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(54) **ANTIBACTERIAL AND ANTIVIRAL COPPER-CONTAINING STAINLESS STEEL, AND PREPARATION METHOD THEREFOR AND USE THEREOF**

(57) The present invention provides an antibacterial and antiviral copper-bearing stainless steel and a preparation method and application of the stainless steel having the same composition. The copper-bearing stainless steel comprises a stainless steel matrix and a copper-rich phase uniformly distributed in the stainless steel matrix, wherein the copper content of the copper-bearing stainless steel is 6-30 wt%. The preparation method for the copper-bearing stainless steel includes production of a small stainless steel product mainly based on powder metallurgy technology, and production of a large stainless steel sheet, bar or tube mainly based on combined processes without a substantial thermal deformation. Compared with traditional antibacterial stainless steel, the present invention has a designed composition containing a sufficient amount of copper-rich precipitated phase, which can achieve not only a good killing effect on bacteria, but also a virus-killing ability comparable to that of pure copper, and can be used for the preparation of a knife, elevator button, railing, handrail, door handle,

cup and etc., as a whole or a component thereof, which can effectively kill bacteria and viruses present on their surfaces.

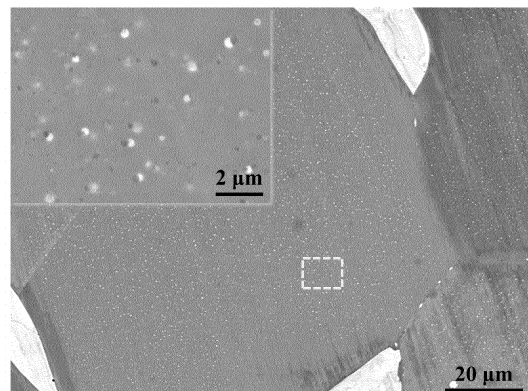


Fig. 2

Description

Technical field

[0001] The present invention belongs to the field of material technology and relates to a high-copper content stainless steel, in particular to a high-performance antibacterial and antiviral copper-bearing stainless steel and its preparation method and application.

Background Art

[0002] Pathogenic bacteria and viruses present in the living environment and in the field of public safety and health have always been a major hidden threat to public safety and health. Millions of people around the world die from bacterial infections every year. Seasonal influenza and periodic outbreaks of various influenza viruses over a long period of time have an inestimable impact on the safety of people's lives and society. Indirect or direct contact with surfaces of bacteria- or viruses-bearing objects is one of the most important ways for pathogenic bacteria and viruses to infect humans, and it is also the main way for various harmful bacteria to infect humans. However, stainless steel, as one of the most widely used materials in daily life utensils, public health facilities, food industry and other key sectors, etc, does not have any antibacterial or antiviral capability itself. For example, the studies have confirmed that the novel coronavirus 2019-nCov, which emerged in 2019, has been shown to be able to survive for several days on ordinary stainless steel surfaces; common pathogenic *E. coli* has also been shown to be able to survive for a long time on stainless steel surfaces. The resulting increased risk of bacterial and viral transmission not only has a huge impact on public health and safety, but also imposes an enormous medical and economic burden on society. There is therefore a growing need to develop stainless steel equipment with excellent antibacterial and antiviral properties.

[0003] Metallic elements such as silver, copper and zinc have natural antibacterial properties. This type of inorganic antibacterial agent has unparalleled advantages such as wide temperature range, broad antibacterial spectrum, low cytotoxicity and no drug resistance. In particular, both silver and copper are widely used in the development of antibacterial stainless steels due to their properties such as high antibacterial ability and low cytotoxicity.

[0004] To achieve permanent antibacterial properties in stainless steel, copper- and silver-bearing antibacterial stainless steels are currently produced mainly by adding copper and silver by integral melting during the casting process. Copper is a common trace element added to steel materials. When the amount of copper added is relatively small, its role is similar to that of nickel in improving the corrosion resistance of the material. For example, the corrosion resistance of rail steel containing 0.2-0.5 wt% copper is generally better than that of ordi-

nary carbon steel. When the copper content exceeds 0.75 wt%, the strength of the material can be improved through solid solution and ageing treatments. When the copper content is further increased, it can be used to prepare a range of copper-bearing antibacterial stainless steels. For example, in the traditional casting process, the cast copper-bearing stainless steels such as austenitic copper-bearing stainless steel with about 2-5.5 wt% of copper added and martensitic stainless steel with 3-4 wt% of copper added, generally have an antibacterial rate against *E. coli* of up to over 98% after heat treatment. Silver is believed to have a stronger antibacterial ability and a broader antibacterial spectrum than that of copper. Research has shown that when silver is added uniformly to stainless steel, the antibacterial rate of silver-bearing stainless steel against *E. coli* can reach over 98% with only about 0.3 wt% of silver added.

[0005] However, it is worth noting that the existing research only focuses on antibacterial stainless steel, and there is still a gap in the research and development of antiviral stainless steel. Research has confirmed that both silver and copper elements have THE ability to kill viruses. For example, silver-bearing composite porous ceramics can kill viruses on their surfaces, and metallic copper surfaces can kill influenza A (H1N1) viruses on them. However, there are no reports that existing silver-bearing stainless steel and copper-bearing stainless steel have excellent antiviral properties. The development of antiviral stainless steel requires new ingredient selection and design as well as process improvement. However, there is still a lack of relevant research and patents.

[0006] In addition, existing copper-bearing antibacterial stainless steels are prepared using traditional casting and thermal processing processes. However, copper is an element that typically causes thermal defects in steel materials. Since the oxidation potential of copper is smaller than that of iron, when the copper content is higher than about 0.2 wt%, and the steel is thermal-processed, the iron element is selectively oxidized at high temperature in preference to copper, resulting in copper-rich phases found on the surface of the material due to an increase in the relative copper content. The melting point and strength of pure copper or copper-rich phases are much lower than those of steel. At high temperatures, these copper-rich phases will diffuse along the grain boundaries of the steel. This penetration and diffusion along the grain boundaries will seriously weaken the force between the steel grains, causing the steel to be scrapped due to cracks or fissures that occur during hot forging or hot rolling. In addition, existing copper-bearing antibacterial stainless steel is prepared using traditional casting and thermal processing processes. However, copper is an element that typically causes thermal defects in steel materials. Since the oxidation potential of copper is smaller than that of iron, when the copper content is higher than about 0.2 wt%, and the steel is thermal-processed, the iron element will be selectively oxidized

in preference to copper at a high temperature, resulting in copper-rich phases found on the surface of the material due to an increase in the relative content of copper. The melting point and strength of pure copper or copper-rich phases are much lower than those of steel. At a high temperature, these copper-rich phases will diffuse along the grain boundaries of the steel. This penetration and diffusion along the grain boundaries will seriously weaken the force between the steel grains, causing the steel to be scrapped due to cracks or fissures occurring during hot forging or hot rolling.. This problem is greatly exacerbated when the copper content is further increased, making the manufacture and practical use of high copper content stainless steel difficult.

