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(54) **POLISHING PAD**

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(57) **ABSTRACT**

A polishing pad which comprises a laminate of an abrasive layer with a cushioning layer. The abrasive layer has a Microrubber A hardness of 75 degrees or higher and a thickness of 0.8-3.0 mm. The cushioning layer comprises an unfoamed elastomer and has a thickness of 0.05-1.5 mm. The abrasive layer has at least two kinds of grooves formed in the surface. One of the two kinds of grooves is first grooves and the other is second grooves. The first grooves each has a groove width of 0.5-1.2 mm, and has a groove pitch of 7.5-50 mm. The second grooves each has a groove width of 1.5-3 mm, and has a groove pitch of 20-50 mm. Each of the first grooves and each of the second grooves are open to side edge faces of the abrasive layer.

POLISHING PAD

FIELD OF THE INVENTION

[0001] The invention relates to a polishing pad. The polishing pad is to be used as a preferable polishing means in the following polishing steps: a polishing step to planarize a surface of a semiconductor substrate and a polishing step to planarize a surface of an insulation layer or a surface of metal wiring formed on a semiconductor substrate.

BACKGROUND OF THE INVENTION

[0002] Circuits with increasingly higher density have been developed every year for large scale integrated circuits (LSI) such as for semiconductor memory devices. Products with higher density require semiconductor devices of increased degrees of lamination. As the degree of lamination increases, more serious problems have been taking place in association with the irregularities caused by the lamination in the principal plane of the semiconductor substrate. Thus, studies on semiconductor substrate planarization processes using Chemical Mechanical Polishing (CMP) technique have been performed with the aim of compensating the decrease in focal depth during exposure due to irregularities resulting from the lamination or improving the wiring density by planarizing a through hole portion.

[0003] A typical chemical mechanical polishing machine comprises a polishing head to hold a semiconductor substrate to be polished, a polishing pad to be used to polish a work piece and a platen to hold the polishing pad. The polishing step for a semiconductor substrate is carried out by using polishing slurry comprising a polishing agent (abrasive grains) and a chemical and causing the semiconductor substrate and the polishing pad to perform relative motion so that the projections on a surface layer of the semiconductor substrate are removed to smooth a layer of a semiconductor substrate surface.

[0004] Generally known polishing pads widely used for chemical mechanical polishing include a two layer polishing pad (for instance, Patent Literature 1) comprising an abrasive layer of rigid polyurethane of a fine foam structure (cell diameter: about 30 μm to 50 μm) adhered to a cushioning layer of polyurethane impregnated nonwoven fabric, soft foamed polyurethane, etc. and a two layer polishing pad (for instance, Patent Literature 2 and Patent Literature 3) comprising the abrasive layer adhered to a cushioning layer of an unfoamed elastomer.

Patent Literature

[0005] Patent Literature 1: JP 06-021028 A

[0006] Patent Literature 2: JP 3685066 B

[0007] Patent Literature 3: JP 3924952 B

SUMMARY OF THE INVENTION

[0008] On conventional two layer polishing pads, laminated pads composed of a cushioning layer of foamed material having a relatively low compression modulus such as polyurethane impregnated nonwoven fabric or soft foamed polyurethane generally have defects such as insufficient planarizing capability and tendency of the planarizing capability deteriorating with a decreasing thickness of an abrasive layer caused by the polishing. On conventional two layer polishing pads, furthermore, laminated pads composed of a cushioning layer of unfoamed elastomer having a high compression modulus or foamed material having a high density generally have defects such as difficulty in achieving stable polishing by using grooves of conventional shapes provided in an abrasive layer and a large pad-to-pad variation in polishing performance.

[0009] Thus, the conventional polishing pads have problems such as insufficient polishing stability, low planarizing capability, and large pad-to-pad variation in polishing performance.

[0010] The invention aims to provide a polishing pad that has a high polishing stability and planarizing capability when used in planarization processes such as for planarizing a semiconductor substrate and for polishing a surface of an insulation layer or a surface of metal wiring formed on a semiconductor substrate, and that has only a small pad-to-pad variation in polishing performance.

[0011] The polishing pad according to embodiments of the invention is described below.

[0012] It is a polishing pad comprising a laminate of an abrasive layer and a cushioning layer, wherein

[0013] (a) the abrasive layer has a Microdurometer-A hardness of 75 or more and a thickness of 0.8 mm to 3.0 mm,

[0014] (b) the cushioning layer is formed of an unfoamed elastomer and has a thickness of 0.05 mm to 1.5 mm,

[0015] (c) the surface of the abrasive layer contains at least two groups of grooves, one of the two groups of grooves being referred to as a first groove group, and the other of the two groups of grooves being referred to as a second groove group,

[0016] (d) the grooves in the first groove group have a groove width of 0.5 mm to 1.2 mm, and are arranged at intervals of 7.5 mm to 50 mm,

[0017] (e) the grooves in the second groove group have a groove width of 1.5 mm to 3 mm, and are arranged at intervals of 20 mm to 50 mm, and

[0018] (f) the grooves in the first groove group and the grooves in the second groove group are open at side faces of the abrasive layer.

[0019] In the polishing pad of the invention, it is preferable that the Microdurometer-A hardness is 80 or more, and the cushioning layer has a thickness of 0.05 mm to 0.5 mm.

[0020] In the polishing pad of the invention, it is preferable that the cushioning layer has a tensile elastic modulus of 15 MPa to 50 MPa.

[0021] In the polishing pad of the invention, it is preferable that the shear adhesive strength between the abrasive layer and the cushioning layer is 3,000 gf/(20×20 mm^2) or more.

[0022] In the polishing pad of the invention, it is preferable that the grooves in the first groove group are arranged in a grid pattern while the grooves in the second groove group are arranged in a grid pattern. In this polishing pad, furthermore, the grooves in the first groove group and those in the second groove group are preferably arranged linearly and parallel to each other.

[0023] In the polishing pad of the invention, it is preferable that the abrasive layer has a foam structure containing a polyurethane polymer and a vinyl compound polymer.

[0024] In the polishing pad of the invention, it is preferable that the polyurethane polymer and the vinyl compound polymer are in an integrated state.

[0025] Here, the expression "the polyurethane polymer and the vinyl compound polymer are in an integrated state" means that the phase of the polyurethane polymer and the phase of the vinyl compound polymer are not separable from each other. This state is indicated by the fact that the infrared spectrum obtained from infrared microspectrometric observation of a 50 μm spot on the abrasive layer contains an infrared absorption spectrum from the polyurethane and an infrared absorption spectrum from the vinyl compound polymer and that a roughly identical infrared spectrum is obtained from different spots over the entire abrasive layer. A typical infrared microspectrometer to be used for this is, for instance, IRμs microspectrometer produced by SPETRA-TECH Co.

[0026] In the polishing pad of the invention, it is preferable that the vinyl compound polymer accounts for 23 wt % to 66 wt %.

[0027] In the polishing pad of the invention, it is preferable that the vinyl compound is in the form of $CH_2{=}CR_1COOR_2$ (R_1: methyl group or ethyl group, R_2: methyl group, ethyl group, propyl group, or butyl group).

[0028] The invention provides a polishing pad having a high polishing stability and planarizing capability, together with a limited pad-to-pad variation in polishing performance.

DETAILED DESCRIPTION OF EMBODIMENTS OF THE INVENTION

[0029] The polishing pad of the invention comprises a laminate of an abrasive layer and a cushioning layer.

[0030] The abrasive layer is made of material having a Microdurometer-A hardness of 75 or more and has a thickness of 0.8 mm to 3.0 mm.

[0031] The Microdurometer-A hardness is the hardness determined with an MD-1 microdurometer supplied by Kobunshi Keiki Co., Ltd. The MD-1 microdurometer can determine the hardness of a very thin or small specimen that is difficult to measure with a conventional hardness tester. This hardness tester is designed and produced as an about ⅕ reduced model of the Model-A spring durometer. The measurements made with it, therefore, can be regarded as equivalent to those made with the Model-A spring durometer. In common polishing pads, the abrasive layer or rigid layer is too thin, with a thickness of 5 mm or less, to determine with a spring durometer. The MD-1 microdurometer serves for determining such a small thickness.

[0032] If the Microdurometer-A hardness is less than 75, the abrasive layer will fail to have a sufficient planarizing capability. If the thickness is less than 0.8 mm, the abrasive layer will also fail to have a sufficient planarizing capability. The abrasive layer will be poor in in-plane uniformity of the thickness exceeds 3.0 mm.

[0033] There are no particular limitations on the material to form the abrasive layer. Such materials include polyethylene, polypropylene, polyester, polyurethane, polyurea, polystyrene, polyvinyl chloride, polyvinylidene fluoride, polymethyl methacrylate, polycarbonate, polyamide, polyacetal, polyimide, epoxy resin, unsaturated polyester resin, melamine resin, phenol resin, ABS resin, bakelite, epoxy resin/paper, epoxy resin/fiber, other various laminates, and various rubbers such as FRP, natural rubber, neoprene (registered trademark) rubber, chloroprene rubber, butadiene rubber, styrene butadiene rubber, acrylonitrile butadiene rubber, ethylene propylene rubber, silicone rubber, and fluorine rubber.

[0034] The abrasive layer may be either of a foam structure or an unfoamed structure. The foam structure is preferable, however, because of higher polishing characteristics in terms of polishing speed and in-plane uniformity, and fewer defects such as dust generation and scratching.

[0035] Generally known methods can be used to produce a foam structure in the abrasive layer. Such methods include, for instance, mixing various foaming agents with a monomer or a polymer, and foam it by heating etc.; dispersing hollow micro beads in a monomer or a polymer, and curing it to convert the micro bead portions into closed cells; mechanically stirring a molten polymer to foam it and cooling it for curing; dissolving a polymer in a solvent to form a solution, producing a sheet-like film from it, immersing it in a solvent poor for the polymer, and extracting only the solvent; and impregnating a monomer in a sheet-like polymer having a foam structure, followed by polymerization and curing. Of these, the process comprising impregnating a monomer in a sheet-like polymer having a foam structure, followed by polymerization and curing, is preferable because it is relatively easy to control the formation of the foam structure in the abrasive layer and the diameter of the cells, and also because the abrasive layer is easy to produce.

[0036] There are no particular limitations on the material for producing a polymer sheet having a foam structure, if the monomer can be impregnated. Such material include fabrics, nonwoven fabrics, and paper, as well as sheets of resin composed mainly of rubber such as polyurethane, polyurea, soft vinyl chloride, natural rubber, neoprene (registered trademark) rubber, chloroprene rubber, butadiene rubber, styrene butadiene rubber, acrylonitrile butadiene rubber, ethylene propylene rubber, silicone rubber, and fluorine rubber. Of these, polyurethane based materials are preferable, because the cell diameter can be controlled relatively easily. The polymer sheet may contain various additives such as polishing agent, lubricant, antistatic agent, antioxidant, and stabilizer with the aim of to producing polishing pads having improved characteristics.

[0037] There are no particular limitations on the type of monomer, if it can be polymerized by addition polymerization, condensation polymerization, polyaddition, addition condensation, and ring opening polymerization. The useful monomers include vinyl compounds, epoxy compounds, isocyanate compounds, and dicarboxylic acid. Of these, vinyl compounds are preferable because their impregnation into a polymer sheet and polymerization can be performed easily. There are no particular limitations, but vinyl compounds are preferable also because their impregnation into polyurethane and polymerization are easy.

