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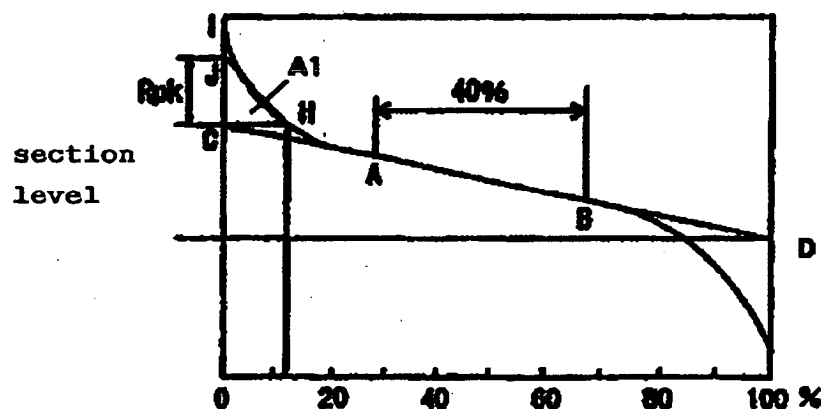
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A request for correction of the description has been filed pursuant to Rule 88 EPC. A decision on the request will be taken during the proceedings before the Examining Division (Guidelines for Examination in the EPO, A-V, 3.).

(54) **Chemical mechanical polishing pad, manufacturing process thereof and chemical mechanical polishing method**

(57) A chemical mechanical polishing pad having a polishing surface with an arithmetic mean roughness (Ra) of 0.1 to 15 μm , a 10-point height (Rz) of 40 to 150 μm , a core roughness depth (Rk) of 12 to 50 μm and a reduced peak height (Rpk) of 7 to 40 μm , a manufactur-

ing process thereof and a chemical mechanical polishing method. Even when the chemical mechanical polishing of a large-diameter wafer as an object to be polished is carried out by this pad, a polished surface having excellent in-plane uniformity and flatness can be formed.

Fig. 4

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DescriptionField of the Invention

[0001] The present invention relates to a chemical mechanical polishing pad, a manufacturing process thereof and a chemical mechanical polishing method.

[0002] More specifically, it relates to a chemical mechanical polishing pad capable of providing a polished surface having excellent in-plane uniformity and flatness when chemical mechanical polishing is made on the surface, a manufacturing process thereof and a chemical mechanical polishing method using the above chemical mechanical polishing pad.

Description of the Prior Art

[0003] In the process for the manufacture of a semiconductor device, CMP (Chemical Mechanical Polishing) is employed as a technique capable of providing an extremely flat surface to a wafer. CMP is a technique for the chemical mechanical polishing of a surface by letting chemical mechanical polishing slurry which is an aqueous dispersion of abrasive grains flow down over the surface of a chemical mechanical polishing pad while the surface to be polished is pressed against and brought into slide contact with the surface of the chemical mechanical polishing pad. It is known that the polishing result is greatly affected by the performance characteristic and properties of the chemical mechanical polishing pad in this CMP.

[0004] There are known chemical mechanical polishing pads such as a polyurethane foamed resin pad containing a large number of pores and a pad containing a large number of fine water-soluble particles dispersed in a nonfoamed matrix (the former is disclosed by JP-A 11-70463 and JP-A 8-216029 and the latter is disclosed by JP-A 2000-34416, JP-A 2000-33552 and JP-A 2001-334455) (the term "JP-A" as used herein means an "unexamined published Japanese patent application").

[0005] Since the improvement of productivity is now desired in the process for the manufacture of a semiconductor, a wafer which needs chemical mechanical polishing is becoming larger in diameter.

[0006] When chemical mechanical polishing is made on a large-diameter wafer by a conventionally known method, the in-plane uniformity and flatness of the polished surface after chemical mechanical polishing may become unsatisfactory.

Summary of the Invention

[0007] It is an object of the present invention which has been made in view of the above problem to provide a chemical mechanical polishing pad capable of providing a polished surface having excellent in-plane uniformity and flatness even when chemical mechanical polishing is made on a large-diameter wafer as an object to be polished, a manufacturing process thereof and a chemical mechanical polishing method.

[0008] Other objects and advantages of the present invention will become apparent from the following description.

[0009] According to the present invention, firstly, the above objects and advantages of the present invention are attained by a chemical mechanical polishing pad having a polishing surface and a non-polishing surface, the polishing surface having an arithmetic mean roughness (Ra) of 0.1 to 15 μm , a 10-point height (Rz) of 40 to 150 μm , a core roughness depth (Rk) of 12 to 50 μm and a reduced peak height (Rpk) of 7 to 40 μm .

[0010] Secondly, the above objects and advantages of the present invention are attained by a process of manufacturing the above chemical mechanical polishing pad, comprising the steps of:

molding a polishing layer; and

sanding at least the surface to be polishing surface of the polishing layer.

[0011] Thirdly, the above objects and advantages of the present invention are attained by a chemical mechanical polishing method comprising chemical mechanical polishing an object to be polished with the above chemical mechanical polishing pad.

Brief Description of Drawings

[0012]

Fig. 1 is a diagram showing the definition of 10-point height (Rz);

Fig. 2 is a diagram showing the definition of a material ratio curve;

Fig. 3 is a diagram showing the definition of core roughness depth (Rk); and
Fig. 4 is a diagram showing the definition of reduced peak height (Rpk).

Detailed Description of the Preferred Embodiment

[0013] The polishing surface of the chemical mechanical polishing pad of the present invention has an arithmetic mean roughness (Ra) of 0.1 to 15 μm, a 10-point height (Rz) of 40 to 150 μm, a core roughness depth (Rk) of 12 to 50 μm and a reduced peak height (Rpk) of 7 to 40 μm.

[0014] These values are defined as the averages of the following numerical values calculated from roughness profiles obtained by measuring a plurality of measurement lines set on the surface of the pad. For example, they can be calculated by a method disclosed by LM Manual (analog version), Version 3.62 published by Mitsuya Shoji Co., Ltd.

