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(54) **Composite contact, vacuum switch and method for manufacturing composite contact**

Kontakt aus Verbundwerkstoff, Vakuumschalter und Herstellungsverfahren des Kontaktes

Conact en matériaux composites, disjoncteur à vide et procédé de fabrication du contact

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Description

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application is based upon and claims the benefit of priority from the prior Japanese Patent Applications No. 2004-82961 filed on March 22, 2004, and No. 2004-258155 filed on September 6, 2004; and the entire contents of which are incorporated herein by reference.

BACKGROUND OF THE INVENTION

Field of the Invention

[0002] The present invention relates to a composite contact realizing consistency of the interruption characteristic with the particularly stable temperature characteristic (temperature rise suppression characteristic), a vacuum switch provided with a vacuum valve including the composite contacts and a method for manufacturing the composite contact.

Description of the Background

[0003] In a vacuum circuit breaker, the three basic requirements of the large current interruption characteristic, withstand voltage characteristic, and welding resistance characteristic are given priority. But there are conflicting characteristics among the requirements, so that all the requirements cannot be met by a single contact material. In addition to the three basic requirements, the temperature characteristic (suppression of excessive temperature rise) and the characteristic of waste resistance of a material are also important. Therefore, many contact materials in practical use are developed so as to mutually compensate for insufficient properties. Mainly because a Cu-Cr contact maintains the three basic requirements to a certain extent, and moreover the vapor pressure characteristics of Cu and Cr at high temperature are approximate to each other, after interruption, the contact surface has a comparatively smooth surface damage characteristic. Generally, the Cu-Cr contact has a stable temperature characteristic.

[0004] Further, as a contact excellent in the withstand voltage characteristic, a Cu-W contact is known. Mainly because the contact maintains the three basic requirements to a certain extent and the fusion temperature property and harness property of tungsten are high, the Cu-W contact generally has a stable arc-proof property and a stable waste resistance property and is widely used.

[0005] However, in recent years, the vacuum circuit breaker has been daily applied to a circuit having a chance of interruption of a larger current or application of a higher voltage, and due to miniaturization of the device, remarkable consumption and a strong welding phenomenon are seen on the contact surface. As a result, even on the Cu-Cr contact and Cu-W contact, instabilization of the temperature characteristic is seen, and a contact meeting the temperature characteristic and interruption characteristic in addition to the three basic requirements has been required. However, no response has been realized and a vacuum valve provided with both characteristics is required.

[0006] Our research shows that the contact characteristic of a Cu-Cr alloy or a Cu-W alloy depend on various factors such as variations in the Cr amount or W amount of the alloy, the particle size and particle size distribution of Cr particles or W particles, the segregation degree of Cr or W, and the degree of voids existing in the alloy. However, although the optimization of these factors is being advanced, in the aforementioned recent adaptation status, variations are seen undesirably in the temperature characteristic.

[0007] An example of the general vacuum valve for executing a current interruption in a high vacuum using the arc diffusion property in a vacuum is shown in Fig. 9. It is structured so that a vacuum container 4 is formed by airtightly sealing end plates 2 and 3 to the openings at both ends of an insulating cylinder 1, and fixed and movable opposite contacts 5 and 6 are separatably installed in the vacuum container 4. Further, a fixed power supply shaft 7 of the contact 5 is airtightly attached to the end plate 2, and a movable power supply shaft 8 of the contact 6 is movably and airtightly attached to the end plate 3 via a bellows 9. The surroundings of the contacts 5 and 6 are surrounded by an arc shield 10, and moreover a bellows cover 11 of the bellows 9 is attached to the movable power supply shaft 8. In such a vacuum valve, when the movable power supply shaft 8 is operated in the pull-out direction and the contacts 5 and 6 are separated by an operation mechanism not drawn, an arc generated between the contacts 5 and 6 is diffused in the vacuum when the current zero point is obtained and is interrupted.

[0008] For the contacts 5 and 6, to maintain and improve the interruption characteristic and temperature rise characteristic, various arts as described in Patents Documents 1 to 8 are proposed.

[0009] In Patent Document 1, as another means for reducing the stagnation and concentration of an arc, a contact having a plurality of contact areas having different boiling temperatures on a contact electrode and assisting a movement of the arc is disclosed.

[0010] In Patent Document 2, as another means for reducing the stagnation and concentration of an arc, a contact having a plurality of contact areas having different boiling temperatures on a contact and assisting a movement of the arc is disclosed.

[0011] In Patent Document 3, as another means for reducing the stagnation and concentration of an arc, as an art for contriving not only a contact material but also the electrode structure to interrupt a large current, an art for installing a coil electrode so as to apply an axial magnetic field in parallel with an arc axis generated between electrodes at the time of interruption is disclosed.

[0012] In Patent Document 4, as a contact aiming at an excellent large current interruption property, a Cu-Cr alloy containing about 50% of Cr (weight percent) is disclosed.

[0013] In Patent Document 5, a contact composed of a plurality of layers such as a first layer and a second layer connected to each other by a conductive component is disclosed.

[0014] In Patent Document 6, a contact composed of a plurality of layers formed in the direction of the thickness from the surface in which the layer close to the surface contains a large amount of an arc-proof component is disclosed.

[0015] In Patent Document 7, a contact made of an alloy composed of 74 to 88% of W with an average particle diameter of 0.4 to 6 μm, 0.001 to 5% of Mo with an average particle diameter of 0.4 to 4 μm, when necessary, 0.001 to 5% of Fe with an average particle diameter of 0.4 to 4 μm, and the remainder of Cu, in which particularly W and Mo are united with each other within a range of average particle size from 0.4 to 10 μm, is proposed.

[0016] In Patent Document 8, a contact in which a 10 to 33% Cu-W alloy layer (area 1) is an arced face, and a 35 to 75% Cu-W alloy layer (area 2) is a contact or a joined face with the conductive shaft, and the area 1 and area 2 are united with each other, and the area 1 has a thickness of at least 0.3 mm, and the area 2 has a thickness of at least 0.5 mm is proposed.

Patent Document 1: Japanese Patent Disclosure (Kokai) Sho 62-64012
Patent Document 2: Japanese Patent Disclosure (Kokai) Sho 63-266720
Patent Document 3: Patent 1140613
Patent Document 4: Japanese Patent Publication (Kokoku) Sho 45-35101
Patent Document 5: Japanese Patent Disclosure (Kokai) Hei 4-206122
Patent Document 6: Japanese Patent Disclosure (Kokai) Hei 9-312120
Patent Document 7: Japanese Patent Disclosure (Kokai) Hei 10-199379
Patent Document 8: Japanese Patent Disclosure (Kokai) 2001-273842

[0017] In any art of Patent Documents 1, 2, and 3, even if a contact composed of the aforementioned two kinds or more of contact electrodes at different arc voltages simply arranged on the same face and an axial magnetic field electrode are used, the arc is concentrated on a part at a low arc voltage. As a result, the contact electrodes do not function so that the arc moves sufficiently, and the characteristics of the art of the axial magnetic field effective in a large current interruption cannot be used effectively. The arc generated by the interruption may be stagnated and concentrated on a part at a low arc voltage on the contact and electrode and from the viewpoint of material and structure, no stable temperature characteristic is obtained.

[0018] In Patent Document 4, the Cu-Cr alloy is widely used as a contact that Cr itself has almost the same vapor pressure characteristic as that of Cu and the high voltage and large current interruption characteristic can be made consistent with each other by a strong gas getter operation. However, since Cr having a high activity is used, during manufacture of a contact material (the sintering process, etc.) and during processing of a contact material to a contact piece, selection of raw material powder, mixing of impurities, and control of the atmosphere are taken into consideration. However, a contact in which the large current interruption characteristic and contact resistance characteristic of the vacuum valve are improved more is desired.

[0019] In Patent Document 5, an arc-proof component exists in any of a plurality of layers and the temperature rise as a whole of the contact cannot be reduced sufficiently.

[0020] In Patent Document 6, similarly to the aforementioned, an arc-proof component exists in any of a plurality of layers and the temperature rise as a whole of the contact cannot be reduced sufficiently.

[0021] In Patent Document 7, Mo is united with W as an auxiliary component, so that the wetting property between Cu and W is improved, and the adhesive strength of W and Mo is improved. Thus W particles are prevented from scattering and falling, and the withstand voltage characteristic and temperature characteristic are improved, though no sufficient temperature characteristic is obtained yet.

[0022] In Patent Document 8, a contact is composed of an area 1 and an area 2, and the area 1 has a fine uniform structure to obtain a stable reignition characteristic, and in the area 2, to increase the conductivity as a whole of the contact, a big Cu phase is provided, and moreover the Cu ratio is made higher than that of the area 1. However, the suppression for the total resistance of the area 1 and area 2 is restricted and the temperature characteristic cannot be improved sufficiently.

[0023] A composite contact is disclosed in the document "DE 198 22 469 A1" and a method for manufacturing it.

SUMMARY OF THE INVENTION

[0024] An object of the present invention is to provide a composite contact realizing consistency of the interruption characteristic with the particularly stable temperature characteristic, a vacuum switch provided with a vacuum valve including the composite contacts and a method for manufacturing the composite contact.

[0025] According to an aspect of the present invention, there is provided a composite contact including a first layer composed of a Cu-Cr mixture wherein powder or granular Cr with an average particle diameter of 0.1 to 150 μm and powder or granular Cu with an average particle diameter of 0.1 to 150 μm are mixed at a rate of 15 to 60 wt% of Cr and the remainder of Cu, and a second layer composed of Cu. The first layer and the second layer are united with each other, while Cu of the first layer enters the second layer within a range from 20 μm to 100 μm from a boundary surface between the first layer and the second layer and Cu in the second layer enters the first layer within a range from 20 μm to 100 μm from the boundary surface.

