



US 20250262715A1

(19) **United States**

(12) **Patent Application Publication**  
**Sonoda et al.**

(10) **Pub. No.: US 2025/0262715 A1**

(43) **Pub. Date: Aug. 21, 2025**

(54) **POLISHING PAD**

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(21) Appl. No.: **19/053,685**

(22) Filed: **Feb. 14, 2025**

(30) **Foreign Application Priority Data**

Feb. 15, 2024 (JP) ..... 2024-020816  
Jan. 17, 2025 (JP) ..... 2025-007084

**Publication Classification**

(51) **Int. Cl.**  
**B24B 37/24** (2012.01)

(52) **U.S. Cl.**  
CPC ..... **B24B 37/24** (2013.01)

(57) **ABSTRACT**

The present invention provides a polishing pad that can polish a material to be polished at a high polishing rate in a polishing process, and can be stably dressed. The polishing pad contains a hydrogenated block copolymer (I) which is in an amount of 5% by mass or more, and which satisfies the following conditions (1) and (2), and which has a value of a static friction coefficient measured in accordance with JIS K7125 of 1.2 or less. <Condition (1)>: The hydrogenated block copolymer (I) is a hydrogenated product of a block copolymer containing a vinyl aromatic monomer unit, and a conjugated diene monomer unit. <Condition (2)>: The hydrogenated block copolymer (I) contains at least one polymer block (a) principally containing a vinyl aromatic monomer unit, and a content of the polymer block (a) principally containing a vinyl aromatic monomer unit in the hydrogenated block copolymer (I) is 10% by mass or more.

**POLISHING PAD****BACKGROUND OF THE INVENTION****Field of the Invention**

[0001] The present invention relates to a polishing pad.

**Description of the Related Art**

[0002] In production of integrated circuits and other electronic devices, a plurality of layers of a conductive material, a semiconductor material, and a dielectric material are deposited on a surface of a semiconductor wafer, or removed from the surface of the semiconductor wafer. Thin layers of a conductive material, a semiconductor material, and a dielectric material can be deposited by a large number of deposition techniques.

[0003] General deposition techniques employed in processing in these days include physical vapor deposition (PVD) known as sputtering, chemical vapor deposition (CVD), plasma enhanced chemical vapor deposition (PECVD), and electrochemical plating (ECP). As material layers are successively deposited and removed, the topmost surface of the wafer becomes non-flat. In subsequent semiconductor processing (e.g., metallization), the wafer needs to have a flat surface, and hence needs to be flattened.

[0004] Flattening is useful for removing unwanted surface topography and surface defects, such as a rough surface, an aggregated material, a crystal lattice damage, a scratch, and a contaminated layer or material.

[0005] Chemical mechanical planarization or chemical mechanical polishing (CMP) is a general technique used for flattening a substrate of a semiconductor wafer or the like. In conventional CMP, a wafer is attached onto a carrier assembly, and is positioned through contact with a polishing pad provided in a CMP apparatus. The carrier assembly provides a controllable pressure to the wafer, and presses the wafer against the polishing pad. The pad is moved (for example, rotated) against the wafer by an external driving force. At the same time, a chemical composition ("slurry") or another polishing solution is provided between the wafer and the polishing pad. In this manner, the surface of the wafer is polished to be flattened by chemical and mechanical effects of the surface of the pad and the slurry. In production of a polishing pad, a variety of compositions and methods are used. The term "semiconductor wafer" as used herein is used to intend to encompass various packages for interconnection at various levels of semiconductor substrates and semiconductor devices, such as unpatterned semiconductors or patterned semiconductors (including single-chip wafers or multi-chip wafers, substrates for light emitting diodes, and other assemblies requiring solder connection).

[0006] Japanese Patent Laid-Open No. 2023-58442 discloses that a high polishing rate can be realized by using a polishing pad containing a styrene-based thermoplastic elastomer.

[0007] It was found, however, that the polishing pad described in Japanese Patent Laid-Open No. 2023-58442 cannot be stably dressed because it has a high friction coefficient due to the styrene-based thermoplastic elastomer contained therein.

[0008] Considering the above-described problem, an object of the present invention is to provide a polishing pad

that can polish a material to be polished at a high polishing rate in a polishing process, and can be stably dressed.

**SUMMARY OF THE INVENTION**

[0009] [1] A polishing pad containing a hydrogenated block copolymer (I) which is in an amount of 5% by mass or more, and which satisfies the following conditions (1) and (2), and which has a value of a static friction coefficient measured in accordance with JIS K7125 of 1.2 or less.

**Condition (1)**

[0010] the hydrogenated block copolymer (I) is a hydrogenated product of a block copolymer containing a vinyl aromatic monomer unit, and a conjugated diene monomer unit; and

**Condition (2)**

[0011] the hydrogenated block copolymer (I) contains at least one polymer block (a) principally containing a vinyl aromatic monomer unit, and a content of the polymer block (a) principally containing a vinyl aromatic monomer unit in the hydrogenated block copolymer (I) is 10% by mass or more.

[0012] [2] The polishing pad according to [1], wherein the hydrogenated block copolymer (I) contains at least one hydrogenated copolymer block (b) containing a vinyl aromatic monomer unit and a conjugated diene monomer unit, and a content of the vinyl aromatic monomer unit in the hydrogenated copolymer block (b) is 5% by mass or more and 79% by mass or less.

[0013] [3] The polishing pad according to [2], wherein a content of the vinyl aromatic monomer unit in the hydrogenated copolymer block (b) is 45% by mass or more and 79% by mass or less.

[0014] [4] The polishing pad according to any one of [1] to [3], wherein the polishing pad contains the hydrogenated block copolymer (I) in an amount of 40% by mass or more.

[0015] [5] The polishing pad according to any one of [1] to [4], wherein the polishing pad contains the hydrogenated block copolymer (I) in an amount of 70% by mass or more.

[0016] [6] The polishing pad according to any one of [1] to [5], wherein the polishing pad has a value of a dynamic friction coefficient measured in accordance with JIS K7125 of 0.6 or less.

[0017] [7] The polishing pad according to any one of [1] to [6], wherein the content of the polymer block (a) principally containing the vinyl aromatic monomer unit in the hydrogenated block copolymer (I) is 15% by mass or more and 40% by mass or less.

[0018] The present invention provides a polishing pad that can polish a material to be polished at a high polishing rate in a polishing process, and can be stably dressed.

**DETAILED DESCRIPTION OF THE INVENTION****Polishing Pad**

[0019] A polishing pad of the present embodiment contains a hydrogenated block copolymer (I) which is in an amount of 5% by mass or more, and which satisfies the

following conditions (1) and (2), and which has a value of a static friction coefficient measured in accordance with JIS K7125 of 1.2 or less.

<Condition (1)>

[0020] the hydrogenated block copolymer (I) is a hydrogenated product of a block copolymer containing a vinyl aromatic monomer unit, and a conjugated diene monomer unit; and

<Condition (2)>

[0021] the hydrogenated block copolymer (I) contains at least one polymer block (a) principally containing a vinyl aromatic monomer unit, and a content of the polymer block (a) principally containing a vinyl aromatic monomer unit in the hydrogenated block copolymer (I) is 10% by mass or more.

[0022] The polishing pad of the present embodiment has the above-described configuration, and hence can polish a material to be polished at a high polishing rate in a polishing process, and can be stably dressed.

[0023] A method for setting the value of the static friction coefficient to 1.2 or less is not especially limited.

[0024] For example, when a vinyl bond content in all conjugated diene monomer units of the hydrogenated block copolymer (I) is equal to or smaller than a prescribed value, the stickiness reduces, and hence a polishing pad having a small static friction coefficient can be obtained, and thus, a stable dressing property tends to be exhibited.

[0025] When a content of all vinyl aromatic monomer units is equal to or larger than a prescribed value, the stickiness of the hydrogenated block copolymer (I) reduces, and hence a polishing pad having a small static friction coefficient can be obtained, and thus, a stable dressing property tends to be exhibited.

[0026] When the content of the polymer block (a) principally containing a vinyl aromatic monomer unit is equal to or larger than a prescribed value, the static friction coefficient reduces because the stickiness of the hydrogenated block copolymer (I) reduces, and in addition, the static friction coefficient of the polishing pad of the present embodiment reduces, and thus a stable dressing property tends to be exhibited.

[0027] The method for reducing the static friction coefficient is, for example, a method in which the stickiness is reduced by, for example, reducing the vinyl bond content in all conjugated diene monomer units in the hydrogenated block copolymer (I), or increasing the content of the polymer block (a) principally containing a vinyl aromatic monomer unit in the hydrogenated block copolymer (I).

[0028] When foam sizes are distributed in a comparatively wide range, the static friction coefficient obtained in the form of a polishing pad can be reduced. For example, when a difference value between a foam size having cumulative volume frequency of 80% and a foam size having cumulative volume frequency of 20% (foam size having cumulative volume frequency of 80%—foam size having cumulative volume frequency of 20%) is large, the static friction coefficient can be reduced.

[0029] The polishing pad of the present embodiment may be adjusted also in the dynamic friction coefficient. Examples of a method for reducing the dynamic friction coefficient include, in addition to the method in which the

static friction coefficient of the hydrogenated block copolymer (I) itself is reduced, a method in which an olefin-based resin (II) is added.

(Hydrogenated Block Copolymer (I))

[0030] The hydrogenated block copolymer (I) used in the polishing pad of the present embodiment is a hydrogenated product of a block copolymer containing a vinyl aromatic monomer unit and a conjugated diene monomer unit (condition (1) described above).

