

DESCRIPTION

AUSTENITIC STAINLESS STEEL SHEET AND METHOD FOR MANUFACTURING
THE SAME

TECHNICAL FIELD

[0001]

The present invention relates to an austenitic stainless steel sheet and a method for manufacturing the same.

BACKGROUND ART

[0002]

Austenitic stainless steel sheets find a wide variety of applications including metal masks. For example, metal masks are manufactured by high-precision working such as etching and laser machining. In such high-precision working, it is known that the smoothness of an etched surface is improved by making the grain size of starting material small and increasing uniformity of grain size.

[0003]

For example, Patent Documents 1, 2, and 3 propose austenitic stainless steel sheets that are manufactured by adjusting chemical compositions and, after final cold rolling, performing annealing at a temperature of 500 to 850°C, which is lower than a normal temperature. In this way, the growth of grains is suppressed, and the smoothness of an etched surface is ensured.

[0004]

In particular, according to the inventions disclosed in Patent Documents 2 and 3, the growth of grains in final annealing is suppressed by adding Nb to cause niobium carbide to precipitate.

LIST OF PRIOR ART DOCUMENTS

PATENT DOCUMENT

[0005]

Patent Document 1: JP2-173214A

Patent Document 2: JP2003-003244A

Patent Document 3: JP2005-320587A

SUMMARY OF INVENTION

PROBLEMS TO BE SOLVED BY THE INVENTION

[0006]

However, in recent years, there has been a need for high-precision working to achieve more smoothness of a worked surface than ever before, and the methods disclosed in Patent Documents 1 to 3 in some cases cannot satisfy the request sufficiently. In particular, in Patent Documents 2 and 3, in order to transform the substructure of a steel sheet containing Nb to lath martensite in final cold rolling, it is necessary to make Nb dissolve in the steel sheet to be subjected to the final cold rolling. Therefore, in Patent Document 2, it is considered that the treatment temperature of process annealing, which is a step previous to final cold rolling, has to be set at a temperature as high as 1100°C. In addition, in Patent Document 3, stress relief annealing (final annealing) is performed in a temperature range from 550°C or higher to 700°C or lower, so as to suppress a warp during etching by means of residual stress relief after temper rolling (final cold rolling). Here, Patent Document 3 focuses on increasing hardness as shown in Table 2 of Patent Document 3. To achieve this, it is necessary to suppress reverse transformation to austenite so as to cause martensite to remain. Therefore, in Patent Document 3, it is considered that a final annealing temperature has to be lowered.

[0007]

As described in Patent Documents 2 and 3, in the case of a material containing Nb, Nb dissolving in an austenite phase leads to a delay in recrystallization, often leaving non-

recrystallized portions. In addition, in actual manufacturing, grains are not subjected to grain refining sufficiently due to cold rolling or variations in annealing temperature in operation, and non-recrystallized portions remain. When such a stainless steel sheet is subjected to high-precision working, the smoothness of the stainless steel sheet may vary.

[0008]

An object of the present invention is to provide an austenitic stainless steel sheet that is suitable for high-precision working such as etching and laser machining, and to provide a method for manufacturing such an austenitic stainless steel sheet industrially with stability.

MEANS FOR SOLVING THE PROBLEMS

[0009]

To solve the problems described above, the present inventors conducted intensive studies and consequently obtained the following findings.

[0010]

(1) As previously recognized, in order to smooth a surface after high-precision working such as etching and laser machining, it is desirable to include fine grains and to include no non-recrystallized portions. In addition, by making the grains into fine, isometric grains, the smoothness of a high-precision worked surface is further improved.

[0011]

(2) In addition, in order to make the grains into fine, isometric grains, only generating martensite by cold rolling and subjecting the martensite to reverse transformation is insufficient.

[0012]

(3) By generating work induced martensite at an initial stage in cold rolling, and further rolling the work induced martensite, it is possible to change the form of the martensite from the lath one to cell one, and as a result, it is possible to obtain a fine, equiaxed grain structure, which is desired.

[0013]

(4) To achieve this, it may be seemingly effective to set a cold rolling ratio at 90% or higher and to make γ unstable by adjusting a chemical composition. However, the former is difficult from an industrial aspect, and the latter contributes to the occurrence of cracks in heat rolling or cold rolling because an excessively unstable γ leads to the production of δ ferrite in melting or hot rolling.

[0014]

(5) Therefore, it is effective to change a γ stability by performing a manufacturing process in which the γ stability is made high at an initial stage of the manufacturing, and α' transformation is brought about in final cold rolling. For this reason, in order to prevent the production of δ ferrite as starting material, the γ stability is set at as low as possible, and annealing (process annealing) is performed before final cold rolling so as to cause C and N, which are γ stabilizing elements, to precipitate. In the cold rolling performed thereafter, this facilitates the generation of α' .

