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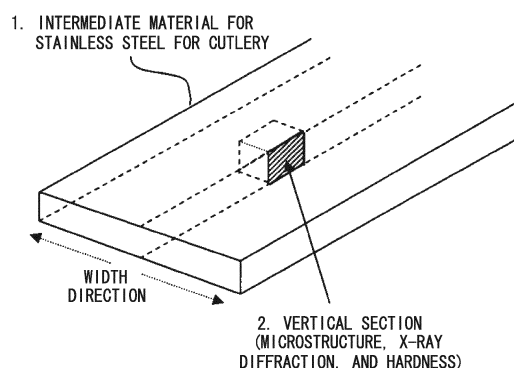
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(54) **STAINLESS STEEL FOR CUTLERY AND MANUFACTURING PROCESS THEREFOR**

(57) The present invention has the ultimate purpose of obtaining cutlery having marked characteristics such as high hardness and high toughness, and provides an intermediate material, an annealed material, and a cold-rolled steel strip for stainless steel for cutlery, and a method for manufacturing them to achieve the purpose. Provided is an intermediate material for stainless steel for cutlery, the intermediate material being a material after hot rolling but before annealing, having a composition, in terms of % by mass, of from 0.46 to 0.72% C, from 0.15 to 0.55% Si, from 0.45 to 1.00% Mn, from 12.5 to 13.9% Cr, from 0 to 1.5% Mo, from 0 to 0.012% B, and the balance being Fe and impurities; and wherein a ratio of a diffraction peak area from an fcc phase (a sum total of diffraction peak areas from (200) plane, (220) plane, and (311) plane) to a diffraction peak area from a bcc phase (a sum total of diffraction peak areas from (200) plane and (211) plane) (the diffraction peak area from the fcc phase/the diffraction peak area from the bcc phase) is 30 or less in an X-ray diffraction of a vertical section.

FIG.1



Description

Technical Field

- 5 **[0001]** The present invention relates to stainless steel for cutlery such as razors, cutters, kitchen knives, knives, and a method of manufacturing the same.

Background Art

- 10 **[0002]** Martensitic stainless steel has been widely used as the material for cutlery such as razors, cutters, kitchen knives, and knives. In particular, a strip of high carbon martensitic stainless steel containing about 13% by mass of Cr and about 0.65% by mass of C is known to be an optimum material for a razor. The high carbon martensitic stainless steel (hereinafter referred to as "stainless steel for cutlery") for these applications is usually used after being subjected to hardening and tempering, and is required to have high hardness and high toughness during use.

- 15 **[0003]** Stainless steel for cutlery is usually manufactured through the following manufacturing process.

[0004] Firstly, a raw material is melted and cast to make a material. Secondly, the material is hot-rolled to make an intermediate material. The material may be subjected to a blooming process such as hot forging or hot rolling.

- [0005]** Subsequently, the intermediate material is subjected to a first annealing to make an annealed material. The annealed material is subjected to cold rolling followed by annealing for removing strain, which are repeated if necessary, thereby manufacturing a cold-rolled steel strip having the intended thickness. The cold-rolled steel strip is subjected to hardening and tempering, thus obtaining stainless steel for cutlery.

[0006] Furthermore, the stainless steel for cutlery is subjected to processing processes such as sharpening and cutting, and thus making an end product. In usual cases, stainless steel for cutlery is dealt on the market in the form of either an annealed material or a cold-rolled steel strip.

- 25 **[0007]** For the above-described stainless steel for cutlery, various proposals have been made as the techniques for achieving high hardness and high toughness. For example, as a typical example, Japanese Patent Application Laid-Open (JP-A) No. H05-039547 (Patent Document 1), which is proposed by the present applicant, proposes the increase in the carbide density of the cold-rolled steel strip before hardening and tempering for stainless steel for cutlery. According to this proposal, short time hardenability of the cold-rolled steel strip is markedly improved, and the stainless steel for cutlery after hardening improves hardness, and marks sharpness of a razor.

Prior Art Document

Patent Document

- 35 **[0008]**

Patent Document 1: JP-A No. H05-039547

40 SUMMARY OF INVENTION

Technical Problem

- 45 **[0009]** As described above, various proposals have been made for the techniques focusing the properties of the cold-rolled steel strip before hardening and tempering for stainless steel for cutlery.

[0010] However, there is almost no study focusing on the properties of the intermediate material after hot rolling but before annealing, and the relationship between the characteristics of the annealed material for stainless steel for cutlery after annealing but before hardening, and the characteristics of the cold-rolled steel strip, which are distributed in the form of half-finished products, and the properties of the intermediate material, are not thoroughly clarified.

- 50 **[0011]** Therefore, because of poor findings regarding the ideal properties of the above-described intermediate material, there is a problem that the excellent potential of stainless steel for cutlery cannot be thoroughly exploited, and it was difficult to both of high hardness and high toughness. In addition, even if the properties of the intermediate material are varied by some kind of factor, there was no known means for detecting the defect in the stage of making the intermediate material for preventing the occurrence of quality failure in the following processes. Therefore, if any defect is not found in the stage of the intermediate material and the decrease in hardness or toughness is first revealed in the following process, the processes completed until then come to nothing, and the cost of the product increases.

55 **[0012]** The invention has a final purpose of efficiently obtaining cutlery having marked characteristics such as high hardness and high toughness by optimizing the intermediate material which influences the structure of stainless steel

for cutlery before hardening, and provides an intermediate material, an annealed material, and a cold-rolled steel strip for stainless steel for cutlery, and a method of manufacture them to achieve the purpose. Solution to Problem

[0013] The inventors studied the properties of stainless steel for cutlery, focusing on the form of carbides as the factor influencing the hardness and toughness.

[0014] According to their finding, in a case in which the distribution of carbides is not uniform because carbides are maldistributed in the structure of the cold-rolled steel strip for stainless steel for cutlery, or carbides having coarse crystal grains and those having fine crystal grains are mixed, the cold-rolled steel strip has lower hardness and toughness after hardening and tempering in comparison with that containing uniformly distributed carbides.

[0015] According to another finding, of the properties of the intermediate material for stainless steel for cutlery, in particular the composition and the amount of an fcc phase influences the distribution of carbides in the structure of the cold-rolled steel strip obtained from the intermediate material.

[0016] Furthermore, they have found that the optimization of the composition of the intermediate material for stainless steel for cutlery and control of the amount of the fcc phase makes the distribution of carbides in the cold-rolled steel strip uniform, and markedly improves the characteristics of the cutlery as the end product, and thus have accomplished the invention.

[0017] More specifically, an aspect of the invention is an intermediate material for stainless steel for cutlery, the intermediate material being a material after hot rolling but before annealing, having a composition, in terms of % by mass, of from 0.46 to 0.72% C, from 0.15 to 0.55% Si, from 0.45 to 1.00% Mn, from 12.5 to 13.9% Cr, from 0 to 1.5% Mo, from 0 to 0.012% B, and the balance being Fe and impurities; and wherein a ratio of a diffraction peak area from an fcc phase (a sum total of diffraction peak areas from (200) plane, (220) plane, and (311) plane) to a diffraction peak area from a bcc phase (a sum total of diffraction peak areas from (200) plane and (211) plane) (the diffraction peak area from the fcc phase/the diffraction peak area from the bcc phase) is 30 or less in an X-ray diffraction of a vertical section.

[0018] The content of B is preferably from 0.0005 to 0.0050%.

[0019] Another aspect of the invention is a method of manufacturing an intermediate material for stainless steel for cutlery, the intermediate material being a material after hot rolling but before annealing, the method including: heating a material, having a composition, in terms of % by mass, of from 0.46 to 0.72% C, from 0.15 to 0.55% Si, from 0.45 to 1.00% Mn, from 12.5 to 13.9% Cr, from 0 to 1.5% Mo, from 0 to 0.012% B, and the balance being Fe and impurities, to from 1100 to 1250°C, and hot rolling the material at a hot rolling end temperature of from 700 to 1000°C; thereby manufacturing the intermediate material, wherein a ratio of a diffraction peak area from an fcc phase (a sum total of diffraction peak areas from (200) plane, (220) plane, and (311) plane) to a diffraction peak area from a bcc phase (a sum total of diffraction peak areas from (200) plane and (211) plane) (the diffraction peak area from the fcc phase/the diffraction peak area from the bcc phase) is 30 or less in an X-ray diffraction of a vertical section.

[0020] Another aspect of the invention is a method of manufacturing an annealed material for stainless steel for cutlery, including the above-described hot rolling, followed by annealing at from 800 to 860°C for from 1 to 100 hours.

[0021] Another aspect of the invention is a method of manufacturing a cold-rolled steel strip for stainless steel for cutlery, including subjecting the above-described annealed material to cold rolling and annealing, thereby manufacturing a cold-rolled steel strip with a thickness less than 1.0 mm.

Advantageous Effects of Invention

[0022] Since the cutlery manufactured from the stainless steel for cutlery of the invention has high hardness and high toughness, the cutlery is particularly suitable for razors having a small thickness. The invention also allows quality control not in the stage of the end product but in the stage of the intermediate material, whereby the occurrence of defects is prevented, and the cost of manufacturing is reduced.

BRIEF DESCRIPTION OF DRAWINGS

[0023]

Fig. 1 is a schematic view showing the position from which the test piece is sampled, and the evaluated plane.

Fig. 2 is a photograph as a substitute of a drawing showing an example of the metal structure of the intermediate material for the stainless steel for cutlery of the invention.

Fig. 3 is a photograph as a substitute of a drawing showing an example of the metal structure of the intermediate material for the stainless steel for cutlery of a comparative example.

Fig. 4 is a photograph as a substitute of a drawing showing an example of the metal structure of the intermediate material for the stainless steel for cutlery of the invention.

Fig. 5 is a photograph as a substitute of a drawing showing an example of the metal structure of the intermediate material for the stainless steel for cutlery of a comparative example.

Fig. 6 is a photograph as a substitute of a drawing showing an example of the metal structure of the intermediate material for the stainless steel for cutlery of the invention.

Fig. 7 is a photograph as a substitute of a drawing showing an example of the metal structure of the intermediate material for the stainless steel for cutlery of the invention.

Fig. 8 is a photograph as a substitute of a drawing showing an example of the metal structure of the annealed material for the stainless steel for cutlery of the invention after hardening-subzero-tempering.

Fig. 9 is a photograph as a substitute of a drawing showing an example of the metal structure of the annealed material for the stainless steel for cutlery of a comparative example after hardening-subzero-tempering.

Fig. 10 is a photograph as a substitute of a drawing showing an example of the metal structure of the annealed material for the stainless steel for cutlery of the invention after hardening-subzero-tempering.

Fig. 11 is a photograph as a substitute of a drawing showing an example of the metal structure of the annealed material for the stainless steel for cutlery of a comparative example after hardening-subzero-tempering.

Fig. 12 is a photograph as a substitute of a drawing showing an example of the metal structure of the annealed material for the stainless steel for cutlery of the invention after hardening-subzero-tempering.

Fig. 13 is a photograph as a substitute of a drawing showing an example of the metal structure of the annealed material for the stainless steel for cutlery of the invention after hardening-subzero-tempering.

Fig. 14 is a photograph as a substitute of a drawing showing an example of the metal structure of the cold-rolled steel strip for the stainless steel for cutlery of the invention.

Fig. 15 is a photograph as a substitute of a drawing showing an example of the metal structure of the cold-rolled steel strip for the stainless steel for cutlery of the invention after hardening-subzero-tempering.

Fig. 16 is a photograph as a substitute of a drawing showing an example of the metal structure of the cold-rolled steel strip for the stainless steel for cutlery of the invention.

Fig. 17 is a photograph as a substitute of a drawing showing an example of the metal structure of the cold-rolled steel strip for the stainless steel for cutlery of the invention after hardening-subzero-tempering.

DESCRIPTION OF EMBODIMENTS

[0024] As described above, the invention is characterized in that it optimizes the alloy composition which influences the form of carbides, and controls the amount of the fcc phase in the intermediate material before annealing, thereby achieving both of high hardness and high toughness in the cutlery as the end product.

[0025] Firstly, the alloy composition contributing to the basic properties defined herein is described below. The content of the respective elements are based on % by mass.