<Vinyl Aromatic Monomer Unit>

[0031] Examples of a vinyl aromatic compound forming the vinyl aromatic monomer unit include, but are not limited to, monomer units derived from styrene,  $\alpha$ -methylstyrene, p-methylstyrene, divinyl benzene, 1,1-diphenyl ethylene, N,N-dimethyl-p-aminoethylstyrene, and N,N-diethyl-p-aminoethylstyrene.

[0032] In particular, from the viewpoint of balance between cost and mechanical strength of a polishing pad containing the hydrogenated block copolymer (I), styrene is preferred.

[0033] One of these monomer units may be singly used, or two or more of these may be used together.

<Conjugated Diene Monomer Unit>

[0034] The conjugated diene monomer unit refers to a monomer unit derived from a diolefin having a pair of conjugated double bonds.

[0035] Examples of such a diolefin include, but are not limited to, 1,3-butadiene, 2-methyl-1,3-butadiene (isoprene), 2,3-dimethyl-1,3-butadiene, 1,3-pentadiene, 2-methyl-1,3-pentadiene, and 1,3-hexadiene.

[0036] In particular, from the viewpoint of balance between good molding processability and mechanical strength, 1,3-butadiene and isoprene are preferred. One of these may be singly used, or two or more of these may be used together.

[0037] Herein, the term “principally contain” regarding the structure of a hydrogenated block copolymer (I) means that the ratio in a prescribed block copolymer or a polymer block is 85% by mass or more, preferably 90% by mass or more, and more preferably 95% by mass or more.

[0038] It is noted that the content of the vinyl aromatic monomer unit in the hydrogenated copolymer block (b) is 5% by mass or more and 79% by mass or less (as described in [2] above), and hence the polymer block (a) and the hydrogenated copolymer block (b) can be definitely distinguished from each other.

<Vinyl Bond Content in All Conjugated Diene Monomer Units>

[0039] In the hydrogenated block copolymer (I), a vinyl bond content in all conjugated diene monomer units is not especially limited, and is preferably 5% by mass or more, more preferably 10% by mass or more, and further preferably 15% by mass or more.

[0040] The vinyl bond content is preferably 80% by mass or less, more preferably 75% by mass or less, and further preferably 70% by mass or less.

[0041] Herein, the term “vinyl bond content” refers to a total amount of conjugated diene monomer units bonded through a 1,2-vinyl bond (conjugated diene incorporated in

a polymer through a 1,2-bond) and bonded through a 3,4-vinyl bond (conjugated diene incorporated in a polymer through a 3,4-bond) (when 1,3-butadiene is used as conjugated diene, however, the vinyl bond content refers to a 1,2-vinyl bond content). The term has a concept including a state in which the 1,2-vinyl bond or the 3,4-vinyl bond has been hydrogenated into a single bond afterward. In other words, although the term “vinyl” is a name referring to a double-bond state, the term “vinyl bond content” used herein encompasses the content of a single bond resulting from hydrogenation of what is called a vinyl bond. When the measurement is performed during a production process of a hydrogenated block copolymer, a sum of 1,2-vinyl bonds and 3,4-vinyl bonds in all conjugated dienes measured before the hydrogenation process corresponds to the “vinyl bond content”.

**[0042]** When the vinyl bond content in all the conjugated diene monomer units of the hydrogenated block copolymer (I) is 5% by mass or more, in the hydrogenation process, precipitation of a hydrogenated conjugated diene block from the solution due to crystallization can be suppressed.

**[0043]** When the vinyl bond content in all the conjugated diene monomer units of the hydrogenated block copolymer (I) is 5% by mass or more, good compatibility with the olefin-based resin (II) described below is exhibited.

**[0044]** When the vinyl bond content in all the conjugated diene monomer unit of the hydrogenated block copolymer (I) is 80% by mass or less, the stickiness reduces, and hence a polishing pad having a small static friction coefficient can be obtained, and thus, a stable dressing property tends to be exhibited.

**[0045]** The vinyl bond content in all the conjugated diene monomer units of the hydrogenated block copolymer (I) can be controlled to fall in the above-described numerical range by, for example, using a modifier such as a tertiary amine compound, or an ether compound described below.

**[0046]** The vinyl bond content in all the conjugated diene monomer units of the hydrogenated block copolymer (I) can be measured by nuclear magnetic resonance (NMR) with a block copolymer before hydrogenation used as a sample, or can be measured with an infrared spectrophotometer described in Examples below. Alternatively, the vinyl bond content can be calculated by counting, in nuclear magnetic resonance (NMR) with the hydrogenated block copolymer used as a sample, a sum of structures having a single bond resulting from the hydrogenation in addition to a vinyl structure not hydrogenated.

#### <Content of All Vinyl Aromatic Monomer Units>

**[0047]** In the hydrogenated block copolymer (I), the content of all vinyl aromatic monomer units is preferably 40% by mass or more and 80% by mass or less, more preferably 50% by mass or more and 80% by mass or less, and further preferably 60% by mass or more and 80% by mass or less.

**[0048]** When the content of all the vinyl aromatic monomer units is 40% by mass or more, the stickiness of the hydrogenated block copolymer (I) reduces, and hence a polishing pad having a small static friction coefficient can be obtained, and thus, a stable dressing property tends to be exhibited.

**[0049]** When the content of all the vinyl aromatic monomer units is 80% by mass or less, adhesion of the polishing pad of the present embodiment to a material to be polished is increased, and thus, high flattening performance can be

exhibited in a polishing process. The content of all the vinyl aromatic monomer units in the hydrogenated block copolymer (I) can be measured with an ultraviolet spectrophotometer with a block copolymer before hydrogenation or a hydrogenated block copolymer after hydrogenation used as a sample.

**[0050]** The content of all the vinyl aromatic monomer units in the hydrogenated block copolymer (I) can be controlled to fall in the above-described numerical range by mainly adjusting the amount of a vinyl aromatic compound to be added to a polymerization reactor, a reaction temperature, and a reaction time.

#### <Polymer Block (a) Principally Containing Vinyl Aromatic Monomer Unit>

**[0051]** The hydrogenated block copolymer (I) used in the polishing pad of the present embodiment contains at least one polymer block (a) principally containing a vinyl aromatic monomer unit (condition (2) described above). Thus, pellet blocking can be prevented.

**[0052]** In the hydrogenated block copolymer (I), the content of the polymer block (a) is 10% by mass or more, preferably 15% by mass or more, and further preferably 20% by mass or more from the viewpoint of reducing the static friction coefficient.

**[0053]** When the content of the polymer block (a) principally containing a vinyl aromatic monomer unit is 10% by mass or more, the stickiness of the hydrogenated block copolymer (I) reduces, and hence the static friction coefficient reduces, and in addition, the static friction coefficient of the polishing pad of the present embodiment reduces, and thus, a stable dressing property tends to be exhibited.

**[0054]** In the hydrogenated block copolymer (I), the content of the polymer block (a) is preferably 50% by mass or less, more preferably 48% by mass or less, further preferably 46% by mass or less, and still further preferably 45% by mass or less.

**[0055]** When the content of the polymer block (a) principally containing a vinyl aromatic monomer unit in the hydrogenated block copolymer (I) is 50% by mass or less, the adhesion of the polishing pad of the present embodiment to a material to be polished is increased, and thus, high flattening performance can be exhibited in the polishing process.

**[0056]** The content of the polymer block (a) in the hydrogenated block copolymer (I) can be measured by a method using a nuclear magnetic resonance apparatus (NMR) with the block copolymer before hydrogenation or the hydrogenated block copolymer used as a sample (a method described in Y. Tanaka, et al., RUBBER CHEMISTRY and TECHNOLOGY, 54, 685 (1981); hereinafter referred to as the “NMR method”).

**[0057]** The content of the polymer block (a) in the hydrogenated block copolymer (I) can be controlled to fall in the above-described numerical range by principally adjusting the amount of a vinyl aromatic compound to be added to a polymerization reactor, a reaction temperature and a reaction time.

#### <Hydrogenated Copolymer Block (b)>

**[0058]** The content of the hydrogenated copolymer block (b) in the hydrogenated block copolymer (I) is preferably 40% by mass or more, more preferably 50% by mass or more, and further preferably 60% by mass or more. When the content of a vinyl aromatic monomer unit in the hydro-

genated copolymer block (b) is 40% by mass or more, the wear resistance of the polishing pad of the present embodiment in the polishing process is improved, and hence a high polishing rate can be retained for a long period of time.

[0059] The hydrogenated block copolymer (I) used in the polishing pad of the present embodiment preferably contains at least one hydrogenated copolymer block (b) containing a vinyl aromatic monomer unit, and a conjugated diene monomer unit.

[0060] The content of the vinyl aromatic monomer unit in the hydrogenated copolymer block (b) is preferably 5% by mass or more, more preferably 15% by mass or more, further preferably 30% by mass or more, and still further preferably 45% by mass or more.

[0061] When the content of the vinyl aromatic monomer unit in the hydrogenated copolymer block (b) is 5% by mass or more, the wear resistance of the polishing pad of the present invention in the polishing process is improved, and hence a high polishing rate can be retained for a long period of time. As a result, excellent durability is obtained.

[0062] The content of the vinyl aromatic monomer unit in the hydrogenated copolymer block (b) is preferably 79% by mass or less, more preferably 75% by mass or less, and further preferably 70% by mass or less.

[0063] When the content of the vinyl aromatic monomer unit in the hydrogenated copolymer block (b) is 79% by mass or less, the adhesion of the polishing pad of the present embodiment to a material to be polished is increased, and thus, high flattening performance can be exhibited in the polishing process.

