(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 2 413 337 A1

(12) EUROPEAN PATENT APPLICATION
published in accordance with Art. 153(4) EPC

(43) Date of publication:
01.02.2012 Bulletin 2012/05

(21) Application number: 10755584.9

(22) Date of filing: 03.03.2010

(51) Int Cl.:
H01H 1/023 (2006.01) *C22C 1/05* (2006.01)
C22C 1/10 (2006.01) *C22C 5/06* (2006.01)
C22C 32/00 (2006.01)

(86) International application number:
PCT/JP2010/001444

(87) International publication number:
WO 2010/109777 (30.09.2010 Gazette 2010/39)

(84) Designated Contracting States:
AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO SE SI SK SM TR

(30) Priority: 24.03.2009 JP 2009071526

(71) Applicant: A.L.M.T. Corp.
Minato-ku
Tokyo 105-0014 (JP)

(72) Inventors:
- HATAKEYAMA, Takashi
Itami-shi
Hyogo 664-0016 (JP)
- UENISHI, Noboru
Itami-shi
Hyogo 664-0016 (JP)
- SUZUKI, Yasuhiko
Itami-shi
Hyogo 664-0016 (JP)
- GOMA, Norihito
Itami-shi
Hyogo 664-0016 (JP)

(74) Representative: Setna, Rohan P.
Boult Wade Tennant
Verulam Gardens
70 Gray's Inn Road
London WC1X 8BT (GB)

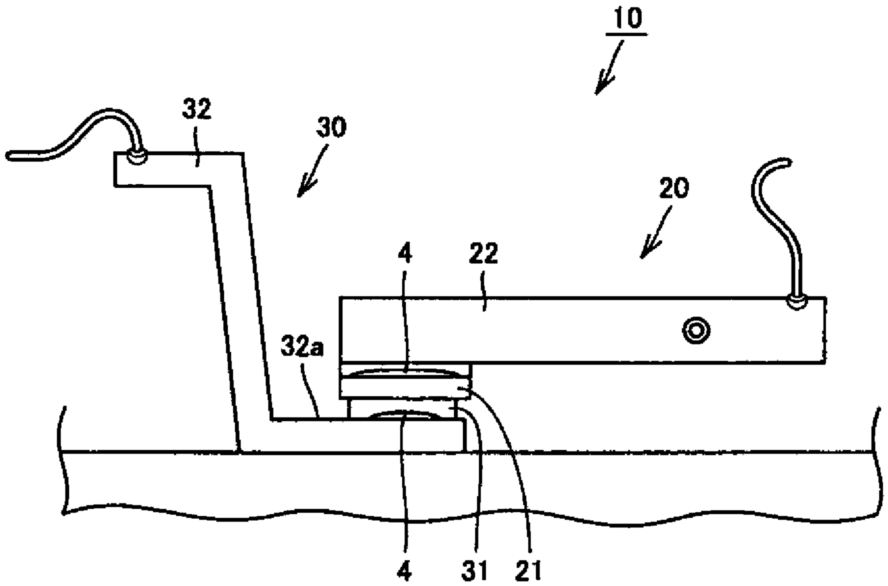
(54) ELECTRICAL CONTACT MATERIAL

(57) Provided are an electrical contact material capable of reducing wear-out rates after breaking tests in an overload test and a short-circuit test of a breaker or the like; and an electrical contact material capable of preventing welding after breaking tests in a short-circuit test of a breaker or the like. The electrical contact material (31) according to one aspect includes 4% by mass or more and 7% by mass or less of graphite, the remainder is composed of silver and an unavoidable impurity, a deflection thereof is greater than or equal to 0.5 mm, a Vickers hardness thereof is greater than or equal to 55, and an oxygen content therein is less than or equal to 100 ppm. It is preferable that the electrical contact material (31) further includes a tungsten carbide. It is preferable that an average particle diameter of the tungsten carbide is greater than or equal to 40 nm and less than or equal to 3 μm and a content of the tungsten carbide is greater than or equal to 2% by mass and less than or equal to 4% by mass. The electrical contact material (31) according to another aspect includes 0.5% by mass or more and 2% by mass or less of graphite, the remainder is composed of silver and an unavoidable impurity, a deflection thereof is greater than or equal to 0.8 mm, a Vickers hardness thereof is greater than or equal to 40, and an oxygen content therein is less than or equal to 100 ppm.

Printed by Jouve, 75001 PARIS (FR)

(Cont. next page)

FIG.1



Description

TECHNICAL FIELD

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

BACKGROUND ART

[0002] Conventionally, an electrical contact material made of a silver-graphite based material has been well known.
[0003] For example, Japanese Patent Application Laid-Open Publication No. 8-239724 (hereinafter, referred to as Patent Document 1) discloses a material for an electrical contact, made of silver, a silver alloy, or a silver composite material, which contains 0.05 through 7% by weight of carbon. In this material for an electrical contact, the carbon which is in the form of carbon black having an average primary particle diameter of less than 150 nm is added to a powder of the silver, the silver alloy, or the silver composite material, and this mixture is subjected to cold hydrostatic pressure compression through extrusion and to sintering.
[0004] Japanese Patent No. 3138965 (hereinafter, referred to as Patent Document 2) discloses a composite material for an electrical contact, which is made of silver, a silver-containing alloy, or a silver-containing composite material and 0.5 through 10% by weight of carbon. This composite material for an electrical contact is formed by subjecting a carbon powder in combination with carbon fibers and a powdery metal composition to a powder metallurgy process so as to have an average length of the carbon fibers being greater than or equal to twice as long as an average diameter of carbon powder particles.
[0005] Japanese Patent Application Laid-Open Publication No. 2007-169701 (hereinafter, referred to as Patent Document 3) discloses a material for an electrical contact, which is a sintered compact of a composite powder whose chief ingredient is a silver powder. This material for an electrical contact is manufactured by conducting a step of mixing a chief material whose chief ingredient is the silver powder and the carbon fine powder through mechanical alloying to obtain a mixed powder, wherein the silver is formed by dispersively mixing a carbon fine powder into the silver powder, a step of compacting this composite powder to form a compact, and a step of sintering this compact.

CITATION LIST

PATENT LITERATURE

[0006]

Patent Document 1: Japanese Patent Application Laid-Open Publication No. 8-239724
Patent Document 2: Japanese Patent No. 3138965
Patent Document 3: Japanese Patent Application Laid-Open Publication No. 2007-169701

SUMMARY OF THE INVENTION

TECHNICAL PROBLEM

[0007] When a breaker is formed by using an electrical contact material made of a silver-graphite based material, since electrical conductivity of the electrical contact material is high, heat is hardly generated and very few adverse effects due to heat generation are caused. However, in a short-circuit breaking test in which the electrical contact material made of the silver-graphite based material is used, there is a problem in that due to a thermal shock and a mechanical shock exerted on the electrical contact material, a wear-out rate of the electrical contact material after the test becomes large.
[0008] Therefore, an object of the present invention is to provide an electrical contact material capable of reducing a wear-out rate after breaking tests in an overload test and a short-circuit test of a breaker and the like.
[0009] In addition, another object of the present invention is to provide an electrical contact material capable of preventing welding after the breaking tests in the overload test and the short-circuit test of a breaker and the like.

SOLUTION TO PROBLEM

[0010] The present inventors have conducted various studies regarding causes of a large wear-out rate of an electrical contact material, caused after a short-circuit breaking test of a breaker using an electrical contact material made of a silver-graphite based material.

[0011] First, since a breaking current of a breaker for a large current, whose rated current value is approximately 100A through 3200A, is large, a relatively large current flows in an electrical contact material incorporated into such a breaker. Therefore, a high thermal resistance rather than high electrical conductivity is required of this electrical contact material. In order to meet this requirement, an electrical contact material in which a content of silver in a silver-graphite based material is relatively low and a content of graphite therein is relatively high is used for the breaker for a large current. Specifically, the electrical contact material used for the breaker for a large current includes 4% by mass or more and 7% by mass or less of graphite, and the remainder is composed of silver and an unavoidable impurity.

[0012] In the breaking test of the breaker for a large current, contact erosion, caused after a short-circuit test in which an operation of turning first on and next off is performed with a large breaking current, is important. It has been considered that since the operation of turning first on and next on is instantaneously performed under a condition of a large breaking current, the wear-out of the electrical contact material in this short-circuit test is caused by large thermal energy and large mechanical shock, exerted on the electrical contact material in the short-circuit breaking test conducted one time.

[0013] However, the present inventors have devoted themselves to studies regarding the causes of the wear-out of the electrical contact material, caused after the short-circuit test of the breaker for a large current, and as a result, found that at least a hardness of the electrical contact material at an ordinary temperature is set to be relatively large, being greater than or equal to a specific value; further, a deflection amount is set to be relatively large, being greater than or equal to a specific value; an oxygen content is suppressed to be less than or equal to a specific value; and an electrical contact material is formed so as to avoid deformation in a state where heat is generated by flowing of a large current (under a high temperature), thereby allowing a wear-out amount after the short-circuit test to be reduced. Based on these findings, an electrical contact material according to one aspect of the present invention has the following features.