[0015] The arithmetic mean roughness (Ra) is a value expressed by the following equation (1) when the x axis of the roughness profile of an evaluation length L is plotted in the direction parallel to the mean line of the roughness profile, the y axis is plotted in the direction of the longitudinal magnification of the roughness profile, and the measured roughness profile is expressed by the equation $y = f(x)$.

$$Ra = \frac{1}{L} \int_0^L |y| dx \quad (1)$$

[0016] The 10-point height (Rz) is a value expressed by the following equation (2) when the x axis of the roughness profile of the evaluation length L is plotted in the direction parallel to the mean line of the roughness profile, they axis is plotted in the direction of the longitudinal magnification of the roughness profile, the distances of the tops of the highest mountain to the fifth highest mountain from the mean line in the direction of the longitudinal magnification are represented by P1 to P5, and the distances to the bottoms of the lowest valley to the fifth lowest valley from the mean line are represented by V1 to V5, respectively (see Fig. 1).

$$Rz = \frac{1}{5} \left(\sum_{i=1}^5 P_i - \sum_{i=1}^5 V_i \right) \quad (2)$$

[0017] The core roughness depth (Rk) and the reduced peak height (Rpk) are defined by a material ratio curve derived from the roughness profile of the evaluation length L.

[0018] The material ratio curve refers to a curve obtained by plotting a section level as the longitudinal axis and a material ratio as the horizontal axis. The term "section level" used herein means a specific value of y when the roughness profile is expressed by the same equation $y = f(x)$ as in the above arithmetic mean roughness (Ra). The term "material ratio" is a percentage of the length of a cut portion to the evaluation length L when the roughness profile is cut at a certain section level. The material ratio is 0 % when the section level is at the top of the highest mountain in the roughness profile and 100 % when the section level is at the bottom of the lowest valley (see Fig. 2).

[0019] The core roughness depth (Rk) is a difference in section level between points C and D when two points A and B the difference in material ratio between which is 40 % and the difference in section level between which is the smallest are set on the material ratio curve defined as described above, the point C is the intersection between a straight line connecting the points A and B and extending in both directions and a line representing a material ratio of 0 %, and the point D is the intersection between the straight line connecting the points A and B and a line representing a material ratio of 100 % (see Fig. 3).

[0020] The reduced peak height (Rpk) is a difference in section level between the points C and J when the intersection between the section level passing through the point C in the definition of the above core roughness depth (Rk) and the material ratio curve is a point H, the intersection between the material ratio curve and the line representing a material ratio of 0 % is point I, and a point J is set on a straight line representing a material ratio of 0 % to ensure that the area surrounded by the line segment CH, line segment CI and the curve HI becomes equal to the area of the triangle CHJ (see Fig. 4. A1 in Fig. 4 is the area surrounded by the line segment CH, line segment CI and the curve HI, that is, the area of the triangle CHJ).

[0021] A plurality of measurement lines for measuring the above arithmetic mean roughness (Ra), 10-point height

(Rz), core roughness depth (Rk) and reduced peak height (Rpk) are set on the pad as follows.

[0022] First, the center points of the plurality of measurement lines are set as follows. As for the center points of the measurement lines, virtual straight lines whose length becomes the longest are drawn from one arbitrary point at one end of the polishing surface of the pad to another point (when the polishing surface of the pad is circular, the above virtual straight lines become the diameter of a circle forming the pad surface) to set 10 to 50 points on the virtual straight lines at roughly equal intervals except for a 5 % area of the length of the virtual straight line from the center to the both sides and 5 % areas of the length of the virtual straight line from the both ends. The number of the center points of the measurement lines is preferably 25 to 50.

[0023] A groove (s) may be formed in the polishing surface of the chemical mechanical polishing pad of the present invention as will be described hereinafter. In this case, the center points of the measurement lines should be set such that the all the measurement lines set as will be described hereinafter are existent in a portion other than the groove (s) in the polishing surface. 10 to 50 measurement points may not be set at roughly equal intervals on the above virtual straight lines according to the shape of the groove(s) formed in the polishing surface. In this case, out of the points set at equal intervals, the above number of points may be secured by excluding the points of the measurement lines partially overlapping with the groove portion. Straight lines intersecting the virtual straight lines for setting the plurality of points and passing through the "center points of the measurement lines" are assumed and taken as measurement lines. The length of the measurement lines may be 1 to 15 mm with the center point of the above measurement line as the center thereof.

[0024] The above roughness profile can be measured by using a commercially available surface roughness meter.

[0025] As for the chemical mechanical polishing pad of the present invention, the arithmetic mean roughness (Ra) of the polishing surface thus measured is 0.1 to 15 μm . This value is preferably 0.1 to 12 μm . The 10-point height (Rz) is 40 to 150 μm . It is preferably 40 to 130 μm . The core roughness depth (Rk) is 12 to 50 μm . It is preferably 12 to 45 μm . The reduced peak height (Rpk) is 7 to 40 μm . It is preferably 7 to 30 μm .

[0026] When the chemical mechanical polishing step is carried out by using the chemical mechanical polishing pad having these values, a polished surface having excellent in-plane uniformity and flatness can be obtained. This effect is marked particularly when a large-diameter wafer is chemically mechanically polished.

[0027] The chemical mechanical polishing pad of the present invention preferably has a thickness distribution of 50 μm or less. The effect of the present invention is advantageously exhibited by setting the thickness distribution of the chemical mechanical polishing pad to 50 μm or less. This value is more preferably 40 μm or less, particularly preferably 30 μm or less. By setting the thickness distribution of the chemical mechanical polishing pad to this range, even when a large-diameter wafer as an object to be polished is chemically mechanically polished, a polished surface having excellent in-plane uniformity and flatness can be obtained.

[0028] The thickness distribution can be calculated from the following equation by measuring the thickness at a plurality of measurement points set on the surface of the pad.

$$\text{Thickness distribution} = (\text{largest measurement value of thickness}) - (\text{smallest measurement value of thickness})$$

[0029] 10 to 50 measurement points are set at equal intervals on virtual straight lines drawn from one arbitrary point at one end of the polishing surface of the pad to another point such that its length becomes the largest (when the polishing surface of the pad is circular, the above virtual straight lines become the diameter of a circle forming the pad surface) excluding a 5 % area of the length of the virtual straight line from the center to the both sides and 5 % areas of the length of the virtual straight line from the both ends. The number of measurement points is preferably 25 to 50.

[0030] A groove(s) may be formed in the polishing surface of the chemical mechanical polishing pad of the present invention as will be described hereinafter. In this case, the measurement points should be set in a portion other than the groove(s) on the polishing surface. There is a case where 10 to 50 measurement points cannot be set at roughly equal intervals on the above virtual straight lines according to the shape of the groove(s) formed in the polishing surface. In this case, out of the points set at roughly equal intervals, the above number of measurement points may be secured by excluding points in the groove(s).

[0031] The thickness at each measurement point can be known by placing the chemical mechanical polishing pad on a horizontal plane and measuring the distance between the measurement point and the horizontal plane. A contact type distance meter may be used to measure the distance between the measurement point and the horizontal plane. One of commercially available products of the above meter is Manual 3-D Meter (of Mitutoyo Corporation).