[0015]

(6) If part of Nb can be caused to precipitate in the form of Nb (C, N) in process annealing, it is possible to suppress the growth of grains by pinning effect, and to reduce the amount of dissolving Nb in final annealing, which is also effective in reducing a ratio of non-recrystallized area.

[0016]

(7) If part of Nb can be caused to precipitate in the form of Nb (C, N) in process annealing, it is possible to decrease the γ stability to the extent that δ ferrite is not produced. For this reason, even when a rolling ratio in operation is lower than assumed, or a final annealing temperature varies, it is possible to make a fine, equiaxed grain structure with stability.

[0017]

(8) To increase the γ stability, the chemical composition of material was also studied in detail. As a result, Cu is an austenite former, as well as an element that allows

for adjusting the stability of an austenite phase, and furthermore, when Mo is contained together, Cu has a synergetic effect with Mo on increasing stacking-fault energy to have a function of suppressing the accumulation of strain in an austenite parent phase. This suppresses excessive work hardening, resulting in a significant reduction in a load in manufacturing a sheet. In addition, in the case of the steel sheet is to be used after being subjected to pressing or bending work before or after being subjected to etching or laser machining, the suppression of excessive work hardening also has an effect of facilitating such forming.

[0018]

(9) As seen from the above, by performing annealing before the final cold rolling at a temperature lower than a normal temperature, niobium carbo-nitride is caused to precipitate, the amounts of dissolving C and dissolving N are adjusted, so as to control the stability of the austenite phase. Thereafter, by performing cold rolling, the work induced martensite to be formed is made into cell α' rather than lath α' in a conventional practice. It is thereby possible in a final annealing step, together with the pinning effect by the niobium carbo-nitride formed in the initial annealing, to obtain isometric grains that are fine grains and have decreased aspect ratios. As a result, it is possible to obtain an austenitic stainless steel sheet containing fine, isometric grains, thereby enhancing the smoothness of an etching worked surface.

[0019]

Based on the findings described above, the present inventors accomplished the present invention. The gist of the present invention is the following austenitic stainless steel sheet and method for manufacturing the austenitic stainless steel sheet.

[0020]

(1) An austenitic stainless steel sheet comprising, by mass %,

C + N: 0.03 to 0.20%,

Si: 0.1 to 1.5%,

Mn: 0.10 to 1.5%,

Cr: 15.0 to 22.0%,

Ni: 4.5 to 10.0%,

Cu: 0.10 to 2.0%,

Mo: 0.1 to 2.0%,

Nb: 0.02 to 0.50%, and

the balance being Fe and impurities, wherein

an average grain size is 5.0 μm or smaller,

a ratio of non-recrystallized area is 3.0% or lower, and

an average aspect ratio of grains is 1.2 or lower.

[0021]

(2) A method for manufacturing the austenitic stainless steel sheet described in the above (1), the method including,

after subjecting base metal to hot rolling, annealing, and cold rolling,

performing process annealing at a treatment temperature of lower than 1000°C, a final cold rolling at a total thickness reduction rate of 50% or higher, and final annealing at a treatment temperature within a temperature range higher than 700°C to 950°C or lower, in this order.

ADVANTAGEOUS EFFECTS OF THE INVENTION

[0022]

According to the present invention, it is possible to obtain an austenitic stainless steel sheet containing fine, isometric grains. Such an austenitic stainless steel sheet is excellent in smoothness of an etching worked surface and thus is suitable for high-precision working such as etching and laser machining. In addition, the present invention allows the austenitic steel described above to be manufactured industrially with stability.

BRIEF DESCRIPTION OF THE DRAWINGS

[0023]

[Figure 1] Figure 1 is a diagram illustrating the difference between a conventional manufacturing method and a manufacturing method according to the present invention.

[Figure 2] Figure 2 is a diagram illustrating the aspect ratios of grains.

DESCRIPTION OF EMBODIMENTS

[0024]

The present invention will be described in detail. Note that mass% will be hereinafter simply denoted by "%".