[0014] The electrical contact material according to the one aspect of the present invention includes 4% by mass or more and 7% by mass or less of graphite, the remainder includes silver and an unavoidable impurity, a deflection thereof is greater than or equal to 0.5 mm, a Vickers hardness thereof is greater than or equal to 55, and an oxygen content therein is less than or equal to 100 ppm.

[0015] In the electrical contact material according to the one aspect of the present invention, it is preferable that a transverse rupture strength is greater than or equal to 210 MPa.

[0016] In addition, in electrical contact material according to the one aspect of the present invention, it is preferable that an average particle diameter of the graphite is greater than or equal to 40 nm and less than or equal to 8 μm.

[0017] Furthermore, in order to prevent welding after a breaking test in a short-circuit test, it is preferable that the electrical contact material according to the one aspect of the present invention further includes a tungsten carbide.

[0018] In this case, it is preferable that an average particle diameter of the tungsten carbide is greater than or equal to 40 nm and less than or equal to 3μ m and a content of the tungsten carbide is greater than or equal to 2% by mass and less than or equal to 4% by mass. It is further preferable that an average particle diameter of the tungsten carbide is greater than or equal to 40 nm and less than or equal to 150 nm.

[0019] Next, since a breaking current of a breaker for a small current, whose rated current value is approximately 1 through 60A, is small, a relatively small current flows in an electrical contact material incorporated into such a breaker. Therefore, high electrical conductivity rather than a high thermal resistance is required of this electrical contact material. In order to meet this requirement, an electrical contact material in which a content of silver in a silver-graphite based material is relatively high and a content of graphite therein is relatively low is used for the breaker for a small current. Specifically, the electrical contact material used for the breaker for a small current includes 0.5% by mass or more and 2% by mass or less of graphite, and the remainder is composed of silver and an unavoidable impurity.

[0020] In a breaking test of the breaker for a small current, contact erosion, caused after an overload test in which an operation of turning first on and next off is repeated at a multitude of times with a small breaking current is, is important. Conventionally, however, it has been considered that since in the breaking test of the breaker for a small current, the operation of turning first on and next off is instantaneously performed under a condition of a small breaking current, a mechanical shock exerted on the electrical contact material when an overload test is conducted at one time is small and the electrical contact material is less damaged by the mechanical shock.

[0021] However, the present inventors have devoted themselves to studies regarding the causes of the wear-out of the electrical contact material, caused after the overload test of the breaker for a small current, and as a result, found that at least a deflection amount of the electrical contact material is set to be relatively large, being greater than or equal to a specific value; further, a hardness of the electrical contact material at an ordinary temperature is set to be relatively large, being greater than or equal to a specific value; an oxygen content is suppressed to be less than or equal to a specific value; and the electrical contact material is formed so as to be capable of enduring a mechanical shock repeated at a multitude of times, thereby allowing a wear-out amount after the overload test to be reduced. Based on these findings, an electrical contact material according to another aspect of the present invention has the following features.

[0022] The electrical contact material according to the another aspect of the present invention includes 0.5% by mass or more and 2% by mass or less of graphite, the remainder includes silver and an unavoidable impurity, a deflection thereof is greater than or equal to 0.8 mm, a Vickers hardness thereof is greater than or equal to 40, and an oxygen content therein is less than or equal to 100 ppm.

[0023] In the electrical contact material according to the another aspect of the present invention, it is preferable that a transverse rupture strength is greater than or equal to 120 MPa.

[0024] In addition, in the electrical contact material according to the another aspect of the present invention, it is preferable that an average particle diameter of the graphite is greater than or equal to 40 nm and less than or equal to 8 μm.

ADVANTAGEOUS EFFECTS OF THE INVENTION

[0025] As described above, according to the present invention, a wear-out rate of an electrical contact material, incorporated into a breaker for a large current, after a short-circuit test can be reduced. In addition, a wear-out rate of an electrical contact material, incorporated into a breaker for a small current, after an overload test can be reduced. In addition, by causing the electrical contact material of the breaker for a large current to further include a tungsten carbide, welding after a breaking test in the short-circuit test can be prevented.

BRIEF DESCRIPTION OF THE DRAWINGS

[0026] 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

[0027] First, a configuration of a breaker into which an electrical contact material as one embodiment of the present invention is incorporated will be described.

[0028] 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.

[0029] 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.

[0030] 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.

[0031] First, in one aspect of the present invention, the electrical contact material 21 on the moving side, incorporated into the breaker 10 for a large current whose rated current value is approximately 100A through 3200A, is made of a silver-tungsten carbide (Ag-WC) based material, and the electrical contact material 31 on the fixed side is made of a silver-graphite (Ag-Gr) based material in which 4% by mass or more and 7% by mass or less of graphite is included, the remainder includes silver and an unavoidable impurity, a deflection is greater than or equal to 0.5 mm, a Vickers hardness is greater than or equal to 55, and an oxygen content is less than or equal to 100 ppm.

[0032] As described above, at least the hardness of the electrical contact material 31 at an ordinary temperature is set to be relatively large, being greater than or equal to the specific value; the deflection amount is set to be relatively large, being greater than or equal to the specific value; the oxygen content is suppressed to be less than or equal to the specific value; and the electrical contact material 31 is formed so as to avoid deformation in a state where heat is generated by flowing of a large current (under a high temperature), thereby allowing a wear-out amount after a short-circuit test to be reduced.

[0033] When in the silver-graphite (Ag-Gr) based material, a content of the graphite is increased, since the graphite particles finely dispersed in the material bring about a pinning effect, the material is reinforced. This enhances the hardness and a transverse rupture strength of the material. If a content of the graphite is less than 4% by mass, the pinning effect cannot be obtained. If a content of the graphite exceeds 7% by mass, since the pinning effect becomes excessive, a deflection amount is decreased.

[0034] Since in the short-circuit test for a large current application, a shock is great, a material having a relatively large strength is required. However, to endure repeated opening and closing (repetitive shocks) of the breaker in an overload test, it is required that a deflection amount is greater than or equal to 0.5 mm. If a deflection amount is less than 0.5 mm, since toughness of the material is low, the above-mentioned repetitive shocks cause cracking in the electrical contact material 31. However, for the reason of difficulty in manufacturing, it is preferable that a deflection amount is less than or equal to 2 mm. Here, the "difficulty in manufacturing" means that however large a deflection amount may be desired to be, 2 mm is the limit thereof in manufacturing.

[0035] Since in the short-circuit test for a large current application, a shock is great, to endure the shock, it is required that a Vickers hardness is greater than or equal to 55. If a Vickers hardness is less than 55, due to an insufficiency of a hardness of a material, a contact shape cannot be maintained in the short-circuit test in which a contact load is large. In the overload test, since a contact load is small, a Vickers hardness hardly exerts an influence on the contact shape. However, because an excessively large hardness increases a contact resistance between contacts, it is preferable that a Vickers hardness is less than or equal to 150.

[0036] If an oxygen content exceeds 100 ppm, since oxygen present in a material is gasified by a high heat of several thousand degrees generated during the short-circuit test, a part of a base material of the electrical contact material 31 is dispersed. This increases a rate at which the electrical contact material 31 is worn out. In the overload test, since a contact load is small, an oxygen content hardly exerts an influence on a rate at which the electrical contact material 31 is worn out. However, for the reason of difficulty in manufacturing, it is preferable that an oxygen content is greater than or equal to 20 ppm. Here, the "difficulty in manufacturing" means that however small an oxygen content may be desired to be, 20 ppm is the limit thereof in manufacturing.

[0037] In the electrical contact material 31 according to the one aspect of the present invention, since in the short-circuit test for a large current application, a shock is great, to endure the shock, it is preferable that a transverse rupture strength is greater than or equal to 210 MPa. If a transverse rupture strength is less than 210 MPa, in the short-circuit test in which a contact load is large, the electrical contact material 31 is destroyed due to an insufficiency of a mechanical strength of the material. In the overload test, since a contact load is small, a transverse rupture strength hardly exerts an influence. However, for the reason of difficulty in manufacturing, it is preferable that a transverse rupture strength is less than or equal to 300 MPa. Here, the "difficulty in manufacturing" means that however large a transverse rupture strength may be desired to be, 300 MPa is the limit thereof in manufacturing.

[0038] In addition, in the electrical contact material 31 according to the one aspect of the present invention, it is preferable that an average particle diameter of the graphite is greater than or equal to 40 nm and less than or equal to 8 μm. If an average particle diameter of the graphite is less than 40 nm, since the graphite particles are excessively fine, the graphite particles are densely crammed into interstices among the silver particles. Therefore, each area where a silver particle and a silver particle are in contact with each other becomes extremely small. Originally, the silver serves to retain a strength of the electrical contact material 31. However, even when a pressure is applied in a state where each area where a silver particle and a silver particle are in contact with each other is extremely small, since the silver becomes incapable of retaining a strength, it is difficult to form a compact. As a result, it is difficult to manufacture the electrical contact material 31. In addition, if an average particle diameter of the graphite exceeds 8 μm, a hardness and a transverse rupture strength of the electrical contact material 31 are reduced.