[0032] The shape of the chemical mechanical polishing pad of the present invention is not particularly limited. It may be disk-like, belt-like or roller-like. Preferably, the shape of the chemical mechanical polishing pad is suitably selected according to a polishing machine. The size of the chemical mechanical polishing pad before use is not particularly

limited. A disk-like chemical mechanical polishing pad had a diameter of, for example, 0.5 to 500 cm, preferably 1.0 to 250 cm, more preferably 20 to 200 cm. It has a thickness of, for example, more than 0.1 mm and 100 mm or less, particularly preferably 1 to 10 mm.

[0033] The chemical mechanical polishing pad of the present invention may have a groove(s) or recessed portion(s) having an arbitrary shape in the polishing surface. The groove (s) or recessed portion(s) serves to hold an aqueous dispersion for chemical mechanical polishing supplied during chemical mechanical polishing and uniformly distribute it to the polished surface of an object to be polished, retains wastes such as chips and polishing liquid waste generated by chemical mechanical polishing temporarily and becomes a route for discharging the wastes to the outside.

[0034] The shape of the above groove(s) is not particularly limited but may be circular, lattice-like or radial. The shape of the above recessed portion(s) is circular or polygonal. The sectional form of the groove(s) or recessed portion(s) is not particularly limited. It may be, for example, rectangular, trapezoidal, U-shaped or V-shaped.

[0035] The number of the grooves or the recessed portions may be one or more.

[0036] The size of the above groove(s) or recessed portion(s) is not particularly limited. The width of the groove (s) or the shortest diameter of the recessed portion(s) may be, for example, 0.1 mm or more, specifically 0.1 to 0.5 mm, more specifically 0.2 to 3.0 mm. The depth of the groove(s) or the recessed portion (s) may be, for example, 0.1 mm or more, specifically 0.1 to 2.5 mm, more specifically 0.2 to 2.0 mm.

[0037] The surface roughness of the inner wall of the above groove (s) or recessed portion(s) is preferably 20 μm or less, more preferably 15 μm or less. By setting the surface roughness of the inner wall of the groove(s) or recessed portion (s) to this range, when chemical mechanical polishing is carried out with this pad, it is possible to prevent the polished surface of the object from being scratched and to contribute to the improvement of the polishing rate and the service life of the polishing pad. The improvement of the polishing rate by setting the surface roughness of the inner wall of the groove(s) or recessed portion(s) to the above range is assumed to be because the function of distributing an aqueous dispersion for chemical mechanical polishing to the polished surface is carried out better. The improvement of the service life of the polishing pad by setting the surface roughness of the inner wall of the groove(s) or recessed portion(s) to the above range is assumed to be because the function of discharging wastes generated by chemical mechanical polishing is carried out more efficiently.

[0038] The above surface roughness can be measured with an optical surface roughness meter or contact type surface roughness meter. Examples of the above optical surface roughness meter include a 3-D surface structural analytical microscope, scanning laser microscope and electron beam surface form analyzer. Examples of the above contact type surface roughness meter include a tracer type surface roughness meter.

[0039] The chemical mechanical polishing pad of the present invention may further have a groove(s) or recessed portion (s) on the non-polishing surface (rear side of the pad).

[0040] The groove(s) or recessed portion(s) contributes to the suppression of the production of a surface defect on the polished surface in the chemical mechanical polishing step. It is assumed that even when foreign matter such as coarse particles which may be contained in the aqueous dispersion for chemical mechanical polishing or cutting chips derived from the production process of the chemical mechanical polishing pad enter between the polishing pad and the object to be polished, the recessed portion(s) serves to ease excessively large pressure generated locally to thereby reduce the number of surface defects on the polished surface.

[0041] The shape of the above groove (s) or recessed portion (s) is not particularly limited. The shape of the groove (s) may be spiral, annular or lattice-like. The shape of the recessed portion(s) may be circular or polygonal.

[0042] The size of the groove(s) or recessed portion(s) may be arbitrary. When the recessed portion(s) is/are circular, it/they may have a diameter of 1 to 300 mm, specifically 5 to 200 mm, more specifically 10 to 150 mm. When the groove (s) is/are spiral, annular or lattice-like, it/they may have a width of 0.1 to 20 mm, specifically 0.1 to 10 mm. The depth of the groove(s) or recessed portion(s) may be, for example, 0.01 to 2.0mm, specifically 0.1 to 1.5 mm, more specifically 0.1 to 1.0 mm regardless of its/their shape.

[0043] The number of the grooves or recessed portions may one or more.

[0044] The chemical mechanical polishing pad of the present invention has a thickness distribution of 50 μm or less as described above and optionally has a groove(s) or recessed portion(s) in the polishing surface and/or the non-polishing surface. Although the process for manufacturing the pad is not particularly limited, the pad can be manufactured by a process comprising the following steps, for example.

- (1) the step of preparing a composition for a chemical mechanical polishing pad;
- (2) the step of molding the above composition for a chemical mechanical polishing pad into a polishing layer; and
- (3) the step of sanding at least the polishing surface of the above polishing layer.

[0045] A detailed description is subsequently given of each of the above steps.

(1) step of preparing a composition for a chemical mechanical polishing pad

[0046] The chemical mechanical polishing pad of the present invention may be made of any material as far as the object of the present invention can be attained. It is preferred that pores having the function of holding an aqueous dispersion for chemical mechanical polishing during chemical mechanical polishing and the function of retaining polishing chips temporarily out of the functions of the chemical mechanical polishing pad should be formed by the time of polishing. Therefore, the chemical mechanical polishing pad is preferably made of a material consisting of water-soluble particles and a water-insoluble matrix containing the water-soluble particles dispersed therein, or a material consisting of cavities and a water-insoluble matrix material containing the cavities dispersed therein, for example, a foam.

[0047] In the former material out of these, the water-soluble particles come into contact with an aqueous medium of slurry containing the aqueous medium and a solid at the time of polishing and dissolve or swell to be eliminated, and the slurry can be held in pores formed by elimination. In the latter material, the slurry can be held in pores formed as the cavities.

[0048] The material of the above "water-insoluble matrix" is not particularly limited but an organic material is preferred because it is easily molded to have a predetermined shape and predetermined properties and can provide suitable hardness and suitable elasticity. Examples of the organic material include thermoplastic resins, elastomers, rubbers such as crosslinked rubbers, and curable resins such as thermally or optically curable resins and resins cured by heat or light. They may be used alone or in combination.

