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(54) **STAINLESS STEEL MATERIAL AND METHOD FOR MANUFACTURING SAME, AND ANTIBACTERIAL/ANTIVIRAL MEMBER**

(57) A stainless steel material has ε-Cu phases exposed on a surface of the stainless steel material. The ε-Cu phases on the surface have an area ratio of 0.1 to 4.0%, an average particle size of 10 to 300 nm, and a maximum interparticle distance of 100 to 1000 nm.

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Description

[Technical Field]

[0001] The present invention relates to a stainless steel material, a method for producing the same, and an antibacterial and antiviral member.

[Background Art]

[0002] Stainless steel is used in a wide range of applications, including kitchen instruments, home appliances, medical devices, interior construction materials for buildings, and transportation equipment, because of its excellent corrosion resistance, and it is also being used in an environment where growth of bacteria and attachment of viruses easily occur. In recent years, there has been an increasing concern about the adverse effects on the human body caused by the growth of bacteria and attachment of viruses, and in particular, antibacterial and antiviral properties have also been required for various materials used in buildings and transportation equipment where many people gather, in addition to medical devices and kitchen instruments that require cleanliness.

[0003] Ag, Cu, and the like are known as metal elements having antibacterial and antiviral properties. Therefore, a prior art proposes a stainless steel material having antibacterial and antiviral properties by adding these metal elements.

[0004] For example, Patent Literature 1 proposes a ferritic stainless steel material having good antibacterial properties, comprising: 0.1% by weight or less of C, 2% by weight or less of Si, 2% by weight or less of Mn, 10 to 30% by weight of Cr, and 0.4 to 3% by weight of Cu, wherein Cu-rich phases (ε-Cu phases) are deposited in a matrix at a proportion of 0.2% by volume or more. The ferritic stainless steel material is produced by subjecting a ferritic stainless steel containing: 0.1% by weight or less of C, 2% by weight or less of Si, 2% by weight or less of Mn, 10 to 30% by weight of Cr, and 0.4 to 3% by weight of Cu to cold rolling and final annealing, followed by an aging treatment at 500 to 800°C to deposit 0.2% by volume or more of Cu-rich phases (ε-Cu phases).

[0005] Further, Patent Literature 2 proposes an austenitic stainless steel material having good antibacterial properties, comprising: 0.1% by weight or less of C, 2% by weight or less of Si, 5% by weight or less of Mn, 10 to 30% by weight of Cr, 5 to 15% by weight of Ni, and 1.0 to 5.0% by weight of Cu, wherein second phases (ε-Cu phases) based on Cu are dispersed in a matrix at a proportion of 0.2% by volume or more. The austenite stainless steel material is produced by subjecting an austenitic stainless steel containing: 0.1% by weight or less of C, 2% by weight or less of Si, 5% by weight or less of Mn, 10 to 30% by weight of Cr, 5 to 15% by weight of Ni, and 1.0 to 5.0% by weight Cu to one or more heat treatments in a temperature range of 500 to 900°C during a period of time from hot rolling to a final product.

[Citation List]

[Patent Literatures]

[0006]

[PTL 1]
Japanese Patent Application Publication No. H09-170053 A
[PTL 2]
Japanese Patent Application Publication No. H09-176800 A

[Summary of Invention]

[Technical Problem]

[0007] In each of the stainless steel materials described in Patent Literatures 1 and 2, the distribution state of the ε-Cu phases on the surface is not properly controlled, so that the desired antibacterial properties may not be obtained or the antibacterial properties may tend to be lost at an early stage.

[0008] Also, since viruses are smaller than bacteria, if the virus adheres between the ε-Cu phases on the surface, substantially no antiviral property may be obtained.

[0009] An object of the present invention is to provide a stainless steel material, a method for producing the same, and an antibacterial and antiviral member, which can maintain antibacterial and antiviral properties for a long period of time.

[Solution to Problem]

[0010] As a result of intensive studies to solve the above problems, the inventors of the present invention have found that the distribution state of the ε-Cu phases on the surface of the stainless steel material (particularly, an area ratio of the ε-Cu phases on the surface, an average particle size of the ε-Cu phases and a maximum interparticle distance of the ε-Cu phases) are closely related to the antibacterial and antiviral properties and their durability, and have completed the present invention.

[0011] Thus, the present invention relates to a stainless steel material having ε-Cu phases exposed on a surface of the stainless steel material, wherein the ε-Cu phases on the surface have an area ratio of 0.1 to 4.0%, an average particle size of 10 to 300 nm, and a maximum interparticle distance of 100 to 1000 nm.

[0012] The present invention also relates to a method for producing a stainless steel material, comprising:

a hot rolling step of hot-rolling a slab having a ferritic composition comprising: on a mass basis, 0.10% or less of C, 4.00% or less of Si, 2.00% or less of Mn, 0.050% or less of P, 0.030% or less of S, 4.00% or less of Ni, 10.00 to 32.00% of Cr, and 0.40 to 4.00% of Cu, the balance being Fe and impurities, or a slab having an austenitic composition comprising: on a mass basis, 0.12% or less of C, 4.00% or less of Si, 6.00% or less of Mn, 0.050% or less of P, 0.030% or less of S, 4.00 to 20. 00% of Ni, 10.00 to 32.00% of Cr, and 2.00 to 6.00% of Cu, the balance being Fe and impurities, to obtain a hot-rolled material, wherein a finish hot rolling ending temperature is 700 to 900°C when the slab has the ferritic composition, or a finish hot rolling ending temperature is 850 to 1050°C when the slab has the austenitic composition;
a cooling step of cooling the hot-rolled material obtained in the hot rolling step from 900 to 500°C at an average cooling rate of 0.2 to 5°C/sec; and
a heat treatment step of heating the hot-rolled material cooled in the cooling step at 750 to 850°C for 4 hours or more.

[0013] Further, the present invention relates to an antibacterial and antiviral member comprising the stainless steel material.

[Advantageous Effects of Invention]

[0014] According to the present invention, it is possible to provide a stainless steel material, a method for producing the same, and an antibacterial and antiviral member, which can maintain antibacterial and antiviral properties for a long period of time.

[Brief Description of Drawings]

[0015] [Fig. 1]
Fig. 1 is a schematic view of a surface of a typical stainless steel material according to the present invention.

[Description of Embodiments]

[0016] The present invention is a stainless steel material having ε-Cu phases exposed on the surface. The ε-Cu phases have an area ratio of 0.1 to 4.0%, an average particle size of 10 to 300 nm, and a maximum interparticle distance of 100 to 1000 nm.

[0017] Here, Fig. 1 shows a schematic view of the surface of a typical stainless steel material according to the present invention.

[0018] As shown in Fig. 1, a stainless steel material 10 has ε-Cu phases 11 exposed on a surface of a matrix phase. A passive film 12 is formed on the surface of the matrix phase where the ε-Cu phases 11 are not exposed.

[0019] By exposing the ε-Cu phases 11 on the surface of the matrix phase, Cu ions can be eluted from the ε-Cu phases 11 when moisture is in contact with the surface of the stainless steel material 10. For example, when a human hand touches the surface of the stainless steel material 10, the Cu ions can be eluted from the ε-Cu phases 11 by the moisture of the hand. Therefore, even if bacteria adhere to the surface, they can be sterilized, and even if viruses adhere to the surface, they can be inactivated and eventually killed.

[0020] The stainless steel material 10 also has a good corrosion resistance, because the passive film 12 is formed on the surface of the matrix phase where the ε-Cu phases 11 are not exposed.

[0021] The composition of the stainless steel material according to the present invention contains, but not particularly limited to, 0.12% or less of C, 4.00% or less of Si, 6.00% or less of Mn, 0.050% or less of P, 0.030% or less of S, 20.00% or less of Ni, 10.00 to 32.00% of Cr, and 0.40 to 6.00% of Cu, the balance being Fe and impurities.

[0022] Here, the "%" expression regarding components as used herein means "% by mass" unless otherwise specified.

[0023] Although the metallographic structure of the stainless steel material according to the present invention is not particularly limited, it is preferably ferritic or austenitic.

[0024] Hereinafter, embodiments of the present invention will be specifically described while being illustrated as ferritic or austenitic stainless steel materials. It is to understand that the present invention is not limited to the following embodiments, and those which have appropriately added changes, improvements and the like to the following embodiments based on knowledge of a person skilled in the art without departing from the spirit of the present invention fall within the scope of the present invention.

(Embodiment 1)

[0025] The ferritic stainless steel material according to Embodiment 1 of the present invention has a composition containing: 0.10% or less of C, 4.00% or less of Si, 2.00% or less of Mn, 0.050% or less of P, 0.030% or less of S, 4.00% or less of Ni, 10.00 to 32.00% of Cr, and 0.40 to 4.00% of Cu, the balance being Fe and impurities.

[0026] As used herein, the term "steel material" means materials having various shapes such as steel plates. Also, the term "steel plate" is a concept including a steel strip. Further, the term "impurities" refers to components which are contaminated by raw materials such as ores and scraps, and various factors in the production steps, when the stainless steel materials are industrially produced, and which are permissible in a range that does not adversely affect the present invention.

[0027] Also, the ferritic stainless steel material according to Embodiment 1 of the present invention further contains one or more selected from: 1.00% or less of Nb, 0.60% or less of Ti, 1.00% or less of V, 2.00% or less of W, 3.00% or less of Mo, 0.050% or less of N, 0.50% or less of Sn, 5.00% or less of Al, 0.50% or less of Zr, 0.50% or less of Co, 0.010% or less of B, 0.10% or less of Ca, and 0.20% or less of REM.

[0028] Each component will be described below in detail.

<C: 0.10% or less>

[0029] C is an element effective for improving the strength of the ferritic stainless steel material and for uniformly dispersing and depositing the ε-Cu phases by forming Cr carbides. However, if the C content is too high, the material becomes hard to deteriorate workability, and in addition, sensitization occurs when the material undergoes thermal effects such as welding, so that the corrosion resistance of the ferritic stainless steel will be deteriorated. Therefore, the upper limit of the C content is controlled to 0.10%, and preferably 0.06%, and more preferably 0.04%, and still more preferably 0.03%. On the other hand, the lower limit of the C content is not particularly limited, but it may preferably be 0.001%, and more preferably 0.003%, and still more preferably 0.005%.