Summary of the Invention

[0007] It is an object of the present invention to provide a stainless steel possessing antibacterial and antiviral abilities and a preparation method and application of a copper-bearing stainless steel having the composition of the stainless steel of the present invention. This stainless steel may optionally contain one or more elements possessing antibacterial or antiviral effects such as silver and zinc. In particular, unlike conventional traditional antibacterial stainless steels, the new antibacterial and antiviral stainless steel of the present invention contains a high content of copper element therein.

[0008] The present inventors have firstly found that silver, as a very effective alloying element added in existing antibacterial stainless steel, cannot endow stainless steel with an antiviral effect. Secondly, the present inventors have found that existing cast copper-bearing antibacterial stainless steel has no an antiviral effect. Only when the copper content reaches a certain critical value, the stainless steel will produce a significant antiviral effect. Finally, existing patents and researches on copper-bearing antibacterial stainless steel all adopt traditional casting techniques to prepare stainless steel, which will encounter insurmountable problem of copper brittleness when used for preparing copper-bearing stainless steel with a high copper content and cannot prepare such a copper-bearing stainless steel successfully.

[0009] Although copper brittleness can be alleviated through some technical means, the higher the copper content, the greater the incompatibility of the thermal processing defects caused by copper brittleness. Existing cast copper-bearing antibacterial stainless steels have a maximum copper content of about 5 wt%, which is basically the upper limit. In actual production, the copper content is preferably 1-3.5 wt%, generally depending on the type of steel. However, the present inventors have found for the first time that stainless steel containing 5 wt% copper has no antiviral effect. It is only when the copper content reaches a critical value of about 10 wt% that the copper-bearing stainless steel exhibits antiviral properties, and it is almost impossible to successfully prepare a copper-bearing stainless steel with such a high

copper content using traditional casting-hot forging and hot rolling technologies.

[0010] The present invention creatively utilizes the advantages of ease of composition regulation, near net-shaping and no need for subsequent deformation processing of powder metallurgy technology, and prepares a series of stainless steels with different copper and silver contents. Combined with the relevant antiviral experiments, the present invention has successfully developed a high-performance antibacterial and antiviral copper-containing stainless steel. As demonstrated by the experiments of the present invention, none of the surfaces of pure silver, existing silver-bearing antibacterial stainless steel and traditional cast copper-bearing antibacterial stainless steel blocks exhibits obvious antiviral properties. However, when the amount of copper added is greater than a certain critical value, the stainless steel surface exhibits significant antiviral properties. This compositional design is necessary to ensure antiviral properties and also one of the innovations of the present invention. The copper-bearing stainless steel with this composition can effectively kill bacteria and viruses, in particular the 2019-nCov virus, on its surface for a long period of time. The copper-bearing stainless steel is only required to have the composition of the present invention, and any minor modifications based on this invention should fall within the scope of protection of the present invention. In addition, the copper-bearing stainless steel in the present invention contains a relatively high copper content. Due to the problem of copper brittleness caused by a high copper content, the copper-bearing stainless steel products having the composition of the present invention cannot be prepared by conventional casting and thermal deformation processes. Therefore, the present invention also provides a preparation method of the copper-bearing stainless steel products having this composition.

[0011] On the one hand, the present invention provides an antibacterial and antiviral copper-bearing stainless steel, the copper-bearing stainless steel comprising a stainless steel matrix and a copper-rich phase uniformly distributed in the stainless steel matrix, wherein the copper content of the copper-bearing stainless steel is 6-30 wt%.

[0012] The antibacterial and antiviral copper-bearing stainless steel provided according to the present invention has the following composition in mass percentages: Cu: 6-30 wt%; Ag: 0-1 wt%; Zn: 0-1.5 wt%; Cr: 11-30 wt%; Mn: 0-20 wt%; Ni: 0-18 wt%; Co: 0-8 wt%; Al: 0-5 wt%; Ti: 0-5 wt%; Mo: 0-4 wt%; V: 0-3 wt%; C $\leq$ 1 wt%, with the remainder being iron and unavoidable impurities.

[0013] The antibacterial and antiviral copper-bearing stainless steel provided according to the present invention may further contain one or more common trace alloying elements selected from such as Nb, Si, Zr, N and B, wherein Si $\leq$ 2 wt%, and the total content of other alloying elements is $\leq$ 3 wt%.

[0014] Preferably, in some embodiments of the

present invention, the copper content of the copper-bearing stainless steel is 8-20 wt%, more preferably 10-15 wt%.

[0015] The above composition of stainless steel components of the present invention are selected typically in consideration of economic applicability and antibacterial and antiviral properties, wherein Cr, Ni, Mo, Mn, Al, V, etc. are typical components of traditional stainless steel, which are mainly used to ensure that stainless steel-related corrosion resistance and mechanical, processing and other properties can meet the corresponding requirements. Although the antibacterial and antiviral copper-bearing stainless steel of the present invention may further contain antibacterial metal elements such as Ag, Zn, etc., it is critical to control the copper content to a certain level (for example, 10-30 wt%), so as to make it have an antiviral ability comparable to that of pure copper.

[0016] Products containing the antibacterial and antiviral copper-bearing stainless steel provided by the present invention are mainly classified into small, complex-shaped stainless steel products, such as door handles, elevator buttons, etc., and large simple-shaped stainless steel products, such as stainless steel sheets, bars and tubes, etc. Among them, the "small stainless steel products" are intended to refer to the products falling within the size range that can be produced by existing or future powder metallurgy technologies, which is not a definite numerical range, but will change with the development of powder metallurgy technology. For example, taking stainless steel as an example, the stainless steel products produced by current metal powder injection molding technology generally have a weight of less than or equal to 500 g; and the large stainless steel products are intended to refer to products such as stainless steel sheets, bars and tubes, etc. in a simple shape produced by combined processes, which densify stainless steel products without relying on a significant thermal deformation. For example, stainless steel sheets with a thickness of about 0.2 to 4 mm can be continuously obtained through a method involving powder rolling, sintering and cold rolling densification of the present invention.