[0038] The useful vinyl compounds include methyl acrylate, methyl methacrylate, ethyl acrylate, ethyl methacrylate, n-butyl acrylate, n-butyl methacrylate, 2-ethylhexyl methacrylate, isodecyl methacrylate, n-lauryl methacrylate, 2-hydroxyethyl methacrylate, 2-hydroxypropyl methacrylate, 2-hydroxybutyl methacrylate, dimethylaminoethyl methacrylate, diethylaminoethyl methacrylate, glycidylmethacrylate, ethylene glycol dimethacrylate, acrylic acid, methacrylic acid, fumaric acid, dimethyl fumarate, diethyl fumarate, dipropyl fumarate, maleic acid, dimethyl maleate, diethyl maleate, dipropyl maleate, phenyl maleimide, cyclohexyl maleimide, isopropyl maleimide, acrylonitrile, acrylic amide, vinyl chloride, vinylidene chloride, styrene, α-methyl styrene, divinylbenzene, ethylene glycol dimethacrylate, and diethylene glycol dimethacrylate. These monomers may be used singly or in combination as a mixture.

[0039] Of the aforementioned vinyl compounds, methyl methacrylate is particularly preferable because it is easy to impregnate into polyurethane, polymerize and cure, and also because a polymer produced by polymerization and curing of polyurethane and a vinyl compound has a high hardness to show high planarizing capability when used for polishing.

[0040] There are no particular limitations on the average cell diameter of the foam structure in the abrasive layer, but it is preferably 20 μm to 300 μm. If the average cell diameter is less than 20 μm, the polishing speed during polishing will decrease and a surface of the polished semiconductor substrate tends to suffer scratching and dust. If the average cell diameter exceeds 300 μm, the abrasive layer tends to lose rigidity, leading to deterioration in polishing characteristics such as planarizing capability and a shorten life of the polishing pad. The average cell diameter is more preferably 30 μm to 250 μm.

[0041] The average cell diameter is determined by observing cross sections of the abrasive layer by SEM at a 200× magnification, using an image processing apparatus to measure the diameters cells recorded in SEM photographs, and calculating their average.

[0042] There are no particular limitations on the density of the abrasive layer, but it is preferably 0.4 g/cm^3 to 1.0 g/cm^3. A density lower than 0.4 g/cm^3 tends to lead to deterioration in the planarizing capability during polishing. A density higher than 1.0 g/cm^3 tends to lead to deterioration in the in-plane uniformity during polishing, and scratching and dust generation in the surface of the polished semiconductor substrate. The density is more preferably 0.5 g/cm^3 to 0.8 g/cm^3.

[0043] The density should be measured with the method described in Japanese Industrial Standard (JIS) K-7222.

[0044] The cushioning layer is formed of an unfoamed elastomer having a thickness of 0.05 mm to 1.5 mm. The cushioning layer serves to achieve a stable polishing rate and high in-plane uniformity. A thickness of less than 0.05 mm is not preferable because it leads to poor in-plane uniformity. A thickness of more than 1.5 mm is not preferable either because it leads to an unstable polishing rate at edges and poor in-plane uniformity.

[0045] The useful unfoamed elastomer materials for the cushioning layer include, but not limited to, natural rubber, nitrile rubber, neoprene (registered trademark) rubber, polybutadiene rubber, chloroprene rubber, thermoplastic polyurethane rubber, thermosetting polyurethane rubber, silicone rubber, and fluorine rubber.

[0046] Of these, polyurethane rubber is preferable, and thermoplastic polyurethane rubber is particularly preferable because it serves to manufacture products having relatively high thickness accuracy, produce moldings without using a mold releasing agent, and develop strong adhesion. Thermoplastic polyurethane, which consists of soft segments with rubber elasticity and hard segments that act as knots in the three dimensional network, can show rubber elasticity at room temperature and plasticize to undergo extrusion molding at high temperature. Specifically, it works as a polyurethane-based block polymer containing hard segments with urethane bonds and works as an elastomer containing soft segments of polyester or polyether.

[0047] The material that forms the cushioning layer may contain various additives, such as antistatic agent, lubricant, stabilizer, and dye, and other resins to add necessary characteristics to the cushioning layer.

[0048] The cushioning layer of the invention preferably has a tensile elastic modulus of 15 MPa to 50 MPa in order to ensure a stable polishing rate and a limited pad-to-pad variation in polishing performance. A tensile elastic modulus less than 15 MPa is not preferable because it will lead to an unstable polishing rate in edge portions and a poor in-plane uniformity. A tensile elastic modulus more than 50 MPa is not preferable either because the polishing rate will not be stable.

[0049] Many grooves are formed over the surface of the abrasive layer to make it possible to hold the polishing slurry strongly, improve the flowability, and efficiently remove polishing sludge from the surface of the abrasive layer. These grooves are divided into at least two groove groups having different groove widths. One of the two groove groups is referred to as a first groove group while the other is referred to as a second groove group.

[0050] The grooves in the first groove group have a groove width of 0.5 mm to 1.2 mm, and the grooves are arranged at groove intervals of 7.5 mm to 50 mm.

[0051] The grooves in the second groove group have a groove width of 1.5 mm to 3 mm, and the grooves are arranged at groove intervals of 20 mm to 50 mm.

[0052] Many grooves belonging to at least either the first groove group or the second groove group are formed over the entire surface of the abrasive layer, and all of the many grooves belonging to the first groove group or the second groove group are open at side faces of the abrasive layer. Although grooves should be formed over the entire surface, however, some groove-free regions may be left if they virtually cause no problems. Furthermore, although all grooves should be open at side faces of the abrasive layer, there may be some grooves that are not open at the side face of the abrasive layer if they virtually cause no problems.

[0053] For the first groove group, the groove pitch is defined as the minimum distance between adjacent grooves in the group existing over the entire surface of the abrasive layer existence. Similarly, for the second groove group, the groove pitch is defined as the minimum distance between adjacent grooves in the group existing over the entire surface of the abrasive layer existence. The grooves in the first groove group are arranged with a constant groove-to-groove distance (groove pitch) over the entire surface of the abrasive layer existence. If the groove pitch for the second groove group is an integral multiple of that for the first groove group, part of the grooves in the first groove group overlap the grooves in the second groove group. In this case, the latter cannot be distinguished from the former, but it is assumed that the latter do exist. For the constant groove-to-groove distance (groove pitch), a small variation attributed to the production process may be allowable.

[0054] If the groove width for the first groove group is less than 0.5 mm, stable polishing will not achieved because of strong adhesion to the wafer, making it difficult for the wafer to be released from the polishing head. On the other hand, the polishing rate will be unstable if the groove width for the first groove group is more than 1.2 mm. The polishing rate will be unstable as well if the groove pitch of the first groove group is less than 7.5 mm. The in-plane uniformity will be poor if the groove pitch of the first groove group is more than 50 mm.

[0055] If the groove width for the second groove group is less than 1.5 mm, the pad-to-pad variation in polishing performance will be significant. The polishing rate will be unstable if the groove width for the second groove group is more than 3 mm. The polishing rate will also be unstable of the groove pitch for the second groove group is less than 20 mm. The in-plane uniformity will be poor if the groove pitch for the second groove group is more than 50 mm.

[0056] There are no particular limitations on the array pattern of the grooves, and they may be arranged in a grid-like, concentric-circle, helical, or radial manner. It is preferable, in particular, that both the array pattern of the grooves in the first groove group and the array pattern of the grooves in the second groove group are grid-like. A grid-like array is preferable because it permits quick removal of polishing sludge during the polishing step, prevention of scratching and achievement of a stable polishing rate. In a grid-like array, it is preferable that the grooves are linear and that the grooves are parallel to each other in order to achieve enhanced position accuracy of the grooves formed and easy operation of groove formation, in addition to the advantages given above.

[0057] If all grooves in the first groove group and the second groove group lead to the side faces of the abrasive layer, that is, open at the side faces, polishing sludge will be removed from the surface of the polishing pad to prevent scratching. Although all grooves should lead to the side faces of the abrasive layer, there may be some grooves that do not lead to the side faces of the abrasive layer if they virtually cause no problems.

[0058] With respect to the depth of the grooves, the difference between the thickness of the abrasive layer and the depth of the grooves is preferably 0.3 mm to 1.0 mm in order to maximize the life of the polishing pad. If the difference between the thickness of the abrasive layer and the depth of the grooves is less than 0.3 mm, the polishing pad will be poor in mechanical strength, leading to formation of creases along grooves when adhering the pad to the platen, which is not preferable. If the difference between the thickness of the abrasive layer and the depth of the grooves is more than 1.0 mm, the life of the polishing pad will shorten, which is not preferable.

[0059] The grooves preferably have a rectangle cross section because significant cross-sectional deformation will not take place during the polishing step, permitting stable polishing characteristics.

[0060] There are no particular limitations on the method used to produce grooves in a surface of the abrasive layer. The appropriate groove production methods include cutting the surface of the abrasive layer with a machine such as router; applying a heated die, hot wire, etc., to the surface of the abrasive layer to dissolve the portions in contact to form grooves; using a grooved mold to prepare an grooved abrasive layer; and using a drill, Thomson blade, etc., to produce holes.

[0061] The abrasive layer and the cushioning layer are combined to form a laminate. This laminate may be produced by adhering the abrasive layer and the cushioning layer directly to each other with a sticker, adhesive, etc., or providing a polymer sheet between the abrasive layer and the cushioning layer and adhering the sheet to each layer with a sticker, adhesive, etc., or by self-adhesion.

[0062] There are no particular limitations on the method to combine the abrasive layer and the cushioning layer into a laminate. Thus, the useful methods for the lamination include using a laminator for applying a double-sided adhesive tape to the abrasive layer or using various coaters for coating the abrasive layer with an adhesive etc., in order to form a sticker layer or an adhesive layer between the abrasive layer and the cushion layer, followed by applying a pressure with a laminator, roll press, flat plate press, etc.; and providing a polymer sheet between the abrasive layer and the cushioning layer and coating them with a sticker or adhesive, followed by applying a pressure with a laminator, roll press, flat plate press, etc. During this step, the laminator, press, etc., may be heated to the extent that it does not have adverse influence on the abrasive layer or the cushioning layer.

[0063] There are no particular limitations on the type of adhesive. The useful adhesives include urethane-, epoxy-, acrylic-, rubber-based and other various adhesives and various double-sided tapes composed of a base material such as film and nonwoven fabric with both faces coated with these adhesives.

[0064] The urethane-based adhesives include, for instance, commercial one- or two-component products.

[0065] The epoxy-based adhesives include, for instance, commercial one- or two-component products. The acrylic- and rubber-based adhesives also include commercial products.

[0066] With respect to the adhesive, a solventless, heat-melting type adhesive is also preferable in view of effect on environment and workability, as well as the aforementioned common adhesive products. Depending on the type, heat-melting type adhesives are generally melted at a temperature of 70° C. to 130° C., applied to one or both surfaces of the adherend with a roll coater etc., applying them to each other while the adhesive maintains adhesiveness, applying a pressure as needed, and allowing the adhesive to cool and solidify to achieve adhesion. After application, some of them will absorb water and moisture from air or the adherend to undergo a cross-linking reaction to achieve an increased adhesive strength.

[0067] The available heat-melting type adhesives include polyester-, modified olefin-, and urethane-based ones, and with respect to their type, there are the aforementioned two types of products as follows: those hardening as it cools after melting and application, and those undergoing cross-linking through reaction with moisture in air after melting, application, cooling, and hardening. With respect to the polyester-based heat-melting type adhesive, modified olefin-based heat-melting type adhesive, and urethane-based heat-melting type adhesive, commercial products are available, and they may be used. Commercial double-sided adhesive tape products are also available, and they may be used.