[0039] Furthermore, in order to prevent welding after a breaking test in the short-circuit test, it is preferable that the electrical contact material 31 according to the one aspect of the present invention further includes a tungsten carbide. The electrical contact material 31 further includes the tungsten carbide (WC), thereby allowing a hardness and a transverse rupture strength of the electrical contact material 31 to be further enhanced. For example, a Vickers hardness can be set to be greater than or equal to 70 and a transverse rupture strength can be set to be greater than or equal to 230 MPa. This allows a wear-out amount after the short-circuit test to be more effectively reduced.

[0040] In the silver-graphite (Ag-Gr) based material, the graphite particles are dispersed, for example, in fibrous form. When a contact and a contact get in contact with each other in the short-circuit test, since a high heat of several thousand degrees is generated, it becomes easy for the silver to liquate. This causes mutual welding of contacts. Therefore, by using the electrical contact material 31 made of a silver-graphite-tungsten carbide (Ag-Gr-WC) based material which further includes the tungsten carbide, it can be prevented that the silver comes up to a surface of the electrical contact material 31. Therefore, even if in the short-circuit test, the contacts get in contact with each other and a high heat is generated, it becomes difficult for the silver to liquate. As a result, the welding after the breaking test in the short-circuit test can be prevented.

[0041] In this case, it is preferable that an average particle diameter of the tungsten carbide is greater than or equal to 40 nm and less than or equal to 3 μm and that a content of the tungsten carbide is greater than or equal to 2% by mass and less than or equal to 4% by mass. If an average particle diameter of the tungsten carbide is less than 40 nm, it is difficult to prepare a powder of the tungsten carbide. If an average particle diameter of the tungsten carbide exceeds 3 μm, a variation of strengths among portions of the electrical contact material 31 is caused. If portions having low strengths come to be connected, the electrical contact material 31 is selectively worn out after the short-circuit test. If a content of the tungsten carbide is less than 2% by mass, since it is impossible to suppress the liquation of the silver, the electrical contact material 31 becomes inferior in welding resistance performance and an effect to enhance a hardness of the electrical contact material 31 is small. If a content of the tungsten carbide exceeds 4% by mass, since electrical conductivity of the electrical contact material 31 is worsened, a heat is easily generated. Therefore, a wear-out amount resulting when the electrical contact material 31 is short-circuited is increased.

[0042] It is further preferable that an average particle diameter of the tungsten carbide is greater than or equal to 40 nm and less than or equal to 150 nm. In a case where an average particle diameter of the tungsten carbide is greater than or equal to 40 nm and less than or equal to 150 nm, since the tungsten carbide particles can be evenly dispersed in the silver, the liquation of the silver can be more effectively suppressed. This allows the welding after the breaking test in the short-circuit test to be prevented. In other words, the welding resistance performance of the electrical contact material 31 can be enhanced. If an average particle diameter of the tungsten carbide exceeds 150 nm, since a multitude of the tungsten carbide particles are present on the surface of the electrical contact material 31, a heat is easily generated. Therefore, a wear-out amount resulting when the electrical contact material 31 is short-circuited is increased.

[0043] In a case where the electrical contact material 31 is prepared by using the silver-graphite-tungsten carbide (Ag-Gr-WC) based material further including the tungsten carbide, it is further preferable that an average particle diameter of the graphite is greater than or equal to 1 μm and less than or equal to 5 μm. In a case where an average particle diameter of the graphite is greater than or equal to 1 μm and less than or equal to 5 μm, since the graphite can be evenly dispersed in the electrical contact material, the electrical contact material can be reinforced. This allows a hardness and a transverse rupture strength of the electrical contact material to be enhanced. If an average particle diameter of the graphite is less than 1 μm, fine graphite particles and tungsten carbide particles are densely crammed into interstices among the silver particles after mixing of the raw powders. Therefore, each area where a silver particle and a silver particle are in contact with each other becomes extremely small. Originally, the silver serves to retain a strength of the electrical contact material 31. However, even when a pressure is applied in a state where each area where a silver particle and a silver particle are in contact with each other is extremely small, since the silver becomes incapable of retaining the strength, it is difficult to form a compact. In this case, as in the case of the graphite particles, because of the presence of the tungsten carbide particles which are fine particles and hinder mutual contacting of the silver particles, a permissible minimum particle diameter of the graphite particles is increased, as compared with that of the silver-graphite based material including only the graphite particles. If an average particle diameter of the graphite exceeds 5 μm, the number of the graphite particles serving as a lubricant for contacting of the silver particles and the tungsten carbide particles is decreased. Therefore, upon mixing the raw powders, the tungsten carbide particles are not evenly dispersed and are flocculated, and it becomes difficult to form an electrical contact material in which the tungsten carbide is evenly dispersed. Therefore, it is likely that an effect obtained by adding the tungsten carbide, that is, an effect to prevent the welding after the breaking test in the short-circuit test by more effectively suppressing the liquation of the silver cannot be obtained.

[0044] Next, in another aspect of the present invention, an electrical contact material 21 on a moving side, incorporated into a breaker 10 for a small current whose rated current value is approximately 1A through 60A, is made of a silver-tungsten carbide (Ag-WC) based material, and an electrical contact material 31 on a fixed side is made of a silver-graphite (Ag-Gr) based material in which 0.5% by mass or more and 2% by mass or less of graphite is included, the remainder includes silver and an unavoidable impurity, a deflection is greater than or equal to 0.8 mm, a Vickers hardness is greater than or equal to 40, and an oxygen content is less than or equal to 100 ppm.

[0045] As described above, at least a deflection amount of the electrical contact material 31 is set to be relatively large, being greater than or equal to a specific value; further, a hardness of the electrical contact material at an ordinary temperature is set to be relatively large, being greater than or equal to a specific value; the oxygen content is suppressed to be less than or equal to a specific value; and the electrical contact material 31 is formed so as to be capable of enduring a mechanical shock repeated at a multitude of times, thereby allowing a wear-out amount after the overload test to be reduced.

[0046] If in the silver-graphite (Ag-Gr) based material, a content of the graphite is increased, since the graphite particles finely dispersed in the material bring about a pinning effect, the material is reinforced. This enhances the hardness and a transverse rupture strength of the material. If a content of the graphite is less than 0.5% by mass, the pinning effect cannot be obtained. If a content of the graphite exceeds 2% by mass, since the pinning effect becomes excessive, a deflection amount is decreased.

[0047] Since in the short-circuit test for a small current application, a shock is small as compared with the large current application, a material having a relatively small strength is required to endure such a shock. Therefore, to endure repeated opening and closing (repetitive loads) of the breaker in the overload test, it is required that a deflection amount is greater than or equal to 0.8 mm. If a deflection amount is less than 0.8 mm, since toughness of the material is low, the above-mentioned repetitive loads cause cracking in the electrical contact material 31. However, for the reason of difficulty in manufacturing, it is preferable that a deflection amount is less than or equal to 2.5 mm. Here, the "difficulty in manufacturing" means that however large a deflection amount may be desired to be, 2.5 mm is the limit thereof in manufacturing.

[0048] Since in the short-circuit test for the small current application, a shock is small as compared with the large current application, to endure the shock, it is required that a Vickers hardness is greater than or equal to 40. If a Vickers hardness is less than 40, due to an insufficiency of the hardness of the material, a contact shape cannot be maintained in the short-circuit test in which a contact load is large. In the overload test, since a contact load is small, a Vickers hardness hardly exerts an influence on the contact shape. However, because an excessively large hardness increases a contact resistance between contacts, it is preferable that a Vickers hardness is less than or equal to 100.

[0049] If an oxygen content exceeds 100 ppm, since oxygen present in a material is gasified by a high heat of several thousand degrees generated during the short-circuit test, a part of a base material of the electrical contact material 31 is dispersed. This increases a rate at which the electrical contact material 31 is worn out. In the overload test, since a contact load is small, an oxygen content hardly exerts an influence on a rate at which the electrical contact material 31 is worn out. However, for the reason of difficulty in manufacturing, it is preferable that an oxygen content is greater than or equal to 30 ppm. Here, the "difficultly in manufacturing" means that however small an oxygen content may be desired to be, 30 ppm is the limit thereof in manufacturing.

[0050] In the electrical contact material 31 according to the another aspect of the present invention, since in the short-circuit test for the small current application, a shock is small as compared with the large current application, to endure the shock, it is preferable that a transverse rupture strength is greater than or equal to 120 MPa. If a transverse rupture strength is less than 120 MPa, in the short-circuit test in which a contact load is large, the electrical contact material 31 is destroyed due to an insufficiency of a mechanical strength of a material. In the overload test, since a contact load is small, a transverse rupture strength hardly exerts an influence. However, for the reason of difficulty in manufacturing, it is preferable that a transverse rupture strength is less than or equal to 280 MPa. Here, the "difficulty in manufacturing" means that however large a transverse rupture strength may be desired to be, 280 MPa is the limit thereof in manufacturing.

