

DESCRIPTION

AUSTENITIC STAINLESS STEEL SHEET

TECHNICAL FIELD

[0001]

The present invention relates to an austenitic stainless steel sheet.

BACKGROUND ART

[0002]

For precision working, particularly photoetching, and subsequent processing in which heat is further applied to a material by diffusion bonding or the like, an austenitic stainless steel sheet is used. Photoetching is a method for processing a metal sheet into substantially the same shape as that of the photoresist pattern, in which a pattern is formed on the surface of a starting material, or the metal sheet, by a photoresist method and thereafter the metal sheet is melted by etching through spraying or immersion. Laser machining is a processing method of melting the surface of a metal sheet by laser based on CAD data, etc., thereby forming holes and predetermined patterns.

[0003]

Since a metal sheet thus processed is used for a metal mask etc., the starting material for the metal sheet is required to have excellent flatness and high hardness, and especially in the photoetching, is required to have a low carbon content for suppressing smut, a smooth etched surface, and further a small warp after half-etching treatment.

[0004]

Moreover, in recent years, there are increasing cases in which stainless steel sheets which have been subjected to photoetching or laser machining are laminated, and are subjected to diffusion bonding treatment at a temperature of not less than about 700°C, thereby producing heat exchangers and complicated flow passage components. For such uses, it is also required to have, besides the above described characteristics, good bondability and small volume change or contraction after being heated.

[0005]

For example, Patent Document 1 discloses a method of flattening and stress relaxation of a material for photoetching by a method (tension annealing method) of adjusting the hardness of stainless steel foil by temper rolling, and thereafter performing heat treatment while applying tension.

[0006]

Patent Document 2 discloses a method for producing a stainless steel sheet excellent in flatness after etching, which includes adjusting hardness of an austenitic stainless steel strip by temper rolling, thereafter performing straightening thereof by a tension leveler, thereafter applying a tension corresponding to 0.7 to 1.0 times of 0.2% yield stress thereto, and further applying annealing treatment at 700 to 800°C.

[0007]

In the stainless steel sheet produced by the method disclosed in Patent Document 2, work strain imparted to the starting material by temper rolling or tension leveler straightening is eliminated by final annealing treatment at 700 to 800°C, and thereby internal residual stress is decreased, thus suppressing warping after half-etching. Further, this stainless steel sheet is characterized in that it exhibits small volume change and thermal contraction even if heat is applied thereto during subsequent diffusion bonding since martensite reversely transforms into austenite during annealing at 700 to 800°C.

[0008]

Further, Patent Document 3 discloses, as a stainless steel having excellent diffusion bondability, a ferritic stainless steel foil which has fine crystal grains whose average grain size in the foil thickness direction is 0.001 to 5 μm , and has an Al content of 0.5 to 8% ("%as used herein regarding chemical composition refers, unless otherwise stated, to "mass%").

LIST OF PRIOR ART DOCUMENTS

PATENT DOCUMENT

[0009]

Patent Document 1: JP4-69229B

Patent Document 2: JP3573047

Patent Document 3: JP3300225

DISCLOSURE OF THE INVENTION

PROBLEMS TO BE SOLVED BY THE INVENTION

[0010]

Since the method disclosed in Patent Document 1 requires a special annealing facility which can apply tension to stainless steel foil in a furnace, or requires to pass a sheet at a low temperature of about 400°C and at a low speed for performing sufficient stress relaxation, a problem that arises is that productivity declines, which leads to increase in production cost of the material for photoetching.

[0011]

Further, although some of the stainless steel foils produced by the method disclosed in Patent Document 1 satisfy required characteristics during photoetching, a problem that arises is that some of them exhibit large volume changes or thermal contraction during, for example, diffusion bonding after photoetching. This problem also arises when heat is applied by laser machining. According to the results of investigation by the present inventors, this problem is attributable to the fact that since deformation induced martensite generated by temper rolling remains after tension annealing, martensite reversely transforms into austenite when heat is applied during subsequent diffusion bonding.

[0012]

The stainless steel sheet produced according to the method disclosed in Patent Document 2 has a problem in that as a result of elimination of work strain, sufficient hardness cannot be obtained by a low carbon content material.

[0013]

Further, although the invention disclosed in Patent Document 3 is directed to a ferritic stainless steel, it is considered that even an austenite stainless steel can be improved in terms of diffusion bondability by refining crystal grains.

[0014]

An objective of the present invention is to provide an austenitic stainless steel sheet, which can simultaneously achieve below listed two required characteristics, which cannot be achieved by the inventions disclosed in Patent Documents 1 and 2: a required characteristic (characteristic I) during photoetching and laser machining, and a required characteristic (characteristic II) when used in applications in which heat is applied by diffusion bonding and laser machining, etc., and which is for example suitable for a material for use in precision working for, for example, laser metal masks , and a production method of the same.

[0015]

(Characteristic I) Required characteristics during photoetching and laser machining include a flat starting material, a high hardness, a low carbon content to suppress smut during photoetching, a small warp even after half-etching treatment, and a smooth etched surface and laser processed surface.

[0016]

(Characteristic II) Required characteristics when used in applications in which heat is applied by diffusion bonding and laser machining, etc. include small volume change and contraction due to heating.

