or smaller, which is formed between the polishing surface and the side surface continuous with the polishing surface, on at least one edge in the groove width direction, and
the second groove has an angle of 60 degrees or larger and 105 degrees or smaller, which is formed between the polishing surface and the side surface continuous with the polishing surface, on both of two edges in the groove width direction.

2. The polishing pad according to claim 1, wherein the second groove has a bottom face.

3. The polishing pad according to claim 2, wherein a groove-area ratio per unitary unit is 5% or higher and 50% or lower, and an area occupying ratio of the first groove per groove area is 30% or higher and 90% or lower.

4. The polishing pad according to any one of claims 1 to 3, wherein the first and second grooves are formed in a lattice shape.

5. The polishing pad according to claim 4, wherein the sum total of groove lengths of the first grooves formed on the polishing surface is 10% or higher and 90% or lower of the sum total of groove lengths of grooves formed on the polishing surface.

6. The polishing pad according to claim 4 or 5, wherein the polishing surface is circular, and the first groove formed on the polishing surface is formed in an area where two straight lines passing through the center of the polishing surface and intersected with each other are included and a distance from at least one of two straight lines is 70% or lower of the radius of the polishing surface.

7. The polishing pad according to any one of claims 4 to 6, wherein the first groove has an angle of larger than 105 degrees and 150 degrees or smaller, which is formed between the polishing surface and the side surface continuous with the polishing surface, on both of two edges in the groove width direction.