[0051] In addition, in the electrical contact material 31 according to the another aspect of the present invention, it is preferable that an average particle diameter of the graphite is greater than or equal to 40 nm and less than or equal to 8 μm. If an average particle diameter of the graphite is less than 40 nm, since the graphite particles are excessively fine, the graphite particles are densely crammed into interstices among the silver particles. Therefore, each area where a silver particle and a silver particle are in contact with each other becomes extremely small. Originally, the silver serves to retain a strength of the electrical contact material 31. However, even when a pressure is applied in a state where each area where a silver particle and a silver particle are in contact with each other is extremely small, since the silver becomes incapable of retaining a strength, it is difficult to form a compact. As a result, it is difficult to manufacture the electrical contact material 31. In addition, if an average particle diameter of the graphite exceeds 8 μm, a hardness and a transverse rupture strength of the electrical contact material 31 are reduced.

[0052] The electrical contact material 31 according to the present invention, made of the silver-graphite (Ag-Gr) based material, is manufactured as described below.

[0053] First, in accordance with predetermined composition, the silver powder and the graphite powder are mixed in, for example, a vacuum of 80 through 150 Pa for, for example, 30 through 60 minutes. Thereafter, a pressure of, for example, 250 through 350 MPa is applied to the mixed powder, thereby forming a compression compact. This compression compact is retained in, for example, an atmosphere of a reducing gas such as hydrogen gas, which has a temperature of, for example, 850˚C through 950˚C, for, for example, 1 through 2 hours, thereby conducting partial sintering. This partially sintered body is subjected to a coining process under a pressure of, for example, 1000 through 1200 MPa so as to allow a true density to be, for example, greater than or equal to 97%. After the partially sintered body subjected to the coining process is preheated by retaining the partially sintered body in an atmosphere of an inert gas such as nitrogen gas or an atmosphere of a reducing gas such as hydrogen gas or an atmosphere in which these gases are mixed, which has a temperature of, for example, 750˚C through 850˚C, for, for example, 1 through 2 hours, an extrusion pressure of 100 through 200 GPa is applied to the partially sintered body, thereby extruding the partially sintered body so as to have a predetermined shape.

[0054] In addition, the electrical contact material 31 according to the present invention, which includes the tungsten carbide and is made of the silver-graphite-tungsten carbide (Ag-Gr-WC) based material, is manufactured as described below.

[0055] First, in accordance with predetermined composition, the silver powder, the graphite powder, and the tungsten carbide powder are mixed in, for example, a vacuum of 80 through 150 Pa for, for example, 30 through 60 minutes. Thereafter, a pressure of, for example, 250 through 350 MPa is applied to the mixed powder, thereby forming a compression compact. This compression compact is retained in, for example, an atmosphere of a reducing gas such as hydrogen gas, which has a temperature of, for example, 850˚C through 950˚C, for, for example, 1 through 2 hours, thereby conducting partial sintering. This partially sintered body is subjected to a coining process under a pressure of, for example, 1000 through 1200 MPa so as to allow a true density to be, for example, greater than or equal to 97%. After the partially sintered body subjected to the coining process is preheated by retaining the partially sintered body in an atmosphere of an inert gas such as nitrogen gas or an atmosphere of a reducing gas such as hydrogen gas or an atmosphere in which these gases are mixed, which has a temperature of, for example, 750˚C through 850˚C, for, for example, 1 through 2 hours, an extrusion pressure of 100 through 200 GPa is applied to the partially sintered body, thereby extruding the partially sintered body so as to have a predetermined shape.

[0056] As described above, to manufacture the electrical contact material 31, according to the present invention by using the silver-graphite (Ag-Gr) based or silver-graphite-tungsten carbide (Ag-Gr-WC) based material, the extruding method is adopted. When the electrical contact material 31 is manufactured by adopting the extruding method, an old powder grain boundary in the raw material powders is torn off, thereby reinforcing a powder grain boundary in the extruded body, which is most fragile in powder metallurgy. This allows a transverse rupture strength and a deflection of the material to be enhanced. In addition, since the material is densified by the extruding method, a hardness of the material can be enhanced. In contrast to this, if a sintering method is adopted, since an old powder grain boundary in the raw material powders remains in a sintered body as it is, a sintered body having a low mechanical strength is obtained, as compared with the extruded body.

[0057] In the manufacturing method according to the present invention, as described above, the raw material powders are mixed in the vacuum. Since a specific gravity of the silver powder as the raw material powder is approximately 4.8 times as large as a specific gravity of the graphite powder, it is difficult to mix the silver powder and the graphite powder by evenly dispersing the silver powder and the graphite powder in the air. Therefore, since the electrical contact material 31 manufactured by using a mixed powder obtained by mixing in the air is incapable of obtaining an effect attained through reinforcement made by evenly dispersing particles, a hardness and a transverse rupture strength are reduced. In contrast to this, the electrical contact material 31 manufactured by using the mixed powder obtained by the mixing in the vacuum is capable of obtaining the effect attained through the reinforcement made by evenly dispersing the particles.

[0058] In addition, In the manufacturing method according to the present invention, as described above, since the compression compact is partially sintered in the reducing gas atmosphere, oxygen attached onto surfaces of the raw material powders is removed. As a result, wear-out amounts after the breaking tests in the overload test and the short-circuit test of the electrical contact material 31 can be reduced. In contrast to this, if a compression compact is partially sintered in an inert gas atmosphere, although oxygen mixed in upon sintering is not present, oxygen attached onto surfaces of the raw material powders is not removed. Therefore, wear-out amounts after the breaking tests of an electrical contact material are boosted.

[0059] Furthermore, in the manufacturing method according to the present invention, as described above, since the partially sintered body is subjected to the coining process and thereafter, to the extruding, a density of the material upon the preheating becomes greater than or equal to 98%. Therefore, an amount of oxygen which enters the material from an inside of a heating furnace upon the preheating can be decreased. This allows, for example, an oxygen content in the finally obtained electrical contact material 31 to be controlled to be greater than or equal to 20 ppm and less than or equal to 100 ppm. In contrast to this, if the partially sintered body is not subjected to the coining process, since a density of the material is approximately 90%, an amount of the oxygen which enters the material from the inside of the heating furnace upon the preheating is increased. Therefore, since oxidation of the silver progresses, an oxygen content of the finally obtained electrical contact material 31 is increased.

EXAMPLES

[0060] Hereinafter, a comparison experiment conducted for confirming effects of the above-described embodiment and using examples and comparison examples will be described below.

[Examples A]

[0061] In the present examples as examples each corresponding to the above-described embodiment, electrical contact materials 31 of fixed sides in the following examples A1 through A9 were prepared. In addition, in the same manner as in the examples according to the present invention, electrical contact materials 31 of fixed sides in comparison examples A1 through A8, in each of which a content of graphite, a deflection, a Vickers hardness, and an oxygen content were out of the ranges in the present invention, were prepared. Further, as comparison examples each corresponding to the conventional example, electrical contact materials 31 of fixed sides in the following comparison examples A11 through A16, A21 through A26, A31 through A36, and A41 through A46 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 100A, 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 a tungsten carbide.

[0062] 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; and a deflection, a transverse rupture strength, a hardness, an oxygen content, and a density 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 and a wear-out rate of each of the electrical contact materials 31 after the short-circuit 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.

[0063] Methods of measuring a deflection, a transverse rupture strength, a hardness, an oxygen content, and a density of each of the electrical contact materials 31, methods of the breaking tests in the overload test and the short-circuit test of each breaker for a large current, and evaluations of the wear-out rates after these breaking tests will be described later.

(Examples A1 through A9) (Comparison examples A1 through A8)

[0064] In examples A1 through A9 and comparison examples A1 through A8, each of the electrical contact materials 31 of a silver-graphite (Ag-Gr) based material including graphite (Gr) whose each content is shown in Table 1 was prepared as described below.

[0065] A graphite (Gr) powder 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 (100Pa) for 30 minutes by using a ball mill so as to have each graphite 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 950°C, for one hour, whereby each of these compression compacts was subjected to partial sintering. Each of these partially sintered bodies was subjected to a coining process under a pressure of 1100 MPa so as to have a true density of greater than or equal to 97%. After each of the partially sintered bodies subjected to the coining process was preheated by retaining each of the partially sintered bodies in a nitrogen gas, which was an inert gas atmosphere and had a temperature of 800°C, for 2 hours, an extrusion pressure of 100 GPa was applied to each of the partially sintered bodies, thereby extruding each of the partially 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. Although an electrical contact material was tried to be prepared by using a graphite powder having an average particle diameter of 10 nm and employing the above-mentioned method, the preparation failed.

(Comparison examples A11 through A16)

[0066] In comparison examples A11 through A16, in accordance with the same steps as in the above-described examples A1 through A9 except that the step of subjecting each of the partially sintered bodies to the coining process was not conducted, each electrical contact material 31 of a silver-graphite (Ag-Gr) based material including graphite (Gr) whose each content is shown in Table 1 was prepared.