C: from 0.46 to 0.72%

[0026] The C content is from 0.46 to 0.72%, thereby achieving sufficient hardness of cutlery, and minimizing the crystallization of the eutectic carbide during casting and solidification. When the C content is less than 0.46%, sufficient hardness of cutlery cannot be achieved. When the C content is more than 0.72%, the amount of crystallization of the eutectic carbide increases because of the balance with the Cr amount, which can cause blade chipping during sharpening. The lower limit of the C content is preferably 0.50%, and more preferably, 0.65%. The upper limit of the C content is preferably 0.70%.

Si: from 0.15 to 0.55%

[0027] Si is added as a deoxidizing agent for smelting. In order to achieve sufficient deoxidizing effect, the residual amount of Si would be 0.15% or more. When the Si content is more than 0.55%, the amount of inclusion increases, and can cause blade chipping during sharpening. Therefore, the Si content is from 0.15 to 0.55%. In addition, Si increases the tempering softening resistance. When Si is added at a proportion of 0.20% or more, sufficient hardness of cutlery will be achieved. Therefore, the lower limit of the Si content is preferably 0.20%, and the upper limit of the Si content is 0.35%.

Mn: from 0.45 to 1.00%

[0028] Mn is also added as a deoxidizing agent for smelting. In order to achieve sufficient deoxidizing effect, the residual amount of Mn would be 0.45% or more. When the Mn content is more than 1.00%, hot workability decreases. Therefore, the Mn content is from 0.45 to 1.00%. The lower limit of the Mn content is preferably 0.65%, and the upper limit of the Mn content is preferably 0.85%.

Cr: from 12.5 to 13.9%

[0029] The Cr content is from 12.5 to 13.9%, thereby achieving sufficient corrosion resistance, and minimizing crystallization of the eutectic carbide during casting and solidification. When the Cr content is less than 12.5%, sufficient corrosion resistance of stainless steel cannot be achieved, and when more than 13.9%, crystallization of the eutectic carbide increases, and can cause blade chipping during sharpening. The lower limit of the Cr amount is preferably 13.0%. The upper limit of the Cr amount is preferably 13.6%.

Mo: from 0 to 1.5%

[0030] Mo is an element which improves corrosion resistance, so that it may be added if necessary at a proportion of up to 1.5%. However, when the Mo content is more than 1.5%, solid-solution strengthening is increased, whereby deformation resistance is increased, and hot workability is deteriorated. Therefore, the Mo content is from 0 to 1.5%.

B: from 0 to 0.012%

[0031] B is an element effective at improving hardness and toughness. In the invention, the toughness can be improved by adjusting the below-described intensity ratio of X-ray, and the improvement in the toughness is more reliably achieved by adding B in advance. Therefore, B may be added at a proportion of up to 0.012%. However, when the B content is more than 0.012%, ductility as hot workability markedly decreases. Therefore, the upper limit of B is 0.012%. In order to more reliably improve hardness and toughness by the addition of B, the B content is preferably from 0.0005 to 0.0050%, because the effect of B addition will be insufficient when the B content is less than 0.0005%.

[0032] The remainder except for the above-described elements is composed of Fe and impurities.

[0033] Typical impurity elements are P, S, Ni, W, V, Cu, Al, Ti, N, and O. The contents of these elements are preferably controlled in the following ranges. $P \leq 0.03\%$, $S \leq 0.005\%$, $Ni \leq 0.15\%$, $W \leq 0.05\%$, $V \leq 0.2\%$, $Cu \leq 0.1\%$, $Al \leq 0.01\%$, $Ti \leq 0.01\%$, $N \leq 0.05\%$, and $O \leq 0.05\%$.

[0034] According to the study by the inventors, a ratio of a diffraction peak area from an fcc phase (a sum total of diffraction peak areas from (200) plane, (220) plane, and (311) plane) to a diffraction peak area from a bcc phase (a sum total of diffraction peak areas from (200) plane and (211) plane) (the diffraction peak area from the fcc phase/the diffraction peak area from the bcc phase) in an X-ray diffraction of the intermediate material for stainless steel for cutlery having the above-described composition is correlated with the toughness of a stainless steel for cutlery obtained using the intermediate material through a manufacturing process including annealing, cold rolling, hardening, and tempering.

[0035] Specifically, when the ratio of the diffraction peak area from the fcc phase to the diffraction peak area from the bcc phase is more than 30 in the X-ray diffraction of the intermediate material for stainless steel for cutlery, the amount of the fcc phase becomes too much. As a result of this, when annealing is performed after hot working, carbides having a high aspect ratio tend to precipitate at the grain boundaries. As a result of this, for example, toughness markedly decreases after hardening and tempering performed before used as cutlery. Therefore, the ratio of the diffraction peak area from the fcc phase to the diffraction peak area from the bcc phase must be 30 or less. The ratio is preferably 20 or less, and more preferably 5 or less. The lower limit may be 0.

[0036] The reason why (200) plane, (220) plane, and (311) plane of an fcc phase and (200) plane and (211) plane of a bcc phase are chosen in the invention is that the above-described direction is a major peak in an X-ray diffraction of the alloy system having the composition defined in the invention. The peaks other than the major peak has a low peak intensity, so that the ratio of the diffraction peak area from the fcc phase to the diffraction peak area from the bcc phase is not so influential. Therefore, the measurement of the major peak will suffice.

[0037] Since the ratio of the diffraction peak area from the fcc phase to the diffraction peak area from the bcc phase is correlated with the actual volume ratio between these phases, it can be evaluated as the value corresponding to the proportion of the constituting phases.

[0038] In a case in which the above-described X-ray diffraction is performed, a vertical section of the intermediate material is irradiated with an X-ray. The term "vertical section" herein means, as shown in Fig. 1, in the surfaces of the test piece sampled in the vicinity of the center of the width of the intermediate material for stainless steel for cutlery 1, the cross section corresponding to the evaluated plane 2 shown in Fig. 1, more specifically the cross section perpendicular to the width direction of the intermediate material. The reason why the vertical section is used for evaluation is that the rolled material has anisotropy that is dependent on the rolling direction, so that the fixity of the evaluated plane allows evaluation under the same conditions. In addition, in a case in which made into cutlery, the vertical section most often corresponds to the blade edge which is most required to have both of high strength and toughness.

[0039] The test piece used for the X-ray diffraction is subjected to mirror plane polishing on the vertical section, and further subjected to electrolytic polishing so as to be adjusted to a test piece for the X-ray diffraction. Subsequently, the electrolytically polished plane is subjected to the X-ray diffraction, and then the ratio of the sum total of diffraction peak

areas of (200) plane, (220) plane, and (311) plane of an fcc phase to the sum total of diffraction peak areas of

[0040] (200) plane and (211) plane of a bcc phase is calculated. In a case in which the area of each diffraction peak is determined, the area of the diffraction peak from which the background strength is subtracted is determined.

[0041] The following section describes the methods of the invention for manufacturing the intermediate material for stainless steel for cutlery, the annealed material for stainless steel for cutlery, and the cold-rolled steel strip for stainless steel for cutlery.

[0042] Firstly, a material for stainless steel for cutlery is manufactured by melting and casting. Examples of the melting include a vacuum melting, an atmospheric melting, a vacuum arc remelting, and an electroslag remelting. Examples of the casting include die casting and continuous casting. If necessary, the material thus obtained may be subjected to homogenization heat treatment. Furthermore, the material may be subjected to a blooming process by hot forging or hot rolling.

[0043] Thereafter, the material is hot-rolled, thereby manufacturing the intermediate material for stainless steel for cutlery. In the hot rolling process, the intermediate material for stainless steel for cutlery is manufactured by hot rolling at a heating temperature of from 1100 to 1250°C, wherein the end temperature of hot rolling is from 700 to 1000°C.

[0044] The reason why the heating temperature is from 1100 to 1250°C is that this temperature range has relatively low deformation resistance and marked hot workability. When the temperature is higher than 1250°C, the temperature range extremely decreases ductility, and tends to cause cracking during hot working. When the temperature is lower than 1100°C, deformation resistance of the material during hot rolling is high, working with a high reduction ratio is difficult, so that reheating must be repeated during hot working. The lower limit of the heating temperature is preferably 1150°C.

[0045] In the invention, the reason why the end temperature of hot rolling is from 700 to 1000°C is that the phase and metal structure are controlled in consideration of the hot workability during manufacturing the intermediate material for stainless steel for cutlery. If the end temperature of hot rolling is higher than 1000°C, the ratio of the diffraction peak area from the fcc phase to the diffraction peak area from the bcc phase is more than 30 in X-ray diffraction, so that the amount of the fcc phase becomes too much. If the amount of the fcc phase is too much, carbides tend to precipitate at the grain boundaries of the fcc phase during annealing performed thereafter. In addition, if the end temperature is too high, residual strain is low, and the crystal grain diameter tends to increase, so that carbides which precipitate at the grain boundaries of the fcc phase during annealing tend to form networks.

[0046] When the end temperature of hot rolling is lower than 700°C, deformation resistance is high, and hot rolling is difficult. Accordingly, the heating temperature in the hot rolling process is from 1100 to 1250°C, and the end temperature of hot rolling is from 700 to 1000°C. The lower limit of the heating temperature is preferably 1150°C, the upper limit of the end temperature is preferably 950°C, the upper limit of the end temperature is more preferably 900°C, and the lower limit of the end temperature is preferably 750°C.

[0047] The intermediate material for stainless steel for cutlery obtained by the hot rolling wherein the end temperature of hot working is from 700 to 1000°C is preferably cooled with water during passing the runout table, and/or during winding with a winding device. The cooling is preferably performed with a water flow which can cool the wound coil to 600°C or lower within 5 minutes from the finishing point of the last pass of hot rolling.

[0048] The reason for this is as follows: the wound coil is once cooled on the surface exposed to atmosphere, but the temperature of the once cooled coil surface is increased again by the heat retained by the coil, so that the metal structures can differ between the front end, center, and rear end of the coil. When the temperature of a part of the wound coil exceeds 600°C within 5 minutes from the finishing point of the final pass of hot rolling, toughness of cutlery may decrease.

[0049] Therefore, it is preferred that the wound coil be cooled with water to 600°C or lower within 5 minutes from the finishing point of the final pass of hot rolling.

[0050] When the above-described hot rolling process is completed, the intermediate material for stainless steel for cutlery having the structure defined in the invention is obtained.

[0051] The intermediate material for stainless steel for cutlery manufactured by the above-described manufacture method is subjected to the first annealing at from 700°C to 860°C for from 1 to 100 hours, and thus manufacturing an annealed material for stainless steel for cutlery in which carbides are precipitated.

[0052] Furthermore, in a case in which the annealed material for stainless steel for cutlery is repeatedly subjected to cold rolling and annealing, a cold-rolled steel strip for stainless steel for cutlery having a thickness of 1.0 mm or less is obtained.

[0053] In a case in which the above-described cold-rolled steel strip for stainless steel for cutlery is subjected to hardening, tempering, and sharpening to make cutlery, if necessary, subzero treatment may be performed after hardening, and surface coating may be performed after tempering.

EXAMPLES

[0054] The invention is further described below with reference to examples.

[0055] Six 10kg steel ingots (materials), A to F, were made by vacuum melting. The chemical compositions of the steel ingots A to F are shown in Table 1.

[Table 1]

(mass%)

Steel ingot	C	Si	Mn	Cr	Mo	B
A	0.69	0.28	0.68	13.39	0.01	0.0001
B	0.70	0.29	0.73	13.29	0.01	0.0018
C	0.70	0.29	0.73	13.25	0.01	0.0102
D	0.58	0.39	0.85	13.29	0.89	0.0002
E	0.70	0.29	0.74	13.19	0.02	0.0005
F	0.50	0.45	0.82	13.42	1.27	0.0004

Steel ingot	P	S	Ni	W	V	Cu	Al	Ti	[N]	[O]
A	0.024	0.0012	0.01	< 0.01	0.02	< 0.01	0.002	0.001	13	61
B	0.024	0.0015	0.01	< 0.01	0.02	< 0.01	0.002	0.001	12	34
C	0.022	0.0015	0.01	< 0.01	0.02	< 0.01	0.003	0.001	12	30

D	0.023	0.0016	0.01	< 0.01	0.02	< 0.01	0.005	0.001	13	28
E	0.021	0.0029	0.01	0.01	0.02	0.01	0.006	0.003	11	31
F	0.026	0.0029	0.01	0.01	0.01	< 0.01	0.009	0.002	10	33

*1. The value of the element within [] is ppm.