[0025]

1. Austenitic Stainless Steel Sheet

(1) Chemical Composition

· C + N: 0.03 to 0.20%

C (carbon) and N (nitrogen) are γ stabilizing elements and suppress the production of δ ferrite during melting and during hot rolling. Therefore, a proper amount of C and N need to be contained. Furthermore, C and N combine with Nb (niobium) during process annealing or during final annealing to precipitate in the form of fine Nb compounds, therefore having an effect of suppressing the growth of grains. In addition, C and N dissolve when a steel sheet is in the state of a heat-rolled sheet and precipitate in the form of niobium carbo-nitride in process annealing, which makes it possible to adjust the γ stability of base metal in the middle of manufacturing process. Consequently, C and N need to be contained 0.03% or more, preferably 0.05% or more, in total. In contrast, if the total content of C and N is excessive, although C and N are caused to precipitate in the form of the Nb compounds in process annealing, part of C and N remains in the form of dissolving C or dissolving N, leading to a high γ stability of base metal in final cold rolling, which results in failing to generate cell martensite sufficiently in final cold rolling. Consequently, the upper limit of the content of C and N is set at 0.20%, preferably 0.16% or less. In addition, the contents C and N are preferably set at 0.01 to 0.10%, and 0.01 to 0.15%, respectively.

[0026]

- Si: 0.1 to 1.5%

Si (silicon) is used as a deoxidizer in melt, contributing to the strengthening of steel. Consequently, the lower limit of the content of Si is set at 0.1%. However, an excessively high content of Si has an adverse effect of decreasing an etching rate. Consequently, the content of Si is set at 1.5% or less, preferably 0.8% or less.

[0027]

- Mn: 0.10 to 1.5%

Mn (manganese) contributes to brittle fracture prevention in hot working and strengthening of steel. Consequently, the lower limit of the content of Mn is set at 0.10%. However, Mn is such a powerful γ forming element that an excessively high content of Mn leads to a small amount of work induced martensite generated in cold rolling, which results in, in annealing carried out afterward, failing to obtain fine grains. Consequently, the content of Mn is set at 1.5% or less, more preferably 1.2% or less.

[0028]

- Cr: 15.0 to 22.0%

Cr (chromium) is a basic element of stainless steel. Having an effect of forming a metal oxide layer on the surface of steel material to increase corrosion resistance, Cr is an indispensable element. The content of Cr is set at 15.0% or more. However, Cr is such a powerful ferrite stabilizing element that an excessively high content of Cr leads to δ ferrite remaining in a large quantity after melt. This δ ferrite significantly degrades the hot workability of starting material. Consequently, the content of Cr is set at 15.0 to 22.0%. A preferable lower limit of the content of Cr is 15.0%, and a preferable upper limit of the content of Cr is 19.0%.

[0029]

- Ni: 4.5 to 10.0%

Ni (nickel) is a γ forming element and an element indispensable to obtain a γ phase at room temperature stably. The lower limit value of the content of Ni is set at 4.5%.

However, an excessively high content of Ni leads to an excessively stabilized γ phase, resulting in the suppression of deformation induced martensitic transformation in cold rolling. Furthermore, Ni is an expensive element, and an increase in the content of Ni leads to a significant rise in cost. Consequently, the upper limit value of the content of Ni is set at 10.0%.

[0030]

· Cu: 0.10 to 2.0%

Cu (copper) is a γ forming element and is an element that allows for adjusting the stability of a γ phase, as with Ni. In addition, Cu has an effect of softening a starting material and thus allows for reducing a load in rolling in the case where cold rolling is performed at a high rolling ratio, such as in the present invention. Furthermore, Cu is an austenite former and an element that allows for adjusting the stability of an austenite phase. When Mo is contained together, Cu has a synergetic effect with Mo on increasing stacking-fault energy, suppressing the accumulation of strain in an austenite parent phase, which in turn suppresses excessive work hardening, resulting in a significant reduction in a load in manufacturing the sheet. In addition, in the case of the steel sheet is to be used after being subjected to pressing or bending work before or after being subjected to etching or laser machining, the suppression of excessive work hardening also has an effect of facilitating such forming. Therefore, the lower limit of the content of Cu is set at 0.10%. In contrast, an excessively high content of Cu causes Cu to segregate on grain boundaries in the process of manufacturing the steel sheet. This grain-boundary segregation significantly degrades hot workability, making the manufacturing difficult. Consequently, the upper limit value of the content of Cu is set at 2.0%. A preferable lower limit of the content of Cu is 0.2%, and a preferable upper limit of the content of Cu is 1.0%.

[0031]

· Mo: 0.1 to 2.0%

Mo (molybdenum) is a γ forming element and is an element that allows for adjusting the stability of a γ phase, as with Ni. In addition, Mo is an element that causes a

homogeneous oxide film to be formed, and thus has an effect of reducing etching unevenness. Furthermore, Mo is an element that has a synergetic effect with Cu on increasing stacking-fault energy, suppressing the accumulation of strain in an austenite parent phase, which in turn suppresses excessive work hardening, resulting in a significant reduction in a load in manufacturing the sheet. In addition, in the case of the steel sheet is to be used after being subjected to working such as pressing or bending before or after being subjected to high-precision working, the suppression of excessive work hardening also has an effect of facilitating such forming. Consequently, the lower limit of the content of Mo is set at 0.1%. However, an excessively high content of Mo also leads to a rise in cost. Consequently, the content of Mo is set at 2.0% or less, preferably 1.0% or less.