MEANS FOR SOLVING THE PROBLEMS

[0017]

Figures 1(a) to 1(c) are explanatory diagrams to conceptually show distribution of work strain in sheet interior and at a sheet surface.

[0018]

As shown in Figure 1(a), work strain distribution in a sheet after straightening by conventional temper rolling and a tension leveler becomes such a distribution as that work strain is larger near the sheet surface and smaller in the sheet interior. When half-etching is performed in this state, compression stress near the sheet surface is released and a warp occurs in which the half-etched surface becomes convex shaped.

[0019]

In contrast to this, as disclosed in Patent Document 2, by performing annealing at

700 to 800°C for about 30 seconds to 10 minutes (SR treatment: which is abbreviation of stress relief and means heat treatment mainly for the purpose of removing residual stress), it is possible to eliminate work strain in the entire sheet including the sheet surface and the sheet interior as shown in Figure 1(b). This indeed suppresses the occurrence of a warp after half-etching. However, as described above, the hardness of the sheet decreases since work strain is eliminated so that the sheet may not satisfy characteristics which have been required recently for an etching material.

[0020]

The inventors of the present invention have conducted diligent study to solve those problems, and have found that it is possible to satisfy hardness required for an etching material while suppressing the occurrence of a warp after half-etching by making a certain level of work strain remain uniformly in the sheet thickness direction as shown in Figure 1(c) not by eliminating work strain in the entire sheet by the SR treatment.

[0021]

However, merely lowering the temperature of conventional SR treatment causes deformation induced martensite (α'), which has been generated by temper rolling and tension leveler straightening, to remain. This leads to increase in volume change during diffusion bonding. Also, merely decreasing the period of time for SR treatment allows for elimination of deformation induced martensite (α'), but does not allow for elimination of work strain so that warp after half-etching will increase.

[0022]

Figures 2(a) to 2(c) are explanatory diagrams to show various SR treatment conditions.

In order to obtain uniform work strain in the sheet thickness direction as shown in Figure 1(c) and decrease the amount of deformation induced martensite, the present inventors have found as a result of having conducted further investigation that, instead of simultaneously promoting reverse transformation of deformation induced martensite into austenite and elimination of work strain by a heat treatment at a high temperature and for a long period of time as in the conventional SR treatment condition as shown in Figure 2(a), it is effective to adopt a SR treatment condition as shown Figures 2(b) and 2(c) including:

heat treatment X, in which deformation induced martensite is reversely transformed into austenite by performing a heat treatment of heating to, as measured at a sheet surface, 700 to 800°C at a temperature rising rate of not less than 10°C/sec in the temperature at sheet surface and holding in the temperature range for not more than 10 seconds, and thereafter cooling at a cooling rate of not less than 10°C/sec after straightening by temper rolling and tension leveler; and a heat treatment Y process, in which work strain is adjusted by performing heat treatment of holding in a temperature range of not less than 600°C and less than 700°C for not less than 10 seconds.

[0023]

Note that there is no restriction on the order of the heat treatment X process and the heat treatment Y process, and the heat treatment Y process may be performed after the heat treatment X process is performed, or the heat treatment X process may be performed after the heat treatment Y process is performed. In either case, it is possible to satisfy characteristics required in the present invention. Moreover, it is also possible to satisfy the characteristics required in the present invention even when the heat treatment Y process is continuously performed following the heat treatment X process, or when the heat treatment X process is continuously performed following the heat treatment Y process.

[0024]

In the chemical composition to which the present invention is directed, deformation induced martensite which is produced by cold rolling or further by tension leveling will be eliminated even in a short holding time as described above, since it reversely transforms into austenite in a shear-type (diffusionless) mode.

[0025]

In an austenitic stainless steel sheet provided by the present invention, since such deformation induced martensite (α') is reduced as described above, a volume change, etc. due to reverse transformation of deformation induced martensite into austenite during heating of diffusion bonding is suppressed. Moreover, when heat is applied by laser machining etc. as well, shape changes attributable to reverse transformation of deformation induced martensite into austenite in a processed surface is suppressed.

[0026]

On the other hand, since almost all of work strain will remain when the SR treatment at not less than 700°C is performed in a short period of time, it is not possible to leave constant work strain uniformly in the sheet thickness direction as shown in Figure 1(c). However, by performing the SR treatment in a lower temperature range for an appropriate time period, diffusion near the surface where much work strain exists preferentially proceeds, allowing constant work strain to uniformly remain in the sheet thickness direction as shown in Figure 1(c).

[0027]

Note that to quantitatively evaluate work strain, a half-value width of a peak obtained by X-ray diffraction measurement can be utilized. A large amount of strain causes the crystalline inter-lattice distance to be elongated or contracted from its original length, and such behavior appears on the half-value width of a peak obtained by X-ray diffraction measurement. That is, as the amount of strain increases, the number of crystalline inter-lattice distance, which is longer or shorter than its original quantity, increases, and thereby the half-value width of a peak increases.

[0028]

The present invention is as listed below.