[0017] On the other hand, the present invention also provides a typical preparation method (the first preparation method) of small copper-bearing stainless steel products that have the above composition. Specifically, the present invention provides a preparation method of an antibacterial and antiviral copper-bearing stainless steel product, the preparation method including: formulating raw material powders according to the composition of the antibacterial and antiviral copper-bearing stainless steel; and sintering the raw material powders by using a powder metallurgy method to obtain the stainless steel product directly.

[0018] On the one hand, since powder metallurgy technology can produce small-sized stainless steel parts of various shapes without using processes such as hot forging and hot rolling, the resulting stainless steel products can achieve a very high copper content without worrying

about copper brittleness problem; and on the other hand, since traditional powder metallurgy technology cannot be used to prepare larger stainless steel products, such as stainless steel sheets, bars, etc., which are widely used in life, the present invention uses traditional powder metallurgy technology to prepare small stainless steel products, such as door handles, elevator buttons, etc.. However, the above method for preparing small stainless steel products should not be limited to the maximum product size that can be achieved by existing powder metallurgy technology. With the further development of powder metallurgy technology, it is expected that the powder metallurgy technology can be used to prepare stainless steel products having the composition of the antibacterial and antiviral copper-bearing stainless steel of the present invention and a size larger than that of the "small stainless steel products" defined above, and such products still fall within the spirit of the present invention.

[0019] According to the method for preparing a small stainless steel product provided by the present invention, the particle size of the raw material powder is only required to meet the usage requirements of the corresponding powder metallurgy process.

[0020] According to the method for preparing a small stainless steel product provided by the present invention, formulating the raw material powders may be carried out by a variety of ways, e.g., by using pre-alloyed copper-bearing metal powder directly formulated according to the composition, or using element powders to formulate the corresponding stainless steel ingredients, or using master alloy powder plus iron powder, as long as the composition fall within the scope of the present invention.

[0021] According to the method for preparing a small stainless steel product provided by the present invention, the powder metallurgy method can be operated in a variety of ways, e.g., using any powder metallurgy processes without severe thermal deformation such as powder injection molding technology, traditional metal powder pressing and sintering technology, powder hot pressing and sintering technology, etc.

[0022] Taking powder injection molding technology as an example, the preparation method may include the following steps:

- (1) weighing raw material powders in proportion according to the composition of the copper-bearing stainless steel, and mixing them evenly;
- (2) mixing the fully mixed powder from step (1) with a binder evenly and then granulating to obtain a feed;
- (3) injection molding the feed obtained in step (2) in a mold to obtain a green body;
- (4) degreasing and sintering the green body obtained in step (3) to obtain a copper-bearing stainless steel product; and
- (5) subjecting the copper-bearing stainless steel product obtained in step (4) to solid solution and aging treatments to obtain the antibacterial and antiviral copper-bearing stainless steel.

[0023] In the preparation method, the binder is only required to meet the requirements of metal injection molding process. For example, it may be either a wax-based binder or a polymer-based binder. Specifically, the binder may be one or more selected from the group consisting of polyformaldehyde, polyethylene, paraffin, etc. Typically, based on the volume of the raw material powders, the amount of the binder may be 25% to 65% (volume percentage).

[0024] In some preferred embodiments, the temperature for the injection molding in step (3) may be 80-220°C.

[0025] In some preferred embodiments, the temperature for the sintering in step (4) may be 1200-1350°C.

[0026] In some preferred embodiments, the conditions for the solid solution treatment in step (3) may include: the temperature is 1000-1300°C and the time is 10-300 minutes.

[0027] In some preferred embodiments, the conditions for the aging treatment in step (3) may include: the temperature is 300-900°C and the time is 30-600 minutes.

[0028] The above preparation method of small copper-bearing stainless steel products of the present invention adopts powder metallurgy technology. Due to the advantages of powder metallurgy technology in preparing small stainless steel products, such as near net-shaping and no need for subsequent thermal deformation process, the resulting stainless steel products can achieve a very high copper content without worrying about copper brittleness problem. At the same time, since the copper-bearing stainless steel products of various shapes obtained by the present invention contain a sufficient amount of copper-rich precipitated phase, the copper-bearing stainless steel can achieve not only a good killing effect on bacteria, but also a virus-killing ability comparable to that of pure copper. The preparation method can be used for the preparation of small stainless steel products such as knives, elevator buttons, door handles, cups, etc., as a whole or a component thereof, which can effectively kill bacteria and viruses present on their surfaces.

[0029] On the other hand, the present invention also provides a typical preparation method (the second preparation method) of a large copper-bearing stainless steel product that fulfills the above composition requirements. The preparation method uses combined processes, which densify the stainless steel product without relying on significant thermal deformation, to prepare large stainless steel products in a simple shape, especially stainless steel sheets, bars, and tubes. Since traditional powder metallurgy technology cannot be used to prepare larger stainless steel products, such as stainless steel sheets, bars, etc., which are widely used in life, the present invention also proposes use of combined processes to avoid significant thermal deformation (such as hot forging, hot rolling) to obtain dense stainless steel sheets, bars or tubes.

[0030] It should be explained that the first method of the present invention, which uses typical traditional pow-

der metallurgy technology such as pressing sintering, metal powder injection molding technology, etc., is a more economical preparation method when used for preparing small and complex-shaped products. However, it is difficult to prepare larger stainless steel products, especially stainless steel sheets, bars and tubes that are widely used. Therefore, it is preferable to use the above first preparation method to produce small and complex-shaped stainless steel products, while the above second preparation method is used to produce stainless steel sheets, bars or tubes.

[0031] In particular, the second preparation method includes:

formulating raw material powders according to the composition of the antibacterial and antiviral copper-bearing stainless steel;
pre-molding the raw material powders to obtain a green body;
sintering the green body to obtain a basically dense sintered part;
completely densifying the sintered part by one or more methods selected from the group consisting of extrusion, cold rolling and hot isostatic pressing to obtain the antibacterial and antiviral copper-bearing stainless steel product.