[0064] It is noted that the content of the vinyl aromatic monomer unit in the hydrogenated copolymer block (b) can be measured using a nuclear magnetic resonance apparatus (NMR) or the like.

[0065] The content of the vinyl aromatic monomer unit in the hydrogenated copolymer block (b) can be controlled to fall in the above-described numerical range by adjusting the amounts of a vinyl aromatic compound and a conjugated diene to be added to a polymerization reactor, a reaction temperature and the like.

<Weight Average Molecular Weight of Hydrogenated Block Copolymer (I)>

[0066] A weight average molecular weight (Mw) of the hydrogenated block copolymer (I) used in the polishing pad of the present embodiment is, from the viewpoints of obtaining extrusion moldability in producing pellets of the hydrogenated block copolymer (I), and good mechanical strength and low stickiness of the polishing pad of the present embodiment, preferably 10,000 or more, more preferably 30,000 or more, and further preferably 50,000 or more.

[0067] The upper limit of the weight average molecular weight is preferably 400,000 or less, more preferably 300,000 or less, and further preferably 250,000 or less. When the weight average molecular weight (Mw) is 300,000 or less, the hydrogenated block copolymer (I) is easily melted at the time of producing (at the time of extrusion molding) pellets of the hydrogenated block copolymer (I), and hence strands are stabilized, which tends to improve extrusion moldability.

[0068] It is noted that the weight average molecular weight of the hydrogenated block copolymer (I) is obtained by performing gel permeation chromatography (GPC) measurement, and using a calibration curve obtained through

measurement of commercially available standard polystyrene (created by using a peak molecular weight of the standard polystyrene).

<Molecular Weight Distribution (Mw/Mn) of Hydrogenated Block Copolymer (I)>

[0069] A molecular weight distribution (Mw/Mn) of the hydrogenated block copolymer (I) used in the polishing pad of the present embodiment is not especially limited, and is preferably 10 or less, more preferably 3 or less, and further preferably 1.5 or less from the viewpoint of processability. The lower limit of the Mw/Mn is preferably 1 or more, more preferably 1.005 or more, and further preferably 1.01 or more from the viewpoint of the processability.

[0070] The weight average molecular weight (Mw) and a number average molecular weight (Mn) of the hydrogenated block copolymer (I) are obtained by performing gel permeation chromatography (GPC) measurement, and obtaining a peak molecular weight in the resultant chromatogram using a calibration curve obtained through measurement of commercially available standard polystyrene (created by using a peak molecular weight of the standard polystyrene). The molecular weight distribution (Mw/Mn) of the hydrogenated block copolymer (I) is obtained based on a ratio between the weight average molecular weight (Mw) and the number average molecular weight (Mn).

<Hydrogenation Rate of Double Bond of Conjugated Diene Monomer Unit in Hydrogenated Block Copolymer (I)>

[0071] A hydrogenation rate of a double bond of the conjugated diene monomer unit in the hydrogenated block copolymer (I) used in the polishing pad of the present embodiment is not especially limited, and is preferably 30% or more, more preferably 50% or more, further preferably 85% or more, and still further preferably 92% or more from the viewpoint of obtaining good heat resistance.

[0072] The hydrogenation rate of a double bond of the conjugated diene monomer unit in the hydrogenated block copolymer (I) can be controlled to fall in the above-described numerical range by adjusting a hydrogenation amount. The hydrogenation rate of the hydrogenated block copolymer (I) can be measured with a nuclear magnetic resonance apparatus (NMR) or the like.

<Structure of Hydrogenated Block Copolymer (I)>

[0073] The structure of the hydrogenated block copolymer (I) of the present embodiment is not especially limited, and examples include structures represented by the following general formulas.

[0074]  $a-b-a$ ,  $(a-b)_n-X$ ,  $c-(b-a)_n$ ,  $c-(a-b)_n$ ,  $c-(a-b-a)_n$ ,  $c-(b-a-b)_n$ ,  $c-(b-c-a)_n$ ,  $a-(c-b-c-a)_n$ ,  $a-c-(b-a)_n$ ,  $a-c-(a-b)_n$ ,  $a-c-(b-a)_n-b$ ,  $c-a-(b-a)_n-c$ ,  $a-c-(b-a)_n-c$ ,  $a-b-(c-a)_n-b$ ,  $a-c-(b-c)_n-a-c$ ,  $c-(a-b-c)_n-a-c$ ,  $a-(c-b)_n-c-a$ ,  $c-(a-c)_n-b-c-a-c$ ,  $[(a-b-c)_n]_m-X$ ,  $[a-(b-c)_n]_m-X$ ,  $[(a-b)_n-c]_m-X$ ,  $[(a-b-a)_n-c]_m-X$ ,  $[(b-a-b)_n-c]_m-X$ ,  $[(c-b-a)_n]_m-X$ ,  $[c-(b-a)_n]_m-X$ ,  $[c-(a-b-a)_n]_m-X$ , and  $[c-(b-a-b)_n]_m-X$ .

[0075] In these general formulas, a represents the polymer block (a) principally containing a vinyl aromatic monomer unit, b represents the hydrogenated copolymer block (b) containing a vinyl aromatic monomer unit and a conjugated diene monomer unit, and c represents the hydrogenated polymer block (c) principally containing a conjugated diene monomer unit.

**[0076]** Also in these general formulas,  $n$  represents an integer of 1 or more, and is preferably an integer of 1 to 5;  $m$  represents an integer of 2 or more, and is preferably an integer of 2 to 11; and  $X$  represents a residue of a coupling agent or a residue of a multifunctional initiator.

<Static Friction Coefficient of Hydrogenated Block Copolymer (I)>

**[0077]** A static friction coefficient of the hydrogenated block copolymer (I) used in the polishing pad of the present embodiment is preferably 2.5 or less, more preferably 2 or less, and further preferably 1.7 or less from the viewpoint of reducing the static friction coefficient of the polishing pad.

**[0078]** An example of the method for reducing the static friction coefficient includes a method in which stickiness is reduced by, for example, in polymerization of  $(a-b)_n-X$  polymer described above, reducing an unreacted component in a di-block polymer coupling reaction, reducing the vinyl bond content in all the conjugated diene monomer units in the hydrogenated block copolymer (I), or increasing the content of the polymer block (a) principally containing a vinyl aromatic monomer unit in the hydrogenated block copolymer (I).

**[0079]** The static friction coefficient can be measured in accordance with JIS K7125.

<Dynamic Friction Coefficient of Hydrogenated Block Copolymer (I)>

**[0080]** A dynamic friction coefficient of the hydrogenated block copolymer (I) used in the polishing pad of the present embodiment is preferably 1 or less, more preferably 0.8 or less, and further preferably 0.5 or less from the viewpoint of reducing the dynamic friction coefficient of the polishing pad.

**[0081]** Examples of a method for reducing the dynamic friction coefficient include the aforementioned method in which the static friction coefficient is reduced, and a method in which the content of the vinyl aromatic monomer unit in the hydrogenated copolymer block (b) is increased.

**[0082]** The dynamic friction coefficient can be measured in accordance with JIS K7125.

<Hardness of Hydrogenated Block Copolymer (I)>

**[0083]** The hydrogenated block copolymer (I) has a value of instant hardness measured with a type A durometer in accordance with JIS K6253 of preferably 60 or more, more preferably 70 or more, further preferably 80 or more, and still further preferably 85 or more from the viewpoint of inhibiting, in polishing a semiconductor, the semiconductor from falling off beyond the edge when the copolymer is used in a polishing pad.

**[0084]** Besides, the hydrogenated block copolymer (I) has a value of instant hardness measured with a type D durometer in accordance with JIS K6253 of preferably 70 or less, more preferably 60 or less, and further preferably 50 or less from the viewpoint of inhibiting occurrence of scratch on a substrate when the copolymer is used in a polishing pad.

**[0085]** The hardness of the hydrogenated block copolymer (I) can be controlled to fall in the above-described numerical range by adjusting the weight average molecular weight of the hydrogenated block copolymer (I), the content of the polymer block (a), the content of the vinyl aromatic monomer unit in the hydrogenated copolymer block (b), the

content of the hydrogenated polymer block (c), the vinyl bond content in the conjugated diene monomer unit, and the hydrogenation rate of a double bond of the conjugated diene monomer unit.

**[0086]** Alternatively, the hardness may be controlled to fall in the above-described numerical range by adjusting a  $\tan\delta$  peak temperature (loss tangent) at  $-25^\circ\text{C}$ . to  $60^\circ\text{C}$ . in a viscoelasticity measurement chart of the hydrogenated block copolymer (I), namely, by adjusting a glass transition temperature derived from the hydrogenated copolymer block (b), by performing, under conditions described below, a polymerization reaction using a prescribed modifier for adjusting the vinyl bond content of the hydrogenated copolymer block (b), adjusting the content of the vinyl aromatic monomer unit in the hydrogenated copolymer block (b), and adjusting the copolymerizability between the vinyl aromatic compound and the conjugated diene.