[0068] Measurement of shear adhesive strength between the abrasive layer and the cushioning layer:

[0069] A sample having a width of 20 mm and length of 60 mm was cut out from the laminate comprising the abrasive layer and the cushioning layer. At a distance of 40 mm from the edge of the sample, an incision is made with an incisive blade such as razor from the surface of the abrasive layer into such a depth that the adhesive layer or polymer sheet is completely severed whereas the cushioning layer is not completely severed. At a distance of 40 mm from the opposite edge of the sample, a similar incision is made from the surface of the cushioning layer into such a depth that the adhesive layer or polymer sheet is completely severed whereas the abrasive layer is not completely severed. An aluminum plate (No. 360, surface polished with water resistant polishing paper) is applied with an adhesive to the surface of the abrasive layer and that of the cushioning layer. After leaving the aluminum plates to stand for one day or more after application to ensure complete solidification of the adhesive, the aluminum plate adhered to the abrasive layer is fixed to the upper pulling jig while the aluminum plate adhered to the cushioning layer is fixed to the lower pulling jig of a universal testing machine (RTG-1250 Tensilon tester supplied by Orientec Co., Ltd.), and the sample is pulled at a moving speed of 300 mm/min to measure the load at the time when the abrasive layer and the cushioning layer are peeled off in the portion having a width of 20 mm and length of 20 mm at the center of the sample. The measured value is taken as shear adhesive strength.

[0070] The shear adhesive strength between the abrasive layer and the cushioning layer is preferably 3,000 gf/(20×20 mm^2) or more. A shear adhesive strength less than 3,000 gf/(20×20 mm^2) is not preferable because a sufficient in-plane uniformity will not be achieved if the initial polishing characteristics are maintained and the polishing characteristics cannot be maintained stably during continuous polishing. The shear adhesive strength is still more preferably 6,000 gf/(20×20 mm^2) or more.

[0071] After the abrasive layer and the cushioning layer is combined into a laminate, it is preferable that a double-sided adhesive tape for polishing platen fixation is preferably applied to the opposite surface of the cushioning layer to the laminating-side surface. The double-sided adhesive tape may be a commercial product.

[0072] The abrasive layer can be produced by preparing an original abrasive layer (raw abrasive layer) from the aforementioned materials and grinding the surface of the original abrasive layer thus prepared. Grinding of the surface of the original abrasive layer serves to reduce the thickness irregularity in the abrasive layer to achieve highly stable polishing characteristics and a shortened start-up time for use. The surface of the abrasive layer may be ground after combining the abrasive layer and the cushioning layer into a laminate.

[0073] There are no particular limitations on the method to grind the surface of the abrasive layer. The useful grinding methods include grinding with sand paper, and grinding with a diamond disk or single point tool. Of these, grinding with sand paper is preferable in view of required cost. For the grinding with sand paper, grinding with a wide belt sander is preferable in view of productivity.

[0074] A polishing pad can be produced by grinding the surface of the abrasive layer using a grinder having a jig roll larger than the polishing pad. The use of a jig roll larger than the polishing pad serves to maintain the uniformity over the entire face of the polishing pad and perform grinding in such a manner that minimizes the thickness variation. A jig roll smaller than the polishing pad is not preferable because the polishing pad will not be held uniformly, failing to achieve uniform grinding and leading to a significant thickness variation.

[0075] There are no particular limitations on the roughness of the sandpaper, but the use of sandpaper of grade 60 to 400 is preferable. Sandpaper of below grade 60 is not preferable because the ground surface will tend to be rough and a longer start-up time will tend to be required for the polishing process. On the other hand, sandpaper of above grade 400 is not preferable either because of low grinding performance and poor workability.

[0076] There are no particular limitations on the abrasive grain material for the sand paper. The useful materials include alumina, white alumina, alumina zirconia, silicon carbide, diamond, garnet, emery, and flint.

[0077] The use of the polishing pad of the invention in combination with slurry such as silica slurry, aluminum oxide slurry, and cerium dioxide slurry serves for local planarization to remove irregularities in insulation membrane and irregularities in metal wiring on semiconductor wafers. It also serves to reduce the global thickness variation and decrease the dishing. As the slurry, commercial products may be used.

[0078] As an insulation layer formed on a semiconductor wafer, there is an interlayer insulating film in metal wiring, a lower insulating film in metal wiring, or a shallow trench isolation using for a separation of components. Metal wiring of aluminum, tungsten, copper, etc., can be formed on a semiconductor wafer, and it can be in the form of damascene, dual damascene, or plug. In the case of metal wiring of copper, the barrier metal of silicon nitride etc. can also be polished.

[0079] At present, oxidized silicon is mainly used as material for insulating film, but insulating film having a low dielectric constant is used in some cases as a solution to the delay time problem.

[0080] The use of the polishing pad of the invention serves to measure the polished state accurately while performing polishing operation in a scratching-free state. The polishing pad of the invention can be used for magnetic heads, hard disks, sapphire, etc., as well as semiconductor wafers.

[0081] The present invention will be illustrated below with reference to examples and comparative examples. The various techniques used for evaluating the polishing pads produced in examples and comparative examples were as described below.

[0082] Tensile Elastic Modulus of Cushioning Layer:

[0083] Measurements were made with a Model-5565 universal testing machine (supplied by Instron) at a temperature of 23° C. and a speed of 5 cm/min. The gradient of the resulting curve was measured to determine the tensile elastic modulus. The test piece was in a dumbbell shape having a width of 5 mm and length of 50 mm.

[0084] Thickness of the Abrasive Layer and Thickness of the Cushioning Layer:

[0085] An ID-125B dial gage (supplied by Mitutoyo Corporation) was used to made measurements at 49 points on the surface of a polishing pad under a measuring pressure of 230 gf, and their average was calculated.

[0086] Microdurometer-A Hardness of the Abrasive Layer:

[0087] An MD-1 Microdurometer-A hardness tester (supplied by Kobunshi Keiki Co., Ltd.) was used for the measurement. The structure of the MD-1 Microdurometer-A hardness tester was as described below.

[0088] 1.1 Sensor Portion

[0089] (1) Loading mechanism: cantilever-type plate spring.

[0090] (2) Spring load: 0 point/2.24 gf, and 100 point/33.85 gf.

[0091] (3) Spring load error: ±0.32 gf.

[0092] (4) Indenter size: diameter 0.16 mm, cylinder shape, height 0.5 mm.

[0093] (5) Displacement sensing mechanism: strain gage.

[0094] (6) Pressure foot size: outside diameter 4 mm, inside diameter 1.5 mm.

[0095] 1.2 Sensor Drive Portion

[0096] (1) Driving mechanism: vertical driving by stepping motor, descending speed control by air damper.

[0097] (2) Vertical stroke: 12 mm.

[0098] (3) Descending speed: 10 mm/sec to 30 mm/sec.

[0099] (4) Height adjustment range: 0 mm to 67 mm (distance between specimen table and sensor pressure plane).

[0100] Density of the Abrasive Layer:

[0101] Measurements were made according to the method specified in JIS K-7222.

[0102] Average Cell Diameter in the Abrasive Layer:

[0103] Using an SEM-2400 scanning electronic microscope (supplied by Hitachi, Ltd.), the cross section of the abrasive layer was observed with a magnification of 200×, and the photograph taken was analyzed with an image processing machine. All cells in the photograph were observed to determine their diameter, and their average was taken as average cell diameter.

[0104] Shear Adhesive Strength Between the Abrasive Layer and the Cushioning Layer:

[0105] A sample having a width of 20 mm and length of 60 mm was cut out from a laminate comprising the abrasive layer and the cushioning layer. At a distance of 40 mm from the edge of the sample, an incision was made with an incisive blade such as razor from the surface of the abrasive layer into such a depth that the adhesive layer or polymer sheet was completely severed whereas the cushioning layer was not completely severed. At a distance of 40 mm from the opposite edge of the sample, a similar incision was made from the surface of the cushioning layer into such a depth that the adhesive layer or polymer sheet was completely severed whereas the abrasive layer was not completely severed.

[0106] An aluminum plate (No. 360, surface polished with water resistant polishing paper) was applied with an adhesive to the surface of the abrasive layer and that of the cushioning layer. After leaving the aluminum plates to stand for one day or more after application to ensure complete solidification of the adhesive, the aluminum plate adhered to the abrasive layer was fixed to the upper pulling jig while the aluminum plate adhered to the cushioning layer was fixed to the lower pulling jig of a universal testing machine (RTG-1250 Tensilon tester supplied by Orientec Co., Ltd.), and the sample was pulled at a moving speed of 300 mm/min to measure the load at the time when the abrasive layer and the cushioning layer were peeled off in the portion having a width of 20 mm and length of 20 mm at the center of the sample. The measured value was taken as shear adhesive strength.

[0107] The polished state was evaluated with the evaluation method (I) for polishing of oxide film and the evaluation method (II) for polishing of metal (tungsten).

[0108] Polishing Performance Evaluation Method (I):

[0109] A polishing pad prepared was fixed to a MIRRA (registered trademark) polishing machine (supplied by Applied Materials, Inc.), and 300 wafers provided with oxide film were polished continuously under the polishing conditions of a platen speed of 93 rpm, polishing head speed of 89 rpm, membrane pressure of 4 psi, retaining ring pressure of 5.5 psi, inner tube pressure of 4 psi, and polishing time of 1 min, while supplying a two-fold diluted slurry (SS-25, supplied by Cabot Corporation) at a flow rate 150 mm/min.

[0110] The evaluation results for polishing stability were divided into groups each for 50 wafers. The difference between the maximum polishing rate and the minimum polishing rate was divided by the average, and the quotient was multiplied by 100. The value obtained was used as index to indicate the stability. To provide an index of in-plane uniformity, the in-plane uniformity measurements made were averaged for each group of 50 wafers. The polishing rate and in-plane uniformity for each polished wafer were determined as follows.

[0111] Using a Lambda Ace (registered trademark) VM-2000 (supplied by Dainippon Screen Mfg. Co., Ltd.), measurements were made at prescribed 198 points in the range of 3 mm from the edge of the wafer. The polishing rate at each point was calculated by Equation (1) shown below, and the in-plane uniformity was calculated by Equation (2) shown below.

Polishing rate=(thickness of oxide film before polishing−thickness of oxide film after polishing)/polishing time (1)

In-plane uniformity (%)=(maximum polishing rate−minimum polishing rate)/(maximum polishing rate+minimum polishing rate)×100 (2)

[0112] Ten polishing pads of different specifications were prepared, and each was subjected to test for continuous polishing of 300 wafers. The average polishing rate for each was determined, and the difference between the maximum and the minimum was calculated. The average polishing rate was determined for each of the ten polishing pads, and the average polishing rate for the ten polishing pads was calculated. The difference between the maximum and the minimum was divided by the average polishing rate for the ten polishing pads. The value obtained was used as index to show the pad-to-pad variation.

