

POLISHING SLURRY

FIELD OF THE INVENTION

[0001]

This invention relates to a polishing slurry that can be used, for example, for precision processing of surfaces of interlayer insulating films formed on optical components, electronic components, precision equipment components, or semiconductor devices such as semiconductor package substrates mounted on these components.

BACKGROUND OF THE INVENTION

[0002]

In recent years, as semiconductor package substrates, including semiconductor integrated circuits, have become more highly integrated and higher in performance, microfabrication technologies such as finer wiring and multilayering have been developed. Chemical mechanical polishing (hereinafter also referred to as a "CMP (Chemical Mechanical Polishing) method") is one such technique, which is frequently used in the manufacturing process of semiconductor integrated circuits, especially in the process of forming fine multilayer wiring.

[0003]

However, miniaturization and multilayering hinder the speed-up of semiconductor integrated circuits due to signal delays caused by increased inter-wiring capacitance. Therefore, low dielectric constant insulating film materials that satisfy various characteristics such as low dielectric constant, low dielectric loss tangent, and high heat resistance are being developed to support high-speed processing. The advantage of using low dielectric constant insulating film materials is that a smaller dielectric constant results in a faster propagation speed, and organic

insulating materials mainly based on a polyimide resin are known to improve transmission speed due to their lower dielectric constant.

[0004]

It is expected that applying the CMP method to polishing of surfaces of resin films such as the polyimide resin can form good-quality interlayer insulating films with low surface roughness, and the process of polishing and removing excess portions of polishing targets containing the resin using the CMP method is being investigated.

[0005]

Patent Literature 1 discloses, as a means of polishing a resin having high rigidity and high strength at a high polishing rate, a polishing composition that contains abrasive grains and a dispersion medium, wherein the old Mohs hardness of the abrasive grains is 8 or more, and the surface acid amount of the abrasive grains as measured by the ammonia temperature-programmed desorption method (NH₃-TPD method) is 0.05 mmol/g or more.

[0006]

Patent Literature 2 discloses a polishing method for polishing an interlayer insulating material comprised of inorganic particles and a resin material, the method including: a step of polishing the interlayer insulating material with a first polishing slurry containing first abrasive particles having an average particle diameter equal to or larger than the average particle diameter of the inorganic particles and a dispersing agent; and a step of further polishing the interlayer insulating material polished with the first polishing slurry with a second polishing slurry containing second abrasive particles having an average particle diameter smaller than the average particle diameter of the inorganic particles and a dispersing agent.

CITATION LIST

Patent Literatures

[0007]

[Patent Literature 1] JP2016-183212 A

[Patent Literature 2] JP2021-141213 A

SUMMARY OF THE INVENTION

[0008]

However, organic interlayer insulating films made of polymer compounds such as polyimide resins have lower mechanical strength than conventional inorganic interlayer insulating films such as SiO₂. If the polishing target with such low mechanical strength is simply physically processed with high-hardness abrasive grains, film defects such as cracks and scratches are likely to occur, and sufficient polishing rate may not be achieved. If two-step polishing is performed to compensate for this, problems arise such as a reduction in process throughput or an increase in the size of the polishing apparatus due to the use of separate platens.

[0009]

In view of the above problems, the present invention provides a polishing slurry that can more efficiently obtain a polished surface with good surface characteristics at a high polishing rate even for polishing targets with relatively low mechanical strength.

[0010]

In order to solve the above problems, in one aspect, the present invention provides a polishing slurry containing α -alumina as abrasive particles in an aqueous medium, wherein the α -alumina has: an average particle diameter (D50) of 80 to 120 nm at a volume-based cumulative value of 50% in a particle size distribution determined by a laser diffraction scattering method; a specific surface area (BET) measured in accordance with JIS-Z8830 (2013) of 20 m²/g or more; and a ratio

(BET/D50) of the specific surface area (BET) to the average particle diameter (D50) of $1.5 \text{ m/g} \times 10^8$ or more.

[0011]

In one embodiment, the polishing slurry according to the present invention has a ratio (TBD/LBD) of tapped bulk density (TBD) to loose bulk density (LBD) measured according to JIS-R9301-2-3 (1999) of 1.5 or less.

[0012]

In another embodiment, the polishing slurry according to the present invention has a specific surface area (BET) of $25 \text{ m}^2/\text{g}$ or more and a ratio (BET/D50) of the specific surface area (BET) to the average particle diameter (D50) of $2.0 \text{ m/g} \times 10^8$ or more.