[0049] Out of these, the above thermoplastic resins include 1,2-polybutadiene resin, polyolefin resins such as polyethylene, polystyrene resins, polyacrylic resins such as (meth)acrylate-based resins, vinyl ester resins (excluding acrylic resins), polyester resins, polyamide resins, fluororesins such as polyvinylidene fluoride, polycarbonate resins and polyacetal resins.

[0050] The above elastomers include diene elastomers such as 1,2-polybutadiene, polyolefin elastomer (TPO), styrene-based elastomers such as styrene-butadiene-styrene block copolymer (SBS) and hydrogenated block copolymers thereof (SEBS), thermoplastic polyurethane elastomers (TPU), thermoplastic elastomers such as polyester elastomers (TPEE) and polyamide elastomers (TPAE), silicone resin elastomers and fluororesin elastomers. The rubbers include conjugated diene rubbers such as butadiene rubber (high cis-butadiene rubber, low cis-butadiene rubber, etc.), isoprene rubber, styrene-butadiene rubber and styrene-isoprene rubber, nitrile rubbers such as acrylonitrile-butadiene rubber, acrylic rubber, ethylene- α -olefin rubbers such as ethylene-propylene rubber and ethylene-propylene-diene rubber, other rubbers such as butyl rubber, silicone rubber and fluorine rubber.

[0051] The above curable resins include urethane resins, epoxy resins, acrylic resins, unsaturated polyester resins, polyurethane-urea resins, urea resins, silicon resins, phenolic resins and vinyl ester resins.

[0052] The above organic materials may be modified by an acid anhydride group, carboxyl group, hydroxyl group, epoxy group or amino group. The affinity for the water-soluble particles to be described hereinafter and slurry of the organic material can be adjusted by modification.

[0053] These organic materials may be used alone or in combination of two or more.

[0054] Further, the organic material may be a partially or wholly crosslinked polymer or non-crosslinked polymer. Therefore, the water-insoluble matrix may be composed of a crosslinked polymer alone, a mixture of a crosslinked polymer and a non-crosslinked polymer, or a non-crosslinked polymer alone. It is preferably composed of a crosslinked polymer alone or a mixture of a crosslinked polymer and a non-crosslinked polymer. When a crosslinked polymer is contained, elastic recovery force is provided to the water-insoluble matrix and displacement caused by shear stress applied to the chemical mechanical polishing pad during polishing can be reduced. Further, it is possible to effectively prevent the pores from being plastically deformed by the excessive extension of the water-insoluble matrix during polishing and dressing and the surface of the chemical mechanical polishing pad from being excessively napped. Therefore, the pores are formed efficiently even during dressing, whereby a reduction in the retainability of the slurry during polishing can be suppressed and further the pad is rarely napped, thereby not impairing polishing flatness. The method of crosslinking the above material is not particularly limited. For example, chemical crosslinking making use of an organic peroxide, sulfur or sulfur compound or radiation crosslinking by applying an electron beam may be employed.

[0055] The crosslinked polymer may be a crosslinked rubber, curable resin, crosslinked thermosetting resin or crosslinked elastomer out of the above organic materials. Out of these, a crosslinked thermoplastic resin and/or crosslinked elastomer all of which are stable to a strong acid or strong alkali contained in many kinds of slurry and are rarely softened by water absorption are preferred. Out of the crosslinked thermoplastic resin and crosslinked elastomer, what is crosslinked with an organic peroxide is more preferred, and crosslinked 1,2-polybutadiene is particularly preferred.

[0056] The content of the crosslinked polymer is not particularly limited but preferably 30 vol% or more, more preferably 50 vol% or more, particularly preferably 70 vol% or more and may be 100 vol% of the water-insoluble matrix.

When the content of the crosslinked polymer in the water-insoluble matrix is lower than 30 vol%, the effect obtained by containing the crosslinked polymer may not be fully obtained.

[0057] The residual elongation after breakage (to be simply referred to as "residual elongation at break" hereinafter) of the above water-insoluble matrix containing a crosslinked polymer can be 100 % or less when a specimen of the above water-insoluble matrix is broken at 80° C in accordance with JIS K 6251. That is, the total distance between bench marks of the specimen after breakage becomes 2 times or less the distance between the bench marks before breakage. This residual elongation at break is preferably 30 % or less, more preferably 10 % or less, particularly preferably 5 % or less and generally 0 % or more. When the above residual elongation at break is higher than 100 %, fine pieces scraped off from the surface of the chemical mechanical polishing pad or stretched at the time of polishing and surface renewal tend to fill the pores disadvantageously. The "residual elongation at break" is an elongation obtained by subtracting the distance between bench marks before the test from the total distance between each bench mark and the broken portion of the broken and divided specimen in a tensile test in which a dumbbell-shaped specimen No. 3 is broken at a tensile rate of 500 mm/min and a test temperature of 80°C in accordance with the "vulcanized rubber tensile test method" specified in JIS K 6251. The test is carried out at 80° C because heat is generated by slide contact at the time of actual polishing.

[0058] The above "water-soluble particles" are particles which are eliminated from the water-insoluble matrix when they come into contact with slurry as an aqueous dispersion in the chemical mechanical polishing pad. This elimination may occur when they dissolve in water contained in the slurry upon their contact with water or when they swell and gel by absorbing this water. Further, this dissolution or swelling is caused not only by their contact with water but also by their contact with an aqueous mixed medium containing an alcohol-based solvent such as methanol.

[0059] The water-soluble particles have the effect of increasing the indentation hardness of the chemical mechanical polishing pad in addition to the effect of forming pores. For example, the shore D hardness of the chemical mechanical polishing pad of the present invention can be set to preferably 35 or more, more preferably 50 to 90, particularly preferably 60 to 85 and generally 100 or less by adding the water-soluble particles. When the shore D hardness is 35 or more, pressure applied to the object to be polished can be increased, and the polishing rate can be thereby improved. In addition, high polishing flatness is obtained. Therefore, the water-soluble particles are particularly preferably made of a solid substance which can ensure sufficiently high indentation hardness for the chemical mechanical polishing pad.