<Si: 4.00% or less>

[0030] Si is a ferrite phase (α phase) generating element, and is an element effective for improving the corrosion resistance and strength of the ferritic stainless steel material. However, if the content of Si is too high, the material becomes hard to deteriorate the workability of the ferritic stainless steel. Therefore, the upper limit of the Si content is controlled to 4.00%, and preferably 2.00%, and more preferably 1.50%, and still more preferably 1.00%. On the other hand, the lower limit of the Si content is not particularly limited, but it may preferably be 0.01%, and more preferably 0.05%, and still more preferably 0.10%.

<Mn: 2.00% or less>

[0031] Mn is an element that improves the heat resistance of the ferritic stainless steel material. However, if the Mn content is too high, the corrosion resistance of the ferritic stainless steel material will be deteriorated. Moreover, the Mn is an austenite phase (γ phase)-forming element, so that it forms γ phases at an elevated temperature (martensite phases at room temperature), thereby deteriorating the workability of the ferritic stainless steel material. Therefore, the upper limit of the Mn content is controlled to 2.00%, and preferably 1.50%, and more preferably 1.20%, and still more preferably 1.00%. On the other hand, the lower limit of the Mn content is not particularly limited, but it may preferably be 0.01%, and more preferably 0.05%, and still more preferably 0.10%.

<P: 0.050% or less>

[0032] If the P content is too high, the corrosion resistance and workability of the ferritic stainless steel material will be deteriorated. Therefore, the upper limit of the P content is controlled to 0.050%, and preferably 0.040%, and more preferably 0.030%. On the other hand, the lower limit of the P content is not particularly limited, but a decrease in the P content results in refining costs, so it is preferably 0.001%, and more preferably 0.005%, and even more preferably 0.010%.

<S: 0.030% or less>

[0033] If the S content is too high, the hot workability will be deteriorated, the producibility of the ferritic stainless steel material will be decreased, and the corrosion resistance will also adversely be affected. Therefore, the upper limit of the S content is controlled to 0.030%, and preferably 0.020%, and more preferably 0.010%. On the other hand, the lower limit of the S content is not particularly limited, but a decrease in the S content results in refining costs, so the S content is preferably 0.0001%, and more preferably 0.0002%, and even more preferably 0.0003%.

<Ni: 4.00% or less>

[0034] Ni is an element that improves the corrosion resistance of the ferritic stainless steel material. However, as with Mn, Ni is an austenite phase (γ phase)-forming element. Therefore, if the Ni content is too high, it will form the γ phases at an elevated temperature (martensite phases at room temperature), and the workability of the ferritic stainless steel will be deteriorated. Further, since Ni is an expensive element, it also leads to an increase in production cost. Therefore, the upper limit of the Ni content is controlled to 4.00%, and preferably 2.00%, and more preferably 1.00%, and still more preferably 0.60%. On the other hand, the lower limit of the Ni content is not particularly limited, but it may preferably be 0.005%, and more preferably 0.01%, and still more preferably 0.03%.

<Cr: 10.00 to 32.00%>

[0035] Cr is an important element to maintain the corrosion resistance of the ferritic stainless steel material. However, if the Cr content is too high, the refining cost will increase, and solid-solution strengthening will harden the steel material, thereby degrading the workability of the ferritic stainless steel material. Therefore, the upper limit of the Cr content is controlled to 32.00%, and preferably 22.00%, and more preferably 20.00%, and still more preferably 18.00%. On the other hand, if the Cr content is too low, any sufficient corrosion resistance cannot be obtained. Therefore, the lower limit of the Cr content is controlled to 10.00%, and preferably 14.00%, and more preferably 15.00%, and still more preferably 16.00%.

<Cu: 0.40 to 4.00%>

[0036] Cu is an element required for depositing the ε-Cu phases that provide antibacterial and antiviral properties. The Cu is also an element that improves the workability of the ferritic stainless steel material. In order to obtain such effects, the lower limit of the Cu content is controlled to 0.40%, and preferably 0.70%, and more preferably 1.00%, and still more preferably 1.30%. On the other hand, if the Cu content is too high, the corrosion resistance of the ferritic stainless steel material will be deteriorated, and low-melting point phases are also formed during casting, resulting in poor hot workability. Therefore, the upper limit of the Cu content is controlled to 4.00%, and preferably 3.00%, and more preferably 2.00%, and still more preferably 1.70%.

<Nb: 1.00% or less>

[0037] Nb is an element that exhibits effects of forming deposits and uniformly depositing the ε-Cu phases around them, and is optionally added. However, if the Nb content is too high, the workability of the ferritic stainless steel material will be deteriorated. Therefore, the upper limit of the Nb content is controlled to 1.00%, and preferably 0.80%, and more preferably 0.60%, and still more preferably 0.55%. On the other hand, the lower limit of the Nb content is not particularly limited, but from the viewpoint of obtaining the effects of Nb, it is preferably 0.05%, and more preferably 0.10%, and still more preferably 0.20%, and particularly preferably 0.25%.

<Ti: 0.60% or less>

[0038] As with Nb, Ti is an element that exhibits effects of forming deposits and uniformly depositing the ε-Cu phases around them, and is optionally added. However, if the content of Ti is too high, it causes surface defects, leading to deterioration of quality and deterioration of workability of the ferritic stainless steel material. Therefore, the upper limit of the Ti content is controlled to 0.60%, and preferably 0.30%. On the other hand, the lower limit of the Ti content is not particularly limited, but from the viewpoint of obtaining the effects of Ti, it is preferably 0.01%, and more preferably 0.03%.

<V: 1.00% or less>

[0039] As with Nb and Ti, V is an element that exhibits effects of forming deposits and uniformly depositing the ε-Cu phases around them, and is optionally added. However, if the V content is too high, it causes surface defects, resulting in deterioration of quality and deterioration of workability of the ferritic stainless steel material. Therefore, the upper limit of the V content is controlled to 1.00%, and preferably 0.50%. On the other hand, the lower limit of the V content is not particularly limited, but from the viewpoint of obtaining the effects of V, it is preferably 0.01%, and more preferably 0.03%.

<W: 2.00% or less>

[0040] As with Nb, Ti and V, W is an element that exhibits effects of forming deposits and uniformly depositing the ε-Cu phases around them, and is optionally added. However, if the W content is too high, it causes surface defects, resulting in deterioration of quality and deterioration of workability of the ferritic stainless steel material. Therefore, the upper limit of the W content is controlled to 2.00%, and preferably 1.00%. On the other hand, the lower limit of the W content is not particularly limited, but from the viewpoint of obtaining the effects of W, it is preferably 0.01%, and more preferably 0.03%.

<Mo: 3.00% or less>

[0041] Mo is an element that improves the corrosion resistance of the ferritic stainless steel material, and is optionally added. However, if the Mo content is too high, the production cost will increase. Therefore, the upper limit of the Mo content is controlled to 3.00%, and preferably 2.00%, and more preferably 1.50%, and still more preferably 1.00%. On the other hand, the lower limit of the Mo content is not particularly limited, but from the viewpoint of obtaining the effects of Mo, it is preferably 0.01%, and more preferably 0.03%, and still more preferably 0.10%.

<N: 0.050% or less>

[0042] As with Mo, N is an element that improves the corrosion resistance of the ferritic stainless steel material, and is optionally added. However, if the N content is too high, the material will become hard to deteriorate the workability of the ferritic stainless steel material. Therefore, the upper limit of the N content is controlled to 0.050%, and preferably 0.030%, and more preferably 0.025%, and still more preferably 0.015%. On the other hand, the lower limit of the N content is not particularly limited, but from the viewpoint of obtaining the effects of N, it is preferably 0.001%, and preferably 0.003%.

<Sn: 0.50% or less>

[0043] As with Mo and N, Sn is an element that improves the corrosion resistance of the ferritic stainless steel material, and is optionally added. However, if the Sn content is too high, the production cost will increase. Therefore, the upper limit of the Sn content is controlled to 0.50%, and preferably 0.30%. On the other hand, the lower limit of the Sn content is not particularly limited, but from the viewpoint of obtaining the effects of Sn, it is preferably 0.01%, and more preferably 0.03%.

<Al: 5.00% or less>

[0044] Al is an element used for deoxidation in a refining step and is optionally added. The Al is also an element that improves the corrosion resistance and oxidation resistance of the ferritic stainless steel material. However, if the Al content is too high, it results in increased amounts of inclusions and deterioration of the quality. Therefore, the upper limit of the Al content is 5.00%, and preferably 3.00%, and more preferably 2.00%, and still more preferably 1.00%. On the other hand, the lower limit of the Al content is not particularly limited, but from the viewpoint of obtaining the effects of Al, it is preferably 0.01%, and more preferably 0.05%.

<Zr: 0.50% or less>

[0045] As with Al, Zr is an element that improves the oxidation resistance of the ferritic stainless steel material, and is optionally added. However, if the Zr content is too high, it will lead to an increase in the production cost. Therefore, the upper limit of the Zr content is controlled to 0.50%, and preferably 0.30%. On the other hand, the lower limit of the Zr content is not particularly limited, but from the viewpoint of obtaining the effects of Zr, it is preferably 0.01%, and more preferably 0.03%.

<Co: 0.50% or less>

[0046] As with Al and Zr, Co is an element that improves the oxidation resistance of the ferritic stainless steel material, and is optionally added. However, if the Co content is too high, it will lead to an increase in the production cost. Therefore, the upper limit of the Co content is controlled to 0.50%, and preferably 0.30%. On the other hand, the lower limit of the Co content is not particularly limited, but from the viewpoint of obtaining the effects of Co, it is preferably 0.01%, and more preferably 0.03%.

<B: 0.010% or less>

[0047] B is an element that improves the hot workability of the ferritic stainless steel material and is optionally added. The B is also an element that improves the secondary workability of the ferritic stainless steel material by strengthening grain boundaries. However, if the content of B is too high, weldability and fatigue strength will be deteriorated. Therefore, the upper limit of the B content is controlled to 0.010%, and preferably 0.070%. On the other hand, the lower limit of the content of B is not particularly limited, but from the viewpoint of obtaining the effects of B, it is preferably 0.001%, and more preferably 0.002%.

<Ca: 0.10% or less>

[0048] As with B, Ca is an element that improves the hot workability of the ferritic stainless steel material, and is optionally added. The Ca is also an element that forms sulfides to suppresses grain boundary segregation of S, thereby improving grain boundary oxidation resistance. However, if the Ca content is too high, it will lead to deterioration of workability. Therefore, the upper limit of the Ca content is controlled to 0.10%, and preferably 0.05%. On the other hand, the lower limit of the Ca content is not particularly limited, but it is preferably 0.001%, and more preferably 0.003%, from the viewpoint of obtaining the effects of Ca.

