

TITLE OF THE INVENTION

SUBSTRATE FOR MAGNETIC RECORDING MEDIUM AND METHOD FOR
MANUFACTURING SAME

5 BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a substrate for
magnetic recording medium and to a method for manufacturing
the substrate for magnetic recording medium.

10 2. Description of the Related Art

The recording density (surface density) of magnetic
recording has increased extremely rapidly and continuously at
yearly rates of 50 to 200% for these past 10 years. At the
mass production level, products with 70 Gbits/inch² are
15 shipped, while surface recording densities several times
higher, namely 160 Gbits/inch², have been reported at the
laboratory level. Surface recording densities at the mass
production level correspond to 80 Gbytes per one platter of a
3.5" HDD (3.5 inch HDD), and correspond to 40 Gbytes per
20 single platter of a 2.5" HDD. At these recording volumes,
installation of single platter recording media gives a
sufficient volume for use in an ordinary desk top personal
computer (equipped with a 3.5" HDD) or a laptop personal
computer (equipped with a 2.5" HDD).

25 It is expected that recording densities will also

continue to improve in the future. However, the conventional horizontal magnetic recording methods are approaching their thermal fluctuation recording limit, and it seems that they will be replaced by perpendicular magnetic recording when recording densities of 100 Gbit/inch² to 200 Gbit/inch² are reached. At the present time it is not certain what the recording limit of perpendicular magnetic recording will be, but it is believed that 1000 Gbit/inch² (1 Tbit/inch²) is achievable. If these types of high recording densities are achieved, it will be possible to obtain a recording volume of 600 to 700 Gbytes per single platter of a 2.5" HDD.

In order to realize such a high recording density, the flying height of the magnetic recording head must be reduced from the conventional 30 nm to 10 nm or less, and smoothing of the substrate surface is essential. However, it has recently been found that problems such as the head adhering to the substrate or a loss of head flying stability occur when micro level surface roughness is too small. That is, a substrate having extremely low waviness and micro waviness and having a roughness of about 0.3 to 2.0 nm is ideal.

(Regarding unevenness of a substrate to be used for a magnetic recording medium having a magnetic film, waviness stands for an observable range of 5 to 100 mm, micro waviness stands for an observable range of 80 μ m to 5 mm, and roughness stands for an observable range of up to 80 μ m.)

At present, glass substrates are textured by tape polishing, but the desired roughness is not achievable and it is not possible to lower the roughness to the desired head height.

5 The methods for surface-roughening silicon substrates include a dry etching method with chlorine (Japanese Patent Application Unexamined Publication No. 7-263406/1995) and a method of treatment with alkali hydroxide (Japanese Patent Application Unexamined Publication No. 53-7144/1978).

10 However, although it is possible to control the degree of surface roughening with these methods, it is not possible to finish the entire substrate with a uniform roughness. That is, because the substrate is etched while the substrate rests motionless in a non-uniform atmosphere during etching,
15 selective etching occurs and defects form due to the effect of process strains residual on the substrate. The reality at present is that it is not possible to obtain a uniform roughness with such simple acid or alkali etching.

20 SUMMARY OF THE INVENTION

 Accordingly, the present invention provides a substrate for a magnetic recording medium in which roughness of the surface of the substrate is controlled, in which head flying stability is maintained, and that has a magnetic film that
25 can achieve high recording densities. The present invention

also provides a method for roughening the surface of the substrate.

In the present invention, in order to address such issues, it has been found as a result of repeated
5 investigations that the roughness of the surface of the substrate can be made uniform preferably by shaking or rotating the surface of a substrate for a magnetic recording medium in an alkali solution, particularly one into which ultrasound has been transmitted and a surfactant has been
10 added. The present invention has been completed by thorough confirmation of the details of these conditions.

More specifically, the present invention provides a silicon substrate for a magnetic recording medium in which a surface to be used for forming a recording layer has 40 to
15 1000 protrusions per one μm^2 with a maximum height of 10 nm or less and average roughness of 0.3 to 2.0 nm, and in which there are no defects or spots of any of the surface.

Furthermore, the present invention provides a method for manufacturing a silicon substrate for a magnetic recording
20 medium comprising a step of etching the surface of the silicon substrate, the step comprising applying ultrasound to the surface of the silicon substrate which has been shaking or rotating. The present invention also provides a magnetic recording medium comprising the silicon substrate.