[0113] Evaluation of Planarizing Capability:

[0114] A 20 mm square die was fixed on an 8-inch silicon wafer. In the left-hand half of this 20 mm square die, aluminum wiring having a width of 30 μm and height of 1.2 μm was formed in a line and space pattern with a 300 μm space whereas in the right-hand half, aluminum wiring having a width of 300 μm and height of 1.2 μm was formed in a line and space pattern with a 30 μm space. On top of it, insulating film of tetraethoxysilane was formed by CVD up to a thickness of 3 μm. The resulting wafer was used for evaluation of the wafer planarizing capability. This wafer for planarizing capability evaluation was polished under the aforementioned polishing conditions, and the height difference between the 300 μm space in the left-hand half and the 300 μm wide line in the right-hand half was used as index of planarizing capability.

[0115] Polishing Performance Evaluation Method (II):

[0116] A polishing pad prepared was fixed to a MIRRA (registered trademark) polishing machine (supplied by Applied Materials, Inc.), and 300 wafers provided with tungsten film were polished continuously under the polishing conditions of a platen speed of 113 rpm, polishing head speed of 110 rpm, membrane pressure of 3.8 psi, retaining ring pressure of 6.0 psi, inner tube pressure of 6.0 psi, and polishing time of 1 min, while supplying a two-fold diluted slurry (W-2000, supplied by Cabot Corporation) adjusted by adding a 2% hydrogen peroxide solution at a flow rate 140 mm/min.

[0117] The evaluation results for polishing stability were divided into groups each for 50 wafers. The difference between the maximum polishing rate and the minimum polishing rate was divided by the average, and the quotient was multiplied by 100. The value obtained was used as index to indicate the stability. To provide an index of in-plane uniformity, the in-plane uniformity measurements made were averaged for each group of 50 wafers. The polishing rate and in-plane uniformity for each polished wafer were determined as follows.

[0118] Using a VR-120S metal film thickness gauge (supplied by supplied by Kokusai Electric Co., Ltd.), measurements were made at prescribed 49 points in the range of 5 mm from the edge of the wafer. The polishing rate at each point was calculated by Equation (3) shown below, and the in-plane uniformity was calculated by Equation (4) shown below.

$$\text{Polishing rate}=(\text{thickness of tungsten film before polishing}-\text{thickness of tungsten film after polishing})/\text{polishing time} \quad (3)$$

$$\text{In-plane uniformity (\%)}=(\text{maximum polishing rate}-\text{minimum polishing rate})/(\text{maximum polishing rate}+\text{minimum polishing rate})\div 2\times 100 \quad (4)$$

[0119] Ten polishing pads of different specifications were prepared, and each was subjected to test for continuous polishing of 300 wafers. The average polishing rate for each was determined, and the difference between the maximum and the minimum was calculated. The average polishing rate was determined for each of the ten polishing pads, and the average polishing rate for the ten polishing pads was calculated. The difference between the maximum and the minimum was divided by the average polishing rate for the ten polishing pads. The value obtained was used as index to show the pad-to-pad variation.

[0120] Evaluation of Planarizing Capability:

[0121] A SKW5-4 pattern wafer marketed by SKW Associate, Inc. was used to evaluate the dishing in the 0.25 μm line-and-space portion. The patterned wafer was fixed to a MIRRA (registered trademark) polishing machine (supplied by Applied Materials, Inc.), and laser endpoint detection was performed under the polishing conditions of a platen speed of 113 rpm, polishing head speed of 110 rpm, membrane pressure of 3.8 psi, retaining ring pressure of 6.0 psi, and inner tube pressure of 6.0 psi, while supplying a two-fold diluted slurry (W-2000, supplied by Cabot Corporation) adjusted by adding a 2% hydrogen peroxide solution at a flow rate 140 mm/min. After the tungsten had been removed, excess polishing was carried out for 16 seconds before stopping the operation. A P-15 machine supplied by KLA-Tenchol was used to evaluate the dishing in the 0.25 μm line-and-space portion of the resulting polished patterned wafer.

Example 1

[0122] A liquid-A consisting of 100 parts by weight of polyether polyol (Sannix (registered trademark) FA-909 supplied by Sanyo Chemical Industries Ltd.), 8 parts by weight of ethylene glycol as chain elongation agent, 1 part by weight of Dabco (registered trademark) 33LV (supplied by Air Products Japan, Inc.) as amine catalyst, 0.1 part by weight of Toyocat (registered trademark) ET (supplied by Tosoh Corporation) as amine catalyst, 0.5 part by weight of Tegostab (registered trademark) B8462 (supplied by Th. Goldschmidt AG) as silicone foam stabilizer, and 0.2 part by weight of water as foaming agent, mixed and maintained at a liquid temperature 40° C., was collision-mixed in a RIM machine at a discharge pressure of 15 MPa with a liquid-B comprising 95 parts by weight of isocyanate (Sanfoam (registered trademark) NC-703) maintained at a liquid temperature 40° C. The material was discharged at a discharge rate of 500 g/sec into a mold maintained at 60° C. and left to stand for 10 minutes to prepare a foamed polyurethane block (Microdurometer-A hardness: 47, density: 0.77 g/cm^3, average cell diameter: 37 μm) with a size of 700 mm×700 mm and thickness of 10 mm. Subsequently, the foamed polyurethane block was sliced with a slicer to a thickness of 3 mm.

[0123] Then, the foamed polyurethane sheet was immersed in methyl methacrylate containing 0.1 part by weight of azobisisobutyronitrile for 45 minutes. The resulting foamed polyurethane sheet impregnated with methyl methacrylate was sandwiched between two glass plates with vinyl chloride gaskets placed in between, and heated at 60° C. for 10 hours and at 120° C. for 3 hours to achieve polymerization and curing. The sheet was then released from between the glass plates and vacuum dried at 50° C. to produce a rigid foamed sheet. Both surfaces of the resulting rigid foamed sheet were ground to a thickness of 2.0 mm to prepare a raw abrasive layer. The resulting raw abrasive layer had a Microdurometer-A hardness of 92, density of 0.77 g/cm^3, and average cell diameter of 47 μm, and polymethyl methacrylate accounted for 54 wt % of the abrasive layer.

[0124] A circular abrasive layer sample having a diameter of 508 mm was cut out from the resulting raw abrasive layer. In the surface of the circular abrasive layer sample thus obtained, a first groove group of grooves having a groove width of 1 mm, groove interval of 10 mm, and groove depth of 1.5 mm arranged in a grid array and a second groove group of grooves having a groove width of 2 mm, groove interval of 30 mm, and groove depth of 1.5 mm arranged in a grid array were produced with a numerical control router (NC router) in such a manner that the grooves of the first groove group and those of the second groove group are parallel to each other. All grooves had a nearly rectangle cross-sectional shape.

[0125] Then, a 442JS double-sided adhesive tape (supplied by Sumitomo 3M Limited) was applied to the abrasive layer using a laminator at a linear pressure of 1 kg/cm. After removing the release paper, it was applied to a cushioning layer comprising a thermoplastic urethane rubber sheet (tensile elastic modulus of 16 MPa) having a thickness of 0.5 mm using a laminator at a linear pressure of 1 kg/cm to prepare a polishing pad. The shear adhesive strength between the abrasive layer and the cushioning layer in the polishing pad thus prepared was 3,000 gf/(20×20 mm^2). Furthermore, a 442JS double-sided adhesive tape (supplied by Sumitomo 3M Limited) was applied to the bottom surface of the cushioning layer using a laminator at a linear pressure of 1 kg/cm.

[0126] The polishing pad thus prepared was fixed in a polishing machine and subjected to continuous polishing test for 300 wafers provided with oxide film under the polishing conditions as described for the polished evaluation method (I). The polishing rate and in-plane uniformity averaged over 50-wafer groups were 2,530 (angstrom/min) and a good 8.3%, respectively. The difference between the maximum and the minimum polishing rate was 120 (angstrom/min), indicating that the stability index was a good 4.7%.

[0127] Using an insulating film of tetraethoxysilane, a wafer having a thickness of 3 μm for planarizing capability evaluation was produced by CVD as described above was polished for 4 min under the aforementioned polishing conditions, followed by measuring the thickness difference. The thickness difference measured was a good 1,200 angstrom. Additional nine polishing pads of the same specifications were prepared and subjected to continuous polishing test for 300 wafers provided with oxide film, and the polishing capability of the 10 pads was determined. The polishing capability was 2,510 (angstrom/min). The difference between the maximum and the minimum polishing rate was 130 (angstrom/min), and the pad-to-pad variation was 5.1%. Thus the results indicated a limited variation.

Example 2

[0128] A circular abrasive layer sample having a diameter of 508 mm was cut out from a raw abrasive layer prepared as in Example 1. In the surface of the circular abrasive layer sample thus obtained, a first groove group of grooves having a groove width of 1.2 mm, groove interval of 12.5 mm, and groove depth of 1.5 mm arranged in a grid array and a second groove group of grooves having a groove width of 3 mm, groove interval of 37.5 mm, and groove depth of 1.5 mm arranged in a grid array were produced with an NC router in such a manner that the grooves of the first groove group and those of the second groove group are parallel to each other. All grooves had a nearly rectangle cross-sectional shape.

[0129] Then, a 442JS double-sided adhesive tape (supplied by Sumitomo 3M Limited) was applied to the abrasive layer using a laminator at a linear pressure of 1 kg/cm. After removing the release paper, it was applied to a cushioning layer comprising a thermoplastic urethane rubber sheet (tensile elastic modulus of 20 MPa) having a thickness of 0.2 mm using a laminator at a linear pressure of 1 kg/cm to prepare a polishing pad. The shear adhesive strength between the abrasive layer and the cushioning layer in the polishing pad thus prepared was 3,000 gf/(20×20 mm^2). Furthermore, a 442JS double-sided adhesive tape (supplied by Sumitomo 3M Limited) was applied to the bottom surface of the cushioning layer using a laminator at a linear pressure of 1 kg/cm.

[0130] The polishing pad thus prepared was fixed in a polishing machine and subjected to continuous polishing test for 300 wafers provided with oxide film under the polishing conditions as described for the polished evaluation method (I). The polishing rate and in-plane uniformity averaged over 50-wafer groups were 2,570 (angstrom/min) and a good 6.3%, respectively. The difference between the maximum and the minimum polishing rate was 115 (angstrom/min), indicating that the stability index was a good 4.5%.

[0131] Using an insulating film of tetraethoxysilane, a wafer having a thickness of 3 μm for planarizing capability evaluation was produced by CVD as described above was polished for 4 min under the aforementioned polishing conditions, followed by measuring the thickness difference. The thickness difference measured was a good 1,000 angstrom. Additional nine polishing pads of the same specifications were prepared and subjected to continuous polishing test for 300 wafers provided with oxide film, and the polishing capability of the 10 pads was determined. The polishing capability was 2,580 (angstrom/min). The difference between the maximum and the minimum polishing rate was 130 (angstrom/min), and the pad-to-pad variation was 5.0%. Thus the results indicated a limited variation.

Example 3

[0132] A circular abrasive layer sample having a diameter of 508 mm was cut out from a raw abrasive layer prepared as in Example 1. In the surface of the circular abrasive layer sample thus obtained, a first groove group of grooves having a groove width of 0.7 mm, groove interval of 7.5 mm, and groove depth of 1.2 mm arranged in a grid array and a second groove group of grooves having a groove width of 2 mm, groove interval of 45 mm, and groove depth of 1.5 mm arranged in a grid array were produced with an NC router in such a manner that the grooves of the first groove group and those of the second groove group are parallel to each other. All grooves had a nearly rectangle cross-sectional shape.

