

## DESCRIPTION

TITLE OF THE INVENTION: POLISHING PAD AND PRODUCTION METHOD THEREFOR, AND PRODUCTION METHOD FOR SEMICONDUCTOR DEVICE

### 5 TECHNICAL FIELD

[0001]

The present invention relates to a polishing pad capable of attaining, with a stable and high polishing efficiency, a planarization processing of an optical matter such as a lens  
10 or a reflecting mirror, a silicon wafer, a glass substrate for a hard disc, aluminum substrate, and a matter or material for which a high-level surface flatness is required in, for example, an ordinary metal polishing processing; a method for producing the same; and a method for producing a semiconductor device.  
15 The polishing pad of the present invention is particularly useful for finish polishing of a silicon wafer or a glass piece.

### BACKGROUND ART

[0002]

20 In general, the mirror polishing of a semiconductor wafer such as a silicon wafer, a lens, a glass substrate, or some other is divided to rough polishing for a main purpose of adjusting the polished matter in flatness and in-plane evenness, and finish polishing for a main purpose of improving the matter in  
25 surface roughness, and removing scratches.

[0003]

The finish polishing is usually attained by causing a  
sueded artificial leather made of a soft foamed polyurethane  
to adhere onto a rotatable table, and rubbing a wafer against  
5 the leather while a polishing agent wherein colloidal silica  
is contained in an aqueous alkali-based solution is supplied  
thereonto (Patent Document 1).

[0004]

However, when the polishing layer, which is made of the  
10 foamed polyurethane used for finish polishing, is low in  
flatness, there is caused a problem that tiny undulations are  
generated in the surface of the matter to be polished. The tiny  
undulations have been in particular considered to be a problem  
in the field of recent finish polishing. Thus, it has been  
15 intensely required in the market to supply a polishing pad  
capable of attaining a further decrease of tiny undulations.

[0005]

The present inventors have suggested a polishing pad  
comprising a polishing layer comprising a thermoset  
20 polyurethane containing, as raw material components, an  
isocyanate component plus active-hydrogen-containing  
compounds comprising 1 to 20% by weight of a  
low-molecular-weight polyol having a functional group number  
of 3 to 8 and a hydroxyl group value of 400 to 1,830 mg KOH  
25 / g and/or a low-molecular-weight polyamine having a

functional group number of 3 to 8 and an amine value of 400 to 1,870 mg KOH / g (Patent Document 2). Although this polishing pad is characterized by being excellent in endurance and self-dressability, it has been made evident that the pad has a room for a further improvement about tiny undulations in a matter to be polished.

[0006]

Patent Document 3 listed up below states that when the microrubber A hardness value of a polishing pad is at least 12 smaller than the Asker C hardness thereof, and the Asker C hardness is 60 or more, the polishing efficiency of the polishing pad can be made compatible with the flattening performance thereof at a high level. However, this document never discloses a specific formulation or composition of a polyurethane foam constituting the polishing pad. Furthermore, the present inventors' investigations have made it evident that only by optimizing the relationship between the microrubber A hardness value of a polishing pad and the Asker C hardness thereof, the polishing pad cannot gain the effect of decreasing tiny undulations as described above.

PRIOR ART DOCUMENTS

PATENT DOCUMENTS

[0007]

Patent Document 1: JP-A-2003-37089

Patent Document 2: JP-B1-4237800

Patent Document 3: JP-A-2008-207319

## SUMMARY OF THE INVENTION

### 5 PROBLEMS TO BE SOLVED BY THE INVENTION

[0008]

In light of the above-mentioned actual situation, the present invention has been made, and an object thereof is to provide a polishing pad capable of decreasing tiny undulations  
10 generated in the surface of a matter to be polished, a method for producing the same, and a method for producing a semiconductor device.

### MEANS FOR SOLVING THE PROBLEMS

15 [0009]

In order to solve the problems, the present inventors have made eager investigations, paying attention to an in-plane variation in the microrubber A hardness of a polishing layer, the variation being obtained by measuring the layer from the  
20 a polishing surface side thereof. As a result, the present inventors have found out that by adjusting the in-plane variation in the microrubber A hardness into 12 or less, the front surface of the polishing pad can be made uniform and tiny undulations generated in the surface of a matter to be polished  
25 can be decreased. Furthermore, the present inventors have made

eager investigations about the formulation/composition for adjusting the in-plane variation in the microrubber A hardness of the polishing layer into 12 or less, so as to find out that the adjustment can be attained by a formulation/composition as described below.

[0010]

Thus, the polishing pad of the present invention is a polishing pad having a polishing layer comprising a thermoset polyurethane foam, wherein the polishing layer has an in-plane variation of 12 or less in microrubber A hardness, the variation being obtained by measuring the polishing layer from a polishing surface side of the layer; the thermoset polyurethane foam contains, as raw material components, an isocyanate component, and active-hydrogen-containing compounds, and the active-hydrogen-containing compounds comprise a trifunctional polyol having at least one terminated hydroxyl group that is a secondary hydroxyl group, and having a hydroxyl group value of 150 to 1,000 mg KOH / g in an amount of 10 to 50 parts by weight for 100 parts by weight of the active-hydrogen-containing compounds.

[0011]

The thermoset polyurethane foam constituting the polishing layer of the polishing pad contains, as raw material components, an isocyanate component plus active-hydrogen-containing compounds comprising 10 to 50 parts

by weight of a trifunctional polyol having at least one terminated hydroxyl group that is a secondary hydroxyl group, and having a hydroxyl group value of 150 to 1,000 mg KOH / g. When a thermoset polyurethane foam yielded from these raw material components constitutes the polishing layer, the in-plane variation in the microrubber A hardness of the polishing layer can be adjusted to 12 or less, the variation being obtained by measuring the polishing layer from the polishing surface side of the layer. As a result, this polishing pad can decrease tiny undulations generated in the surface of a matter to be polished. The reason why such advantageous effects can be gained is unclear; however, it is assumed that through the trifunctional polyol, three-dimensional crossed moieties are introduced into the thermoset polyurethane, resulting in the matter that the in-plane variation in the microrubber A hardness of the polishing layer is set to 12 or less.