*2. The balance other than the above elements is composed of Fe and unavoidable impurities.

[0056] The materials to be hot-rolled having a width of 45 mm, a length of 1000 mm, and a thickness of 20 mm were made from the steel ingots A to D. These materials to be hot-rolled are subjected to hot rolling under the following three types of conditions, and the intermediate materials of stainless steel for cutlery were obtained.

- (1) Materials A to D: heated to 1180°C, and hot-rolled at an end temperature of 850°C.
- (2) Materials A to C: heated to 1200°C, and hot-rolled at an end temperature of 1050°C.
- (3) Materials E and F: heated to 1180°C, and hot-rolled at an end temperature of 900°C.

[0057] The alloy C which had been hot-rolled under the conditions (2) caused cracking during hot rolling, so that the operation was suspended.

[0058] In this test, the length was insufficient for being wound into a coil, but it was confirmed that the intermediate material for stainless steel for cutlery was cooled to 600°C within 5 minutes from the finishing point of the final pass of hot rolling.

[0059] A test piece was sampled in the vicinity of the center of the width of each of the intermediate material for stainless steel for cutlery. The sampling position of the test piece is the position shown in Fig. 1, and the vertical section as the evaluated plane 2 is subjected to an observation of a metal structure, an X-ray diffraction, and an evaluation of hardness.

[0060] On the vertical section of the sampled test piece, the metal structure was observed, and hardness and a ratio of a diffraction peak area from an fcc phase to a diffraction peak area from a bcc phase in an X-ray diffraction were measured. The test piece used for the X-ray diffraction was subjected to mirror polishing on the vertical section, and further subjected to electrolytic polishing to be suitable as a test piece for the X-ray diffraction.

[0061] Figs. 2 to 7 show the photographs as substitutes of drawings showing the metal structure of the materials Nos. 1 to 6 whose metal structures were observed. Table 2 shows hardness and the ratio of the diffraction peak area from

the fcc phase to the diffraction peak area from the bcc phase in X-ray diffraction. In addition, Table 3 shows the diffraction peak area from the fcc and bcc phases for each plane index.

[0062] The observation of the metal structure was performed by mirror-polishing the vertical section of the test piece, corroding it in a ferric chloride aqueous solution, and then observing it using a scanning electron microscope.

[0063] The ratio of the diffraction peak area from the fcc phase to the diffraction peak area from the bcc phase in the X-ray diffraction was determined by a ratio of a diffraction peak area from an fcc phase (a sum total of diffraction peak areas from (200) plane, (220) plane, and (311) plane) to a diffraction peak area from a bcc phase (a sum total of diffraction peak areas from (200) plane and (211) plane) (the diffraction peak area from the fcc phase/the diffraction peak area from the bcc phase) in an X-ray diffraction. The X-ray diffraction measurement used RINT2500V manufactured by Rigaku Corporation, the radiation source used Co.

[0064] The hardness was determined by polishing the sampled test piece with #1200 abrasive paper, and then measuring a hardness using Vickers hardness tester under a load of 98.1 (N). The hardness is the average of five points.

[Table 2]

No.	Material	Heating temperature	End temperature	fcc/bcc ratio (X-ray diffraction)	Hardness (Hv)	Remarks
1	A	1180°C	850°C	5.0	385	The invention
2	A	1200°C	1050°C	31.3	324	Comparative example
3	B	1180°C	850°C	2.3	515	The invention
4	B	1200°C	1050°C	36.0	290	Comparative example
5	C	1180°C	850°C	1.2	575	The invention
6	D	1180°C	850°C	2.3	423	The invention
7	E	1180°C	900°C	15.9	422	The invention
8	F	1180°C	900°C	3.3	477	The invention

[Table 3]

No.	fcc phase diffraction peak area (arbitrary unit)			Sum total of fcc phase	bcc phase diffraction peak area (arbitrary unit)		Sum total of bcc phase	fcc/bcc	Remarks
	(200)	(220)	(311)		(200)	(211)			
1	50.0	13.6	19.7	83.3	5.4	11.2	16.7	5.0	The invention
2	40.9	24.4	31.6	96.9	1.4	1.7	3.1	31.3	Comparative example
3	34.8	14.0	20.8	69.7	9.1	21.2	30.3	2.3	The invention
4	50.9	16.9	29.5	97.3	0.8	1.9	2.7	36.0	Comparative example
5	29.2	9.7	15.6	54.5	15.3	30.2	45.5	1.2	The invention
6	34.8	14.0	20.8	69.7	9.1	21.1	30.3	2.3	The invention
7	48.8	18.6	26.7	94.1	1.5	4.4	5.9	15.9	The invention
8	29.5	21.7	25.4	76.6	7.6	15.8	23.4	3.3	The invention

[0065] Subsequently, the intermediate materials of stainless steel for cutlery shown in Table 2 were subjected to hardening, subzero treatment, and tempering, which are performed before used as cutlery.

[0066] An intermediate material for sampling a test piece having a width of 40 mm, a length of 100 mm, and a thickness of 1 mm was cut out from each of the intermediate material for stainless steel for cutlery. At this time, the intermediate

material for sampling a test piece was cut out so as to contain the vicinity of the center of the width of the rolled material shown in Fig. 1.

[0067] The intermediate material for sampling a test piece was annealed at 840°C for 5 hours to make an annealed material, and then, for hardening, maintained at 1100°C for 3 minutes and water-cooled. Furthermore, after the hardening,

the material was maintained at -75°C for 30 minutes for subzero treatment, and then tempered at 150°C for 3 minutes.

[0068] Five pieces of test pieces for three point bending test having a width of 5 mm, a length of 70 mm, and a thickness of 0.5 mm were made from the intermediate materials for sampling a test piece after the above-described heat treatment.

[0069] In addition, other test pieces were sampled from the position corresponding to the position shown in Fig. 1 (in the vicinity of the center of the width of the rolled material) in such a manner that the vertical section as the evaluated plane 2 is used for the observation of the metal structure and the evaluation of hardness. Figs. 8 to 13 show the photographs of the metal structure (Nos. 1 to 6). Table 4 shows hardness, absorption energy by the three point bending test, bending strength by the three point bending test, and deflection by the three point bending test.

[0070] The observation of the metal structure was performed by mirror-polishing the vertical section of the test piece, corroding it in a ferric chloride aqueous solution, and then observing it using a scanning electron microscope. In the three point bending test, a test piece having a width of 5 mm, a length of 70 mm, and a thickness of 0.5 mm was measured over a span of 50 mm. The data of the hardness and three point bending test are the average of five points.

[0071]

[Table 4]

No.	Hardness (Hv)	Absorbed energy (N·mm)	Bending strength (N·mm ²)	Deflection (mm)	Remarks
1	770	593	2799	6.24	The invention
2	762	421	2289	5.16	Comparative example
3	792	704	2880	6.62	The invention
4	786	230	1825	3.77	Comparative example
5	792	580	2721	5.94	The invention
6	719	757	2861	6.93	The invention
7	752	553	2524	5.91	The invention
8	696	444	2341	5.21	The invention

[0072] From Tables 2 and 4, in a case in which the ratio of the diffraction peak area from the fcc phase to the diffraction peak area from the bcc phase is 30 or less in the X-ray diffraction of the intermediate material for stainless steel for cutlery after heat treatment including annealing-hardening-subzero treatment-tempering, the material has high toughness, which is evaluated by the absorption energy in the three point bending test, while maintaining high hardness even after heat treatment including annealing-hardening-subzero treatment-tempering.

[0073] The reason for this is likely due to the difference in the metal structure after heat treatment including annealing-hardening-subzero treatment-tempering. Specifically, in a case in which the ratio of the diffraction peak area from the fcc phase to the diffraction peak area from the bcc phase is more than 30 in the X-ray diffraction of the rolled material for stainless steel for cutlery, as shown in Figs. 9 and 11, the carbides having a high aspect ratio are linked at the boundaries in the rolled material for stainless steel for cutlery after heat treatment, which likely causes the decrease in toughness.

[0074] In this regard, in a case in which the ratio of the diffraction peak area from the fcc phase to the diffraction peak area from the bcc phase in the X-ray diffraction is 30 or less, as shown by Figs. 8, 10, 12, and 13, the carbides after heat treatment are more dispersed, so that the structure is likely more preferable from the viewpoint of toughness.

[0075] These results suggest that cutlery having high hardness and high toughness is produced from the intermediate material for stainless steel for cutlery of the invention by subjecting it to heat treatment including annealing-hardening-subzero treatment-tempering.

[0076] Furthermore, besides the ratio of the diffraction peak area from the fcc phase to the diffraction peak area from the bcc phase in the X-ray diffraction, the inclusion of B in the proportion of 0.0050% or less further improves the balance between hardness and toughness.

[0077] Subsequently, an intermediate material for sampling a test piece having a width of 40 mm, a length of 100 mm,

and a thickness of 1.5 mm was cut out from each of the intermediate materials of stainless steel for cutlery shown in the above-described Nos. 1 and 3. At this time, the intermediate material for sampling a test piece so as to contain the vicinity of the center of the width of the intermediate material shown in Fig. 1.

[0078] The intermediate material for sampling a test piece was annealed at 840°C for 10 hours, and then cold-rolled using a compact cold rolling machine; a cold-rolled material was obtained without rupture until the thickness became 0.075 mm. As a result of this, it was confirmed that a cold-rolled steel strip can also be obtained.

[0079] Subsequently, the cold-rolled material was, for hardening, maintained at 1100°C for 40 seconds and then water-cooled. Furthermore, after the above-described hardening, the material was maintained at -75°C for 30 minutes for subzero treatment, and then maintained at 150°C for 30 seconds for tempering.

[0080] Using the cold-rolled material and the material for sampling a test after the heat treatment including annealing-hardening-subzero treatment-tempering, test pieces were sampled from the position corresponding to the position shown in Fig. 1 (in the vicinity of the center of the width of the rolled material), and the test pieces were sampled in such a manner that the vertical section as the evaluated plane 2 is used for the observation of the metal structure and the evaluation of hardness. Fig. 14 to 17 show the photographs as substitutes of drawings showing the metal structure before and after the above-described heat treatment (Nos. 1 and 3), and Table 5 show the hardness.

[Table 5]

No.	Hardness before heat treatment (HV)	Hardness after heat treatment (HV)	Remarks
1	398	796	The invention
3	400	798	The invention

[0081] The results shown in Figs. 14 to 17 and Table 5 indicate that the cold-rolled material of the invention, and the stainless steel for cutlery after hardening, subzero treatment, and tempering contained no carbide having a high aspect ratio which can deteriorate toughness, and spherical carbides contributing to good toughness are finely dispersed in them. In addition, the hardness after hardening, subzero treatment, and tempering was 790 HV or more.

[0082] From the above results, it was confirmed that a metal structure and hardness suitable for cutlery are achieved by subjecting the intermediate material for stainless steel for cutlery of the invention to annealing and cold rolling, followed by hardening, subzero treatment, and tempering.

Industrial Applicability

[0083] The cutlery made from the intermediate material and cold-rolled steel strip for stainless steel for cutlery of the invention has marked hardness and toughness, and thus can be used for razors and other applications.