[0133] Then, a 442JS double-sided adhesive tape (supplied by Sumitomo 3M Limited) was applied to the abrasive layer using a laminator at a linear pressure of 1 kg/cm. After removing the release paper, it was applied to a cushioning layer comprising a thermoplastic urethane rubber sheet (tensile elastic modulus of 35 MPa) having a thickness of 0.05 mm using a laminator at a linear pressure of 1 kg/cm to prepare a polishing pad. The shear adhesive strength between the abrasive layer and the cushioning layer in the polishing pad thus prepared was 3,000 gf/(20×20 mm^2). Furthermore, a 442JS double-sided adhesive tape (supplied by Sumitomo 3M Limited) was applied to the bottom surface of the cushioning layer using a laminator at a linear pressure of 1 kg/cm.

[0134] The polishing pad thus prepared was fixed in a polishing machine and subjected to continuous polishing test for 300 wafers provided with oxide film under the polishing conditions as described for the polished evaluation method (I). The polishing rate and in-plane uniformity averaged over 50-wafer groups were 2,500 (angstrom/min) and a good 5.3%, respectively. The difference between the maximum and the minimum polishing rate was 100 (angstrom/min), indicating that the stability index was a good 4.0%.

[0135] Using an insulating film of tetraethoxysilane, a wafer having a thickness of 3 μm for planarizing capability evaluation was produced by CVD as described above was polished for 4 min under the aforementioned polishing conditions, followed by measuring the thickness difference. The thickness difference measured was a good 900 angstrom. Additional nine polishing pads of the same specifications were prepared and subjected to continuous polishing test for 300 wafers provided with oxide film, and the polishing capability of the 10 pads was determined. The polishing capability was 2,490 (angstrom/min). The difference between the maximum and the minimum polishing rate was 130 (angstrom/min), and the pad-to-pad variation was 5.2%. Thus the results indicated a limited variation.

Example 4

[0136] Both surfaces of the rigid foamed sheet produced in Example 1 were ground to a thickness of 1.0 mm to prepare a raw abrasive layer. A circular abrasive layer sample having a diameter of 508 mm was cut out from the raw abrasive layer thus prepared. In the surface of the circular abrasive layer sample thus obtained, a first groove group of grooves having a groove width of 0.8 mm, groove interval of 10.0 mm, and groove depth of 0.4 mm arranged in a grid array and a second groove group of grooves having a groove width of 2.3 mm, groove interval of 30 mm, and groove depth of 0.4 mm arranged in a grid array were produced with an NC router in such a manner that the grooves of the first groove group and those of the second groove group are parallel to each other. All grooves had a nearly rectangle cross-sectional shape.

[0137] A reactive hot melt adhesive composed primarily of urethane (Hi-Bon (registered trademark) YR713-1W, supplied by Hitachi Kasei Polymer Co., Ltd.) was melted on a roll coater heated at a roll temperature of 120° C., and an abrasive layer was brought into contact with the roll coater in order to coat the abrasive layer with the adhesive. Within one minute after the coating with the adhesive, a cushioning layer comprising a thermosetting urethane rubber sheet (tensile elastic modulus of 48 MPa) having a thickness of 0.05 mm was placed on the adhesive applied, immediately followed by applying a roll press linear pressure of 1.5 kg/cm to bond them together to prepare a polishing pad. After solidification, the thickness of the adhesive was 80 μm. The shear adhesive strength between the abrasive layer and the cushioning layer in the polishing pad thus prepared was 12,500 gf/(20×20 mm^2). Furthermore, a 442JS double-sided adhesive tape (supplied by Sumitomo 3M Limited) was applied to the bottom surface of the cushioning layer using a laminator at a linear pressure of 1 kg/cm.

[0138] The polishing pad thus prepared was fixed in a polishing machine and subjected to continuous polishing test for 300 wafers provided with oxide film under the polishing conditions as described for the polished evaluation method (I). The polishing rate and in-plane uniformity averaged over 50-wafer groups were 2,700 (angstrom/min) and a good 7.5%, respectively. The difference between the maximum and the minimum polishing rate was 100 (angstrom/min), indicating that the stability index was a good 3.7%.

[0139] Using an insulating film of tetraethoxysilane, a wafer having a thickness of 3 μm for planarizing capability evaluation was produced by CVD as described above was polished for 4 min under the aforementioned polishing conditions, followed by measuring the thickness difference. The thickness difference measured was a good 1,000 angstrom. Additional nine polishing pads of the same specifications were prepared and subjected to continuous polishing test for 300 wafers provided with oxide film, and the polishing capability of the 10 pads was determined. The polishing capability was 2,690 (angstrom/min). The difference between the maximum and the minimum polishing rate was 110 (angstrom/min), and the pad-to-pad variation was 4.1%. Thus the results indicated a limited variation.

Example 5

[0140] Both surfaces of the rigid foamed sheet produced in Example 1 were ground to a thickness of 0.8 mm to prepare a raw abrasive layer. A circular abrasive layer sample having a diameter of 508 mm was cut out from the raw abrasive layer thus prepared. In the surface of the circular abrasive layer sample thus obtained, a first groove group of grooves having a groove width of 1.0 mm, groove interval of 10.0 mm, and groove depth of 0.2 mm arranged in a grid array and a second groove group of grooves having a groove width of 2.0 mm, groove interval of 30 mm, and groove depth of 0.2 mm arranged in a grid array were produced with an NC router in such a manner that the grooves of the first groove group and those of the second groove group are parallel to each other. All grooves had a nearly rectangle cross-sectional shape.

[0141] A reactive hot melt adhesive composed primarily of urethane (Hi-Bon (registered trademark) YR713-1W, supplied by Hitachi Kasei Polymer Co., Ltd.) was melted on a roll coater heated at a roll temperature of 120° C., and an abrasive layer was brought into contact with the roll coater in order to coat the abrasive layer with the adhesive.

[0142] Within one minute after the coating with the adhesive, a cushioning layer comprising a thermoplastic urethane rubber sheet (tensile elastic modulus of 18 MPa) having a thickness of 0.2 mm was placed on the adhesive applied, immediately followed by applying a roll press linear pressure of 1.5 kg/cm to bond them together to prepare a polishing pad. After solidification, the thickness of the adhesive was 50 μm. The shear adhesive strength between the abrasive layer and the cushioning layer in the polishing pad thus prepared was 9,500 gf/(20×20 mm^2). Furthermore, a 442JS double-sided adhesive tape (supplied by Sumitomo 3M Limited) was applied to the bottom surface of the cushioning layer using a laminator at a linear pressure of 1 kg/cm.

[0143] The polishing pad thus prepared was fixed in a polishing machine and subjected to continuous polishing test for 300 wafers provided with oxide film under the polishing conditions as described for the polished evaluation method (I). The polishing rate and in-plane uniformity averaged over 50-wafer groups were 2,300 (angstrom/min) and a good 8.5%, respectively. The difference between the maximum and the minimum polishing rate was 80 (angstrom/min), indicating that the stability index was a good 3.5%.

[0144] Using an insulating film of tetraethoxysilane, a wafer having a thickness of 3 μm for planarizing capability evaluation was produced by CVD as described above was polished for 4 min under the aforementioned polishing conditions, followed by measuring the thickness difference. The thickness difference measured was a good 1,350 angstrom. Additional nine polishing pads of the same specifications were prepared and subjected to continuous polishing test for 300 wafers provided with oxide film, and the polishing capability of the 10 pads was determined. The polishing capability was 2,340 (angstrom/min). The difference between the maximum and the minimum polishing rate was 90 (angstrom/min), and the pad-to-pad variation was 3.8%. Thus the results indicated a limited variation.

Example 6

[0145] Both surfaces of the rigid foamed sheet produced in Example 1 were ground to a thickness of 1.5 mm to prepare a raw abrasive layer. A circular abrasive layer sample having a diameter of 508 mm was cut out from the raw abrasive layer thus prepared. In the surface of the circular abrasive layer sample thus obtained, a first groove group of grooves having a groove width of 1.0 mm, groove interval of 45.0 mm, and groove depth of 0.7 mm arranged in a grid array and a second groove group B of grooves having a groove width of 2.0 mm, groove interval of 45 mm, and groove depth of 0.9 mm arranged in a grid array were produced with an NC router in such a manner that the grooves of the first groove group and those of the second groove group were shifted from each other by half the groove pitch so that they were parallel to each other without overlapping each other. All grooves had a nearly rectangle cross-sectional shape.

[0146] A reactive hot melt adhesive composed primarily of urethane (Hi-Bon (registered trademark) YR713-1W, supplied by Hitachi Kasei Polymer Co., Ltd.) was melted on a roll coater heated at a roll temperature of 120° C., and the abrasive layer was brought into contact with the roll coater in order to coat the abrasive layer with the adhesive. Within one minute after the coating with the adhesive, a cushioning layer comprising a thermoplastic urethane rubber sheet (tensile elastic modulus of 24 MPa) having a thickness of 0.15 mm was placed on the adhesive applied, immediately followed by applying a roll press linear pressure of 1.5 kg/cm to bond them together to prepare a polishing pad. After solidification, the thickness of the adhesive was 50 μm. The shear adhesive strength between the abrasive layer and the cushioning layer in the polishing pad thus prepared was 9,500 gf/(20×20 mm^2). Furthermore, a 442JS double-sided adhesive tape (supplied by Sumitomo 3M Limited) was applied to the bottom surface of the cushioning layer using a laminator at a linear pressure of 1 kg/cm.

[0147] The polishing pad thus prepared was fixed in a polishing machine and subjected to continuous polishing test for 300 wafers provided with tungsten film under the polishing conditions as described for the polished evaluation method (II). The polishing rate and in-plane uniformity averaged over 50-wafer groups were 4,500 (angstrom/min) and a good 3.5%, respectively. The difference between the maximum and the minimum polishing rate was 144 (angstrom/min), indicating that the stability index was a good 3.2%.

[0148] A wafer for tungsten film planarizing capability evaluation was polished under the aforementioned polishing conditions, followed by measuring the thickness difference. The thickness difference measured was a good 350 angstrom. Additional nine polishing pads of the same specifications were prepared and subjected to continuous polishing test for 300 wafers provided with tungsten film, and the polishing capability of the 10 pads was determined. The polishing capability was 4,480 (angstrom/min). The difference between the maximum and the minimum polishing rate was 188 (angstrom/min), and the pad-to-pad variation was 4.2%. Thus the results indicated a limited variation.

Example 7

[0149] A liquid-A consisting of 100 parts by weight of polyether polyol (Sannix (registered trademark) FA-909 supplied by Sanyo Chemical Industries Ltd.), 8 parts by weight of ethylene glycol as chain elongation agent, 1 part by weight of Dabco (registered trademark) 33LV (supplied by Air Products Japan, Inc.) as amine catalyst, 0.1 part by weight of Toyocat (registered trademark) ET (supplied by Tosoh Corporation) as amine catalyst, 0.5 part by weight of Tegostab (registered trademark) B8462 (supplied by Th. Goldschmidt AG) as silicone foam stabilizer, and 1.0 part by weight of water as foaming agent, mixed and maintained at a liquid temperature 40° C., was collision-mixed in a RIM machine at a discharge pressure of 15 MPa with a liquid-B comprising 95 parts by weight of isocyanate (Sanfoam (registered trademark) NC-703) maintained at a liquid temperature 40° C. The material was discharged at a discharge rate of 500 g/sec into a mold maintained at 60° C. and left to stand for 10 minutes to prepare a foamed polyurethane block (Microdurometer-A hardness: 38, density: 0.55 g/cm^3, average cell diameter: 63 μm) having a size of 700×700 mm and thickness of 10 mm. Subsequently, the foamed polyurethane block was sliced with a slicer to a thickness of 3 mm to produce a foamed polyurethane sheet.