25 With the present invention, it is possible to adjust

the flying height of the magnetic recording head to lower than has been conventionally possible, and to realize high recording density.

5 BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 (A) conceptually shows a relationship between a magnetic recording medium in which a silicon substrate of the present invention is used, and a head, and FIG. 1 (B) is a diagram that schematically shows a relationship between a magnetic recording medium in which a conventional silicon
10 substrate is used, and the head.

FIG. 2 (A) is the result of AFM observation of the surface of an un-etched substrate of Comparative Example 11, and FIG. 2 (B) is the result of AFM observation of the
15 surface of an etched substrate of Example 2.

FIG. 3 (A) is a sketch of defects observed on the surface of the substrate produced by treating the substrate obtained in Example 2 with ultrasound, and FIG. 3 (B) is a sketch of defects observed on the surface of the substrate
20 obtained in Comparative Example 8 that has not been treated with ultrasound. Both were observed under a focus lamp.

FIG. 4 (A) is a result of observation of a topographical image taken by OSA, of the substrate obtained in Example 3 in which the application of ultrasound was
25 combined with rotation of the substrate. FIG. 4 (B) is a

result of observing a topographical image taken by OSA, of the substrate obtained in Comparative Example 9 in which only ultrasound was applied.

5 DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

According to the present invention, it is possible to impart a uniform roughness particularly to a surface of a substrate for a magnetic recording medium in which silicon is used, preferably by shaking or rotating the surface of the
10 substrate in an alkali solution containing a surfactant in which ultrasound is being transmitted.

There is no particular limitation to the silicon substrate used in the present invention. The silicon substrate may include a monocrystalline or polycrystalline
15 silicon substrate, and a p-type or n-type silicon substrate. And there is also no particular limitation to the manufacturing method of the silicon substrate. That is, the substrate can be prepared even from recycled wafers to be discarded, for example, because the silicon substrate is not
20 influenced by the silicon's own electrical properties. Thus, the substrates used in the present invention can be characterized in that their raw material costs can be kept low.

In etching, the application of ultrasound is for the
25 purpose of preventing selective etching from occurring on the

surface of the silicon substrate. The vibration of the etching solution with ultrasound can generate uniform etching so that a uniform roughness will be imparted to the substrate for a magnetic recording medium. Furthermore, it seems that
5 ultrasound has an effect of preventing the attachment of gas (hydrogen) on the substrate surface and preventing the reattachment of impurities and grit. In order to give uniform and effective control of the roughness of the surface of the substrate, the frequency of the ultrasound may be
10 preferably 30 to 3000 kHz.

The substrate is shaken and rotated in order to receive the ultrasound evenly over the entire substrate. It seems that this combination may be effective because of the nature of ultrasound. Shaking of the substrate means the action of
15 rocking or shaking, and may include, for example, moving the substrate vertically, or moving it from side to side.

It is preferable that shaking or rotation occurs 1 to 80 times per minute to give uniform control of the roughness of the substrate surface. Herein, one shake is counted as
20 one vertical cycle or one horizontal cycle, for example.

The etching agent to be used during etching may be preferably an alkali solution containing a surfactant, a mixture containing a surfactant and an alkaline salt, and an alkali detergent having a pH value of 10 to 13. Even more
25 preferable is the use of an alkali etching agent which has

been is adjusted to have a pH value of 11 to 12. This pH range may be preferable because the roughness of the surface of the substrate can be uniformly and effectively controlled.

Preferably, the alkaline salt can be one or more salts
5 selected from the group consisting of potassium hydroxide, sodium hydroxide, sodium carbonate, sodium hydrogencarbonate, ammonium hydroxide, potassium carbonate and potassium hydrogencarbonate.

The alkaline salt may be added so that the potassium
10 hydroxide, sodium hydroxide or the like will provide a predetermined pH. It may be preferable that the amount of the alkaline salt is adjusted so that it will be about 0.001 to 1M in the etching solution.