[0032] Because of combining the characteristics of no macro-segregation of powder metallurgy technology and no need of significant thermal deformation at a high temperature, the process combination as described in the present invention can fully avoid the problem of thermal deformation and processing cracking caused by a high copper content.

[0033] According to the method for preparing a large stainless steel product provided by the present invention, the particle size of the raw material powder is only required to meet the use requirements of the corresponding powder metallurgy process.

[0034] According to the method for preparing a large stainless steel product provided by the present invention, formulating the raw material powders may be carried out by a variety of ways, e.g., by using pre-alloyed copper-bearing metal powder directly formulated according to the composition, or using element powders to formulate the corresponding stainless steel ingredients, or using master alloy powder plus iron powder, as long as the composition falls within the scope of the present invention.

[0035] According to the method for preparing a large stainless steel product provided by the present invention, the pre-molding technical means may be powder rolling, cold press molding, hot press molding, isostatic pressing and other powder metallurgy pre-molding technologies.

[0036] According to the method for preparing a large stainless steel product provided by the present invention, the sintering process may be vacuum sintering, inert atmosphere sintering and other means. It is mainly aimed

to preliminarily densify the sintered part, or make the sintered part have a certain strength for subsequent processing.

[0037] According to the method for preparing a large stainless steel product provided by the present invention, the complete densification process may adopt technical means such as extrusion, cold rolling, warm rolling, hot isostatic pressing, etc.. It is mainly aimed to completely densify the sintered part to obtain a large stainless steel product with various properties meeting the requirements.

[0038] Taking the preparation of stainless steel sheet by powder-rolling technology combination as an example, the second preparation method may include the following steps:

- (1) weighing raw material powders according to the composition of the copper-bearing stainless steel;
- (2) pouring the raw material powders from step (1) into a powder rolling mill to make a green body;
- (3) subjecting the green body obtained in step (2) to a sintering treatment to obtain a preliminarily dense sintered part;
- (4) subjecting the sintered part obtained in step (3) to cold rolling so as to completely densify it and obtain a copper-bearing stainless steel material;
- (5) subjecting the copper-bearing stainless steel material obtained in step (4) to solid solution and aging treatments.

[0039] In some preferred embodiments, the step (2) includes adjusting the spacing and power of the powder rolling mill before pouring the powders, and setting the spacing of the powder rolling mill to be 0.2-4 mm.

[0040] In some preferred embodiments, the temperature for the sintering treatment in step (3) may be 1100-1350°C, and the time may be 30-300 minutes.

[0041] In some preferred embodiments, the deformation amount of the cold rolling treatment in step (4) may be 5-60%.

[0042] In some preferred embodiments, the conditions for the solid solution treatment in step (5) may include: the temperature is 1000-1300°C and the time is 10-300 minutes.

[0043] In some preferred embodiments, the conditions for the aging treatment in step (5) may include: the temperature is 300-900°C, and the time is 30-600 minutes.

[0044] The above combinations of processes can all effectively reduce or eliminate the occurrence of copper brittleness. However, the present invention is not limited to a specific process. Any stainless steel that has the chemical composition as described in the present invention should fall within the protection scope of the present invention.

[0045] On the other hand, the present invention also provides a stainless steel appliance, the stainless steel appliance including a medical appliance or a appliance for living or public place, wherein the stainless steel ap-

pliance comprises the antibacterial and antiviral stainless steel provided by the present invention. For example, the stainless steel appliance includes knives, elevator buttons, door handles, railings and handrails, as a whole or a component thereof.

[0046] Compared with traditional copper-bearing stainless steel, the antibacterial and antiviral copper-bearing stainless steel of the present invention contains a sufficient amount of copper-rich precipitated phases therein, which can achieve not only a good killing effect on bacteria, but also a virus-killing ability comparable to that of pure copper. The stainless steel appliance prepared by using the antibacterial and antiviral copper-bearing stainless steel of the present invention can effectively kill bacteria and viruses present on its surface.

Brief Description of the Drawings

[0047]

Fig. 1 is an SEM image of the stainless steel containing 10 wt% of copper prepared by the method of Example 2 of the present invention.

Fig. 2 is an SEM image of the stainless steel containing 20 wt% of copper prepared by the method of Example 2 of the present invention.

Fig. 3 is a photograph of the stainless steel discs containing 10 wt% of copper prepared by the method of Example 2 of the present invention.

Fig. 4 is a photograph of the elevator buttons made of the stainless steel containing 20 wt% of copper prepared using the method of Example 2 of the present invention.

Best Modes for Carrying Out the Invention

[0048] The present invention is further described in detail below in combination with the specific embodiments, wherein the given examples are for illustrative purposes only, and are not intended to limit the scope of the invention.

Example 1

[0049] This example is used to illustrate a method of preparing a stainless steel disc with a high copper content using powder metallurgy technology. The preparation method includes the following steps:

- (1) On the basis of the composition of 304 stainless steel, 304-10wt% Cu pre-alloyed powder with an additional 10 wt% copper added was prepared.
- (2) The 304-10wt% Cu pre-alloyed powder from step (1) was pressed into a green disc through cold press molding.
- (3) The green disc obtained in step (2) was placed into an atmosphere sintering furnace, with argon gas being a protective gas, and held at 1350°C for 2

hours to complete the sintering process to obtain a stainless steel disc.

(4) The stainless steel disc obtained in step (3) was held at 1100°C for 1 hour and then quenched, and subsequently an aging treatment was performed at 700°C for 6 hours to obtain an antibacterial and antiviral copper-bearing stainless steel disc of the present invention.

Example 2

[0050] This example is used to illustrate a method of preparing a stainless steel disc with a high copper content using powder metallurgy technology. The preparation method includes the following steps:

(1) On the basis of the composition of 316L stainless steel, 10 wt% copper powder was added to a 316L pre-alloyed powder, and the two powders were mixed evenly to obtain a 316L-10 wt% copper mixed powder.

(2) The 316L-10 wt% copper mixed powder obtained in step (1) was pressed into a green disc through cold press molding.

(3) The green disc obtained in step (2) was placed into an atmosphere sintering furnace, with argon gas being a protective gas, and held at 1350°C for 2 hours to complete the sintering process to obtain a stainless steel disc.

(4) The stainless steel disc obtained in step (3) was held at 1100°C for 1 hour and then quenched, and subsequently an aging treatment was performed at 700°C for 6 hours to obtain an antibacterial and antiviral copper-bearing stainless steel disc of the present invention.