[0060] The material of the water-soluble particles is not particularly limited. They are, for example, organic water-soluble particles or inorganic water-soluble particles. Examples of the material for forming the organic water-soluble particles include saccharides (polysaccharides such as starch, dextrin and cyclodextrin, lactose, mannitol, etc.), celluloses (such as hydroxypropyl cellulose, methyl cellulose, etc.), protein, polyvinyl alcohol, polyvinyl pyrrolidone, polyacrylic acid, polyethylene oxide, water-soluble photosensitive resins, sulfonated polyisoprene and sulfonated polyisoprene copolymers. Examples of the material for forming the inorganic water-soluble particles include potassium acetate, potassium nitrate, potassium carbonate, potassium hydrogencarbonate, potassium chloride, potassium bromide, potassium phosphate and magnesium nitrate. These water-soluble particles may be used alone or in combination of two or more. The water-soluble particles may be made of a predetermined single material, or two or more different materials.

[0061] The water-soluble particles have an average particle diameter of preferably 0.1 to 500 μm, more preferably 0.5 to 100 μm. The pores are as big as preferably 0.1 to 500 μm, more preferably 0.5 to 100 μm. When the average particle diameter of the water-soluble particles is smaller than 0.1 μm, the formed pores become smaller in size than the abrasive grains in use, whereby a chemical mechanical polishing pad capable of holding slurry completely may be hardly obtained. When the average particle diameter is larger than 500 μm, the formed pores become too big, whereby the mechanical strength and polishing rate of the obtained chemical mechanical polishing pad may lower.

[0062] The content of the water-soluble particles is preferably 1 to 90 vol%, more preferably 1 to 60 vol%, particularly preferably 2 to 40 vol% based on 100 vol% of the total of the water-insoluble matrix and the water-soluble particles. When the content of the water-soluble particles is lower than 1 vol%, pores are not fully formed in the obtained chemical mechanical polishing pad and the polishing rate may lower. When the content of the water-soluble particles is higher than 90 vol%, it may be difficult to completely prevent the water-soluble particles existent in the interior of the obtained chemical mechanical polishing pad from swelling or dissolving, thereby making it difficult to maintain the hardness and mechanical strength of the obtained chemical mechanical polishing pad at appropriate values.

[0063] It is preferred that the water-soluble particles should dissolve in water only when they are exposed to the surface layer of the chemical mechanical polishing pad and should not absorb moisture or swell when they are existent in the interior of the chemical mechanical polishing pad. Therefore, the water-soluble particles may have an outer shell for suppressing moisture absorption on at least part of their outermost portion. This outer shell may be physically adsorbed to the water-soluble particle, chemically bonded to the water-soluble particle, or in contact with the water-soluble particle by physical adsorption and chemical bonding. The outer shell is made of epoxy resin, polyimide, polyamide or polysilicate. Even when it is formed on only part of the water-soluble particle, the above effect can be fully obtained.

[0064] The above water-insoluble matrix may contain a compatibilizing agent to control its affinity for the water-

soluble particles and the dispersibility of the water-soluble particles in the water-insoluble matrix. Examples of the compatibilizing agent include homopolymers, block copolymers and random copolymers modified by an acid anhydride group, carboxyl group, hydroxyl group, epoxy group, oxazoline group or amino group, nonionic surfactants and coupling agents.

[0065] The water-insoluble matrix material constituting the chemical mechanical polishing pad comprising the latter water-insoluble matrix material (foam, etc.) containing cavities dispersed therein is, for example, a polyurethane, melamine resin, polyester, polysulfone or polyvinyl acetate.

[0066] The average size of the cavities dispersed in the water-insoluble matrix material is preferably 0.1 to 500 μm , more preferably 0.5 to 100 μm .

[0067] There is a case where a chemical mechanical polishing pad comprising a water-insoluble matrix material containing cavities dispersed therein, for example, a foam may not satisfy the requirements for the arithmetic mean roughness (Ra), 10-point height (Rz), core roughness depth (Rk) and reduced peak height (Rpk) of the pad surface that the chemical mechanical polishing pad of the present invention should have according to the sizes of the cavities. Therefore, the chemical mechanical polishing pad of the present invention preferably has a polishing layer made of a material consisting of water-soluble particles and a water-insoluble matrix containing the water-soluble particles dispersed therein.

[0068] The method of obtaining the composition for a chemical mechanical polishing pad from the above material is not particularly limited. For example, the composition can be obtained by kneading together required materials including a predetermined organic material by means of a kneader. A conventionally known kneader may be used, such as a roll, kneader, Banbury mixer or extruder (single-screw, multiple-screw).

[0069] The composition for a chemical mechanical polishing pad containing water-soluble particles for obtaining a chemical mechanical polishing pad containing water-soluble particles can be obtained, for example, by kneading together a water-insoluble matrix, water-soluble particles and other additives. In general, they are kneaded together under heating so that they can be easily processed at the time of kneading. The water-soluble particles are preferably solid at the kneading temperature. When they are solid, they can be dispersed with the above preferred average particle diameter irrespective of their compatibility with the water-insoluble matrix. Therefore, in this case, the type of the water-soluble particles is preferably selected according to the processing temperature of the water-insoluble matrix in use.

(2) step of molding a polishing layer from the composition for a chemical mechanical polishing pad

[0070] The method of forming a polishing layer which should become the chemical mechanical polishing pad of the present invention is not particularly limited. For example, the composition for a chemical mechanical polishing pad which will become a polishing layer is prepared and molded into a desired rough form to produce the polishing layer. At this point, a metal mold having a pattern which should become a groove(s) and/or recessed portion(s) to be formed on the front surface and/or rear surface of the polishing layer is used to mold the composition for a chemical mechanical polishing pad, thereby making it possible to form the groove(s) and/or recessed portion(s) together with the rough form of the polishing layer at the same time. When the groove(s) and/or recessed portion(s) are/is formed by molding, this step can be simplified and the surface roughness of the inner wall of the groove(s) and/or recessed portion(s) can be made 20 μm or less easily.

[0071] The groove(s) and/or recessed portion(s) on the front surface and/or rear surface of the polishing layer may be formed by cutting or counterboring after a polishing layer having none of them is produced. To form the groove(s) and/or recessed portion(s) by cutting or counterboring, the step of forming the groove(s) and/or recessed portion(s) may be carried out before or after (3) the sanding step which will be described next.

(3) step of sanding at least the polishing surface of the above polishing layer

[0072] Thereafter, at least the polishing surface of the thus formed polishing layer is sanded.

[0073] The term "sanding" means polishing with sandpaper. The sandpaper is obtained by bonding abrasive grains to a backing material such as sheet-like or belt-like paper or cloth by an adhesive. The material of the abrasive grains is fine crystals of a natural mineral or fine grains of an artificial inorganic compound. Examples of the natural mineral include emery and garnet and examples of the artificial inorganic compound include aluminum oxide and silicon carbide.