The surfactant in the etching solution may preferably
15 include one or more surfactants selected from the group consisting of non-ionic surfactants such as polyoxyalkylene alkyl ether and polyoxyalkylene alkyl phenyl ether; anionic surfactants such as alkylbenzenesulfonic acid and salts thereof, alkyl phosphate, polyoxyalkylene alkyl phenyl ether
20 sulfonic acid and salts thereof and polyoxyalkylene alkyl ether sulfonic acid and salts thereof; and cationic surfactants such as a fluorine-based surfactant; a salt of high amine and halogen acid (wherein the amine contains at least one alkyl group containing 10 to 20 carbon atoms),
25 halogenated alkylpyridinium and tertiary ammonium salts. The

surfactant may be more preferably a non-ionic or anionic surfactant.

Specific examples of the surfactant may include compounds such as sodium laurylsulfate, tetraethyl ammonium chloride, polyoxyethylene-(10) octyl phenyl ether, polyoxyethylene-(10) octyl ethyl ether, LIPON-F (manufactured by Lion Corporation), CLEAN THROUGH (manufactured by Kao Corporation) and EXCEM LIGHT (manufactured by Kyoeisha Chemical Co. Ltd).

It may be preferable that the concentration of the surfactant in the etching solution is 0.01 to 10% by weight. This range may be preferable from the point of view of wettability, prevention of re-adhesion of grit, prevention of bubbles attached to the surface of the substrate, and productivity (including cost and waste solution treatment). More specifically, when the concentration is less than 0.01% by weight, there may be deterioration of the wettability of the substrate surface and its ability to reduce grit attached, or there may be cases in which air bubbles start to adhere. If the concentration is greater than 10% by weight, problems of cost and treatment of the waste solution may start to occur.

The surfactant is added to improve the wettability of the surface of the substrate and to realize uniform etching.

The surfactant may also have a role of preventing gas

(hydrogen) which has been generated during the etching from adhering to the surface of the substrate so that uneven etching can be prevented. The surfactant may have a further role of preventing the re-adherence of impurities or grit
5 that has been present in the etching solution.

Furthermore, from the view of prevention of selective etching and mass production, it may be preferable that the temperature of the etching agent is maintained at room temperature or is heated to 20 to 90°C during the etching.

10 It may be particularly preferable that an etching agent contains 1% by weight or less of surfactant and 0.1 mol or less of alkali hydroxide and has a pH value of about 12.

It may be preferable that the substrate is polished and washed before the step of etching.

15 There is no particular limitation to the polishing, but one example is polishing with a non-woven cloth using colloidal silica or the like, and then polishing using a polishing cloth (suede-type).

The washing may be preferably performed by chemical
20 washing such as RCA washing in use of H_2O_2 - NH_4OH , or scrubbing in use of a detergent.

The process of etching may be preferably performed by applying ultrasound to the alkali solution containing a surfactant, and immersing the polished and washed substrate
25 while rotating the substrate at 1 to 80 rpm (in the case of

shaking, the vertical motion is 1 to 80 times per minute).
The immersion may preferably last about 1 to 300 minutes
(rotation and immersion occur simultaneously).

During etching, any one of lack of shaking or rotating,
5 lack of application of ultrasound, and lack of a surfactant
in an etching agent may cause the selective etching of the
surface of the silicon substrate so that defects or spots are
generated and a uniform roughness is not obtained.

The scrubbing and drying, immediately following the
10 step of etching, may provide a substrate for a magnetic
recording medium having a uniform roughness.

The scrubbing may be preferably performed using a brush,
or a relatively soft substance such as a sponge (of PVA or
urethane, for example). The drying may be preferably
15 performed by hot air, cool air or spin drying.

Furthermore, when the substrate is not washed
immediately following the step of etching, it may be
preferable to store the substrate with a surfactant at a pH
value of about 3 to 6. When the substrate is stored in an
20 alkali of pH 8 or greater or in a strong acid solution of pH
2 or less, then etching continues and the desired surface
condition may not be obtained. That is, it is possible to
ensure a uniform roughness by storing the substrate in an
acidic detergent solution after the step of etching. This is
25 because storage in an acidic detergent solution prevents the

etching from proceeding any further, and because there is a possibility that etching may proceed due to residual alkali that adheres to the surface of the substrate if the substrate is stored in water.