Example 3

[0051] This example is used to illustrate a method of preparing a stainless steel disc with a high copper content using powder metallurgy technology. The preparation method includes the following steps:

(1) Based on mass parts, 20 parts chromium powder, 17 parts nickel powder, 10 parts copper, 3.5 parts molybdenum powder, 1.6 parts manganese, and 0.75 parts silicon, with the remainder being iron powder (100 parts in total), were taken and mixed evenly.

(2) The mixed powder from step (1) was mixed with 13 wt% polymer binder (the main components of which are polyformaldehyde, polyethylene and a small amount of paraffin), and a feed for metal injection molding was obtained through mixing and granulation.

(3) By an injection molding machine, the feed from step (2) was injection molded into a green body of elevator buttons.

(4) The green body of elevator buttons obtained in step (3) was degreased to remove the polymer binder.

(5) The sample obtained in step (4) was sintered under an argon protective atmosphere, and held at 1350°C for 2 hours to complete the sintering to obtain sintered parts of elevator button.

(6) The sintered parts of elevator button obtained in step (5) was held at 1100°C for 1 hour and then quenched, and subsequently an aging treatment was performed at 700°C for 6 hours to obtain stainless steel elevator buttons with antibacterial and antiviral effects.

Example 4

[0052] This example is used to illustrate a method of preparing a large copper-bearing stainless steel product as described in the present invention. The preparation method includes the following steps:

(1) On the basis of the composition of 304 stainless steel, a 304-10wt% Cu pre-alloyed powder with an additional 10wt% copper added was prepared.

(2) The spacing and power of a powder rolling mill were adjusted, and the 304-10wt%Cu pre-alloyed powder from step (1) was poured into the powder rolling mill to obtain a green body of stainless steel sheet.

(3) The green body of sheet obtained in step (2) was placed into an atmosphere sintering furnace, with argon gas being a protective gas, and held at 1350°C for 2 hours to obtain a basically densified sintered part.

(4) The sintered part obtained in step (3) was subjected to a cold rolling treatment so as to completely densify the sheet.

(5) The stainless steel sheet obtained in step (4) was held at 1050°C for 30 minutes and then quenched, and subsequently an aging treatment was performed at 700°C for 6 hours to obtain a stainless steel sheet with antibacterial and antiviral effects of the present invention.

Example 5

[0053] This example is used to illustrate a preparation method of a large copper-bearing stainless steel product as described in the present invention. The preparation method includes the following steps:

(1) On the basis of the composition of 304 stainless steel, a 304-10wt% Cu pre-alloyed powder with an additional 10 wt% copper added was prepared.

(2) The 304-10wt% Cu pre-alloyed powder from step (1) was poured into a rubber mold for bar, and the mold was placed into a cold isostatic press. The pressure was set to 180MPa and the pressure was main-

tained for 5 minutes to obtain a green body of stainless steel bar.

(3) The green body of bar obtained in step (2) was placed into a vacuum sintering furnace and held at 1350°C for 2 hours to obtain a basically densified sintered part.

(4) The bar sintered part obtained in step (3) was subjected to an extrusion treatment so that the sintered part was completely densified during the extrusion, and simultaneously a stainless steel bar with a corresponding size was obtained.

(5) The stainless steel bar obtained in step (4) was held at 1050°C for 30 minutes and then quenched, and subsequently an aging treatment was performed at 700°C for 6 hours to obtain a stainless steel bar with antibacterial and antiviral effects of the present invention.

Product Characterization

[0054] Fig. 1 is an SEM image of the stainless steel containing 10 wt% copper prepared by the method of Example 2 of the present invention, in which, the white particles are the copper-rich phases in the matrix. Fig. 2 is an SEM image of the stainless steel containing 20 wt% copper prepared by the method of Example 2 of the present invention, in which the white particles are the copper-rich phases in the matrix. From Figs. 1 and 2, it can be seen that the copper-rich phases are essentially uniformly distributed in the stainless steel matrix.

[0055] Fig. 3 is a photograph of the stainless steel discs containing 10 wt% copper prepared by the method of Example 2 of the present invention. Fig. 4 is a photograph of the elevator buttons made of the stainless steel containing 20 wt% copper prepared using the method of Example 2 of the present invention. As can be seen from Figs. 3 and 4, the antibacterial and antiviral copper-bearing stainless steel material of the present invention has a surface which is silvery white in color and smooth and clean. In contrast, 316L stainless steel containing 10 wt% copper which was prepared using existing casting, hot forging, and hot rolling methods, caused fissures or cracks occurring on the surface of cast large stainless steel material during the hot forging or hot rolling process, and directly lead to material breakage in the severe cases. Therefore, the preparation method of the present invention has solved the "copper brittleness problem".

The antibacterial and antiviral performance test

[0056] In accordance with JIS Z2801 2010 standard, *E. coli* was cultured on the surface of the disc obtained in Example 2 at 37°C for 24 hours. The surface was washed with phosphate buffer solution (PBS), and the resulting bacterial solution was put and cultured on a counting plate for 24 hours. After counting, it was found that there were many bacterial colonies on an ordinary stainless steel as the control group, but almost no bac-

terial colonies appeared on the copper-bearing stainless steel as the experimental group. Therefore, after calculation, the antibacterial rate of this stainless steel disc can reach above 99%.

[0057] In addition, the experiments, in which a certain amount of novel coronavirus was added dropwise onto the sample surfaces and the stability and decay rate of the novel coronavirus on the surfaces of ordinary 316L stainless steel, 316L stainless steel containing 5 wt% copper, 316L stainless steel containing 10 wt% copper as obtained in Example 2 and pure copper were tested over different time periods. The experiments show that the stainless steel obtained by the present invention can effectively shorten the survival time of 2019- nCov virus on its surface. Compared with the surfaces of ordinary stainless steel and 5 wt% copper-containing stainless steel on which a large number of viruses still survived after 24h, the number of novel coronavirus on the surface of the stainless steel obtained by the present invention had been greatly reduced after only 3 hrs, and completely inactivated after 24 hrs.

[0058] The above are only the specific embodiments of the present invention. However, the protection scope of the present invention is not limited thereto. Any stainless steel having a chemical composition falling within the scope of the present invention should fall within the protection scope of the present invention. Those skilled in the art should understand that any changes or substitutions within the technical scope as disclosed in the present invention that can be easily conceived of by those skilled in the art fall within the protection scope and the scope of disclosure of the present invention.