[0026] According to another aspect of the present invention, there is provided the composite contact according to Claim 1, Claim 8 or Claim 11, wherein, the powder or granular Cr with an average particle diameter of 0.1 to 150 μm is replaced with any of powder or granular W, carbide of W, Mo, and carbide of Mo with an average particle diameter of 0.1 to 15 μm. The Cu-Cr mixture is replaced with any of a Cu-W mixture, a mixture of Cu and carbide of W, a mixture of Cu and Mo, and a mixture of Cu and carbide of Mo, wherein any of powder or granular W, carbide of W, Mo, and carbide of Mo with an average particle diameter of 0.1 to 15 μm and powder or granular Cu with an average particle diameter 0.1 to 15 μm are mixed at a rate of 50 to 90 wt% of any of W, carbide of W, Mo, and carbide of Mo and the remainder of Cu.

[0027] According to a further aspect of the present invention, there is provided a vacuum switch provided with a vacuum valve including the composite contacts according to claim 1.

[0028] According to still another aspect of the present invention, there is provided a method for manufacturing a composite contact, comprising the steps of, step for preparing a first layer composed of a Cu-Cr mixture wherein powder or granular Cr with an average particle diameter of 0.1 to 150 μm and powder or granular Cu with an average particle diameter of 0.1 to 150 μm are mixed at a rate of 15 to 60 wt% of Cr and the remainder of Cu, step for preparing a second layer composed of Cu, step for placing the first layer to contact with the second layer, and step for primary heating the second layer and the first layer contacted with the second layer at a temperature of 900 to 1150°C, thereby to realize alloying of the Cu-Cr mixture in the first layer and alloying of the boundary surface between the first and second layers at the same time and to unite the first layer and the second layer.

[0029] The present invention can provide a composite contact realizing consistency of the interruption characteristic with the particularly stable temperature characteristic, a vacuum switch provided with a vacuum valve including the composite contacts and a method for manufacturing the composite contact, and contribute to realization of high performance of a vacuum switch.

BRIEF DESCRIPTION OF THE DRAWINGS

[0030] A more complete appreciation of the invention and many of the attendant advantages thereof will be readily obtained as the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying drawings, wherein:

Fig. 1 is a table showing evaluation conditions of Examples 1 to 9 and Comparison examples 1 to 10 of vacuum valve composite contacts according to the present invention;
Fig. 2 is a table showing evaluation results of Examples 1 to 9 and Comparison examples 1 to 10 of vacuum valve composite contacts according to the present invention;
Fig. 3 is a table showing evaluation conditions of Examples 10 to 22 and Comparison examples 11 to 14 of vacuum valve composite contacts according to the present invention;
Fig. 4 is a table showing evaluation results of Examples 10 to 22 and Comparison examples 11 to 14 of vacuum valve composite contacts according to the present invention;
Fig. 5 is a table showing evaluation conditions of Examples 31 to 42 and Comparison examples 18 to 29 of vacuum valve composite contacts according to the present invention;
Fig. 6 is a table showing evaluation results of Examples 31 to 42 and Comparison examples 18 to 29 of vacuum valve composite contacts according to the present invention;
Fig. 7 is a table showing evaluation conditions of Examples 43 to 58 and Comparison examples 30 to 31 of vacuum valve composite contacts according to the present invention;
Fig. 8 is a table showing evaluation results of Examples 43 to 58 and Comparison examples 30 to 31 of vacuum valve composite contacts according to the present invention; and
Fig. 9 is a cross sectional view showing a configuration example of a representative vacuum valve in which the vacuum valve composite contacts relating to the present invention are used.

DETAILED DESCRIPTION OF THE INVENTION

[0031] Referring now to the drawings, wherein like reference numerals designate identical or corresponding parts throughout the several views, the embodiments of this invention will be described below.

[0032] Hereinafter, the embodiments of the present invention will be explained in detail.

[0033] A first embodiment of the present invention is a vacuum valve composite contact characterized in that in a structural body in which with the surface of a second layer composed of Cu, a first layer composed of a Cu-Cr mixture wherein powder or granular Cr with an average particle diameter (diameters of unspherical particles are converted to those of spherical particles) of 0.1 to 150 μm and powder or granular Cu with a similar average particle diameter are mixed at a rate of 15 to 60 wt% of

Cr and the remainder of Cu makes contact, the first layer and second layer kept in contact with each other are united with each other by the primary heating process at a temperature between 900°C and 1150°C for, for example, 0.25 hours so as to realize alloying of the Cu-Cr mixture and alloying of the boundary surface of the first and second layers at the same time, and the first and second layers are united with each other while mutually letting Cu of the second layer and Cu of the first layer enter within a range from 20 μm to 100 μm from the boundary surface. More in detail, the first and second layers must be electrically united with each other.

[0034] By doing this, in the temperature rise test under the same condition (on one end face of the power supply shaft with a diameter of 20 mm, a contact with a diameter of 42 mm and a thickness of 3 mm is attached by brazing so as to make both contacts touch, and a load of 100 kg is applied between them, and the surface temperature of the side of the power supply shaft is measured), the temperature rise value can be improved by about 4 to 5°C (suppressed to a lower value), and it contributes to the improvement of the temperature characteristic which is an object of the present invention.

[0035] Here, powder or granular Cr with an average particle diameter (diameters of unspherical particles are converted to those of spherical particles) of 0.1 to 150 μm may be replaced with powder or granular W with an average particle diameter (diameters of unspherical particles are converted to those of spherical particles) of Q. 1 to 15 μm and a Cu-Cr mixture may be replaced with a Cu-W mixture wherein powder or granular W and powder or granular Cu with a similar average particle diameter are mixed at a rate of 50 to 90 wt% of W and the remainder of Cu.

[0036] Namely, a point of manufacture under the condition of this embodiment is that the first and second layers are in contact with each other, so that before the primary heating or in the temperature rise process, particularly the removal of the gas component existing in the Cu-Cr mixture (or the Cu-W mixture) out of the mixture is easy and efficient and after all, the gas amount in the Cu-Cr alloy (or Cu-W alloy) after sintering can be reduced.

[0037] Another point of manufacture under the condition of this embodiment is that alloying of Cu and Cr of the Cu-Cr mixture (or alloying of Cu and W of the Cu-W mixture) and alloying of the neighborhood of the boundary surface of the first and second layers are realized at the same time, when Cu of the second layer enters the Cu-Cr alloy (or the Cu-W alloy) of the first layer and Cu of the Cu-Cr alloy (or the Cu-Cr alloy) of the first layer enters Cu of the second layer mutually within a range from 20 μm to 100 μm. An advantage by simultaneous realization of the two kinds of alloying is that the inside of the Cu-Cr alloy (or the Cu-W alloy) and the boundary surface of the first and second layers can be united with each other without being contaminated by the atmosphere (during the heat treatment, during preparation before sintering, or during storage). As a result, reduction in the gas amount inside the Cu-Cr alloy (or the Cu-W alloy), improvement of the boundary surface strength between the first and second layers, and improvement of the thermal conductivity (temperature characteristic) can be realized. Furthermore, in the process of both Cu to enter within a range from 20 μm to 100 μm, both Cus continue to enter while removing faults (fine gaps, impurities, gas components, etc.) existing on the opposite side from the neighborhood of the boundary surface of the first and second layers and can clean the neighborhood of the boundary surface, thus a composite contact having an excellent temperature characteristic is obtained.

[0038] Further, when Cu in the first layer and Cu in the second layer mutually enter the other layer to alloy the neighborhood of the boundary surface of the first and second layers, the boundary surface may remain as it was. However, when the alloying proceeds more and the boundary surface almost disappear, the temperature characteristic and interruption characteristic are improved more.

[0039] The reason that the temperature of the primary heating process is set to 900 to 1150°C is that when the temperature is lower than 900°C, the temperature of the Cu-Cr composite contact (or the Cu-W composite contact) after alloying is increased high (the temperature characteristic is inferior) and the interruption characteristic becomes inferior, while when the temperature is higher than 1150°C, voids remain easily inside the composite contact, and the temperature characteristic is reduced undesirably.

[0040] If the heating time is less than 0.25 hours, the temperature rise of the Cu-Cr composite contact after alloyed is large and the interruption characteristic is also inferior. If the heating time is more than 5 hours, the sufficient strength of the composite contact is obtained, but the other parts are softened unnecessarily, and it is economically inferior.

[0041] Here, the state that "Cu in the first layer and Cu in the second layer mutually enter just within a range from 20 μm to 100 μm" means that Cu in the first layer enters the second layer just within a range from 20 μm to 100 μm through the boundary surface and Cu in the second layer enters the first layer just within a range from 20 μm to 100 μm through the boundary surface. Namely, even if the amount is 100 μm or more, when the other one is less than 20 μm (the entry amount from the boundary surface is less than 20 μm), the mechanical contact strength between the first and second layers is insufficient, and a warp occurs, and separation from the boundary part occurs undesirably. When the entry amount is more than 100 μm, the strength is desirably sufficient. However, for a long processing time needed for such as more than 100 μm, the contact characteristic is changed due to composition changes of the constituent components in the first layer, and the other parts are softened unnecessarily, and it is economically inferior, thus it is excluded.

[0042] Further, as for the entry amount from the boundary surface, the distance (depth) of the entry into the first layer or the second layer from the boundary surface varies, so that the average value thereof is assumed as the entry amount.

[0043] Obtaining the state that "Cu in the first layer and Cu in the second layer mutually enter just within a range from 20 μm to 100 μm" is decided by the mutual relation between the degree of progress of sintering of the first layer and the entry degree of Cu in the neighborhood of the boundary surface between the first and second layers and is neither decided nor predicted only by the magnitudes of temperature, time, and material diffusion coefficient as in general diffusion. Namely, the degree of progress of sintering of the first layer depends on the particle diameter of Cr (or W), the purity of Cr (or W), and control of the quality of the atmosphere at the time thermal unification. The entry degree of Cu in the neighborhood of the boundary surface between the first and second layers depends on the contact status (contact area, contact force, contact surface cleanliness) of the first and second layers and control of the purity of the first and second layers.