**[0087]** The hardness of the hydrogenated block copolymer (I) tends to be improved by, for example, increasing the content of the polymer block (a) in the hydrogenated block copolymer (I), increasing the content of the vinyl aromatic monomer unit in the hydrogenated copolymer block (b), reducing the content of the hydrogenated polymer block (c), reducing the hydrogenation rate of a double bond of the conjugated diene monomer unit, and increasing the  $\tan\delta$  peak temperature ( $^\circ\text{C}$ .) at  $-20^\circ\text{C}$ . to  $60^\circ\text{C}$ . For increasing the  $\tan\delta$  peak temperature ( $^\circ\text{C}$ .) at  $-20^\circ\text{C}$ . to  $60^\circ\text{C}$ ., it is particularly effective to increase the content of the vinyl aromatic monomer unit in the hydrogenated copolymer block (b), and to increase the vinyl bond content in the hydrogenated copolymer block (b). The  $\tan\delta$  peak temperature ( $^\circ\text{C}$ .) can be controlled also by adjusting the copolymerizability between the vinyl aromatic compound and the conjugated diene through adjustment of polymerization conditions described below.

( $\tan\delta$  (loss tangent) Peak Temperature in Viscoelasticity Measurement Chart of Hydrogenated Block Copolymer (I))

**[0088]** The hydrogenated block copolymer (I) of the present embodiment has, in a viscoelasticity measurement chart, at least one peak of  $\tan\delta$  (loss tangent) at preferably  $-25^\circ\text{C}$ . or more and  $60^\circ\text{C}$ . or less, more preferably  $-15^\circ\text{C}$ . or more and  $50^\circ\text{C}$ . or less, further preferably  $-5^\circ\text{C}$ . or more and  $40^\circ\text{C}$ . or less, and still further preferably  $0^\circ\text{C}$ . or more and  $30^\circ\text{C}$ . or less.

**[0089]** Such a peak of  $\tan\delta$  is derived from the hydrogenated copolymer block (b) in the hydrogenated block copolymer (I). It is preferable, from the viewpoint of improving the flattening performance of the polishing pad exhibited in polishing, that at least one such peak is present in a range of  $-25^\circ\text{C}$ . or more and  $60^\circ\text{C}$ . or less.

**[0090]** As described above, the hydrogenated copolymer block (b) is obtained by hydrogenating a copolymer block containing a conjugated diene monomer unit and a vinyl aromatic monomer unit.

**[0091]** In the hydrogenated block copolymer (I) of the present embodiment, in order that at least one peak of  $\tan\delta$  (loss tangent) is present in the range of  $-25^\circ\text{C}$ . or more and  $60^\circ\text{C}$ . or less, it is effective to control a mass ratio of the conjugated diene monomer unit/the vinyl aromatic monomer unit, and the mass ratio of the conjugated diene monomer unit/the vinyl aromatic monomer unit is preferably 79/21 to 16/84, more preferably 75/35 to 18/82, and further preferably 70/30 to 25/75.

**[0092]** In order that at least one peak of  $\tan\delta$  (loss tangent) is present in the range of 0° C. or more and 30° C. or less, it is effective to control the mass ratio of the conjugated diene monomer unit/the vinyl aromatic monomer unit, and the mass ratio of the conjugated diene monomer unit/the vinyl aromatic monomer unit is preferably 65/35 to 16/84, more preferably 60/40 to 25/75, and further preferably 55/45 to 30/70. In order to obtain a hydrogenated block copolymer (I) having at least one peak of  $\tan\delta$  (loss tangent) in the range of -25° C. or more and 60° C. or less, a block copolymer, which is obtained by performing, under conditions described below, a polymerization reaction using a prescribed modifier for adjusting the vinyl bond content of the hydrogenated copolymer block (b), adjusting the content of the vinyl aromatic monomer unit in the hydrogenated copolymer block (b), and adjusting the copolymerizability between the vinyl aromatic compound and the conjugated diene, may be hydrogenated.

**[0093]** The  $\tan\delta$  of the hydrogenated block copolymer (I) can be measured with a viscoelasticity measuring device (manufactured by TA Instruments Japan Inc., ARES) under conditions of a strain of 0.5%, a frequency of 1 Hz, and a rate of temperature increase of 3° C./min.

(Method for Producing Hydrogenated Block Copolymer Composition)

**[0094]** A hydrogenated block copolymer composition used as a starting material of the polishing pad of the present embodiment can be produced by a conventionally known method.

**[0095]** Examples of the method for producing a hydrogenated block copolymer composition of the present embodiment include, but are not limited to, a method in which respective components (the hydrogenated block copolymer (I), the polyolefin-based resin (II) described below, and another additive if necessary) are melt kneaded using a mixer, such as a Bunbury mixer, a single screw extruder, a twin screw extruder, a Ko Kneader, or a multi-screw extruder, and a method in which the respective components are dissolved or dispersed in a solvent to be mixed, followed by removal of the solvent by heating.

**[0096]** In particular, a melt kneading method using an extruder is suitably employed from the viewpoints of productivity and good kneadability.

**[0097]** The shape of the hydrogenated block copolymer composition can be, but is not limited to, an arbitrary shape such as a pellet shape, a sheet shape, a strand shape, or a chip shape. After the melt kneading, a molded article may be directly produced.

(Hardness of Hydrogenated Block Copolymer Composition)

**[0098]** The hydrogenated block copolymer composition used as the starting material of the polishing pad of the present embodiment has, when used in the polishing pad, a value of hardness of preferably 60 or more, more preferably 70 or more, further preferably 80 or more, and still further preferably 85 or more from the viewpoint of inhibiting a semiconductor from falling off beyond the edge in polishing the semiconductor.

**[0099]** Besides, the hydrogenated block copolymer composition has, when used in the polishing pad, a value of instant hardness measured with a type D durometer in accordance with JIS K6253 of preferably 70 or less, more

preferably 60 or less, and further preferably 50 or less from the viewpoint of inhibiting occurrence of scratch on a substrate.

**[0100]** The hardness of the hydrogenated block copolymer composition can be controlled by adjusting the hardness of the hydrogenated block copolymer (I) contained in the hydrogenated block copolymer composition, the flexural strength of the component (II), and the composition ratio between the components (I) and (II).

(Static Friction Coefficient of Hydrogenated Block Copolymer Composition)

**[0101]** A static friction coefficient of the hydrogenated block copolymer composition used in the polishing pad of the present embodiment is preferably 2.5 or less, more preferably 2 or less, and further preferably 1.7 or less from the viewpoint of reducing the static friction coefficient of the polishing pad.

**[0102]** An example of a method for reducing the static friction coefficient includes, in addition to a method in which the static friction coefficient of the hydrogenated block copolymer (I) itself is reduced, a method in which the olefin-based resin (II) is added. The static friction coefficient can be measured in accordance with JIS K7125.

(Dynamic Friction Coefficient of Hydrogenated Block Copolymer Composition)

**[0103]** A dynamic friction coefficient of the hydrogenated block copolymer composition used in the polishing pad of the present embodiment is preferably 1 or less, more preferably 0.8 or less, and further preferably 0.5 or less from the viewpoint of reducing the dynamic friction coefficient of the polishing pad.

**[0104]** An example of a method for reducing the dynamic friction coefficient includes, in addition to a method in which the dynamic friction coefficient of the hydrogenated block copolymer (I) itself is reduced, a method in which the olefin-based resin (II) is added.

**[0105]** The dynamic friction coefficient can be measured in accordance with JIS K7125.

<Olefin-based Resin (II)>

**[0106]** The hydrogenated block copolymer composition contained in the foam body of the present embodiment contains the olefin-based resin (II).

**[0107]** Examples of the olefin-based resin (II) used in the foam body of the present embodiment include, but are not limited to, homopolymers of  $\alpha$ -olefins such as polyethylene (PE), polypropylene (PP), 1-butene, 1-pentene, 1-hexene, 3-methyl-1-butene, 4-methyl-1-pentene, and 1-octene. Other examples include a random copolymer or a block copolymer containing a combination of olefins selected from the group consisting of ethylene, propylene, butene, pentene, hexene and octene.

**[0108]** Specific examples include ethylene and/or propylene- $\alpha$ -olefin copolymers such as an ethylene-propylene copolymer, an ethylene-1-butene copolymer, an ethylene-3-methyl-1-butene copolymer, an ethylene-4-methyl-1-pentene copolymer, an ethylene-1-hexene copolymer, an ethylene-1-octene copolymer, an ethylene-1-decene copolymer, a propylene-1-butene copolymer, a propylene-1-hexene copolymer, a propylene-1-octene copolymer, a propylene-4-methyl-1-pentene copolymer, an ethylene-propylene-1-

butene copolymer, a propylene-1-hexene-ethylene copolymer, and a propylene-1-octene-ethylene copolymer.

[0109] A copolymer of ethylene and/or propylene encompasses a copolymer with another unsaturated monomer excluding the xx-olefin.

[0110] Examples of the copolymer with another unsaturated monomer include, but are not limited to, copolymers of ethylene and/or propylene with unsaturated organic acids or derivatives thereof, such as acrylic acid, methacrylic acid, maleic acid, itaconic acid, methyl acrylate, methyl methacrylate, maleic anhydride, aryl maleimide, and alkyl maleimide; copolymers of ethylene and/or propylene with vinyl esters such as vinyl acetate; and copolymers of ethylene and/or propylene with non-conjugated dienes such as dicyclopentadiene, 4-ethylidene-2-norbornene, 4-methyl-1,4-hexadiene, and 5-methyl-1,4-hexadiene. The olefin-based resin (II) preferably contains at least one polypropylene-based resin from the viewpoint of obtaining economic efficiency, and good compatibility contained in the hydrogenated block copolymer composition contained in the foam body of the present embodiment to attain high transparency.

[0111] The olefin-based resin (II) may be modified with a prescribed functional group.

[0112] The functional group is not especially limited, and examples include an epoxy group, a carboxy group, an acid anhydride group, and a hydroxyl group.