5 Examples of the surfactant for storing may preferably include a non-ionic surfactant agent such as polyoxyalkylene alkyl ether. The surfactant may be present at a concentration of 0.01 to 10% by weight in the storage solution. Water may be preferable as the solvent of the storage solution. It may be preferable to hold the pH at about 3 to 6, and the solution may be adjusted using an acid such as hydrochloric acid, nitric acid, sulfuric acid, acetic acid, or a salt of thereof.

15 The substrate for a magnetic recording medium of the present invention is characterized by the following. The substrate is extremely flat, apart from the roughness (for a substrate used for a magnetic recording medium having a magnetic film, unevenness may be expressed by waviness in a range of 5 to 100 mm, micro-waviness in a range of 80 μm to 5 mm, and roughness in a range of up to 80 μm). The number of protrusions on the surface for recording information is 40 to 1000 per 1 μm^2 , preferably 40 to 500 per 1 μm^2 , the maximum height of the protrusions is 10 nm or less, and the surface roughness is in a range of 0.3 to 2.0 nm. As a result, there is no adhesion even if the magnetic recording head comes

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within 10 nm of the surface of the substrate so that the flying of the head is stable.

When the number of protrusions on the surface on or above which information will be recorded is outside the range
5 of 40 to 1000 per 1 μm^2 , the flying characteristics of the head become unstable.

When the maximum height exceeds 10 nm, if the flying height of the head is lowered in order to increase the recording density, then the head and the substrate will make
10 contact. Moreover, since the flying height of the head is 10 nm or less, it is necessary to ensure the maximum height of the indentations or unevenness on the surface of the substrate is not more than 10 nm.

Furthermore, when the average roughness is less than
15 0.3 nm, adhesion occurs between the head and the substrate in addition to a reduction in the flying stability of the head. When the average roughness is greater than 2.0 nm, then it is not possible to obtain a substrate surface for high recording density.

20 It should be noted that the maximum height and the average roughness are measured with an atomic force microscope (AFM), using the observation area of 10 μm square. The number of protrusions is measured visually by AFM observation.

25 FIG. 1 (A) conceptually shows a relationship between a

magnetic recording medium 1 in which a silicon substrate of the present invention is used, and a head 2. FIG. 1 (B) is a diagram that schematically shows a relationship between a magnetic recording medium 11 in which a conventional silicon
5 substrate is used, and the head 2. In FIG. 1 (A), buoyancy is generated by rotation of the substrate and the buoyance of the head is improved so that there is no adhesion. On the other hand, in FIG. 1 (B), since the buoyancy is not generated by the rotation of the substrate, the buoyance of
10 the head is unstable so that adhesion also occurs.

The roughness (Ra) is 0.30 to 2.00 nm in FIG. 1 (A), and less than 0.30 nm in FIG. 1 (A). However, the effect of the present invention cannot be obtained by focusing on the roughness (Ra) alone. The effect of the present invention is
15 obtained by providing a substrate with a metal film having a predetermined number of protrusions and a predetermined maximum height, in addition to a predetermined roughness. Stated simply, the effect of the present invention is obtained by providing conditions in which the head moves like
20 an air hockey puck.

A substrate of the present application which has been etched in this way can be coated with a recording layer and used as a recording medium.

The silicon substrate of the present invention may be
25 used as a magnetic recording medium by comprising a recording

layer for recording information.

Before the placement of the recording layer, it may be preferable to provide an under-layer comprising one or more elements selected from the group consisting of Cr, Ni, P, Co, Zr, Mn, Fe, Ti, Cu, Zn, Nb, Mo, Tc, Ru, Pd, Ag, Cd, In, Sn, Sb, Hf, Ta, W, Re, Os, Ir, Pt and Au.

There is no particular limitation to the recording layer, examples of which may include a cobalt recording layer and Co-Cr-Ta. The recording layer may be provided by any method known. There is also no limitation to the thickness of the recording layer, and this may be any ordinary thickness.

A carbon protection layer or a fluorine-based lubricating layer may also be provided above the recording layer.

The invention is described below based on examples. However, it should not be construed that the present invention is limited to these.

