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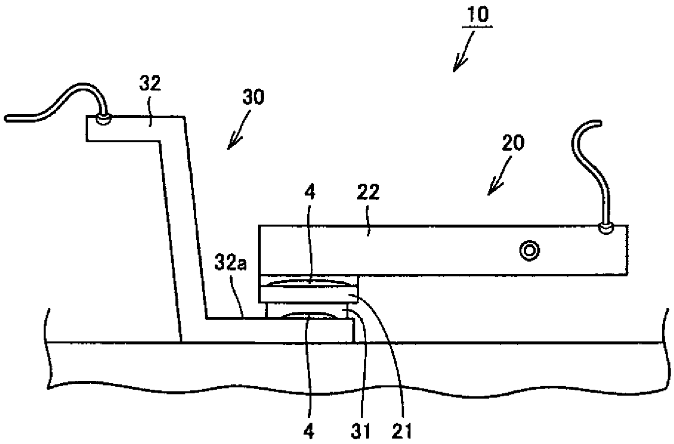
(54) **ELECTRICAL CONTACT MATERIAL**

(57) Provided is an electrical contact material excellent in welding resistance, wear-out resistance, and temperature performance. The electrical contact material (31) includes more than 30% by mass and 55% by mass or less of tungsten carbide and 2% by mass or more and 5% by mass or less of graphite, the remainder including silver and an unavoidable impurity, the electrical contact material (31): having a relative density of 98.0% or more; an oxygen content of 450 ppm or less; an electrical conductivity of 45% IACS or more; and a transverse rupture strength of 350 MPa or more.

FIG.1



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Description

TECHNICAL FIELD

[0001] The present invention relates generally to electrical contact materials and more particularly, to an electrical contact material formed of a silver-tungsten carbide-graphite (Ag-WC-Gr) based material and used for an interrupter switch (breaker) or the like.

BACKGROUND ART

[0002] Conventionally, an electrical contact material formed of a silver-tungsten carbide based material including a given quantity or more of tungsten carbide as a heat-resistant non-oxide is commonly used in a breaker or the like whose rated current value is 200A or more. In this electrical contact material, graphite is added in order to suppress a temperature rise by preventing the tungsten carbide from being oxidized under a high heat condition upon breaking (temperature performance) and to enhance welding resistance.

[0003] For example, Japanese Patent Application Laid-Open Publication No. 58-11753 (hereinafter, referred to as Patent Literature 1) discloses an electrical contact material which includes: 5% through 70% by weight of a carbide, such as a tungsten carbide, of IVa, Va, or VIa group metal in an element periodic table; 1% through 11% by weight of graphite; 5% through 60% by weight of iron group metal; and 0.1% through 30% by weight of a nitride of IVa, Va, VIa, or VIIa group metal, the remainder consisting of silver, with the carbide and the nitride dispersed in the iron group metal and the silver.

[0004] In addition, Japanese Patent Application Laid-Open Publication No. 58-11754 (hereinafter, referred to as Patent Literature 2) discloses an electrical contact material which includes: 5% through 70% by weight of a carbide, such as a tungsten carbide, of IVa, Va, or VIa group metal in an element periodic table; 1% through 11% by weight of graphite; 5% through 60% by weight of iron group metal; and 0.1% through 5% by weight of IVa, Va, VIa, or VIIa group metal, the remainder consisting of silver, with the carbide and the IVa, Va, VIa, or VIIa group metal dissolved in a solid state or dispersed in the iron group metal and the silver.

CITATION LIST

PATENT LITERATURE

[0005]

Patent Literature 1: Japanese Patent Application Laid-Open Publication No. 58-11753
Patent Literature 2: Japanese Patent Application Laid-Open Publication No. 58-11754

SUMMARY OF THE INVENTION

TECHNICAL PROBLEM

[0006] Since wettability of the heat-resistant non-oxide such as the tungsten carbide and the silver is bad, the above-mentioned electrical contact material is manufactured by employing a powder metallurgy method, instead of a melting method. In the powder metallurgy method, a starting material powder is subjected to compression compacting, thereby preparing a compact, and this compact is sintered. In the sintered body obtained as mentioned above, interstices (pores) are present among combined powder particles.

[0007] Therefore, since the obtained electrical contact material has a low relative density and is not densified, an electrical conductivity becomes low. In a breaker configured by using this electrical contact material, this causes heat generated at a contact upon breaking to be increased. Accordingly, there arises a problem in that the obtained electrical contact material is inferior in welding resistance, wear-out resistance, and temperature performance.

[0008] In order to solve the above-mentioned problem, in each of the methods for manufacturing the electrical contact materials disclosed in Patent Literature 1 and Patent Literature 2, the relative density is enhanced by repressurizing the sintered body. However, the relative density obtained by this method is less than 95%. Therefore, an electrical conductivity of the electrical contact material becomes low. This makes the welding resistance, the wear-out resistance, and the temperature performance of the electrical contact material insufficient. In order to solve this, it is required to make a contact area of the electrical contact material large.

[0009] Therefore, an object of the present invention is to provide an electrical contact material excellent in welding resistance, wear-out resistance, and temperature performance.

SOLUTION TO PROBLEM

[0010] An electrical contact material according to the present invention includes more than 30% by mass and 55% by mass or less of tungsten carbide and 2% by mass or more and 5% by mass or less of graphite, the remainder including silver and an unavoidable impurity, the electrical contact material: having a relative density of 98.0% or more; an oxygen content of 450 ppm or less; an electrical conductivity of 45% IACS or more; and a transverse rupture strength of 350 MPa or more.
[0011] In the electrical contact material according to the present invention, it is preferable that an average particle diameter of the tungsten carbide is 0.5 μm or more and 5 μm or less.
[0012] In addition, in the electrical contact material according to the present invention, it is preferable that an average particle diameter of the graphite is 1 μm or more and 50 μm or less.