An austenitic stainless steel sheet, comprising:

a chemical composition comprising: in mass%,

C: not more than 0.03%,

Si: not more than 1.0%,

Mn: not more than 1.5%,

Cr: 15.0 to 20.0%,

Ni: 6.0 to 9.0%,

N: 0.03 to 0.15%,

Nb: 0 to 0.50%,

V: 0 to 0.50%,

Ti: 0 to 0.20%,

Cu: 0 to 1.5%, and

Mo: 0 to 2.0%,

with the balance being Fe and inevitable impurities, wherein
 an Md30 value calculated by below described Formula (1) is 30.0 to 50.0°C; and

a metal micro-structure, wherein

an average value of amount of deformation induced martensite is not more than 5.0% in volume ratio,

an average value of austenite grain diameter is not more than 5.0 μm, and

X-ray diffraction half-value widths of γ(220) phase respectively at a sheet surface and sheet center are not less than 0.50°, and difference thereof is not more than 0.10°:

Md30 value (°C) = 497 - 462(C + N) - 9.2(Si) - 8.1(Mn) - 13.7(Cr) - 20(Ni + Cu) - 18.7(Mo) (1),

where, each symbol of element in Formula (1) represents a content of each element.

[0029]

Note that the austenitic stainless steel sheet according to the present invention can be produced by, for example, subjecting a cold-rolled austenitic stainless steel strip to temper rolling at a rolling reduction of not less than 30% to adjust its hardness, thereafter to straightening by a tension leveler as needed, and thereafter to below described heat treatment including heat treatment X and heat treatment Y:

Heat treatment X: heat treatment of heating to 700 to 800°C at a temperature rising rate of not less than 10°C/sec as measured at a sheet surface and holding in the temperature range for not more than 10 seconds, and thereafter cooling at a cooling rate of not less than 10°C/sec as measured at a sheet surface;

Heat treatment Y: heat treatment of holding in a temperature range of not less than 600°C and less than 700°C for not less than 10 seconds.

ADVANTAGEOUS EFFECTS OF THE INVENTION

[0030]

According to the present invention, it is possible to obtain an austenitic stainless

steel sheet which simultaneously achieves required characteristics during photoetching and laser machining (such as a flat starting material, a high hardness, a low carbon content to suppress smut during photoetching, a small warp even after half-etching treatment, and a smooth etched surface and laser processed surface), and required characteristics when used in applications in which heat is applied by diffusion bonding and laser machining (such as small volume change and contraction due to heating). The austenitic stainless steel sheet of the present invention is for example suitable for a material for use in precision working for, for example, laser metal masks.

BRIEF DESCRIPTION OF THE DRAWINGS

[0031]

[Figure 1] Figures 1(a) to 1(c) are diagrams to conceptually show a distribution of work strain in sheet interior and at a sheet surface.

[Figure 2] Figures 2(a) to 2(c) are explanatory diagrams to show various SR treatment conditions.

MODE FOR CARRYING OUT THE INVENTION

[0032]

Embodiments for carrying out the present invention will be described.

1. An austenitic stainless steel sheet according to the present invention

While the present invention is directed to a metastable austenitic stainless steel, from the viewpoints of smoothness of etched surface, etc. it is desirable that average crystal grain diameter is small and no smut is produced during etching so that the chemical composition is specified as follows.

[0033]

(1-1) Chemical composition

[C: not more than 0.03%]

When C content is more than 0.03%, C precipitates as a coarse Cr carbide at crystal grain boundaries during production, and causes occurrence of smut during etching so that the C content is preferably as little as possible. However, since C is an element

which can raise the strength of steel sheet inexpensively, it may be contained within a range of not more than 0.03% in which there is no adverse effect of smut. For this reason, the C content is set to be not more than 0.03%. For uses in which smoothness after etching is strictly required, it is preferable to make the C content not more than 0.02%. The C content is preferably not more than 0.012%.

[0034]

[Si: not more than 1.0%]

Si is used as a deoxidizing material during melting, and also contributes to strengthening of steel. However, when the Si content is more than 1.0%, etching rate will be decreased. Therefore, the Si content is set to be not more than 1.0%. It is preferably not more than 0.8%, and more preferably not more than 0.6%. The Si content is further preferably not more than 0.3%.

[0035]

[Mn: not more than 1.5%]

Mn contributes to prevention of brittle fracture during hot working and strengthening of steel. However, since Mn is a strong austenite forming element, when the Mn content is more than 1.5%, deformation induced martensite generated during cold rolling decreases, and it becomes unable to obtain fine crystal grains in subsequent annealing. Therefore, the Mn content is set to be not more than 1.5%. It is preferably not more than 1.2%.

[0036]

[Cr: 15.0 to 20.0%]

Cr is a fundamental element for stainless steel, and by being contained not less than 15.0%, it forms metal oxide layer on the surface of steel material, thus improving corrosion resistance. However, since Cr is a strong ferrite stabilizing element, when the Cr content is more than 20.0%, δ ferrite is produced, and the δ ferrite deteriorates hot workability of the starting material. Therefore, the Cr content is set to be not less than 15.0% and not more than 20.0%.