[0150] Then, the foamed polyurethane sheet was immersed in methyl methacrylate containing 0.1 part by weight of azobisisobutyronitrile for 10 minutes. The resulting foamed polyurethane sheet impregnated with methyl methacrylate was sandwiched between two glass plates with vinyl chloride gaskets placed in between, and heated at 60° C. for 10 hours and at 120° C. for 3 hours to achieve polymerization and curing. The sheet was then released from between the glass plates and vacuum dried at 50° C. to produce a rigid foamed sheet. Both surfaces of the resulting rigid foamed sheet were ground to a thickness of 1.5 mm to prepare a raw abrasive layer. The resulting raw abrasive layer had a Microdurometer-A hardness of 80, density of 0.56 g/cm^3, and average cell diameter of 65 μm, and polymethyl methacrylate accounted for 47 wt % of the abrasive layer.

[0151] A circular abrasive layer sample having a diameter of 508 mm was cut out from the raw abrasive layer thus prepared. In the surface of the circular abrasive layer sample thus obtained, a first groove group of grooves having a groove width of 1.0 mm, groove interval of 40.0 mm, and groove depth of 0.9 mm arranged in a grid array and a second groove group of grooves having a groove width of 2.0 mm, groove interval of 40 mm, and groove depth of 0.9 mm arranged in a grid array were produced with an NC router in such a manner that the grooves of the first groove group and those of the second groove group were shifted from each other by half the groove pitch so that they were parallel to each other without overlapping each other. All grooves had a nearly rectangle cross-sectional shape.

[0152] A reactive hot melt adhesive composed primarily of urethane (Hi-Bon (registered trademark) YR713-1W, supplied by Hitachi Kasei Polymer Co., Ltd.) was melted on a roll coater heated at a roll temperature of 120° C., and the abrasive layer was brought into contact with the roll coater in order to coat the abrasive layer with the adhesive. Within one minute after the coating with the adhesive, a polyester film having a thickness of 0.1 mm was placed on the adhesive applied, immediately followed by applying a roll press linear pressure of 1.5 kg/cm to bond them together. A Hi-Bon (registered trademark) YR713-1W adhesive (supplied by Hitachi Kasei Polymer Co., Ltd.) was melted on a roll coater heated at a roll temperature of 120° C., and the roll coater was used to spread it over the polyester film surface of the laminate sheet composed of the abrasive layer and the 0.1 mm thick polyester film.

[0153] Within one minute after the coating with the adhesive, a cushioning layer comprising a thermoplastic urethane rubber sheet (tensile elastic modulus of 24 MPa) having a thickness of 0.5 mm was placed quickly on the polyester film surface at a roll press line pressure of 1.5 kg/cm, immediately followed by applying a roll press linear pressure of 1.5 kg/cm to bond them together to prepare a polishing pad. After solidification, the thickness of the adhesive was 50 μm. The shear adhesive strength between the abrasive layer and the cushioning layer in the polishing pad thus prepared was 9,500 gf/(20×20 mm^2). Furthermore, a 442JS double-sided adhesive tape (supplied by Sumitomo 3M Limited) was applied to the bottom surface of the cushioning layer using a laminator at a linear pressure of 1 kg/cm.

[0154] The polishing pad thus prepared was fixed in a polishing machine and subjected to continuous polishing test for 300 wafers provided with tungsten film under the polishing conditions as described for the polished evaluation method (II). The polishing rate and in-plane uniformity averaged over 50-wafer groups were 4,700 (angstrom/min) and a good 5.0%, respectively. The difference between the maximum and the minimum polishing rate was 146 (angstrom/min), indicating that the stability index was a good 3.1%.

[0155] A wafer for tungsten film planarizing capability evaluation was polished under the aforementioned polishing conditions, followed by measuring the thickness difference. The thickness difference measured was a good 400 angstrom. Additional nine polishing pads of the same specifications were prepared and subjected to continuous polishing test for 300 wafers provided with tungsten film, and the polishing capability of the 10 pads was determined. The polishing capability was 4,780 (angstrom/min). The difference between the maximum and the minimum polishing rate was 177 (angstrom/min), and the pad-to-pad variation was 3.7%. Thus the results indicated a limited variation.

Example 8

[0156] A foamed polyurethane block as in Example 7 was prepared and sliced with a slicer to prepare foamed polyurethane sheets having a thickness of 3 mm.

[0157] Then, the foamed polyurethane sheet was immersed in methyl methacrylate containing 0.1 part by weight of azobisisobutyronitrile for 8 minutes. The resulting foamed polyurethane sheet impregnated with methyl methacrylate was sandwiched between two glass plates with vinyl chloride gaskets placed in between, and heated at 60° C. for 10 hours and at 120° C. for 3 hours to achieve polymerization and curing. The sheet was then released from between the glass plates and vacuum dried at 50° C. to produce a rigid foamed sheet. Both surfaces of the resulting rigid foamed sheet were ground to a thickness of 1.5 mm to prepare a raw abrasive layer. The resulting raw abrasive layer had a Microdurometer-A hardness of 76, density of 0.54 g/cm^3, and average cell diameter of 62 μm, and polymethyl methacrylate accounted for 41 wt % of the abrasive layer.

[0158] A circular abrasive layer sample having a diameter of 508 mm was cut out from the raw abrasive layer thus prepared. In the surface of the circular abrasive layer sample thus obtained, a first groove group of grooves having a groove width of 1.0 mm, groove interval of 40.0 mm, and groove depth of 0.9 mm arranged in a grid array and a second groove group of grooves having a groove width of 2.0 mm, groove interval of 40 mm, and groove depth of 0.9 mm arranged in a grid array were produced with an NC router in such a manner that the grooves of the first groove group and those of the second groove group were shifted from each other by half the groove pitch so that they were parallel to each other without overlapping each other. All grooves had a nearly rectangle cross-sectional shape.

[0159] A reactive hot melt adhesive composed primarily of urethane (Hi-Bon (registered trademark) YR713-1W, supplied by Hitachi Kasei Polymer Co., Ltd.) was melted on a roll coater heated at a roll temperature of 120° C., and the abrasive layer was brought into contact with the roll coater in order to coat the abrasive layer with the adhesive. Within one minute after the coating with the adhesive, a polyester film having a thickness of 0.1 mm was placed on the adhesive applied, immediately followed by applying a roll press linear pressure of 1.5 kg/cm to bond them together. A Hi-Bon (registered trademark) YR713-1W adhesive (supplied by Hitachi Kasei Polymer Co., Ltd.) was melted on a roll coater heated at a roll temperature of 120° C., and the roll coater was used to spread it over the polyester film surface of the laminate sheet composed of the abrasive layer and the 0.1 mm thick polyester film.

[0160] Within one minute after the coating with the adhesive, a cushioning layer comprising a thermoplastic urethane rubber sheet (tensile elastic modulus of 18 MPa) having a thickness of 1.5 mm was placed quickly on the polyester film surface at a roll press line pressure of 1.5 kg/cm, immediately followed by applying a roll press linear pressure of 1.5 kg/cm to bond them together to prepare a polishing pad. After solidification, the thickness of the adhesive was 50 μm. The shear adhesive strength between the abrasive layer and the cushioning layer in the polishing pad thus prepared was 9,300 gf/(20×20 mm^2). Furthermore, a 442JS double-sided adhesive tape (supplied by Sumitomo 3M Limited) was applied to the bottom surface of the cushioning layer using a laminator at a linear pressure of 1 kg/cm.

[0161] The polishing pad thus prepared was fixed in a polishing machine and subjected to continuous polishing test for 300 wafers provided with tungsten film under the polishing conditions as described for the polished evaluation method (II). The polishing rate and in-plane uniformity averaged over 50-wafer groups were 4,900 (angstrom/min) and a good 5.0%, respectively. The difference between the maximum and the minimum polishing rate was 157 (angstrom/min), indicating that the stability index was a good 3.2%.

[0162] A wafer for tungsten film planarizing capability evaluation was polished under the aforementioned polishing conditions, followed by measuring the thickness difference. The thickness difference measured was a good 450 angstrom. Additional nine polishing pads of the same specifications were prepared and subjected to continuous polishing test for 300 wafers provided with tungsten film, and the polishing capability of the 10 pads was determined. The polishing capability was 4,850 (angstrom/min). The difference between the maximum and the minimum polishing rate was 175 (angstrom/min), and the pad-to-pad variation was 3.6%. Thus the results indicated a limited variation.

Comparative Example 1

[0163] A circular abrasive layer sample having a diameter of 508 mm was cut out from a raw abrasive layer prepared as in Example 1. In the surface of the circular abrasive layer sample thus obtained, a first groove group of grooves having a groove width of 0.4 mm, groove interval of 3 mm, and groove depth of 1.5 mm arranged in a grid array and a second groove group of grooves having a groove width of 1.5 mm, groove interval of 20 mm, and groove depth of 1.5 mm arranged in a grid array were produced with an NC router in such a manner that the grooves of the first groove group and those of the second groove group are parallel to each other. All grooves had a rectangle cross-sectional shape.

[0164] Then, a 442JS double-sided adhesive tape (supplied by Sumitomo 3M Limited) was applied to the abrasive layer using a laminator at a linear pressure of 1 kg/cm. After removing the release paper, it was applied to a cushioning layer comprising a thermoplastic urethane rubber sheet (tensile elastic modulus of 25 MPa) having a thickness of 0.3 mm using a laminator at a linear pressure of 1 kg/cm to prepare a polishing pad. The shear adhesive strength between the abrasive layer and the cushioning layer in the polishing pad thus prepared was 3,000 gf/(20×20 mm^2). Furthermore, a 442JS double-sided adhesive tape (supplied by Sumitomo 3M Limited) was applied to the bottom surface of the cushioning layer using a laminator at a linear pressure of 1 kg/cm.

[0165] The polishing pad thus prepared was fixed in a polishing machine and subjected to continuous polishing test for 300 wafers provided with oxide film under the polishing conditions as described for the polished evaluation method (I). However, wafers stuck to the abrasive layer during the test, making it impossible to performed continuous polishing stably.

Comparative Example 2

[0166] Both surfaces of the rigid foamed sheet produced in Example 1 were ground to a thickness of 1.5 mm to prepare a raw abrasive layer. A circular abrasive layer sample having a diameter of 508 mm was cut out from the raw abrasive layer thus prepared. In the surface of the circular abrasive layer sample thus obtained, a first groove group of grooves having a groove width of 1.3 mm, groove interval of 5.0 mm, and groove depth of 0.9 mm arranged in a grid array and a second groove group of grooves having a groove width of 2.0 mm, groove interval of 25 mm, and groove depth of 0.9 mm arranged in a grid array were produced with an NC router in such a manner that the grooves of the first groove group and those of the second groove group are parallel to each other. All grooves had a nearly rectangle cross-sectional shape.