ADVANTAGEOUS EFFECTS OF THE INVENTION

[0013] According to the present invention, since a relative density is 98.0% or more, an oxygen content is 450 ppm or less, an electrical conductivity is 45% IACS or more, and a transverse rupture strength is 350 MPa or more, an electrical contact material excellent in welding resistance, wear-out resistance, and temperature performance can be provided.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014]

Fig. 1 is a side view illustrating a layout of a fixed side contact member and a moving side contact member, constituting a breaker into which an electrical contact material as one embodiment of the present invention is incorporated, in a closed state.
Fig. 2 is a side view illustrating a layout of the fixed side contact member and the moving side contact member, constituting the breaker into which the electrical contact material as the one embodiment of the present invention is incorporated, in an open state.

DESCRIPTION OF EMBODIMENTS

[0015] First, a configuration of a breaker into which an electrical contact material as one embodiment of the present invention is incorporated will be described.
[0016] As shown in Fig. 1 and Fig. 2, a breaker 10 includes: a fixed-side contact member 30; and a moving-side contact member 20 arranged so as to be repeatedly movable to be capable of contacting the fixed-side contact member 30 and of separating from the fixed-side contact member 30. A junction body of an electrical contact material 31 and a metal base 32 constitutes the fixed-side contact member 30. A junction body of an electrical contact material 21 and a metal base 22 constitutes the moving-side contact member 20. An electrical contact material 31 according to the embodiment of the present invention is used in one part of the fixed-side contact member 30 of the breaker 10. The electrical contact material 31 shown in Fig. 1 and Fig. 2 is one example of the "electrical contact material" according to the present invention.
[0017] In the fixed-side contact member 30, the electrical contact material 31 and the metal base 32 are joined to each other via a brazing filler metal 4, with an upper surface of a junction part 32a being a joint surface, the junction part 32a integrally formed on a side of the metal base 32. In the moving-side contact member 20, the electrical contact material 21 and the metal base 22 are joined to each other via a brazing filler metal 4, with an upper surface of a junction part being a joint surface, the junction part integrally formed on a side of the metal base 22.
[0018] The moving-side contact member 20 and the fixed-side contact member 30 are configured as described above. Therefore, in a case where a current exceeding a permissible current value of the breaker 10 flows for a predetermined period of time, a built-in contact tripping device (not shown) operates, thereby shifting a state of the breaker 10 from a state where the electrical contact material 21 of the moving-side contact member 20 is in contact with the electrical contact material 31 of the fixed-side contact member 30 as shown in Fig. 1 (closed state) to a state where the electrical contact material 21 of the moving-side contact member 20 is instantaneously pulled apart from the electrical contact material 31 of the fixed-side contact member 30 in a direction indicated by an arrow Q as shown in Fig. 2 and thereby breaking the current. As described above, the breaker 10 is configured. As shown in Fig. 1 and Fig. 2, in the fixed-side contact member 30, a side of an end portion of the metal base 32, where the electrical contact material 31 is not provided, is connected to a primary side (power source side) terminal of the breaker 10, and in the moving-side contact member 20, an end portion of the metal base 22, where the electrical contact material 21 is not provided, is connected to a secondary side (load side) terminal of the breaker 10.

[0019] In the above-described embodiment, the electrical contact material 21 on the moving side, incorporated into the breaker 10, is formed of a silver-tungsten carbide (Ag-WC) based material, and the electrical contact material 31 on the fixed side as the electrical contact material according to the present invention is formed of a silver-tungsten carbide-graphite (Ag-WC-Gr) based material and includes: more than 30% by mass and 55% by mass or less of tungsten carbide (WC); and 2% by mass or more and 5% by mass or less of graphite (Gr), the remainder including silver (Ag) and an unavoidable impurity, and a relative density is 98.0% or more, an oxygen content is 450 ppm or less, an electrical conductivity is 45% IACS or more, and a transverse rupture strength is 350 MPa or more.

[0020] In the electrical contact material according to the present invention, first, more than 30% by mass and 55% by mass or less of the tungsten carbide as the heat-resistant non-oxide which is a refractory is included, thereby obtaining an advantage in that arc resistance, welding resistance, and wear-out resistance can be enhanced so as to achieve a given level or more. If a content of the tungsten carbide is 30% by mass or less, because not only the above-mentioned advantage cannot be obtained, but also it is likely that the transverse rupture strength is less than 350 MPa. If the content of the tungsten carbide exceeds 55% by mass, because the electrical conductivity is reduced, the material does not function as a contact for a breaker, a magnetic switch, or the like. Specifically, if the content of the tungsten carbide exceeds 55% by mass, it is likely that the electrical conductivity is less than 45% IACS. It is preferable that the content of the tungsten carbide is 40% by mass or more and 50% by mass or less.

[0021] In addition, in the electrical contact material according to the present invention, 2% by mass or more and 5% by mass or less of the graphite is included, thereby obtaining advantages in that the tungsten carbide as the heat-resistant non-oxide is prevented from being oxidized under a high heat condition upon breaking and the welding resistance is enhanced. If a content of the graphite is less than 2% by mass, the above-mentioned advantages cannot be obtained. If the content of the graphite exceeds 5% by mass, compacting of the material is impossible. It is preferable that the content of the graphite is 2% by mass or more and 4% by mass or less.