Examples 1 to 20 and Comparative Examples 1 to 11

A substrate for a magnetic recording medium member having an external diameter of 65 mm, an inside diameter of 20 mm and a thickness of 0.64 mm was fabricated from monocrystalline silicon. A multiple number of substrates were prepared by polishing the substrate firstly with (i)

Suba400 (manufactured by Rodel Co.), which is a non-woven cloth, together with colloidal silica (3%-SSS, manufactured by Nissan Chemical Co.), and secondly with Supreme RN-H (manufactured by Rodel Co.) together with colloidal silica (3%-SSS, manufactured by Nissan Chemical Co) so as to have a roughness of 0.1 nm (as measured by AFM, measured with a viewing field of 10 μm square).

The substrates were etched according to the conditions shown in Table 1. Immediately following the step of etching, the substrates were scrubbed and dried. Then, the condition of the surface was visually inspected with a focus lamp (to check for defects and spots) and observed under an AFM, wherein the image of the surface topography was scrutinized.

Measurement of Roughness and Maximum Height, and Measurement of Protrusions

Atomic force microscopy observation of the substrate was performed using an atomic force microscope (Scanning Probe Microscope JSPM-4200, manufactured by JEOL) to measure the surface roughness. The observation area was set to 10 μm square. The protrusions were measured visually through AFM observation.

FIG. 2 (A) is the result of AFM observation of an un-etched surface of the substrate of Comparative Example 11, and FIG. 2 (B) is the result of AFM observation of an etched

surface of the substrate of Example 2.

Visual Inspection with Focus Lamp

The substrates were visually inspected for the presence
5 and number of defects and particles using a focus lamp
(manufactured by Yamada Optical Co.) with a brightness of
100,000 lux. FIG. 3 (A) is a sketch of defects observed on
the surface of the substrate obtained in Example 2 in which
the substrate was treated with ultrasound. FIG. 3 (B) is a
10 sketch of defects observed on the surface of the substrate
obtained in Comparative Example 8 in which the substrate was
not treated with ultrasound. Both were observed under a
focus lamp. Absolutely no defects were found on the former,
while innumerable defects were seen on the latter.

External Imaging with an Optical Surface Analyzer

An image of the surface topography was observed using
an OSA (manufactured by Candela Corporation).

Investigation of the pH

The roughness of the surface and the external
appearance were investigated, while varying the pH of the
etching solution from 9 to 14 using KOH. When the pH value
was 9, there was substantially no change in the roughness.

25 When the pH value was 14, there was a tendency for the

surface to become rugged and for defects to occur. On the other hand, when the pH was 10 to 13, no defects or spots were generated and it was possible to control the number of protrusions and the roughness.

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Investigation of the Surfactant

The roughness of the surface of the substrate and the external appearance were investigated, while varying the concentration of the surfactant from 0.005 to 20% by weight.

10 When the concentration was 0.005% by weight or less, the wettability of the surface of the substrate was reduced and defects and spots of the surface of the substrate occurred after the etching. When the concentration was 20% by weight or more, although the range of the number of protrusions was
15 excellent, there were cases in which the average surface roughness did not increase. On the other hand, when the concentration was from 0.01 to 10% by weight, no defects or spots were generated and control of the number of protrusions and the roughness was excellent. It was also confirmed that
20 the average roughness tends to drop as the concentration of the surfactant increases.

Investigation of the Temperature

The roughness of the surface and the external
25 appearance were investigated, while varying the temperature

of the etching solution from 10 to 100°C. When the temperature of the etching solution was 10°C or less, there were cases in which etching did not proceed and there was no etching effect. When the temperature was 100°C or greater,
5 innumerable bubbles were generated from the substrate because of rapid reaction with the alkali, and there were cases in which defects and spots occurred on the surface of the substrate. On the other hand, when the temperature of the etching solution was from 20 to 90°C, there was no generation
10 of defects or spots on the surface and there was excellent control of the number of protrusions and the roughness.

Investigation of the Ultrasound Frequency

The application or non-application, as well as the
15 frequency of the ultrasound in the etching solution was investigated. The surface of the substrate which had been etched without use of ultrasound was found to have defects and spots caused by selective etching. On the other hand, all substrates to which ultrasound had been applied had
20 neither defects nor spots, and the number of protrusions and the roughness could be excellently controlled.