<REM: 0.20% or less>

[0049] As with B and Ca, REM (rare earth element) is at least one element that improves the hot workability of the ferritic stainless steel material, and is optionally added. The REM is also at least one element that improves corrosion resistance by forming sulfides which are difficult to be eluted and suppressing the formation of MnS that is a starting point for corrosion. However, if the REM content is too high, it will lead to an increase in production cost. Therefore, the upper limit of the REM content is controlled to 0.20%, and preferably 0.10%. On the other hand, the lower limit of the REM content is not particularly limited, but it is preferably 0.001%, and more preferably 0.01%, from the viewpoint of obtaining the effects of REM.

[0050] As used herein, the "REM" is a generic term for two elements, scandium (Sc) and yttrium (Y), and fifteen elements (lanthanoids) from lanthanum (La) to lutetium (Lu). These may be used alone or as a mixture of two or more.

[0051] Next, the characteristics of the ε-Cu phases exposed on the surface of the ferritic stainless steel material according to Embodiment 1 of the present invention will be described in detail.

<Area ratio: 0.1 to 4.0%>

[0052] The larger the area ratio of the ε-Cu phases exposed on the surface, the higher the amount of eluted Cu ions, so that the antibacterial and antiviral properties can be enhanced. The area ratio of the ε-Cu phases mainly depends on the crystal structure and the Cu content. Therefore, in view the Cu content in the ferritic stainless steel material, the upper limit of the area ratio of the ε-Cu phases is controlled to 4.0%, and preferably 2.0%, and more preferably 1.9%, and even more preferably 1.8%. On the other hand, the lower limit of the area ratio of the ε-Cu phases is controlled to 0.1%, and preferably 0.3%, and more preferably 0.6%, from the viewpoint of ensuring antibacterial and antiviral properties.

[0053] As used herein, the "area ratio of the ε-Cu phases exposed on the surface" can be calculated by observing the surface of the stainless steel material with a TEM (transmission electron microscope). More particularly, the "area ratio of the ε-Cu phases exposed on the surface" can be calculated by taking TEM images at three or more randomly selected positions on a surface of a stainless steel material, and then image-analyzing the TEM images to measure areas of the ε-Cu phases, and dividing the areas of the ε-Cu phases by an area of a field of view. Although the area of the field of view is not particularly limited, it is preferably 10 μm^2 or more in total for the taken positions.

<Average Particle Size: 10 to 300 nm>

[0054] As an average particle size of the ε-Cu phases exposed on the surface is larger, the Cu ions can be eluted for a longer period of time, so that the durability of the antibacterial and antiviral properties is improved. However, an excessively large average particle size of the ε-Cu phases tends to increase an interparticle distance of the ε-Cu phases exposed on the surface. Therefore, when bacteria or viruses adhere to the distance between the particles of the ε-Cu phases exposed on the surface, sufficient antibacterial and antiviral properties may not be obtained. Therefore, the upper limit of the average particle size of the ε-Cu phases is controlled to 300 nm, and preferably 250 nm, and more preferably 200 nm. On the other hand, the lower limit of the average particle size of the ε-Cu phases is controlled to 10 nm, and preferably 30 nm, and more preferably 50 nm, from the viewpoint of ensuring the elution durability of Cu ions.

[0055] As used herein, the "average particle size of the ε-Cu phases exposed on the surface" can be calculated by observing the surface of the stainless steel material with a TEM (transmission electron microscope). More particularly, TEM images can be taken at three or more randomly selected positions on the surface of the stainless steel material, the TEM images can be then image-analyzed to obtain equivalent circle diameters of the ε-Cu phases, and an average value thereof can be determined to be "the average particle size of the ε-Cu phases exposed on the surface".

<Maximum Interparticle Distance: 100 to 1000 nm>

[0056] In general, the size of bacterium is 0.5 to 3 μm, while the size of virus is very small, 10 to 200 nm. Therefore, if the maximum interparticle distance of the ε-Cu phases exposed on the surface is too large, sufficient antiviral properties may not be obtained particularly when viruses adhere between the particles of the ε-Cu phases exposed on the surface. Therefore, the upper limit of the maximum interparticle distance of the ε-Cu phases is controlled to 1000 nm, and preferably 800 nm, and more preferably 500 nm. On the other hand, as the maximum interparticle distance of the ε-Cu phases exposed on the surface is lower, the antibacterial and antiviral properties can be more enhanced. In the case of a relatively large ε-Cu phase having an average particle size of 10 to 300 nm, the lower limit of the maximum interparticle distance of the ε-Cu phases would be 100 nm, in view of the growth process of the ε-Cu phases due to a heat treatment. Therefore, the lower limit of the maximum interparticle distance of the ε-Cu phases is controlled to 100 nm, and preferably 150 nm, and more preferably 200 nm.

[0057] As used herein, the "maximum interparticle distance of the ε-Cu phases exposed on the surface" can be calculated by observing the surface of the stainless steel material with a TEM (transmission electron microscope). More particularly, TEM images are taken at three or more randomly selected positions on the surface of the stainless steel material, the TEM images are then image-analyzed, and the position of the center of gravity (generating point) of each ε-Cu phase is determined and then Voronoi-sectioned. The distance between the centers of gravity of the ε-Cu phases in the adjacent Voronoi regions is then measured as the interparticle distance, and the maximum value thereof can be determined to be the "maximum interparticle distance of the ε-Cu phases exposed on the surface".

[0058] The ferritic stainless steel material according to Embodiment 1 of the present invention preferably has a Vickers hardness of 160 Hv or less. The control to such a Vickers hardness can ensure the workability, so that it can be used for various applications.

[0059] Although the lower limit of the Vickers hardness is not particularly limited, it is generally 100 Hv.

[0060] As used herein, the "Vickers hardness" can be measured according to JIS Z2244: 2009. In the measurement of Vickers hardness, the measurement load is 10 kg, the measurement is performed at five or more randomly selected positions, and an average value thereof is determined to be the result of Vickers hardness.

[0061] The ferritic stainless steel material according to Embodiment 1 of the present invention preferably has an antibacterial activity value of 2.0 or more in an antibacterial test according to JIS Z2801: 2010. Such an antibacterial activity value can ensure objectively high antibacterial properties.

[0062] As used herein, the "antibacterial test" is performed in accordance with JIS Z2801: 2010, using *Staphylococcus aureus* as the bacterium.

[0063] The ferritic stainless steel material according to Embodiment 1 of the present invention preferably has an antiviral activity value of 2.0 or more in an antiviral test according to ISO 21702: 2019. Such an antiviral activity value can ensure objectively high antiviral properties.

[0064] As used herein, the "antiviral test" is performed in accordance with ISO 21702: 2019, using influenza A virus as the virus.

[0065] Although the type of the ferritic stainless steel material according to Embodiment 1 of the present invention is not particularly limited, it is preferably a hot-rolled material or a cold-rolled material.

[0066] In the case of the hot-rolled material, the thickness is generally 3 mm or more. In the case of the cold-rolled material, the thickness is generally less than 3 mm.

[0067] The ferritic stainless steel material according to Embodiment 1 of the present invention can be produced by a method including a hot rolling step, a cooling step, and a heat treatment step.

[0068] The hot-rolling step is a step of hot-rolling a slab having the above composition to obtain a hot-rolled material. More particularly, the hot-rolled material is obtained by subjecting a slab having the above composition to rough rolling, followed by finish hot rolling. The hot-rolled material may be wound into a coil.

[0069] Although the slab having the above composition is not particularly limited, for example, it can be obtained by melting stainless steel having the above composition and forging or casting it.

[0070] The finish hot rolling is carried out so that a finish hot rolling ending temperature is 700 to 900°C. By controlling the finish hot rolling ending temperature to such a temperature range, fine "seeds" of the ε-Cu phase can be easily deposited in a small amount and in a uniform manner from the end of the finish hot rolling to the cooling step. As a result, the growth of the ε-Cu phases in the heat treatment step allows the distribution of the ε-Cu phases on the surface to be controlled as described above. On the other hand, if the finish hot rolling ending temperature is lower than 700°C, the fine "seeds" of the ε-Cu phases are not sufficiently deposited from the end of the finish hot rolling to the cooling step. As a result, the growth of the ε-Cu phases in the heat treatment step results in an excessively large average particle size and maximum interparticle distance of the ε-Cu phases on the surface. On the other hand, if the finish hot rolling ending temperature is more than 900°C, the structure becomes coarse so that the workability and toughness are deteriorated.

[0071] It should be noted that other conditions for the hot rolling step may be appropriately set according to the composition of the slab, and are not particularly limited.

[0072] The cooling step is a step for depositing the fine "seeds" of the ε-Cu phases, and carried out by cooling the hot-rolled material obtained in the hot rolling step from 900 to 500°C at an average cooling rate of 0.2 to 5°C/sec. By gently cooling under such conditions, the fine "seeds" of the ε-Cu phases can be deposited in a small amount and a uniform manner in the deposition temperature range (900 to 500°C) of the ε-Cu phases. Since the fine "seeds" of the ε-Cu phases are preferentially grown in the heat treatment step, relatively large ε-Cu phases become uniformly dispersed. As a result, the distribution state of the ε-Cu phases on the surface can be controlled as described above. From the viewpoint of stably obtaining such effects, the average cooling rate is preferably 1 to 5°C/sec, and more preferably 2 to 4°C/sec. In contrast, when cooling it from 900 to 500°C at an average cooling rate of higher than 5°C/sec, the fine "seeds" of the ε-Cu phases are not sufficiently deposited. As a result, the growth of the ε-Cu phases in the heat treatment step results in an excessively large average particle size and maximum interparticle distance of the ε-Cu phases on the surface. Further, when cooling it from 900 to 500°C at an average cooling rate of less than 0.2°C/sec, the amount of the fine "seeds" of the ε-Cu phases deposited is increased. As a result, a large amount of relatively small ε-Cu phases becomes deposited in the heat treatment step.

[0073] The cooling method in the cooling step is not particularly limited, and any method known in the art can be used. For example, only by placing the hot-rolled material wound into a coil in a heat insulating box, it is possible to gently cool the material under the above cooling conditions by recuperation. Also, the cooling temperature can be finely adjusted by controlling an amount of a feed gas (for example, an Ar gas) fed into the heat insulating box.