[0074] The size of the abrasive grains used for the above sanding step is preferably 20 to 200 μm , more preferably 25 to 150 μm . The grit size of the sandpaper is preferably 80 to 600, more preferably 120 to 400.

[0075] Sandpaper having a larger width than the polishing surface of the above polishing layer is preferably used for sanding.

[0076] Sanding can be carried out by fixing the above polishing layer on a horizontal plane with the polishing surface facing up, bringing the entire polishing surface into contact with the sandpaper and moving the sandpaper relative to the polishing surface at a relative rate of preferably 0.1 to 100 m/min, more preferably 0.5 to 50 m/min. This movement

may be rotational movement or linear movement with the contact portion between the polishing surface of the polishing layer and the sandpaper as a standard.

[0077] The amount of the polishing layer sanded out, that is, removed by sanding is preferably 0.05 to 3.0 mm, more preferably 0.1 to 2.0 mm.

[0078] Sanding may be carried out only with a single type of sandpaper or with different types of sandpapers which differ in grit size in multiple stages. Out of these, sanding is preferably carried out with different types of sandpapers which differ in grit size in multiple stages. The number of stages is preferably 2 to 10, more preferably 3 to 6. The thickness of the polishing layer sanded out, that is, removed in each stage is preferably 0.01 to 1.5 mm, more preferably 0.1 to 1.0 mm. When sanding is carried out with different types of sandpapers which differ in grit size in multiple stages, a sandpaper having a larger grit size is preferably first used, followed by a sandpaper having a smaller grit size.

[0079] The above sanding can be carried out by using a sandblasting apparatus, belt polishing machine, barrel polishing machine, puff polishing machine, ring polishing machine, electrolytic polishing machine or electrolytic and grain polishing machine. Out of these, a belt polishing machine is preferably used. Commercially available products of the belt polishing machine include the TS130D polishing machine of Amitec Co., Ltd., the T-142DG wide belt sander of Kikukawa Tekkosho Co., Ltd., and the wide belt sander of Meinan Machinery Works, Inc.

[0080] A chemical mechanical polishing pad having a thickness distribution of 50 μm or less and a polishing surface with an arithmetic mean roughness (Ra) of 0.1 to 15 μm , a 10-point height (Rz) of 40 to 150 μm , a core roughness depth (Rk) of 12 to 50 μm and a reduced peak height (Rpk) of 7 to 40 μm can be easily obtained by carrying out this sanding.

[0081] A description is subsequently given of the chemical mechanical polishing method of the present invention.

[0082] The chemical mechanical polishing method of the present invention is the same as a known chemical mechanical polishing method except that the above chemical mechanical polishing pad of the present invention is set in a commercially available polishing machine.

[0083] The type of the surface to be polished is not particularly limited but a metal film, barrier metal film or insulating film which is a wire material may be used. Examples of the material of the above metal film include tungsten, aluminum, copper and alloys containing at least one of these metals. Examples of the material of the above barrier metal film include tantalum, titanium, tantalum nitride and titanium nitride. Examples of the material of the insulating film include silicon oxide. The type of the aqueous dispersion for chemical mechanical polishing should be suitably selected according to the type of the surface to be polished and the purpose of chemical mechanical polishing.

[0084] The object to be polished by the chemical mechanical polishing method of the present invention is preferably a semiconductor wafer having at least one of the above materials on the surface to be polished. Although the semiconductor wafer may be of any size, for the chemical mechanical polishing of a large-diameter semiconductor wafer, the advantage of the chemical mechanical polishing method of the present invention appears markedly. The large-diameter semiconductor wafer means a semiconductor wafer having a diameter larger than 8 inches, preferably 10 inches or more.

[0085] As described above, the chemical mechanical polishing pad of the present invention has an advantage that stability at the time of polishing a wafer is increased by setting the surface roughness of the pad to a certain range. That is, with a conventionally known polishing pad, break-in dressing is necessary before a brand-new pad is set in the polishing machine to polish a wafer. By setting the above surface roughness, stable polishing performance is obtained from the first wafer after the pad is set in the polishing machine without carrying out break-in dressing or by carrying out break-in dressing for a shorter period of time than in the prior art.

[0086] According to the present invention, there are provided a chemical mechanical polishing pad which can provide a polished surface having excellent in-plane uniformity and flatness even when chemical mechanical polishing is made on a large-diameter wafer as an object to be polished, a manufacturing process thereof and a chemical mechanical polishing method.

Examples

Example 1

[0087] 98 vol% of 1,2-polybutadiene (JSR RB830 of JSR Corporation) and 2 vol% of β -cyclodextrin (Dexy Pearl β -100 of Bio Research Corporation of Yokohama) as a water-soluble substance were kneaded together by an extruder heated at 155°C. Thereafter, Percumyl D40 (trade name, manufactured by NOF Corporation, containing 40 % by mass of dicumyl peroxide) was added in an amount of 1.0 part by mass (equivalent to 0.4 parts by mass in terms of pure dicumyl peroxide) based on 100 parts by mass of 1,2-polybutadiene and further kneaded with the above kneaded product, and the resulting product was crosslinked in a press mold at 170°C for 18 minutes to obtain a disk-like molded product having a diameter of 810 cm and a thickness of 3.3 mm. This molded product was set in the insertion port of a wide belt sanding apparatus (of Meinan Machinery Works, Inc.) and moved at a rate of 0.1 m/sec to sand the surface

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of the molded product with sandpapers having grit sizes of 120, 150, 220 and 320 (of Novatec Co., Ltd.) by turning a roller at a revolution of 500 rpm to remove 0.04 mm from the surface with each step. As a result, a molded product having an average thickness of 2.5 mm, a thickness distribution of 20 μm , an arithmetic mean roughness (Ra) of 4.4 μm , a 10-point height (Rz) of 125 μm , a core roughness depth (Rk) of 16 μm and a reduced peak height (Rpk) of 14 μm was obtained.

[0088] The relative speed between the molded product and the sandpaper on the contact surface between the molded product and the sandpaper for above sanding was 5 m/min.

[0089] The above thickness distribution was calculated based on the following equation from thicknesses measured at 33 points equally apart from one another of the polishing surface of the molded product in the diameter direction excluding a 40 mm area from the center to the both sides and 40 mm areas from the both ends by the manual 3-D meter (of Mitutoyo Corporation).

$$\text{Thickness distribution} = (\text{largest measurement value of thickness}) - (\text{smallest measurement value of thickness})$$

[0090] The arithmetic mean roughness (Ra), 10-point height (Rz), core roughness depth (Rk) and reduced peak height (Rpk) are all average values calculated from the roughness profiles obtained by measuring 10 measurement lines (evaluation length of 10 mm) perpendicular to the diameter direction of the pad with 10 points equally apart from one another in the diameter direction of the polishing surface of the molded product excluding 40 mm areas from the both ends as the centers by the 1LM21P of Laser Tech Co., Ltd.