[0012]

It is preferred in the polishing pad that the active-hydrogen-containing compounds comprise a bifunctional polyol having at least one terminated hydroxyl group that is a secondary hydroxyl group, and having a hydroxyl group value of 1,000 to 1,500 mg KOH / g in an amount of 0 to 20 parts by weight for 100 parts by weight of the active-hydrogen-containing compounds. The use of this

bifunctional polyol as a chain extender makes it possible to decrease the in-plane variation in the microrubber A hardness of the polishing layer, the variation being obtained by measuring the polishing layer from the polishing surface side of the layer. As a result, the polishing pad makes it possible to attain a further decrease in tiny undulations generated in the surface of a matter to be polished.

[0013]

In the polishing pad, it is preferred that the thermoset polyurethane foam has substantially spherical bubbles having an average bubble diameter of 20 to 300  $\mu\text{m}$ . When the polishing layer is formed by use of the thermoset polyurethane foam, which has substantially spherical bubbles having an average bubble diameter of 20 to 300  $\mu\text{m}$ , the polishing layer can be improved in endurance. Thus, when the polishing pad of the present invention is used, the polishing pad can keep high planarization characteristics over a long term, and is also improved in polishing rate stability. The wording "substantially spherical" denotes a spherical form and an elliptic form.

Bubbles in an elliptic form denote bubbles having a ratio between the long diameter L and the short diameter S (ratio of L/S) of 5 or less, preferably 3 or less, more preferably 1.5 or less.

[0014]

The present invention also relates to a method for

producing a polishing pad, comprising the step of using a mechanical foaming method to prepare a foam-dispersed urethane composition containing, as raw material components, an isocyanate component plus active-hydrogen-containing

5 compounds comprising a trifunctional polyol compound in an amount of 10 to 50 parts by weight, this trifunctional polyol compound being a compound having at least one terminated hydroxyl group that is a secondary hydroxyl group, and having a hydroxyl group value of 150 to 1,000 mg KOH / g; the step  
10 of painting the foam-dispersed urethane composition onto a planar member; the step of setting the foam-dispersed urethane composition to form a polishing layer comprising a thermoset polyurethane foam having substantially spherical bubbles having an average bubble diameter of 20 to 300  $\mu\text{m}$ ; and the step  
15 of adjusting the polishing layer into a uniform thickness. This producing method makes it possible to produce a polishing pad which decreases tiny undulations generated in the surface of a matter to be polished.

[0015]

20 Furthermore, the present invention relates to a method for producing a semiconductor device, comprising the step of using the polishing pad described in any one of the above-mentioned paragraphs concerned to polish a surface of a semiconductor wafer.

25

## BRIEF DESCRIPTION OF THE DRAWING

[0016]

Fig. 1 is a schematic structural view illustrating a polishing machine used in a method for producing a semiconductor device.

## MODE FOR CARRYING OUT THE INVENTION

[0017]

The polishing pad of the present invention has a polishing layer constituting a thermoset polyurethane foam, which may be referred to as a "polyurethane foam" hereinafter.

[0018]

Polyurethane resin is excellent in abrasion resistance, and can be a polymer that can easily obtained with various physical properties by changing the composition of raw materials thereof variously; and further therein, substantially spherical fine bubbles can easily be formed by a mechanical foaming method (examples thereof including a mechanical frothing method). For these reasons, polyurethane resin is a material particularly preferable for the constituting material of the polishing layer.

[0019]

Polyurethane resin mainly contains an isocyanate component, and active-hydrogen-containing compounds (such as a high-molecular-weight polyol, a low-molecular-weight polyol,

a low-molecular-weight polyamine, and a chain extender).

[0020]

As the isocyanate component, any compound known in the field of polyurethane may be used without especial restriction.

5 Examples thereof include aromatic diisocyanates such as 2,4-toluene diisocyanate, 2,6-toluene diisocyanate, 2,2'-diphenylmethane diisocyanate, 2,4'-diphenylmethane diisocyanate, 4,4'-diphenylmethane diisocyanate, polymeric MDI, carbodiimide-modified MDI (for example, MILLIONATE MTL  
10 (trade name) manufactured by Nippon Polyurethane Industry Co., Ltd.), 1,5-naphthalene diisocyanate, p-phenylene diisocyanate, m-phenylene diisocyanate, p-xylylene diisocyanate, and m-xylylene diisocyanate; aliphatic diisocyanates such as ethylene diisocyanate, 2,2,4-trimethylhexamethylene  
15 diisocyanate, and 1,6-hexamethylene diisocyanate; and alicyclic diisocyanates such as 1,4-cyclohexane diisocyanate, 4,4'-dicyclohexylmethane diisocyanate, isophorone diisocyanate, and norbornane diisocyanate. These may be used alone or in combination of two or more thereof.

20 [0021]

It is preferred to use, out of the above-mentioned isocyanate components, an aromatic diisocyanate. It is particularly preferred to use at least one of toluene diisocyanate, diphenylmethane diisocyanate, and  
25 carbodiimide-modified diphenylmethane diisocyanate.

[0022]

It is important for the present invention to comprise a trifunctional polyol having at least one terminated hydroxyl group that is a secondary hydroxyl group, and having a hydroxyl group value of 150 to 1,000 mg KOH / g. This trifunctional polyol may be synthesized by adding propylene oxide (PO) to a trifunctional initiator such as glycerin or trimethylolpropane by a method known by those skilled in the art. The hydroxyl group value can be adjusted by changing the addition amount of PO, and is in particular preferably adjusted into the range of 150 to 500 mg KOH / g. The content of the trifunctional polyol, which has at least one terminated hydroxyl group that is a secondary hydroxyl group and has a hydroxyl group value of 150 to 1,500 mg KOH / g, in the active-hydrogen-containing compounds is set into the range of 15 to 40 parts by weight for 100 parts by weight of the compounds.