[0044] Cu of the second layer in this embodiment is, for example, a Cu plate, a Cu sintered article, and a Cu molded product. With the surface of the second layer, the first layer composed of a Cu-Cr mixture (or a Cu-W mixture) wherein powder or granular article (hereinafter, represented by powder) Cr with an average particle diameter of 0.1 to 150 μm (or powder or granular (hereinafter, represented by powder) W with an average particle diameter of 0.1 to 15 μm) and powder or granular (hereinafter, represented by powder) Cu with a similar average particle diameter are uniformly mixed must make contact and be installed. Further, in this embodiment, in the state that the Cu-Cr mixture (or the Cu-W mixture) (the first layer) is installed on the surface of Cu (the second layer), the two layers must make contact with each other, and there is no vertical position relationship in arrangement between them. Further, a case that Cu (the second layer) is loaded on the top of the Cu-Cr mixture (or the Cu-W mixture) is included.

[0045] As an average particle diameter of Cr (or W) in the first layer in this embodiment, when powder of 0.1 μm or less is used, the gas amount contained in the Cu-Cr alloy (or the Cu-W alloy) after alloying is apt to increase, and not only the current interruption characteristic is reduced but also the temperature characteristic is reduced (the temperature rise value is increased). Further, as an average particle diameter of Cr in the first layer, when powder of 150 μm or more (in a case of W, powder of 15 μm or more) is used, the temperature characteristic of the contact after composition is undesirably reduced (greatly varied). The interruption current characteristic is also varied. As mentioned above, selection of the particle diameter of Cr powder (or W powder) is useful as an auxiliary art to accomplish the object of the present invention.

[0046] Cu of the second layer of the present invention is preferably of low hardness. The Vickers hardness (hereinafter, referred to as Hv) of Cu in this case is Hv = 60 or less, preferably Hv = 50 or less, though the hardness of general Cu is about Hv = 60 to 80 or so (or when the first layer is a Cu-W alloy, the hardness of Cu of the second layer is Hv = 60 or less, though the hardness of general Cu is Hv = 60 to 80 or so). By reducing the hardness, when laminating the first layer and second layer, the boundary surface of the two layers are put into a preferable contact state (a favorable state for Cu in the first layer and Cu in the second layer to mutually enter 20 μm or more). As a result, changing the Cu-Cr mixture to a Cu-Cr alloy (or changing the Cu-W mixture to a Cu-W alloy) and alloying the boundary surface between the first layer and the second layer can be realized at the same time. Here, first layer and second layer are united with each other, while Cu of the second layer and Cu of the first layer mutually enter within a range from 20 μm to 100 μm from the boundary surface, and a preferable temperature characteristic is obtained.

[0047] In this embodiment, when the Cu phase in the first layer and Cu and Cr in the Cu-Cr alloy (or Cu and W in the Cu-W alloy) are sufficiently softened to low hardness, a good contact state is obtained similarly and a preferable temperature characteristic is obtained. The Vickers hardness of Cu in this case is Hv = 60 or less, preferably Hv = 50 or less, though the hardness of general Cu is Hv = 60 to 80 or so. Although the hardness of general Cr is Hv = 220 to 270 or so, the hardness of Cr is Hv = 220 or less, preferably Hv = 200. (Or, in a case of the Cu-W alloy, the Vickers hardness of Cu is Hv = 60 or less, though the hardness of general Cu is Hv = 60 to 80 or so. Although the hardness of general W is Hv = 400 to 500 or so, the hardness of W is preferably Hv = 360 or less.) These hardness can be adjusted by the pre-heat treatment and adjustment of the purity. As mentioned above, selection of the hardness is an auxiliary art to accomplish the object of the present invention.

[0048] The second embodiment of the present invention is a vacuum valve composite contact characterized in that in a structural body in which with the surface of a second layer composed of Cu, a first layer composed of a Cu-Cr mixture wherein powder or granular Cr with an average particle diameter (diameters of unspherical particles are converted to those of spherical particles) of 0.1 to 150 μm and powder or granular Cu with a similar average particle diameter are mixed at a rate of 15 to 60 wt% of Cr and the remainder of Cu makes contact, the first layer and the second layer are united with each other by the primary pressurizing process at pressure of 6 ton/cm^2 or less and then united with each other by the primary heating process at a temperature between 900°C and 1150°C so as to realize alloying of the Cu-Cr mixture and alloying of the boundary surface of the first and second layers at the same time, and the first and second layers are united with each other while mutually letting Cu of the second layer and Cu of the first layer enter within a range from 20 μm to 100 μm from the boundary surface.

[0049] Here, powder or granular Cr with an average particle diameter (diameters of unspherical particles are converted to those of spherical particles) of 0.1 to 150 μm may be replaced with powder or granular W with an average particle diameter (diameters of unspherical particles are converted to those of spherical particles) of 0.1 to 15 μm and a Cu-Cr mixture may be replaced with a Cu-W mixture wherein powder or granular W and powder or granular Cu with a similar average particle diameter are mixed at a rate of 50 to 90 wt% of W and the remainder of Cu.

[0050] Namely, in this embodiment, firstly, so as to bring Cu fully into contact with the Cu-Cr mixture (or the Cu-W mixture), the two layers are preferably brought into contact at a contact pressure of 6 ton/cm^2 or less including 0 and are loaded, and then so as to increase the relative density of the Cu-Cr mixture (or the Cu-W mixture) after sintering to 90% or more, the mixture is heated and sintered, for example, at 900°C, so that the Cu-Cr mixture is alloyed to a Cu-Cr alloy (or the Cu-W mixture is alloyed to a Cu-W alloy) and is connected to Cu (the second layer).

[0051] Further, in this embodiment, the reason that the primary pressurizing process as an auxiliary art is set to 6 ton/cm^2 or less is that when the pressure is more than 6 ton/cm^2, a one-side touch phenomenon (contact only on one specific part, concentration of the contact points) occurs on the contact surfaces between the two layers, and it is not preferable for reservation of the contact area, and at the time of current interruption or switching, the temperature rise value is varied undesirably. The lower limit is defined as that a case that one of Cu and the Cu-Cr mixture (or the Cu-W mixture) opposite to it acts its own weight on the other is included. Zero indicates the own weight.

[0052] Further, in this embodiment, the reason that the primary heating process as an auxiliary art is set to 1150°C or less is that when the temperature is higher than 1150°C, not only generation of voids is seen in the first layer of the composite contact but also the alloying of the boundary surface between the first and second layers of the composite contact proceeds excessively, and the Cu entry amount is hardly controlled to 100 μm or less, and a stable temperature characteristic cannot be obtained. As for the primary heating time, it is similarly required more than 0.25 hours.

[0053] Further, in this embodiment, in the state that the Cu-Cr mixture (or the Cu-W mixture) (the first layer) is installed on the surface of Cu (the second layer), the two layers must make contact with each other, and there is no vertical position relationship in arrangement between them. Further, a case that Cu (the second layer) is loaded on the top of the Cu-Cr mixture (or the Cu-W mixture) is included.

[0054] The third embodiment of the present invention is a vacuum valve composite contact characterized in that in a structural body in which with the surface of a second layer composed of Cu, a first layer composed of a Cu-Cr mixture wherein powder or granular Cr with an average particle diameter (diameters of unspherical particles are converted to those of spherical particles) of 0.1 to 150 μm and powder or granular Cu with a similar average particle diameter are mixed at a rate of 15 to 60 wt% of Cr and the remainder of Cu makes contact, the first layer and the second layer are united with each other by the primary heating process at a temperature between 900°C and 1150°C and then united with each other by the primary pressurizing process at pressure of 6 ton/cm^2 or less so as to realize alloying of the Cu-Cr mixture and alloying of the boundary surface of the first and second layers at the same time, and the first and second layers are united with each other while mutually letting Cu of the second layer and Cu of the first layer enter within a range from 20 μm to 100 μm from the boundary surface.

[0055] Here, powder or granular Cr with an average particle diameter (diameters of unspherical particles are converted to those of spherical particles) of 0.1 to 150 μm may be replaced with powder or granular W with an average particle diameter (diameters of unspherical particles are converted to those of spherical particles) of 0.1 to 15 μm and a Cu-Cr mixture may be replaced with a Cu-W mixture wherein powder or granular W and powder or granular Cu with a similar average particle diameter are mixed at a rate of 50 to 90 wt% of W and the remainder of Cu.

[0056] Namely, in this embodiment, instead of the unification by the primary heating process after the unification by the primary pressurizing process as in the second embodiment, unification by the primary heating process is executed first and then unification by the primary pressurizing process is executed. Even if the order of the unification by the primary pressurizing process and the unification by the primary heating process is interchanged like this, the same effect as that of the second embodiment can be obtained.

[0057] The fourth embodiment of the present invention is a vacuum valve composite contact characterized in that in a structural body in which with the surface of a second layer composed of Cu, a first layer composed of a Cu-Cr mixture wherein powder or granular Cr with an average particle diameter (diameters of unspherical particles are converted to those of spherical particles) of 0.1 to 150 μm and powder or granular Cu with a similar average particle diameter are mixed at a rate of 15 to 60 wt% of Cr to the remainder of Cu makes contact, the first layer and the second layer kept primarily pressurized at pressure of 6 ton/cm^2 or less are united with each other by the primary heating process at a temperature between 900°C and 1150°C so as to realize alloying of the Cu-Cr mixture and alloying of the boundary surface of the first and second layers at the same time, and the first and second layers are united with each other while mutually letting Cu of the second layer and Cu of the first layer enter within a range from 20 μm to 100 μm from the boundary surface.