[0013]

In one further embodiment, the polishing slurry according to the present invention contains 0.01 to 10% by mass of abrasive particles and 0.0001 to 1% by mass of nitric acid as a dispersing agent.

[0014]

In one further embodiment, the polishing slurry according to the present invention is a free abrasive polishing slurry used for polishing an insulating material containing a polyimide resin.

[0015]

The present invention provides a polishing slurry that can more efficiently obtain a polished surface with good surface characteristics at a high polishing rate, even for polishing targets with relatively low mechanical strength.

DETAILED DESCRIPTION OF THE INVENTION

[0016]

Hereinafter, embodiments of the present invention will be described.

(Polishing Target)

Although the polishing targets are not limited, the polishing slurry according to the embodiment of the present invention is suitable, for example, for the free abrasive polishing process of insulating films (especially interlayer insulating films) formed on semiconductor devices and the like.

[0017]

The interlayer insulating film is used as an insulating film to fill and insulate the spaces between miniaturized wiring made of copper, aluminum, or the like, and to make circuit patterns multilayered. In the multilayering of circuit patterns, the interlayer insulating film formed on the semiconductor substrate is planarized by the CMP method, new wiring patterns are then formed thereon by optical exposure using photolithography to form circuits, and predetermined circuits are stacked by repeating this operation. Specifically, a conductive layer is formed into a circuit on the surface of a base substrate (e.g., a Bakelite substrate, a glass epoxy substrate, a resin substrate such as epoxy and polyester, or a composite substrate thereof), and an interlayer insulating film is laminated thereover. The substrate surface is then planarized so that the interlayer insulating film on the substrate is polished to expose the conductive layer.

[0018]

For example, a polyimide resin, polyester resin, epoxy resin, and the like can be suitably used as materials for such interlayer insulating films. Among these, in the present embodiment, polyimide films having a polyimide resin as main component (50 wt% or more) can be suitably processed. The polyimide films are generally composed mainly of aromatic polyimide obtained by imidizing (dehydrating and cyclizing) polyamide acid by heating at high temperatures. The polyimide films may also be those into which fluorine atoms or alicyclic groups have been introduced as substituents to achieve a lower dielectric constant, those which have been made

nanoporous to reduce film density, those to which a low dielectric constant additive has been physically added, those in which the linearity of the main chain backbone has been increased to achieve a lower coefficient of thermal expansion, or those to which low-expansion fibers, whiskers, or particles have been added.

[0019]

The polyimide film used as the interlayer insulating material has relatively low mechanical strength compared to SiO₂ films and the like. However, with the polishing slurry according to the embodiment of the present invention, a polished surface with good surface characteristics can be obtained at a higher polishing rate even for such materials with low mechanical strength.

[0020]

Although not limited to the following, interlayer insulating films that can be polished using the polishing slurry according to the embodiment of the present invention preferably have a Young's modulus of 0.1 to 20.0 GPa, more preferably 1.0 to 10.0 GPa, and still more preferably approximately 3.0 to 8.0 GPa. It should be noted that the Young's modulus can be evaluated based on JIS-Z2255 (2003).

[0021]

(Polishing Slurry)

The polishing slurry according to the embodiment of the present invention contains α -alumina as abrasive particles (abrasive grains) in an aqueous medium. The aqueous medium is not particularly limited as long as it is an aqueous medium capable of dispersing abrasive particles, but it may preferably be water that does not contain impurities. For example, pure water, ultrapure water, distilled water, and the like are suitably used. The α -alumina dispersed in the aqueous medium preferably has an average particle diameter (D50) of 80 to 120 nm at a volume-based cumulative value of 50% in the particle size distribution determined by the laser diffraction scattering method. For example, an organic interlayer insulating film such

as a polyimide resin has lower mechanical strength than conventional inorganic interlayer insulating films such as SiO₂. Therefore, simply using high-hardness α -alumina as abrasive grains is likely to cause film defects such as cracks and scratches. By adjusting the average particle diameter (D50) of α -alumina dispersed in the aqueous medium to a relatively small size of 80 to 120 nm, the polishing rate can be improved while minimizing film defects, even for polishing targets having low mechanical strength. The average particle diameter (D50) of α -alumina is more preferably 90 to 120 nm, and still more preferably 95 to 110 nm.