(Comparison examples A21 through A26)

[0067] In comparison examples A21 through A26, in accordance with the same steps as in the above-described examples A1 through A9 except that a silver powder and a graphite powder were mixed in the air, each electrical contact material 31 of a silver-graphite (Ag-Gr) based material including graphite (Gr) whose each content is shown in Table 1 was prepared.

(Comparison examples A31 through A36)

[0068] In comparison examples A31 through A36, in accordance with the same steps as in the above-described examples A1 through A9 except that each compression compact was retained in a nitrogen gas, which was a protective gas atmosphere and had a temperature of 950˚C, for one hour, whereby each compression compact was subjected to partial sintering, each electrical contact material 31 of a silver-graphite (Ag-Gr) based material including graphite (Gr) whose each content is shown in Table 1 was prepared.

(Comparison examples A41 through A46)

[0069] In comparison examples A41 through A46, each electrical contact material 31 of a silver-graphite (Ag-Gr) based material including graphite (Gr) whose each content is shown in Table 1 was prepared as described below.

[0070] Each graphite (Gr) powder 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 each graphite 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 plate-like compression compact having a planar shape of a 10 mm square and a thickness of 1 mm. Each of these compression compacts was retained in a vacuum which had a temperature of 900˚C, for one hour, whereby each of these compression compacts was subjected to partial sintering. Each of these partially sintered bodies was subjected to a coining process under a pressure of 500 MPa so as to have a true density of greater than or equal to 97%. As described above, each of the electrical contact materials 31 was obtained.

(Deflection)

[0071] The deflections [mm] of the prepared electrical contact materials were measured in conformity with JIS H5501.

(Transverse rupture strength)

[0072] 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.

(Hardness)

[0073] Each Vickers hardness [HV] of each of the prepared electrical contact materials was measured by using a Vickers hardness meter in conformity with JIS Z 2244.

(Oxygen content)

[0074] Measurement of each oxygen content 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.

(Density)

[0075] A density (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.

(Breaking test (overload test) of breaker for large current)

[0076] 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 when the calculated wear-out rate was less than or equal to 5%, "○" shows when the calculated wear-out rate was less than or equal to 10%, and "×" shows when the wear-out rate exceeded 10%.

[0077] (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)

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

[0078] 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 when the calculated wear-out rate was less than or equal to 10%, "○" shows when the calculated wear-out rate was less than or equal to 40%, and "×" shows when the wear-out rate exceeded 40%.

[0079]

[Table 1]

	Gr average particle diameter	content [% by mass]	Gr Deflection [mm]	Transverse rupture strength [MPa]	Hardness [HV]	content [ppm]	Oxygen Density [%]	Overload test Wear-out rate	Short-circuit test Wear-out rate
Example A1	40 nm	4	0.6	240	75	60	99	◎	◎
Example A2	40 nm	5	0.5	250	79	70	99	○	○
Example A3	40 nm	7	0.5	260	82	100	99	○	○
Example A4	3 μm	4	0.8	240	68	46	99	◎	◎
Example A5	3 μm	5	0.7	240	72	50	99	◎	◎
Example A6	3 μm	7	0.6	250	78	70	99	◎	◎
Example A7	8 μm	4	0.7	210	55	35	99	◎	○
Example A8	8 μm	5	0.7	210	55	45	99	◎	○
Example A9	8 μm	7	0.7	220	57	46	99	◎	○
Comparison example A1	40 nm	8	0.4	266	85	110	99	×	×
Comparison example A2	8 μm	3	0.7	200	53	30	99	◎	×
Comparison example A3	8 μm	8	0.4	225	58	50	99	×	×
Comparison example A4	10 μm	3	1.2	115	39	30	99	◎	×
Comparison example A5	10 μm	4	0.9	160	45	40	99	◎	×
Comparison example A6	10 μm	5	0.8	190	51	40	99	◎	×
Comparison example A7	10 μm	7	0.7	190	53	50	99	◎	×
Comparison example A8	10 μm	8	0.5	200	54	50	99	○	×

(continued)

	Gr average particle diameter	content [% by mass]	Gr Deflection [mm]	Transverse rupture strength [MPa]	Hardness [HV]	content [ppm]	Oxygen Density [%]	Overload test Wear-out rate	Short-circuit test Wear-out rate
Comparison example A11	40 nm	4	<u>0.4</u>	230	73	<u>490</u>	99	×	×
Comparison example A12	40 nm	7	<u>0.3</u>	255	80	<u>530</u>	99	×	×
Comparison example A13	3 μm	4	0.7	240	64	<u>440</u>	99	◎	×
Comparison example A14	3 μm	7	0.5	250	72	<u>465</u>	99	○	×
Comparison example A15	8 μm	4	0.8	<u>200</u>	<u>50</u>	<u>385</u>	99	◎	×
Comparison example A16	8 μm	7	0.6	210	<u>54</u>	<u>395</u>	99	◎	×
Comparison example A21	40 nm	4	0.9	<u>190</u>	<u>45</u>	60	99	◎	×
Comparison example A22	40 nm	7	0.8	210	<u>52</u>	100	99	◎	×
Comparison example A23	3 μm	4	1.1	<u>190</u>	<u>38</u>	50	99	◎	×
Comparison example A24	3 μm	7	0.9	<u>200</u>	<u>48</u>	70	99	◎	×
Comparison example A25	8 μm	4	1.2	<u>160</u>	<u>25</u>	40	99	◎	×
Comparison example A26	8 μm	7	1	<u>170</u>	<u>27</u>	50	99	◎	×
Comparison example A31	40 nm	4	0.6	240	75	<u>180</u>	99	◎	×
Comparison example A32	40 nm	7	0.5	260	82	<u>230</u>	99	○	×

(continued)

	Gr average particle diameter	content [% by mass]	Gr Deflection [mm]	Transverse rupture strength [MPa]	Hardness [HV]	content [ppm]	Oxygen Density [%]	Overload test Wear-out rate	Short-circuit test Wear-out rate
Comparison example A33	3 μm	4	0.8	240	68	160	99	◎	×
Comparison example A34	3 μm	7	0.6	250	78	190	99	◎	×
Comparison example A35	8 μm	4	0.9	210	55	150	99	◎	×
Comparison example A36	8 μm	7	0.7	220	57	170	99	◎	×
Comparison example A41	40 nm	4	0.3	190	48	60	85	×	×
Comparison example A42	40 nm	7	0.2	205	54	90	85	×	×
Comparison example A43	3 μm	4	0.4	190	41	40	90	×	×
Comparison example A44	3 μm	7	0.3	200	50	70	90	×	×
Comparison example A45	8 μm	4	0.4	160	38	35	93	×	×
Comparison example A46	8 μm	7	0.3	170	48	40	93	×	×

[0080] It is seen from Table 1 that in the breaker for a large current, whose rated current value was 100A, at least the Vickers hardness of the electrical contact material at the ordinary temperature was set to be relatively large, being greater than or equal to 55; the deflection amount was set to be relatively large, being greater than or equal to 0.5 mm; the oxygen content was suppressed to be less than or equal to a 100 ppm; and the electrical contact material was formed so as to avoid deformation in a state where heat is generated by flowing of the large current (under a high temperature), thereby allowing not only the wear-out amount after the overload test but also the wear-out amount after the short-circuit test to be reduced.

[Examples B]

[0081] In the present examples as examples each corresponding to the above-described embodiment, electrical contact materials 31 of fixed sides in the following examples B1 through B9 were prepared. In addition, in the same manner as in the examples according to the present invention, electrical contact materials 31 of fixed sides in comparison examples B1 through B8, in each of which a content of graphite, a deflection, a Vickers hardness, and an oxygen content were out of the ranges in the present invention, were prepared. Further, as comparison examples each corresponding to the conventional example, electrical contact materials 31 of fixed sides in the following comparison examples B11 through B16, B21 through B26, B31 through B36, and B41 through B46 were prepared. By using each breaker for a small current, which was configured by incorporating each of these electrical contact materials 31 and whose rated current value was 30A, 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 a tungsten carbide.

[0082] 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; and a deflection, a transverse rupture strength, a hardness, an oxygen content, and a density of each of the electrical contact materials 31 are shown in below Table 2. In addition, the evaluation results regarding a wear-out rate of each of the electrical contact materials 31 after the overload test and a wear-out rate of each of the electrical contact materials 31 after the short-circuit test are also shown in Table 2. The underlined numerical values in Table 2 show that the underlined numerical values are out of the ranges in the present invention.

[0083] Methods of measuring a deflection, a transverse rupture strength, a e hardness, an oxygen content, and a density of each of the electrical contact materials 31 are the same as in the above-described examples A. Methods of the breaking tests of each breaker for a small current in the overload test and the short-circuit test and evaluations of the wear-out rates after these breaking tests will be described later.

(Examples B1 through B9) (Comparison examples B1 through B8)

[0084] In examples B1 through B9 and comparison examples B1 through B8, each of the electrical contact materials 31 of a silver-graphite (Ag-Gr) based material including graphite (Gr) whose each content is shown in Table 2 was prepared as described below.