[0167] A reactive hot melt adhesive composed primarily of urethane (Hi-Bon (registered trademark) YR713-1W, supplied by Hitachi Kasei Polymer Co., Ltd.) was melted on a roll coater heated at a roll temperature of 120° C., and an abrasive layer was brought into contact with the roll coater in order to coat the abrasive layer with the adhesive. Within one minute after the coating with the adhesive, a cushioning layer comprising a thermoplastic urethane rubber sheet (tensile elastic modulus of 25 MPa) having a thickness of 0.3 mm was placed on the adhesive applied, immediately followed by applying a roll press linear pressure of 1.5 kg/cm to bond them together to prepare a polishing pad. After solidification, the thickness of the adhesive was 60 μm. The shear adhesive strength between the abrasive layer and the cushioning layer in the polishing pad thus prepared was 10,500 gf/(20×20 mm^2). Furthermore, a 442JS double-sided adhesive tape (supplied by Sumitomo 3M Limited) was applied to the bottom surface of the cushioning layer using a laminator at a linear pressure of 1 kg/cm.

[0168] The polishing pad thus prepared was fixed in a polishing machine and subjected to continuous polishing test for 300 wafers provided with oxide film under the polishing conditions as described for the polished evaluation method (I). The polishing rate and in-plane uniformity averaged over 50-wafer groups were 2,600 (angstrom/min) and a good 6.5%, respectively. The difference between the maximum and the minimum polishing rate was 300 (angstrom/min), indicating that the stability index was 11.5%. This showed that polishing was not performed stably.

Comparative Example 3

[0169] Both surfaces of the rigid foamed sheet produced in Example 1 were ground to a thickness of 1.5 mm to prepare a raw abrasive layer. A circular abrasive layer sample having a diameter of 508 mm was cut out from the raw abrasive layer thus prepared. In the surface of the circular abrasive layer sample thus obtained, a first groove group of grooves having a groove width of 1 mm, groove interval of 5.0 mm, and groove depth of 0.9 mm arranged in a grid array and a second groove group of grooves having a groove width of 2.0 mm, groove interval of 15 mm, and groove depth of 0.9 mm arranged in a grid array were produced with an NC router in such a manner that the grooves of the first groove group and those of the second groove group are parallel to each other. All grooves had a nearly rectangle cross-sectional shape.

[0170] A reactive hot melt adhesive composed primarily of urethane (Hi-Bon (registered trademark) YR713-1W, supplied by Hitachi Kasei Polymer Co., Ltd.) was melted on a roll coater heated at a roll temperature of 120° C., and an abrasive layer was brought into contact with the roll coater in order to coat the abrasive layer with the adhesive. Within one minute after the coating with the adhesive, a cushioning layer comprising a thermoplastic urethane rubber sheet (tensile elastic modulus of 25 MPa) having a thickness of 0.3 mm was placed on the adhesive applied, immediately followed by applying a roll press linear pressure of 1.5 kg/cm to bond them together to prepare a polishing pad. After solidification, the thickness of the adhesive was 60 μm. The shear adhesive strength between the abrasive layer and the cushioning layer in the polishing pad thus prepared was 10,500 gf/(20×20 mm^2). Furthermore, a 442JS double-sided adhesive tape (supplied by Sumitomo 3M Limited) was applied to the bottom surface of the cushioning layer using a laminator at a linear pressure of 1 kg/cm.

[0171] The polishing pad thus prepared was fixed in a polishing machine and subjected to continuous polishing test for 300 wafers provided with oxide film under the polishing conditions as described for the polished evaluation method (I). The polishing rate and in-plane uniformity averaged over 50-wafer groups were 2,600 (angstrom/min) and a good 6.5%, respectively. The difference between the maximum and the minimum polishing rate was 400 (angstrom/min), indicating that the stability index was 15.4%. This showed that polishing was not performed stably.

Comparative Example 4

[0172] Both surfaces of the rigid foamed sheet produced in Example 1 were ground to a thickness of 1.5 mm to prepare a raw abrasive layer. A circular abrasive layer sample having a diameter of 508 mm was cut out from the raw abrasive layer thus prepared. In the surface of the circular abrasive layer sample thus obtained, a first groove group of grooves having a groove width of 1 mm, groove interval of 2.0 mm, and groove depth of 0.9 mm arranged in a grid array and a second groove group of grooves having a groove width of 2.0 mm, groove interval of 20 mm, and groove depth of 0.9 mm arranged in a grid array were produced with an NC router in such a manner that the grooves of the first groove group and those of the second groove group are parallel to each other. All grooves had a nearly rectangle cross-sectional shape.

[0173] A reactive hot melt adhesive composed primarily of urethane (Hi-Bon (registered trademark) YR713-1W, supplied by Hitachi Kasei Polymer Co., Ltd.) was melted on a roll coater heated at a roll temperature of 120° C., and an abrasive layer was brought into contact with the roll coater in order to coat the abrasive layer with the adhesive. Within one minute after the coating with the adhesive, a cushioning layer comprising a thermoplastic urethane rubber sheet (tensile elastic modulus of 25 MPa) having a thickness of 0.3 mm was placed on the adhesive applied, immediately followed by applying a roll press linear pressure of 1.5 kg/cm to bond them together to prepare a polishing pad. After solidification, the thickness of the adhesive was 60 μm. The shear adhesive strength between the abrasive layer and the cushioning layer in the polishing pad thus prepared was 10,500 gf/(20×20 mm^2). Furthermore, a 442JS double-sided adhesive tape (supplied by Sumitomo 3M Limited) was applied to the bottom surface of the cushioning layer using a laminator at a linear pressure of 1 kg/cm.

[0174] The polishing pad thus prepared was fixed in a polishing machine and subjected to continuous polishing test for 300 wafers provided with oxide film under the polishing conditions as described for the polished evaluation method (I). The polishing rate and in-plane uniformity averaged over 50-wafer groups were 2,500 (angstrom/min) and a good 6.5%, respectively. The difference between the maximum and the minimum polishing rate was 350 (angstrom/min), indicating that the stability index was 14%. This showed that polishing was not performed stably.

Comparative Example 5

[0175] Both surfaces of the rigid foamed sheet produced in Example 1 were ground to a thickness of 1.5 mm to prepare a raw abrasive layer. A circular abrasive layer sample having a diameter of 508 mm was cut out from the raw abrasive layer thus prepared. In the surface of the circular abrasive layer sample thus obtained, a first groove group of grooves having a groove width of 1 mm, groove interval of 5.0 mm, and groove depth of 0.9 mm arranged in a grid array and a second groove group of grooves having a groove width of 2.0 mm, groove interval of 55 mm, and groove depth of 0.9 mm arranged in a grid array were produced with an NC router in such a manner that the grooves of the first groove group and those of the second groove group are parallel to each other. All grooves had a nearly rectangle cross-sectional shape.

[0176] A reactive hot melt adhesive composed primarily of urethane (Hi-Bon (registered trademark) YR713-1W, supplied by Hitachi Kasei Polymer Co., Ltd.) was melted on a roll coater heated at a roll temperature of 120° C., and an abrasive layer was brought into contact with the roll coater in order to coat the abrasive layer with the adhesive. Within one minute after the coating with the adhesive, a cushioning layer comprising a thermoplastic urethane rubber sheet (tensile elastic modulus of 25 MPa) having a thickness of 0.3 mm was placed on the adhesive applied, immediately followed by applying a roll press linear pressure of 1.5 kg/cm to bond them together to prepare a polishing pad. After solidification, the thickness of the adhesive was 60 μm. The shear adhesive strength between the abrasive layer and the cushioning layer in the polishing pad thus prepared was 10,500 gf/(20×20 mm^2). Furthermore, a 442JS double-sided adhesive tape (supplied by Sumitomo 3M Limited) was applied to the bottom surface of the cushioning layer using a laminator at a linear pressure of 1 kg/cm.

[0177] The polishing pad thus prepared was fixed in a polishing machine and subjected to continuous polishing test for 300 wafers provided with oxide film under the polishing conditions as described for the polished evaluation method (I). The polishing rate and in-plane uniformity averaged over 50-wafer groups were 2,500 (angstrom/min) and a faulty 13.0%, respectively.

Comparative Example 6

[0178] Both surfaces of the rigid foamed sheet produced in Example 1 were ground to a thickness of 1.5 mm to prepare a raw abrasive layer. A circular abrasive layer sample having a diameter of 508 mm was cut out from the raw abrasive layer thus prepared. In the surface of the circular abrasive layer sample thus obtained, a first groove group of grooves having a groove width of 1 mm, groove interval of 5.0 mm, and groove depth of 0.9 mm arranged in a grid array and a second groove group of grooves having a groove width of 1.4 mm, groove interval of 25 mm, and groove depth of 0.9 mm arranged in a grid array were produced with an NC router in such a manner that the grooves of the first groove group and those of the second groove group are parallel to each other. All grooves had a nearly rectangle cross-sectional shape.

[0179] A reactive hot melt adhesive composed primarily of urethane (Hi-Bon (registered trademark) YR713-1W, supplied by Hitachi Kasei Polymer Co., Ltd.) was melted on a roll coater heated at a roll temperature of 120° C., and an abrasive layer was brought into contact with the roll coater in order to coat the abrasive layer with the adhesive. Within one minute after the coating with the adhesive, a cushioning layer comprising a thermoplastic urethane rubber sheet (tensile elastic modulus of 25 MPa) having a thickness of 0.3 mm was placed on the adhesive applied, immediately followed by applying a roll press linear pressure of 1.5 kg/cm to bond them together to prepare a polishing pad. After solidification, the thickness of the adhesive was 60 μm. The shear adhesive strength between the abrasive layer and the cushioning layer in the polishing pad thus prepared was 10,500 gf/(20×20 mm^2). Furthermore, a 442JS double-sided adhesive tape (supplied by Sumitomo 3M Limited) was applied to the bottom surface of the cushioning layer using a laminator at a linear pressure of 1 kg/cm.

[0180] The polishing pad thus prepared was fixed in a polishing machine and subjected to continuous polishing test for 300 wafers provided with oxide film under the polishing conditions as described for the polished evaluation method (I). The polishing rate and in-plane uniformity averaged over 50-wafer groups were 2,500 (angstrom/min) and a good 7.5%, respectively. The difference between the maximum and the minimum polishing rate was 100 (angstrom/min), indicating that the stability index was a good 3.7%.

[0181] Using an insulating film of tetraethoxysilane, a wafer having a thickness of 3 μm for planarizing capability evaluation was produced by CVD as described above was polished for 4 min under the aforementioned polishing conditions, followed by measuring the thickness difference. The thickness difference measured was a good 1,100 angstrom. Additional nine polishing pads of the same specifications were prepared and subjected to continuous polishing test for 300 wafers provided with oxide film, and the polishing capability of the 10 pads was determined. The polishing capability was 2,790 (angstrom/min). The difference between the maximum and the minimum polishing rate was 350 (angstrom/min), and the pad-to-pad variation was 12.5%. Thus the results indicated a significant variation.

Comparative Example 7

[0182] Both surfaces of the rigid foamed sheet produced in Example 1 were ground to a thickness of 1.5 mm to prepare a raw abrasive layer. A circular abrasive layer sample having a diameter of 508 mm was cut out from the raw abrasive layer thus prepared. In the surface of the circular abrasive layer sample thus obtained, a first groove group of grooves having a groove width of 1 mm, groove interval of 5.0 mm, and groove depth of 0.9 mm arranged in a grid array and a second groove group of grooves having a groove width of 3.2 mm, groove interval of 25 mm, and groove depth of 0.9 mm arranged in a grid array were produced with an NC router in such a manner that the grooves of the first groove group and those of the second groove group are parallel to each other. All grooves had a nearly rectangle cross-sectional shape.