[0037]

[Ni: 6.0 to 9.0%]

Ni is an austenite forming element and an element for stably obtaining austenite phase at room temperature. Therefore, the lower limit of the Ni content is set to be 6.0%. The lower limit is preferably 6.1%. However, when the Ni content is more than 9.0%, the austenite phase is excessively stabilized, thus suppressing deformation induced martensite transformation during cold rolling. Further, since Ni is an expensive element, increase in the Ni content leads to significant increase in cost. Therefore, the upper limit of the Ni content is set to be 9.0%. The upper limit is preferably 8.9%.

[0038]

[N: 0.03 to 0.15%]

N, like C, is a solid solution strengthening element and contributes to strength enhancement of steel. Moreover, N combines with Nb to precipitate as fine Nb compounds during annealing, and has an effect of suppressing the crystal grain growth. Therefore, the N content is set to be not less than 0.03%. However, when the N content is more than 0.15%, a large number of coarse nitrides are produced in the production process of steel sheet, and these coarse nitrides work as fracture starting points, thereby significantly deteriorating hot workability, and making production difficult. Therefore, the N content is set to be not more than 0.15%. The upper limit thereof is preferably 0.13%.

[0039]

[Md30 value determined by Formula (1): not less than 30.0°C and not more than 50.0°C]

The metastable austenitic stainless steel to which the present invention is directed allows for obtaining fine crystal grains by utilizing austenite to deformation induced martensite (martensite) transformation during cold rolling, and deformation induced martensite to austenite reverse transformation in subsequent heat treatment. When the Md30 value is less than 30.0°C, austenite stability is high, and it is difficult to produce enough deformation induced martensite during cold rolling. On the other hand, when Md30 value is more than 50.0°C, the austenite stability is low, leading to increase in the load of cold rolling. Therefore, the Md30 value is set to be not less than 30.0°C and not more than 50.0°C. The lower limit thereof is preferably 36.0°C, and the upper limit thereof is preferably 48.0°C.

[0040]

[Nb: 0 to 0.50%]

[V: 0 to 0.50%]

[Ti: 0 to 0.20%]

Nb, V, and Ti are elements which form fine carbides or nitrides, and are effective in suppressing crystal grain growth by a pinning effect, thereby refining crystal grains of the starting material. Refining of crystal grains contributes to improvement in smoothness of etched surface, or the like. Therefore, those elements may be contained. However, when the content of any of Nb, V, Ti is excessive, it suppresses recrystallization, and has an adverse effect of causing unrecrystallized part to remain in a large amount after annealing. Moreover, addition of these elements in a large amount directly leads to cost increase of the starting material. Therefore, upper limit values of these elements when they are contained are set to be 0.50% for Nb and V, and 0.20% for Ti. The lower limits of contents of these elements are preferably 0.001% for Nb, 0.001% for V, and 0.001% for Ti.

[0041]

[Mo: 0 to 2.0%]

Mo may be added appropriately, since it improves corrosion resistance of material. However, when the Mo content is more than 2.0%, it hinders etching and leads to cost increase as well. Therefore, when Mo is contained, its content is set to be not more than 2.0%. Its content is preferably not more than 1.8%, and more preferably not more than 1.0%. The lower limit of the Mo content is preferably 0.001%.

[0042]

[Cu: 0 to 1.5%]

Cu may be added appropriately, since it is an austenite forming element, and an element which can adjust the stability of austenite phase. However, when the Cu content is more than 1.5%, it segregates at grain boundaries in the production process, and such grain boundary segregation significantly deteriorates hot workability, thereby making the production difficult. Therefore, when Cu is contained, the upper limit value of its content is set to be 1.5%. It is preferably not more than 1.4%. The lower limit of the Cu content

is preferably 0.001%.

[0043]

(1-2) Metal micro-structure

[Average value of amount of deformation induced martensite: not more than 5.0% in volume ratio]

When deformation induced martensite is present in a large amount, it transforms into austenite phase when it is applied with heat by diffusion bonding and laser machining, and this causes a volume change. Therefore, the average value of the amount of deformation induced martensite is set to be not more than 5.0% in volume ratio. The average value of amount of deformation induced martensite is calculated from an integrated intensity of a peak obtained by X-ray diffraction measurement (B. D. Cullity, "Element Of X-Ray Diffraction," Addison-Wesley, 1978). The average value of the amount of deformation induced martensite is specifically determined from the below-described Formulas (2) and (3). Here, C_γ and C_α are volume ratios of austenite phase and martensite phase, I_γ and I_α are integrated intensities of X-ray diffraction peaks of austenite phase and martensite phase, and R_γ and R_α are coefficients determined by the below-described Formula (4), respectively. Here, v is a volume of a unit cell, F is a structural factor, p is a multiplicity factor, Θ is an incident angle, and e^{-2M} is a temperature factor.

$$C_\gamma + C_\alpha = 1 \dots (2)$$

$$I_\gamma/I_\alpha = R_\gamma C_\gamma / R_\alpha C_\alpha \dots (3)$$

$$R = (1/v^2)[F^2 p(1 + \cos^2 2\Theta) / (\sin^2 \Theta \cos \Theta)] [e^{-2M}] \dots (4)$$

[0044]

[Average value of austenite grain diameter: not more than 5.0 μm]

By making the average value of austenite grain diameter to be as small as not more than 5.0 μm , the etched surface becomes smooth, and diffusion bondability is improved. Therefore, in the present invention, the upper limit of the average value of austenite grain diameter is set to be 5.0 μm .