[0074] The heat treatment step is a step of growing the fine ε-Cu phase "seeds" deposited in the cooling step, and is performed by heating the hot-rolled material cooled in the cooling step at 750 to 850°C for 4 hours or more. By performing the heat treatment under such conditions, it is possible to control the distribution state of the ε-Cu phases on the surface as described above. From the viewpoint of stably obtaining such effects, the heating time is preferably 6 to 48 hours, and more preferably 8 to 36 hours. On the other hand, if the heating temperature is less than 750°C or the heating time is less than 4 hours, the fine "seeds" of the ε-Cu phases are not sufficiently grown, so that the average particle size of the ε-Cu phases becomes too small. Moreover, if the heating temperature is more than 850°C, the ε-Cu phases will be dissolved in the matrix phase.

[0075] After the heat treatment step, it may further carry out a surface layer removing step performing washing with an acid and/or polishing, as needed. The surface layer removing step can remove scales and a Cr-poor layer formed on the surface.

[0076] The thickness of the surface layer to be removed in the surface layer removing step is not particularly limited, and it may be appropriately adjusted according to the composition of the slab. For example, when removing the Cr-poor layer, it is preferable to remove a surface layer having a thickness of 10 μm or more.

[0077] When the ferritic stainless steel material is the cold-rolled material, a cold rolling and annealing step of performing a cold rolling, followed by an annealing treatment within 300 seconds, may be further carried out after the heat treatment step. When the surface layer removing step is performed after the heat treatment step, the cold rolling and annealing step may be carried out after the surface layer removing step, or the surface layer removing step may be carried out after the cold rolling and annealing step.

[0078] By carrying out the annealing treatment within 300 seconds, any strain caused by cold rolling can be removed while suppressing the influence on the ε-Cu phases exposed on the surface.

[0079] The conditions for the cold rolling and annealing treatment may be appropriately adjusted according to the composition of the slab, and they are not particularly limited.

[0080] The ferritic stainless steel material according to Embodiment 1 of the present invention can maintain antibacterial and antiviral properties for a long period of time, so that it can be used as an antibacterial and antiviral member. Further, the ferritic stainless steel material according to Embodiment 1 of the present invention can have a Vickers hardness of 160 Hv or less, so that it can be easily processed into a shape suitable for antibacterial and antiviral member.

(Embodiment 2)

[0081] The austenitic stainless steel material according to Embodiment 2 of the present invention has a composition containing: 0.12% or less of C, 4.00% or less of Si, 6.00% or less of Mn, 0.050% or less of P, 0.030% or less of S, 4.00 to 20.00% of Ni, 10.00 to 32.00% of Cr, and 2.00 to 6.00% of Cu, the balance being Fe and impurities.

[0082] Further, the austenitic stainless steel material according to Embodiment 2 of the present invention may further contain one or more selected from: 1.00% or less of Nb, 1.00% or less of Ti, 1.00% or less of V, 2.00% or less of W, 6.00% or less of Mo, 0.350% or less of N, 0.50% or less of Sn, 5.00% or less of Al, 0.50% or less of Zr, 0.50% or less of Co, 0.020% or less of B, 0.10% or less of Ca, and 0.20% or less of REM.

[0083] Each component will be described below in detail.

<C: 0.12% or less>

[0084] C is an austenite-forming element, and is effective for improving the strength of the austenitic stainless steel material and for uniformly dispersing and depositing the ε-Cu phases by forming Cr carbides. However, if the C content is too high, the material becomes hard to deteriorate workability, and in addition, sensitization occurs when the material undergoes thermal effects such as welding, so that the corrosion resistance of the austenitic stainless steel will be deteriorated. Therefore, the upper limit of the C content is controlled to 0.12%, and preferably 0.10%, and more preferably 0.09%, and still more preferably 0.08%. On the other hand, the lower limit of the C content is not particularly limited, but it may preferably be 0.001%, and more preferably 0.003%, and still more preferably 0.005%.

<Si: 4.00% or less>

[0085] Si is an element effective to improve the corrosion resistance and strength of the austenitic stainless steel material. However, if the content of Si is too high, the material will become hard to deteriorate the workability of the austenitic stainless steel. Also, the Si is a ferrite phase (α phase)-forming element, so that it causes destabilization of the austenite phases (γ phases) and formation of the ferrite phases. Therefore, the upper limit of the Si content is controlled to 4.00%, and preferably 3.00%, and more preferably 2.00%, and still more preferably 1.50%. On the other hand, the lower limit of the Si content is not particularly limited, but it may preferably be 0.01%, and more preferably 0.05%, and still more preferably 0.10%.

<Mn: 6.00% or less>

[0086] Mn is an austenite phase (γ phase)-forming element. Also, the M generate MnS, and the MnS acts as a nucleus for the ε-Cu phase. However, if the Mn content is too high, the corrosion resistance of the austenitic stainless steel material will decrease. Therefore, the upper limit of the Mn content is controlled to 6.00%, and preferably 4.00%, and more preferably 3.00%, and still more preferably 2.50%. On the other hand, the lower limit of the Mn content is not particularly limited, but it may preferably be 0.01%, and more preferably 0.05%, and still more preferably 0.10%.

<P: 0.050% or less>

[0087] If the P content is too high, the corrosion resistance and workability of the austenitic stainless steel material will be deteriorated. Therefore, the upper limit of the P content is controlled to 0.050%, and preferably 0.040%, and more preferably 0.035%. On the other hand, the lower limit of the P content is not particularly limited, but a decrease in the P content results in refining costs, so it is preferably 0.001%, and more preferably 0.005%, and even more preferably 0.010%.

<S: 0.030% or less>

[0088] If the S content is too high, the hot workability will be deteriorated to decrease the producibility of the austenitic stainless steel material, and the corrosion resistance is also adversely affected. Therefore, the upper limit of the S content is controlled to 0.030%, and preferably 0.020%, and more preferably 0.010%. On the other hand, the lower limit of the S content is not particularly limited, but a decrease in the S content results in refining costs, so the S content is preferably 0.0001%, and more preferably 0.0002%, and even more preferably 0.0003%.

<Ni: 4.00 to 20.00%>

[0089] As with Mn, Ni is an austenite phase (γ phase)-forming element, and improve the corrosion resistance and the workability. Since Ni is an expensive element, an excessively high content of N leads to an increase in production cost. Therefore, the upper limit of the Ni content is controlled to less than 20.00%, and preferably 15.00% or less, and more preferably 12.00% or less, and still more preferably 10.00% or less. On the other hand, if the content of N is too low, the corrosion resistance of the austenitic stainless steel material will be deteriorated. Therefore, the lower limit of the Ni content is controlled to 4.00%, and preferably 6.00%, and more preferably 8.00%, and still more preferably 8.50%.

<Cr: 10.00 to 32.00%>

[0090] Cr is an important element to maintain the corrosion resistance of the austenitic stainless steel material. However, if the Cr content is too high, the refining cost will increase, and solid-solution strengthening will harden the steel material, thereby degrading the workability of the austenitic stainless steel material. Therefore, the upper limit of the Cr content is controlled to 32.00%, and preferably 25.00%, and more preferably 22.00%, and still more preferably 20.00%. On the other hand, if the Cr content is too low, any sufficient corrosion resistance cannot be obtained. Therefore, the lower limit of the Cr content is controlled to 10.00%, and preferably 14.00%, and more preferably 15.00%, and still more preferably 18.00%.

<Cu: 2.00 to 6.00%>

[0091] Cu is an element required for depositing the ε-Cu phases that provide antibacterial and antiviral properties. The Cu is also an element that improves the workability of the austenitic stainless steel material. In order to obtain such effects, the lower limit of the Cu content is controlled to 2.00%, and preferably 2.50%, and more preferably 3.00%, and still more preferably 3.60%. On the other hand, if the Cu content is too high, the corrosion resistance of the austenitic stainless steel material will be deteriorated, and low melting point phases will also be formed during casting, resulting in poor hot workability. Therefore, the upper limit of the Cu content is controlled to 6.00%, and preferably 5.00%, and more preferably 4.80%, and still more preferably 4.50%.

<Nb: 1.00% or less, Ti: 1.00% or less, V: 1.00% or less, W: 2.00% or less>

[0092] Nb, Ti, V and W are elements that form carbides or nitrides to reduce sensitization due to grain boundary segregation of C or N and improve grain boundary corrosion resistance, and are optionally added. However, if the contents of Nb, Ti, V, and W are too high, they cause surface defects, leading to deterioration of quality and deterioration of workability of the austenitic stainless steel material. Therefore, the upper limit of each content of Nb, Ti and V is controlled to 1.00%, and preferably 0.50%. Also, the upper limit of the W content is controlled to 2.00%, and preferably 1.50%. On the other hand, the lower limit of each content of Nb, Ti, V and W is not particularly limited, but from the viewpoint of obtaining the effects of these elements, it is 0.01%, and preferably 0.02%.

<Mo: 6.00% or less>

[0093] Mo is an element that improves the corrosion resistance of the austenitic stainless steel material, and is optionally added. However, if the Mo content is too high, the production cost will increase. Therefore, the upper limit of the Mo content is controlled to 6.00%, and preferably 5.00%, and more preferably 3.00%, and still more preferably 2.00%. On the other hand, the lower limit of the Mo content is not particularly limited, but from the viewpoint of obtaining the effects of Mo, it is preferably 0.01%, and more preferably 0.03%, and still more preferably 0.10%.

<N: 0.350% or less>

[0094] As with Mo, N is an element that improves the corrosion resistance of the austenitic stainless steel material, and is optionally added. However, if the N content is too high, the material will become hard to deteriorate the workability of the ferritic stainless steel material. Therefore, the upper limit of the N content is controlled to 0.350%, and preferably 0.200%, and more preferably 0.150%, and still more preferably 0.050%. On the other hand, the lower limit of the N content is not particularly limited, but from the viewpoint of obtaining the effects of N, it is preferably 0.001%, and preferably 0.003%.

<Sn: 0.50% or less>

[0095] As with Mo and N, Sn is an element that improves the corrosion resistance of the austenitic stainless steel material, and is optionally added. However, if the Sn content is too high, it leads to deterioration of the hot rolling workability of the austenitic stainless steel material. Therefore, the upper limit of the Sn content is controlled to 0.50%, and preferably

0.30%. On the other hand, the lower limit of the Sn content is not particularly limited, but from the viewpoint of obtaining the effects of Sn, it is preferably 0.01%, and more preferably 0.02%.