[0058] Here, powder or granular Cr with an average particle diameter (diameters of unspherical particles are converted to those of spherical particles) of 0.1 to 150 μm may be replaced with powder or granular W with an average particle diameter (diameters of unspherical particles are converted to those of spherical particles) of 0.1 to 15 μm and a Cu-Cr mixture may be replaced with a Cu-W mixture wherein powder or granular W and powder or granular Cu with a similar average particle diameter are mixed at a rate of 50 to 90 wt% of W and the remainder of Cu.

[0059] Namely, by this embodiment, the unification by the pressurizing process and the unification by the heating process are executed at the same time, so that the first and second layers are less contaminated, have a higher quality, and can be united with each other efficiently in a shorter time than those of the second and third embodiments, and a composite contact having a more excellent temperature characteristic is obtained.

[0060] The fifth embodiment of the present invention is a vacuum valve composite contact characterized in that in a structural body in which with the surface of a second layer composed of Cu, a first layer composed of a Cu-Cr mixture wherein powder or granular Cr with an average particle diameter (diameters of unspherical particles are converted to those of spherical particles) of 0.1 to 150 μm and powder or granular Cu with a similar average particle diameter are mixed at a rate of 15 to 60 wt% of Cr and the remainder of Cu makes contact, the unification of the first layer and second layer by the primary pressurizing process at pressure of 6 ton/cm^2 or less and the unification by the primary heating process at a temperature between 900°C and 1150°C are executed at the same time or either of them is executed and then the other is executed. Then at least one of the unification by the secondary pressurizing process at pressure of 4 ton/cm^2 or more and the unification by the second heating process at 1080°C or less is executed so as to realize the alloying of the Cu-Cr mixture and the alloying of the boundary surface of the first and second layers at the same time, and the first and second layers are united with each other while mutually letting Cu of the second layer and Cu of the first layer enter within a range from 20 μm to 100 μm from the boundary surface.

[0061] Here, powder or granular Cr with an average particle diameter (diameters of unspherical particles are converted to those of spherical particles) of 0.1 to 150 μm may be replaced with powder or granular W with an average particle diameter (diameters of unspherical particles are converted to those of spherical particles) of 0.1 to 15 μm and a Cu-Cr mixture may be replaced with a Cu-W mixture wherein powder or granular W and powder or granular Cu with a similar average particle diameter are mixed at a rate of 50 to 90 wt% of W and the remainder of Cu.

[0062] Namely, by this embodiment, for the first and second layers, the unification by the primary pressurizing process and the unification by the primary heating process are executed at the same time or either of them is executed and then the other is executed, and then moreover, at least one of the unification by the secondary pressurizing process and the unification by the secondary heating process is executed, so that the first and second layers can be united with each other efficiently in a shorter time than that of the first to fourth embodiments, and a composite contact having a more excellent temperature characteristic is obtained.

[0063] If the temperature in the secondary heating process is more than 1080°C, when the secondary pressurizing process is set to a pressure of 4 ton/cm^2, the effect is similar to those obtained by the primary heating process and primary pressurizing process. If the temperature in the secondary heating process is 1080°C or more, the reaction at the boundary surface is excessively advanced, and thereby the composite contact becomes easy to fragile.

[0064] Further, in this embodiment, the reason that the secondary pressurizing process as an auxiliary art is set to pressure of 4 ton/cm^2 or more is that it is useful in realization of higher density of the first layer.

[0065] Further, in this embodiment, the reason that the temperature of the secondary heating process as an auxiliary art is set to 1080°C or less is that it is useful in suppression of an occurrence of cracking in the first layer after the unification by heating and prevention of generation of voids.

[0066] The sixth embodiment of the present invention is characterized in that in the vacuum valve composite contact described in any of the first to fifth embodiments, after alloying of the Cu-Cr mixture (or the Cu-W mixture) and alloying of the boundary surface between the first and second layers are realized at the same time, Cu of the second layer is a Cu plate or a Cu sintered article practically having the relative density value of Cu.

[0067] Namely, according to this embodiment, when the second layer is assumed as a Cu plate practically having the relative density value of Cu, that is, a relative density of at least 8.0 gr/cc, high temperature conductivity of the second layer is realized and a composite contact having an excellent temperature characteristic is obtained. Further, in a Cu plate having a relative density of lower than 8.0 gr/cc, the generation of heat becomes undesirably higher, and the temperature characteristic is reduced, and the mechanical strength is insufficient, thus the composite contact is undesirably deformed (Cu having a relative density of 8.0 gr/cc is equivalent to about 90% of the density of pure Cu). In a composite contact using Fe or SUS as a second layer, the temperature characteristic is undesirably reduced.

[0068] Further, according to this embodiment, when the second layer is assumed as a Cu sintered article practically having the relative density value of Cu, that is, a relative density of at least 8.0 gr/cc and very little voids remaining in the Cu sintered article are deformed, they perform a buffer action for easing external force at the time of current interruption.

As a result, generation of a minute arc on the composite contact surface can be suppressed, so that a composite contact having a temperature characteristic for suppressing the surface roughness of the composite contact surface, contributing to realization of high conductivity, and suppressing the temperature rise of the contact surface low is obtained.

[0069] Further, in a Cu sintered article having a relative density of lower than 8.0 gr/cc, the generation of heat becomes undesirably higher, and the temperature characteristic is reduced, and the mechanical strength is insufficient, thus the composite contact is undesirably deformed

[0070] Further, W of the first to sixth embodiments mentioned above may be replaced with any of a carbide of W, Mo, and a carbide of Mo. Furthermore, a part of or all of Cu in the first layer may be replaced with Ag.

[0071] The seventh embodiment of the present invention is characterized in that in the vacuum valve composite contact described in any of the first to sixth embodiments, after alloying of the Cu-Cr mixture and alloying of the boundary surface between the first and second layers are realized at the same time, Cu of the first layer contains an amount of 0.5 wt% or less of at least one of Cr, Al, Si, and Fe.

[0072] Namely, according to this embodiment, Cu of the first layer contains an amount of 0.5 wt% or less of at least one of Cr, Al, Si, and Fe, so that the interruption characteristic is improved, thus a composite contact having a stable temperature characteristic free of mechanical changes is obtained. When the amount of at least one of Cr, Al, Si, and Fe is more than 0.5 wt%, the temperature characteristic is reduced. As mentioned above, selection of the component of at least one of Cr, Al, Si, and Fe in less than a predetermined amount in Cu of the first layer is useful as an auxiliary art for accomplishment of the object of the present invention.

[0073] The eighth embodiment of the present invention is characterized in that in the vacuum valve composite contact described in any of the first to seventh embodiments, the thickness of the first layer is set between 0.5 mm and 3.0 mm, and the thickness of the second layer is set between 0.5 mm and 3.0 mm, and the total thickness of the first layer and second layer is set between 1.0 mm and 5.0 mm (when the first layer is a Cu-W mixture, the thickness of the first layer is set between 0.5 mm and 5.0 mm, and the thickness of the second layer is set between 1.0 mm and 3.0 mm, and the total thickness of the first layer and second layer is set between 1.5 mm and 7.0 mm), and the first layer is a contact surface, and the second layer is a support pedestal of the first layer.

[0074] Namely, according to this embodiment, by an auxiliary art for optimizing the thickness of the first layer, the thickness of the second layer, and the total thickness thereof playing an important role in the electric resistance, not only the material resistance as a whole can be reduced but also the thickness is also reduced (made smaller) more within a predetermined range, so that the whole composite contact elastically responds to mechanical external force at the time of interruption. As an effect of optimization of the thickness of the first and second layers (the thickness of the composite contact), the first and second layers are thin for external force applied to the contact surface at the time of interruption or switching, so that it is important to obtain an effect that the contact surface can follow while flexibly reserving the contact area. When the first and second layers are thick beyond the aforementioned upper limits, the contact surface becomes point contact and cannot follow while flexibly reserving the contact area, and the actual contact area is not increased, and the effect of improvement of the temperature characteristic is low.

[0075] As mentioned above, when the thickness of the first and second layers is set to an appropriate value within a range of a predetermined value, not only an auxiliary effect that the material resistance can be reduced is obtained but also it acts so as to ensure the actual contact area of the contact surface large, and by the synergistic effect thereof, it has an action of contributing to more stabilization of the temperature characteristic.

[0076] The knowledge for the synergistic effect is that the effect is not simple pursuit of an optimal value only by changing the material thickness. A precondition is that the selection of the thickness within the range that for deformation by external force, the whole composite contact can follow the deformation, the selection of Cu and 15 to 60 wt% of Cr as the first layer (or selection of Cu and 15 to 90 wt% of W), the selection of Cu having a relative density of 8.0 gr/cc or more which is fully softened as the second layer, and the first and second layers are laminated and are used respectively as a contact surface and a support member. By the combination of the above-described precondition and a main condition that Cu of the second layer and Cu of the first layer have boundary surface through which they mutually enter within a range from 20 μm to 100 μm, the synergistic effect depends on a composite contribution that these factors mutually affect closely the temperature characteristic.

[0077] As a result, a composite contact that the temperature rise is reduced and an excellent temperature characteristic is provided is obtained.

[0078] Further, as an auxiliary art, when the thickness of the first layer is less than 0.5 mm, if the number of interruptions and the number of switchings are increased, in all of or a part of the material of the first layer, evaporation, scattering, and consumption are seen, and for example, by trouble of generation of a welding fault or a withstand voltage fault due to exposure of the second layer, surface roughness is caused undesirably. Inversely, when the thickness of the first layer is more than 3 mm (when the first layer is Cu-W mixture, more than 5 mm), the electric resistance of the material is increased in correspondence to it, and not only the temperature of the contact surface undesirably rises greatly but also the actual contact area cannot be ensured undesirably.