[0045]

The average value of austenite grain diameter is calculated as follow. First, a

section perpendicular to rolling direction of the starting material is measured by EBSD (Electron Backscatter Diffraction), then an average area S per one crystal grain is calculated from the number of crystal grains included in a predetermined area regarding a region surrounded by a boundary of an orientation difference of not less than 15° as one crystal grain, and an austenite grain diameter D determined by the below-described Formula (5) is calculated from the average area S .

$$D = (2S/\pi)^{0.5} \dots (5)$$

[0046]

[X-ray diffraction half-value width of austenite $\gamma(220)$ phase measured at a sheet surface and sheet center respectively: both are not less than 0.50° and difference thereof: is not more than 0.10°]

As described above, one fundamental concept of the present invention is to control the distribution of the amount of strain in the sheet thickness direction. In the present invention, to maintain the hardness of the starting material, the amount of strain respectively at a sheet surface and sheet center needs to be more than a fixed amount, and this is specified as a half-value width of not less than 0.5° .

[0047]

Further, to suppress warp and deformation of a sheet due to half-etching, it is necessary that difference between the respective amounts of strain at a sheet surface and sheet center is small, and this is specified as that difference between respective half-value widths at the sheet surface and the sheet center is not more than 0.1° .

[0048]

In the X-ray diffraction measurement, Co-K α ray is used as characteristic X-ray, and a half-value width of $\gamma(220)$ is used. Measurement at a central part of sheet thickness is performed such that measurement is made at a polished surface which is chemically polished until the sheet thickness becomes half with one side being masked.

[0049]

2. Production method

(2-1) Temper rolling and tension leveler straightening

In the austenitic stainless steel sheet according to the present invention, a cold

rolled austenitic stainless steel strip having the above described chemical composition is subjected to temper rolling at a rolling reduction of not less than 30% to adjust its hardness. That is, the hardness is adjusted by performing temper rolling after finish annealing. Specifically, to ensure hardness not less than a level of 304-H specification which is specified as HV 370, temper rolling at a rolling reduction of not less than 30% is performed.

[0050]

Since an austenitic stainless steel sheet after temper rolling may become wave-shaped, to ensure the flatness of the sheet, it is desirable to perform tension leveling treatment by a tension leveler to straighten the shape.

[0051]

The temper rolling and tension leveler straightening may be performed by any common means well-known as such a kind, and will not be limited to particular means.

[0052]

(2-2) SR treatment

A conventional SR treatment is applied at about 700 to 800°C for a fixed time period, as shown in Figure 2(a), thereby eliminating work strain of the entire sheet as shown in Figure 1(b).

[0053]

In contrast, the method of the present invention adjusts work strain by applying heat treatment including the below described heat treatment X and heat treatment Y:

Heat treatment X: heat treatment X of heating to 700 to 800°C at a temperature rising rate of not less than 10°C/sec as measured at a sheet surface and holding in the temperature range for not more than 10 seconds, thereafter cooling at a cooling rate at a sheet surface of not less than 10°C/sec, and

Heat treatment Y: heat treatment of holding in a temperature range of not less than 600°C and less than 700°C for not less than 10 seconds.

[0054]

The heat treatment in the method of the present invention may be any heat treatment including the heat treatment X and the heat treatment Y, in which, for example,

the heat treatment Y is performed after the heat treatment X is performed, or the heat treatment X is performed after the heat treatment Y is performed as shown in Figure 2(b) or 2(c). This allows, as shown in Figure 1(c), fixed work strain to uniformly remain in the sheet thickness direction, thus making it possible to satisfy hardness required for an etching material while suppressing the occurrence of a warp after half-etching.

[0055]

In the heat treatment X, when the temperature rising rate is less than 10°C/sec, when the heat treatment temperature is more than 800°, when the heat treatment time is more than 10 seconds, or when the cooling rate is less than 10°C/sec, not only reverse transformation into austenite becomes excessive, but also work strain will excessively relaxed, thus making it difficult to obtain desired strength. On the other hand, when the heat treatment temperature is as low as less than 700°, the reverse transformation into austenite becomes insufficient. Therefore, heat treatment is performed by heating to 700 to 800°C at a temperature rising rate at a sheet surface of not less than 10°C/sec, and holding in the temperature range for not more than 10 seconds, and thereafter cooling at a cooling rate at a sheet surface of not less than 10°C/sec. Although the temperature rising rate depends on the performance of the facility to be used, it is preferably not more than 50°C/sec in the viewpoint of performing uniform heating to suppress defective shapes due to thermal strain. The cooling rate is preferably not more than 20°C/sec. In the viewpoint of eliminating only work strain near the surface of steel sheet, the heat treatment Y is performed by holding in a temperature range of not less than 600°C and less than 700°C for not less than 10 seconds. The heat treatment time is preferably not more than 180 seconds.