[0023]

It is also preferred for the present invention to comprise a bifunctional polyol having at least one terminated hydroxyl group that is a secondary hydroxyl group, and having a hydroxyl group value of 1,000 to 1,500 mg KOH / g in an amount of 0 to 20 parts by weight for 100 parts by weight of the active-hydrogen-containing compounds. The amount is more preferably from 5 to 20 parts by weight, in particular preferably from 10 to 20 parts by weight therefor. The use of

this bifunctional polyol as a chain extender makes it possible to make a further decrease in the in-plane variation in the microrubber A hardness of the polishing layer, the variation being obtained by measuring the polishing layer from the  
5 polishing surface side of the layer. Examples of the bifunctional polyol, which has at least one terminated hydroxyl group that is a secondary hydroxyl group and has a hydroxyl group value of 1,000 to 1,500 mg KOH / g, include 1,2-propylene glycol, 1,3-butanediol, and 2,3-butanediol.

10 [0024]

In the present invention, as any one of the active-hydrogen-containing compounds, the following may be used besides the above-mentioned trifunctional polyol, and bifunctional polyol: an active-hydrogen-containing compound  
15 usable ordinarily in technical fields of polyurethane, for example, a high-molecular-weight polyol, a low-molecular-weight polyol, a low-molecular-weight polyamine, or a chain extender.

[0025]

20 Examples of the high-molecular-weight polyol include any polyether polyol, typical examples thereof including polytetramethylene ether glycol, and polyethylene glycol; any polyester polyol, a typical example thereof including polybutylene adipate; any polyester polycarbonate polyol,  
25 examples thereof including polycaprolactone polyol, and a

reaction material made from a polyester glycol, such as polycaprolactone, and an alkylene carbonate; any polyester polycarbonate polyol yielded by causing ethylene carbonate to react with a polyhydric alcohol, and next causing the resultant  
5 reaction mixture to react with an organic dicarboxylic acid; any polycarbonate polyol yielded by transesterification reaction between a polyhydroxy compound and an aryl carbonate; and any polymer polyol that is a polyether polyol wherein polymer particles are dispersed. These may be used alone or  
10 in combination of two or more thereof.

[0026]

Examples of the low-molecular-weight polyol include trimethylolpropane, glycerin, diglycerin, 1,2,6-hexanetriol, triethanolamine, pentaerythritol, tetramethylolcyclohexane,  
15 methylglucoside, and alkylene oxide adducts of these examples. These may be used alone or in combination of two or more thereof.

[0027]

Examples of the low-molecular-weight polyamine include ethylenediamine, tolylenediamine, diphenylmethanediamine,  
20 and alkylene oxide (such as EO or PO) adducts of these amines. These may be used alone or in combination of two or more thereof.

[0028]

The following may be together used: ethylene glycol, 1,2-butanediol, 1,4-butanediol, 1,6-hexanediol,  
25 neopentylglycol, 1,4-cyclohexanedimethanol,

3-methyl-1,5-pentanediol, diethylene glycol, triethylene glycol, and any low-molecular-weight polyol. The following may also be together used: monoethanolamine, diethanolamine, 2-(2-aminoethylamino)ethanol, monopropanolamine, and any  
5 other alcoholamine.

[0029]

The chain extender is an organic compound having at least two active hydrogen groups. Examples of the active hydrogen groups include hydroxyl groups, primary or secondary amino  
10 groups, and thiol groups (SH). Specific examples of the chain extender include 4,4'-methylenebis(o-chloroaniline) (MOCA), 2,6-dichloro-p-phenylenediamine, 4,4'-methylenebis(2,3-dichloroaniline), 3,5-bis(methylthio)-2,4-toluenediamine,  
15 3,5-bis(methylthio)-2,6-toluenediamine, 3,5-diethyltoluene-2,4-diamine, 3,5-diethyltoluene-2,6-diamine, trimethylene glycol-di-p-aminobenzoate, 1,2-bis(2-aminophenylthio)ethane, 4,4'-diamino-3,3'-diethyl-5,5'-dimethyldiphenylmethane,  
20 N,N'-di-sec-butyl-4,4'-diaminodiphenylmethane, 3,3'-diethyl-4,4'-diaminodiphenylmethane, m-xylylenediamine, N,N'-di-sec-butyl-p-phenylenediamine, m-phenylenediamine, p-xylylenediamine, and other polyamines; and the above-mentioned low-molecular-weight polyols or  
25 low-molecular-weight polyamines. These may be used alone or

in combination of two or more thereof.

[0030]

The ratio between the isocyanate component and the active-hydrogen-containing compounds may be variously changed in accordance with the molecular weight of each of these materials, desired physical properties of the polyurethane foam, and others. In order to give a foam having desired properties, the following index is preferably from 0.80 to 1.20, more preferably from 0.90 to 1.15: the number (NCO index) of isocyanate groups of the isocyanate component relative to the number of entire active hydrogen groups (hydroxyl groups + amino groups) of the active-hydrogen-containing compounds. If the number of the isocyanate groups is out of this range, the resultant polyurethane tends to undergo curing insufficiency not to gain a required specific gravity, hardness, compressibility nor some other property.

[0031]

The polyurethane resin may be produced by a known urethanizing technique such as melting technique or solution technique. When cost, working environment and others are considered, it is preferred to produce the resin by melting technique. For the production of the polyurethane resin, either a prepolymer method or one-shot method may be used.

[0032]

The thermoset polyurethane foam which is a forming matter

for the polishing layer may be produced by a mechanical foaming method (examples thereof including a mechanical frothing method).

[0033]

5            Particularly preferred is a mechanical foaming method using a silicone surfactant that is a copolymer of a polyalkylsiloxane and a polyether. Examples of a preferred compound as the silicone surfactant include SH-192 and L-5340 (manufactured by Dow Corning Toray silicone Co., Ltd.), and  
10 B8443 (manufactured by Goldschmidt GmbH).

[0034]

          If necessary, the following may be added (to the resin): a stabilizer such as an antioxidant, a lubricant, a pigment, a filler, an antistatic agent, and other additives.