Claims

1. An antibacterial and antiviral copper-bearing stainless steel, the copper-bearing stainless steel comprising a stainless steel matrix and a copper-rich phase uniformly distributed in the stainless steel matrix, wherein the copper content of the copper-bearing stainless steel is 6-30 wt%.
2. The antibacterial and antiviral copper-bearing stainless steel according to claim 1, wherein the copper-bearing stainless steel comprises the following composition in mass percentages: Cu: 6-30 wt%; Ag: 0-1 wt%; Zn: 0-1.5 wt%; Cr: 11-30 wt%; Mn: 0-20 wt%; Ni: 0-18 wt%; Co: 0-8 wt%; Al: 0-5 wt%; Ti: 0-5 wt%; Mo: 0-4 wt%; V: 0-3 wt%; C≤1 wt%, with the remainder being iron and unavoidable impurities.
3. The antibacterial and antiviral copper-bearing stainless steel according to claim 1 or 2, wherein the copper-bearing stainless steel may further contain one or more elements selected from the group consisting of Nb, Si, Zr, N and B, wherein Si≤2 wt%, and the total content of the other alloying elements is ≤3 wt%.

4. The antibacterial and antiviral copper-bearing stainless steel according to any one of claims 1 to 3, wherein the copper content of the copper-bearing stainless steel is 8-20 wt%, more preferably 10-15 wt%.
5. A preparation method of the antibacterial and antiviral copper-bearing stainless steel according to any one of claims 1 to 4, the preparation method including: formulating a raw material powder according to the composition of the antibacterial and antiviral copper-bearing stainless steel, wherein the raw material powder comprise 6-30 wt% of copper powder; and molding the raw material powder into a stainless steel product by using a powder metallurgy method.
6. The preparation method according to claim 5, wherein the molding includes metal injection molding technology, powder pressing sintering technology, and/or hot pressing sintering technology.
7. The preparation method according to claim 5, wherein the preparation method includes the following steps:
- (1) weighing the raw material powder according to the composition of the antibacterial and antiviral copper-bearing stainless steel;
 - (2) mixing the raw material powder from step (1) with a binder evenly and then granulating to obtain a feed;
 - (3) injection molding the feed material obtained in step (2) to obtain a green body;
 - (4) degreasing and sintering the green body obtained in step (3) to obtain a copper-bearing stainless steel product;
 - (5) subjecting the copper-bearing stainless steel product obtained in step (4) to solid solution and aging treatments to obtain the antibacterial and antiviral copper-bearing stainless steel.
8. A preparation method of the antibacterial and antiviral copper-bearing stainless steel according to any one of claims 1 to 4, the preparation method including:
- formulating a raw material powder according to the composition of the antibacterial and antiviral copper-bearing stainless steel, wherein the raw material powder comprises 6-30 wt% of copper powder;
 - pre-molding the raw material powder to obtain a green body;
 - sintering the green body to obtain a preliminarily dense sintered part;
 - completely densifying the sintered part by one or more methods selected from extrusion, cold rolling and hot isostatic pressing to obtain the antibacterial and antiviral copper-bearing stainless steel product.
9. The preparation method according to claim 8, wherein the preparation method includes the following steps:
- (1) weighing the raw material powder according to the composition of the copper-bearing stainless steel;
 - (2) pouring the raw material powder from step (1) into a powder rolling mill to make a green body;
 - (3) subjecting the green body obtained in step (2) to sintering treatment to obtain a preliminarily dense sintered part;
 - (4) subjecting the sintered part obtained in step (3) to cold rolling so as to completely densify it and obtain a copper-bearing stainless steel material;
 - (5) subjecting the copper-bearing stainless steel material obtained in step (4) to solid solution and aging treatments.
10. A stainless steel appliance, the stainless steel appliance including a medical appliance or an appliance for living or public place, wherein the stainless steel appliance comprises the antibacterial and antiviral stainless steel of anyone of claims 1 to 4, preferably, the stainless steel appliance includes a knife, elevator button, door handle, railing and handrail, as a whole or a component thereof.