[0032]

· Nb: 0.02 to 0.50%

Nb (niobium) forms a fine carbide or a fine nitride, suppressing the growth of grains by a pinning effect. In addition, Nb is caused to precipitate in the form of niobium carbonitride in process annealing, which reduces the content of C and the content of N in base metal, decreasing an austenite stability to the extent that δ ferrite is not produced. As a result, in cold rolling after the process annealing, a parent phase undergoes martensitic transformation at an early stage, and thereafter cell martensite is generated in a large quantity. In addition, while having an effect of suppressing the growth of grains, Nb delays recrystallization during annealing in its dissolving state, causing a non-recrystallized portion to remain after the annealing. Taking these effects into consideration, the lower limit value of the content of Nb is set at 0.02%. However, an excessively high content of Nb in its dissolving state leads to a delay in the recrystallization during the annealing, leaving non-recrystallized portions in a large quantity. The non-recrystallized portions remaining in a large quantity causes a decrease in the smoothness of a product having been subjected to high-precision working. Consequently, the upper limit value of the content of Nb is set at 0.50%. A preferable

lower limit of the content of Nb is 0.04%, and a preferable upper limit of the content of Nb is 0.20%.

[0033]

· Balance: Fe and impurities

In manufacturing stainless steel, scrap raw materials are often used from the viewpoint of promoting recycling. For this reason, stainless steel has various impurity elements inevitably mixed in. It is difficult to uniquely determine the contents of the impurity elements. Therefore, impurities in the present invention mean elements that are contained in an amount by which the operational advantages of the present invention are not inhibited. Such impurities include, for example, P: 0.05% or less, and S: 0.03% or less.

[0034]

· Other Respects

Md30 is a temperature at which 50% of all steel micro-structures are transformed to martensite with 30% of strain, which is one of the indexes representing how easily deformation induced martensitic transformation occurs. For this reason, Md30 preferably falls within a range from 30 to 55°C. This is because the work induced martensitic transformation easily occurs within this range.

[0035]

SFE stands for stacking-fault energy, which is one of the indexes representing how a stacking fault easily forms. An excessively low SFE easily leads to the formation of a stacking fault, making it difficult to bring about deformation induced martensitic transformation sufficiently. For this reason, SFE is preferably set at 3 mJ/cm² or higher. This is because, within this range, it is easy to suppress the formation of stacking fault and promote deformation induced martensitic transformation sufficiently. A preferable upper limit of SFE is 100 mJ/cm².

[0036]

(2) Steel Micro-Structure of Austenitic Stainless Steel Sheet

- Average Crystal Grain Diameter: 5.0 μm or smaller

The smaller an average grain size is, the lower the roughness of a high-precision worked surface is. This effect appears remarkably in particular with an average grain size of 5.0 μm or smaller. For this reason, the average grain size is set at 5.0 μm or smaller. To enhance the effect even more, the average grain size is desirably set at 3.0 μm or smaller. An excessively small average grain size leads to a rise in manufacturing cost, and thus the lower limit of the average grain size is set at 0.3 μm . Taking a balance with a manufacturing cost into consideration, the lower limit of the average grain size is desirably set at 0.5 μm . The average grain size represents the diameter of a circle that has the same area as an average grain area calculated by planimetry.

[0037]

- Ratio of non-recrystallized area: 3.0% or lower

When non-recrystallized portions remain in a stainless steel sheet in a large quantity, only the portions are etched more preferentially to surrounding recrystallization grains in performing etching on the stainless steel sheet, and as a result, the smoothness of the stainless steel sheet may be lost. For this reason, a non-recrystallization residual rate at which the smoothness is not lost is preferably set at 3.0% or lower. Producing a starting material having an excessively low non-recrystallized grain portion rate brings a decrease in efficiency of manufacturing, and thus the lower limit of the non-recrystallization residual rate is desirably 0.5%.

[0038]

- Average Aspect Ratio of Crystal Grains: 1.2 or lower

The closer grains come to fine, isometric grains, the lower the roughness of a high-precision worked surface is. For this reason, the average aspect ratio (the length of the major axis of a grain/the length of the minor axis of the grain) of grains is set at 1.2 or lower. The length of a major axis in the present invention represents the length of the major axis of a grain that is subjected to elliptical approximation. In addition, the length of a minor axis in the present invention represents the length of the minor axis of a grain

that is subjected to great elliptical approximation. For example, assuming that grains take shapes illustrated in Figure 2, the longer line segment is a major axis, and the shorter line segment is a minor axis. The lower the average aspect ratio is, the better, and the lower limit of the average aspect ratio is preferably set at 1.0%.