15 [0035]

          A description will be made hereinafter about examples of a method for producing the thermoset polyurethane foam constituting the polishing layer. This polyurethane foam producing method has the following steps:

20 [0036]

          (1) A silicone surfactant is added to at least one of a first component including an isocyanate component, and a second component including active-hydrogen-containing compounds, and then the component to which the silicone surfactant is added  
25 is mechanically stirred in the presence of a nonreactive gas

to disperse the nonreactive gas thereinto as fine bubbles. In this way, a foam-dispersed liquid is prepared. The remnant component is added to the foam-dispersed liquid. The components therein are mixed with each other to prepare a foam-dispersed urethane composition.

[0037]

(2) A silicone surfactant is added to at least one of a first component including an isocyanate component, and a second component including active-hydrogen-containing compounds, and then the first and second components are mechanically stirred in the presence of a nonreactive gas to disperse the nonreactive gas thereinto as fine bubbles to prepare a foam-dispersed urethane composition.

[0038]

The foam-dispersed urethane composition may be prepared by a mechanical frothing method. The mechanical frothing method is a method of: putting raw material components into a mixing chamber of a mixing head while a nonreactive gas is incorporated thereinto; and mixing and stirring the components by means of a mixer such as an Oakes mixer, thereby making the nonreactive gas into the state of fine bubbles and further dispersing the bubbles into the raw material mixture. The mechanical frothing method is a preferred method since the method makes it possible to adjust the density of the polyurethane foam easily by the adjustment of the incorporated

amount of the nonreactive gas. Moreover, the method gives a good production-efficiency since the method makes it possible to shape continuously a polyurethane foam having substantially spherical fine bubbles having an average bubble diameter of 20  
5 to 300  $\mu\text{m}$ .

[0039]

Thereafter, the foam-dispersed urethane composition prepared by this method is painted onto a planar member, and then the foam-dispersed urethane composition is cured to form  
10 a thermoset polyurethane foam (polishing layer) directly onto the planar member.

[0040]

The nonreactive gas used to form the fine bubbles is preferably an incombustible gas, and specific examples thereof  
15 include nitrogen, oxygen and carbon dioxide gases, rare gases such as helium and argon, and any mixed gas of two or more of these gases. The gas from which water is removed by drying is most preferred from the viewpoint of costs.

[0041]

20 As a stirring machine for making the nonreactive gas in the form of fine bubbles, and further dispersing the bubbles, a known stirring machine may be used without especial restriction. Specific examples of the machine include a homogenizer, a Dissolver, a biaxial planetary mixer, and a  
25 mechanical frothing machine. The shape of one or more stirring

vanes of the stirring machine is not particularly limited. A whipper-shaped stirring vane is preferred since the use thereof gives fine bubbles.

[0042]

5           It is also preferred to use different stirring machines for the stirring for preparing the foam-dispersed liquid in the forming step, and for the stirring for mixing the first and second components to each other. In the mixing step, the stirring is not required to be stirring for forming bubbles,  
10   and the use of a stirring machine that does not generate large bubbles is preferred. Such a stirring machine is preferably a planetary mixer. Even when the same stirring machine is used in the foaming step of preparing the foam-dispersed liquid and the mixing step of mixing the individual components with each  
15   other, no problem is caused. It is also preferred to use the machine while stirring conditions are adjusted, for example, the rotating speed of the stirring vane(s) is adjusted as the need arises.

[0043]

20           In the polishing pad according to the present invention, a substrate layer may be laminated on the polishing layer. When the substrate layer is laminated on the polishing layer, the substrate layer is not particularly limited. Examples thereof include nylon, polypropylene, polyethylene, polyester,  
25   polyvinyl chloride, and other plastic films; a polyurethane

foam, a polyethylene foam, and other high-molecular-weight resin foams; rubbery resins such as butadiene rubber and isoprene rubber; and photosensitive resins. It is preferred to use, out of these examples, nylon, polypropylene,

5 polyethylene, polyester, polyvinyl chloride, and other plastic films; and polyurethane foam, polyethylene foam, and other high-molecular-weight resin foams. The substrate layer may be a double-sided tape, or a single-sided adhesive tape (the single-sided adhesive layer thereof is to be bonded to a  
10 platen).

[0044]

The substrate layer preferably has a hardness equal to or more than that of the polyurethane foam to give toughness to the polishing pad. The thickness of the substrate layer  
15 (when the layer is a double-sided tape or a single-sided adhesive tape, the thickness of its substrate) is not particularly limited, and is preferably from 20 to 1,000  $\mu\text{m}$ , more preferably from 50 to 800  $\mu\text{m}$  from the viewpoint of strength and flexibility.

20 [0045]

Examples of the means that can be adopted to paint the foam-dispersed urethane composition onto the planar member include gravure, kiss and comma and other roll coaters; slot, fountain and other die coaters; a squeeze coater; a curtain  
25 coater; and other painting means. However, the means may be

any means capable of forming a uniform painted film on the planar member.

[0046]

It is highly preferable to heat the polyurethane foam  
5 obtained by painting the foam-dispersed urethane composition  
onto the planar member and causing the components to react with  
each other until the composition comes not to flow, thereby  
post-curing the composition since the post-curing produces an  
effect of improving the polyurethane foam in physical  
10 properties. The post-curing is preferably performed at 40 to  
70°C for 10 minutes to 24 hours, and this operation is also  
preferably performed under a normal pressure since the shape  
of the bubbles is stabilized.

[0047]

15 In the production of the polyurethane foam, a tertiary  
amine catalyst, or any other known catalyst may be used for  
promoting the polyurethane reaction. The kind and the addition  
amount of the catalyst are selected, considering a period when  
a mixture yielded after the step of mixing the individual  
20 components with each other is flowing in order to be painted  
onto the planar member.

[0048]

The polyurethane foam may be produced in a batch manner  
of weighing the individual components, charging the components  
25 into a container and then stirring the components mechanically,

or in a continuous production manner of supplying the individual components and the nonreactive gas continuously to a stirring machine, stirring these components mechanically, feeding out the foam-dispersed urethane composition and then shaping the composition into a shaped product.