[0091] Concentric grooves having a width of 0.5 mm, a pitch of 2 mm and a depth of 1.0 mm were formed in the sanded surface of the molded product with a cutting machine (of Kato Machinery Co., Ltd.) to manufacture a chemical mechanical polishing pad. The surface roughness of the inner walls of the grooves was 6 μm .

[0092] This chemical mechanical polishing pad was set in the Applied Reflexion chemical mechanical polishing machine of Applied Material Co., Ltd. to carry out break-in dressing while deionized water was supplied under the following conditions.

Revolution of platen: 120 rpm
Supply rate of deionized water: 100 ml/min
Polishing time: 600 seconds

[0093] Thereafter, chemical mechanical polishing was made on a 12-inch wafer having a PETEOS film as an object to be polished under the following conditions. The PETEOS film was a silicon oxide film formed from tetraethyl silicate (TEOS) by a chemical vapor deposition method using plasma as a promoting condition.

Revolution of platen: 120 rpm
Revolution of polishing head: 36 rpm
Polishing pressure:

Retainer ring pressure = 7.5 psi
Pressure of zone 1 = 6.0 psi
Pressure of zone 2 = 3.0 psi
Pressure of zone 3 = 3.5 psi

Supply rate of aqueous dispersion: 300 ml/min
Polishing time: 60 seconds
Aqueous dispersion for chemical mechanical polishing: CMS1101 (of JSR Corporation)

[0094] The thickness of the PETEOS film before and after chemical mechanical polishing was measured at 33 points equally apart from one another in the diameter direction of the 12-inch wafer having a PETEOS film excluding 5 mm areas from the both ends as the object to be polished. The polishing rate and the in-plane uniformity were calculated from the measurement results based on the following equation. Amount of polishing = thickness before polishing - thickness after polishing

$$\text{Polishing rate} = \Sigma (\text{amount of polishing}) / \text{polishing time}$$

In-plane uniformity (standard deviation of amount of
polishing ÷ average amount of polishing) x 100 (%)

[0095] The results are shown in Table 1. It can be said that in-plane uniformity is satisfactory when the in-plane uniformity is 3 % or less.

Example 2

[0096] A molded product having an average thickness of 2.5 mm, a thickness distribution of 20 μm , an arithmetic mean roughness (Ra) of 3.4 μm , a 10-point height (Rz) of 108 μm , a core roughness depth (Rk) of 18 μm and a reduced peak height (Rpk) of 16 μm was obtained in the same manner as in Example 1 except that 80 vol% of 1,2-polybutadiene, 20 vol% of β -cyclodextrin and 0.8 part by mass (equivalent to 0.32 part by mass in terms of pure dicumyl peroxide) of Percumyl D40 based on 100 parts by mass of 1,2-polybutadiene were used.

[0097] Concentric grooves having a width of 0.5 mm, a pitch of 2 mm, a depth of 1.0 mm and a surface roughness of the inner wall of 5 μm were formed in the sanded surface of the molded product in the same manner as in Example 1 to manufacture a chemical mechanical polishing pad.

[0098] Evaluations were made by using this chemical mechanical polishing pad in the same manner as in Example 1. The results are shown in Table 1.

Example 3

[0099] A molded product having an average thickness of 2.5 mm, a thickness distribution of 25 μm , an arithmetic mean roughness (Ra) of 3.8 μm , a 10-point height (Rz) of 115 μm , a core roughness depth (Rk) of 15 μm and a reduced peak height (Rpk) of 14 μm was obtained in the same manner as in Example 1 except that 64 vol% of 1,2-polybutadiene, 16 vol% of a styrene-butadiene block copolymer (TR2827 of JSR Corporation) and 20 vol% of β -cyclodextrin were used.

[0100] Concentric grooves having a width of 0.5 mm, a pitch of 2 mm, a depth of 1.0 mm and a surface roughness of the inner wall of 4.5 μm were formed in the sanded surface of the molded product in the same manner as in Example 1 to manufacture a chemical mechanical polishing pad.

[0101] Evaluations were made by using this chemical mechanical polishing pad in the same manner as in Example 1. The results are shown in Table 1.

Comparative Example 1

[0102] A molded product having an average thickness of 2.5 mm, a thickness distribution of 70 μm , an arithmetic mean roughness (Ra) of 1.5 μm , a 10-point height (Rz) of 25 μm , a core roughness depth (Rk) of 8 μm and a reduced peak height (Rpk) of 6 μm was obtained in the same manner as in Example 1 except that a mold having an average thickness of 2.5 mm was used to obtain a molded product and the molded product was not sanded.

[0103] Concentric grooves having a width of 0.5 mm, a pitch of 2 mm, a depth of 1.0 mm and a surface roughness of the inner wall of 5.5 μm were formed in the polishing surface of the molded product in the same manner as in Example 1 to manufacture a chemical mechanical polishing pad.

[0104] Evaluations were made by using this chemical mechanical polishing pad in the same manner as in Example 1. The results are shown in Table 1.

Table 1

	Polishing rate ($\text{\AA}/\text{min}$)	in-plane uniformity (%)
Example 1	2850	1.0
Example 2	2700	2.0
Example 3	2750	1.5
Comparative Example 1	2800	8.0

Example 4

[0105] The chemical mechanical polishing of a 12-inch wafer having a PETEOS film was carried out in the same

manner as in Example 1 except that break-in dressing was not carried out. Subsequently, chemical mechanical polishing was made continuously on 10 12-inch wafers having a PETEOS film. The polishing rate of each wafer is shown in Table 2.

Comparative Example 2

[0106] Chemical mechanical polishing was made on 10 wafers in the same manner as in Example 4 except that the chemical mechanical polishing pad manufactured in the same manner as in Comparative Example 1 was used. The polishing rate of each wafer is shown in Table 2.

Table 2

Polishing order of wafers	Polishing rate (Å/min)	
	Example 4	Comparative Example 2
1	2830	1830
2	2850	1850
3	2870	1910
4	2820	2100
5	2840	2510
6	2850	2840
7	2880	2860
8	2870	2870
9	2850	2840
10	2840	2830

[0107] A chemical mechanical polishing pad having a polishing surface with an arithmetic mean roughness (Ra) of 0.1 to 15 μm, a 10-point height, (Rz) of 40 to 150 μm, a core roughness depth (Rk) of 12 to 50 μm and a reduced peak height (Rpk) of 7 to 40 μm, a manufacturing process thereof and a chemical mechanical polishing method. Even when the chemical mechanical polishing of a large-diameter wafer as an object to be polished is carried out by this pad, a polished surface having excellent in-plane uniformity and flatness can be formed.