[0022] Furthermore, in the electrical contact material according to the present invention, the remainder includes: the silver and the unavoidable impurity, and in order to ensure the electrical conductivity of the contact, it is preferable that 40% by mass or more and 68% by mass or less of the silver is included. If a content of the silver is less than 40% by mass, the electrical conductivity is reduced, and the material is not suited to an electrical contact material for a breaker, a magnetic switch, or the like. If the content of the silver exceeds 68% by mass, because the content of the tungsten carbide as the heat-resistant non-oxide which is the refractory becomes small, it is made impossible to enhance the arc resistance, the welding resistance, and the wear-out resistance so as to achieve a given level or more. It is preferable that the content of the silver is 45% by mass or more and 60% by mass or less.

[0023] In the electrical contact material according to the present invention, as the remainder, 0% by mass or more and 3% by mass or less of at least one kind of an element or a carbide selected from the group consisting of iron (Fe), nickel (Ni), cobalt (Co), chromium (Cr), molybdenum (Mo), copper (Cu), tantalum (Ta), vanadium (V), magnesium (Mg), zinc (Zn), and tin (Sn) and carbides of these elements may be included. If a content of the above-mentioned element or carbide exceeds 3% by mass, it is likely that the electrical conductivity is less than 45% IACS. It is preferable that the content of the above-mentioned element or carbide is 1% by mass or less.

[0024] In the electrical contact material according to the present invention, the relative density is 98.0% or more, thereby allowing excellent welding resistance and wear-out resistance to be obtained. If the relative density is less than 98.0%, because it is likely that the electrical conductivity is less than 45% IACS, the electrical contact material is inferior in the welding resistance and the wear-out resistance. It is preferable that the relative density is 99.0% or more and 100% or less.

[0025] In the electrical contact material according to the present invention, the oxygen content is 450 ppm or less, thereby excellent wear-out resistance to be obtained. If the oxygen content exceeds 450 ppm, oxygen remaining in the electrical contact material is abruptly released upon breaking, whereby it is likely that wear-out of a contact becomes large. Specifically, if the oxygen content exceeds 450 ppm, since oxygen present in the material is gasified by a high heat of several thousand degrees generated during a short-circuit test, a part of a base material of the electrical contact material is dispersed. This increases a rate at which the electrical contact material is worn out. It is preferable that the oxygen content is 350 ppm or less. In an overload test, since a contact load is small, the oxygen content hardly exerts an influence on a rate at which the electrical contact material is worn out. However, for the reason of difficulty in manufacturing, it is preferable that the oxygen content is 120 ppm or more. Here, the "difficulty in manufacturing" means that however small an oxygen content may be desired to be, 120 ppm is the limit thereof in manufacturing.

[0026] In the electrical contact material according to the present invention, the electrical conductivity is 45% IACS or more, thereby allowing excellent welding resistance, wear-out resistance, and temperature performance to be obtained. If the electrical conductivity is less than 45% IACS, the welding resistance, the wear-out resistance, and the temperature performance become worse. However, for the reason of difficulty in manufacturing, it is preferable that the electrical conductivity is 65% IACS or less. Here, the "difficulty in manufacturing" means that however large the electrical conductivity may be desired to be, 65% IACS is the limit thereof in manufacturing.

[0027] In the electrical contact material according to the present invention, since in the short-circuit test for a large current application, a shock is great, to endure the shock, the transverse rupture strength is 350 MPa or more. If the transverse rupture strength is less than 350 MPa, in the short-circuit test in which a contact load is large, the electrical contact material is destroyed due to an insufficiency of a mechanical strength of the material. It is preferable that the transverse rupture strength is 380 MPa or more. In the overload test, since a contact load is small, the transverse rupture strength hardly exerts an influence. However, for the reason of difficulty in manufacturing, it is preferable that the transverse rupture strength is less than or equal to 580 MPa. Here, the "difficulty in manufacturing" means that however large the transverse rupture strength may be desired to be, 580 MPa is the limit thereof in manufacturing.

[0028] In the electrical contact material according to the present invention, it is preferable that an average particle diameter of the tungsten carbide is 0.5 μm or more and 5 μm or less. If the average particle diameter of the tungsten carbide is less than 0.5 μm, compacting of the material is impossible. If the average particle diameter of the tungsten carbide exceeds 5 μm, a variation of strengths among portions of the electrical contact material is caused. If portions having low strengths come to be connected, the electrical contact material is selectively worn out after the short-circuit test. As a result, it is likely that the arc resistance, the welding resistance, and the wear-out resistance become worse.

[0029] In addition, in the electrical contact material according to the present invention, it is preferable that an average particle diameter of the graphite is 1 μm or more and 50 μm or less. If the average particle diameter of the graphite is less than 1 μm, compacting of the material is impossible. In addition, if the average particle diameter of the graphite exceeds 50 μm, a variation of strengths among portions of the electrical contact material is caused. If portions having low strengths come to be connected, the electrical contact material is selectively worn out after the short-circuit test. As a result, it is likely that the arc resistance, the welding resistance, and the wear-out resistance become worse.

[0030] The electrical contact material formed of the silver-tungsten carbide-graphite (Ag-WC-Gr) based material according to the present invention is manufactured as described below.

[0031] (Powder preparation)

[0032] An average particle diameter of the prepared silver (Ag) powder is 0.5 μm or more and 10 μm or less, an average particle diameter of the prepared tungsten carbide (WC) powder is 0.5 μm or more and 5 μm or less, and an average particle diameter of the prepared graphite (Gr) powder is 1 μm or more and 50 μm or less. If the average particle diameter of each of the powders is less than each of the respective lower limits, flocculation of the powders becomes intense and the particles of the powders cannot be evenly dispersed, whereby an area of the silver eluted onto a surface of the electrical contact material becomes large. As a result, it is likely that welding performance of the electrical contact material becomes worse. If the average particle diameter of each of the powders exceeds each of the respective upper limits, in each of the powders, distances among particles become large and the particles thereof cannot be finely dispersed, whereby an area of the silver eluted onto a surface of the electrical contact material becomes large. As a result, it is likely that welding performance of the electrical contact material becomes worse. It is preferable that the average particle diameter of the silver (Ag) powder is 1 μm or more and 5 μm or less, the average particle diameter of the tungsten carbide (WC) powder is 1 μm or more and 3 μm or less, and the average particle diameter of the graphite (Gr) powder is 3 μm or more and 10 μm or less.