[0022]

In polishing resin materials having low mechanical strength, such as organic interlayer insulating films made of the polyimide resin, simply using α -alumina with a small average particle diameter (D50) and large specific surface area (BET) as abrasive grains may not yield a polished surface with a sufficient polishing rate and good surface characteristics. Polished surfaces with good surface characteristics can be obtained at a high polishing rate by increasing the specific surface area within a moderate particle diameter range where film defects are unlikely to occur.

[0023]

In the present embodiment, the specific surface area (BET) of the α -alumina is preferably 20 m²/g or more, more preferably 25 m²/g or more, and still more preferably 30 m²/g or more. If the specific surface area (BET) of α -alumina is too high, dispersion becomes difficult, which may increase the load on the dispersion process, generate undispersed material, and eventually cause scratches on the polishing target. Therefore, in one embodiment, the specific surface area (BET) is preferably 120 m²/g or less, more preferably 80 m²/g or less, and still more preferably 50 m²/g or less. It should be noted that the specific surface area (BET) can be measured according to JIS-Z8830 (2013).

[0024]

Furthermore, by adjusting a ratio of the specific surface area (BET) to the average particle diameter (D50) of α -alumina used as abrasive particles (BET/D50) to an appropriate range, the polishing of resin materials with low mechanical strength, such as organic interlayer insulating films made of the polyimide resin, can be suitably performed. The ratio BET/D50 is preferably $1.5 \text{ m/g} \times 10^8$ or more, more preferably $2.0 \text{ m/g} \times 10^8$ or more, and still more preferably $2.5 \text{ m/g} \times 10^8$ or more. In order to ensure appropriate surface roughness and a sufficient polishing rate, the ratio BET/D50 may preferably be $15.0 \text{ m/g} \times 10^8$ or less, more preferably $10.0 \text{ m/g} \times 10^8$ or less, and still more preferably $6.3 \text{ m/g} \times 10^8$ or less.

[0025]

If a loose bulk density (LBD) of α -alumina is too high, it may cause an increase in the proportion of primary particles with a large particle diameter, resulting in reduced surface characteristics after polishing. If it is too low, it may cause an increase in the proportion of alumina with a low α -phase conversion ratio, resulting in a reduced polishing rate. The LBD is preferably 0.6 g/cm^3 or more, more preferably 0.7 g/cm^3 or more, and still more preferably 0.8 g/cm^3 or more. The upper limit of LBD is not particularly limited, but it may preferably be 1.7 g/cm^3 or less, and more preferably 1.3 g/cm^3 or less.

[0026]

If a tapped bulk density (TBD) of α -alumina is too high, it may cause an increase in the proportion of primary particles with a large particle diameter, resulting in reduced surface characteristics after polishing. If it is too low, it may cause an increase in the proportion of alumina with a low α -phase conversion ratio, resulting in a reduced polishing rate. The TBD is preferably 0.8 g/cm^3 or more, more preferably 0.9 g/cm^3 or more, and still more preferably 1.0 g/cm^3 or more. The upper limit of TBD is not particularly limited, but it may preferably be 2.0 g/cm^3 or less,

and more preferably 1.5 g/cm³ or less. The loose bulk density (LBD) and tapped bulk density (TBD) can be measured according to JIS-R9301-2-3 (1999).

[0027]

In the present embodiment, the ratio (TBD/LBD) of the tapped bulk density (TBD) to the loose bulk density (LBD) measured according to JIS-R9301-2-3 (1999) is preferably 1.5 or less. The small difference between the TBD and LBD values means that there is no significant change in porosity after tapping, and that the bulk density of the individual secondary particles (agglomerated particles) contained in the average particle diameter (D50) of α -alumina is higher, i.e., the cohesive force of the secondary particles is higher. The presence of many particles that maintain the form of agglomerated particles even after dispersion to a moderate particle diameter enables a polished surface with good surface characteristics to be obtained at a high polishing rate within the relatively small moderate particle diameter range. The ratio TBD/LBD is more preferably 1.00 to 1.50, and still more preferably 1.00 to 1.35.

[0028]

The content of abrasive particles in the aqueous medium can be set as desired depending on the application. Although not particularly limited, in order to obtain a sufficient polishing rate while providing good surface characteristics, it may preferably be 0.01 to 10% by mass, more preferably 0.05 to 5% by mass, and even more preferably 0.1 to 1% by mass.