FIG.1A

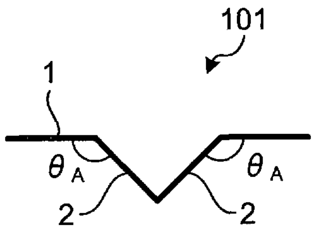


FIG.1B

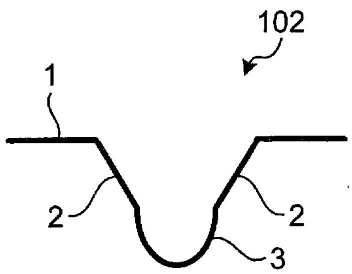


FIG.1C

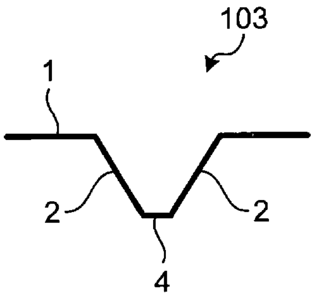


FIG.1D

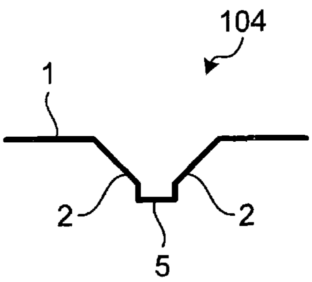


FIG.2A

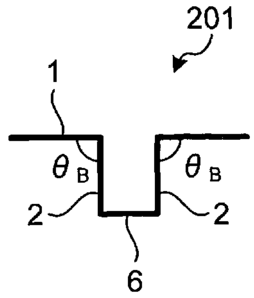


FIG.2B

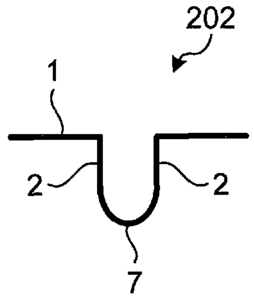


FIG.2C

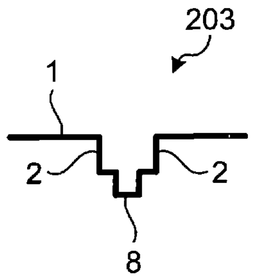


FIG.2D

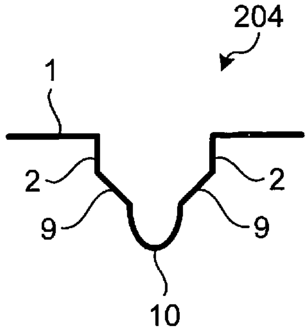


FIG.2E

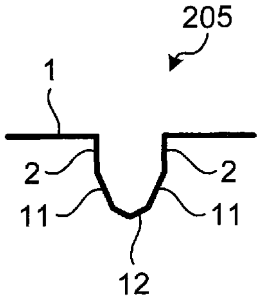


FIG.2F

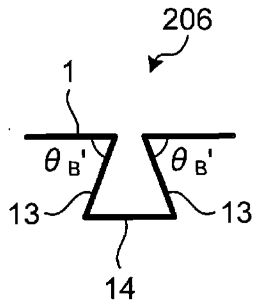


FIG.3A

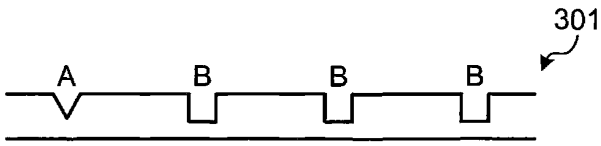


FIG.3B

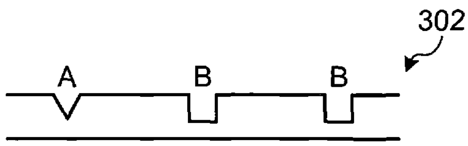


FIG.3C

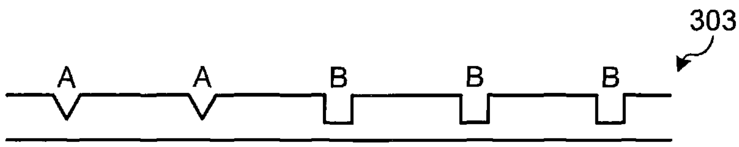


FIG.3D

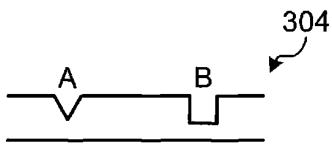


FIG.3E

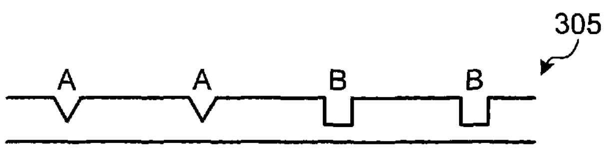


FIG.3F

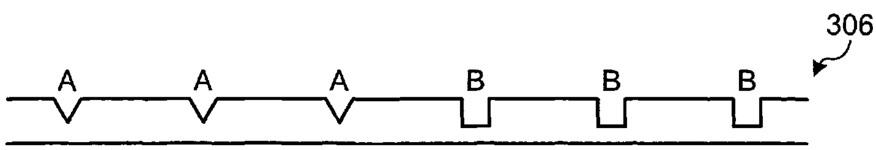


FIG.3G

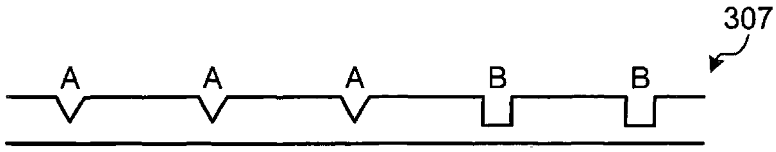


FIG.3H

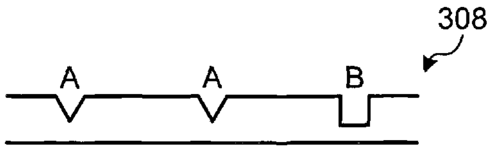


FIG.3I

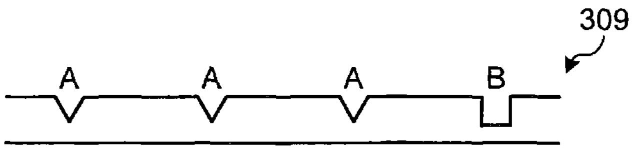
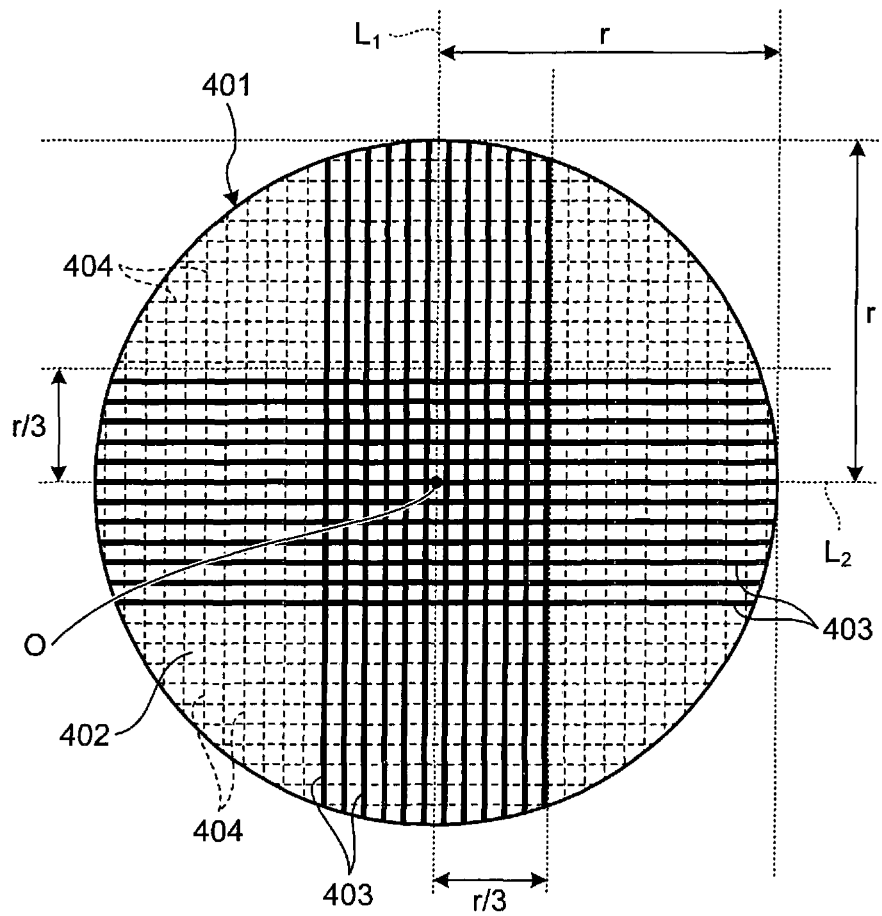


FIG.4



INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2012/073538

A. CLASSIFICATION OF SUBJECT MATTER
H01L21/304(2006.01)i, *B24B37/26*(2012.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H01L21/304, B24B37/26

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Jitsuyo Shinan Koho	1922-1996	Jitsuyo Shinan Toroku Koho	1996-2012
Kokai Jitsuyo Shinan Koho	1971-2012	Toroku Jitsuyo Shinan Koho	1994-2012