[0033] It is preferable that a purity of each of the silver (Ag) powder, the tungsten carbide (WC) powder, and the graphite (Gr) powder is 99.5% or more. If the purity of each of the powders is less than 99.5%, impurities, such as oxygen (O) and carbon (C), present in grain boundaries of the powders are increased, whereby it is likely that an electrical conductivity of the electrical contact material is reduced.

[0034] (Mixing step)

[0035] Next, in accordance with predetermined composition, the silver powder, the tungsten carbide powder, and the graphite powder are mixed in, for example, a dry-type ball mill in a vacuum of 80 Pa or more and 150 Pa or less for, for example, 30 minutes or more and 60 minutes or less. The raw material powders are mixed in the vacuum in the above-mentioned manner, thereby allowing the fine raw material powders to be evenly mixed and the particles to be evenly dispersed. This allows a mechanical strength such as a transverse rupture strength of the electrical contact material to be increased and resistance to the short-circuit test, in which a contact load is large, to be enhanced. If the pressure of the atmosphere in which the mixing is conducted is less than 80 Pa, it is likely that a cost of producing a high vacuum is increased. If the pressure of the atmosphere in which the mixing is conducted exceeds 150 Pa, a degree of the vacuum becomes insufficient, whereby it is likely that the particles of each of the raw material powders having large differences in specific gravities cannot be evenly dispersed. If the mixing time is less than 30 minutes, the mixing becomes insufficient, whereby it is likely that the particles of each of the raw material powders cannot be evenly dispersed. If the mixing time exceeds 60 minutes, it is likely that productivity becomes worse.

[0036] (Compression Compacting step)

[0037] Thereafter, a pressure of, for example, 250 MPa or more and 350 MPa or less is applied to the mixed powder, thereby forming a compression compact. This step is conducted in order to allow an electrical contact material having a higher relative density to be obtained by conducting a coining step and an extrusion step which are the subsequent steps. If the press pressure is less than 250 MPa, a deformation amount in the coining step becomes large, whereby it is likely that pressurization which allows the relative density to be 93% or more cannot be conducted by the coining step conducted once. If the press pressure exceeds 350 MPa, the relative density of the pressed body exceeds 85%, thereby making interstices in the pressed body small. As a result, it is likely that, in the sintering step which is the subsequent step, reduction of an inside of the material becomes insufficient, whereby oxygen remains.

[0038] (Sintering step)

[0039] The obtained compression compact is retained in, for example, a reducing gas atmosphere such as a hydrogen gas having, for example, a temperature of 1000°C or more and 1100°C or less for, for example, 1 hour or more and 2 hours or less, thereby conducing sintering. The compression compact is subjected to the sintering in the reducing gas atmosphere in the above-mentioned manner, thereby allowing a quantity of oxygen as an impurity adsorbed to the inside of the electrical contact material to be reduced. If the sintering temperature is less than 1000°C, the sintering cannot be completed. If the sintering temperature exceeds 1100°C, a large amount of gas is generated, whereby it is likely that the material is foamed. If the sintering time is less than 1 hour, the sintering cannot be completed. If the sintering time exceeds 2 hours, it is likely that productivity becomes worse.

[0040] (Coining step)

[0041] The obtained sintered body is subjected to a coining process under a pressure of, for example, 1000 MPa or more and 1200 MPa or less so as to allow a relative density to be 93% or more and 99% or less. This step is conducted in order to allow an electrical contact material having a higher relative density to be obtained by conducting the extrusion step which is the subsequent step. In addition, this step is conducted in order to reduce a quantity of oxygen as an impurity entering an inside of the material upon preheating at the extrusion step. If the coining pressure is less than 1000 MPa, it is likely that a relative density of the material is approximately 90%. If the coining pressure exceeds 1200 MPa, it is likely that durability of a mold to be used becomes worse. If the relative density after the coining step is less than 93%, it is likely that a quantity of the oxygen as the impurity entering the inside of the material upon the preheating at the extrusion step is increased. If the relative density after the coining step exceeds 99%, it is likely that even if a further pressure is applied, a relative density is not enhanced due to spring-back and productivity becomes worse.

[0042] (Extrusion step)

[0043] The sintered body subjected to the coining process is preheated by retaining in, for example, an atmosphere of a reducing gas such as a hydrogen gas or an atmosphere of an inert gas such as a nitrogen gas, having, for example, a temperature of 850°C or more and 920°C or less, for, for example, 1 hour or more and 2 hours or less, and thereafter, an extrusion pressure of 180 GPa or more and 250 Gpa or less is applied to the sintered body, thereby extruding the sintered body so as to have a predetermined shape.

[0044] As described above, the electrical contact material formed of the silver-tungsten carbide-graphite (Ag-WC-Gr) based material according to the present invention is manufactured.

[0045] According to the conventional manufacturing method in which the press working and the sintering are combined, it is difficult to enhance a relative density. In addition, in the conventional manufacturing method, old powder grain boundaries in the raw material powders, in which large amounts of impurities such as oxygen and carbon are present, are easily maintained even after the sintering. Therefore, in the grain boundaries of the electrical contact material after the sintering, the impurities such as the oxygen and the carbon remain in a concentrated manner. These remaining impurities reduce an electrical conductivity and a transverse rupture strength of the material.