[0039]

2. Method of Producing Austenitic Stainless Steel Sheet

(1) Hot Rolling, Annealing, and Cold Rolling

As base metal to be subjected to hot rolling in the present invention, it is preferable to use an ingot or a slab, the ingot being formed by melting molten steel having a chemical composition mentioned above, using a converter or an electric furnace, and casting the molten steel in a mold, the slab being obtained by continuous casting. In the case of using an ingot, the base metal is preferably subjected to working such as cutting working, so as to have a shape that allows hot rolling. In the case of using a slab, the slab is preferably manufactured by continuous casting (so as to have a thickness of about 120 to 280 mm, a width of about 700 to 1200 mm, and a length of about 8 to 10 m). It is preferable that, after being heated in a temperature range from about 1100 to 1300°C, this ingot or slab is subjected to hot rolling so as to be made into a heat-rolled steel sheet having a thickness of about 2 to 10 mm. It is preferable that the heat-rolled steel sheet is thereafter subjected to annealing treatment performed at 1000 to 1200°C, subjected to pickling treatment similar to that performed in conventional practice, and further subjected to cold rolling at a rolling ratio of 20 to 70% so as to be made into a cold-rolled steel sheet having a thickness of about 0.2 to 2.0 mm.

[0040]

(2) Process annealing

In the present invention, a steel sheet obtained in cold rolling is subjected to process annealing in a temperature range lower than 1000°C. This process annealing is annealing performed immediately before final cold rolling, which will be described later. In the process annealing, part of Nb does not dissolve but precipitate in the form of niobium

carbo-nitride, so that it is possible to obtain an effect of decreasing the austenite stability of the base metal to the extent that δ ferrite is not produced. As illustrated in Figure 1, if an process annealing temperature exceeds 1050°C, Nb dissolves in the steel, and lath martensitic transformation occurs in the final cold rolling, which leads to a delay in recrystallization in the final annealing, leaving non-recrystallized portions. In addition, the non-recrystallized portions remaining may cause unevenness in smoothness in high-precision working. Therefore, in the present invention, the process annealing is performed at a treatment temperature within a temperature range lower than 1000°C.

[0041]

The lower the treatment temperature is, the more the dissolving C and the dissolving N decrease, thereby in turn decreasing the austenite stability, which has an advantage in the formation of cell martensite. Therefore, a preferable treatment temperature is 980°C or lower, in particular preferably 950°C or lower. Meanwhile, in order to cause the niobium carbo-nitride to precipitate sufficiently and in order to soften the steel sheet to reduce the load in the cold rolling that is the next step, the lower limit of the treatment temperature is preferably 700°C, more preferably 800°C. In addition, in order to cause the niobium carbo-nitride to precipitate sufficiently, that is, in order to decrease the dissolving C and the dissolving N to decrease the austenite stability of the base metal to some extent, an annealing retention time is desirably from 5 to 300 seconds. In addition, although a rate of temperature increase up to the treatment temperature and a cooling rate after annealing are not limited in particular, they are preferably 10 to 30°C/s and 10 to 20°C/s (from a retention temperature down to 300°C), respectively, from the viewpoint of suppressing the generation of chromium carbo-nitride, which easily coarsen. An atmosphere of the process annealing is not limited in particular.

[0042]

The generation of the niobium carbo-nitride can be determined through an observation under a transmission electron microscope (TEM). A precipitation amount of the niobium carbo-nitride that is effective in bringing about cell transformation in the final

cold rolling depends on the γ stability of the base metal, and the intended effect can be obtained by causing about 0.01% of Nb of Nb in the steel sheet to precipitate.

[0043]

3. Final Cold Rolling

The steel sheet obtained by the process annealing is subjected to the final cold rolling at a total thickness reduction rate of 50% or higher. The final cold rolling is cold rolling that is the last to be performed of the steps to manufacture the austenitic stainless steel sheet of the present invention. To achieve an objective of the present invention, it is necessary to generate deformation induced martensite in the cold rolling after the process annealing, and further to transform the form of the martensite from lath one to cell one. To achieve this, the cold rolling is performed at a total thickness reduction rate of 50% or higher. The total thickness reduction rate is more desirably set at 60% or higher. In contrast, an excessively high total thickness reduction rate leads to a decrease in quality, and thus the total thickness reduction rate is preferably set at 100% or lower. Whether the martensite is cell or not can be observed under a transmission electron microscope (TEM). In this observation, martensite having a relatively granular cell structure is found generated inside linear laths, and thus it is easy to distinguish between cell-type martensite and lath martensite.