[0079] On the other hand, if the thickness of the second layer is less than 0.5 mm (when the first layer is a Cu-W mixture, less than 1 mm), when the second layer is used as a support pedestal of the first layer, the strength is insufficient and the composite contact is deformed as a whole undesirably. The deformation causes non-uniformity of the contact state and reduction in the temperature characteristic. When the thickness of the second layer is more than 3 mm, the deformation capacity of the first layer to flexibly follow in order to ensure the contact area is reduced, and the contact area of the first layer is not increased, and not only the improvement effect of the temperature characteristic is low but also the electric resistance of the material is increased in correspondence to it, and the temperature of the contact surface is undesirably increased greatly. Furthermore, the total value of the thickness of the first layer and the thickness of the second layer, by the same reason, is preferably 5 mm or less (when the first layer is a Cu-W mixture, 7 mm or less).

[0080] The ninth embodiment of the present invention is characterized in that in the vacuum valve composite contact described in any of the first to seventh embodiments, Cu of the first layer composed of a Cu-Cr mixture contains 0.001 to 1 wt% of at least one of Bi, Te, and Sb.

[0081] Namely, this embodiment is useful in further improvement of the welding resistance characteristic.

[0082] Next, the operations of these embodiments will be explained.

[0083] In the vacuum circuit breaker, when there are quality faults in the contact material, a case that the interruption characteristic and temperature characteristic are varied or a desired function is not fulfilled is seen.

[0084] The inventors examined the contact material used for a vacuum valve, compared it with the vacuum valve characteristic, and found that the following (a) - (f) strongly take part in the temperature characteristic.

(a) the intrinsic resistance of the contact material itself.
(b) the intrinsic resistance of the fixed power supply shaft itself.
(c) the intrinsic resistance of the movable power supply shaft itself.
(d) the thickness of the contact material and the thickness of the Cu layer.
(e) the junction status between the contact and the fixed power supply shaft.
(f) the junction status between the contact and the movable power supply shaft.

[0085] In addition to it, (g) the deterioration status of the surface of the contact surface (surface roughness, adhesion degree of contaminants) due to the lapse of interruption or switching also takes part in reduction in the temperature characteristic.

[0086] Firstly, (a), (b), and (c) can be confirmed beforehand, by controlling the obstruction conditions for effectively fulfilling the present invention such as, with respect to the composition ratio of the contact material, application of 15 to 60% Cr-Cu (or 50 to 90% W-Cu), for Cu of the second layer, a relative density of 8.0 gr/cc or more, and for example, use of a Cu plate or a Cu sintered article, that is, when the contact material and the materials of the fixed and movable power supply shafts are decided. When the amount of Cr in the Cu-Cr alloy of the first layer is less than 15% (or when the amount of W in the Cu-W alloy is less than 50%), the arc-proof property when the current is interrupted is not sufficient, so that the material of the contact surface area is damaged severely, and the contact resistance is changed remarkably, and the temperature characteristic is reduced. When the amount of Cr is 15% or more (or the amount of W is 50% or more), the arc-proof property is improved and the temperature characteristic is stabilized. However, at the composite contact that a Cu-Cr alloy in which the amount of Cr is more than 60% (or a Cu-W alloy in which the amount of W is more than 90%) is arranged in the first layer of the present invention, a reduction in the interruption characteristic is seen and the temperature characteristic (heat conduction) is reduced undesirably.

[0087] Next, (d) is related to the thickness of the first and second layers. The first effect for that the thickness of the first and second layers is reduced is that, since the thickness of the first layer, the thickness of the second layer, and the total thickness thereof which have an important role in the electric resistance due to the material itself and thermal diffusion are optimized respectively, the material resistance as a whole can be reduced. At the contact of the vacuum valve, the contact surface area receiving an arc by current interruption is fused and evaporated by the received energy, and remarkable roughness and material consumption are caused, and a crater several μm to several 100 μm deep from the contact surface may be formed. Therefore, in this embodiment, as a thickness of the Cu-Cr contact (or the Cu-W contact) of the first layer, a thickness of 0.5 mm or more sufficiently thicker than the depth of the crater is selected, so that even if remarkable roughness and material consumption are caused, the Cu-Cr contact (or the Cu-W contact) of the first layer can remain in the contact surface area, and a stable temperature characteristic is obtained. When the thickness of the first layer is less than 0.5 mm, it is insufficient to fully prevent the second layer from exposure. When the thickness of the first layer is 3 mm or more (when the first layer is a Cu-W mixture, 5 mm or more), an increase in the resistance occurs, and therefore these values are decided as limit values. As a result, a Cu-Cr contact (first layer) with a thickness of 0.5 mm to 3.0 mm (when the first layer is a Cu-W mixture, 5 mm or less) is arranged, and the second layer (Cu) is arranged as a support pedestal for preventing the first layer from deformation, thus a stable temperature characteristic is fulfilled.

[0088] The second effect for that the thickness of the first and second layers is reduced is that, since the first and second layers are sufficiently thin, for external force applied to the contact surface at the time of interruption or switching, the layers follow flexibly while ensuring the three-point contact. When the first and second layers are thick beyond the aforementioned upper limit values, the contact surface becomes point contact and cannot follow while flexibly reserving the contact area, and the actual contact area is not increased, and no stable temperature characteristic can be fulfilled. In the contact art of the power circuit breaker, the first and second layers are optimized as a predetermined constitution, thus to use the flexibility and ensure the temperature characteristic is a new perception which is not seen conventionally.

[0089] As mentioned above, when the thickness of the first and second layers is set within the range of predetermined values, not only a general effect that the material resistance can be reduced but also an effect that the first and second layers are set to predetermined thicknesses preferable to integrally deform and the actual contact area of the contact surface is ensured are fulfilled. By the synergistic effect thereof, it contributes to more stabilization of the temperature characteristic.

[0090] Further, (e) and (f) depend on acceptance or rejection of the junction status and are variable factors which are most difficult to confirm. In brazing of Ag generally carried out to connect the first and second layers, the temperature characteristic varies with the existence of an Ag brazing layer and becomes a variable factor. Therefore, this embodiment, to prevent the status of (e) and (f) from acting on the temperature characteristic as a variable factor, eliminates the existence of the Ag brazing layer and realizes a status that Cu in the Cu-Cr contact of the first layer and Cu of the second layer mutually enter by a predetermined amount, thereby ensures the strength after the first and second layers are united with each other and excludes the variable factor for the temperature characteristic.

[0091] And, (g) varies with the status of interruption or switching every moment and is difficult to fix the quantity.

[0092] Namely, when the current is interrupted, the arced contact surface region of the Cu-Cr alloy (or the Cu-W alloy) of the first layer is repeatedly subject to fusion, evaporation, and scattering, and the contact surface is roughened remarkably, and the material is consumed, and temperature rise and reduction in the interruption characteristic are caused. The contact surface subject to such repetition of fusion, evaporation, and scattering is greatly changed in the surface status thereof every moment whenever the current is interrupted. Therefore, when a sufficient contact area is ensured, the temperature rise value is low and a stable temperature characteristic is obtained. However, the surface configuration varies every interruption, so that there is no guarantee given to ensuring of sufficient contact at the next interruption, and the temperature characteristic becomes unstable, and the interruption characteristic also becomes unstable. On the other hand, in this embodiment, suppression of generation of an arc by the aforementioned effect is taken into consideration by an auxiliary art for optimally selecting a range of the thickness of the first and second layers, and the temperature characteristic is stabilized.

[Embodiment]

[0093] To stabilize the temperature characteristic of the composite contact of the present invention for laminating the first layer having a function as a contact and the second layer having a support function, it is found that three points of firstly stabilization of the temperature characteristic of the Cu-Cr contact (or the Cu-W contact) of the first layer directly taking part in the contact phenomenon, stabilization of the temperature characteristic of the second layer supporting the first layer, and furthermore stabilization of the temperature characteristic in the neighborhood of the boundary surface where the first layer and second layer are laminated are important.

[0094] Under these knowledge, the embodiments of the present invention will be explained in detail.

[0095] Firstly, methods and conditions for evaluating the interruption characteristic, temperature characteristic, and related characteristics are indicated below.

<u>(1) Temperature characteristic (temperature rise value)</u>

[0096] A composite contact piece composed of the first layer and second layer manufactured under a predetermined condition is loaded on a test vacuum valve and is assembled. Then while giving a continuous current of 200 A and a load of 20 kg/cm^2 to the contact, the surface temperature of the terminal portion of the test vacuum valve is measured on a noncontact basis using a highly sensitive infrared thermometer, and the difference between the measured value and the room temperature is obtained as a temperature rise value, and the temperature characteristic is decided.

[0097] On the basis of the value of an example 2 which will be described later, a case that the temperature rise value is preferably lower than 0.8 times of the value of the example 2 is assumed as Evaluation A, the value between 0.8 times and 0.9 times (0.8 times is included) is Evaluation B, the value between 0.9 times and 1.05 times (0.9 times is included) as Evaluation C, and the value between 1.05 times and 1.15 times (1.05 times is included) as Evaluation D. On the other hand, a case that the value between 1.15 times and 1.3 times (1.15 times is included) which is more unstable than the value of the example 2 is assumed as Evaluation X, the value between 1.3 times and 1.5 times (1.3 times is included) as Evaluation Y, and the value of 1.5 times or more as Evaluation Z. Here, the evaluation is indicated by relative values (A to D: good characteristics, X to Z: bad characteristics).

(2) Interruption characteristic

[0098] An experimental valve for the interruption test having a contact with a diameter of 70 mm is attached to a switchgear, is baked and voltage-aged. Then it is connected to a circuit at 24 kV and 50 Hz, and the interruption limit is compared and evaluated for three test vacuum valves while increasing the current almost by 1 KA each time. The numerical values indicated are relative values when the interruption limited value of an example 2 is set to 1.0.