Investigation of Rotation or Shaking

FIG. 4 (A) is a result of observation of a
25 topographical image taken by OSA, of a substrate obtained in

Example 3 in which the application of ultrasound was combined with rotation of the substrate. FIG. 4 (B) is a result of observing a topographical image taken by OSA, of a substrate obtained in Comparative Example 9 in which only ultrasound
5 was applied. Although the substrate obtained in Comparative Example 9 had no defects, the entire surface of the substrate had large undulations.

The substrate surfaces which had not been rotated or shaken at all in this way had unevenness and etching non-
10 uniformities across their entire surfaces. On the other hand, substrates that had been rotated or shaken had neither defects nor spots, and the number of protrusions and roughness could be excellently controlled. However, at a rotation or shaking frequency of 100 times per minute or
15 higher, there were cases in which the bubbles of the gas generated during etching were entrained in the etching solution, causing spots of the surface of the substrate.

Head Flying Test

20 A Cr under-layer of 100 nm, a Co-Cr-Ta magnetic recording layer of 60 nm, and a protective layer of 30 nm, were formed in that order by RF sputtering on the silicon substrate of Examples 1 to 3, and Comparative Examples 1 and
11 (non-treated example) at a substrate temperature of 250°C
25 in an argon gas atmosphere. After coating these magnetic

recording media with a lubricant, the flying height was set to 6 nm and the flying stability of the head was observed. In addition, the presence of adhesion between the head and the substrate was checked while performing a contact
5 start/stop (CSS).

As a result, the flying stability of the head for Examples 1 to 3 was high and there was no adhesion during the CSS test. The stability for Examples 2 and 3 was particularly high and excellent results were obtained. On
10 the other hand, the head flying stability for Comparative Examples 1 and 11 was poor. The stability for the non-treated Comparative Example 11 was particularly poor and head adhesion occurred during the CSS test. Although the stability for Comparative Example 1 was slightly better than
15 that for Comparative Example 11, an excellent result could not be obtained since etching was insufficient. A head flying test could not be performed with substrates obtained in the other Comparative Examples because of defects or spots on the surface of the substrate.

20

Observation of Defects and Spots of the Substrate Surface

As a result of inspection of OSA images of defects and spots generated on the surface of the substrates, it was found that the defects and spots were projections. It seems
25 that these were formed because etching had not occurred on

the defect parts due to selective etching caused by distortions through polishing.

Results Shown in Tables 1 and 2

5 Even if the flying height, which is indispensable for realizing high recording densities, is set low, it is possible to stabilize the flying of the head and prevent head adhesion during CSS testing. It is the result of the present invention imparting specific protrusions and roughness to the
10 surface of a substrate.

 Furthermore, the surface of the substrate may be easily roughened by etching the surface of the silicon substrate through the method of the present invention.

Table 1

	surfactant concentration (%) *1	pH *2	temperature of etching solution (°C)	immersion period (min)	ultra-sound (kHz)	number of rotation (/min)	number of shaking (/min)	number of protrusions per μm^2	average roughness (nm)	maximum height (nm)	defects	spots
Example	1	10.0	50	20	45	20	0	40	0.30	1.50	none	none
	2	11.0	50	20	45	20	0	150	0.60	3.20	none	none
	3	12.0	50	20	45	20	0	500	1.00	6.00	none	none
	4	13.0	50	20	45	20	0	400	1.50	9.00	none	none
	5	12.0	60	15	45	30	0	400	1.50	8.50	none	none
	6	12.0	60	15	45	30	0	450	1.30	8.00	none	none
	7	12.0	60	15	45	30	0	500	0.80	4.00	none	none
	8	12.0	60	15	45	30	0	500	0.60	3.60	none	none
	9	12.0	20	30	45	15	0	45	0.30	1.20	none	none
	10	12.0	40	30	45	15	0	70	0.30	1.30	none	none
	11	12.0	60	30	45	15	0	450	1.20	6.00	none	none
	12	12.0	90	30	45	15	0	250	1.80	9.00	none	none
	13	12.0	60	20	30	10	0	500	1.00	5.00	none	none
	14	12.0	60	20	45	10	0	500	1.00	5.30	none	none
	15	12.0	60	20	100	10	0	450	0.80	4.50	none	none
	16	12.0	60	20	1000	10	0	450	0.80	4.30	none	none
	17	12.0	60	20	3000	10	0	450	0.75	4.00	none	none
	18	12.0	50	20	45	0	10	450	0.85	6.50	none	none
	19	12.0	50	20	45	1	0	450	0.85	6.00	none	none
	20	12.0	50	20	45	40	0	450	1.00	7.20	none	none
	21	12.0	50	20	45	80	0	450	1.20	7.20	none	none

*1 Polyoxyethylene alkyl ether was used as a surfactant.