Claims

1. A chemical mechanical polishing pad having a polishing surface and a nonpolishing surface, the polishing surface having an arithmetic mean roughness (Ra) of 0.1 to 15 μm, a 10-point height (Rz) of 40 to 150 μm, a core roughness depth (Rk) of 12 to 50 μm and a reduced peak height (Rpk) of 7 to 40 μm.
2. The chemical mechanical polishing pad according to claim 1 having a thickness distribution of 50 μm or less.
3. A process of manufacturing the chemical mechanical polishing pad of claim 1 or 2, comprising the steps of:
 - molding a polishing layer; and
 - sanding at least the surface to be polishing surface of the polishing layer.
4. A chemical mechanical polishing method comprising chemical mechanical polishing an object to be polished with the chemical mechanical polishing pad of claim 1 or 2.

Fig.1

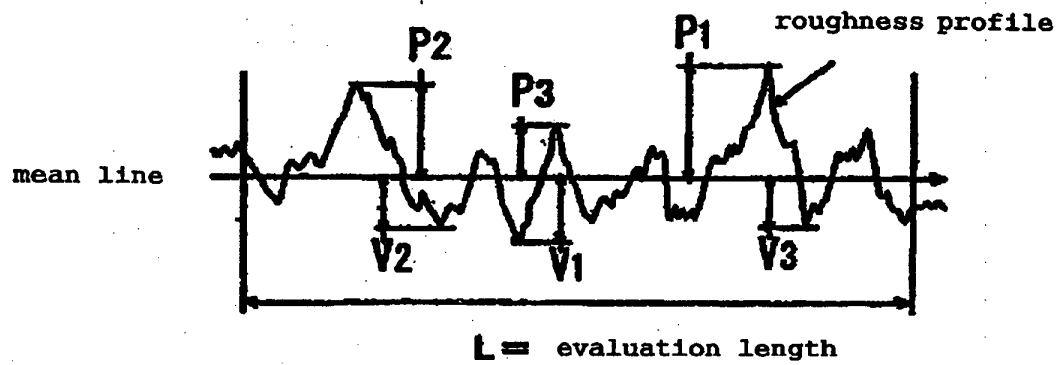


Fig.2

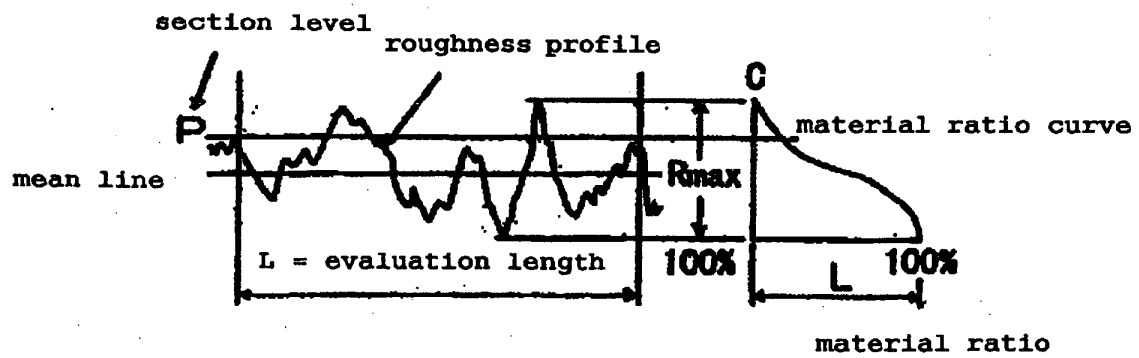


Fig.3

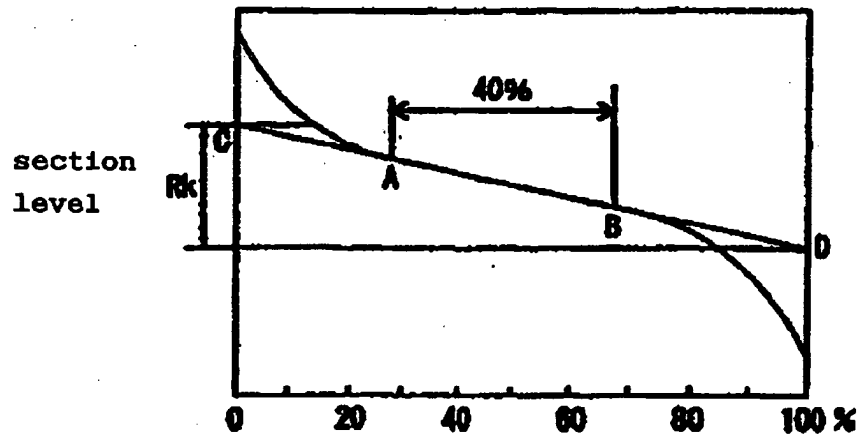
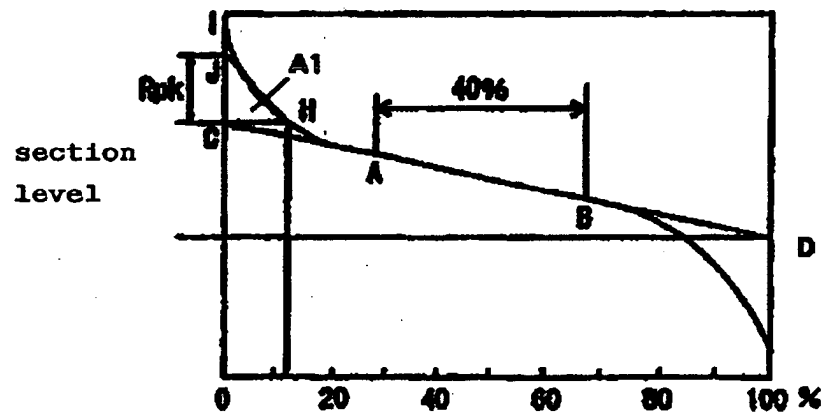


Fig.4





European Patent
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EUROPEAN SEARCH REPORT

Application Number
EP 05 00 8645

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Place of search Munich		Date of completion of the search 24 May 2005	Examiner Koller, S
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

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**ANNEX TO THE EUROPEAN SEARCH REPORT
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The members are as contained in the European Patent Office EDP file on
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