[0113] A functional group-containing compound or a denaturant to be used for modifying the olefin-based resin (II) is not especially limited, and includes the following compounds:

[0114] Unsaturated epoxides such as glycidyl methacrylate, glycidyl acrylate, vinyl glycidyl ether, and allyl glycidyl ether; and unsaturated organic acids such as maleic acid, fumaric acid, itaconic acid, citraconic acid, allyl succinic acid, maleic anhydride, fumaric anhydride, and itaconic anhydride. Other unlimited examples include an ionomer and chlorinated polyolefin.

[0115] From the viewpoints of obtaining economic efficiency and good compatibility in the hydrogenated block copolymer composition contained in the foam body of the present embodiment to attain high transparency, the olefin-based resin (II) is preferably a polypropylene-based resin such as a polypropylene homopolymer or an ethylene-propylene random or block copolymer.

[0116] In particular, from the viewpoint of the transparency and flexibility, the olefin-based resin (II) is more preferably an ethylene-propylene random copolymer.

[0117] The olefin-based resin (II) may contain a single material, or may contain two or more materials.

#### <Content of Component (I) in Hydrogenated Block Copolymer Composition>

[0118] The content of the hydrogenated block copolymer (I) in the hydrogenated block copolymer composition used as the starting material of the polishing pad of the present embodiment is 5% by mass or more, preferably 40% by mass or more, and more preferably 70% by mass or more from the viewpoint of improving the polishing rate and the flattening performance in a semiconductor polishing process when the composition is used in the polishing pad. The upper limit of the content may be 100% by mass.

[0119] When the content of the hydrogenated block copolymer (I) in the hydrogenated block copolymer composition is 40% by mass or more, a more excellent polishing rate is obtained.

#### [Foam Body]

[0120] The polishing pad of the present embodiment is preferably a foam body.

[0121] In the present embodiment, the foam body includes foams.

[0122] Since the polishing pad of the present embodiment is a foam body, the value of the static friction coefficient can be easily adjusted to fall in the prescribed range.

#### (Average Foam Size, Distribution, and Closed Cell Ratio of Foam Body)

[0123] An average foam size of the foam body used in the present embodiment is not especially limited, and is preferably 20 to 500  $\mu\text{m}$ , more preferably 30 to 300  $\mu\text{m}$ , and particularly preferably 40 to 200  $\mu\text{m}$  from the viewpoint of retaining good slurry particle retention with clogging of slurry particles suppressed.

[0124] The average foam size of the foam body used in the present embodiment can be obtained as an arithmetic mean value of foam sizes obtained based on a volume of each foam described below.

[0125] A foam size distribution of the foam body can be obtained based on a volume-based foam size distribution curve described below.

[0126] The difference value between a foam size having cumulative volume frequency of 80% and a foam size having cumulative volume frequency of 20% is preferably 50  $\mu\text{m}$  or more from the viewpoint of adjusting the static friction coefficient to the above-described range.

[0127] When the difference value between a foam size having cumulative volume frequency of 80% and a foam size having cumulative volume frequency of 20% (foam size having cumulative volume frequency of 80%-foam size having cumulative volume frequency of 20%) is large, foam sizes can be distributed in a comparatively wide range. As a result, the static friction coefficient of the resultant polishing pad can be reduced.

[0128] A closed cell ratio of the foam body can be obtained by measuring a closed cell ratio (%) of the foam body in accordance with ASTM D1940-62T. The closed cell ratio is not especially limited, and is preferably 5% or more, more preferably 7% or more, and particularly preferably 10% or more from the viewpoint of retaining good slurry particle retention.

[0129] The average foam size, the distribution, and the closed cell ratio of the foam body used in the polishing pad can be adjusted by changing the amount of a foaming agent to be compounded, the viscosity of the composition, and foaming conditions.

[0130] The volume-based foam size distribution curve can be obtained with an X-ray CT scanner (for example, TDM1000H-1 manufactured by Yamato Scientific Co., Ltd.) as follows.

[0131] The volume of each foam included in a measurement target range of a resin foam body is measured, and a diameter of a true sphere having the same volume is defined as the foam size of the foam.



[0132] Here, the term “average foam size” means an arithmetic mean value of foam sizes obtained based on the volumes of respective foams [=sum of respective foam sizes/number of foams].

[0133] The volume-based foam size distribution curve can be obtained based on data of a number-based foam size distribution curve.

[0134] Specifically, the number of foams is obtained at a constant interval from a foam size of 0  $\mu\text{m}$ , and a number-based foam size distribution curve is obtained by assuming that the “number of foams in each interval” is the “number of foams having the upper limit size of the interval”. Based on data of the number-based foam size distribution curve, a sum of volumes of foams is obtained at a constant interval from the foam size of 0  $\mu\text{m}$ , and the volume-based foam size distribution curve can be obtained by assuming that the “sum of volumes of foams” is the “volume of foams having the upper limit size of the interval”.

[0135] The constant interval is preferably set to 20  $\mu\text{m}$  or less from the viewpoint of accurately determining a peak position.

#### [Method for Producing Foam Body]

[0136] A method for producing a foam body for a polishing pad of the present embodiment is not especially limited, and for example, includes a method in which a foaming agent and a crosslinking agent are added to a hydrogenated block copolymer composition to be melted for mixing, and the resultant is thermally foamed in a mold to produce a foam body. The resultant foam body may be appropriately cut into a desired size to be used as the polishing pad.

[0137] The crosslinking agent used in the present embodiment is not especially limited, and is preferably a radical generator that has a decomposition temperature equal to or higher than a flow start temperature of a resin to be used, and is decomposed by heating to generate a free radical, thereby forming a crosslinking bond between or in molecules. Specific examples include organic peroxides, such as dicumyl peroxide, 1,1-di-*t*-butyl peroxy-3,3,5-trimethyl cyclohexane, 2,5-dimethyl-2,5-di-*t*-butyl peroxy hexane, 2,5-dimethyl-2,5-di-*tert*-butyl peroxy hexane,  $\alpha$ ,  $\alpha$ -di-*tert*-butyl peroxy di-isopropylbenzene, tertiary butyl peroxy ketone, and tertiary butyl peroxy benzoate. In accordance with the type of resin to be used, an optimal organic peroxide should be selected.

[0138] The foaming agent is not especially limited, and an inorganic foaming agent, an organic foaming agent, or a physical foaming agent can be used.

[0139] Examples of the inorganic foaming agent include, but are not limited to, sodium bicarbonate, ammonium carbonate, ammonium bicarbonate, ammonium nitrite, an azide compound, sodium borohydride, aluminum acetate, and a metal powder.

[0140] Examples of the organic foaming agent include, but are not limited to, azodicarbonamide, azobisformamide, azobisisobutyronitrile, barium azodicarboxylate, N,N'-dinitrosopentamethylenetetramine, N,N'-dinitroso-N,N'-dimethylterephthalamide, benzenesulfonyl hydrazide, *p*-toluenesulfonyl hydrazide, *p,p'*-oxybisbenzenesulfonyl hydrazide, and *p*-toluenesulfonyl semicarbazide.

[0141] Examples of the physical foaming agent include, but are not limited to, hydrocarbons such as pentane, butane, and hexane; halogenated hydrocarbons such as methyl chloride and methylene chloride; a gas such as nitrogen, carbon

dioxide, and air; and fluorinated hydrocarbons such as trichlorofluoromethane, dichlorodifluoromethane, trichlorotrifluoroethane, chlorodifluoroethane, and hydrofluorocarbon.

[0142] These foaming agents may be used in combination.

#### (Foaming Aid)

[0143] In the process for producing the foam body, a foaming aid may be used together with the foaming agent.

[0144] The foaming aid is not especially limited, and those generally conventionally used as a foaming aid can be used.

[0145] Examples include a urea compound, a zinc compound such as zinc oxide, zinc stearate, zinc benzenesulfinate, zinc toluenesulfonate, zinc trifluoromethanesulfonate, and zinc carbonate, and a lead compound such as lead dioxide, and tribasic lead.

#### (Nucleating Foaming Agent)

[0146] In the process for producing the foam body, a nucleating foaming agent may be used.

[0147] The nucleating foaming agent is not especially limited, and those generally conventionally used as a nucleating foaming agent can be used.

[0148] Examples include titanium oxide, talc, kaolin, clay, calcium silicate, silica, sodium citrate, calcium carbonate, diatomite, calcined perlite, zeolite, bentonite, glass, limestone, calcium sulfate, aluminum oxide, titanium oxide, magnesium carbonate, sodium carbonate, ferrous carbonate, and a polytetrafluoroethylene powder.

#### (Foaming Ratio)

[0149] A foaming ratio of the foam body used in the present embodiment is not especially limited, and is preferably 1.5 to 4-fold, more preferably 1.7 to 3.5-fold, and particularly preferably 2 to 3-fold from the viewpoint of obtaining a good polishing rate.

[0150] The foaming ratio and the like of the foam body can be adjusted by changing the amount of the foaming agent to be compounded, the viscosity of the composition, and the foaming conditions.

[0151] The shape of a polishing base of the polishing pad of the present embodiment is not especially limited, can be, for example, a disk shape, a polygonal column shape, or the like, and can be appropriately selected in accordance with a polishing device in which the polishing pad of the present embodiment is attached to be used.

[0152] Also the size of the polishing base is not especially limited, and for example, when the polishing base is in a disk shape, the diameter may be 150 to 1200 mm, and preferably 500 to 800 mm, and the thickness may be 1.0 to 5.0 mm, and preferably 1.5 to 3.0 mm.