Reference (1): Experimental valve for interruption test

[0099] As an interruption test valve, an insulating container made of ceramics (main component: Al_2O_3) in which the average surface roughness of the end face is ground to about 1.5 μm is prepared. The ceramics insulating container is subject to the pre-heating process at 1600°C before assembly. As a sealing metal fitting, a 42% Ni-Fe alloy with a plate thickness of 2 mm is prepared. As a brazing material, a 72% Ag-Cu alloy plate with a thickness of 0.1 mm is prepared. The aforementioned prepared members are arranged between the joined articles (the end face of the ceramics insulating container and sealing metal fitting) so as to be subject to air-tight sealing junction. In a vacuum atmosphere at $5x10^{-4}$ Pa, the test valve is assembled by the air-tight sealing step between the sealing metal fitting and the ceramics insulating container.

Reference (2): Evaluation of Cu entry amount

[0100] An important point of the composite contact of the present invention is that when the two layers are united with each other how much Cu in the first layer and Cu in the second layer mutually enter, and to measure the entry amount is important.

[0101] Measurement of the Cu entry amount is examined by the section in the neighborhood of the boundary surface where the first layer and second layer make contact with each other. In Cu in Cu-Cr (or Cu-W) of the first layer, a radioactive substance (^{64}Cu) is doped. In this case, in Cu in the second layer, no radioactive substance (^{64}Cu) is doped. The two layers are made contact with each other, are heated, and are united with each other. Then in the section in the neighborhood of the boundary surface, the amount of a radioactive substance (^{64}Cu) existing in Cu in the second layer, is determined as Cu entering from the first layer by, for example, an IMA (ion micro-analyzer).

[0102] Next, in Cu in the second layer, a radioactive substance (^{64}Cu) of Cu is doped. In this case, in Cu in Cu-Cr (or Cu-W) of the first layer, no radioactive substance (^{64}Cu) is doped. The two layers are made contact with each other, are heated, and are united with each other. Then in the cut section, the amount of a radioactive substance (^{64}Cu) existing in Cu in the first layer is determined as Cu entering from the second layer by, for example, the IMA (ion micro-analyzer).

[0103] By doing this, the distances that both Cus mutually enter from the boundary surface are obtained. For measurement, in addition to the IMA, an XMA (X-ray micro-analyzer) is also used to confirm the reliability of the measured values.

[0104] Namely, the distance of the entered Cu is obtained by the pre-experiment using test pieces, details of which are described below.

(1) For Cu of the second layer, a Cu plate in which a radioactive substance (^{64}Cu) is doped beforehand is prepared. For the first layer, using Cu powder in which no radioactive substance (^{64}Cu) is doped, Cu-Cr mixed powder (or Cu-W mixed powder) in which Cu powder is mixed with Cr powder (or W powder) as raw powder are prepared. For example, the two layers, in the state that they are kept unchanged (in the loaded state), are united with each other by a predetermined heating process (unification by the primary heating at 900 to 1150°C) to form a composite contact.

(2) Inversely, a Cu plate (the second layer) in which no radioactive substance (^{64}Cu) is doped is prepared. For the first layer, using Cu powder in which a radioactive substance (^{64}Cu) is doped and Cr powder (or W powder), Cu-Cr mixed powder (or Cu-W mixed powder) in which they are mixed is prepared. The two layers, in the state that they are kept unchanged (in the loaded state), are united with each other by a predetermined heating process (unification by the primary heating at 900°C to 1150°C) to form a composite contact.

[0105] In this way, a composite contact containing a radioactive substance (^{64}Cu) in either of the Cu layer (the second layer) and the Cu-Cr alloy (or the CuW alloy) (the first layer) is formed and the relationship with the radioactive substance (^{64}Cu) entry amount corresponding to the heating condition is measured. By knowing the relationship between them by the pre-experiment, the amount of entered Cu is inferred without doping a radioactive substance (^{64}Cu) in the Cu plate and Cu powder used to manufacture all composite contacts actually to be supplied to the example and comparison example.

Reference (3): Example of manufacturing condition of composite contact

[0106] In the examples and comparison examples of the present invention, the steps (a to g) used after Cu (the second layer) and the Cu-Cr mixture (or Cu-W mixture) (the first layer) are made contact with each other are indicated below.

Step: → (Contents of step after making contact)

[0107]

Step a: Two layers are made only in contact. → Mechanical pressing
Step b: Two layers are made only in contact. → Primary heating (lower than 900°C)
Step b: Two layers are made only in contact. → Primary heating (900°C to 1150°C) for 0.5 to 3 hours
Step b: Two layers are made only in contact. → Primary heating (higher than 1150°C)
Step c: Two layers are made only in contact. → Primary heating (1050°C) for 0.5 to 3 hours → Primary pressurizing (6 t/cm^2 or less)
Step d: Two layers are made only in contact. → Contact by primary pressurizing (6 t/cm^2 or less) → Primary heating (1150°C) for 0.5 to 3 hours
Step e: Two layers are made only in contact. → Primary heating (1050°C) for 0.5 to 3 hours → Primary pressurizing (6 t/cm^2 or less) → Secondary heating (900°C) for 0.5 to 3 hours → Secondary pressurizing (4 t/cm^2 or more)
Step f: Two layers are made only in contact. → Contact by primary pressurizing kept (weight kept loaded) → Primary heating (1050°C) for 0.5 to 3 hours
Step g: Two layers are made only in contact. → Primary pressurizing (6 t/cm^2 or less) → Primary heating (1050°C) for 0.5 to 3 hours → Secondary pressurizing (4 t/cm^2 or more) → Secondary heating (900°C) for 0.5 to 3 hours

[0108] In each of Steps a - g, the primary heating and the secondary heating were executed in the atmosphere of hydrogen gas or in vacuum.

[0109] In the following description with respect to the examples and the comparison examples, the atmosphere and the time required for executing the primary heating and the secondary heating in each of Steps a - g are not described for the sake of simplicity of the description. Please refer to the above-description, if necessary.

[0110] Hereinafter, by referring to Figs. 1 to 4, the examples and comparison examples when the first layer is a Cu-Cr mixture will be explained in detail.

(Examples 1 to 5 and comparison examples 1 to 7)

[0111] In these examples and comparison examples, except the example 3, a Cu plate is used as Cu of the second layer.

[0112] Namely, in the explanation, a pure Cu plate with a thickness of 2 mm is used as a representative material of the second layer, and a Cu-25% Cr alloy with a thickness of 1 mm is used as a representative material of the first layer.

[0113] The Cu plate is pre-heated at 500°C or higher for 10 minutes or more. Cu in the Cu-Cr mixed powder is pre-heated at 350°C or higher for about one hour and then is used. Cr in the Cu-Cr mixed powder is pre-heated at 1350°C or higher for about 30 minutes or more and then is used.

[0114] As Cu and Cr for the first layer, Cu-Cr mixed powder (the first layer) in which Cr (chromium) powder with an average particle diameter of 44 to 105 μm and Cu (copper) powder with the same average particle diameter are uniformly mixed at a predetermined ratio (25 wt% Cr - Cu) is prepared. As Cu for the second layer, a Cu plate rolled to a thickness of 2 mm is prepared.

[0115] As a step after Cu and the Cu-Cr mixture are made contact with each other, in the comparison example 1, Step a is adopted, in the comparison examples 2 to 5, Step b is adopted, and in the examples 1 to 5, Step b is adopted. In the comparison examples 6 and 7, a predetermined thickness is left by a method for removing a part of the surface layer by a mechanical process.

[0116] The two layers are made contact, as they were, with each other (kept loaded) and as at Step a, are united with each other by mechanically pressed at a pressure of 8 t/cm^2 and the entry of Cu in the neighborhood of the boundary surface is almost 0 (Comparison example 1).

[0117] The two layers are made contact, as they were, each other (kept loaded) and are subject to the primary heating process at 700°C at Step b, and Cu in the first layer enters the second layer by 2 to 5 μm, and Cu in the second layer enters the first layer by 3 to 5 μm (Comparison example 2).

[0118] The two layers are made contact, as they were, with each other (kept loaded) and are subject to the primary heating process at 800°C at Step b, and Cu in the first layer enters the second layer by 15 to 17 μm, and Cu in the second layer enters the first layer by 15 to 17 μm (Comparison example 3).

[0119] The two layers are made contact, as they were, with each other (kept loaded) and are selectively subject to the primary heating process at 900 to 1150°C for about one hour at Step b, and alloying of the Cu-Cr mixture (the first layer) and alloying of the boundary surface between the first and second layers are realized at the same time. Thus, a composite contact in which the two layers are united with each other while Cu of the second layer and Cu in the first layer mutually enter within a range from 20μ m to 100 μm from the boundary surface is obtained (Examples 1, 2, 4 and 5).

[0120] The two layers are made contact, as they were, with each other (kept loaded) and are subject to the primary heating process at 1250°C for about one hour at Step b, and alloying of the Cu-Cr mixture (the first layer) and alloying of the boundary surface between the first and second layers are realized at the same time. Thus, a composite contact in which Cu of the second layer and Cu in the first layer enter within a range from 100 μm to 110 μm from the boundary surface is obtained (Comparison example 4).

[0121] The two layers are made contact, as they were, with each other (kept loaded) and are subject to the primary heating process at 1300°C at Step b, and alloying of the Cu-Cr mixture (the first layer) and alloying of the boundary surface between the first and second layers are realized at the same time. Thus, a composite contact in which Cu of the second layer and Cu in the first layer enter within a range from 110 μm to 120 μm from the boundary surface is obtained (Comparison example 5).