[0049]

In the polishing pad producing method of the present invention, it is necessary that after or while a polyurethane foam is formed onto a planar member, the polyurethane foam is adjusted into a uniform thickness. The method for adjusting the polyurethane foam into a uniform thickness is not particularly limited, and examples thereof include a method of buffing the foam with a polishing member, and a method of pressing the foam by use of a pressing plate. When the foam is buffed, a polishing layer having, on the polyurethane foam surface, no skin layer is yielded. When the foam is pressed, a polishing layer having, on the polyurethane foam surface, a skin layer is yielded. Conditions for the pressing are not particularly limited; preferably, the temperature of the foam is adjusted to the glass transition point or higher.

[0050]

The foam-dispersed urethane composition prepared in the above-mentioned manner is painted onto a releasing sheet, and a substrate layer is laminated onto the foam-dispersed urethane composition. Thereafter, by curing the foam-dispersed

urethane composition while a pressing means is used to make the composition into a uniform thickness, a polyurethane foam may be formed. This method is a particularly preferred method since the polishing layer can be controlled into a highly uniform thickness.

[0051]

The material for forming the releasing sheet is not particularly limited, and examples thereof may be the same resins and papers for the above-mentioned substrate layer. The releasing sheet is preferably a sheet small in dimension change based on heat. The surface of the releasing layer may be subjected to releasing treatment.

[0052]

The pressing means for making, into a uniform thickness, the sandwich sheet composed of the releasing sheet, the foam-dispersed urethane composition (foam-dispersed urethane layer) and the substrate layer is not particularly limited. For example, a coater roller, a nip roller or some other is used to compress the sandwich sheet into a constant thickness.

Considering that after the compressing, the size of the bubbles in the foamed layer becomes about 1.2 to 2 times larger than that before the compressing, it is preferred at the compressing time to make "50 to 85% of the thickness of the cured polyurethane foam" equal to a value of "the clearance of the coater or the nip" - "the thickness of the substrate layer and the releasing

sheet". In order to yield a polyurethane foam having a specific gravity of 0.2 to 0.5, it is preferred that the foam-dispersed urethane composition has a specific gravity of 0.24 to 1 before passed through the roll.

5 [0053]

After the sandwich sheet is made into the uniform thickness, the polyurethane foam obtained by causing the components concerned to react with each other until the foam comes not to flow is heated to be post-cured. Conditions for  
10 the post-curing are the same as described above.

[0054]

Thereafter, the releasing sheet underneath the polyurethane foam is peeled. In this case, a skin layer is being formed on the polyurethane foam. When the polyurethane foam  
15 is formed by a mechanical foaming method as described above, the unevenness of the bubbles is less generated in the lower surface side of the polyurethane foam than in the upper surface side. When the lower surface side of the thus-formed polyurethane foam is used as a polishing surface, this polishing  
20 surface is a surface wherein the unevenness of the bubbles is small. Thus, the polishing pad is made better in polishing rate stability. The skin layer may be removed by buffing the polyurethane foam after the releasing sheet is peeled.

[0055]

25 The thickness of the polyurethane foam is not

particularly limited, and is preferably from 0.2 to 3 mm, more preferably from 0.5 to 2 mm.

[0056]

The polyurethane foam produced by the above-mentioned  
5 production method has substantially spherical bubbles. The polyurethane foam according to the present invention may be a foam having continuous bubbles, or a foam having independent bubbles.

[0057]

10 The average bubble diameter of the bubbles in the polyurethane foam is from 20 to 300  $\mu\text{m}$ , preferably from 50 to 100  $\mu\text{m}$ . When the bubbles are continuous bubbles, the average diameter of circular openings in the surfaces of the bubbles is preferably 100  $\mu\text{m}$  or less, more preferably 50  $\mu\text{m}$  or less.

15 [0058]

The specific gravity of the polyurethane foam is preferably from 0.3 to 0.6, more preferably from 0.3 to 0.5. If the specific gravity is less than 0.3, the polishing layer or pad tends to be too high in porosity so as to be deteriorated  
20 in endurance. On the other hand, if the specific gravity is more than 0.6, it is necessary to make the raw materials into a low crosslinkage density in order to make the polishing layer into a predetermined elastic modulus. In this case, the polishing pad tends to be increased in permanent strain to be  
25 deteriorated in endurance.

[0059]

The microrubber A hardness of the polyurethane foam is preferably from 40 to 90 degrees, more preferably from 50 to 90 degrees, the hardness being obtained by measuring the foam  
5 from the polishing layer side thereof. If the microrubber A hardness of the polyurethane foam is out of this range, the surface of a matter to be polished is easily scratched.

[0060]

About the hardness of the polyurethane foam, the Asker  
10 C hardness thereof is preferably from 10 to 90 degrees, more preferably from 20 to 80 degrees. If the Asker C hardness is less than 10, the polishing pad tends to be lowered in endurance, and a matter to be polished tends to be deteriorated in flatness after polished. On the other hand, if the hardness is more than  
15 90 degrees, the front surface of a matter to be polished is easily scratched.

[0061]

The shape of the polishing pad of the present invention is not particularly limited, and may be a long strip shape having  
20 a length of about 5 to 10 m, or may be a round shape having a diameter of about 50 to 150 cm.

[0062]

The front surface of the polishing layer may have a convexo-concave structure for holding/renewing a slurry. The  
25 polishing layer made of the foam has many openings at its

polishing surface to have a function of holding/renewing a slurry, and when the convexo-concave structure is formed in the polishing surface, the holding and renewing of a slurry can be more effectively attained. Moreover, the structure makes it possible to prevent a matter to be polished from being broken by adsorption between the pad and the matter to be polished. The form of the convexo-concave structure is not particularly limited as far as the form holds/renews a slurry. Examples of the convexo-concave structure include X (stripe) grooves, XY lattice grooves, concentric grooves, through holes, blind holes, polygonal columns, circular columns, a spiral groove, eccentric grooves, radial grooves, and any combination of two or more of these grooves. These convexo-concave structures each generally have therein regularity. However, in order to render the structure a structure having a desired performance of holding/renewing a slurry, the structure may be changed in groove pith, groove width, groove depth or some other inside individual areas thereof.