[0153] The polishing base of the polishing pad of the present embodiment may have a groove on a polishing surface. This groove functions as a channel that holds an aqueous dispersion supplied in polishing to uniformly distribute the dispersion on the polishing surface, and temporarily keeps wastes such as a polishing swarf and used aqueous dispersion to externally discharge the wastes.

[0154] The shape of the groove is not especially limited, and may be, for example, a spiral shape, a concentric shape, a radial shape, or the like.

[0155] The polishing base of the polishing pad of the present embodiment may have a recess on a non-polishing

surface (back surface). This recess has functions of releasing excessive stress that may be locally caused in polishing, and more effectively inhibiting occurrence of a surface defect such as a scratch on a polished surface.

**[0156]** The shape of the recess is not especially limited, and may be, for example, a circular shape, a polygonal shape, a spiral shape, a concentric shape, a radial shape, or the like.

**[0157]** The polishing pad of the present embodiment may have a portion having another function in addition to the polishing portion. An example of the portion having another function includes a window portion for detecting an end-point with an optical endpoint detector. For the window portion, for example, a material having, when the thickness is 2 mm, a transmittance of light of any wavelength of 100 to 300 nm of preferably 0.1% or more, and more preferably 2% or more, or having a cumulative transmittance in any wavelength region from 100 to 300 nm of preferably 0.1% or more, and more preferably 2% or more may be used. The material of the window portion is not especially limited as long as it satisfies the above-described optical property, and may have a similar composition to that of the polishing base described above.

**[0158]** A method for producing the polishing base included in the polishing pad of the present embodiment is not especially limited, and a method for forming a groove and a recess (hereinafter, together referred to as the “groove and the like”) optionally included in the polishing base is not also especially limited. For example, a composition for a chemical mechanical polishing pad to be used as the polishing base of the polishing pad is prepared in advance, and after molding the composition into a desired outline shape, the groove and the like may be formed thereon by machining. Alternatively, when the composition for a polishing pad is molded with a mold having a pattern of the groove and the like, the outline and the groove and the like of the polishing base can be simultaneously formed.

**[0159]** A method for obtaining the composition for a polishing pad is not especially limited. For example, the composition may be obtained by mixing necessary materials including a prescribed organic material with a mixer or the like. Any conventionally known mixers may be used. Examples of the mixer include a roll, kneader, a Bunbury mixer, and a (single screw or multi-screw) extruder.

**[0160]** The polishing pad of the present embodiment may include only the polishing base described above, or may be a multilayer pad including a supporting layer on the non-polishing surface side of the above-described polishing base.

**[0161]** The supporting layer is a layer supporting the polishing base on the back surface of the polishing surface. The property of the supporting layer is not especially limited, and the supporting layer is preferably softer than the polishing base. When a softer supporting layer is included, even if the thickness of the polishing base is small, for example, 1.0 mm or less, the polishing base can be prevented from rising at the time of polishing, or the surface of a polishing layer can be prevented from bending, and thus, the polishing can be stably performed.

**[0162]** The supporting layer may be a porous body (foam body), or a non-porous body. The plane shape thereof is not especially limited, and may be the same as or different from that of the polishing layer. The plane shape of the supporting layer can be, for example, a circular shape, or a polygonal shape (a square or the like).

**[0163]** The thickness thereof is not also especially limited, and can be, for example, preferably 0.1 to 5 mm, and more preferably 0.5 to 2 mm.

**[0164]** A material constituting the supporting layer is not also especially limited, and an organic material is preferably used because such a material is easily molded into desired shape and property, and can be provided with appropriate elasticity or the like.

**[0165]** The polishing pad of the present embodiment described so far can suppress occurrence of a scratch on a polished surface, and provides a high quality polished surface.

**[0166]** The polishing pad may be obtained by solution impregnation of a nonwoven substrate or a suede substrate with the hydrogenated block copolymer (I).

**[0167]** A fiber included in a nonwoven fabric used in the nonwoven substrate is not especially limited, and examples thereof include an aromatic polyester fiber containing one or more of polyethylene terephthalate (PET), isophthalic acid modified polyethylene terephthalate, sulfoisophthalic acid modified polyethylene terephthalate, polybutylene terephthalate, and polyhexamethylene terephthalate; an aliphatic polyester fiber containing one or more of polylactic acid, polyethylene succinate, polybutylene succinate, polybutylene succinate adipate, and a polyhydroxybutyrate-polyhydroxyvalerate copolymer; a polyamide fiber containing one or more of polyamide 6, polyamide 66, polyamide 10, polyamide 11, polyamide 12, and polyamide 6-12; a polyolefin fiber containing one or more of polypropylene, polyethylene, polybutene, polymethylpentene, and chlorinated polyolefin; a modified polyvinyl alcohol fiber containing modified polyvinyl alcohol having 25 to 70 mol % of ethylene unit; and an elastomer fiber containing an elastomer such as a polyurethane elastomer, a polyamide elastomer, or a polyester elastomer. One of these fibers may be singly used, or a combination of two or more of these may be used.

**[0168]** A solvent used in the solution impregnation is not especially limited, and examples thereof include methyl ethyl ketone (MEK); an aliphatic hydrocarbon such as n-butane, isobutane, n-pentane, n-hexane, n-heptane, or n-octane; an alicyclic hydrocarbon such as cyclohexane, cycloheptane, or methylcycloheptane; and an aromatic hydrocarbon such as benzene, toluene, xylene, and ethylbenzene.

#### <Hardness of Polishing Pad>

**[0169]** A value of instant hardness of the polishing pad measured with a type A durometer in accordance with JIS K6253 or a spring-type Asker C type durometer in accordance with SRIS 0101 is, when used in the polishing pad, preferably 30 C or more, more preferably 35 C or more, further preferably 40 C (corresponding to 20 A) or more, and still further preferably 45 C (corresponding to 22 A) or more from the viewpoint of inhibiting, in polishing a semiconductor, the semiconductor from falling off beyond the edge.

**[0170]** Besides, when used in the polishing pad, a value of instant hardness of the polishing pad measured with a type A or D durometer in accordance with JIS K6253 is preferably 35 D (corresponding to 90 A) or less, more preferably 80 A or less, and further preferably 70 A or less from the viewpoint of inhibiting occurrence of a scratch on the substrate.

(Static Friction Coefficient of Polishing Pad)

[0171] A static friction coefficient of the polishing pad of the present embodiment is preferably 1.2 or less, more preferably 1.0 or less, and further preferably 0.9 or less.

[0172] Examples of a method for reducing the static friction coefficient include, in addition to a method in which the static friction coefficient of the hydrogenated block copolymer composition itself is reduced, a method in which a foam size distribution is improved, and a method in which a groove is formed.

[0173] When the static friction coefficient of the polishing pad is within the above-described range, stable dressing performance can be exhibited.

[0174] The static friction coefficient can be measured in accordance with JIS K7125.

(Dynamic Friction Coefficient of Polishing Pad)

[0175] A dynamic friction coefficient of the polishing pad of the present embodiment is preferably 0.65 or less, more preferably 0.60 or less, and further preferably 0.55 or less from the viewpoint of reducing the dynamic friction coefficient of the polishing pad.

[0176] Examples of a method for reducing the dynamic friction coefficient include, in addition to a method in which the dynamic friction coefficient of the hydrogenated block copolymer composition itself is reduced, a method in which a foam size distribution is improved, and a method in which a groove is formed.

[0177] When the dynamic friction coefficient of the polishing pad is within the above-described range, the polishing pad is not worn even if a semiconductor or the like is polished for a long period of time, and thus, a high polishing rate can be retained.

[0178] The dynamic friction coefficient can be measured in accordance with JIS K7125.

[0179] A dressing process of subjecting the surface and/or the back surface of the polishing layer to dressing processing (grinding processing) may be performed. A method of the dressing processing (grinding processing) is not especially limited, and the grinding may be performed by any known method. A specific example includes grinding with a diamond dresser.

[0180] The polishing pad of the present embodiment may be attached to a commercially available polishing device to be used in a polishing process by a known method.

[0181] The polishing pad of the present embodiment can be used in a wide range of polishing process for producing a semiconductor device.

[0182] A material to be polished that can be polished with the polishing pad of the present embodiment is not especially limited, and examples include materials requiring flatness, such as a silicon wafer, glass, a magnetic disc, sapphire, and a semiconductor of SiC, GaN or the like. In particular, a method for producing a polished product of the present embodiment may be suitably used as a method for producing a semiconductor of SiC, GaN, or the like.

[0183] A polishing slurry may contain, in accordance with the material to be polished and polishing conditions, water, a chemical component of an oxidizing agent typified by hydrogen peroxide and potassium permanganate, an additive, an abrasive grain (polishing particle; for example, SiC, SiO<sub>2</sub>, Al<sub>2</sub>O<sub>3</sub>, or CeO<sub>2</sub>), or the like.

[0184] A double-sided tape for fixing the polishing pad on the polishing device is not especially limited, and can be optionally selected from double-sided tapes known in this technical field.

## EXAMPLES

[0185] Now, the present embodiment will be described in detail with reference to specific examples and comparative examples, and it is noted that the present embodiment is not limited to these examples and comparative examples.

[0186] Measurement methods and evaluation methods of physical properties applied in the examples and comparative examples are as follows.

[0187] The structure specification and the physical property measurement of hydrogenated block copolymers used in foam bodies of the examples and comparative examples were conducted as follows.