[0046] In contrast to this, the sintered body subjected to the coining process is extruded as described above, thereby allowing the relative density to be enhanced, causing the old powder grain boundaries to be elongated and silver particles having a high purity to contact one another, and making an influence of the old powder grain boundaries in the raw material powder extremely small. As a result, since not only a relative density of 98% or more can be obtained, but also a quantity of the impurities remaining in the grain boundaries can be decreased, the electrical conductivity and the transverse rupture strength of the electrical contact material are enhanced.

[0047] If the preheating temperature is less than 850°C, deformation resistance of the extruded material is increased, whereby it is likely that the material cannot be extruded. If the preheating temperature exceeds 920°C, the temperature upon the extrusion exceeds a melting point of the silver, whereby it is likely that a surface of the extruded material is foamed. If the preheating time is less than 1 hour, since the heating causing the heat to reach the inside of the material is not conducted, the deformation resistance is increased, whereby it is likely that the material cannot be extruded. If the preheating time exceeds 2 hours, the material is sufficiently and evenly heated, whereby it is likely that productivity becomes worse.

[0048] If the extrusion pressure is less than 180 GPa, it is likely that a relative density of the extruded material is reduced. If the extrusion pressure exceeds 250 GPa, it is likely that an extrusion die is broken.

[0049] In each of the methods for manufacturing electrical contact materials, disclosed in Patent Literature 1 and Patent Literature 2, the sintered body is repressurized, thereby enhancing the relative density. However, as described above, in the grain boundaries of the electrical contact material after the sintering, the impurities such as the oxygen and the carbon remain in the concentrated manner. These remaining impurities causes a problem in that the electrical conductivity and the transverse rupture strength of the material are reduced. In addition, when the sintered body is repressurized, it is required to restrain an outer circumferential direction of the sintered body without interstices. Therefore, it is required to individually set a sintered body in a mold to be pressurized. As a result, there arises a problem in that a production cost is increased.

[0050] In contrast to this, in order to manufacture the above-described electrical contact material formed of the silver-tungsten carbide-graphite (Ag-WC-Gr) based material, according to the present invention, the extrusion method is adopted. Therefore, the electrical contact material having the relative density of 98% or more can be manufactured by employing the method of high mass production performance. As a result, the production cost can be reduced.

[0051] In summary, in the electrical contact material according to the present invention, a high electrical conductivity in the material including 10% by mass or more and 30% by mass or less of the tungsten carbide which is the refractory can be obtained. Since this allows heat generation upon breaking to be reduced, the welding resistance, the wear-out resistance, and the temperature performance can be enhanced. In addition, since the transverse rupture strength of the electrical contact material according to the present invention is high, as compared with the conventional electrical contact material, destruction of the contact in the short-circuit test in which a contact load is large can be reduced.

EXAMPLES

[0052] Hereinafter, a comparison experiment conducted for confirming effects of the above-described embodiment and using examples and comparison examples will be described below.

[0053] [Examples]

[0054] In the present examples as examples each corresponding to the above-described embodiment, electrical contact materials 31 of fixed sides in the following examples 1 through 15 were prepared. In addition, as comparison examples using the conventional manufacturing method, the electrical contact materials 31 of fixed sides according to the following comparison examples 1 through 4 were prepared. By using each breaker for a large current, which was configured by incorporating each of these electrical contact materials 31 and whose rated current value was 125A, breaking tests in an overload test and a short-circuit test were conducted. Each electrical contact material 21 on a moving side was configured by using a material in which 50% by mass of silver was included and the remainder was composed of tungsten carbide.

[0055] In the examples according to the present invention and the comparison examples, an average particle diameter of a graphite (Gr) powder used for preparing each of the electrical contact materials 31; a content of graphite (Gr) in each of the prepared electrical contact materials 31; an average particle diameter of the tungsten carbide (WC) powder; a content of the tungsten carbide (WC) in each of the prepared electrical contact material 31; and a relative density, an oxygen content, an electrical conductivity, and a transverse rupture strength of each of the electrical contact materials 31 are shown in below Table 1. In addition, the evaluation results regarding a wear-out rate of each of the electrical contact materials 31 after the overload test, a wear-out rate of each of the electrical contact materials 31 after the short-circuit test, and a temperature test are also shown in Table 1. The underlined numerical values in Table 1 show that the underlined numerical values are out of the ranges in the present invention.

[0056] Methods of measuring a relative density, an oxygen content, an electrical conductivity, and a transverse rupture strength, methods of the breaking tests in the overload test and the short-circuit test of each breaker for a large current, evaluations of the wear-out rates after these breaking tests, and a method and an evaluation of the temperature test will be described later.

[0057] (Examples 1 through 15)

[0058] In examples 1 through 15, each of the electrical contact materials 31 formed of the silver-tungsten carbide-graphite (Ag-WC-Gr) based material including the graphite (Gr) and the tungsten carbide (WC) whose contents are shown in Table 1 was prepared as described below.

[0059] A graphite (Gr) powder and a tungsten carbide (WC) powder each having an average particle diameter shown in Table 1 and a silver (Ag) powder having an average particle diameter of 3 μm were mixed in a vacuum (100 Pa) for 45 minutes by using a dry-type ball mill so as to have a Gr content and a WC content shown in Table 1. A pressure of 300 MPa was applied to each of the obtained mixed powders by using a press, thereby forming each disc-like compression compact having a thickness of 300 mm and an external diameter of 80 mm. Each of these compression compacts was retained in a hydrogen gas, which was a reducing gas atmosphere and had a temperature of 1050°C, for 1.5 hours, whereby each of these compression compacts was subjected to sintering. Each of these sintered bodies was subjected to a coining process under a pressure of 1100 MPa so as to have a true density of 97% or more. Each of the sintered bodies subjected to the coining process was preheated by retaining each of the sintered bodies in a hydrogen gas, which was a reducing gas atmosphere and had a temperature of 900°C, for 1.5 hours, and thereafter, an extrusion pressure of 220 GPa was applied to each of the sintered bodies, thereby extruding each of the sintered bodies so as to obtain each rod-like body having a cross section of a 10 mm square. Each of the obtained rod-like bodies was cut so as to have a thickness of 1 mm, thereby preparing each electrical contact material 31.