Explanation of References

[0084]

- 1 intermediate material for stainless steel for cutlery
- 2 vertical section

Claims

1. An intermediate material for stainless steel for cutlery, the intermediate material being a material after hot rolling but before annealing, having a composition, in terms of % by mass, of from 0.46 to 0.72% C, from 0.15 to 0.55% Si, from 0.45 to 1.00% Mn, from 12.5 to 13.9% Cr, from 0 to 1.5% Mo, from 0 to 0.012% B, and the balance being Fe and impurities; and wherein a ratio of a diffraction peak area from an fcc phase (a sum total of diffraction peak areas from (200) plane, (220) plane, and (311) plane) to a diffraction peak area from a bcc phase (a sum total of diffraction peak areas from (200) plane and (211) plane) (the diffraction peak area from the fcc phase/the diffraction peak area from the bcc phase) is 30 or less in an X-ray diffraction of a vertical section.
2. The intermediate material for stainless steel for cutlery according to claim 1, wherein the content of B is from 0.0005 to 0.0050%.
3. A method of manufacturing an intermediate material for stainless steel for cutlery, the intermediate material being

a material after hot rolling but before annealing, the method comprising: heating a material, having a composition, in terms of % by mass, of from 0.46 to 0.72% C, from 0.15 to 0.55% Si, from 0.45 to 1.00% Mn, from 12.5 to 13.9% Cr, from 0 to 1.5% Mo, from 0 to 0.012% B, and the balance being Fe and impurities, to from 1100 to 1250°C, and hot rolling the material at a hot rolling end temperature of from 700 to 1000°C; thereby manufacturing the intermediate material, wherein a ratio of a diffraction peak area from an fcc phase (a sum total of diffraction peak areas from (200) plane, (220) plane, and (311) plane) to a diffraction peak area from a bcc phase (a sum total of diffraction peak areas from (200) plane and (211) plane) (the diffraction peak area from the fcc phase/the diffraction peak area from the bcc phase) is 30 or less in an X-ray diffraction of a vertical section.

4. The method of manufacturing an intermediate material for stainless steel for cutlery according to claim 3, wherein the content of B is from 0.0005 to 0.0050%.
5. A method of manufacturing an annealed material for stainless steel for cutlery, the method comprising subjecting the intermediate material for stainless steel for cutlery manufactured by the method according to claim 3 or 4 to annealing at from 800 to 860°C for from 1 to 100 hours.
6. A method of manufacturing a cold-rolled steel strip for stainless steel for cutlery, the method comprising subjecting the annealed material for stainless steel for cutlery manufactured by the method according to claim 5 to cold rolling and annealing, thereby manufacturing a cold-rolled steel strip with a thickness of less than 1.0 mm.

FIG.1

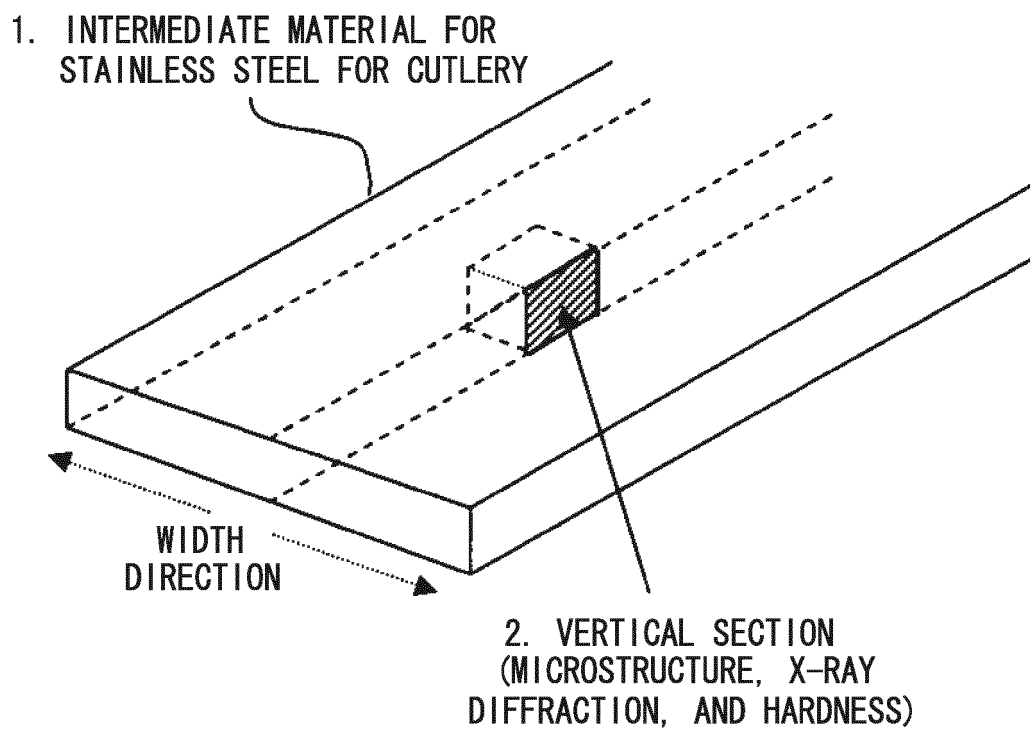
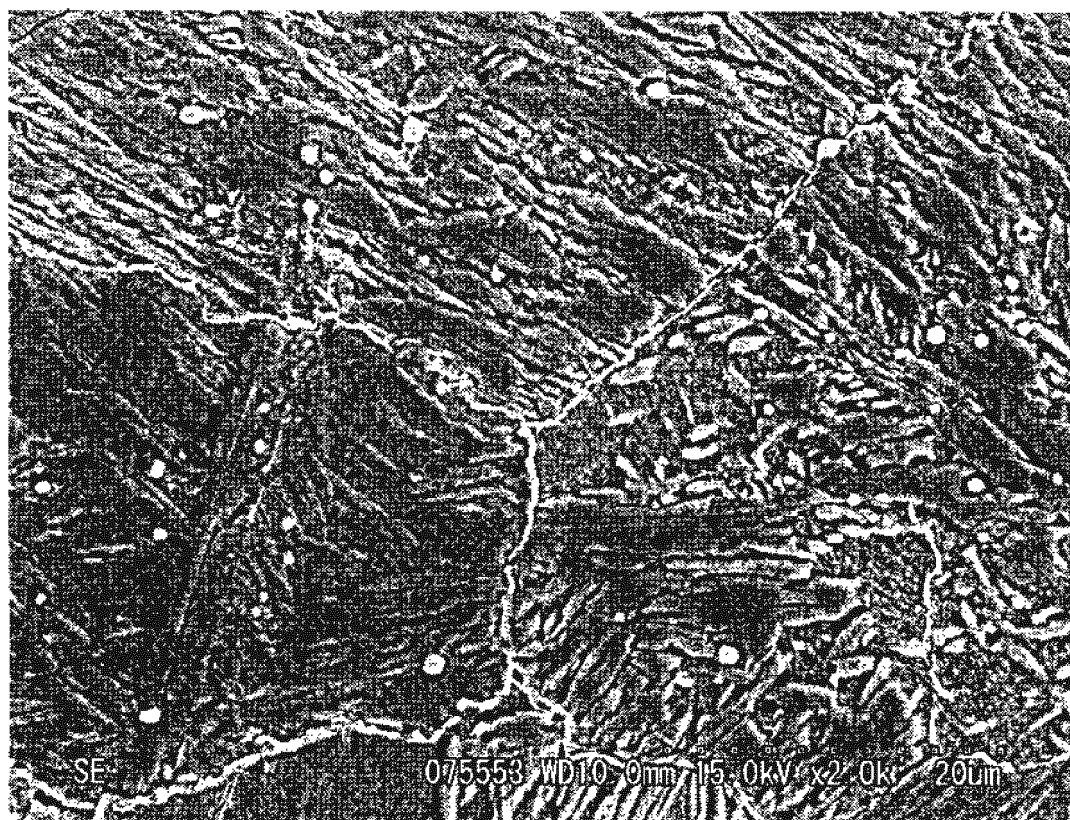


FIG.2

INTERMEDIATE MATERIAL ALLOY A (No. 1) OF THE INVENTION
HOT ROLLING CONDITIONS: HEATING TEMPERATURE 1180°C, HOT
ROLLING END TEMPERATURE 850°C



20 μ m

FIG.3

INTERMEDIATE MATERIAL ALLOY A (No.2) OF COMPARATIVE EXAMPLE
HOT ROLLING CONDITIONS: HEATING TEMPERATURE 1200°C, HOT
ROLLING END TEMPERATURE 1050°C

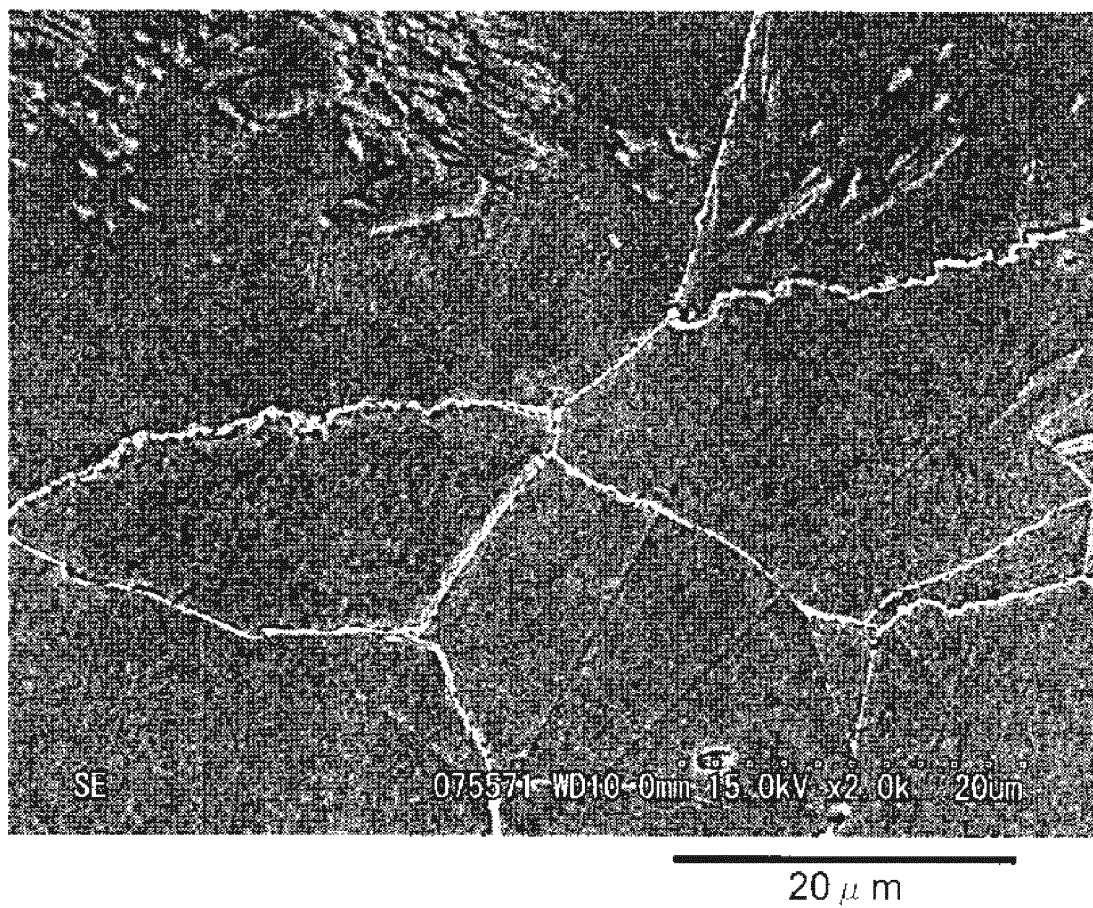
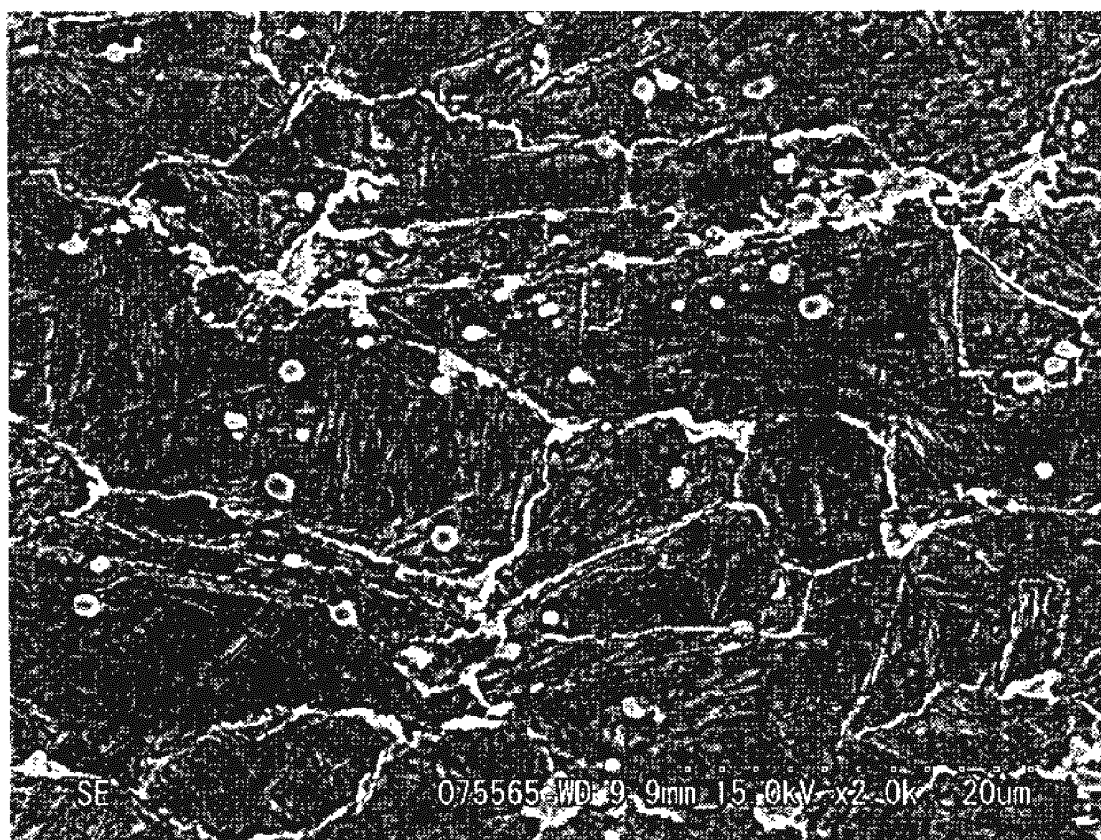