[0029]

The α -phase conversion ratio of α -alumina used as abrasive particles is not particularly limited, but from the viewpoint of polishing materials with relatively low mechanical properties at a sufficient polishing rate, the α -phase conversion ratio is preferably 40 to 65%, and more preferably 45 to 60%. It should be noted that the α -phase conversion ratio of α -alumina can be determined from an integrated intensity ratio of (113) plane diffraction lines by X-ray diffraction measurement.

[0030]

The polishing slurry is preferably prepared to contain abrasive particles and a dispersing agent. By containing the dispersing agent in the polishing slurry, the effect of efficiently dispersing the abrasive particles and promptly supplying them to the surface of the polishing target can be obtained. Known dispersing agents can be used, such as those which utilize steric hindrance of molecular chains in surfactants or those which improve dispersion by electrical repulsion of particle surface potentials. In particular, since α -alumina, an oxide with high polarity, is used as abrasive particles in the present embodiment, ionic polymer surfactants such as polyacrylate and polystyrene sulfonate, and acids such as hydrochloric acid, nitric acid, citric acid, and acetic acid can be used. From the viewpoint of avoiding surface contamination of semiconductor package substrates and the like (ease of cleaning) and obtaining moderate erosion to the resin material contained in the interlayer insulating material, it is preferable to use the acid as the dispersing agent. In particular, in the case of organic interlayer insulating films made of the polyimide resin, nitric acid can be preferably used as the dispersing agent. The content of nitric acid is not particularly limited, but it may be, for example, 0.0001 to 1% by mass, preferably 0.001 to 0.1% by mass, and more preferably 0.002 to 0.05% by mass.

[0031]

The polishing slurry is preferably further prepared to include a thickening agent. In one embodiment, α -alumina with a TBD/LBD of 1.5 or less is suitably used, and the bulk density of the individual secondary particles (agglomerated particles) contained in the abrasive particles is high. Therefore, by further incorporating a thickening agent into the polishing slurry, precipitation of agglomerated particles of α -alumina having high bulk density can be prevented, and the dispersion stability of the abrasive particles can be improved.

[0032]

The thickening agent that can be used herein includes surfactants or water-soluble polymers. The water-soluble polymers are particularly suitable for preventing precipitation of agglomerated particles of α -alumina and enhancing dispersion stability.

[0033]

Examples of water-soluble polymers that can be used herein include polycarboxylic acid-based water-soluble polymers as anionic polymers, such as polyacrylic acid-based water-soluble polymers including polyacrylic acid or its salts and acrylic acid-(meth)acrylate copolymers or their salts, as well as cellulose derivatives such as alginate and carboxymethylcellulose. Nonionic materials include cellulose derivatives such as hydroxyethyl cellulose, polyvinyl alcohol, polyvinylpyrrolidone, polyethylene glycol, and polyacrylamide. Examples of cationic water-soluble polymers include polyethyleneimine.

[0034]

In the present embodiment, the nonionic water-soluble polymers can be suitably used from the viewpoint of ensuring the function of the thickening agent in preventing precipitation of agglomerated particles of α -alumina as abrasive particles, enhancing dispersion stability, and suppressing polishing inhibition such as a decrease in polishing rate for the polishing target due to an excessive increase in viscosity. The appropriate content of the water-soluble polymer is 0.01 to 1% by mass, preferably 0.1 to 0.9% by mass, of the total polishing slurry.

[0035]

The polishing slurry according to the embodiment of the present invention is suitably used for polishing interlayer insulating materials having polyimide resin as the main component. However, polishing of interlayer insulating materials may require planarization of metal wiring made of copper, aluminum, or the like together with interlayer insulating films by the CMP method. In such cases, oxidizing agents,

complexing agents, antioxidants, pH adjusting agents, and the like may be incorporated as needed.

[0036]

The oxidizing agents function to moderately oxidize and ionize metal films such as copper, while the complexing agents promote the ionization of metal films such as copper. The antioxidants can also suppress excessive etching of the metal film by oxidizing agents and complexing agents, and by adjusting their concentrations, the polishing rate for the metal film can be adjusted within a suitable range.