[0060] (Comparison Example 1)

[0061] In comparison example 1, an electrical contact material 31 of a silver-tungsten carbide-graphite (Ag-WC-Gr) based material including a graphite (Gr) and a tungsten carbide (WC) whose contents are shown in Table 1 was prepared as described below.

[0062] The graphite (Gr) powder and the tungsten carbide (WC) powder each having an average particle diameter shown in Table 1 and a silver (Ag) powder having an average particle diameter of 3 μm were mixed in the air for 30 minutes by hand work so as to have a Gr content and a WC content shown in Table 1. A pressure of 300 MPa was applied to the obtained mixed powder by using a press, thereby forming a plate-like compression compact having a planar shape of a 10 mm square and a thickness of 1 mm. This compression compact was retained in a vacuum which had a temperature of 900°C, for 1 hour, whereby this compression compact was subjected to sintering. This sintered body was subjected to a coining process under a pressure of 500 MPa so as to have a true density of 97% or more. As described above, the electrical contact material 31 was obtained.

[0063] (Comparison Example 2)

[0064] In comparison example 2, in accordance with the same steps as in the above-described examples 1 through 15 except that the step of subjecting the sintered body to the coining process was not conducted, an electrical contact material 31 of a silver-tungsten carbide-graphite (Ag-WC-Gr) based material including a graphite (Gr) and a tungsten carbide (WC) having the same average particle diameters and contents as those of example 1 as shown in Table 1 was prepared.

[0065] (Comparison Example 3)

[0066] In comparison example 3, in accordance with the same steps as in the above-described examples 1 through 15 except that a compression compact was retained in a nitrogen gas, which was a protective gas atmosphere and had a temperature of 950°C, for 1 hour, whereby the compression compact was subjected to sintering, an electrical contact material 31 of a silver-tungsten carbide-graphite (Ag-WC-Gr) based material including a graphite (Gr) and a tungsten carbide (WC) having the same average particle diameters and contents as those of example 1 as shown in Table 1 was prepared.

[0067] (Comparison Example 4)

[0068] In comparison example 4, in accordance with the same steps as in the above-described examples 1 through 15 except that a silver powder, a graphite powder, and a tungsten carbide powder were mixed in the air, an electrical contact material 31 of a silver-tungsten carbide-graphite (Ag-WC-Gr) based material including a graphite (Gr) and a tungsten carbide (WC) having the same average particle diameters and contents as those of example 1 as shown in Table 1 was prepared.

[0069] (Relative density)

[0070] A relative density [%] of each of the prepared electrical contact materials was calculated by dividing a density, which was calculated by dividing a weight of each of the electrical contact materials by a volume (a value obtained as the product by calculating the expression: a length dimension × a width dimension × a thickness dimension) of each of the electrical contact materials, by a theoretical density of each of the materials.

[0071] (Oxygen content)

[0072] Measurement of each oxygen content [ppm] remaining in each of the prepared electrical contact materials was conducted by employing an infrared absorption method and using an oxygen analyzer (model: BMGA520) produced by HORIBA, Ltd.

[0073] (Electrical conductivity)

[0074] By using a sample of each of the electrical contact materials, having a cross section shape of a 10 mm square, an electrical conductivity [% IACS] was measured by means of SIGMATESTER (manufactured by FOERSTER INSTRUMENTS, model: SIGMATEST D).

[0075] (Transverse rupture strength)

[0076] Each sample for a transverse test, having a size of 5 mm × 2 mm × 30 mm, was prepared by using the same material as each of the prepared electrical contact materials. By using each of these samples, each transverse rupture strength [MPa] was measured under the condition that a distance between fulcra was 15 mm and a head speed was 1 mm/min.

[0077] (Breaking test (overload test) of breaker for large current)

[0078] In an overload test, a load voltage of 220V and a breaking current of 600A were set. As a test method, a CO duty (a test in which a breaker is set in a circuit in which a breaking current of 600A flows with a load voltage of 220V, and in a state where a switch of the breaker is off, the switch is turned on in a forced manner, thereby instantaneously breaking a current) was performed at 50 times. A wear-out rate of each of the electrical contact materials 31 after the overload test was calculated by using the following expression. In Table 1, as evaluations of the wear-out rate, "◎" shows that the calculated wear-out rate was less than or equal to 5%, "o" shows that the calculated wear-out rate was less than or equal to 10%, and "×" shows that the wear-out rate exceeded 10%.

[0079] (Wear-out rate of electrical contact material) = [[(Thickness of electrical contact material before test) - (Thickness of electrical contact material after test)]/(Thickness of electrical contact material before test)] × 100(%) --- (Expression 1)

[0080] (Breaking test (short-circuit test) of breaker for large current)

[0081] In a short-circuit test, a load voltage of 220V and a breaking current of 5000A were set. As a test method, an O duty (a test in which in a state where a switch of a breaker is on, a breaking current is flowed, thereby breaking a current) and a CO duty (a test in which a breaker is set in a circuit in which a breaking current of 5000A flows with a load voltage of 220V, and in a state where a switch of the breaker is off, the switch is turned on in a forced manner, thereby instantaneously breaking a current) were performed in the following procedure. In other words, in this short-circuit test, as an operating duty, the O duty at one time and the CO duties at three times were performed in this order. A wear-out rate of each of the electrical contact materials 31 after the short-circuit test was calculated by using the above-mentioned (Expression 1). In Table 1, as evaluations of the wear-out rate, "◎" shows that the calculated wear-out rate was less than or equal to 10%, "o" shows that the calculated wear-out rate was less than or equal to 40%, and "×" shows that the wear-out rate exceeded 40%.