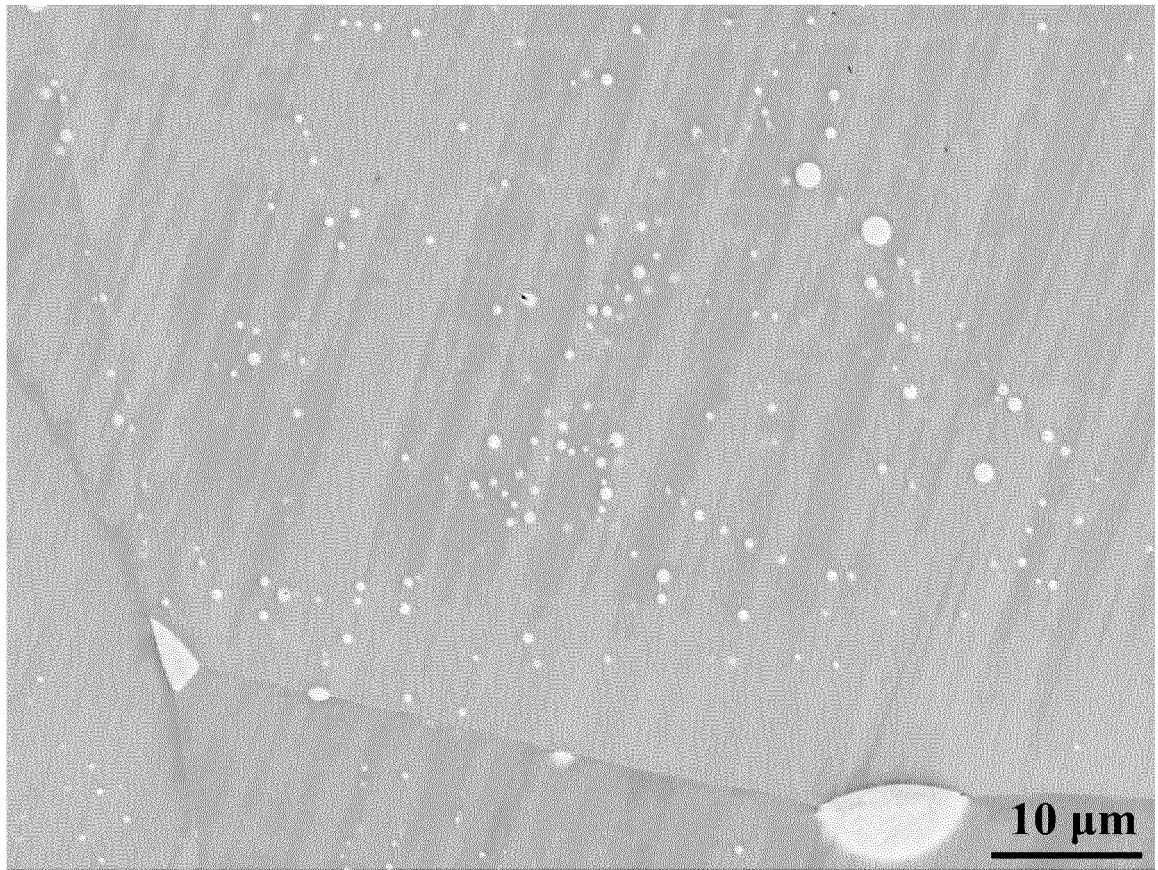


Fig. 1

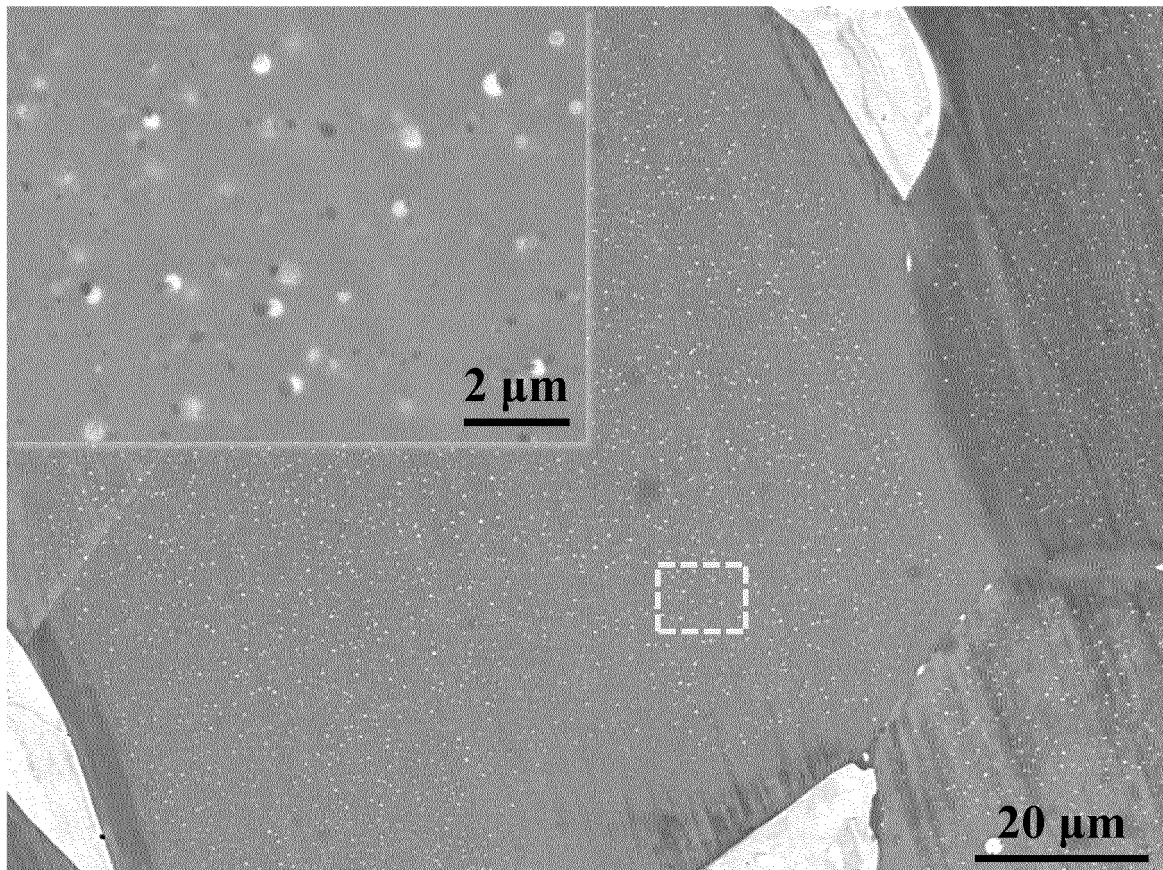


Fig. 2

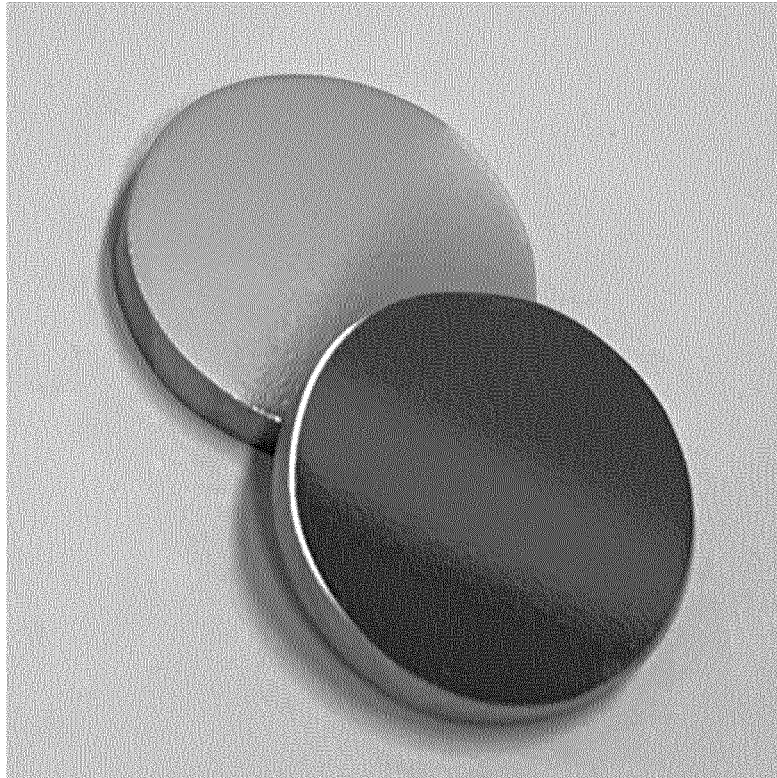


Fig. 3

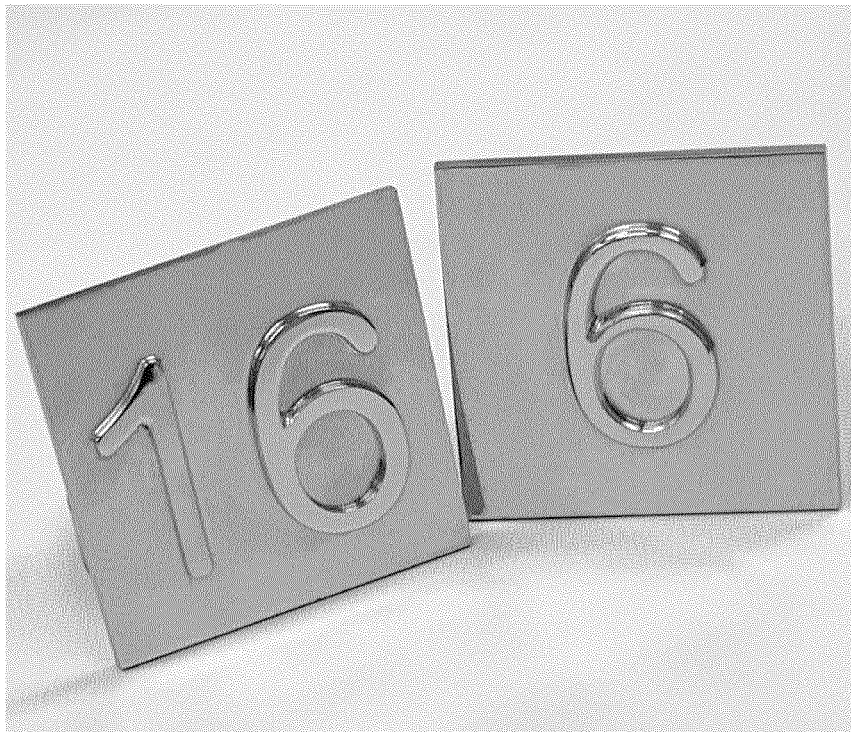


Fig. 4

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2021/130229

A. CLASSIFICATION OF SUBJECT MATTER C22C 38/16(2006.01)i; C22C 38/18(2006.01)i; C22C 38/20(2006.01)i; C22C 38/38(2006.01)i; C22C 38/54(2006.01)i 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) C22C Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched																					
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) CNTXT; CNABS; DWPI; CNKI: 抗菌, 抗病毒, 不锈钢, 铜, 粉末冶金, 熔炼, bacteri+, microb+, virus+, stainless, rustless, cu, copper, powder metallur+, melt+																					
C. DOCUMENTS CONSIDERED TO BE RELEVANT <table border="1"> <thead> <tr> <th>Category*</th> <th>Citation of document, with indication, where appropriate, of the relevant passages</th> <th>Relevant to claim No.</th> </tr> </thead> <tbody> <tr> <td>X</td> <td>CN 102260832 A (BAOSHAN IRON & STEEL CO., LTD.) 30 November 2011 (2011-11-30) description, paragraphs 3, 7-8, and 25-33</td> <td>1-10</td> </tr> <tr> <td>X</td> <td>JP H1143748 A (HITACHI LTD.) 16 February 1999 (1999-02-16) claims 1-13</td> <td>1-10</td> </tr> <tr> <td>X</td> <td>CN 111411309 A (JIANGSU MINGXING WATER SUPPLY EQUIPMENT CO., LTD.) 14 July 2020 (2020-07-14) claims 1, 4 and 5</td> <td>1-3, 10</td> </tr> <tr> <td>X</td> <td>CN 111318675 A (BINZHOU YANGXINHUAMEI STAINLESS STEEL PRODUCTS CO., LTD.) 23 June 2020 (2020-06-23) claim 1</td> <td>1-4, 10</td> </tr> <tr> <td>X</td> <td>CN 114196891 A (SHANXI TAIGANG STAINLESS STEEL CO., LTD.) 18 March 2022 (2022-03-18) claim 1, and description, paragraph 3</td> <td>1-3, 10</td> </tr> <tr> <td>X</td> <td>CN 111910122 A (NINGBO BAOXIN STAINLESS STEEL CO., LTD.) 10 November 2020 (2020-11-10) claim 1, and description, paragraph 3</td> <td>1-3, 10</td> </tr> </tbody> </table>	Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.	