[0063]

The method for forming the convexo-concave structure is not particularly limited, and examples thereof include a method of using a tool, such as a bite having a predetermined size, to cut the polishing layer mechanically, a method of causing a resin to flow in a mold having a predetermined surface shape, and curing the resin to form the structure, a method of pressing

a resin by use of a pressing plate having a predetermined surface shape to form the structure, a method of using photolithography to form the structure, a method of using a printing method to form the structure, and a method of using a laser ray, such as  
5 a carbon dioxide gas laser ray, to form the structure.

[0064]

The polishing pad of the present invention may be a pad wherein a cushion sheet is bonded onto a non-polishing surface side of a polishing layer. When a substrate layer is laminated  
10 onto the polishing layer, it is preferred to laminate the polishing layer, the substrate layer, and the cushion sheet in this order.

[0065]

The cushion sheet (cushion layer) is a member  
15 compensating for properties of the polishing layer. The cushion sheet is required in order to make both of planarity and uniformity, which have a tradeoff relationship with each other in chemical mechanical polishing, compatible with each other. The planarity is the following flatness at the time of  
20 polishing a matter to be polished which has fine irregularities generated when a pattern is formed in the matter: the flatness of the patterned region. The uniformity is the evenness of the whole of the matter to be polished. In accordance with properties of the polishing layer, the planarity is improved,  
25 and in accordance with properties of the cushion sheet, the

uniformity is improved. In the polishing pad of the present invention, it is preferred to use, as the cushion sheet, a sheet softer than the polishing layer.

[0066]

5           Examples of the cushion sheet include fiber nonwoven fabrics, such as a polyester nonwoven fabric, a nylon nonwoven fabric, and an acrylic nonwoven fabric; resin-impregnated nonwoven fabrics, such as a polyester nonwoven fabric into which polyurethane is impregnated; high-molecular-weight resin  
10   foams, such as a polyurethane foam, and a polyethylene foam; and rubbery resins, such as butadiene rubber and isoprene rubber; and photosensitive resins.

[0067]

          The means for bonding the cushion sheet is, for example,  
15   a means of sandwiching the polishing layer and the cushion layer between pieces of a double-sided tape, and then pressing the sandwich.

[0068]

          In the polishing pad of the present invention, a  
20   double-sided tape may be laid on the surface thereof which is to be bonded to a platen.

[0069]

          A semiconductor device is produced through a process of using the above-mentioned polishing pad to polish a surface of  
25   a semiconductor wafer. The semiconductor wafer is generally

a matter wherein a wiring metal and an oxide film are laminated on a silicon wafer. The method and machine for polishing the semiconductor wafer are not particularly limited. For example, as illustrated in Fig. 1, the polishing is performed by use of a polishing machine equipped with a polishing table 2 for supporting a polishing pad 1, a supporter (polishing head) 5 for supporting a semiconductor wafer 4, a backing member for applying an even pressure to the wafer, and a mechanism for supplying a polishing agent 3. The polishing pad 1 is bonded onto the polishing table 2 through, for example, a double-sided tape to be fitted on the table 2. The polishing table 2 and the supporter 5 are arranged in such a manner that the polishing pad 1 and the semiconductor wafer 4 supported on these members 2 and 5, respectively, are faced to each other. The members 2 and 5 have rotating axes 6 and 7, respectively. In the vicinity of the supporter 5, a pressing mechanism is located for pushing the semiconductor wafer 4 onto the polishing pad 1. The semiconductor wafer 4 is polished by pushing the semiconductor wafer 4 onto the polishing pad 1 while the polishing table 2 and the supporter 5 are rotated, and further supplying a slurry thereto. The flow rate of the slurry is not particularly limited, as well as the load for the polishing, the rotation number of the polishing table, and the rotation number of the wafer. These are appropriately adjusted.

[0070]

In this way, the surface roughness of the surface of the semiconductor wafer 4 is improved, and scratches therein are removed. Thereafter, the wafer is subjected to dicing, bonding, packaging and others to produce a semiconductor device. The semiconductor device is used in, for example, an arithmetic processing device, or a memory. A lens, or a glass substrate for a hard disc can be finish-polished in the same manner as described above.

## 10 EXAMPLES

[0071]

Hereinafter, the present invention will be described by way of working examples. However, the present invention is not limited to these working examples.

## 15 [0072]

### Measurement of Microrubber A Hardness:

A microrubber A hardness meter MD-1 (manufactured by Kobunshi Keiki Co., Ltd.,) is used to make a measurement. Specifically, a polishing layer of a thermoset polyurethane foam is cut out into a size of 30 mm x 30 mm to prepare a sample. About each of any five points of this sample, from a polishing surface side thereof, the hardness value is measured. The average value thereof is defined as the microrubber A hardness. The difference between the maximum value and the minimum value of the respective hardness values measured at the five points

is defined as the in-plane variation in the microrubber A hardness.

[0073]

Tiny Undulations:

5           A noncontact profilometer (New View 6300, manufactured by Zygo Corp.) is used to measure the Ra of each of five points of the front surface of a matter to be polished under conditions that the lens power is 2.5, the zooming power is 0.5, and its bandpass filter is set to 200 to 1,250  $\mu\text{m}$ . The average value  
10   (nm) thereof is defined as the tiny undulations. When the tiny undulations are measured, the used polished matter is a polished matter obtained by polishing according to the following polishing manner.

[0074]

15           Polishing Manner:

Double-sided Polisher Setting Conditions

Double-sided polisher: 9B type double-sided polisher, manufactured by SpeedFam Co., Ltd.

Processing pressure: 100  $\text{g}/\text{cm}^2$

20           Table rotation number: 50 rpm

Polishing agent supply rate: 4 L/min

Charged substrates: TS-10SX, manufactured by Ohara Inc.