[0044]

4. Final Annealing

The steel sheet obtained by the final cold rolling is further subjected to the final annealing at a temperature higher than 700°C to 950°C or lower. The final annealing is annealing that is the last to be performed of the steps to manufacture the austenitic stainless steel sheet of the present invention. In the case of performing temper rolling, the final annealing is annealing that is the last to be performed of steps performed before the temper rolling. In the final annealing, the cell-type martensite generated in the previous operation is subjected to reverse transformation to fine, isometric austenite grains. At this point, an excessively low final annealing temperature leads to insufficient recrystallization,

and thus non-recrystallized grains having large aspect ratios remain. In contrast, an excessively high final annealing temperature causes grains to coarsen. Therefore, a final annealing temperature is set at higher than 700°C to 950°C or lower. To make the effect more apparent, the lower limit of the final annealing temperature is preferably set at 800°C, and the upper limit of the final annealing temperature is preferably set at 930°C. An atmosphere of the final annealing is not limited in particular.

[0045]

In addition, from the viewpoint of the eradication of non-recrystallized grains and the suppression of coarsening grains, an annealing retention time is desirably from 5 to 300 seconds. Although a rate of temperature increase up to the annealing temperature and a cooling rate after the annealing are not limited in particular, the rate of temperature increase is preferably set at 15 to 50°C/s, and the cooling rate is preferably set at 15 to 45°C/s (from a retention temperature down to 300°C), from the viewpoint of sufficient recrystallization for the reverse transformation to isometric austenite grains and for the suppression of coarsening grains, and from the viewpoint of suppressing coarse chromium carbo-nitride, which inhibit etchability.

EXAMPLE

[0046]

The chemical compositions of steels being specimens are shown in Table 1. Steels A to G have chemical compositions that satisfy the specifications of the present invention, and steels H to N are comparative examples outside the scope of the present invention. Small ingots having the chemical compositions shown in Table 1 were subjected to melt and cutting working to be made into hot-rolling starting materials having a thickness of 40 mm. Thereafter, the materials were subjected to hot rolling to have a thickness of 4 mm, subjected to post-heat-rolling annealing at 1200°C, and thereafter subjected to cold rolling to have a thickness of 2 mm. Thereafter, the materials were subjected to annealing at 1150°C and subjected to cold rolling to have a predetermined sheet thickness. Cold

rolling ratios in the cold rolling performed after the annealing at 1150°C, namely the cold rolling performed before the process annealing were calculated inversely so that the thicknesses of the materials after the final cold rolling became 0.4 mm when the final cold rolling was performed at rolling ratios shown in Table 2.

[0047]

Thereafter, the materials were subjected to the process annealing, the final cold rolling, and the final annealing under conditions shown in Table 2, so that steel sheets having a thickness of 0.4 mm were obtained. In the process annealing, the temperatures of the materials were raised up to the process annealing temperatures at a rate of temperature increase of 10 to 30°C/s, the materials were retained for 5 to 300 seconds at process annealing temperatures shown in Table 2, and thereafter the temperatures of the materials were lowered at a temperature drop rate of 10 to 20°C/s (from the retention temperatures down to 300°C). In addition, in the final annealing, after the final cold rolling, the temperatures of the materials were raised up to the final annealing temperatures at a rate of temperature increase of 15 to 30°C/s, the materials were retained for 5 to 300 seconds at final annealing temperatures shown in Table 2, and thereafter the temperatures of the materials were lowered at a temperature drop rate of 15 to 30°C/s (from the retention temperatures down to 300°C).

[0048]

A micro-structure picture of the vertical section of each obtained steel sheet was captured under a scanning electron microscope, the vertical section being perpendicular to a rolling direction, and an average grain size, an average aspect ratio of grains, and a non-recrystallized portion residual rate were calculated. The average grain size and the average aspect ratio of grains were both calculated from the result of measuring 50 or more grains in each steel sheet. The non-recrystallized portion residual rate was obtained by putting 100 or more lattice points on the captured picture, confirming whether each of the lattice points is a grain or a non-recrystallized portion, and thereafter calculating the ratio

of the number of lattice points being non-recrystallized portions to the number of all lattice points.

[0049]

In addition, to evaluate a high-precision workability, an average roughness of a worked surface was examined in the present example. The average roughness was measured using a surface roughness meter after etching each steel sheet with ferric chloride solution until the sheet thickness of the steel sheet was halved. In each of directions perpendicular and parallel to the rolling direction, three profile roughnesses (arithmetic average roughnesses) over 4 mm were measured, the results of measuring the six arithmetic average roughnesses were further averaged to obtain a value, and the value is evaluated as a representative value. Having an average roughness of 0.10 μm or lower was determined to have on a good level for a metal mask. The results are shown in Table 2.