[0037]

The oxidizing agents that can be used herein include peroxides such as H_2O_2 , Na_2O_2 , Ba_2O_2 , and $(\text{C}_6\text{H}_5\text{CO})_2\text{O}_2$, hypochlorous acid (HClO), perchloric acid, nitric acid, ozonated water, and organic peroxides such as peracetic acid and nitrobenzene. In particular, hydrogen peroxide (H_2O_2), which does not contain metal components and does not generate harmful byproducts, is suitably used. The appropriate content of the oxidizing agent is 0.01 to 15% by mass, preferably 0.1 to 10% by mass, of the total polishing slurry.

[0038]

Known organic acids such as carboxylic acids and amino acids can be used as the complexing agents. Examples of the organic acids include glycine, alanine, valine, serine, threonine, cysteine, phenylalanine, proline, asparagine, aspartic acid, lysine, histidine, arginine, formic acid, acetic acid, propionic acid, butyric acid, valeric acid, 2-methylbutyric acid, n-hexanoic acid, 3,3-dimethylbutyric acid, 2-ethylbutyric acid, 4-methylpentanoic acid, n-heptanoic acid, 2-methylhexanoic acid, n-octanoic acid, 2-ethylhexanoic acid, benzoic acid, glycolic acid, salicylic acid, glyceric acid, oxalic acid, malonic acid, succinic acid, glutaric acid, adipic acid, pimelic acid, maleic acid, phthalic acid, malic acid, tartaric acid, citric acid, lactic

acid, and salts thereof such as ammonium salts and alkali metal salts, or mixtures thereof. Glycine, an amino acid having both an amino group and a carboxyl group, is particularly suitable for dissolving metals that are difficult to dissolve. The appropriate content of the complexing agent is 0.01 to 5% by mass, preferably 0.05 to 3% by mass, and more preferably 0.1 to 1% by mass, of the total polishing slurry.

[0039]

Examples of the antioxidants that can be used herein include benzotriazole, 1,2,3-triazole, 1,2,4-triazole, benzofuroxane, 2,1,3-benzothiazole, o-phenylenediamine, m-phenylenediamine, catechol, o-aminophenol, 2-mercaptobenzothiazole, 2-mercaptobenzimidazole, 2-mercaptobenzoxazole, melamine, and derivatives thereof. The appropriate content of the antioxidant is 0.001 to 1% by mass, preferably 0.01 to 0.1% by mass, of the total polishing slurry.

[0040]

The appropriate pH of the polishing slurry is preferably 3 to 8, and more preferably 4 to 7, from the viewpoints of polishing rate, slurry viscosity, and dispersion stability of abrasive particles. The pH of the polishing slurry can be adjusted by known methods. When nitric acid is used as the dispersing agent for the polishing slurry, it is preferable to use an alkali. Alkali metal hydroxides such as sodium hydroxide and potassium hydroxide, alkali metal carbonates such as sodium carbonate and potassium carbonate, ammonia, amines, and the like can be used. Among these, it is appropriate to add ammonia to adjust the pH to an appropriate range.

[0041]

(Method for Producing Polishing Slurry)

The polishing slurry according to the embodiment of the present invention can be produced, for example, by mixing abrasive particles and a dispersing agent in an aqueous medium with stirring, and then diluting the mixture. For example, by adding

water and a dispersing agent such as nitric acid to abrasive particles, mixing the abrasive particles with stirring using a bead mill or the like so that the average particle diameter (D50) is 80 to 120 nm, diluting it with water so that the abrasive particle content is 0.01 to 10% by mass, and further adjusting the pH, a polishing slurry (free abrasive polishing slurry) suitable for polishing an insulating material containing polyimide resin can be produced.

[0042]

(Polishing Method)

The polishing slurry according to the embodiment of the present invention can be suitably used to perform free abrasive polishing of insulating films containing the polyimide resin formed on substrates of semiconductor devices. The polishing apparatus is not particularly limited, and a variety of common polishing apparatuses can be used, including single-sided and double-sided apparatuses. For example, when using the single-sided polishing apparatus, the semiconductor substrate is held by a carrier or other holding device, and the polishing slurry according to the embodiment of the present invention is supplied to the surface of the insulating film containing the polyimide resin formed on the semiconductor substrate. The surface plate to which the specified polishing pad is attached is then pressed against the polishing target, and the surface plate is rotated to polish the surface of the insulating film at or above the specified polishing rate.