The number of the charged substrates: 25

25           Each of the substrates is continuously polished until the

substrate thickness is turned to 85% of the initial thickness.  
The used polishing agent is prepared by the following method:  
[0075]

Polishing Agent Preparing Method:

5        To water is added a product SHOROX A-10 (manufactured by  
Showa Denko K.K.), and these are mixed with each other to prepare  
a polishing agent to have a specific gravity of 1.06 to 1.09.  
[0076]

Raw Materials:

10       Individual raw materials used are as follows:

(i) Active-hydrogen-containing compounds

Polycaprolactone polyol: "PLACCEL 210N (PCL210N)",  
manufactured by Daicel Chemical Industries, Ltd.; the number  
of functional groups: 2, and hydroxyl group value: 110 mg KOH  
15    / g

Polycaprolactone polyol: "PLACCEL 220 (PCL220)"  
manufactured by Daicel Chemical Industries, Ltd.; the number  
of functional groups: 2, and hydroxyl group value: 56 mg KOH  
/ g,

20       Polycaprolactone polyol: "PLACCEL 305 (PCL305)"  
manufactured by Daicel Chemical Industries, Ltd.; the number  
of functional groups: 3, and hydroxyl group value: 305 mg KOH  
/ g,

Polytetramethylene ether glycol "PTMG1000",  
25    manufactured by Mitsubishi Chemical Corp.; the number of

functional groups: 2, and hydroxyl group value: 110 mg KOH / g,

Polytetramethylene ether glycol "PTMG3000",  
manufactured by Mitsubishi Chemical Corp.; the number of  
5 functional groups: 2, and hydroxyl group value: 37 mg KOH / g

1,4-Butanediol (1,4-BD), manufactured by Nacalai Tesque  
Inc.; the number of functional groups: 2, and hydroxyl group  
value: 1,247 mg KOH / g,

10 Trifunctional polyol having at least one terminated  
hydroxyl group that is a secondary hydroxyl group:

(a) Propylene oxide adduct of trimethylolpropane,  
"EXCENOL 400MP", manufactured by Asahi Glass Co., Ltd.; the  
number of functional groups: 3, and hydroxyl group value: 415  
15 mg KOH / g,

(b) Propylene oxide adduct of glycerin, "MN400",  
manufactured by Mitsui Chemicals, Inc.; the number of  
functional groups: 3, and hydroxyl group value: 415 mg KOH  
/ g,

20 (c) Propylene oxide adduct of glycerin, "MN1000",  
manufactured by Mitsui Chemicals, Inc.; the number of  
functional groups: 3, and hydroxyl group value: 160 mg KOH  
/ g,

(d) Propylene oxide adduct of glycerin, "MN2000",  
25 manufactured by Mitsui Chemicals, Inc.; the number of

functional groups: 3, and hydroxyl group value: 112 mg KOH / g,

(e) Propylene oxide adduct of trimethylolpropane, "EXCENOL 890MP", manufactured by Asahi Glass Co., Ltd.; the  
5 number of functional groups: 3, and hydroxyl group value: 865 mg KOH / g,

Bifunctional polyols having at least one terminated hydroxyl group that is a secondary hydroxyl group:

(a) 1,2-Propylene glycol (1,2-PG), manufactured by  
10 Nacalai Tesque Inc.; the number of functional groups: 2, and hydroxyl group value: 1,472 mg KOH / g,

(b) 1,3-Butanediol (1,3-BD), manufactured by Nacalai Tesque Inc.; the number of functional groups: 2, and hydroxyl group value: 1,247 mg KOH / g,

15 (iii) Foaming agent

"B8443", manufactured by Goldschmidt GmbH.

(iv) Isocyanate component

Carbodiimide-modified diphenylmethane diisocyanate (MDI) "MILLIONATE MTL", manufactured by Nippon Polyurethane  
20 Industry Co., Ltd.

[0077]

Examples 1 to 5, and Comparative Examples 1 to 3

An active-hydrogen-containing compound and an foaming agent were charged into a container to give blend proportions  
25 in the upper columns in Table 1 (each of numbers therein

represents the number of parts by weight of one of the raw materials when the total amount of the polyol compounds is regarded as 100 parts by weight), and stirring vanes were used to stir the blended components vigorously at a rotation number  
5 of 900 rpm for 4 minutes to take bubbles into the reaction system. Thereafter, the carbodiimide-modified MDI was added thereto to give NCO index values listed in Table 1, and the reaction system was stirred for about 1 minute to prepare each foam-dispersed urethane composition.

10 [0078]

The prepared foam-dispersed urethane composition was painted onto a releasing sheet that was a PET sheet (manufactured by Toyobo Co., Ltd.; thickness: 75  $\mu\text{m}$ ) subjected to releasing treatment to form a foam-dispersed urethane layer.

15 The foam-dispersed urethane layer was covered with a substrate layer that was a PET sheet (manufactured by Toyobo Co., Ltd., thickness: 188  $\mu\text{m}$ ). A nip roll was used to make the foam-dispersed urethane layer into a thickness of 1.5 mm, and the workpiece was primarily cured at 40°C for 30 minutes.

20 Thereafter, the workpiece was secondly cured at 70°C for 3 hours to form a polyurethane foam (foamed layer). This producing method corresponds to a one-shot method since the active-hydrogen-containing compounds were caused to react directly with the isocyanate component to produce the

25 polyurethane foam.

[0079]

Thereafter, the releasing sheet was peeled. Next, a slicer (manufactured by Fecken-Kirfel Gmbh & Co.) was used to make the polyurethane foam into a thickness of 1.3 mm. In this way, the precision of the thickness was adjusted. Thereafter, a laminator was used to bond a double-sided tape (Double Tack Tape, manufactured by Sekisui Chemical Co., Ltd.) onto the front surface of the substrate layer to manufacture a polishing pad.