<Al: 5.00% or less>

[0096] Al is an element used for deoxidation in a refining step and is optionally added. The Al is also an element that improves the corrosion resistance and oxidation resistance of the austenitic stainless steel material. However, if the Al content is too high, the amount of inclusions produced will be increased and the quality will be deteriorated. Therefore, the upper limit of the Al content is 5.00%, and preferably 3.00%, and more preferably 2.00%, and still more preferably 1.00%. On the other hand, the lower limit of the Al content is not particularly limited, but from the viewpoint of obtaining the effects of Al, it is preferably 0.01%, and more preferably 0.03%.

<Zr: 0.50% or less>

[0097] As with Al, Zr is an element that improves the oxidation resistance of the austenitic stainless steel material, and is optionally added. However, if the Zr content is too high, it will lead to an increase in the production cost. Therefore, the upper limit of the Zr content is controlled to 0.50%, and preferably 0.30%. On the other hand, the lower limit of the Zr content is not particularly limited, but from the viewpoint of obtaining the effects of Zr, it is preferably 0.01%, and more preferably 0.03%.

<Co: 0.50% or less>

[0098] As with Al and Zr, Co is an element that improves the oxidation resistance of the austenitic stainless steel material, and is optionally added. However, if the Co content is too high, it will lead to an increase in the production cost. Therefore, the upper limit of the Co content is controlled to 0.50%, and preferably 0.30%. On the other hand, the lower limit of the Co content is not particularly limited, but from the viewpoint of obtaining the effects of Co, it is preferably 0.01%, and more preferably 0.03%.

<B: 0.020% or less>

[0099] B is an element that improves the hot workability and is optionally added. However, if the content of B is too high, the corrosion resistance and weldability of the austenitic stainless steel material will be deteriorated. Therefore, the upper limit of the B content is controlled to 0.020%, and preferably 0.015%, and more preferably 0.010%, and still more preferably 0.005%. On the other hand, the lower limit of the content of B is not particularly limited, but from the viewpoint of obtaining the effects of B, it is 0.0001%, and preferably 0.0003%, and more preferably 0.0005%.

<Ca: 0.10% or less>

[0100] As with B, Ca is an element that improves the hot workability of the austenitic stainless steel material, and is optionally added. The Ca is also an element that forms sulfides to suppresses grain boundary segregation of S, thereby improving grain boundary oxidation resistance. However, if the Ca content is too high, it will lead to deterioration of workability. Therefore, the upper limit of the Ca content is controlled to 0.10%, and preferably 0.05%. On the other hand, the lower limit of the Ca content is not particularly limited, but it is preferably 0.001%, and more preferably 0.003%, from the viewpoint of obtaining the effects of Ca.

<REM: 0.20% or less>

[0101] As with B and Ca, REM (rare earth element) is at least one element that improves the hot workability of the austenitic stainless steel material, and is optionally added. The REM is also at least one element that improves the corrosion resistance by forming sulfides which are difficult to be eluted and suppressing the formation of MnS that is a starting point for corrosion. However, if the REM content is too high, it will lead to an increase in the production cost. Therefore, the upper limit of the REM content is controlled to 0.20%, and preferably 0.10%. On the other hand, the lower limit of the REM content is not particularly limited, but it is preferably 0.001%, and more preferably 0.01%, from the viewpoint of obtaining the effects of REM.

[0102] It should be noted that the REM may be used alone or as a mixture of two or more.

[0103] Next, the characteristics of the ε-Cu phases exposed on the surface of the austenitic stainless steel material according to Embodiment 2 of the present invention will be described in detail.

<Area Ratio: 0.1 to 4.0%>

[0104] The larger the area ratio of the ε-Cu phases exposed on the surface, the higher the amount of eluted Cu ions, so that the antibacterial and antiviral properties can be enhanced. The area ratio of the ε-Cu phases mainly depends on the crystal structure and the Cu content. Therefore, in view the Cu content in the austenitic stainless steel material, the upper limit of the area ratio of the ε-Cu phases is controlled to 4.0%, and preferably 3.0%, and more preferably 2.0%. On the other hand, the lower limit of the area ratio of the ε-Cu phases is controlled to 0.1%, and preferably 0.3%, and more preferably 0.6%, from the viewpoint of ensuring antibacterial and antiviral properties.

<Average Particle Size: 10 to 300 nm>

[0105] As an average particle size of the ε-Cu phases exposed on the surface is higher, the Cu ions can be eluted for a longer period of time, so that the durability of the antibacterial and antiviral properties is improved. However, an excessively high average particle size of the ε-Cu phases tends to increase an interparticle distance of the ε-Cu phases exposed on the surface. Therefore, when bacteria or viruses adhere to the distance between the particles of the ε-Cu phases exposed on the surface, sufficient antibacterial and antiviral properties may not be obtained. Therefore, the upper limit of the average particle size of the ε-Cu phases is controlled to 300 nm, and preferably 250 nm, and more preferably 200 nm, and even more preferably 150 nm. On the other hand, the lower limit of the average particle size of the ε-Cu phases is controlled to 10 nm, and preferably 20 nm, and more preferably 30 nm, from the viewpoint of ensuring the elution durability of Cu ions.

<Maximum Interparticle Distance: 100 to 1000 nm>

[0106] In general, the size of a bacterium is 0.5 to 3 μm, while the size of virus is very small, 10 to 200 nm. Therefore, if the maximum interparticle distance of the ε-Cu phases exposed on the surface is too large, sufficient antiviral properties may not be obtained particularly when viruses adhere between the particles of the ε-Cu phases exposed on the surface. Therefore, the upper limit of the maximum interparticle distance of the ε-Cu phases is controlled to 1000 nm, and preferably 800 nm, and more preferably 500 nm. On the other hand, as the maximum interparticle distance of the ε-Cu phases exposed on the surface is lower, the antibacterial and antiviral properties can be more enhanced. In the case of a relatively large ε-Cu phase having an average particle size of 10 to 300 nm, the lower limit of the maximum interparticle distance of the ε-Cu phases would be 100 nm, in view of the growth process of the ε-Cu phases due to a heat treatment. Therefore, the lower limit of the maximum interparticle distance of the ε-Cu phases is controlled to 100 nm, and preferably 150 nm, and more preferably 200 nm.

[0107] The austenitic stainless steel material according to Embodiment 2 of the present invention preferably has a Vickers hardness of 190 Hv or less, more preferably 180 Hv or less. The control to such a Vickers hardness can ensure the workability, so that it can be used for various applications.

[0108] Although the lower limit of the Vickers hardness is not particularly limited, it is generally 100 Hv.

[0109] The austenitic stainless steel material according to Embodiment 2 of the present invention preferably has an antibacterial activity value of 2.0 or more in an antibacterial test according to JIS Z2801: 2010. Such an antibacterial activity value can ensure objectively high antibacterial properties.

[0110] The austenitic stainless steel material according to Embodiment 2 of the present invention preferably has an antiviral activity value of 2.0 or more in an antiviral test according to ISO 21702: 2019. Such an antiviral activity value can ensure objectively high antiviral properties.

[0111] Although the type of the austenitic stainless steel material according to Embodiment 2 of the present invention is not particularly limited, it is preferably a hot-rolled material or a cold-rolled material.

[0112] In the case of the hot-rolled material, the thickness is generally 3 mm or more. In the case of the cold-rolled material, the thickness is generally less than 3 mm.

[0113] The austenitic stainless steel material according to Embodiment 2 of the present invention can be produced by a method including a hot rolling step, a cooling step, and a heat treatment step.

[0114] The hot-rolling step is a step of hot-rolling a slab having the above composition to obtain a hot-rolled material. More particularly, the hot-rolled material is obtained by subjecting a slab having the above composition to rough rolling, followed by finish hot rolling. The hot-rolled material may be wound into a coil.

[0115] Although the slab having the above composition is not particularly limited, for example, it can be obtained by melting stainless steel having the above composition and forging or casting it.

[0116] The finish hot rolling is carried out so that a finish hot rolling ending temperature is 850 to 1050°C. By controlling the final hot rolling temperature to such a temperature range, fine "seeds" of the ε-Cu phase can be easily deposited in a small amount and in a uniform manner from the end of the final hot rolling to the cooling step. As a result, the growth of the ε-Cu phases in the heat treatment step allows the distribution of the ε-Cu phases on the surface to be controlled as described above. On the other hand, if the finish hot rolling ending temperature is lower than 850°C, the fine "seeds" of the ε-Cu phases are not sufficiently deposited from the end of the finish hot rolling finish to the cooling step. As a result, the growth of the ε-Cu phases in the heat treatment step results in an excessively high average particle size and maximum interparticle distance of the ε-Cu phases on the surface. On the other hand, if the finish hot rolling ending temperature is more than 1050°C, the structure becomes coarse so that the workability and toughness are deteriorated. Also, multiple rolling and heat treatments are required for returning the coarsened structure to a fine structure, leading to increased production costs.

[0117] It should be noted that other conditions for the hot rolling step may be appropriately set according to the composition of the slab, and are not particularly limited.

[0118] The cooling step is a step for depositing the fine "seeds" of the ε-Cu phases, and carried out by cooling the hot-rolled material obtained in the hot rolling step from 900 to 500°C at an average cooling rate of 0.2 to 5°C/sec. By gently cooling under such conditions, the fine "seeds" of the ε-Cu phases can be deposited in a small amount and in a uniform manner in the deposition temperature range (900 to 500°C) of the ε-Cu phases. Since the fine "seeds" of the ε-Cu phases are preferentially grown in the heat treatment step, relatively large ε-Cu phases become uniformly dispersed. As a result, the distribution state of the ε-Cu phases on the surface can be controlled as described above. From the viewpoint of stably obtaining such effects, the average cooling rate is preferably 1 to 5°C/sec, and more preferably 2 to 4°C/sec. In contrast, when cooling it from 900 to 500°C at an average cooling rate of higher than 5°C/sec, the fine "seeds" of the ε-Cu phases are not sufficiently deposited. As a result, the growth of the ε-Cu phases in the heat treatment step results in an excessively high average particle size and maximum interparticle distance of the ε-Cu phases on the surface. Further, when cooling it from 900 to 500°C at an average cooling rate of less than 0.2°C/sec, the amount of the fine "seeds" of the ε-Cu phases deposited is increased. As a result, a large amount of relatively small ε-Cu phases becomes deposited in the heat treatment step.

[0119] The cooling method in the cooling step is not particularly limited, and any method known in the art can be used. For example, only by placing the hot-rolled material wound into a coil in a heat insulating box, it is possible to gently cool the material under the above cooling conditions by recuperation. Also, the cooling temperature can be finely adjusted by controlling an amount of a feed gas (for example, an Ar gas) fed into the heat insulating box.