### Method for Specifying Structure of Hydrogenated Block Copolymer

#### (1) Content of All Vinyl Aromatic Monomer Units (styrene) in Hydrogenated Block Copolymer (I)

[0188] A hydrogenated block copolymer was used to measure a content of all vinyl aromatic monomer units (styrene) with a UV spectrophotometer (UV-2450, manufactured by Shimadzu Corporation).

#### (2) Hydrogenation Rate of Double Bond of Conjugated Diene Monomer Unit in Hydrogenated Block Copolymer (I)

[0189] A hydrogenation rate of a double bond of the conjugated diene monomer unit was measured by using the hydrogenated block copolymer with a nuclear magnetic resonance apparatus (ECS400, manufactured by JEOL RESONANCE Inc.).

#### (3) Content of Polymer Block (a) in Hydrogenated Block Copolymer (I)

[0190] The content of the polymer block (a) principally containing a vinyl aromatic monomer unit was measured by using the hydrogenated block copolymer with a nuclear magnetic resonance apparatus (NMR) (by a method described in Y. Tanaka, et al., RUBBER CHEMISTRY and TECHNOLOGY, 54, 685 (1981); hereinafter referred to as the "NMR method").

#### (4) Content of Hydrogenated Copolymer Block (b) in Hydrogenated Block Copolymer (I)

[0191] The content of the hydrogenated copolymer block (b) in the hydrogenated block copolymer (I) was calculated in accordance with a calculation formula, 100-(content of hydrogenated copolymer block (a) in hydrogenated block copolymer (I)).

#### (5) Vinyl Bond Content in Hydrogenated Block Copolymer (I)

[0192] The vinyl bond content was measured by using the hydrogenated block copolymer with a nuclear magnetic resonance apparatus (NMR).

[0193] The vinyl bond content in the conjugated diene monomer unit in the hydrogenated block copolymer was

obtained based on a ratio of a total area of 1,2-bond and 3,4-bond peaks to a total area of all peaks involved in the conjugated diene monomer unit (1,2-bond, 3,4-bond, and 1,4-bond peaks) among peaks obtained by NMR measurement.

(6) Content of Vinyl Aromatic Monomer Unit in Hydrogenated Copolymer Block (b) Contained in Hydrogenated Block Copolymer (I)

**[0194]** Based on a difference between the content of all vinyl aromatic monomer units in the hydrogenated block copolymer (I) measured as described in (1) above, and the content of the polymer block (a) principally containing a vinyl aromatic monomer unit in the hydrogenated block copolymer (I) measured as described in (3) above, the content of the vinyl aromatic monomer unit in the hydrogenated copolymer block (b) in the entire polymer was calculated, and based on a ratio to the content of the hydrogenated copolymer block (b) in the hydrogenated block copolymer (I) measured as described in (4) above, the content of the vinyl aromatic monomer unit in the hydrogenated copolymer block (b) was calculated.

Methods for Measuring Physical Properties of Hydrogenated Block Copolymer

(1) Hardness

**[0195]** Values of 0 seconds hardness and 15 seconds hardness were measured respectively with a type A durometer and a type D durometer in accordance with JIS K6253.

**[0196]** Hardness values obtained 0 seconds and 15 seconds after a probe of the durometer touched a measurement sample were measured.

**[0197]** In a table below, these hardness values are shown respectively as Hardness (JIS-A, 0 seconds), Hardness (JIS-A, 15 seconds), Hardness (JIS-D, 0 seconds), and Hardness (JIS-D, 15 seconds).

**[0198]** When the hardness measured with the type D durometer had a value less than 20, the value obtained with the type A durometer was used as the hardness value, and when the hardness measured with the type A durometer had a value over 90, the value obtained with the type D durometer was used.

**[0199]** As a guide, hardness of 94 measured with a type A durometer corresponds to hardness of 45 measured with a type D durometer.

(2) Melt Flow Rate (MFR, unit: g/10 min)

**[0200]** An MFR was measured under conditions of a temperature of 230° C. and a load of 2.16 kg in accordance with JIS K7210.

(3) Static Friction Coefficient

**[0201]** In accordance with JIS K7125, a 200 g load of brass was placed with a contact area of 63 mm×63 mm on a 2 mm press produced by a method described below by using each of hydrogenated block copolymers (I)-1 to (I)-4 as a starting material, and a test was started within 3 seconds thereafter to move the brass in parallel against the test piece at a test speed of 100 mm/min. Here, a test force with which the test piece started to move was divided by the contact area to obtain a static friction coefficient.

(4) Dynamic Friction Coefficient

**[0202]** In accordance with JIS K7125, a test was performed by the same method as in (3) described above, and a dynamic friction coefficient was obtained by dividing, by the contact area, an average of test forces at which the test force was stabilized after the test piece started to move.

Method for Measuring Physical Properties of Polishing Pad

(1) Average Foam Size

**[0203]** The volume of each foam included in a polishing pad was measured with an X-ray CT scanner (for example, TDM1000H-1 manufactured by Yamato Scientific Co., Ltd.), and a diameter of a true sphere having the same volume was defined as the foam size of the foam. An arithmetic mean value of foam sizes obtained based on the volumes of respective foams [=sum of respective foam sizes/number of foams] was determined as the average foam size.

(2) Foam Size Distribution

**[0204]** An X-ray CT scanner (for example, TDM1000H-1 manufactured by Yamato Scientific Co., Ltd.) was used to obtain a volume-based foam size distribution curve of foams in a polishing pad, and when a difference value between a foam size having cumulative volume frequency of 80% and a foam size having cumulative volume frequency of 20% (foam size having cumulative volume frequency of 80%-foam size having cumulative volume frequency of 20%) was 50 μm or more, the foam size distribution was determined to be wide, and when was 50 μm or less, the foam size distribution was determined to be narrow.

(3) Static Friction Coefficient

**[0205]** Each of the produced polishing pads was used to measure the static friction coefficient by the same method employed for measuring the static friction coefficient of the hydrogenated block copolymer.

(4) Dynamic Friction Coefficient

**[0206]** Each of the produced polishing pads was used to measure the dynamic friction coefficient by the same method employed for measuring the dynamic friction coefficient of the hydrogenated block copolymer.

(5) Dressing Property

**[0207]** After adhering a double-sided tape DF8391S manufactured by TOYOCEM CO., LTD. to each of the produced polishing pads, the resultant polishing pad was fixed on a surface plate of a 15-inch single side polishing device (manufactured by HITECHNOTH Corporation), and subjected to dressing with a metal bond SD #270 at a rotation speed of the surface plate of 60 rpm. When the frictional force was so high that the polishing pad could not be dressed, it was evaluated to have a dressing property B, and when the polishing pad could be dressed, it was evaluated to have a dressing property A.

## (6) Polishing Rate

[0208] After dressing each polishing pad for 1 hour by the method described in (5), the resultant was subjected to a polishing test under conditions shown in Table 1 below. 4-inch SiC substrates used for the polishing were precidentally processed to make the surface roughness uniform before use.

TABLE 1

Item	Conditions
Apparatus	15-inch single side polishing device (manufactured by HITECHNOTH Corporation, surface plate diameter: 380φ 380φ)
Material to be polished	Φ4-inch SiC substrate 4H N4 off Si surface, dummy grade
Slurry	COMPOL 202 SC manufactured by Fujimi Incorporated (permanganate-based)
Load (surface pressure)	15 kg (160 g/cm <sup>2</sup> )
Rotation speed	60 rpm
Polishing time	15 min
Slurry supply	1 way dripper, 4 mL/min
Chiller set temperature	25° C.

## (7) Stability of Polishing Rate (Durability)

[0209] A polishing rate VO immediately after starting the polishing and a polishing rate V1 10 minutes after starting the polishing were compared with each other, and the stability of the polishing rate was evaluated as A when  $(V1/VO) \times 100$  was 70 or more, evaluated as B when it was 50 to 70, evaluated as C when it was 30 to 50, and evaluated as D when it was 30 or less.

## Production of Hydrogenated Block Copolymer (I)

## Preparation of Hydrogenation Catalyst

[0210] A hydrogenation catalyst to be used in producing a hydrogenated block copolymer in an example and a comparative example described later was prepared as follows.

[0211] A reaction vessel equipped with a stirrer having been replaced with nitrogen was charged with 1 liter of dried and purified cyclohexane.

[0212] Next, 100 mmol of bis(η<sup>5</sup>-cyclopentadienyl) titanium dichloride was added thereto.

[0213] A n-hexane solution containing 200 mmol of trimethyl aluminum was added to the resultant under sufficient stirring, followed by a reaction at room temperature for about 3 days. Thus, a hydrogenation catalyst was obtained.

## Production Example 1: Hydrogenated block copolymers (I)-1

[0214] A tank reactor (having a capacity of 10 L) equipped with a stirrer and a jacket was used for performing batch polymerization.

[0215] First, a cyclohexane solution (concentration of 20% by mass) containing 15 parts by mass of styrene was charged.

[0216] Next, n-butyllithium was added in a ratio of 0.107 parts by mass with respect to 100 parts by mass of all monomers, N,N,N',N'-tetramethylethylenediamine (herein-

after referred to as the "TMEDA") was added in a ratio of 0.9 moles per mole of n-butyllithium, and the resultant was polymerized at 65° C. for 1 hour.

[0217] Next, a cyclohexane solution (concentration of 20% by mass) containing 29 parts by mass of butadiene and 41 parts by mass of styrene was added thereto, followed by polymerization at 80° C. for 2 hours. Finally, a cyclohexane solution (concentration of 20% by mass) containing 15 parts by mass of styrene was added thereto, followed by polymerization at 65° C. for 1 hour. Thereafter, methanol was added thereto to stop the polymerization reaction.