[0043]

According to the polishing method using the polishing slurry of the present invention, even for materials with relatively low mechanical strength, such as insulating materials containing the polyimide resin, a polished surface with good surface characteristics can be obtained at a high polishing rate by a single polishing process, without repeating the polishing process in stages. This enables an efficient polishing process to be achieved.

[0044]

According to the polishing method according to the embodiment of the present invention, the polishing rate can be 200 nm/min or more, further 300 nm/min or more, and still further 350 nm/min or more. Although the recommended upper limit of the polishing rate is not particularly specified, it may typically be 3000 nm/min or less, and further 1500 nm/min or less, as excessively high rates may make it difficult to adjust the desired amount of material removal. Although not limited to the following, the polishing load on the insulating film containing the polyimide resin can be, for example, 0.1 to 10.0 psi, and preferably 1.0 to 5.0 psi. By such a treatment, a polished surface with good planar characteristics having a surface roughness (centerline average roughness Ra_{75}) based on Annex JB of JIS-B0601 (2013) of 10 nm or less, further 5.0 nm or less, and still further 2.0 nm or less is obtained on the surface of the insulating film.

EXAMPLES

[0045]

The following Examples of the present invention are provided to better understand the invention and its advantages, and are not intended to limit the invention.

[0046]

<Polishing Slurry>

Using the various abrasive particles shown in Table 1, 0.2% by mass of nitric acid was added to an abrasive particle/water mixture containing 30% by mass of abrasive particles, dispersed using a bead mill, and then diluted with water to prepare polishing slurries each having an abrasive particle content (abrasive grain concentration) of 0.5% by mass and an average particle diameter (D_{50}) of the

abrasive particles at the values shown in Table 1. The pH of the polishing slurry was adjusted to pH 6 by adding ammonia.

[0047]

<Measurement of Particle Diameter>

The particle diameter of abrasive particles in the polishing slurry was measured using a laser diffraction/scattering particle size distribution analyzer (LA-960, manufactured by HORIBA, Ltd.). The particle diameter value used was the average particle diameter (D50) at the volume-based cumulative value of 50% in the particle size distribution determined by the laser diffraction scattering method.

[0048]

<Polishing Target>

Polyimide (of photosensitive positive type, manufactured by Advance Materials Technology, Inc.) was coated on a silicon wafer with a diameter of $\phi 200$ mm using a spin coater and thermally cured to produce a polyimide film having a thickness of 10 μm on the silicon wafer.

[0049]

<Polishing Conditions>

A Mirra CMP apparatus manufactured by Applied Materials, Inc. was used as the polishing apparatus, and polishing was performed under the conditions shown below. A polishing pad (IC1400, manufactured by Nitta DuPont Co., Ltd.) was attached to the surface plate of the polishing apparatus.

Down Force = 2.0 psi;

Head Speed / Platen Speed = 120/117 rpm;

Slurry Flow = 200 ml/min; and

Polish Time = 30 sec.

[0050]

<Measurement of Polishing Rate>

The polishing rate was calculated by measuring the change in film thickness of the polishing target (polyimide film) before and after polishing using filmTec1000 manufactured by SCI, as an amount of film thickness decreased per polishing time.

[0051]

<Measurement of Surface Roughness>

The surface roughness was measured using a scanning probe microscope (Nanoscope V, manufactured by Bruker Japan Ltd.). The surface roughness value used was the centerline average roughness Ra_{75} defined in Annex JB of JIS-B0601 (2013).

[0052]

<Experimental Results>

The results of polishing with polishing slurries using various abrasive particles are shown in Table 1 below.

[0053]

[Table 1]

	Abrasive Particles	Crystal System	Particle Diameter (μm)	BET (m^2/g)	BET/D50 ($\text{m}^2/\text{g} \times 10^8$)	Loose Bulk Density LBD (g/cm^3)	Tapped Bulk Density TBD (g/cm^3)	TBD/LBD (-)	Polishing Rate (nm/min)	Surface Roughness (nm)
Example 1	Alumina	α	0.109	31.7	2.90	0.9	1.2	1.33	359	1.8
Comparative Example 1			0.108	12.5	1.16	0.8	1.1	1.38	155	1.1
Comparative Example 2			0.118	4.6	0.29	0.5	1.0	2.00	178	1.7
Comparative Example 3			0.095	17.8	1.88	0.7	1.1	1.57	150	1.1
Comparative Example 4			0.103	11.0	1.07	0.9	1.3	1.44	131	1.0
Reference Example 1	Silica	θ	0.109	80.0	7.32	-	-	-	140	0.6
Reference Example 2		-	0.130	-	-	-	-	-	10	-