FIG.4

INTERMEDIATE MATERIAL ALLOY B (No. 3) OF THE INVENTION
HOT ROLLING CONDITIONS: HEATING TEMPERATURE 1180°C, HOT
ROLLING END TEMPERATURE 850°C



20 μ m

FIG.5

INTERMEDIATE MATERIAL ALLOY B (No. 4) OF COMPARATIVE EXAMPLE
HOT ROLLING CONDITIONS: HEATING TEMPERATURE 1200°C, HOT
ROLLING END TEMPERATURE 1050°C

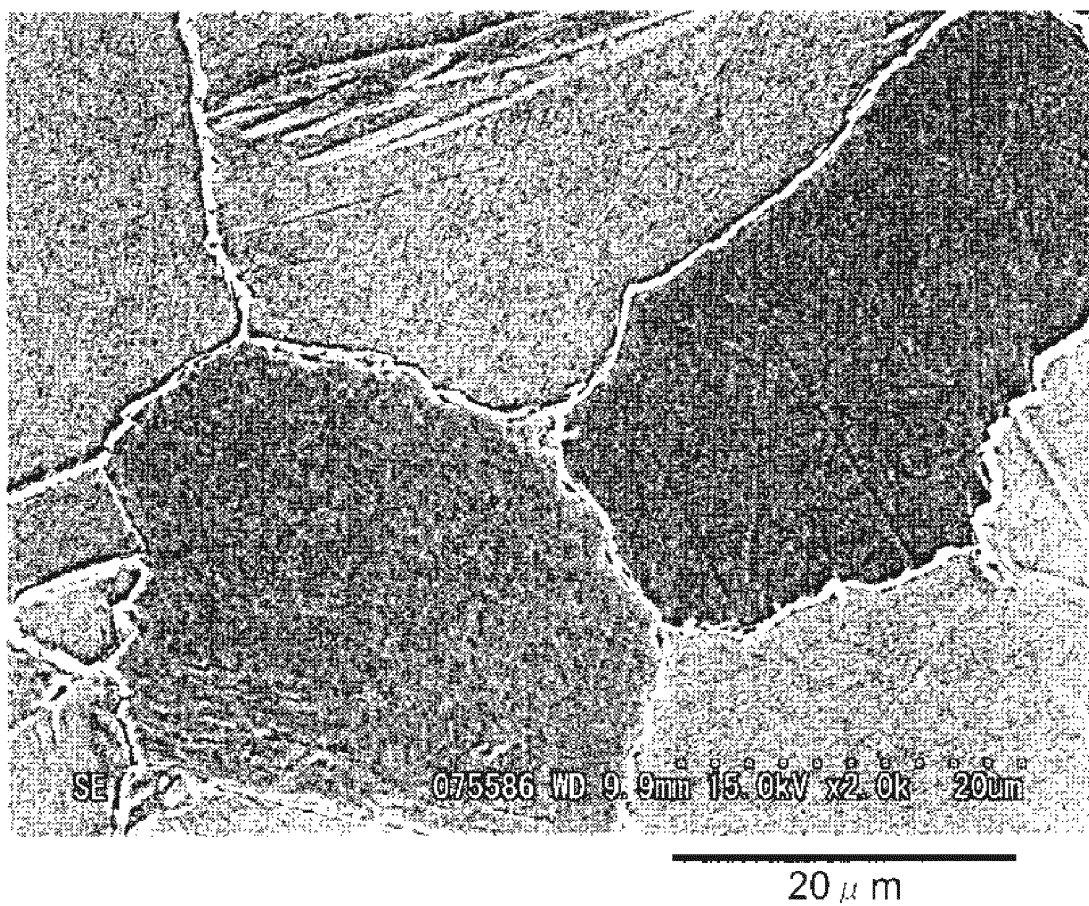
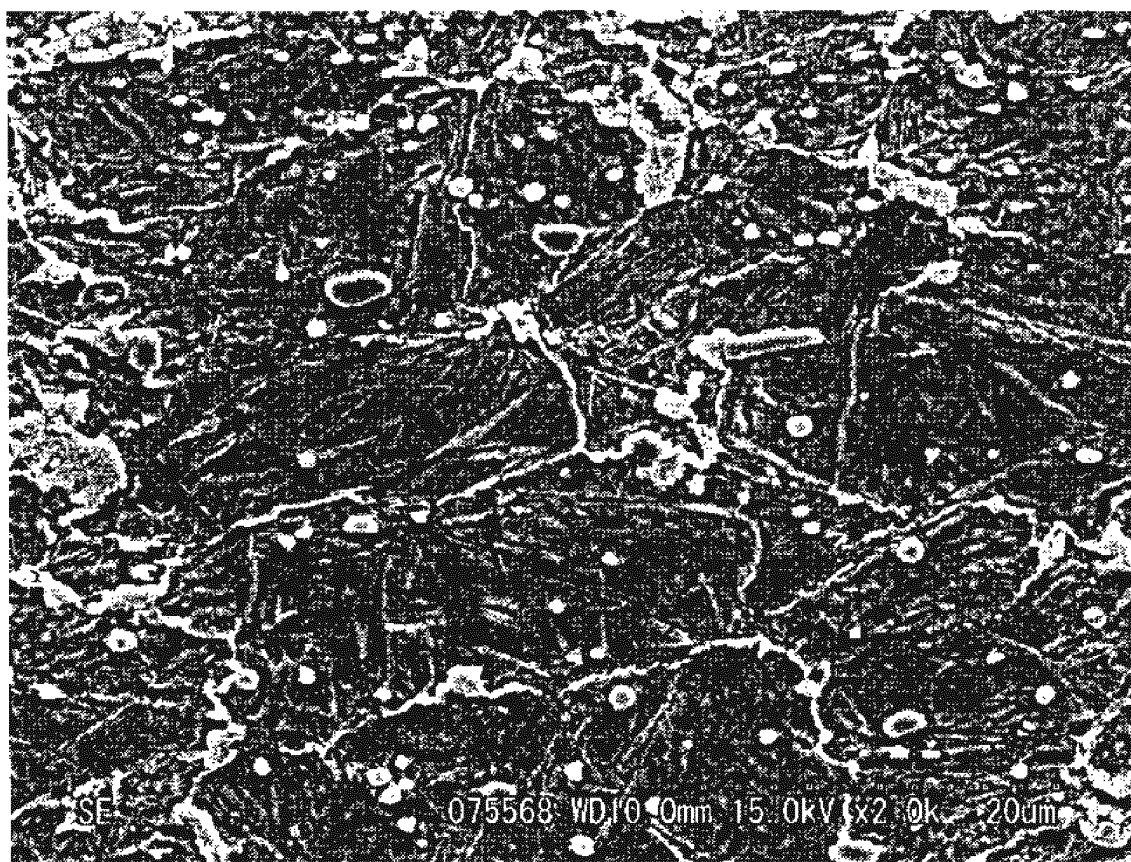


FIG.6

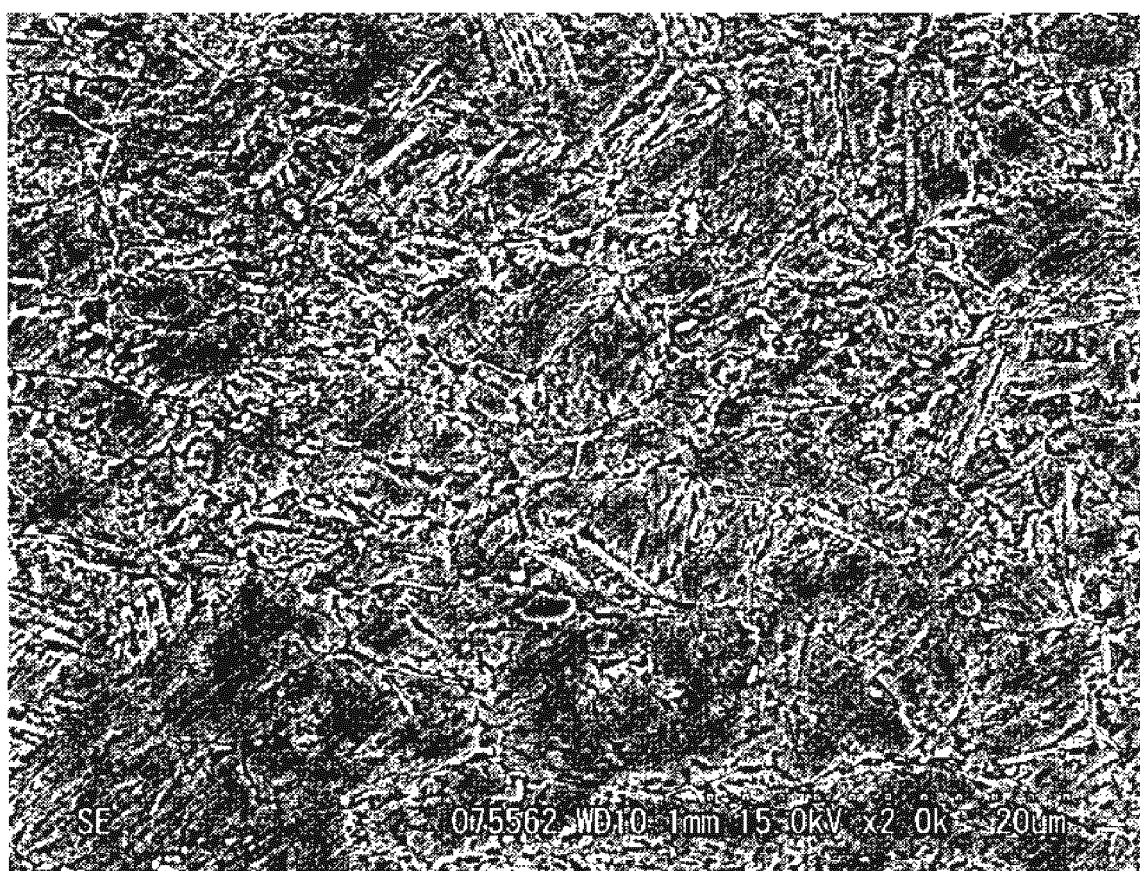
INTERMEDIATE MATERIAL ALLOY C (No. 5) OF THE INVENTION
HOT ROLLING CONDITIONS: HEATING TEMPERATURE 1180°C, HOT
ROLLING END TEMPERATURE 850°C



20 μ m

FIG.7

INTERMEDIATE MATERIAL ALLOY D (No. 6) OF THE INVENTION
HOT ROLLING CONDITIONS: HEATING TEMPERATURE 1180°C, HOT
ROLLING END TEMPERATURE 850°C