X	CN 102260832 A (BAOSHAN IRON & STEEL CO., LTD.) 30 November 2011 (2011-11-30) description, paragraphs 3, 7-8, and 25-33	1-10	X	JP H1143748 A (HITACHI LTD.) 16 February 1999 (1999-02-16) claims 1-13	1-10	X	CN 111411309 A (JIANGSU MINGXING WATER SUPPLY EQUIPMENT CO., LTD.) 14 July 2020 (2020-07-14) claims 1, 4 and 5	1-3, 10	X	CN 111318675 A (BINZHOU YANGXINHUAMEI STAINLESS STEEL PRODUCTS CO., LTD.) 23 June 2020 (2020-06-23) claim 1	1-4, 10	X	CN 114196891 A (SHANXI TAIGANG STAINLESS STEEL CO., LTD.) 18 March 2022 (2022-03-18) claim 1, and description, paragraph 3	1-3, 10	X	CN 111910122 A (NINGBO BAOXIN STAINLESS STEEL CO., LTD.) 10 November 2020 (2020-11-10) claim 1, and description, paragraph 3	1-3, 10
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Date of the actual completion of the international search 26 April 2022	Date of mailing of the international search report 13 May 2022																				
Name and mailing address of the ISA/CN China National Intellectual Property Administration (ISA/CN) No. 6, Xitucheng Road, Jimenqiao, Haidian District, Beijing 100088, China Facsimile No. (86-10)62019451	Authorized officer Telephone No.																				

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

PCT/CN2021/130229

Patent document cited in search report	Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
CN 102260832 A	30 November 2011	CN 102260832 B	06 February 2013
JP H1143748 A	16 February 1999	None	
CN 111411309 A	14 July 2020	None	
CN 111318675 A	23 June 2020	None	
CN 114196891 A	18 March 2022	None	
CN 111910122 A	10 November 2020	None	

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