[0054]

Example 1 in which α -alumina was used as abrasive particles, the particle diameter was in the range of 80 to 120 nm, the specific surface area (BET) was 20 m^2/g or more, and the ratio of specific surface area (BET) to average particle diameter (D50) (BET/D50) was $1.5 \text{ m}^2/\text{g} \times 10^8$ or more could provide a higher polishing rate than Comparative Examples 1 to 4. The surface roughness of the

polyimide film was good, with $Ra_{75} = 2.0$ nm or less. In Example 1, the ratio (TBD/LBD) of tapped bulk density (TBD) to loose bulk density (LBD) was 1.5 or less.

[0055]

In Comparative Examples 1 to 4 in which α -alumina was used as abrasive particles, the average particle diameter (D50) was adjusted within the range of 80 to 120 nm, and the surface roughness after polishing was good in all cases. However, the polishing rate was lower than that of Example 1. Comparative Example 4 had a BET of less than $20 \text{ m}^2/\text{g}$ and a BET/D50 of less than $1.5 \text{ m/g} \times 10^8$, indicating that BET and BET/D50 were not in a suitable range. Although the ratio TBD/LBD was 1.5 or less, the polishing rate was lower than that of Example 1. In Comparative Example 3, the ratio BET/D50 was $1.5 \text{ m/g} \times 10^8$ or more, but BET was less than $20 \text{ m}^2/\text{g}$ and the ratio TBD/LBD exceeded 1.5, resulting in a lower polishing rate than Example 1. Comparative Example 2 had a lower polishing rate due to a smaller BET value and a larger TBD/LBD value. Comparative Example 1 had a smaller BET and a BET/D50 of less than $1.5 \text{ m/g} \times 10^8$, resulting in a lower polishing rate. Neither Reference Example 1 nor Reference Example 2, which used θ -alumina and silica as abrasive particles, respectively, achieved a higher polishing rate than Example 1. These results indicate that sufficiently high-speed polishing with excellent planarization can be achieved in polishing materials with low mechanical strength used for interlayer insulating films such as polyimide resin, by using α -alumina as abrasive particles, ensuring that the α -alumina has an average particle diameter (D50) of 80 to 120 nm at a volume-based cumulative value of 50% in the particle size distribution determined by the laser diffraction scattering method, the specific surface area (BET) measured in accordance with JIS-Z8830 (2013) is $20 \text{ m}^2/\text{g}$ or more, and the ratio of the specific surface area (BET) to the average particle diameter (D50) (BET/D50) is $1.5 \text{ m/g} \times 10^8$ or more, and further preferably the ratio

(TBD/LBD) of tapped bulk density (TBD) to loose bulk density (LBD) measured according to JIS-R9301-2-3 (1999) is 1.5 or less.

CLAIMS

1. A polishing slurry comprising α -alumina as abrasive particles in an aqueous medium,
wherein the α -alumina has:
an average particle diameter (D50) of 80 to 120 nm at a volume-based cumulative value of 50% in a particle size distribution determined by a laser diffraction scattering method;
a specific surface area (BET) measured in accordance with JIS-Z8830 (2013) of 20 m²/g or more; and
a ratio (BET/D50) of the specific surface area (BET) to the average particle diameter (D50) of 1.5 m/g $\times$ 10⁸ or more.
2. The polishing slurry according to claim 1, wherein a ratio (TBD/LBD) of tapped bulk density (TBD) to loose bulk density (LBD) measured in accordance with JIS-R9301-2-3 (1999) is 1.5 or less.
3. The polishing slurry according to claim 1 or 2, wherein the specific surface area (BET) is 25 m²/g or more and the ratio (BET/D50) of the specific surface area (BET) to the average particle diameter (D50) is 2.0 m/g $\times$ 10⁸ or more.
4. The polishing slurry according to claim 1 or 2, wherein the content of the abrasive particles is 0.01 to 10% by mass and 0.0001 to 1% by mass of nitric acid is contained as a dispersing agent.

5. The polishing slurry according to claim 1 or 2, wherein the polishing slurry is a free abrasive polishing slurry used for polishing an insulating material comprising a polyimide resin.