[0120] The heat treatment step is a step of growing the fine ε-Cu phase "seeds" deposited in the cooling step, and is performed by heating the hot-rolled material cooled in the cooling step at 750 to 850°C for 4 hours or more. By performing the heat treatment under such conditions, it is possible to control the distribution state of the ε-Cu phases on the surface as described above. From the viewpoint of stably obtaining such effects, the heating time is preferably 6 to 48 hours, and more preferably 8 to 36 hours. On the other hand, when the heating temperature is less than 750°C or the heating time is less than 4 hours, the fine "seeds" of the ε-Cu phases are not sufficiently grown, so that the average particle size of the ε-Cu phases becomes too small. Moreover, when the heating temperature is more than 850°C, the ε-Cu phases will be dissolved in the matrix phase.

[0121] After the heat treatment step, it may further carry out a surface layer removing step performing washing with an acid and/or polishing, as needed. The surface layer removing step can remove scales and a Cr-poor layer formed on the surface.

[0122] The thickness of the surface layer to be removed in the surface layer removing step is not particularly limited, and it may be appropriately adjusted according to the composition of the slab. For example, when removing the Cr-poor layer, it is preferable to remove a surface layer having a thickness of 10 μm or more.

[0123] When the austenitic stainless steel material is the cold-rolled material, a cold rolling and annealing step of performing the cold rolling, followed by annealing within 300 seconds, may be further carried out after the heat treatment step. When the surface layer removing step is performed after the heat treatment step, the cold rolling and annealing step may be carried out after the surface layer removing step, or the surface layer removing step may be carried out after the cold rolling and annealing step.

[0124] By carrying out the annealing treatment within 300 seconds, any strain caused by cold rolling can be removed while suppressing the influence on the ε-Cu phases exposed on the surface.

[0125] The conditions for the cold rolling and annealing treatment may be appropriately adjusted according to the composition of the slab, and are not particularly limited.

[0126] The austenitic stainless steel material according to Embodiment 2 of the present invention can maintain antibacterial and antiviral properties for a long period of time, so that it can be used as an antibacterial and antiviral member. Further, the austenitic stainless steel material according to Embodiment 2 of the present invention can have a Vickers hardness of 190 Hv or less, so that it can be easily processed into a shape suitable for antibacterial and antiviral member.

[0127] The antibacterial and antiviral member of the present invention includes the above stainless steel material (for example, the ferritic stainless steel material according to Embodiment 1 of the present invention and/or the austenitic stainless steel material according to Embodiment 2 of the present invention). The above stainless steel material used for the antibacterial and antiviral member may be processed into various shapes by methods known in the art.

[0128] The antibacterial and antiviral member according to the present invention can further include members other than the stainless steel material described above.

[0129] Examples of the antibacterial and antiviral member includes, but not limited to, various members requiring the antibacterial properties and antiviral properties, which are used for kitchen instruments, home appliances, medical devices, interior construction materials for buildings, transportation equipment, laboratory instruments, sanitary appliances, and the like.

[Examples]

[0130] The content of the present invention will be described below in detail with reference to Examples, but the present invention is not construed as being limited thereto.

<Ferritic Stainless Steel Material>

[0131] Each of stainless steels having the ferritic compositions of steel types A to J as shown in Table 1 (the balance being Fe and impurities) were melted and forged to form a slab, which was then hot-rolled into a thickness of 3 mm to obtain a hot-rolled material by controlling the finish hot rolling ending temperature as shown in Table 2. The hot-rolled material was wound into a coil, rapidly placed in a heat insulating box, and then cooled from 900 to 500°C at the average cooling rate as shown in Table 2. The average cooling rate was adjusted by an amount of an Ar gas fed into the heat insulating box. The cooled hot-rolled material was then subjected to a heat treatment by heating it using a batch annealing furnace in an air atmosphere at 800°C for the heating time as shown in Table 2. The heat-treated hot-rolled material was then cut out into a size of 100 mm (rolling direction) × 100 mm (width direction) by a cutting process, and then washed with an acid to remove scales, and finished by polishing with a P400 buff (#400) to obtain a ferritic stainless steel material.

[Table 1]

Steel Type	Composition (% by mass)								
	C	Si	Mn	P	S	Ni	Cr	Cu	Other
A	0.01	0.15	0.12	0.028	0.005	0.04	16.11	1.40	Nb:0.30
B	0.02	0.51	0.25	0.024	0.003	0.30	16.89	1.55	--
C	0.03	0.85	0.80	0.030	0.001	0.52	17.61	1.65	Nb:0.51, Sn:0.05 B:0.003
D	0.02	0.55	0.25	0.025	0.002	0.44	16.55	1.55	Ti:0.21
E	0.02	0.56	0.30	0.025	0.002	0.22	16.80	1.55	Nb:0.46, V:0.20 Mo:1.98, Zr:0.10 REM:0.03
F	0.02	0.48	0.15	0.024	0.003	0.25	16.22	1.55	Nb:0.46, W:0.20 Al:2.11, Ca:0.02
G	0.01	0.55	0.22	0.022	0.002	0.24	16.65	1.55	Nb:0.45, N:0.022 Co:0.11
H	0.05	0.41	0.50	0.028	0.003	0.04	16.15	<u>0.01</u>	Nb:0.01, Ti:0.04 Mo:0.21, N:0.010 Al: 0.01
I	0.03	0.40	0.34	0.031	0.003	0.22	18.01	<u>0.39</u>	Nb:0.25, Ti:0.04 Mo:0.04, N:0.019 Al:0.05
J	0.02	0.55	0.35	0.010	0.001	0.04	18.15	2.55	Nb:0.45, N:0.020 Al:0.03
The underlines indicate that they are outside the scope of the present invention.									

[Table 2]

Nos.	Steel Type	Finish Hot Rolling Ending Temperature (°C)	Average Cooling Rate (°C/s)	Heating Time for Heat Treatment (Hour)	Classification
1-1	A	850	3.0	24	Example
1-2	B	850	3.0	24	Example
1-3	C	850	3.0	24	Example
1-4	D	850	3.0	24	Example
1-5	E	850	3.0	24	Example
1-6	F	850	3.0	24	Example
1-7	G	850	3.0	24	Example
1-8	A	850	0.5	24	Example
1-9	A	850	5.0	24	Example
1-10	A	850	3.0	4	Example
1-11	A	850	3.0	48	Example
1-12	B	<u>650</u>	<u>6.0</u>	24	Comp.
1-13	B	850	<u>10.0</u>	24	Comp.
1-14	B	850	<u>15.0</u>	24	Comp.
1-15	B	850	<u>0.016</u>	24	Comp.
1-16	N	850	3.0	24	Comp.
1-17	I	850	3.0	24	Comp.
1-18	J	850	3.0	24	Comp.
The underlines indicate that they are outside the scope of the present invention.					

[0132] The resulting ferritic stainless steel materials were evaluated as follows:

(Area Ratio of ε-Cu Phases Exposed on Surface)

[0133] A disc having a diameter of 3 mm was cut out from each ferritic stainless steel material, and one side was ground to a thickness of 0.5 mm, and the ground side was then electropolished to prepare a sample. TEM images were taken at 10 randomly selected portions (total field of view: 15 μm^2) on the electropolished surface of the sample, and the TEM images were then image-analyzed to measure areas of the ε-Cu phases. The area ratio of the ε-Cu phases was calculated by dividing the measured ε-Cu phase areas by the area of the field of view.

(Average Particle Size of ε-Cu Phases Exposed on Surface)

[0134] The TEM images obtained by the same method as that of the area ratio described above were image-analyzed to determine equivalent circle diameters of the ε-Cu phases (30 phases), and an average value thereof was calculated to obtain an average particle diameter of the ε-Cu phases.

(Maximum Interparticle Distance of ε-Cu Phases Exposed on Surface)

[0135] The TEM image obtained by the same method as that of the area ratio described above was image-analyzed, and a distance between the centers of gravity of the ε-Cu phases in the adjacent Voronoi regions was measured as the interparticle distance according to the method described above, and a maximum value thereof was determined to obtain the maximum interparticle distance of the ε-Cu phases.

(Antibacterial Test: Antibacterial Activity Value)

[0136] After cutting out a sample having a size of 50 mm (rolling direction) x 50 mm (width direction) from each ferritic stainless steel material, an antibacterial test was conducted in accordance with JIS Z2801: 2010 to determine an antibacterial activity value (initial). In the antibacterial test, *Staphylococcus aureus* was used as a bacterium, and a polyethylene film having a size of 40 mm × 40 mm was used as an adhesion film. Further, an amount of bacteria solution inoculated was 0.4 mL, and the entire surface of the sample was lightly wiped with a local gauze soaked with ethanol having a purity of 99% or more immediately before the start of the test, and sufficiently dried. The test was then started.

[0137] Further, in order to evaluate the durability of the antibacterial effect, the sample was immersed in 500 mL of water and maintained in a constant temperature bath at 80 °C for 16 hours, and the antibacterial test was then conducted by the same method as described above to determine an antibacterial activity value (after immersion in water).

(Antiviral Test: Antiviral Activity Value)

[0138] After cutting out a sample having a size of 50 mm (rolling direction) × 50 mm (width direction) from each ferritic stainless steel material, an antiviral test was conducted in accordance with ISO 21702: 2019 to determine an antiviral activity value (initial). In the antiviral test, influenza A virus was used as a virus, and a polyethylene film having a size of 40 mm × 40 mm was used as an adhesion film. Further, an amount of virus suspension inoculated was 0.4 mL, and the entire surface of the sample was lightly wiped with a local gauze soaked with ethanol having a purity of 99% or more immediately before the start of the test, and sufficiently dried. The test was then started.

[0139] Further, in order to evaluate the durability of the antiviral effect, the sample was immersed in 500 mL of water and maintained in a constant temperature bath at 80 °C for 16 hours, and the antiviral test was then conducted by the same method as described above to determine an antiviral activity value (after immersion in water).

(Vickers Hardness)

[0140] The Vickers hardness was measured according to JIS Z2244: 2009. For the measurement, a Vickers hardness tester HV-100 manufactured by Mitutoyo Corporation was used, the measurement load was 10 kg, the surface Vickers hardness was measured at 10 randomly selected portions, and an average value thereof was determined to be the result.

[0141] The above evaluation results are shown in Table 3.