[0082] (Welding test of breaker for large current)

[0083] In the welding test, a load voltage of 265V and a breaking current of 5000A were set. As a test method, an O duty (a test in which in a state where a switch of a breaker is on, a breaking current is flowed, thereby breaking a current) and a CO duty (a test in which a breaker is set in a circuit in which a breaking current of 5000A flows with a load voltage of 265V, and in a state where a switch of the breaker is off, the switch is turned on in a forced manner, thereby instantaneously breaking a current) were performed in the following procedure. In other words, in this welding test, as an operating duty, the O duty at one time and the CO duties at five times were performed in this order. A welding condition of each of the electrical contact materials 31 during the welding test or after the welding test was evaluated. In Table 1, as evaluations of the welding condition, "◎" shows that no welding of each of the contacts occurred at all, "o" shows that the welding was easily detached by turning on/off each of the breakers (light welding), "x" shows that the welding was not easily detached by turning on/off each of the breakers (heavy welding).

[0084] (Temperature test)

[0085] A rated current was applied after the overload test and after the breaking test, and when a temperature became stable, a temperature of a terminal of a breaker was measured. In Table 1, "◎" shows that a temperature rise was less than 75K, "o" shows that the temperature rise was 75K or more and less than 80K, and "×" shows that the temperature rise was 80K or more.

[0086] [Table 1]

	Gr average particle diameter [μm]	Gr content [% by mass]	WC average particle diameter [μm]	WC content [% by mass]	Relative density [%]	Oxygen content [ppm]	Electrical conductivity [%IACS]	Transverse rupture strength [MPa]	Overload test Wear-out rate	Short-circuit test Wear-out rate	Welding test	Temperature test
Example 1	5	3	1	45	99.1	300	54	410	◎	◎	◎	◎
Example 2	5	3	1	31	99.2	260	57	350	◎	◎	o	◎
Example 3	5	3	1	40	99.0	280	55	380	◎	◎	◎	◎
Example 4	5	3	1	50	98.5	350	50	460	◎	o	◎	o
Example 5	5	3	1	55	98.1	410	45	510	◎	o	◎	o
Example 6	5	2	1	45	99.0	250	56	400	◎	◎	◎	o
Example 7	5	4	1	45	99.2	320	50	420	◎	o	◎	◎
Example 8	5	5	1	45	99.2	350	46	430	o	o	◎	◎
Example 9	5	3	0.6	45	99.0	450	48	460	◎	◎	◎	o
Example 10	5	3	3	45	99.4	210	61	380	◎	o	◎	◎
Example 11	5	3	5	45	99.6	120	65	350	o	o	o	◎
Example 12	1	3	1	45	98.3	360	50	370	◎	o	◎	◎
Example 13	10	3	1	45	99.2	240	55	385	◎	◎	o	◎
Example 14	25	3	1	45	99.4	230	56	390	◎	o	o	◎
Example 15	50	3	1	45	99.6	200	57	380	o	o	o	◎
Comparison Example 1	5	3	1	45	93.7	380	40	260	×	×	×	×
Comparison Example 2	5	3	1	45	97.1	530	43	300	o	×	×	×
Comparison Example 3	5	3	1	45	98.5	590	44	270	×	×	×	×
Comparison Example 4	5	3	1	45	98.6	390	54	275	o	×	×	×

[0087] It is seen from Table 1 that in the breaker for a large current using the electrical contact material 31 of the silver-tungsten carbide-graphite (Ag-WC-Gr) based material and having the rated current value of 125A, each of the electrical contact materials 31 (examples 1 through 15) was configured such that more than 30% by mass and 55% by mass or less of the tungsten carbide and 2% by mass or more and 5% by mass or less of the graphite were included, the remainder including the silver and unavoidable impurity, the relative density was 98.0% or more, the oxygen content is 450 ppm or less, the electrical conductivity was 45% IACS or more, and the transverse rupture strength was 350 MPa or more, thereby allowing not only the wear-out rate after the overload test but also the wear-out amount after the short-circuit test to be reduced, the welding after the breaking test by the short-circuit test to be prevented, and further, the temperature rise after the overload test and after the breaking test to be suppressed.

[0088] The described embodiment and examples are to be considered in all respects only as illustrative and not restrictive. It is intended that the scope of the invention is, therefore, indicated by the appended claims rather than the foregoing description of the embodiment and examples and that all modifications and variations coming within the meaning and equivalency range of the appended claims are embraced within their scope.

[0089] For example, in the above-described embodiment and examples, an example in which each of the electrical contact materials 31 according to the present invention is applied to the fixed-side contact member 30 of the breaker 10 is described. However, the present invention is not limited to this example, and each of the electrical contact materials according to the present invention may be used for either the moving-side contact member 20 or the fixed-side contact member 30 of the breaker 10. It is preferable that the electrical contact material according to the present invention is incorporated into a breaker 10 whose rated current value is approximately 100A through 1600A, and it is more preferable that the electrical contact material according to the present invention is incorporated into a breaker 10 whose rated current value is 100A or more and less than 800A.

[0090] In addition, in the above-described embodiment and examples, an example in which the electrical contact material 31 according to the present invention is used for the breaker 10 as one example of a switch is described. However, the present invention is not limited to this example, and the electrical contact material according to the present invention may be used for, for example, a switch (switching device), such as an electromagnetic switch, other than the breaker.