[0218] A block copolymer obtained in this manner had a styrene content of 71% by mass, a polystyrene block content of 30% by mass, a vinyl bond content of 46% by mass, and a weight average molecular weight of 60,000.

[0219] To the thus obtained block copolymer, the hydrogenation catalyst prepared as described above was added in an amount of 100 ppm, in terms of Ti, per 100 parts by mass of the block copolymer, followed by a hydrogenation reaction at a hydrogen pressure of 0.7 MPa and a temperature of 65° C.

[0220] Next, octadecyl-3-(3,5-di-t-butyl-4-hydroxyphenyl) propionate, used as a stabilizer, was added in an amount of 0.3 parts by mass with respect to 100 parts by mass of the block copolymer to obtain a hydrogenated block copolymer (I)-1.

[0221] The hydrogenated block copolymer (I)-1 thus obtained had a hydrogenation rate of 98%. The other physical properties thereof are shown in Table 2.

## Production Examples 2 to 7: Hydrogenated Block Copolymers (I)-2 to (I)-7

[0222] In the method for producing the hydrogenated block copolymer (I)-1, the polymerization method and the hydrogenation condition were adjusted to produce hydrogenated block copolymers (I)-2 to (I)-7. The physical properties of these are shown in Tables 2 and 3 below.

## Production of Press Molded Sheet

[0223] Each of hydrogenated block copolymers (I)-1 to (I)-7 produced as described above was rolled out with a 4-inch roll at 160° C., the resultant was subjected to press molding with an oil hydraulic press at 200° C. and 100 kg/cm<sup>2</sup>, and thus, a press molded sheet having a size of 130 mm × 220 mm and a thickness of 2 mm was produced.

## Production of Hydrogenated Block Copolymer Composition

[0224] Hydrogenated block copolymer compositions were produced by respectively using the hydrogenated block copolymers (I)-1 to (I)-7, and the following component (II).

## Olefin-based Resin (II)

## Component (II)-1

[0225] Olefin-based resin: low density polyethylene resin, L2340 (manufactured by Asahi Kasei Corp.)

## Production of Starting Material of Hydrogenated Block Copolymer Composition Used in Example 2

[0226] The hydrogenated block copolymer (I)-1 formed into a pellet shape and the olefin-based resin (II) were

compounded in a ratio (parts by mass) shown in Table 3, the resultant was kneaded with a twin screw extruder (TEX-30) into a pellet shape, and thus, a hydrogenated block copolymer composition was obtained.

[0227] Conditions for extrusion were a cylinder temperature of 230° C., and a screw speed of 300 rpm.

#### Production of Polishing Pad

[0228] As shown as Examples 1 to 9, the hydrogenated block copolymers (I)-1 to (I)-7 were used to produce foam bodies having a foaming ratio of 2.7-fold by employing compositions shown in Table 3 by a known method. Each of the thus obtained foam bodies was cut into a cylindrical

foam body having an inner diameter of 400 mm and a thickness of 2 mm to be used as a polishing pad.

[0229] As shown as Comparative Examples 1 and 2, the hydrogenated block copolymer (I)-2 or the olefin-based resin (II) was used to produce foam bodies having a foaming ratio of 2.7-fold by employing compositions shown in Table 3 by a known method. Each of the thus obtained foam bodies was cut into a cylindrical foam body having an inner diameter of 400 mm and a thickness of 2 mm to be used as a polishing pad.

[0230] Table 2 below shows the physical properties of the hydrogenated block copolymers (I), and Table 3 shows the physical properties of the polishing pads, and property evaluation results.

TABLE 2

	Pro. Ex. 1	Pro. Ex. 2	Pro. Ex. 3	Pro. Ex. 4	Pro. Ex. 5	Pro. Ex. 6	Pro. Ex. 7
Hydrogenated block copolymer	(I)-1	(I)-2	(I)-3	(I)-4	(I)-5	(I)-6	(I)-7
Content of all vinyl aromatic monomer units (mass %)	71	67	34	42	19	43	67
Content of polymer block (a) (mass %)	30	20	30	42	19	43	67
Content of hydrogenated copolymer block (b) (mass %)	70	80	70	0	0	0	0
Content of vinyl aromatic monomer unit in hydrogenated copolymer block (b) (mass %)	59	59	6	0	0	0	0
Content of vinyl aromatic monomer unit in hydrogenated copolymer block (b) in entire polymer (mass %)	41	47	4	0	0	0	0
Content of conjugated diene in hydrogenated copolymer block (b) in entire polymer (mass %)	29	33	64	0	0	0	0
Vinyl bond content in hydrogenated block copolymer (I) (mass %)	46	20	46	36	36	78	41
Hydrogenation rate of double bond of conjugated diene monomer unit (%)	98	98	98	98	98	98	98
MFR (230° C., 2.16 kg)	101	5	5	0.9	14	2.4	1.6
Hardness (JIS-A, 0 s)	92	82	78	—	61	—	—
Hardness (JIS-A, 15 s)	84	67	77	—	58	—	—
Hardness (JIS-D, 0 s)	—	—	—	39	—	39	67
Hardness (JIS-D, 15 s)	—	—	—	40	—	38	64
Static friction coefficient	1.48	2.25	1.81	0.90	2.5	0.98	0.7
Dynamic friction coefficient	0.43	0.62	1.22	0.96	1.3	1.04	0.55

TABLE 3

	Ex. 1	Ex. 2	Ex. 3	Ex. 4	Ex. 5	Ex. 6	Ex. 7	Ex. 8	Ex. 9	Com. Ex. 1	Com. Ex. 2
Hydrogenated block copolymer (I)-1	100	—	—	—	—	—	—	—	—	—	—
Hydrogenated block copolymer (I)-2	—	70	—	—	100	—	—	—	—	100	—
Hydrogenated block copolymer (I)-3	—	—	100	—	—	—	—	—	—	—	—
Hydrogenated block copolymer (I)-4	—	—	—	100	—	—	—	—	—	—	—
Hydrogenated block copolymer (I)-5	—	—	—	—	—	100	—	—	30	—	—
Hydrogenated block copolymer (I)-6	—	—	—	—	—	—	100	—	—	—	—
Hydrogenated block copolymer (I)-7	—	—	—	—	—	—	—	100	—	—	—
Olefin-based resin (II)-1	—	30	—	—	—	—	—	—	70	—	100
Average foam size (μm)	110	105	103	99	120	112	115	102	122	100	120
Foam size distribution	wide	narrow	wide	wide	wide	wide	wide	wide	wide	narrow	narrow
Static friction coefficient	0.83	0.84	0.91	0.80	0.86	1.11	0.89	0.61	0.70	1.26	0.30
Dynamic friction coefficient	0.49	0.52	0.70	0.61	0.51	0.72	0.65	0.45	0.32	0.61	0.20

TABLE 3-continued

	Ex. 1	Ex. 2	Ex. 3	Ex. 4	Ex. 5	Ex. 6	Ex. 7	Ex. 8	Ex. 9	Com. Ex.1	Com. Ex. 2
Dressing property	A	A	A	A	A	A	A	A	A	B	A
Polishing rate (nm/h)	1635	1330	1450	1450	921	1402	1430	1540	650	cannot be polished	<500
Durability	A	A	B	C	B	C	C	C	C	A	A

[0231] The entire contents of the disclosure of the Japanese Patent Application No. 2024-020816, filed on Feb. 15, 2024 and the Japanese Patent Application No. 2025-007084, filed on Jan. 17, 2025 are incorporated herein by reference. All literatures, patent applications, and technical standards described herein are incorporated herein by reference to the same extent as though each individual literature, patent application, or technical standard was specifically and individually indicated as being incorporated by reference.

What is claimed is:

1. A polishing pad comprising a hydrogenated block copolymer (I) which is in an amount of 5% by mass or more, and which satisfies the following conditions (1) and (2), and which has a value of a static friction coefficient measured in accordance with JIS K7125 of 1.2 or less.

<Condition (1)>

the hydrogenated block copolymer (I) is a hydrogenated product of a block copolymer containing a vinyl aromatic monomer unit, and a conjugated diene monomer unit; and

<Condition (2)>

the hydrogenated block copolymer (I) contains at least one polymer block (a) principally containing a vinyl aromatic monomer unit, and a content of the polymer block (a) principally containing a vinyl aromatic monomer unit in the hydrogenated block copolymer (I) is 10% by mass or more.

2. The polishing pad according to claim 1, wherein the hydrogenated block copolymer (I) contains at least one hydrogenated copolymer block (b) containing a vinyl aromatic monomer unit, and a conjugated diene monomer unit, and
- a content of the vinyl aromatic monomer unit in the hydrogenated copolymer block (b) is 5% by mass or more and 79% by mass or less.
3. The polishing pad according to claim 2, wherein the content of the vinyl aromatic monomer unit in the hydrogenated copolymer block (b) is 45% by mass or more and 79% by mass or less.
4. The polishing pad according to claim 1, wherein the polishing pad comprises the hydrogenated block copolymer (I) in an amount of 40% by mass or more.
5. The polishing pad according to claim 1, wherein the polishing pad comprises the hydrogenated block copolymer (I) in an amount of 70% by mass or more.
6. The polishing pad according to claim 1, wherein the polishing pad has a value of a dynamic friction coefficient measured in accordance with JIS K7125 of 0.6 or less.
7. The polishing pad according to claim 1, wherein the content of the polymer block (a) principally containing the vinyl aromatic monomer unit in the hydrogenated block 10 copolymer (I) is 15% by mass or more and 40% by mass or less.

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