20 μ m

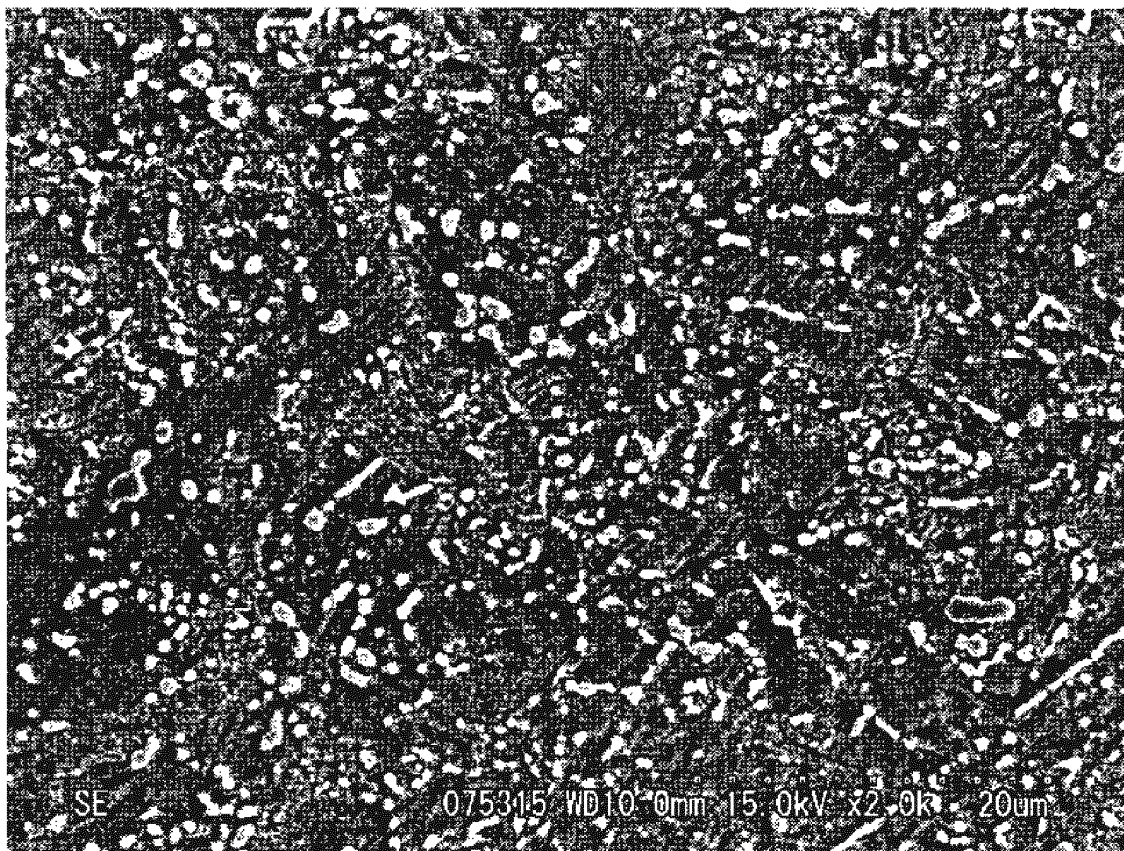
FIG.8

ALLOY A (No. 1) OF THE INVENTION

HOT ROLLING CONDITIONS: HEATING TEMPERATURE 1180°C, HOT
ROLLING END TEMPERATURE 850°C

MANUFACTURING PROCESS:

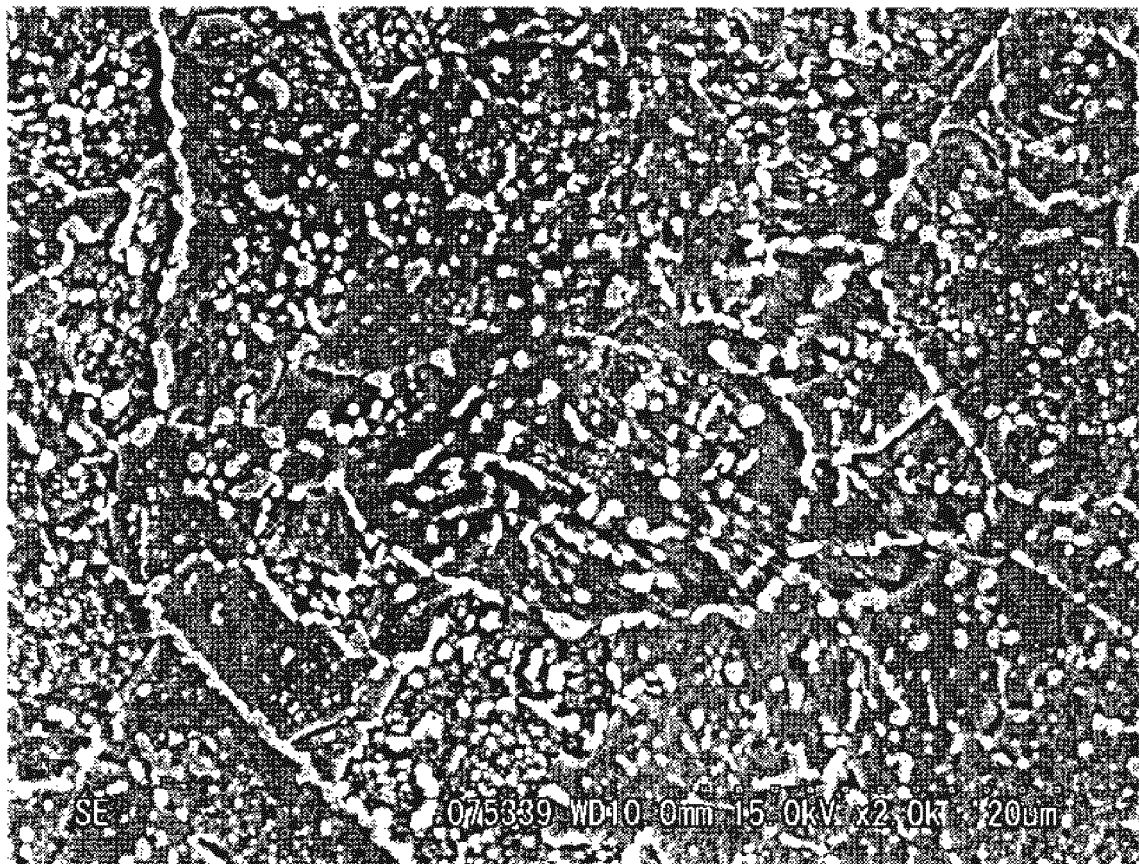
HOT ROLLING-ANNEALING-HARDENING-SUBZERO TREATMENT-TEMPERING



20 μ m

FIG.9

ALLOY A (No. 2) OF COMPARATIVE EXAMPLE
HOT ROLLING CONDITIONS: HEATING TEMPERATURE 1200°C, HOT
ROLLING END TEMPERATURE 1050°C
MANUFACTURING PROCESS:
HOT ROLLING-ANNEALING-HARDENING-SUBZERO TREATMENT-TEMPERING



20 μ m

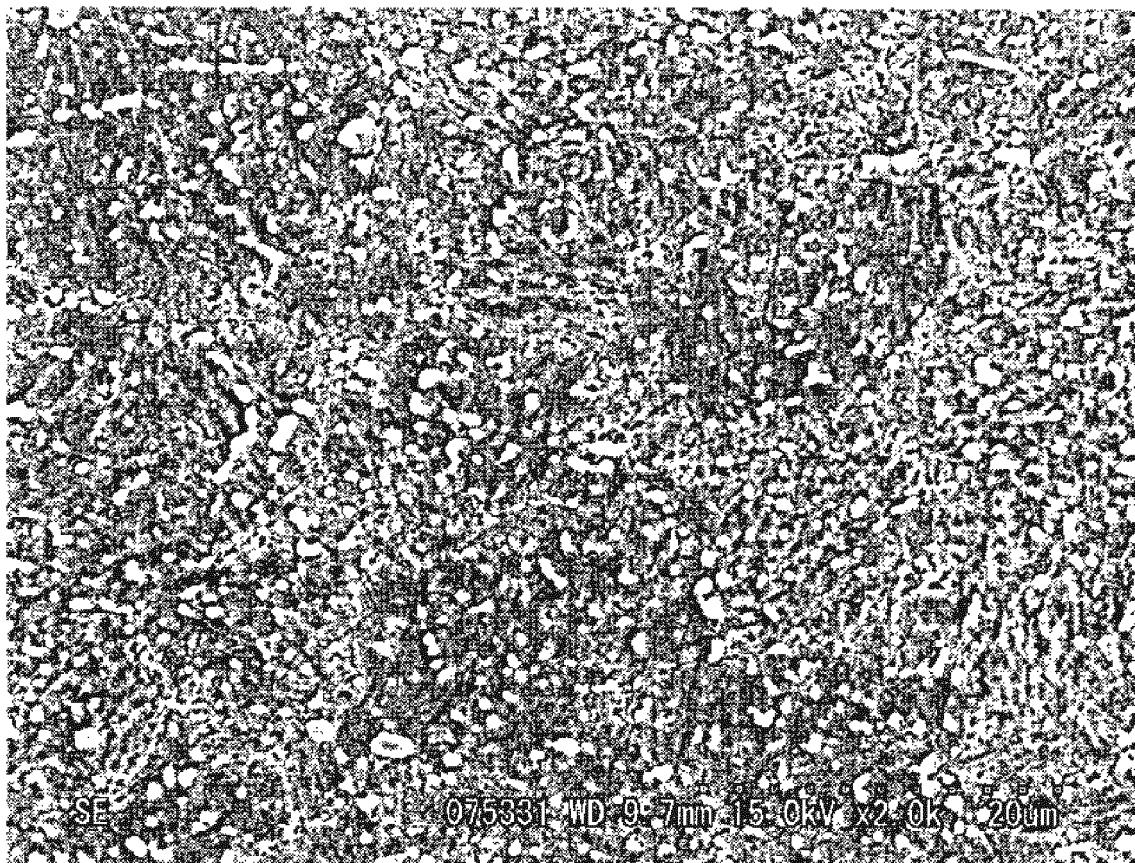
FIG.10

ALLOY B (No. 3) OF THE INVENTION

HOT ROLLING CONDITIONS: HEATING TEMPERATURE 1180°C, HOT
ROLLING END TEMPERATURE 850°C

MANUFACTURING PROCESS:

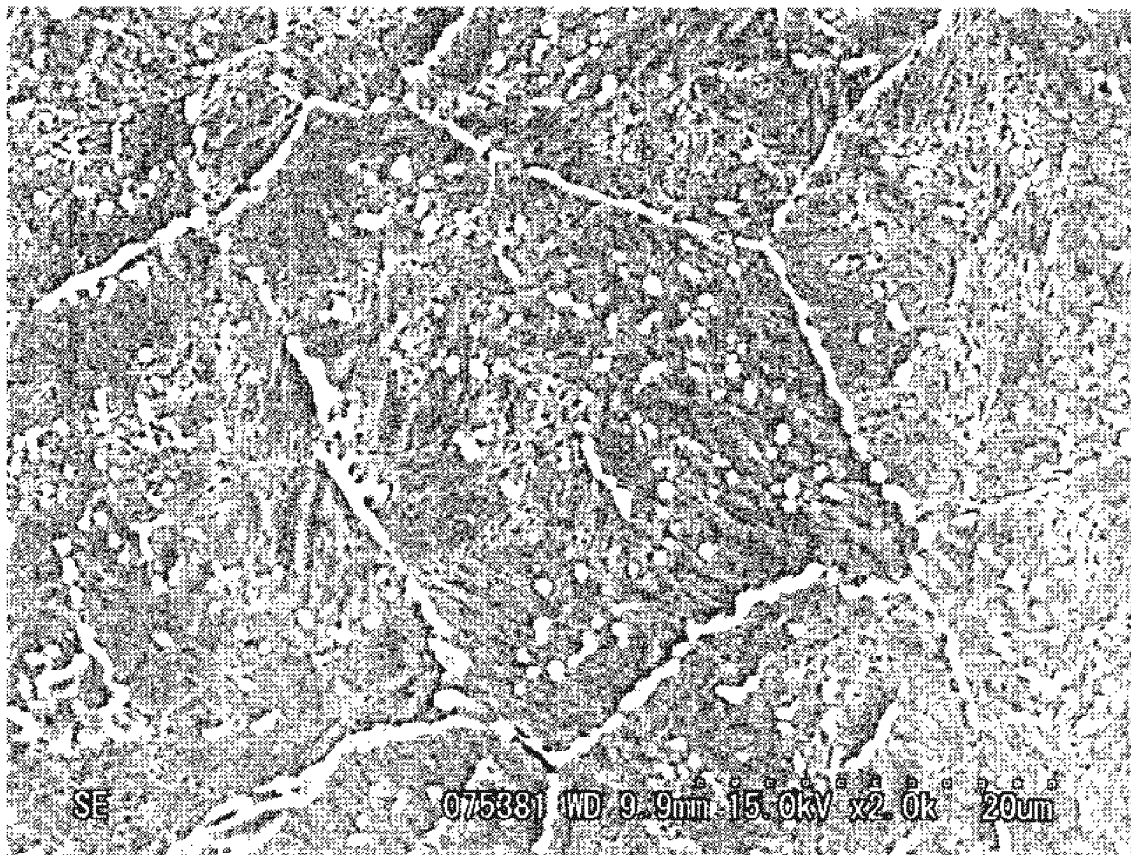
HOT ROLLING-ANNEALING-HARDENING-SUBZERO TREATMENT-TEMPERING



20 μ m

FIG.11

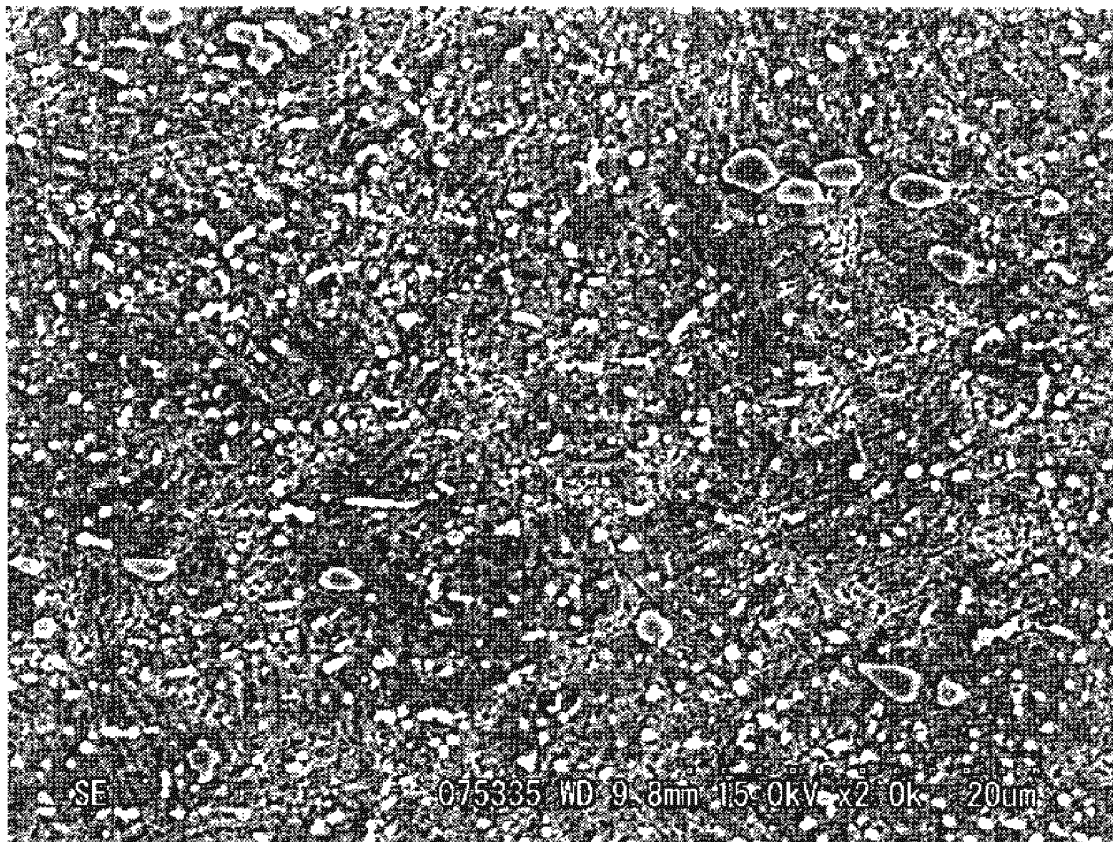
ALLOY B (No. 4) OF COMPARATIVE EXAMPLE
HOT ROLLING CONDITIONS: HEATING TEMPERATURE 1200°C, HOT
ROLLING END TEMPERATURE 1050°C
MANUFACTURING PROCESS:
HOT ROLLING-ANNEALING-HARDENING-SUBZERO TREATMENT-TEMPERING



20 μ m

FIG.12

ALLOY C (No. 5) OF THE INVENTION
HOT ROLLING CONDITIONS: HEATING TEMPERATURE 1180°C, HOT
ROLLING END TEMPERATURE 850°C
MANUFACTURING PROCESS:
HOT ROLLING-ANNEALING-HARDENING-SUBZERO TREATMENT-TEMPERING



20 μ m

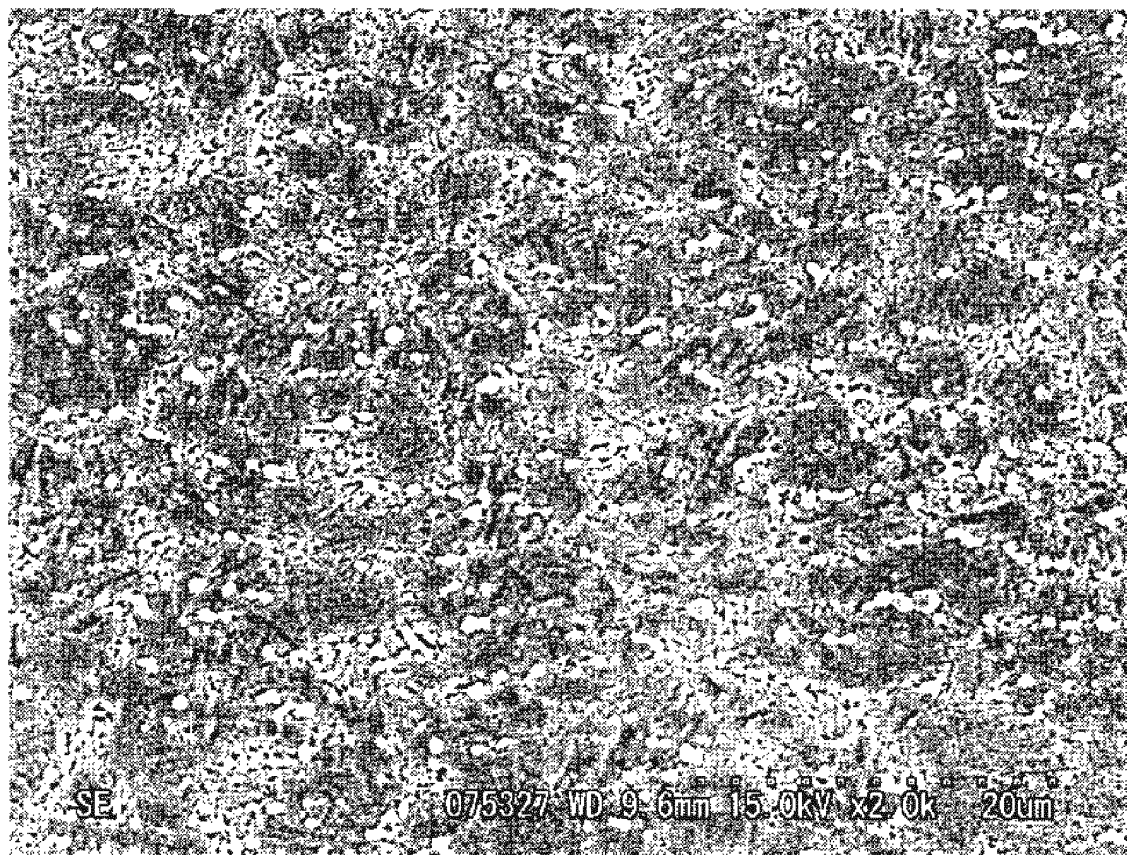
FIG.13

ALLOY D (No. 6) OF THE INVENTION

HOT ROLLING CONDITIONS: HEATING TEMPERATURE 1180°C, HOT
ROLLING END TEMPERATURE 850°C

MANUFACTURING PROCESS:

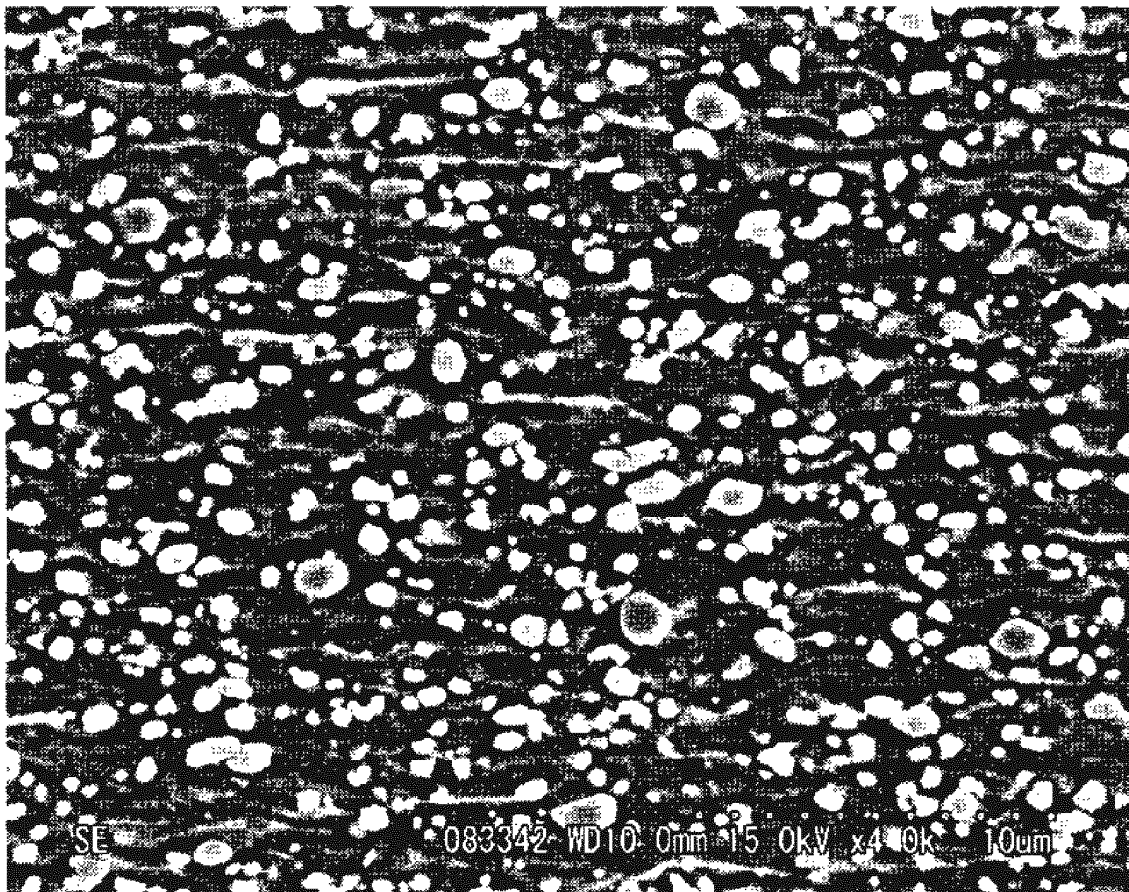
HOT ROLLING-ANNEALING-HARDENING-SUBZERO TREATMENT-TEMPERING



20 μ m

FIG.14

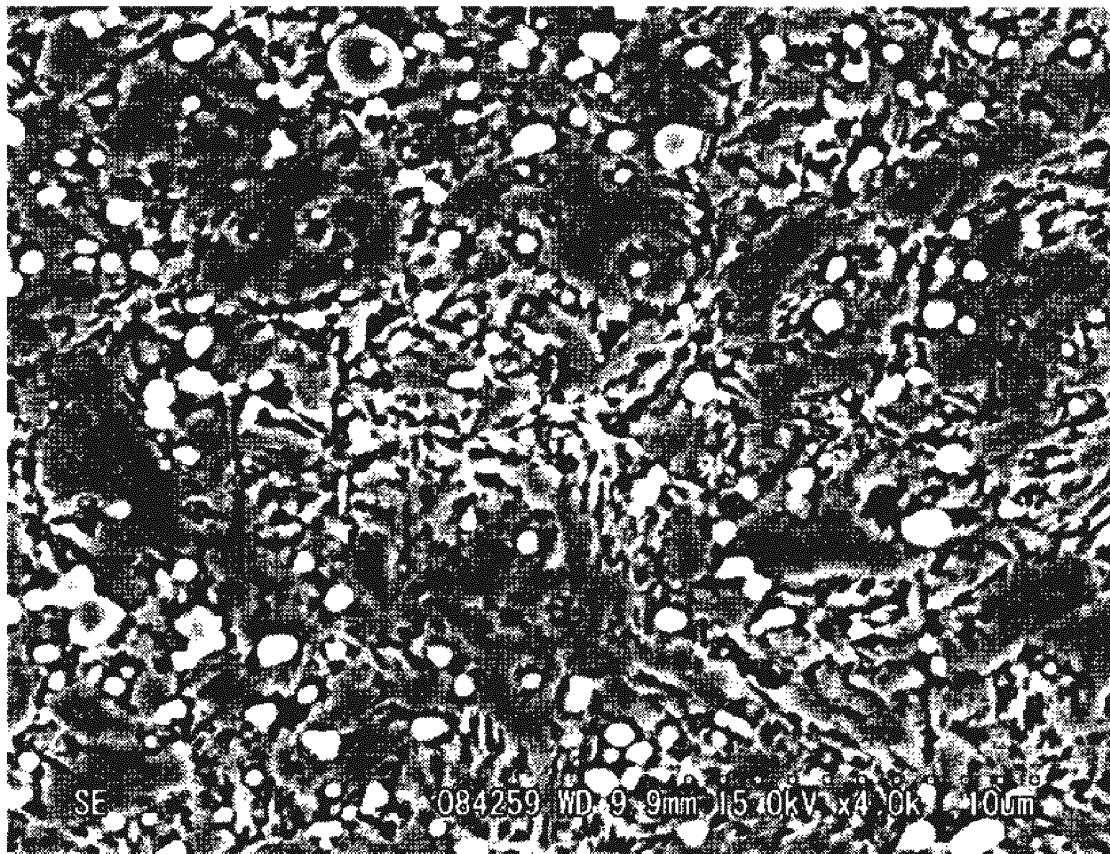
ALLOY A (No. 1) OF THE INVENTION
HOT ROLLING CONDITIONS: HEATING TEMPERATURE
1180°C, HOT ROLLING END TEMPERATURE 850°C
MANUFACTURING PROCESS: HOT ROLLING-ANNEALING-COLD ROLLING



10 μ m

FIG.15

ALLOY A (No. 1) OF THE INVENTION
HOT ROLLING CONDITIONS: HEATING TEMPERATURE 1180°C' HOT
ROLLING END TEMPERATURE 850°C
MANUFACTURING PROCESS: HOT ROLLING-ANNEALING-COLD ROLLING-
HARDENING-SUBZERO TREATMENT-TEMPERING



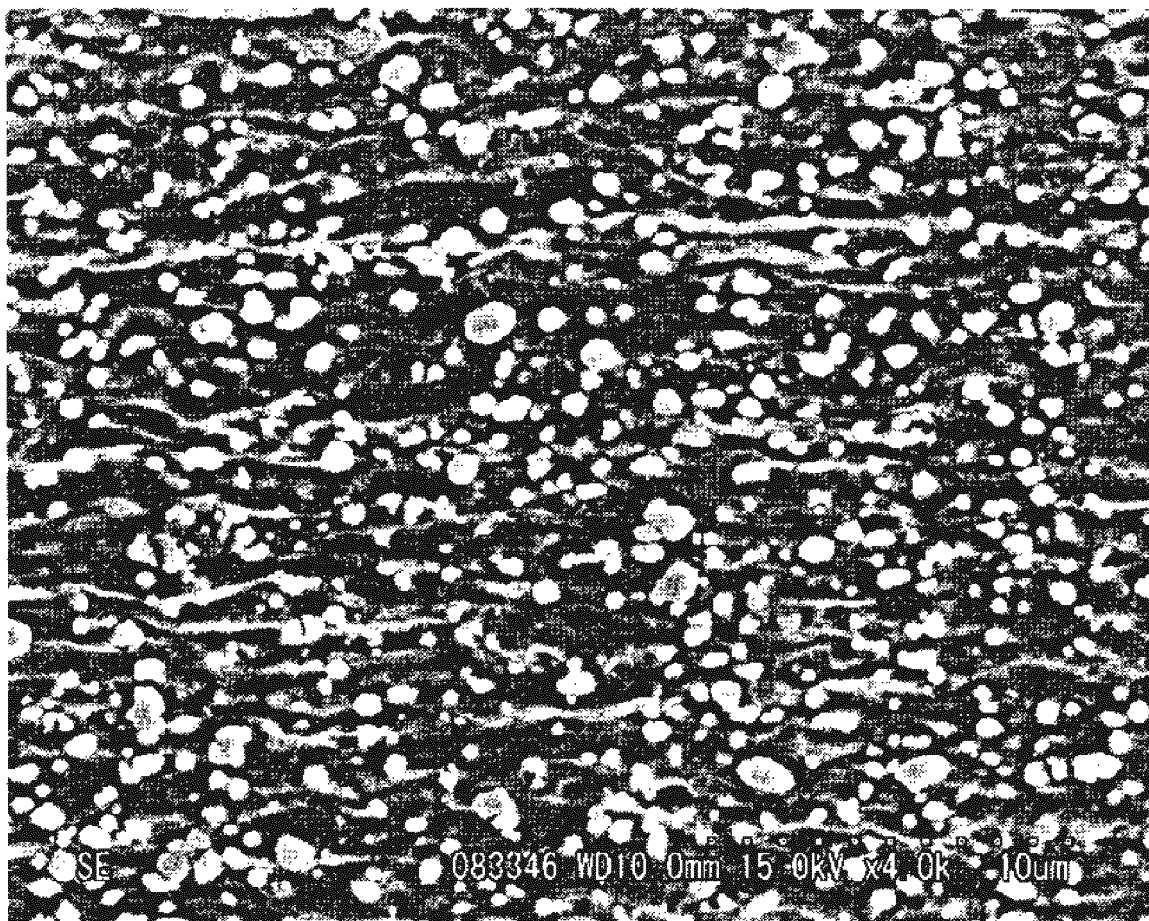
10 μ m

FIG.16

ALLOY B (No. 3) OF THE INVENTION

HOT ROLLING CONDITIONS: HEATING TEMPERATURE 1180°C, HOT
ROLLING END TEMPERATURE 850°C

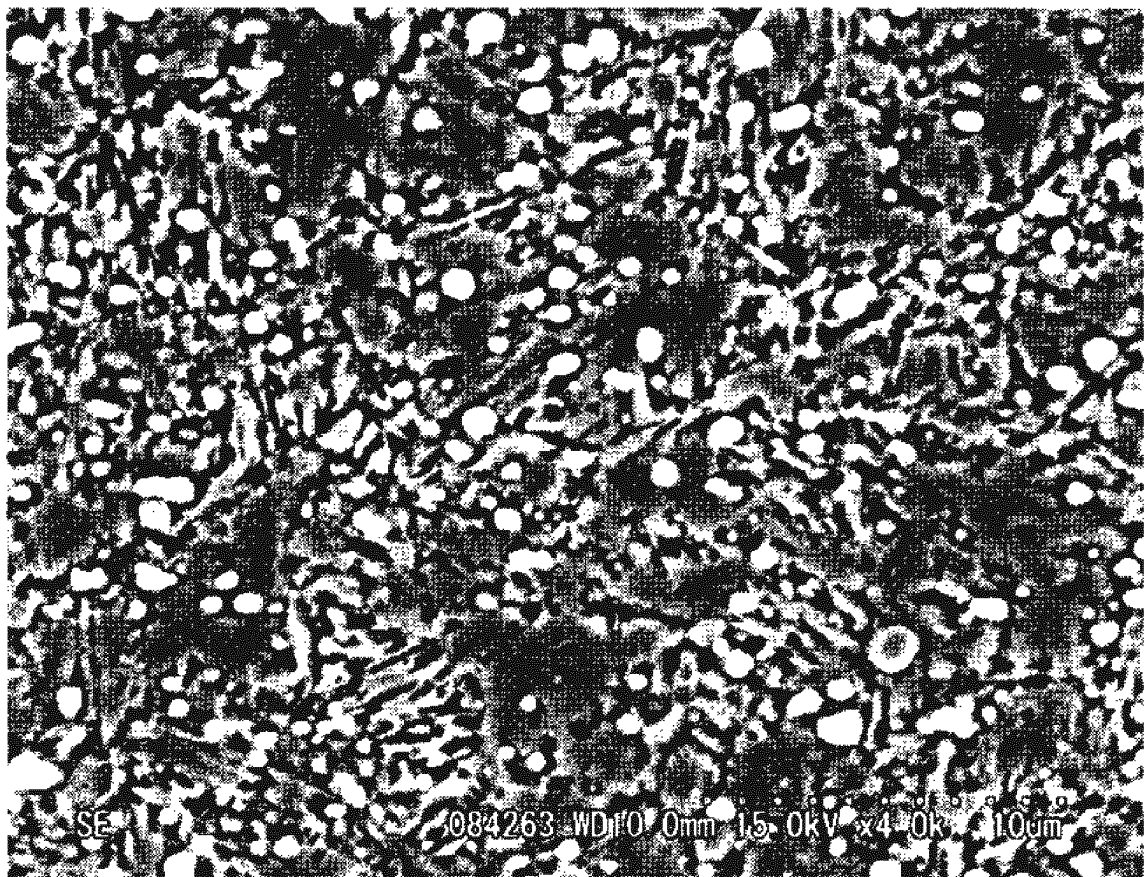
MANUFACTURING PROCESS: HOT ROLLING—ANNEALING—COLD ROLLING



10 μ m

FIG.17

ALLOY B (No. 3) OF THE INVENTION
HOT ROLLING CONDITIONS: HEATING TEMPERATURE
1180°C, HOT ROLLING END TEMPERATURE 850°C
MANUFACTURING PROCESS: HOT ROLLING-ANNEALING-COLD
ROLLING-HARDENING-SUBZERO TREATMENT-TEMPERING



10 μ m

5

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2012/073621

A. CLASSIFICATION OF SUBJECT MATTER

C22C38/32(2006.01)i, C21D8/02(2006.01)i, C21D9/46(2006.01)i

10

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

C22C38/00-38/60, C21D8/00-8/04, C21D9/46-9/48

15

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Jitsuyo Shinan Koho 1922-1996 Jitsuyo Shinan Toroku Koho 1996-2012

Kokai Jitsuyo Shinan Koho 1971-2012 Toroku Jitsuyo Shinan Koho 1994-2012

20

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

25

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 9-020923 A (Sumitomo Metal Industries, Ltd.), 21 January 1997 (21.01.1997), claims; paragraphs [0001], [0038]; table 1 (Family: none)	1-6
A	JP 2007-224405 A (JFE Steel Corp.), 06 September 2007 (06.09.2007), claims; paragraphs [0001], [0022]; table 1 (Family: none)	1-6
A	JP 2009-270196 A (Hitachi Metals, Ltd.), 19 November 2009 (19.11.2009), claims; paragraph [0013]; table 1 (Family: none)	1-6

40

☐ Further documents are listed in the continuation of Box C.☐ See patent family annex.

45

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"&" document member of the same patent family

50

Date of the actual completion of the international search
28 November, 2012 (28.11.12)Date of mailing of the international search report
11 December, 2012 (11.12.12)

55

Name and mailing address of the ISA/
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REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP H05039547 A [0007] [0008]