[0056]

Moreover, the heat treatment may successively proceed to the heat treatment Y during cooling in the heat treatment X as shown in Figure 2(b), or may be performed by cooling to a temperature (for example, room temperature) lower than the temperature of the heat treatment Y by the cooling in the heat treatment X, and thereafter reheating to perform the heat treatment Y as shown in Figure 2(c).

[0057]

By the production method described above, the above described austenitic stainless steel sheet according to the present invention can be produced.

EXAMPLE

[0058]

Table 1 shows chemical compositions of Steel types A to K used in the present example. Steel types A to H satisfied the chemical composition specified in the present invention, and Steel types I, J, and K did not satisfy the chemical composition specified in the present invention.

[0059]

[Table 1]

Table 1

Classification	Steel type	Chemical composition (mass%, Balance: Fe and inevitable impurities)											Md30
		C	Si	Mn	Mo	Cr	Ni	Cu	N	Nb	V	Ti	
Inventive Examples	A	0.013	0.30	1.20	0.30	17.6	6.6	0.3	0.125	0.049	-	-	36.03
	B	0.018	0.50	0.80	0.30	18.2	8.1	0.2	0.045	0.075	-	-	35.86
	C	0.012	0.30	1.18	1.20	17.1	6.5	0.2	0.088	-	0.022	-	47.77
	D	0.028	0.30	0.30	0.20	18.1	8.1	0.2	0.035	0.025	0.010	-	44.99
	E	0.020	0.80	0.50	0.70	15.4	8.9	0.5	0.060	-	-	-	36.56
	F	0.020	0.80	0.40	1.80	17.1	6.3	1.4	0.030	-	-	0.150	41.37
	G	0.013	0.20	0.40	-	18.2	8.8	-	0.042	0.120	0.056	0.014	41.17
	H	0.017	0.40	0.40	0.30	17.5	6.6	-	0.124	-	0.250	0.030	47.58
Comparative Examples	I	0.047*	0.58	0.71	0.25	18.2	8.1	0.3	0.050	0.001	-	-	19.08*
	J	0.013	0.30	0.40	0.30	21.0*	6.4	0.3	0.125	-	-	-	-0.07*
	K	0.025	0.50	0.80	0.30	16.1	6.1	0.2	0.130	-	-	0.310*	62.13*

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

[0060]

Small ingots having chemical compositions of Steel types A to K were melted, and after being successively subjected to cutting, hot rolling, annealing and descaling, they were each formed into a stainless steel sheet having a sheet thickness of 0.2 mm by repeating cold rolling and annealing for 3 times. The average crystal grain diameter of each stainless steel sheet at this point was about 2 μm for any one excepting Steel types I and J. Steel types I and J, which do not satisfy the chemical composition specified by the present invention was not able to obtain fine crystal grain micro-structure in the above described processes.

[0061]

Thereafter, each stainless steel sheet was subjected to temper rolling at a temper rolling reduction shown in Table 2, thereafter to tension leveler straightening, and further to SR treatment at conditions shown in Table 2. Thereafter, measurements of the amount of deformation induced martensite (α'), average value of austenite grain diameter, X-ray diffraction, and cross-section hardness of each stainless steel sheet finished with SR treatment were performed by using the above described measurement methods.

[0062]

Further, average roughness and warp of etched surface after half-etching, and deformation ratio after heating test were measured.

[0063]

Specifically, the roughness of the half-etched surface was an arithmetic average roughness measured by a contact-type roughness meter, after masking one side of a strip-shaped test specimen of 10 mm $\times$ 100 mm and thereafter chemically melting from another side until the sheet thickness becomes half with ferric chloride solution. The measurement direction was direction perpendicular to the rolling direction, and measurement length was 4 mm, an average of 5 measured arithmetic average roughnesses was taken. The warp after half-etching was thereafter measured by the curvature in the longitudinal direction. Further, by making a hole of a diameter of 10 mm in the specimen with photoetching in advance, and thereafter heating it at 1000°C for 5 minutes, the deformation ratio after heating test was calculated from a ratio of the sizes of the hole before and after heating.

[0064]

Evaluation of laminate bondability was performed as follows: after putting one stainless steel sheet as a disc-shaped test specimen of 8 mm diameter on top of another, and holding them at 750°C for 30 seconds while applying a load of 60 MPa thereto, bondability was evaluated as "○" when the two test specimens were bonded to each other and as "×" when they were not bonded to each other.

[0065]

Note that in Table 2, the holding temperature of the heat treatment Y means a reaching temperature, and the holding time means a time period in which the steel sheet

was subjected to heat treatment in a temperature range of not less than 600°C and less than 700°C.

[0066]

Test results are summarized in Table 2.