[0183] A reactive hot melt adhesive composed primarily of urethane (Hi-Bon (registered trademark) YR713-1W, supplied by Hitachi Kasei Polymer Co., Ltd.) was melted on a roll coater heated at a roll temperature of 120° C., and an abrasive layer was brought into contact with the roll coater in order to coat the abrasive layer with the adhesive. Within one minute after the coating with the adhesive, a cushioning layer comprising a thermoplastic urethane rubber sheet (tensile elastic modulus of 25 MPa) having a thickness of 0.3 mm was placed on the adhesive applied, immediately followed by applying a roll press linear pressure of 1.5 kg/cm to bond them together to prepare a polishing pad. After solidification, the thickness of the adhesive was 60 μm. The shear adhesive strength between the abrasive layer and the cushioning layer in the polishing pad thus prepared was 10,500 gf/(20×20 mm^2). Furthermore, a 442JS double-sided adhesive tape (supplied by Sumitomo 3M Limited) was applied to the bottom surface of the cushioning layer using a laminator at a linear pressure of 1 kg/cm.

[0184] The polishing pad thus prepared was fixed in a polishing machine and subjected to continuous polishing test for 300 wafers provided with oxide film under the polishing conditions as described for the polished evaluation method (I). The polishing rate and in-plane uniformity averaged over 50-wafer groups were 2,600 (angstrom/min) and a good 7.5%, respectively. The difference between the maximum and the minimum polishing rate was 400 (angstrom/min), indicating that the stability index was a faulty 15.3%.

Comparative Example 8

[0185] A circular abrasive layer sample having a diameter of 508 mm was cut out from a raw abrasive layer prepared as in Example 1. In the surface of the circular abrasive layer sample thus obtained, a first groove group of grooves having a groove width of 1.2 mm, groove interval of 12.5 mm, and groove depth of 1.5 mm arranged in a grid array and a second groove group of grooves having a groove width of 3 mm, groove interval of 37.5 mm, and groove depth of 1.5 mm arranged in a grid array were produced with an NC router in such a manner that the grooves of the first groove group and those of the second groove group are parallel to each other. All grooves had a nearly rectangle cross-sectional shape.

[0186] A reactive hot melt adhesive composed primarily of urethane (Hi-Bon (registered trademark) YR713-1W, supplied by Hitachi Kasei Polymer Co., Ltd.) was melted on a roll coater heated at a roll temperature of 120° C., and an abrasive layer was brought into contact with the roll coater in order to coat the abrasive layer with the adhesive. Within one minute after the coating with the adhesive, a cushioning layer comprising a thermoplastic polyurethane urethane sheet (tensile elastic modulus of 25 MPa) having a thickness of 1.7 mm was placed on the adhesive applied, immediately followed by applying a roll press linear pressure of 1.5 kg/cm to bond them together to prepare a polishing pad. After solidification, the thickness of the adhesive was 70 μm. The shear adhesive strength between the abrasive layer and the cushioning layer in the polishing pad thus prepared was 9,500 gf/(20×20 mm^2). Furthermore, a 442JS double-sided adhesive tape (supplied by Sumitomo 3M Limited) was applied to the bottom surface of the cushioning layer using a laminator at a linear pressure of 1 kg/cm.

[0187] The polishing pad thus prepared was fixed in a polishing machine and subjected to continuous polishing test for 300 wafers provided with oxide film under the polishing conditions as described for the polished evaluation method (I). The polishing rate and in-plane uniformity averaged over 50-wafer groups were 2,570 (angstrom/min) and a faulty 13.0%, respectively.

Comparative Example 9

[0188] A circular abrasive layer sample having a diameter of 508 mm was cut out from a raw abrasive layer prepared as in Example 1. In the surface of the circular abrasive layer sample thus obtained, a first groove group of grooves having a groove width of 1.2 mm, groove interval of 12.5 mm, and groove depth of 1.5 mm arranged in a grid array and a second groove group of grooves having a groove width of 3 mm, groove interval of 37.5 mm, and groove depth of 1.5 mm arranged in a grid array were produced with an NC router in such a manner that the grooves of the first groove group and those of the second groove group are parallel to each other. All grooves had a nearly rectangle cross-sectional shape.

[0189] A reactive hot melt adhesive composed primarily of urethane (Hi-Bon (registered trademark) YR713-1W, supplied by Hitachi Kasei Polymer Co., Ltd.) was melted on a roll coater heated at a roll temperature of 120° C., and an abrasive layer was brought into contact with the roll coater in order to coat the abrasive layer with the adhesive. Within one minute after the coating with the adhesive, a cushioning layer comprising a thermosetting rigid polyurethane urethane sheet (tensile elastic modulus of 53 MPa) with a thickness of 0.5 mm was placed on the adhesive applied, immediately followed by applying a roll press linear pressure of 1.5 kg/cm to bond them together to prepare a polishing pad. After solidification, the thickness of the adhesive was 70 μm. The shear adhesive strength between the abrasive layer and the cushioning layer in the polishing pad thus prepared was 8,500 gf/(20×20 mm^2). Furthermore, a 442JS double-sided adhesive tape (supplied by Sumitomo 3M Limited) was applied to the bottom surface of the cushioning layer using a laminator at a linear pressure of 1 kg/cm.

[0190] The polishing pad thus prepared was fixed in a polishing machine and subjected to continuous polishing test for 300 wafers provided with oxide film under the polishing conditions as described for the polished evaluation method (I). The polishing rate and in-plane uniformity averaged over 50-wafer groups were 2,500 (angstrom/min) and a good 7.5%, respectively. The difference between the maximum and the minimum polishing rate was 400 (angstrom/min), indicating that the stability index was a faulty 16%.

[0191] Major results obtained in Examples and Comparative examples described above are shown in Tables 1, 2 and 3 for easy comparison.

TABLE 1

	Abrasive layer		Cushioning layer	
	Micro-durometer-A hardness	Thickness (mm)	Tensile elastic modulus (MPa)	Thickness (mm)
Example 1	92	2.0	16	0.5
Example 2	92	2.0	20	0.2
Example 3	92	2.0	35	0.05
Example 4	92	1.0	48	0.05
Example 5	92	0.8	18	0.2
Example 6	92	1.5	24	0.15
Example 7	80	1.5	24	0.5
Example 8	76	1.5	18	1.5
Comparative example 1	92	2.0	25	0.3
Comparative example 2	92	1.5	25	0.3
Comparative example 3	92	1.5	25	0.3
Comparative example 4	92	1.5	25	0.3
Comparative example 5	92	1.5	25	0.3
Comparative example 6	92	1.5	25	0.3
Comparative example 7	92	1.5	25	0.3
Comparative example 8	92	2.0	25	1.7
Comparative example 9	92	2.0	53	0.5

TABLE 2

	First groove group			Second groove group		
	Groove width (mm)	Groove interval (mm)	Groove depth (mm)	Groove width (mm)	Groove interval (mm)	Groove depth (mm)
Example 1	1.0	10.0	1.5	2.0	30.0	1.5
Example 2	1.2	12.5	1.5	3.0	37.5	1.5
Example 3	0.7	7.5	1.2	2.0	45.0	1.5
Example 4	0.8	10.0	0.4	2.3	30.0	0.4
Example 5	1.0	10.0	0.2	2.0	30.0	0.2
Example 6	1.0	45.0	0.7	2.0	45.0	0.9
Example 7	1.0	40.0	0.9	2.0	40.0	0.9
Example 8	1.0	40.0	0.9	2.0	40.0	0.9
Comparative example 1	0.4	3.0	1.5	1.5	20.0	1.5
Comparative example 2	1.3	5.0	0.9	2.0	25.0	0.9
Comparative example 3	1.0	5.0	0.9	2.0	15.0	0.9
Comparative example 4	1.0	2.0	0.9	2.0	20.0	0.9
Comparative example 5	1.0	5.0	0.9	2.0	55.0	0.9
Comparative example 6	1.0	5.0	0.9	1.4	25.0	0.9
Comparative example 7	1.0	5.0	0.9	3.2	25.0	0.9
Comparative example 8	1.2	12.5	1.5	3.0	37.5	1.5
Comparative example 9	1.2	12.5	1.5	3.0	37.5	1.5

TABLE 3

	Polishing stability (%)	In-plane uniformity (%)	Planar-izing capability (angstrom)	Pad-to-pad variation (%)
Example 1	4.7	8.3	1200	5.1
Example 2	4.5	6.3	1000	5.0
Example 3	4.0	5.3	900	5.2
Example 4	3.7	7.5	1000	4.1
Example 5	3.5	8.5	1350	3.8
Example 6	3.2	3.5	350	4.2
Example 7	3.1	5.0	400	3.7
Example 8	3.2	5.0	450	3.6
Comparative example 1	Wafers sticking, stable polishing impossible			
Comparative example 2	11.5	—	—	—
Comparative example 3	15.4	—	—	—
Comparative example 4	14.0	—	—	—
Comparative example 5	—	13.0	—	—
Comparative example 6	3.7	7.5	1100	12.5
Comparative example 7	15.3	7.5	—	—
Comparative example 8	—	13.0	—	—
Comparative example 9	16.0	7.5	—	—

INDUSTRIAL APPLICABILITY

[0192] The invention provides a polishing pad having a high polishing stability and planarizing capability, together with a limited pad-to-pad variation in polishing performance.

1. A polishing pad comprising a laminate of an abrasive layer and a cushioning layer, wherein

(a) said abrasive layer has a Microdurometer-A hardness of 75 or more and a thickness of 0.8 mm to 3.0 mm,

(b) said cushioning layer is formed of an unfoamed elastomer and has a thickness of 0.05 mm to 1.5 mm,

(c) the surface of said abrasive layer contains at least two groups of grooves, one of said two groups of grooves being referred to as a first groove group, and the other of said two groups of grooves being referred to as a second groove group,

(d) the grooves in said first groove group have a groove width of 0.5 mm to 1.2 mm, and are arranged at intervals of 7.5 mm to 50 mm,

(e) the grooves in said second groove group have a groove width of 1.5 mm to 3 mm, and are arranged at intervals of 20 mm to 50 mm, and

(f) the grooves in said first groove group and the grooves in said second groove group are open at side faces of said abrasive layer.

2. The polishing pad as claimed in claim 1, wherein said Microdurometer-A hardness is 80 or more, and said cushioning layer has a thickness of 0.05 mm to 0.5 mm.

3. The polishing pad as claimed in claim 1, wherein said cushioning layer has a tensile elastic modulus of 15 MPa to 50 MPa.

4. The polishing pad as claimed in claim 1, wherein the shear adhesive strength between said abrasive layer and said cushioning layer is 3,000 gf/(20×20 mm^2) or more.

5. The polishing pad as claimed in claim 1, wherein the grooves in said first groove group are arranged in a grid pattern while the grooves in said second groove group are arranged in a grid pattern.

6. The polishing pad as claimed in claim 5, wherein the grooves in said first groove group and those in said second groove group are arranged linearly and parallel to each other.

7. The polishing pad as claimed in claim 1, wherein said abrasive layer has a foam structure containing a polyurethane polymer and a vinyl compound polymer.

8. The polishing pad as claimed in claim 7, wherein said polyurethane polymer and said vinyl compound polymer are in an integrated state.

9. The polishing pad as claimed in claim 7, wherein said vinyl compound polymer accounts for 23 wt % to 66 wt %.

10. The polishing pad as claimed in claim 9, wherein said vinyl compound is in the form of $CH_2{=}CR_1COOR_2$ (R_1: methyl group or ethyl group, R_2: methyl group, ethyl group, propyl group, or butyl group).

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