[0085] Each graphite (Gr) powder having an average particle diameter shown in Table 2 and a silver (Ag) powder having an average particle diameter of 3 μm were mixed in a vacuum (100Pa) for 30 minutes by using a ball mill so as to have each graphite content shown in Table 2. 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 950˚C, for one hour, whereby each of these compression compacts was subjected to partial sintering. Each of these partially sintered bodies was subjected to a coining process under a pressure of 1100 MPa so as to have a true density of greater than or equal to 97%. After each of the partially sintered bodies subjected to the coining process was preheated by retaining each of the partially sintered bodies in a nitrogen gas, which was an inert gas atmosphere and had a temperature of 800˚C, for 2 hours, an extrusion pressure of 100 GPa was applied to each of the partially sintered bodies, thereby extruding each of the partially 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. Although an electrical contact material was tried to be prepared by using a graphite powder having an average particle diameter of 10 nm and employing the above-mentioned method, the preparation failed.

(Comparison examples B11 through B16)

[0086] In comparison examples B11 through B16, in accordance with the same steps as in the above-described examples B1 through B9 except that the step of subjecting each of the partially sintered bodies to the coining process was not conducted, each electrical contact material 31 of a silver-graphite (Ag-Gr) based material including graphite (Gr) whose each content is shown in Table 2 was prepared.

(Comparison examples B21 through B26)

[0087] In comparison examples B21 through B26, in accordance with the same steps as in the above-described examples B1 through B9 except that a silver powder and a graphite powder were mixed in the air, each electrical contact material 31 of a silver-graphite (Ag-Gr) based material including graphite (Gr) whose each content is shown in Table 2 was prepared.

(Comparison examples B31 through B36)

[0088] In comparison examples B31 through B36, in accordance with the same steps as in the above-described examples B1 through B9 except that each compression compact was retained in a nitrogen gas, which was a protective gas atmosphere and had a temperature of 950˚C, for one hour, whereby each compression compact was subjected to partial sintering, each electrical contact material 31 of a silver-graphite (Ag-Gr) based material including graphite (Gr) whose each content is shown in Table 2 was prepared.

(Comparison examples B41 through B46)

[0089] In comparison examples B41 through B46, each electrical contact material 31 of a silver-graphite (Ag-Gr) based material including graphite (Gr) whose each content is shown in Table 2 was prepared as described below.

[0090] Each graphite (Gr) powder having an average particle diameter shown in Table 2 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 each graphite content shown in Table 2. A pressure of 300 MPa was applied to each of the obtained mixed powders by using a press, thereby forming each plate-like compression compact having a planar shape of a 10 mm square and a thickness of 1 mm. Each of these compression compacts was retained in a vacuum which had a temperature of 900˚C, for one hour, whereby each of these compression compacts was subjected to partial sintering. Each of these partially sintered bodies was subjected to a coining process under a pressure of 500 MPa so as to have a true density of greater than or equal to 97%. As described above, each of the electrical contact materials 31 was obtained.

(Breaking test (overload test) of breaker for small current)

[0091] In an endurance test, a load voltage of 220V and a breaking current of 180A 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 180A 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 above-mentioned (Expression 1). In Table 2, as evaluations of the wear-out rate, "◎" shows when the calculated wear-out rate was less than or equal to 5%, "○" shows when the calculated wear-out rate was less than or equal to 10%, and "×" shows when the wear-out rate exceeded 10%.

(Breaking test (short-circuit test) of breaker for small current)

[0092] In a short-circuit test, a load voltage of 220V and a breaking current of 300A 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 300A 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 2, as evaluations of the wear-out rate, "◎" shows when the calculated wear-out rate was less than or equal to 10%, "○" shows when the calculated wear-out rate was less than or equal to 40%, and "×" shows when the wear-out rate exceeded 40%.

[0093]

[Table 2]

	Gr average particle diameter	Gr content [% by mass]	[mm]	Deflection Transverse rupture Hardness strength [MPa]	[HV]	Oxygen content [ppm]	[%]	Overload test Wear-out rate	Short-circuit test Wear-out rate
Example B1	40 nm	0.5	0.9	180	53	45	99	○	◎
Example B2	40 nm	1	0.8	220	60 50		99	○	◎
Example B3	40 nm	2	0.8	220	65	50	99	○	◎
Example B4	3 μm	0.5	1	130	48	45	99	◎	○
Example B5	3 μm	1	0.9	150	52	45	99	◎	◎
Example B6	3 μm	2	0.8	180	58	50	99	○	◎
Example B7	8 μm	0.5	1.3	120	42	20	99	◎	○
Example B8	8 μm	1	1.1	130	47	20	99	◎	○
Example B9	8 μm	2	0.9	150	50	30	99	◎	◎
Comparison example B1	40 nm	3	0.6	230	70	60	99	×	◎
Comparison example B2	8 μm	0.1	1.5	100	39	20	99	◎	×
Comparison example B3	8 μm	3	0.7	200	53	30	99	×	◎
Comparison example B4	10 μm	0.1	1.7	98	27	20	99	◎	×
Comparison example B5	10 μm	0.5	1.6	100	32	20	99	◎	×
Comparison example B6	10 μm	1	1.4	105	35	20	99	◎	×
Comparison example B7	10 μm	2	1.3	110	38	30	99	◎	×
Comparison example B8	10 μm	3	1.2	115	39	30	99	◎	×
Comparison example B11	40 nm	0.5	0.9	180	53	475	99	○	×
Comparison example B12	40 nm	2	0.8	220	65	480	99	○	×
Comparison example B13	3 μm	0.5	0.8	130	48	445	99	○	×
Comparison example B14	3 μm	2	0.7	180	55	455	99	×	×

(continued)

	Gr average particle diameter	Gr content [% by mass]	[mm]	Deflection Transverse rupture Hardness strength [MPa]	[HV]	Oxygen content [ppm]	[%]	Overload test Wear-out rate	Short-circuit test Wear-out rate
Comparison example B15	8 μm	0.5	0.9	120	42	370	99	◎	×
Comparison example B16	8 μm	2	0.8	150	49	380	99	○	×
Comparison example B21	40 nm	0.5	0.9	100	25	45	99	○	×
Comparison example B22	40 nm	2	0.8	115	38	50	99	○	×
Comparison example B23	3 μm	0.5	1	95	22	45	99	◎	×
Comparison example B24	3 μm	2	0.8	110	35	50	99	○	×
Comparison example B25	8 μm	0.5	1.3	80	15	20	99	◎	×
Comparison example B26	8 μm	2	0.9	100	22	30	99	◎	×
Comparison example B31	40 nm	0.5	0.9	220	55	170	99	◎	×
Comparison example B32	40 nm	2	0.8	230	64	170	99	○	×
Comparison example B33	3 μm	0.5	1.1	130	45	160	99	◎	×
Comparison example B34	3 μm	2	0.8	220	55	170	99	○	×
Comparison example B35	8 μm	0.5	1.3	120	38	140	99	◎	×
Comparison example B36	8 μm	2	0.9	150	50	150	99	◎	×

(continued)

	Gr average particle diameter	Gr content [% by mass]	[mm]	Deflection Transverse rupture Hardness strength [MPa]	[HV]	Oxygen content [ppm]	[%]	Overload test Wear-out rate	Short-circuit test Wear-out rate
Comparison example B41	40 nm	0.5	0.7	100	32	45	90	×	×
Comparison example B42	40 nm	2	0.4	115	39	50	88	×	×
Comparison example B43	3 μm	0.5	0.6	100	25	45	95	×	×
Comparison example B44	3 μm	2	0.5	115	38	50	90	×	×
Comparison example B45	8 μm	0.5	0.5	88	20	20	96	×	×
Comparison example B46	8 μm	2	0.4	110	35	30	92	×	×

[0094] It is seen from Table 2 that in the breaker for a small current, whose rated current value was 30A, at least the deflection amount was set to be relatively large, being greater than or equal to 0.8 mm; the Vickers hardness of the electrical contact material at the ordinary temperature was set to be relatively large, being greater than or equal to 40; the oxygen content was suppressed to be less than or equal to a 100 ppm; and the electrical contact material was formed so as to be capable of enduring the mechanical shock repeated at a multitude of times, thereby allowing not only the wear-out amount after the short-circuit test but also the wear-out amount after the overload test to be reduced.

[Examples C]

[0095] In the present examples as examples each corresponding to the above-described embodiment, electrical contact materials 31 of fixed sides in the following examples C1 through C20 were prepared. In addition, as comparison examples each corresponding to the conventional example, electrical contact materials 31 of fixed sides in the following comparison examples C107, C207, C307, and C407 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 100A, 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 a tungsten carbide.