[Table 3]

Nos.	Steel Type	ε-Cu Phase			Antibacterial Activity Value		Antiviral Activity Value		Vickers Hardness (Hv)	Classification
		Area Ratio (%)	Average Particle Size (nm)	Maximum Interparticle Distance (nm)	Initial	After Immersion in Water	Initial	After Immersion in Water		
1-1	A	0.9	90	280	2.3	2.1	2.7	2.1	150	Example
1-2	B	1.0	120	265	2.3	2.1	2.8	2.2	153	Example
1-3	C	1.1	152	257	2.5	2.3	2.9	2.3	155	Example
1-4	D	1.0	110	270	2.3	2.1	2.8	2.2	151	Example
1-5	E	1.0	102	298	2.3	2.1	2.8	2.2	155	Example
1-6	F	1.0	111	280	2.3	2.1	2.8	2.2	152	Example
1-7	G	1.0	115	257	2.3	2.3	2.9	2.3	155	Example
1-8	A	1.1	120	230	2.3	2.2	2.9	2.3	150	Example
1-9	A	0.9	100	250	2.3	2.1	2.8	2.1	151	Example
1-10	A	0.9	80	277	2.3	2.1	2.8	2.1	155	Example
1-11	A	1.1	150	300	2.3	2.2	2.9	2.3	150	Example
1-12	B	0.5	250	1020	2.2	2.0	1.3	0.8	152	Comp.
1-13	B	0.3	330	1050	2.1	2.0	1.1	0.4	155	Comp.
1-14	B	1.5	550	483	2.5	2.3	1.7	1.0	151	Comp.
1-15	B	1.0	42	95	2.3	1.1	2.8	1.1	173	Comp.
1-15	H	0.0	0	0	0.0	0.0	0.0	0.0	158	Comp.
1-17	I	0.2	7	520	1.3	0.0	1.1	0.0	163	Comp.
1-18	J	(Note 1)								Comp.

* The underlines indicate that they are outside the scope of the present invention.
* Note 1 indicates that the measurement was not performed because cracks occurred during hot rolling and the ferritic stainless steel material could not be produced.

[0142] As shown in Table 3, each of the ferritic stainless steel materials Nos. 1-1 to 1-11 (Examples of the present invention) had the predetermined composition and distribution state of the ε-Cu phases on the surface, so that all the results of the antibacterial activity value (initial and after immersion in water), the antiviral activity value (initial and after immersion in water) and Vickers hardness were good.

[0143] However, the ferritic stainless steel material No. 1-12 (Comparative Example) had the excessively high maximum interparticle distance of the ε-Cu phases, because the finish hot rolling ending temperature was too low and the average cooling rate was too high. As a result, the antiviral properties (the antiviral activity value of 2.0 or more) were not obtained.

[0144] Each of the ferritic stainless steel materials Nos. 1-13 and 1-14 (Comparative Examples) had the higher average particle size of the ε-Cu phases and the higher maximum interparticle distance, because the average cooling rate was too high. As a result, the antiviral properties (the antiviral activity value of 2.0 or more) were not obtained.

[0145] The ferritic stainless steel material No. 1-15 (Comparative Example) had the lower maximum interparticle distance of the ε-Cu phases, because the average cooling rate was too low. As a result, the antibacterial activity value and the antiviral activity value after immersion in water were lower, and the effect of maintaining the antibacterial and antiviral properties was not sufficient.

[0146] Each of the ferritic stainless steel materials Nos. 1-16 and 1-17 (Comparative Examples) did not have the predetermined composition, so that the distribution state of the ε-Cu phases on the surface could not be appropriately controlled. As a result, the antibacterial properties (the antibacterial activity value of 2.0 or more) and the antiviral properties (the antiviral activity value of 2.0 or more) were not obtained.

[0147] No. 1-18 (Comparative Example) generated cracks during the hot rolling, and a ferritic stainless steel material could not be produced.

<Austenitic Stainless Steel Material>

[0148] Each of stainless steels having the austenitic compositions of steel types a to j as shown in Table 4 (the balance being Fe and impurities) were melted and forged to form a slab, which was then hot-rolled into a thickness of 3 mm to obtain a hot-rolled material by controlling the finish hot rolling ending temperature as shown in Table 5. The hot-rolled material was wound into a coil, rapidly placed in a heat insulating box, and then cooled from 900 to 500°C at the average cooling rate as shown in Table 5. The average cooling rate was adjusted by an amount of an Ar gas fed into the heat insulating box. The cooled hot-rolled material was then subjected to a heat treatment by heating it using a batch annealing furnace in an air atmosphere at 800°C for the heating time as shown in Table 5. The heat-treated hot-rolled material was then cut out into a size of 100 mm (rolling direction) × 100 mm (width direction) by a cutting process, and then washed with an acid to remove scales, and finished by polishing with a P400 buff (#400) to obtain an austenitic stainless steel material.

[Table 4]

Steel Type	Composition (% by mass)								
	C	Si	Mn	P	S	Ni	Cr	Cu	Other
a	0.01	0.25	1.20	0.028	0.001	8.50	18.01	3.61	--
b	0.04	0.55	1.77	0.024	0.002	9.39	18.31	3.77	--
c	0.08	0.85	2.50	0.030	0.005	9.91	19.73	4.45	--
d	0.03	0.51	1.80	0.025	0.002	9.41	18.27	3.81	Nb:0.20, B:0.005
e	0.06	0.31	1.99	0.026	0.002	9.68	18.20	3.90	Ti:0.15, Mo:2.00 Co:0.12
f	0.03	0.70	1.00	0.025	0.002	9.00	18.05	3.65	V:0.04, N:0.051 Zr:0.10, Ca:0.02
g	0.05	0.55	1.75	0.025	0.002	9.11	18.21	3.75	W:0.05, Sn:0.05 Al:0.09, REM:0.01
h	0.05	0.41	0.65	0.028	0.003	8.00	18.01	0.19	Mo:0.04, N:0.210 Al:0.01
i	0.02	0.51	0.34	0.031	0.003	7.50	17.88	1.91	Mo:0.04, N:0.039 Al:0.03, B:0.002
j	0.02	0.25	1.20	0.020	0.001	9.50	18.51	7.55	N:0.022, B:0.002

(continued)

Steel Type	Composition (% by mass)								
	C	Si	Mn	P	S	Ni	Cr	Cu	Other
The underlines indicate that they are outside the scope of the present invention.									

[Table 5]

Nos.	Steel Type	Finish Hot Rolling Ending Temperature (°C)	Average Cooling Rate (°C/s)	Heating Time for Heat Treatment (Hour)	Classification
2-1	a	950	3.0	24	Example
2-2	b	950	3.0	24	Example
2-3	c	950	3.0	24	Example
2-4	d	950	3.0	24	Example
2-5	e	950	3.0	24	Example
2-6	f	950	3.0	24	Example
2-7	g	950	3.0	24	Example
2-8	a	950	0.5	24	Example
2-9	a	950	5.0	24	Example
2-10	a	950	3.0	4	Example
2-11	a	950	3.0	48	Example
2-12	b	<u>800</u>	<u>6.0</u>	24	Comp.
2-13	b	900	<u>10.0</u>	24	Comp.
2-14	b	950	<u>15.0</u>	24	Comp.
2-15	b	950	<u>0.016</u>	24	Comp.
2-16	<u>h</u>	950	3.0	24	Comp.
2-17	<u>i</u>	950	3.0	24	Comp.
2-18	<u>j</u>	950	3.0	24	Comp.
The underlines indicate that they are outside the scope of the present invention.					

[0149] The resulting austenitic stainless steel materials were evaluated by the same method as that of the above ferritic stainless steel materials. The evaluation results are shown in Table 6.

[Table 6]

Nos.	Steel Type	ε-Cu Phase			Antibacterial Activity Value		Antiviral Activity Value		Vickers Hardness (Hv)	Classification
		Area Ratio (%)	Average Particle Size (nm)	Maximum Interparticie Distance (nm)	Initial	After Immersion in Water	Initial	After Immersion in Water		
2-1	a	1.3	45	230	2.5	2.3	2.7	2.3	171	Example
2-2	b	1.5	49	238	2.6	2.4	2.8	2.4	176	Example
2-3	c	1.8	75	223	2.7	2.6	2.9	2.5	180	Example
2-4	d	1.5	48	218	2.7	2.3	2.9	2.5	175	Example
2-5	e	1.5	49	245	2.7	2.3	2.9	2.5	180	Example
2-6	f	1.5	47	250	2.7	2.3	2.9	2.5	185	Example
2-7	g	1.5	49	245	2.7	2.3	2.9	2.5	155	Example
2-8	a	1.4	51	200	2.7	2.3	2.9	2.3	170	Example
29	a	1.2	47	210	2.6	2.3	2.8	2.2	175	Example
2-10	a	1.2	40	230	2.6	2.3	2.8	2.2	178	Example
2-11	a	1.4	90	250	2.7	2.3	2.9	2.3	168	Example
2-12	b	0.8	$\underline{310}$	940	2.2	2.0	1.4	0.9	154	Comp.
2-13	b	0.4	150	$\underline{1050}$	2.1	2.0	1.1	0.4	155	Comp.
2-14	b	1.4	138	$\underline{1005}$	2.5	2.3	1.7	1.1	190	Comp.
2-15	b	1.8	2	$\underline{45}$	2.7	1.2	2.9	1.5	210	Comp.
2-16	$\underline{h}$	$\underline{0.0}$	0	0	0.0	0.0	0.0	0.0	181	Comp.
2-17	$\underline{i}$	0.2	$\underline{6}$	580	1.5	0.0	1.2	0.0	168	Comp.
2-18	$\underline{j}$	(Note 1)								Comp.

· The underlines indicate that they are outside the scope of the present invention.
· Note 1 indicates that the measurement was not performed because cracks occurred during hot rolling and the austenitic stainless steel material could not be produced.

[0150] As shown in Table 6, each of the austenitic stainless steel materials Nos. 2-1 to 2-11 (Examples of the present invention) had the predetermined composition and distribution state of the ε-Cu phases on the surface, so that all the results of the antibacterial activity value (initial and after immersion in water), the antiviral activity value (initial and after immersion in water) and Vickers hardness were good.

[0151] However, the austenitic stainless steel material No. 2-12 (Comparative Example) had the excessively high average particle size of the ε-Cu phases, because the finish hot rolling ending temperature was too low and the average cooling rate was too high. As a result, the antiviral properties (the antiviral activity value of 2.0 or more) were not obtained.