[0050]

[Table 1]

Table 1

Classification	Chemical composition (mass%, Balance: Fe and impurities)												
		C	Si	Mn	Cr	Ni	Cu	Mo	Nb	N	C+N	Md ₃₀	SFE
Inventive Example	A	0.02	0.5	0.8	18.2	8.1	0.2	0.3	0.08	0.045	0.065	34.9	19.03
	B	0.02	0.4	1.2	17.2	6.7	0.3	0.3	0.05	0.121	0.141	37.2	12.79
	C	0.03	0.5	1.1	17.2	7.1	0.3	0.3	0.10	0.061	0.091	52.2	14.95
	D	0.03	0.5	0.7	18.1	7.1	1.5	0.2	0.06	0.034	0.064	33.5	35.69
	E	0.02	0.5	0.5	15.9	7.2	1.5	1.6	0.06	0.032	0.052	44.0	47.00
	F	0.03	0.4	0.8	20.8	4.9	0.3	0.4	0.06	0.061	0.091	48.8	3.80
	G	0.03	1.3	0.2	18.5	5.8	0.6	0.6	0.06	0.058	0.088	53.8	13.29
Comparative Example	H	0.01	0.4	1.2	17.8	6.7	0.3	0.3	0.002*	0.010	0.020*	84.9	13.21
	I	0.02	0.6	1.0	18.2	8.1	0.2	0.3	0.002*	0.051	0.071	29.6	19.67
	J	0.08	0.5	0.8	18.2	10.2*	0.2	0.3	0.05	0.129	0.209*	50.0	-6.00
	K	0.03	0.5	0.2	17.2	6.7	0.05*	0.05*	0.06	0.053	0.083	82.2	2.62
	L	0.04	0.5	0.3	18.5	8.1	2.5	0.3	0.06	0.053	0.093	-22.7	60.42
	M	0.03	0.5	0.2	18.5	8.0	0.3	0.3	0.78*	0.042	0.072	33.4	18.56
	N	0.03	0.5	1.8*	18.5	10.9*	0.2	0.3	0.08	0.045	0.075	-24.0	35.00

* indicates deviation from the range specified in the present invention.

[0051]

[Table 2]

Table 2

Classification	No.	Chemical composition	Intermediate Annealing Temperature (°C)	Final Cold-Rolling Reduction Rate (%)	Final Temperature (°C)	Average Grain Size (μm)	Non-Recrystallization Portion Residual Rate (%)	Average Aspect Ratio	Average roughness (μm)
Inventive Example	1	A	920	67	890	1.5	1.1	1.1	0.08
	2	A	980	67	920	2.1	0.0	1.1	0.10
	3	A	980	72	850	1.3	1.2	1.2	0.08
	4	B	990	60	850	1.1	0.5	1.1	0.08
	5	C	920	67	890	1.1	0.8	1.1	0.07
	6	D	980	75	890	1.2	0.5	1.1	0.08
	7	E	980	82	790	0.9	1.1	1.2	0.07
	8	F	990	74	920	1.5	0.2	1.1	0.08
	9	G	980	67	890	1.0	0.5	1.1	0.07
	10	A	700	77	940	0.7	0.2	1.1	0.06
	11	A	800	75	930	0.7	0.2	1.1	0.06
	12	A	900	82	930	0.8	0.2	1.1	0.07
Comparative Example	13	A	1100#	67	890	2.5	4.7	1.5*	0.15
	14	A	920	40#	950	5.1*	1.4	1.5*	0.18
	15	A	920	67	1020#	18.0*	1.1	1.1	0.32
	16	A	920	70	680#	0.9*	28.0*	1.7*	0.25
	17	B	1120#	60	870	1.5	8.5*	1.4*	0.16
	18	B	920	70	600#	-	-	-	0.38
	19	H*	920	67	920	5.2*	1.1	1.1	0.14
	20	I*	920	67	890	1.5	4.1*	1.1	0.16
	21	J*	920	67	830	1.3	6.1*	1.3*	0.22
	22	K*	920	67	890	-	-	-	0.35
	23	L*	920	72	870	6.2*	3.5*	1.1	0.15
	24	M*	900	67	870	1.5	8.1*	1.1	0.16
	25	N*	920	67	870	5.5*	2.2	1.1	0.13

* indicates deviation from the range specified in the present invention regarding steel plate.

indicates deviation from the range specified in the present invention regarding manufacturing method.

[0052]

Steel sheets 1 to 12 in Table 2 are inventive examples of the present invention, which are excellent in smoothness of their high-precision worked surfaces. It is noted that samples were taken from steel sheets after being subjected to the final cold rolling and before being subjected to the final annealing, and were subjected to structure observation under a TEM, and it was confirmed that transformation to cell-type martensite had occurred. In addition, as to the smoothness of a high-precision worked surface, an average roughness of an etched surface measured using a surface roughness meter is used

as an index, the etched surface being obtained by etching a steel sheet with ferric chloride solution until the sheet thickness of the steel sheet is halved.