[0096] 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 each tungsten carbide (WC) powder; a content of a tungsten carbide (WC) in each of the prepared electrical contact materials 31; and a deflection, a transverse rupture strength, a hardness, an oxygen content, and a density of each of the electrical contact materials 31 are shown in below Table 3. In addition, the evaluation results regarding a wear-out rate of each of the electrical contact materials 31 after an overload test and a wear-out rate of each of the electrical contact materials 31 after a short-circuit test are also shown in Table 3. The underlined numerical values in Table 3 show that the underlined numerical values are out of the ranges in the present invention.

[0097] Methods of measuring the deflection, the transverse rupture strength, the hardness, the oxygen content, and the density of each of the electrical contact materials 31 are the same as in the above-described examples A. Methods of the breaking tests in the overload test and the short-circuit test of each breaker for a large current and evaluations of the wear-out rates after these breaking tests are also the same as in the above-described examples A.

(Examples C1 through C20)

[0098] In examples C1 through C20, each of the electrical contact materials 31 of a silver-graphite-tungsten carbide (Ag-Gr-WC) based material including graphite (Gr) and a tungsten carbide (WC) whose contents are shown in Table 3 was prepared as described below.

[0099] Each graphite (Gr) powder and each tungsten carbide (WC) powder, having an average particle diameter shown in Table 3, and a silver (Ag) powder having an average particle diameter of 3 μm were mixed in a vacuum (100Pa) for 30 minutes by using a ball mill so as to have each graphite content and each tungsten carbide content shown in Table 3. 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 950˚C, for one hour, whereby each of these compression compacts was subjected to partial sintering. Each of these partially sintered bodies was subjected to a coining process under a pressure of 1100 MPa so as to have a true density of greater than or equal to 97%. After each of the partially sintered bodies subjected to the coining process was preheated by retaining each of the partially sintered bodies in a nitrogen gas, which was an inert gas atmosphere and had a temperature of 800˚C, for 2 hours, an extrusion pressure of 100 GPa was applied to each of the partially sintered bodies, thereby extruding each of the partially 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.

(Comparison example C107)

[0100] In comparison example C107, in accordance with the same steps as in the above-described examples C1 through C20 except that the step of subjecting each of the partially sintered bodies to the coining process was not conducted, each electrical contact material 31 of a silver-graphite-tungsten carbide (Ag-Gr-WC) based material including graphite (Gr) and a tungsten carbide (WC), whose content and average particle diameter were the same as in example C7 as shown in Table 3 was prepared.

(Comparison example C207)

[0101] In comparison example C207, in accordance with the same steps as in the above-described examples C1 through C20 except that a silver powder, a graphite powder, and a tungsten carbide powder were mixed in the air, each electrical contact material 31 of a silver-graphite-tungsten carbide (Ag-Gr-WC) based material including graphite (Gr) and a tungsten carbide (WC), whose content and average particle diameter were the same as in example C7 as shown in Table 3 was prepared.

(Comparison example C307)

[0102] In comparison example C307, in accordance with the same steps as in the above-described examples C1 through C20 except that each compression compact was retained in a nitrogen gas, which was a protective gas atmosphere and had a temperature of 950˚C, for one hour, whereby each compression compact was subjected to partial sintering, each electrical contact material 31 of a silver-graphite-tungsten carbide (Ag-Gr-WC) based material including graphite (Gr) and a tungsten carbide (WC), whose content and average particle diameter were the same as in example C7 as shown in Table 3 was prepared.

(Comparison example C407)

[0103] In comparison example C407, an electrical contact material 31 of a silver-graphite-tungsten carbide (Ag-Gr-WC) based material including graphite (Gr) and a tungsten carbide (WC) whose contents are shown in Table 3 was prepared as described below.

[0104] A graphite (Gr) powder and a tungsten carbide (WC) powder, having an average particle diameter shown in Table 3, 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 graphite content and a tungsten carbide content shown in Table 3. 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. The compression compact was retained in a vacuum which had a temperature of 900˚C, for one hour, whereby the compression compact was subjected to partial sintering. The partially sintered body was subjected to a coining process under a pressure of 500 MPa so as to have a true density of greater than or equal to 97%. As described above, the electrical contact material 31 was obtained.

[0105]

[Table 3]

	Gr average particle diameter [µm]	Gr content [% by mass]	WC average particle diameter	WC content [% by mass]	Deflection [mm]	Transverse rupture strength [MPa]	Hardness [HV]	Oxygen content [mm]	Density [%]	Overload test Wear-out rate	Short-circuit test Wear-out rate
Example C1	3	5	40 nm	2	0.7	270	75	80	99	◎	◎
Example C2	3	5	80 nm	2	0.8	260	85	70	99	◎	◎
Example C3	3	5	150 nm	2	0.8	255	80	70	99	◎	○
Example C4	3	5	1 µm	2	0.8	240	78	60	99	◎	○
Example C5	3	5	3 µm	2	0.9	235	75	60	99	◎	○
Example C6	3	5	40 nm	3	0.7	280	95	85	99	◎	◎
Example C7	3	5	80 nm	3	0.7	275	93	80	99	◎	◎
Example C8	3	5	150 nm	3	0.7	275	88	70	99	◎	◎
Example C9	3	5	1 µm	3	0.8	260	86	70	99	◎	◎
Example C10	3	5	3 µm	3	0.8	250	82	60	99	◎	○
Example C11	3	5	40 nm	4	0.5	300	115	95	98	○	◎
Example C12	3	5	80 nm	4	0.5	295	110	90	99	○	◎
Example C13	3	5	150 nm	4	0.6	290	110	80	99	○	◎
Example C14	3	5	1 µm	4	0.7	285	100	80	99	◎	◎
Example C15	3	5	3 µm	4	0.8	275	95	70	99	◎	◎
Example C16	2	4	80 nm	3	0.7	285	90	85	99	◎	◎

(continued)

	Gr average particle diameter [μm]	Gr content [% by mass]	WC average particle diameter	WC content [% by mass]	Deflection [mm]	Transverse rupture strength [MPa]	Hardness [HV]	Oxygen content [mm]	Density [%]	Overload test Wear-out rate	Short-circuit test Wear-out rate
Example C17	2	5	80 nm	3	0.7	275	85	90	99	◎	◎
Example C18	4	7	80 nm	3	0..5	260	70	100	95	○	○
Example C19	5	4	80 nm	3	0.7	270	75	85	99	◎	◎
Example C20	1	4	1 μm	3	0.6	250	78	90	99	○	○
Comparison example C107	3	5	80 nm	3	0.6	270	90	<u>540</u>	99	○	×
Comparison example C207	3	5	80 nm	3	0,8	<u>200</u>	<u>62</u>	90	99	◎	×
Comparison example C307	3	5	80 nm	3	0.7	275	93	<u>310</u>	99	◎	×
Comparison example C407	3	5	80 nm	3	<u>0.3</u>	<u>200</u>	<u>60</u>	80	90	×	×

[0106] It is seen from Table 3 that in the breaker for a large current, in which the electrical contact material 31 of the silver-graphite-tungsten carbide (Ag-Gr-WC) based material was used and whose rated current value was 100A, at least the Vickers hardness of the electrical contact material at the ordinary temperature was set to be relatively large, being greater than or equal to 55; the deflection amount was set to be relatively large, being greater than or equal to 0.5 mm; the oxygen content was suppressed to be less than or equal to a 100 ppm; and the electrical contact material was formed so as to avoid deformation in a state where heat is generated by flowing of the large current (under a high temperature), thereby allowing not only the wear-out amount after the overload test but also the wear-out amount after the short-circuit test to be reduced.

[Example D]

[0107] In the present examples as examples each corresponding to the above-described embodiment, electrical contact materials 31 of fixed sides in the following examples D1 through D9 were prepared. In the same manner as in the examples according to the present invention, electrical contact materials 31 of fixed sides in comparison examples D1 through D4, in each of which an average particle diameter of a tungsten carbide powder and a content of a tungsten carbide were out of the preferable ranges in the present invention, 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 100A, a welding test was 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 a tungsten carbide.

[0108] 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 each tungsten carbide (WC) powder; and a content of a tungsten carbide (WC) in each of the prepared electrical contact materials 31 are shown in below Table 4. In addition, the evaluation results regarding the welding test are also shown in Table 4. The underlined numerical values in Table 4 show that the underlined numerical values are out of the preferable ranges in the present invention.

[0109] Methods of measuring a deflection, a transverse rupture strength, a hardness, an oxygen content, and a density of each of the electrical contact materials 31 are the same as in the above-described examples A. A method of the welding test of each breaker for a large current and an evaluation of the welding test will be described later.

(Examples D1 through D9) (Comparison examples D1 through D4)

[0110] In examples D1 through D9 and comparison examples D1 through D4, each of the electrical contact materials 31 of a silver-graphite-tungsten carbide (Ag-Gr-WC) based material including graphite (Gr) and a tungsten carbide (WC) whose contents are shown in Table 4 was prepared as described below.