[0122] The two layers are made contact, as they were, with each other (kept loaded), and using the composite contacts manufactured in the examples 1, 2, 4 and 5 mentioned above, the thickness of Cu is reduced to 2 to 5 μm by mechanically removing one surface (the second layer), and the other surface (the first layer) is not mechanically processed and is kept unchanged at 30 to 35 μm (Comparison example 6). Inversely, the first layer is mechanically removed, thus the thickness of Cu is reduced to 2 to 5 μm and the second layer is not mechanically processed and is kept unchanged at 30 to 35 μm (Comparison example 7). In this way, composite contacts different in thickness are manufactured (Comparison examples 6 and 7).

[0123] Further, the evaluation of the present invention is made such that the temperature characteristic and interruption characteristic are treated as the reference values when the entry amount of Cu from the first layer into the second layer and the entry amount of Cu from the second layer into the first layer are respectively set to 30 to 35 μm and 30 to 35 μm (Example 2).

[0124] The temperature characteristic and interruption characteristic are evaluated for each composite contact. When the entry amount of Cu from the first layer into the second layer and the entry amount of Cu from the second layer into the first layer are set to almost zero, 2 to 5 μm, and 3 to 5 μm, for the reference value of the example 2, temperature rise values of 1.5 times (Evaluation Z), 1.3 to 1.5 times, and 1.5 times or more (Evaluations Y and Z) are obtained, and they are disqualified. The interruption characteristic, for the reference value of the example 2, is reduced to 0.3 times and 0.5 times, and moreover in the interruption test, the first layer and second layer are separated undesirably (Comparison examples 1 and 2).

[0125] Further, when the entry amount of Cu from the first layer into the second layer and the entry amount of Cu from the second layer into the first layer are set to 15 to 17 μm, and 15 to 17 μm, for the reference value of the example 2, temperature rise values of 1.15 to 1.3 times and 1.3 to 1.5 times (Evaluations X and Y) are obtained, and they are disqualified. The interruption characteristics, for the reference value of the example 2, are reduced to 0.8 to 0.9 times, and moreover in the interruption test, the first layer and second layer are separated undesirably (Comparison example 3).

[0126] On the other hand, when the entry amount of Cu from the first layer into the second layer and the entry amount of Cu from the second layer into the first layer are respectively set to 20 to 25 μm and 20 to 25 μm (Example 1), the temperature characteristic is similar to the reference value of the example 2 (Evaluations C and D). Furthermore, the interruption characteristic indicates 0.9 to 1.0 times and is similar to the reference value of the example 2, that is, within the qualified range.

[0127] When the entry amount of Cu from the first layer into the second layer and the entry amount of Cu from the second layer into the first layer are respectively set to 45 to 50 μm and 45 to 50 μm (Example 4), the temperature characteristic is similar to the reference value of the example 2 or more (Evaluations B and C). The interruption characteristic indicates satisfactorily 1.0 to 1.1 times.

[0128] When the entry amount of Cu from the first layer into the second layer and the entry amount of Cu from the second layer into the first layer are respectively set to 95 to 100 μm and 95 to 100 μm (Example 5), for the reference value of the example 2, temperature rise values of 0.8 to 0.9 times (Evaluation B) are obtained. The interruption characteristic indicates satisfactorily 1.0 to 1.1 times.

[0129] However, when the entry amount of Cu from the first layer into the second layer and the entry amount of Cu from the second layer into the first layer are respectively set to 100 to 110 μm and 100 to 110 μm (Comparison example 4) or set to 110 to 120 μm and 110 to 120 μm (Comparison example 5), for the reference value of the example 2, the temperature rise values are 1.15 to 1.3 times and 1.3 to 1.5 times (Evaluations X and Y) or 1.05 to 1.15 times and 1.5 times or more (Evaluations D to Z). The interruption characteristic, for the reference value of the example 2, indicates 0.8 times to 1.0 times or 0.7 times to 1.0 times, and qualified values and disqualified values coexist undesirably. On each contact surface after the interruption test, composition changes and generation of internal voids due to evaporation are seen. This seems to be a cause.

[0130] Further, when either of the entry amount of Cu from the first layer into the second layer and the entry amount of Cu from the second layer into the first layer is set to 2 to 5 μm (Comparison examples 6 and 7), the temperature characteristic, for the reference value of the example 2, indicates 1.05 to 1.15 times, 1.3 to 1.5 times, or 1.15 to 1.3 times (Evaluations D to Y, Evaluations D to X) and variations are seen. The interruption characteristic, for the reference value of the example 2, indicates 0.8 times to 1.0 times and qualified values and disqualified values coexist undesirably.

[0131] From the aforementioned, the entry amount of Cu from the first layer into the second layer and the entry amount of Cu from the second layer into the first layer are preferably set within a range from 20 to 100 μm according to the examples 1, 2, 4 and 5.

(Example 3)

[0132] In the example 3, as Cu of the second layer, a Cu sintered plate is used.

[0133] Namely, as Cu and Cr for the first layer, Cu-Cr mixed powder (the first layer) in which Cr (chromium) powder with an average particle diameter of 44 to 105 μm and Cu (copper) powder with the same average particle diameter are uniformly mixed at a predetermined ratio (25 wt% Cr - Cu) is prepared. As Cu for the second layer, a Cu sintered plate, which has a relative density of 8.0 gr/cc or more and is rolled to a thickness of 2 mm, is prepared.

[0134] On the top of the Cu sintered article (the second layer), the Cu-Cr mixed powder (the first layer) is placed, and the two layers are kept unchanged (kept loaded) and are subject to a predetermined primary heating process (900 to 1150°C) for about one hour (at Step b), and Cu-Cr alloying of the Cu-Cr mixed powder (the first layer) and alloying of the boundary surface between the first and second layers are realized at the same time. Thus, a composite contact characterized in that the two (the first and second layers) are united with each other while Cu of the second layer and Cu in the first layer mutually enter within a range from 20 μm to 100 μm from the boundary surface is obtained, and the temperature characteristic and interruption characteristic are evaluated. As a result, even if the second layer is a Cu sintered plate, the same tendency is obtained (Example 3). Further, Cu of the Cu-Cr mixed powder and Cr of the Cu-Cr mixed powder are heated respectively at 350°C or higher for about one hour and 1350°C or higher for about one hour before use.

(Examples 6 and 7 and comparison examples 8 and 9)

[0135] As Cu and Cr for the first layer, Cu-Cr mixed powders in which Cr (chromium) powder with an average particle diameter of 44 to 105 μm and Cu (copper) powder with the same average particle diameter are mixed at a predetermined ratio (5 to 90% Cr - Cu) are prepared. As Cu for the second layer, a Cu plate is prepared.

[0136] On the top of the Cu plate (the second layer), the Cu-Cr mixed powder (the first layer) is placed, and the two layers are made contact with each other, as they were, (kept loaded), are united with each other by the primary pressuring process at a pressure of 6 t/cm^2 or less, for example, of 2 t/cm^2, and then are subject to the primary heating process at 900 to 1150°C for about one hour, and alloying of the Cu-Cr mixed powder (the first layer) and alloying of the boundary surface between the first and second layers are realized at the same time. Thus, composite contacts in which the two (the first and second layer) are united with each other while Cu of the second layer and Cu in the first layer mutually enter within a range from 20 μm to 100 μm from the boundary surface are obtained (Step d).

[0137] In the temperature characteristic and interruption characteristic when the entry amount of Cu from the first layer into the second layer and the entry amount of Cu from the second layer into the first layer are set respectively to 30 to 35 μm and 30 to 35 μm, using each Cu-Cr composite contact having a Cr amount of 5 to 90%, an effect of controlling the entry amount of Cu from the first layer into the second layer and the entry amount of Cu from the second layer into the first layer which is a gist of the present invention is examined.

[0138] For the reference value of the example 2, in 15% Cr-Cu (Example 6) and 60% Cr-Cu (Example 7), the temperature characteristics indicate 0.8 to 0.9 times (Evaluation B) and 1.0 times (Evaluation C), respectively. The interruption characteristics ensure 0.9 times of the reference value of the example 2 and both characteristics are satisfactory.

[0139] On the other hand, in 5% Cr-Cu (Comparison example 8), for the reference value of the example 2, the temperature characteristic indicates 0.8 to 0.9 times (Evaluation B) in the qualified range, though the interruption characteristic is undesirably reduced to 0.7 times, and the characteristics are disqualified as a whole. On the contact surface after interruption, remarkable surface roughness is seen (Comparison example 8).

[0140] Furthermore, in 90% Cr-Cu (Comparison example 9), for the reference value of the example 2, the temperature characteristic undesirably indicate 1.15 to 1.3 times (Evaluation X) and 1.3 to 1.5 times (Evaluation Y) and are disqualified. The interruption characteristic is greatly reduced to 0.4 times for the reference value of the example 2 and is disqualified (Comparison example 9).

[0141] From the aforementioned, the Cu-Cr alloy (Examples 6 and 7) having a Cr amount of 15 to 60% Cr of the first layer is preferable, and more preferably, selection of the Cu-Cr alloy (Example 2) having 25% Cr is useful as an auxiliary art for executing the present invention.

(Examples 8 and 9 and comparison example 10)

[0142] A Cu plate (the second layer) similar to the aforementioned and a Cu-Cr mixed powder (the first layer) similar to the aforementioned are prepared. On the top of the Cu plate, the aforementioned Cu-Cr mixed powder (the first layer) is placed and the layers are united with each other by the primary pressuring process at a pressure of 6 t/cm^2 or less, (after cooling), are united with each other by the primary heating process at 950 to 1150°C for about one hour, then are secondarily pressurized at a pressure of 4 t/cm^2 or more, and are united with each by the secondary heating process at 1080°C or lower, for example, at 950°C (Step g).