*2 Potassium hydroxide was used for adjustment of pH.

Table 2

	surfactant concentration (%) *1	pH #2	temperature of etching solution (°C)	immersion period (min)	ultra-sound (kHz)	number of rotation (/min)	number of shaking (/min)	number of protrusions per μm^2	average roughness (nm)	maximum height (nm)	defects	spots
Comp. Ex.	1	9.0	50	20	45	20	0	15	0.15	0.80	none	none
	2	14.0	50	20	45	20	0	30	2.50	12.00	present	present
	3	12.0	60	15	45	30	0	400	3.20	15.50	present	present
	4	12.0	60	15	45	30	0	500	0.20	1.00	none	none
	5	12.0	100	30	45	15	0	100	3.00	16.00	present	present
	6	12.0	10	30	45	15	0	10	0.10	0.50	none	none
	7	12.0	50	20	45	20	0	500	1.80	11.00	present	present
	8	12.0	50	20	none	20	0	500	0.80	5.60	present	present
	9	12.0	50	20	45	none	none	500	1.00	6.50	present	present
	10	12.0	50	20	45	100	10	450	1.50	10.50	present	present
	11	-	-	-	-	-	-	10	0.10	0.40	none	none

*1 Polyoxyethylene alkyl ether was used as a surfactant.

*2 Potassium hydroxide was used for adjustment of pH.

*3 Only potassium hydroxide was used.

CLAIMS

1. A method for manufacturing a surface-treated silicon substrate for a magnetic recording medium, the method comprising:

a step of etching a surface of a silicon substrate wherein ultrasound is applied to the surface of the silicon substrate with the silicon substrate shaken or rotated.

2. The method for manufacturing a surface-treated silicon substrate for a magnetic recording medium according to claim 1, wherein said ultrasound has a frequency of 20 to 3000 kHz.

3. The method for manufacturing a surface-treated silicon substrate for a magnetic recording medium according to claim 1, wherein the substrate is shaken or rotated 1 to 80 times per minute in said step of etching.

4. The method for manufacturing a surface-treated silicon substrate for a magnetic recording medium according to claim 1, wherein said step of etching comprises use of an etching agent comprising an alkaline salt and a surfactant, and having pH of 10 to 13.

5. The method for manufacturing a surface-treated silicon substrate for a magnetic recording medium according to claim 4, wherein said surfactant is one or more selected from the group consisting of polyoxyalkylene alkyl ether, polyoxyalkylene alkyl phenyl ether, alkylbenzenesulfonic acid

and salts thereof, alkyl phosphate, polyoxyalkylene alkyl phenyl ether sulfonic acid and salts thereof, polyoxyalkylene alkyl ether sulfonic acid and salts thereof, fluorine-based surfactant, salts of high amine and halogenated acid, halogenated alkylpyridinium and tertiary ammonium salts.

6. The method for manufacturing a surface-treated silicon substrate for a magnetic recording medium according to claim 4, wherein said alkaline salt is one or more selected from the group consisting of potassium hydroxide, sodium hydroxide, sodium carbonate, sodium hydrogencarbonate, ammonium hydroxide, potassium carbonate and potassium hydrogencarbonate.

7. The method for manufacturing a surface-treated silicon substrate for a magnetic recording medium according to claim 4, wherein said etching agent comprises said surfactant at a concentration of 0.01 to 10% by weight.

8. The method for manufacturing a surface-treated silicon substrate for a magnetic recording medium according to claim 1, wherein temperature of said etching agent is 20 to 90°C.

9. A magnetic recording medium comprising a surface-treated silicon substrate for a magnetic recording medium, a surface of the substrate having 40 to 1000 protrusions per one μm^2 with a maximum height of 10 nm or less and average roughness of 0.3 to 2.0 nm, wherein there are no defects or spots of the entire surface.