[0053]

Steel sheets 13 to 25 are comparative examples, which are poor in the smoothness of their high-precision worked surface, which will be described below in detail.

[0054]

As to the steel sheet 13, the process annealing temperature was high, and the precipitation of niobium carbo-nitride did not occur in the process annealing. Therefore, martensite generated in the final rolling was mostly of lath. Although the average grain diameter after the final annealing was relatively small, non-recrystallized portions remain in a large quantity, and the average aspect ratio of grains was also high.

[0055]

As to the steel sheet 14, the final cold rolling ratio was insufficient. Therefore, generated martensite was small in number and mostly of lath, and the average aspect ratio of grains after the final annealing was also high.

[0056]

As to the steel sheet 15, the final annealing temperature was high. Therefore, grains grew large, and the smoothness of a worked surface was poor.

[0057]

As to the steel sheet 16, the final annealing temperature was low. Therefore, recrystallized grains were small, but non-recrystallized portions remained in a very large quantity, and the average roughness of a worked surface was high.

[0058]

As to the steel sheet 17, the process annealing temperature was high, and the precipitation of niobium carbo-nitride did not occur in the process annealing. Therefore, martensite generated in the final rolling performed after the process annealing was mostly of lath. Although the average grain diameter after the final annealing was relatively small,

non-recrystallized portions remain in a large quantity, and the average aspect ratio of grains was also high.

[0059]

As to the steel sheet 18, although the process annealing temperature satisfied the specifications of the present invention, the final annealing temperature was low. Therefore, the reverse transformation from martensite generated in the final cold rolling to austenite was insufficient, and thus a grain size and the like could not be calculated by a normal method. In addition, the steel micro-structure of this steel sheet was made up of a large quantity of martensite and non-recrystallized austenite, and thus the roughness of a high-precision worked surface was extremely high.

[0060]

Steel sheets 19 to 25 had the chemical compositions that were outside the scope of the present invention and thus were comparative examples in which at least one of an average grain size, a ratio of non-recrystallized area, and an average aspect ratio of grains was outside the scope specified in the present invention.

[0061]

As to the steel sheets 19 and 20, the amount of Nb was low. Therefore, although the process annealing was performed at low temperatures, austenite stabilities could not be adjusted.

[0062]

As to the steel sheet 21, the amount of Ni and, the amount of C + N were high. Therefore, an austenite stability was extremely high, and thus cell martensite was not generated in the final cold rolling.

[0063]

As to the steel sheet 22, Cu was low, and thus an austenite stability was low. Therefore, martensite remained in a large quantity after the final annealing, a grain size and the like could not be calculated. In addition, roughness after working was also high.

[0064]

As to the steel sheet 23, Cu was contained in a large quantity. Therefore, cell martensite was not generated in the final cold rolling.

[0065]

As to the steel sheet 24, Nb was contained in a large quantity. Therefore, non-recrystallized portions remained in a large quantity even after the final annealing.

[0066]

As to the steel sheet 25, the amounts of Mn and Ni were large, and thus an austenite stability was extremely high. Therefore, cell martensite is not generated even in the final cold rolling.

INDUSTRIAL APPLICABILITY

[0067]

According to the present invention, it is possible to obtain an austenitic stainless steel sheet containing fine, isometric grains. Such an austenitic stainless steel sheet is excellent in smoothness of an etching worked surface and thus is suitable for high-precision working such as etching and laser machining. In addition, the present invention allows the austenitic steel described above to be manufactured industrially with stability.

CLAIMS

[Claim 1]

An austenitic stainless steel sheet comprising, by mass %,

C + N: 0.03 to 0.20%,

Si: 0.1 to 1.5%,

Mn: 0.10 to 1.5%,

Cr: 15.0 to 22.0%,

Ni: 4.5 to 10.0%,

Cu: 0.10 to 2.0%,

Mo: 0.1 to 2.0%,

Nb: 0.02 to 0.50%, and

the balance being Fe and impurities, wherein

an average grain size is 5.0 μm or smaller,

a ratio of non-recrystallized area is 3.0% or lower, and

an average aspect ratio of grains is 1.2 or lower.

[Claim 2]

A method for manufacturing the austenitic stainless steel sheet according to claim 1, the method comprising,

after subjecting base metal to hot rolling, annealing, and cold rolling,

performing process annealing at a treatment temperature of lower than 1000°C, a final cold rolling at a total thickness reduction rate of 50% or higher, and final annealing at a treatment temperature within a temperature range higher than 700°C to 950°C or lower, in this order.