[0111] Each graphite (Gr) powder and each tungsten carbide (WC) powder, having an average particle diameter shown in Table 4, and a silver (Ag) powder having an average particle diameter of 3 μm were mixed in a vacuum (100Pa) for 30 minutes by using a ball mill so as to have each graphite content and each tungsten carbide content shown in Table 4. 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 950˚C, for one hour, whereby each of these compression compacts was subjected to partial sintering. Each of these partially sintered bodies was subjected to a coining process under a pressure of 1100 MPa so as to have a true density of greater than or equal to 97%. After each of the partially sintered bodies subjected to the coining process was preheated by retaining each of the partially sintered bodies in a nitrogen gas, which was an inert gas atmosphere and had a temperature of 800˚C, for 2 hours, an extrusion pressure of 100 GPa was applied to each of the partially sintered bodies, thereby extruding each of the partially 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.

(Welding test of breaker for large current)

[0112] 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 4, as evaluations of the welding condition, "◎" shows when no welding of each of the contacts occurred at all, "○" shows when the welding was easily detached by turning on/off each of the breakers (light welding), "×" shows when the welding was not easily detached by turning on/off each of the breakers (heavy welding).

[0113]

[Table 4]

	Gr average particle diameter [μm]	Gr content [% by mass]	WC average particle	WC content test [% by mass]	Wending
Example D1	3	5	80 nm	2	○
Example D2	3	5	80 nm	3	◎
Example D3	3	5	80 nm	4	◎
Example D4	3	5	40 nm	3	◎
Example D5	3	5	150 nm	3	○
Example D6	1	5	80 nm	3	◎
Example D7	5	5	80 nm	3	○
Example D8	3	4	80 nm	3	○
Example D9	3	7	80 nm	3	◎
Comparison example D1	3	5	80 nm	<u>1</u>	×
Comparison example D 2	3	5	80 nm	<u>5</u>	×
Comparison example D 3	3	5	<u>250 nm</u>	3	×
Comparison example D 4	3	5	<u>1.5 μm</u>	3	×

[0114] It is seen from Table 4 that in the breaker for a large current, whose rated current value was 100A, the electrical contact material was formed by using the silver-graphite-tungsten carbide based material whose average particle diameter of the tungsten carbide was greater than or equal to 40 nm and less than or equal to 150 nm and content of the tungsten carbide was greater than or equal to 2% by mass and less than or equal to 4% by mass, thereby allowing the welding after the breaking test in the short-circuit test to be prevented.

[0115] The described embodiment and examples herein 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.

[0116] 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.

[0117] In addition, in the above-described embodiment and examples, an example in which each of the electrical contact materials 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 each of the electrical contact materials 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

[0118] An electrical contact material according to the present invention is used by being incorporated into a breaker for a large current, whose rated current value is 100 through 3200A, or a breaker for a small current, whose rated current value is 1 through 60A.

REFERENCE SIGNS LIST

[0119] 10: breaker, 21, 31: electrical contact material.

Claims

1. An electrical contact material including 4% by mass or more and 7% by mass or less of graphite, the remainder including silver and an unavoidable impurity, the electrical contact material having: a deflection being greater than or equal to 0.5 mm; a Vickers hardness being greater than or equal to 55; and an oxygen content being less than or equal to 100 ppm.

2. The electrical contact material according to claim 1, wherein a transverse rupture strength is greater than or equal to 210 MPa.

3. The electrical contact material according to claim 1, wherein an average particle diameter of the graphite is greater than or equal to 40 nm and less than or equal to 8 μm.

4. The electrical contact material according to claim 1, further including a tungsten carbide.

5. The electrical contact material according to claim 4, wherein an average particle diameter of the tungsten carbide is greater than or equal to 40 nm and less than or equal to 3 μm and a content of the tungsten carbide is greater than or equal to 2% by mass and less than or equal to 4% by mass.

6. The electrical contact material according to claim 5, wherein an average particle diameter of the tungsten carbide is greater than or equal to 40 nm and less than or equal to 150 nm.

7. An electrical contact material including 0.5% by mass or more and 2% by mass or less of graphite, the remainder including silver and an unavoidable impurity, the electrical contact material having: a deflection being greater than or equal to 0.8 mm; a Vickers hardness being greater than or equal to 40; and an oxygen content being less than or equal to 100 ppm.

8. The electrical contact material according to claim 7, wherein a transverse rupture strength is greater than or equal to 120 MPa.

9. The electrical contact material according to claim 7, wherein an average particle diameter of the graphite is greater than or equal to 40 nm and less than or equal to 8 μm.

FIG.1

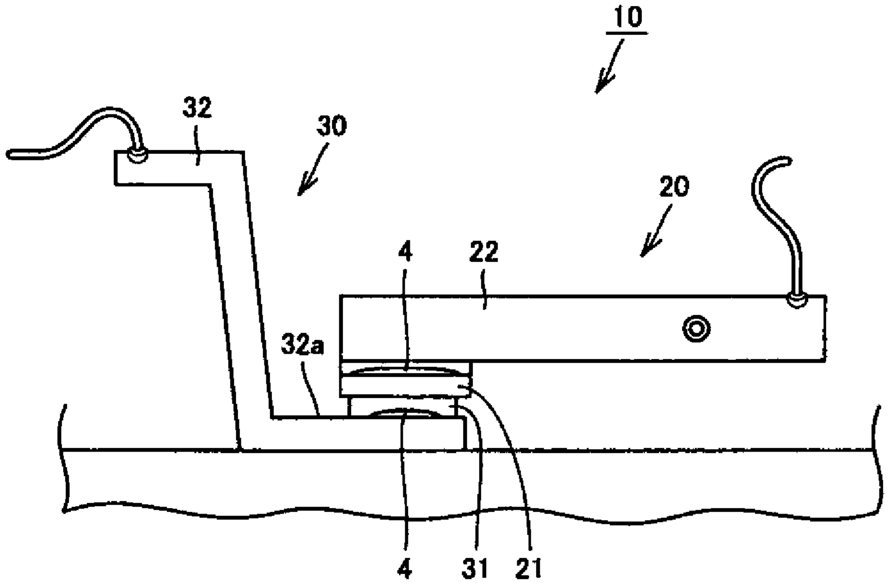
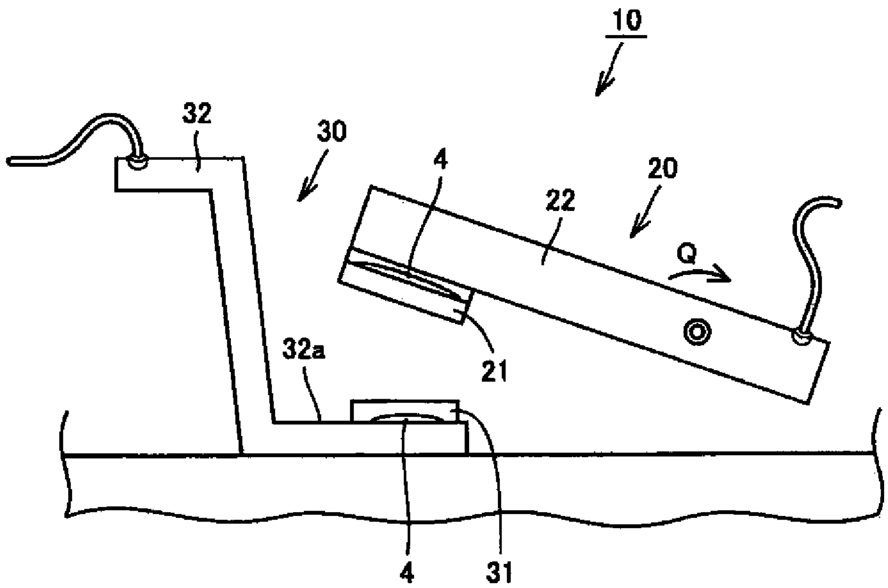


FIG.2



INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2010/001444

A. CLASSIFICATION OF SUBJECT MATTER
H01H1/023(2006.01)i, *C22C1/05*(2006.01)i, *C22C1/10*(2006.01)i, *C22C5/06*(2006.01)i, *C22C32/00*(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)
H01H1/023-1/0237, C22C1/05, C22C1/10, C22C5/06, C22C32/00

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	1996-2010
Kokai Jitsuyo Shinan Koho	1971-2010	Toroku Jitsuyo Shinan Koho	1994-2010

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 2005-120427 A (Matsushita Electric Works, Ltd.), 12 May 2005 (12.05.2005), entire text; all drawings (Family: none)	1-9
A	JP 11-507174 A (Square D. Co.), 22 June 1999 (22.06.1999), entire text; all drawings & US 5831186 A & EP 830697 A1 & WO 1997/037363 A1	1-9
A	JP 52-147768 A (Sumitomo Electric Industries, Ltd.), 08 December 1977 (08.12.1977), entire text; all drawings (Family: none)	1-9

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

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
05 April, 2010 (05.04.10)	13 April, 2010 (13.04.10)

Name and mailing address of the ISA/	Authorized officer
Japanese Patent Office	
Facsimile No.	Telephone No.

Form PCT/ISA/210 (second sheet) (July 2009)

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- JP 8239724 A **[0003] [0006]**
- JP 3138965 B **[0004] [0006]**
- JP 2007169701 A **[0005] [0006]**