[0067]

[Table 2]

Table 2

Classification	Steel plate	Steel type	Temper rolling reduction %	First SR			Second SR			Characteristics after SR					After half-etching		Deformation after healing %	Laminate bondability				
				Temp. rising rate °C/s	Holding temp. °C	Holding time s	Cooling rate °C/s	Temp. rising rate °C/s	Holding temp. °C	Holding time s	Cooling rate °C/s	α' amount %	Average grain diameter of γ μm	Surface	Center	Difference			Cross-section hardness HV	Average roughness μm	Curvature mm ⁻¹	
Inventive Examples	1	A	40	15	780	10	10	15	650	20	20	2.0	1.8	0.600	0.572	0.028	399	0.14	0.0009	0.019	O	
	2	A	40	15	740	10	10	15	650	20	22	2.2	1.5	0.621	0.595	0.026	410	0.14	0.0012	0.020	O	
	3	B	40	15	760	10	10	15	680	20	13	2.0	1.3	0.638	0.632	0.006	415	0.13	0.0005	0.019	O	
	4	C	40	15	790	5	10	10	680	20	23	0.8	1.3	0.599	0.580	0.019	393	0.13	0.0018	0.015	O	
	5	D	45	15	760	10	10	15	680	30	25	1.2	1.1	0.553	0.521	0.032	392	0.15	0.0015	0.019	O	
Inventive Examples	6	E	45	15	780	10	10	10	680	30	19	1.9	3.5	0.602	0.580	0.022	395	0.18	0.0016	0.019	O	
	7	F	45	15	780	10	10	15	680	30	15	2.1	1.8	0.605	0.572	0.033	402	0.14	0.0020	0.018	O	
	8	G	45	15	780	10	10	10	680	30	29	2.9	1.3	0.640	0.621	0.019	410	0.13	0.0012	0.016	O	
	9	H	45	15	780	10	10	15	620	180	21	2.2	1.5	0.611	0.599	0.012	400	0.14	0.0009	0.019	O	
	10	C	40	15	650	20	10	15	770	10	18	2.0	1.6	0.612	0.583	0.029	403	0.13	0.0011	0.017	O	
Inventive Examples	11	C	40	15	680	30	10	15	750	10	14	2.3	1.5	0.606	0.577	0.029	411	0.16	0.0014	0.019	O	
	12	I*	45	15	780	10	10	15	650	20	20	2.5	7.0*	0.615	0.588	0.027	402	0.28	0.0010	0.020	x	
	13	J*	45	15	780	10	10	15	680	30	15	0.0	8.0*	0.605	0.580	0.025	378	0.30	0.0012	0.019	x	
	14	K*	45	15	780	10	10	15	680	30	11	5.2*	1.3*	0.687	0.578	0.109*	420	0.20	0.0150	0.040	x	
	15	C	20	15	760	10	10	10	650	20	5	1.4	1.5	0.179*	0.163*	0.016	355*	0.14	0.0005	0.019	O	
Comparative Examples	16	C	40	15	760	60*	10	-	-	-	-	0.5	1.6	0.155*	0.121*	0.034	342*	0.14	0.0021	0.013	O	
	17	C	40	15	760	10	10	10	-	-	-	2.1	1.5	0.677	0.524	0.153*	401	0.14	0.0230	0.020	O	
	18	C	40	15	650*	10	10	10	-	-	-	7.1*	1.4	0.772	0.652	0.120*	415	0.15	0.0220	0.041	O	
	19	C	40	5*	760	10	10	10	5	650	20	4	0.4	1.5	0.421*	0.401*	0.020	365*	0.15	0.0005	0.013	O
	20	C	40	15	600*	10	10	15	650	20	3	8.5	1.4	0.711	0.600	0.111*	420	0.16	0.0210	0.045	O	
Comparative Examples	21	C	40	15	760	10	5*	15	650	20	1	1.2	1.5	0.440*	0.417*	0.023	366*	0.14	0.0005	0.016	O	
	22	C	40	15	760	10	10	5	730*	30	19	0.5	1.5	0.222*	0.157*	0.065	357*	0.14	0.0070	0.013	O	
	23	C	40	15	680	30	10	10	750	30*	16	0.3	1.6	0.134*	0.122*	0.012	340*	0.14	0.0012	0.019	O	
	24	C	40	15	680	30	10	10	690*	10	11	5.1*	1.8	0.559	0.541	0.018	426	0.14	0.0141	0.042	O	
	25	C	40	-	-	-	-	-	-	-	-	20.0*	1.3	0.802	0.651	0.151*	422	0.18	0.0370	0.060	x	

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

[0068]

All of Steel sheets 1 to 11 in Table 2 were Inventive Examples which satisfied the present invention. On the other hand, Steel sheets 12 to 25 were steels for comparison which did not satisfy the present invention.

[0069]

In Steel sheets 1 to 11, the cross-section hardness was 392 to 415 Hv, the average roughness after half-etching was 0.13 to 0.18 μm , the curvature was 0.0005 to 0.0020 mm^{-1} , and the deformation ratio after heating test was 0.015 to 0.020. Steel sheets 1 to 11 possessed the above described characteristics I and II at the same time, and proved to be austenitic stainless steel sheets for precision working suitable for, for example, a laser metal masks.

[0070]

In contrast, in Steel sheet 12, since the C content was out of the range of the present invention, the average value of austenite grain diameter was 7 μm , thus not providing fine crystal grains so that the smoothness of the half-etched surface was poor and the laminate bondability was unsatisfactory as well.

[0071]

In Steel sheet 13, since the Md30 value was smaller than the range of the present invention, the average value of austenite grain diameter was 8 μm , thus not providing fine crystal grains so that the smoothness of the half-etched surface was poor and the laminate bondability was unsatisfactory.