INDUSTRIAL APPLICABILITY

[0091] An electrical contact material according to the present invention is used by being incorporated into a breaker whose rated current value is 100A through 1600A.

REFERENCE SIGNS LIST

[0092] 10: breaker, 21, 31: electrical contact material.

Claims

1. An electrical contact material (31) including more than 30% by mass and 55% by mass or less of tungsten carbide and 2% by mass or more and 5% by mass or less of graphite, the remainder including silver and an unavoidable impurity, the electrical contact material (31): having a relative density of 98.0% or more; an oxygen content of 450 ppm or less; an electrical conductivity of 45% IACS or more; and a transverse rupture strength of 350 MPa or more.

2. The electrical contact material (31) according to claim 1, wherein an average particle diameter of the tungsten carbide is 0.5 μm or more and 5 μm or less.

3. The electrical contact material (31) according to claim 1, wherein an average particle diameter of the graphite is 1 μm or more and 50 μm or less.

FIG.1

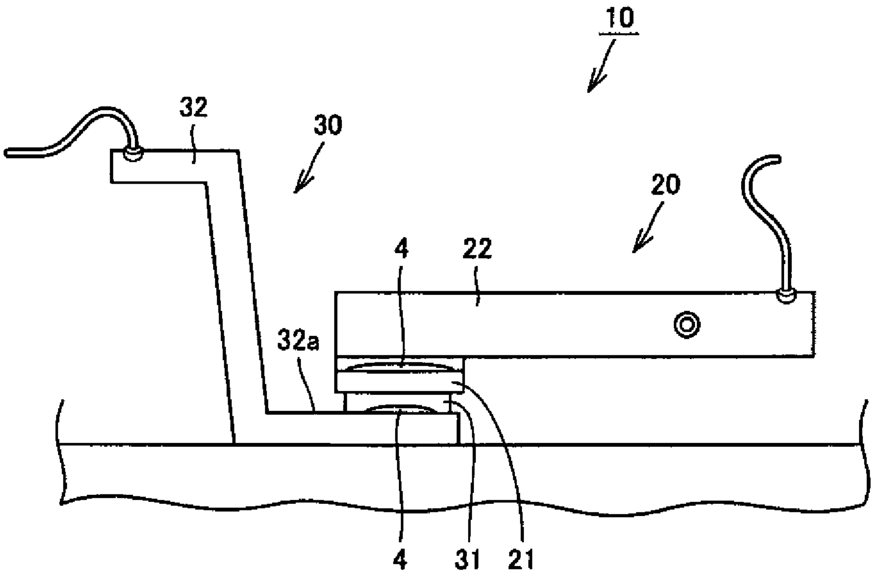
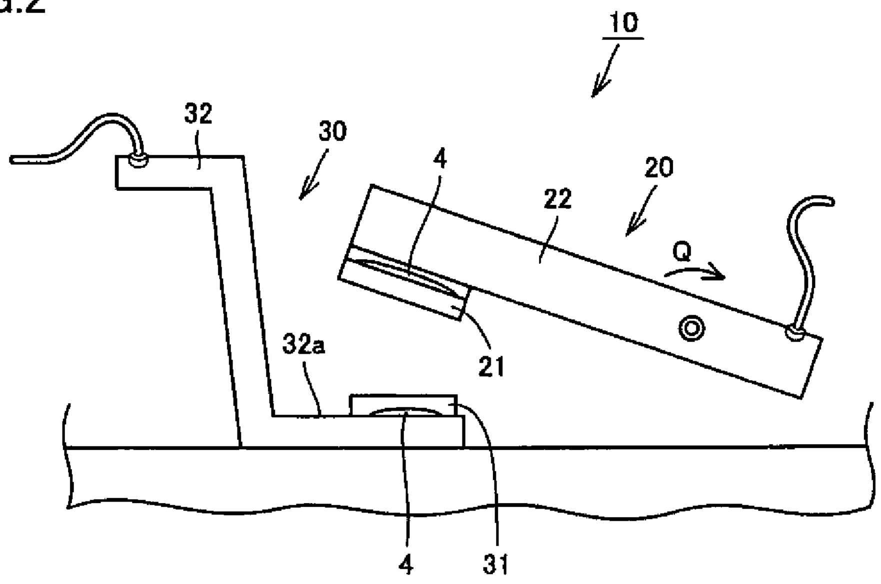


FIG.2



INTERNATIONAL SEARCH REPORT

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A. CLASSIFICATION OF SUBJECT MATTER
C22C32/00(2006.01)i, *C22C5/06*(2006.01)i, *C22C29/08*(2006.01)i, *H01H1/021*(2006.01)i, *H01H1/023*(2006.01)i, *C22C1/05*(2006.01)n

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)
C22C32/00, C22C5/06, C22C29/08, H01H1/021, H01H1/023, C22C1/05

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

Jitsuyo Shinan Koho	1922-1996	Jitsuyo Shinan Toroku Koho	1996-2011
Kokai Jitsuyo Shinan Koho	1971-2011	Toroku Jitsuyo Shinan Koho	1994-2011

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	JP 52-147768 A (Sumitomo Electric Industries, Ltd.), 08 December 1977 (08.12.1977), claims; tables 2, 3 (Family: none)	1-3
A	JP 7-192565 A (Toshiba Corp.), 28 July 1995 (28.07.1995), claims 1 to 4 (Family: none)	1-3
A	JP 58-11754 A (Sumitomo Electric Industries, Ltd.), 22 January 1983 (22.01.1983), claims; tables 1, 2, 3 & US 4457780 A & FR 2503926 A1 & DE 3213265 A	1-3

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

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Date of the actual completion of the international search	Date of mailing of the international search report
25 August, 2011 (25.08.11)	06 September, 2011 (06.09.11)

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- JP 58011754 A **[0004] [0005]**