[0152] Each of the austenitic stainless steel materials Nos. 2-13 and 2-14 (Comparative Examples) had the higher maximum interparticle distance, because the average cooling rate was too high. As a result, the antiviral properties (the antiviral activity value of 2.0 or more) were not obtained.

[0153] The austenitic stainless steel material No. 2-15 (Comparative Example) had the lower average particle size of the ε-Cu phases, because the average cooling rate was too low. As a result, the antibacterial activity value and the antiviral activity value after immersion in water were lower, and the effect of maintaining the antibacterial and antiviral properties was not sufficient.

[0154] Each of the austenitic stainless steel materials Nos. 2-16 and 2-17 (Comparative Examples) did not have the predetermined composition, so that the distribution state of the ε-Cu phases on the surface could not be appropriately controlled. As a result, the antibacterial properties (the antibacterial activity value of 2.0 or more) and the antiviral properties (the antiviral activity value of 2.0 or more) were not obtained.

[0155] No. 2-18 (Comparative Example) did not have the predetermined composition, so that cracks were generated during the hot rolling, and an austenitic stainless steel material could not be produced.

[0156] As can be seen from the above results, according to the present invention, it is possible to provide a stainless steel material, a method for producing the same, and an antibacterial and antiviral member, which can maintain antibacterial and antiviral properties for a long period of time.

[Description of Reference Numerals]

[0157]

10 stainless steel material
11 ε-Cu phase
12 passive film

Claims

1. A stainless steel material having ε-Cu phases exposed on a surface of the stainless steel material, wherein the ε-Cu phases on the surface have an area ratio of 0.1 to 4.0%, an average particle size of 10 to 300 nm, and a maximum interparticle distance of 100 to 1000 nm.

2. The stainless steel material according to claim 1, wherein the stainless steel material has a composition comprising: on a mass basis, 0.12% or less of C, 4.00% or less of Si, 6.00% or less of Mn, 0.050% or less of P, 0.030% or less of S, 20.00% or less of Ni, 10.00 to 32.00% of Cr, and 0.40 to 6.00% of Cu, the balance being Fe and impurities.

3. The stainless steel material according to 2, wherein the stainless steel material is a ferritic stainless steel material having a C content of 0.10% or less, a Mn content of 2.00% or less, a Ni content of 4.00% or less, and a Cu content of 0.40 to 4.00%.

4. The stainless steel material according to claim 3, further comprising one or more selected from: on a mass basis, 1.00% or less of Nb, 0.60% or less of Ti, 1.00% or less of V, 2.00% or less of W, 3.00% or less of Mo, 0.050% or less of N, 0.50% or less of Sn, 5.00% or less of Al, 0.50% or less of Zr, 0.50% or less of Co, 0.010% or less of B, 0.10% or less of Ca, and 0.20% or less of REM.

5. The stainless steel material according to claim 3 or 4, wherein the stainless steel material has a Vickers hardness of 160 Hv or less.

6. The stainless steel material according to claim 2, wherein the stainless steel material is an austenitic stainless steel having a Ni content of 4.00 to 20.00% and a Cu content of 2.00 to 6.00%.

7. The stainless steel material according to claim 6, further comprising one or more selected from: on a mass basis, 1.00% or less of Nb, 1.00% or less of Ti, 1.00% or less of V, 2.00% or less of W, 6.00% or less of Mo, 0.350% or less of N, 0.50% or less of Sn, 5.00% or less of Al, 0.50% or less of Zr, 0.50% or less of Co, 0.020% or less of B, 0.10% or less of Ca, and 0.20% or less of REM.

8. The stainless steel material according to claim 6 or 7, wherein the stainless steel material has a Vickers hardness of 190 Hv or less.

9. The stainless steel material according to any one of claims 1 to 8, wherein the stainless steel material has an antibacterial activity value of 2.0 or more in an antibacterial test according to JIS Z2801: 2010.

10. The stainless steel material according to any one of claims 1 to 9, wherein the stainless steel material has an antiviral activity value of 2.0 or more in an antiviral test according to ISO 21702: 2019.

11. A method for producing a stainless steel material, comprising:

a hot rolling step of hot-rolling a slab having a ferritic composition comprising: on a mass basis, 0.10% or less of C, 4.00% or less of Si, 2.00% or less of Mn, 0.050% or less of P, 0.030% or less of S, 4.00% or less of Ni, 10.00 to 32.00% of Cr, and 0.40 to 4.00% of Cu, the balance being Fe and impurities, or a slab having an austenitic composition comprising: on a mass basis, 0.12% or less of C, 4.00% or less of Si, 6.00% or less of Mn, 0.050% or less of P, 0.030% or less of S, 4.00 to 20. 00% of Ni, 10.00 to 32.00% of Cr, and 2.00 to 6.00% of Cu, the balance being Fe and impurities, to obtain a hot-rolled material, wherein a finish hot rolling ending temperature is 700 to 900°C when the slab has the ferritic composition, or a finish hot rolling ending temperature is 850 to 1050°C when the slab has the austenitic composition;
a cooling step of cooling the hot-rolled material obtained in the hot rolling step from 900 to 500°C at an average cooling rate of 0.2 to 5°C/sec; and
a heat treatment step of heating the hot-rolled material cooled in the cooling step at 750 to 850°C for 4 hours or more.

12. The method for producing the stainless steel material according to claim 11,

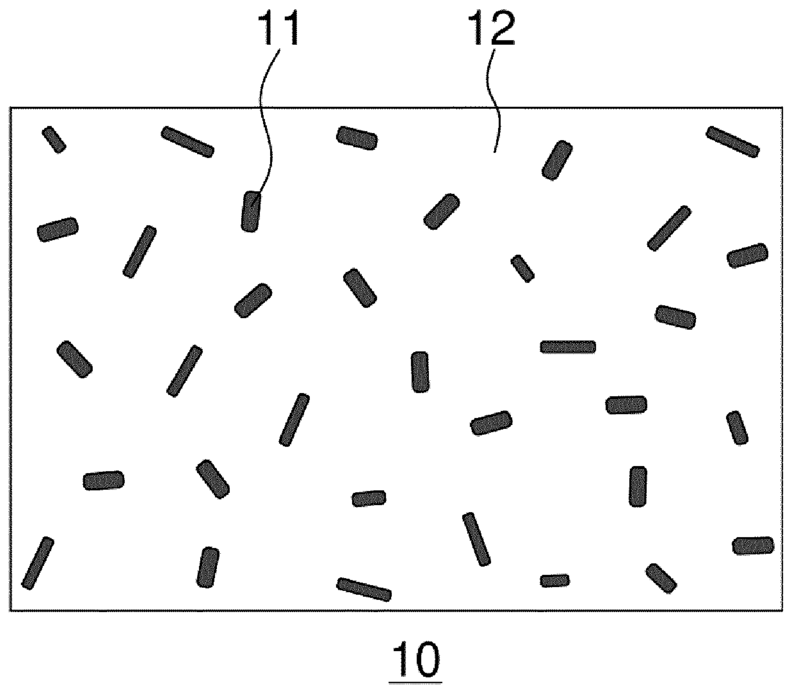
wherein the slab having the ferritic composition further comprises, on a mass basis, 1.00% or less of Nb, 0.60% or less of Ti, 1.00% or less of V, 2.00% or less of W, 3.00% or less of Mo, 0.050% or less of N, 0.50% or less of Sn, 5.00% or less of Al, 0.50% or less of Zr, 0.50% or less of Co, 0.010 % or less of B, 0.10% or less of Ca, and 0.20% or less of REM,
wherein the slab having the austenitic composition further comprises, on a mass basis, 1.00% or less of Nb, 1.00% or less of Ti, 1.00% or less of V, 2.00% or less of W, 6.00% or less of Mo, 0.350% or less of N, 0.50% or less of Sn, 5.00% or less of Al, 0.50% or less of Zr, 0.50% or less of Co, 0.020 % or less of B, 0.10% or less of Ca, and 0.20% or less of REM.

13. The method for producing the stainless steel material according to claim 11 or 12, further comprising a surface layer removal step of performing washing with an acid and/or polishing after the heat treatment step.

14. The method for producing the stainless steel material according to any one of claims 11 to 13, further comprising a cold rolling and annealing step of performing a cold rolling, followed by an annealing treatment within 300 seconds.

15. An antibacterial and antiviral member comprising the stainless steel material according to any one of claims 1 to 10.

[Fig. 1]



INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2022/011738

A. CLASSIFICATION OF SUBJECT MATTER

C21D 9/46(2006.01)i; ***C22C 38/00***(2006.01)i; ***C22C 38/58***(2006.01)i
FI: C22C38/00 302Z; C22C38/58; C21D9/46 R; C21D9/46 Q

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)

C21D9/46; C22C38/00; C22C38/58

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

Published examined utility model applications of Japan 1922-1996
Published unexamined utility model applications of Japan 1971-2022
Registered utility model specifications of Japan 1996-2022
Published registered utility model applications of Japan 1994-2022

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	鈴木 聡ほか, Cu含有ステンレス鋼の抗菌性, 鉄と鋼, 2014, vol. 100, no. 8, pp. 97-104 entire text, (SUZUKI, Satoshi et al. Antimicrobiability of Cu Contained Stainless Steels. Tetsu-to-Hagane.)	1-15
A	JP 2017-206725 A (JFE STEEL CORP) 24 November 2017 (2017-11-24) entire text, all drawings	1-15
A	CN 102876990 A (ZHANG, Lei) 16 January 2013 (2013-01-16) entire text	1-15
A	JP 2012-162760 A (NIPPON STEEL & SUMIKIN STAINLESS STEEL CORP) 30 August 2012 (2012-08-30) entire text	1-15

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

* Special categories of cited documents:
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Date of the actual completion of the international search	Date of mailing of the international search report
17 May 2022	**31 May 2022**
Name and mailing address of the ISA/JP **Japan Patent Office (ISA/JP)** **3-4-3 Kasumigaseki, Chiyoda-ku, Tokyo 100-8915** **Japan**	Authorized officer Telephone No.

Form PCT/ISA/210 (second sheet) (January 2015)

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/JP2022/011738

Patent document cited in search report			Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
JP	2017-206725	A	24 November 2017	(Family: none)	
CN	102876990	A	16 January 2013	(Family: none)	
JP	2012-162760	A	30 August 2012	(Family: none)	

Form PCT/ISA/210 (patent family annex) (January 2015)

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP H09170053 A **[0006]**
- JP H09176800 A **[0006]**