[0072]

In Steel sheet 14, since the Md30 value was larger than the range of the present invention, deformation induced martensite (α') remained in a large amount and deformation after heating test was large.

[0073]

In Steel sheet 15, since the temper rolling reduction was lower than the lower limit of the range of the present invention, X-ray half-value widths at the sheet surface and the sheet center respectively were small, and the cross-section hardness was small as well.

[0074]

In Steel sheet 16, since the SR treatment was performed at a traditional general condition, almost no work strain remained so that the X-ray half-value width was small, and the cross-section hardness was small as well.

[0075]

In Steel sheet 17, since the SR treatment at a traditional general condition was performed in a reduced period of time, the amount of deformation induced martensite (α') was reduced, but most of work strain was not eliminated so that there was almost no difference between respective work strain at the sheet surface and the sheet center, and the warp after half-etching was large.

[0076]

In Steel sheet 18, since the SR treatment at a traditional general condition was performed at a reduced temperature, the deformation induced martensite (α') remained in a large amount so that deformation after heating test was large.

[0077]

In Steel sheet 19, while a two-stage SR treatment was performed, since the temperature rising rate in the SR treatment of the first stage was lower than a range specified in the present invention, a larger amount of work strain was eliminated so that a sufficient hardness was not obtained.

[0078]

In Steel sheet 20, while a two-stage SR treatment was performed, since the holding temperature of the first-stage SR treatment was lower than the range specified in the present invention, deformation induced martensite (α') remained in a large amount.

[0079]

In Steel sheet 21, while a two-stage SR treatment was performed, since the cooling rate of the first stage SR treatment was lower than the range specified in the present invention, a large amount of work strain was eliminated so that sufficient hardness was not obtained.

[0080]

In Steel sheet 22, while two-stage SR treatment was performed, since the SR treatment temperature of the second stage was more than the range specified in the present

invention, a large amount of work strain was eliminated so that sufficient hardness was not obtained.

[0081]

In Steel sheet 23, a two-stage SR treatment was performed, in which a first-stage heat treatment for adjustment and elimination of work strain, and a second-stage heat treatment for performing reverse transformation of deformation induced martensite into austenite were performed in that order. Since the SR treatment holding time of the second-stage heat treatment was more than the range specified in the present invention, work strain was eliminated in a large amount so that sufficient hardness was not obtained.

[0082]

In Steel sheet 24, a two-stage SR treatment was performed, in which a first-stage heat treatment for adjusting and eliminating work strain and a second-stage heat treatment for performing reverse transformation of deformation induced martensite into austenite were performed in that order. Since the SR treatment temperature of the above described second-stage heat treatment was lower than the range specified in the present invention, deformation induced martensite remained in a large amount so that a curvature after half-etching and deformation after heating test were large.

[0083]

Further, in Steel sheet 25, since the SR treatment itself was not applied, besides a large amount of deformation induced martensite (α') remained, the respective X-ray half-value widths at the sheet surface and the sheet center increased so that both of the warp after half-etching and the deformation ratio after heating test were unsatisfactory.

[0084]

Note that in the present example, although description has been made taking five Steel types A to H as examples, it is without saying that the present invention will be applied in the same way to a metastable austenitic stainless steel having a chemical composition which does not deviate from the scope of the present invention.

CLAIMS

1. An austenitic stainless steel sheet, having:
a chemical composition comprising: in mass%,
C: not more than 0.03%,
Si: not more than 1.0%,
Mn: not more than 1.5%,
Cr: 15.0 to 20.0%,
Ni: 6.0 to 9.0%,
N: 0.03 to 0.15%,
Nb: 0 to 0.50%,
V: 0 to 0.50%,
Ti: 0 to 0.20%,
Cu: 0 to 1.5%, and
Mo: 0 to 2.0%,
with the balance being Fe and in evitable impurities, wherein
an Md30 value calculated by Formula (1) below is 30.0 to 50.0°C; and
a metal micro-structure, wherein
an average amount of deformation induced martensite is not more than
5.0% in volume ratio,
an average austenite grain diameter is not more than 5.0 μm , and
X-ray diffraction half-value widths of $\gamma(220)$ phase respectively at a sheet
surface and sheet center are no less than 0.50°, and difference thereof is not more than
0.10°:

$$\text{Md30 value (}^\circ\text{C)} = 497 - 462(\text{C} + \text{N}) - 9.2(\text{Si}) - 8.1(\text{Mn}) - 13.7(\text{Cr}) - 20(\text{Ni} + \text{Cu}) - 18.7(\text{Mo}) \dots (1),$$
where, each symbol of element in Formula (1) represents a content of each
element.
2. The austenitic stainless steel sheet according to claim 1, wherein
the chemical composition contains one or more kinds selected from, in mass%,

Nb: 0.001 to 0.50%, V: 0.001 to 0.50%, and Ti: 0.001 to 0.20%.

3. The austenitic stainless steel sheet according to claim 1 or 2, wherein
the chemical composition contains, in mass%, Cu: 0.001 to 1.5% and/or Mo:
0.001 to 2.0%.