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2003-511848 A (Koninklijke Philips Electronics N.V.), 25 March 2003 (25.03.2003), paragraphs [0016] to [0017]; fig. 1A to 1B & US 6346032 B1 & EP 1305139 A & WO 2001/024969 A2 & DE 60044469 D & CN 1337898 A	1-7
A	JP 2010-528885 A (Applied Materials Inc.), 26 August 2010 (26.08.2010), paragraphs [0016], [0024]; fig. 3 & US 2008/0305729 A1 & WO 2008/154185 A2 & TW 200906543 A	1-7

☒ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
15 October, 2012 (15.10.12)	30 October, 2012 (30.10.12)

Name and mailing address of the ISA/	Authorized officer
Japanese Patent Office	
Facsimile No.	Telephone No.

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2012/073538

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2006-165323 A (Seiko Epson Corp.), 22 June 2006 (22.06.2006), paragraphs [0055] to [0057]; fig. 9 to 10 (Family: none)	1-7
A	JP 2000-286218 A (Nikon Corp.), 13 October 2000 (13.10.2000), paragraph [0025]; fig. 5 & US 6749714 B1 & EP 1211023 A1 & WO 2000/059680 A1 & DE 60039054 D & TW 511174 B & TW 530348 B & CN 1551303 A & CN 1345264 A	1-7
A	JP 2009-82995 A (Covalent Materials Corp.), 23 April 2009 (23.04.2009), claim 1; paragraphs [0016], [0039] to [0040]; fig. 5 to 6 (Family: none)	1-7

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REFERENCES CITED IN THE DESCRIPTION

Patent documents cited in the description

- JP 2001212752 A **[0007]**
- JP 2010045306 A **[0007]**
- JP 2004186392 A **[0007]**