[0080]

[Table 1]

|                                              |                | The number of functional groups | Hydroxyl group value (mg KOH / g) | Terminated hydroxyl group | Example 1 | Example 2 | Example 3 | Example 4 | Example 5 | Comparative Example 1 | Comparative Example 2 | Comparative Example 3 |
|----------------------------------------------|----------------|---------------------------------|-----------------------------------|---------------------------|-----------|-----------|-----------|-----------|-----------|-----------------------|-----------------------|-----------------------|
| Active-hydrogen-containing compound          | PCL210N        | 2                               | 110                               | Not present               | -         | 36        | -         | -         | -         | -                     | -                     | -                     |
|                                              | PCL220         | 2                               | 56                                | Not present               | 65        | -         | 65        | -         | 75        | -                     | 40                    | 65                    |
|                                              | PTMG1000       | 2                               | 110                               | Not present               | -         | -         | -         | 47        | -         | -                     | -                     | -                     |
|                                              | PTMG3000       | 2                               | 37                                | Not present               | -         | 36        | -         | -         | -         | 60                    | -                     | -                     |
|                                              | PCL305         | 3                               | 305                               | Not present               | -         | -         | -         | -         | -         | 25                    | -                     | -                     |
|                                              | 400MP          | 3                               | 410                               | Present                   | 20        | -         | -         | -         | 15        | -                     | 45                    | -                     |
|                                              | MN400          | 3                               | 415                               | Present                   | -         | 15        | -         | 35        | -         | -                     | -                     | -                     |
|                                              | MN1000         | 3                               | 160                               | Present                   | -         | -         | 20        | -         | -         | -                     | -                     | -                     |
|                                              | MN2000         | 3                               | 112                               | Present                   | -         | -         | -         | -         | -         | -                     | -                     | 20                    |
|                                              | 1, 2-PG        | 2                               | 1472                              | Present                   | 13        | -         | 13        | -         | -         | -                     | 13                    | 13                    |
|                                              | 1, 3-BD        | 2                               | 1247                              | Present                   | -         | -         | -         | 13        | 5         | -                     | -                     | -                     |
|                                              | 1, 4-BD        | 2                               | 1247                              | Not present               | -         | 13        | -         | -         | -         | 13                    | -                     | -                     |
|                                              | 890MP          | 3                               | 865                               | Present                   | 2         | -         | 2         | 5         | 5         | 2                     | 2                     | 2                     |
| Isocyanate component                         | MILLIONATE MTL |                                 |                                   |                           | 88.11     | 78.31     | 78.68     | 113.25    | 59.38     | 78.91                 | 118.01                | 75.95                 |
| Foaming agent                                | B8443          |                                 |                                   |                           | 6         | 6         | 6         | 6         | 6         | 6                     | 6                     | 6                     |
| NCO INDEX                                    |                |                                 |                                   |                           | 1.1       | 1.1       | 1.1       | 1.1       | 1.1       | 1.1                   | 1.1                   | 1.1                   |
| Microrubber A hardness                       |                |                                 |                                   |                           | 84.0      | 55.9      | 49.8      | 89.2      | 56.0      | 76.3                  | 91.1                  | 26.2                  |
| In-plane variation in microrubber A hardness |                |                                 |                                   |                           | 8.0       | 11.9      | 10.5      | 12.0      | 9.1       | 15.2                  | 13.9                  | 13.0                  |
| Tiny undulations (nm)                        |                |                                 |                                   |                           | 0.343     | 0.398     | 0.37      | 0.333     | 0.320     | 0.522                 | 0.578                 | 0.687                 |

[0081]

It is understood from the results in Table 1 that according to each of the polishing pads of Examples 1 to 5, tiny undulations generated in the surface of the polished matter were  
5 decreased since the in-plane variation in the microrubber A hardness of the polishing layer of the pad was 12 or less.

#### DESCRIPTION OF REFERENCE SIGNS

[0082]

- 10           1: polishing pad
- 2: polishing table
- 3: polishing agent (slurry)
- 4: matter to be polished (semiconductor wafer, lens or  
glass plate)
- 15           5: supporter (polishing head)
- 6, and 7: rotating axes

## CLAIMS

1. A polishing pad, having a polishing layer comprising a thermoset polyurethane foam,

5 wherein the polishing layer has an in-plane variation of 12 or less in microrubber A hardness, the variation being obtained by measuring the polishing layer from a polishing surface side of the layer,

the thermoset polyurethane foam contains, as raw material  
10 components, an isocyanate component and active-hydrogen-containing compounds, and

the active-hydrogen-containing compounds comprise a trifunctional polyol having at least one terminated hydroxyl group that is a secondary hydroxyl group, and having a hydroxyl  
15 group value of 150 to 1,000 mg KOH / g in an amount of 10 to 50 parts by weight for 100 parts by weight of the active-hydrogen-containing compounds.

2. The polishing pad according to claim 1, wherein the  
20 active-hydrogen-containing compounds comprise a bifunctional polyol having at least one terminated hydroxyl group that is a secondary hydroxyl group, and having a hydroxyl group value of 1,000 to 1,500 mg KOH / g in an amount of 0 to 20 parts by weight for 100 parts by weight of the  
25 active-hydrogen-containing compounds.

3. The polishing pad according to claim 1, wherein the thermoset polyurethane foam has substantially spherical bubbles having an average bubble diameter of 20 to 300  $\mu\text{m}$ .

5

4. A method for producing a polishing pad, comprising the step of using a mechanical foaming method to prepare a foam-dispersed urethane composition containing, as raw material components, an isocyanate component plus  
10 active-hydrogen-containing compounds comprising a trifunctional polyol compound in an amount of 10 to 50 parts by weight for 100 parts by weight of the active-hydrogen-containing compounds, the trifunctional polyol compound being a compound having at least one terminated  
15 hydroxyl group that is a secondary hydroxyl group, and having a hydroxyl group value of 150 to 1,000 mg KOH / g; the step of painting the foam-dispersed urethane composition onto a planar member; the step of setting the foam-dispersed urethane composition to form a polishing layer comprising a thermoset  
20 polyurethane foam having substantially spherical bubbles having an average bubble diameter of 20 to 300  $\mu\text{m}$ ; and the step of adjusting the polishing layer into a uniform thickness.

5. A method for producing a semiconductor device,  
25 comprising the step of using the polishing pad recited in claim

1 to polish a surface of a semiconductor wafer.