[0143] When the average particle diameter of Cr in the Cu-Cr alloy (the first layer) is 0.5 to 44 μm (Example 8), the temperature characteristic indicates Evaluation D of 1.05 to under 1.15 times, and the interruption characteristic indicates 0.9 to 1.0 times, and the two are within the qualified range. Even when the average particle diameter of Cr is 105 to 150 μm (Example 9), the temperature characteristic indicates Evaluation C similar to that of the reference example 2, and the interruption characteristic indicates 1.1 times, and the two are within the qualified range. On the other hand, when the average particle diameter of Cr is 150 to 300 μm (Comparison example 10), the temperature characteristic indicates Evaluation C similar to that of the reference example 2 and is qualified, though the interruption characteristic undesirably indicates large variations such as 0.7 to 1.0 times.

(Examples 10 to 12 and comparison examples 11 and 12)

[0144] On the top of the Cu plate (the second layer), the aforementioned Cu-Cr mixed powder (the first layer) is placed, and the two layers are made contact with each other, as they were, (kept loaded), are united with each other by the primary heating process at 900 to 1150°C, for example, at 1050°C for about one hour. And then, they are united with each other by the primary pressuring process at a pressure of 6 t/cm^2 or less, for example, at a pressure of 4 t/cm^2, and Cr-Cu alloying of the Cu-Cr mixed powder (the first layer) and alloying of the boundary surface between the first and second layers are realized at the same time. Thus, composite contacts in which the two (the first and second layers) are united with each other while Cu of the second layer and Cu in the first layer mutually enter within a range from 20 μm to 100 μm from the boundary surface are obtained (Step c).

[0145] When the thicknesses of the first layer are set respectively to 0.5 mm, 1 to 2 mm, and 3.0 mm (Examples 10 to 12), the temperature characteristics indicate values similar to the reference value of the example 2 (Evaluations B-C and C). The interruption characteristics indicate 0.9 to 1.0 times similar to the reference value of the example 2 within the qualified range.

[0146] However, when the thickness of the first layer is set to 0.1 mm or less (Comparison example 11), compared with the reference value of the example 2, the temperature characteristic indicates the similar value (Evaluation B) and is qualified, though the interruption characteristic is greatly reduced to 0.5 to 0.7 times, and the characteristics are disqualified as a whole.

[0147] Furthermore, when the thickness of the first layer is set to 5 to 6 mm (Comparison example 12), for the reference value of the example 2, the temperature rise indicates 1.05 to 1.15 times (Evaluation D) and is within the qualified range, though the interruption characteristic indicates 0.8 times for the reference value of the example 2, and the characteristics are disqualified as a whole.

[0148] From the aforementioned, selection of 0.5 to 3.0 mm as a thickness of the first layer is useful as an auxiliary art for executing the present invention.

(Examples 13 and 14 and comparison examples 13 and 14)

[0149] When the thicknesses of the second layer are set respectively to 0.5 mm and 3.0 mm (Examples 13 and 14), the temperature characteristics indicate values similar to the reference value of the example 2 (Evaluation C). The interruption characteristics indicate almost similar 1.0 times and the two characteristics are similar to the reference values of the example 2 and are qualified.

[0150] However, when the thickness of the second layer is set to 0.3 mm or less (Comparison example 13), compared with the reference value of the example 2, the temperature characteristic indicates similar or larger values (Evaluation B and C) and is qualified, though the interruption characteristic is reduced to 0.6 to 0.8 times, and the characteristics are disqualified as a whole. Furthermore, when the thickness of the second layer is set to 6.0 mm (Comparison example 14), for the reference value of the example 2, the temperature rise indicates 1.05 to 1.15 times (Evaluation D) and is qualified, though the interruption characteristic indicates 0.8 times for the reference value of the example 2 and is disqualified.

[0151] From the aforementioned, selection of 0.5 to 3.0 mm as a thickness of the second layer is useful as an auxiliary art for executing the present invention.

[0152] Further, when either of the first layer and second layer does not meet the condition of the thickness, the composite contact does not meet the interruption characteristic (Comparison examples 11 and 13).

(Examples 15 and 16)

[0153] The case that as a step after the second layer and the first layer are made contact with each other, the two make contact, as they were, with each other (loaded) and then are subject to the primary heating process, and Cu-Cr alloying of the Cu-Cr mixed powder (the first layer) and alloying of the boundary surface between the first and second layers are realized at the same time, and composite contacts in which the two (the first and second layers) are united with each other while Cu of the second layer and Cu in the first layer mutually enter within a range from 20 μm to 100 μm from the boundary surface are obtained is indicated in the examples 1 to 5 (Step b).

[0154] The case that the first and second layers are subject to the primary pressurizing process after the primary heating process at Step b, and Cu-Cr alloying of the Cu-Cr mixed powder (the first layer) and alloying of the boundary surface between the first and second layers are realized at the same time, and composite contacts in which the two (the first and second layers) are united with each other while Cu of the second layer and Cu in the first layer mutually enter within a range from 20 μm to 100 μm from the boundary surface are obtained is indicated in the examples 10 to 12 (Step c).

[0155] The case that the first and second layers are made contact with each other (loaded), are subject to the primary pressurizing process, and then subject to the primary heating process, and Cu-Cr alloying of the Cu-Cr mixed powder (the first layer) and alloying of the boundary surface between the first and second layers are realized at the same time, and composite contacts in which the two (the first and second layers) are united with each other while Cu of the second layer and Cu in the first layer mutually enter within a range from 20 μm to 100 μm from the boundary surface are obtained is indicated in the examples 6 and 7 (Step d).

[0156] Furthermore, the case that after the primary pressurizing process and primary heating process at Step d, the first and second layers are further subject to the secondary pressurizing process and secondary heating process, and Cu-Cr alloying of the Cu-Cr mixed powder (the first layer) and alloying of the boundary surface between the first and second layers are realized at the same time, and composite contacts in which the two (the first and second layers) are united with each other while Cu of the second layer and Cu in the first layer mutually enter within a range from 20 μm to 100 μm from the boundary surface are obtained is indicated in the examples 8 and 9 (Step g).

[0157] However, the present invention can manufacture other composite contacts without being limited to these steps b, c, d, and g.

[0158] For example, after the primary heating process and primary pressurizing process at Step c, the first and second layers are further subject to the secondary heating process and secondary pressurizing process, and Cu-Cr alloying of the Cu-Cr mixed powder (the first layer) and alloying of the boundary surface between the first and second layers are realized at the same time, and a composite contact in which the two (the first and second layers) are united with each other while Cu of the second layer and Cu in the first layer mutually enter within a range from 20 μm to 100 μm from the boundary surface is obtained (Example 15, Step e). The temperature characteristic indicates values similar to the reference value of the example 2 (Evaluation A). Furthermore, the interruption characteristic indicates 1.2 times higher than the reference value of the example 2 and is qualified.

[0159] Further, with respect to the secondary heating process and secondary pressurizing process performed after the primary heating process and primary pressurizing process, only the secondary heating process may be performed or only the secondary pressurizing process may be performed.

[0160] Next, the two (the first and second layer) are made contact with each other (loaded) and then are subject to the primary heating process while giving a weight of 2 kg/cm^2, and alloying of the Cu-Cr mixed powder (the first layer) and alloying of the boundary surface between the first and second layers are realized at the same time, and a composite contact in which the two (the first and second layers) are united with each other while Cu of the second layer and Cu in the first layer mutually enter within a range from 20 μm to 100 μm from the boundary surface is obtained (Example 16, Step f). The temperature characteristic indicates values similar to the reference value of the example 2 (Evaluations A and B). Furthermore, the interruption characteristic indicates 1.1 to 1.2 times higher than the reference value of the example 2 and is qualified.

(Examples 17 to 20)

[0161] As raw powder of Cu-Cr mixed powder (the first layer), Cu containing Cr of 0.35wt% or less instead of pure Cu is prepared. For the Cu plate (the second layer), pure Cu sufficiently softened is prepared and a composite contact is manufactured (Example 17). The temperature characteristic indicates values similar to the reference value of the example 2 (Evaluation C). Furthermore, the interruption characteristic indicates 1.1 times higher than the reference value of the example 2 and is qualified.

[0162] As raw powder of Cu-Cr mixed powder (the first layer), Cu containing Al of 0.5wt% or less instead of pure Cu is prepared. For the Cu plate (the second layer), pure Cu sufficiently softened is prepared and a composite contact is manufactured (Example 18). The temperature characteristic indicates values similar to the reference value of the example 2 (Evaluation C). Furthermore, the interruption characteristic indicates 1.1 times higher than the reference value of the example 2 and is qualified.

[0163] As raw powder of Cu-Cr mixed powder (the first layer), Cu containing Si of 0.5wt% or less instead of pure Cu is prepared. For the Cu plate (the second layer), pure Cu sufficiently softened is prepared and a composite contact is manufactured (Example 19). The temperature characteristic indicates values similar to the reference value of the example 2 (Evaluation C). Furthermore, the interruption characteristic indicates 1.1 times higher than the reference value of the example 2 and is qualified.

[0164] As raw powder of Cu-Cr mixed powder (the first layer), Cu containing Fe of 0.5wt% or less instead of pure Cu is prepared. For the Cu plate (the second layer), pure Cu sufficiently softened is prepared and a composite contact is manufactured (Example 20). The temperature characteristic indicates values similar to the reference value of the example 2 (Evaluation C). Furthermore, the interruption characteristic indicates 1.1 times higher than the reference value of the example 2 and is qualified.

[0165] From the aforementioned, containing of 0.5 wt% or less of at least one of Cr, Al, Si, and Fe in Cu of the first layer is useful in further improvement of the interruption characteristic and temperature characteristic.

(Example 21)

[0166] In the case that the thickness of the first layer is set to 0.5 mm to 3.0 mm, and the thickness of the second layer is set to 0.5 mm to 3.0 mm, and the total thickness of the first and second layers is set to 1.0 mm to 5.0 mm, alloying of the Cu-Cr mixture and alloying of the boundary surface between the first and second layers are realized at the same time. Thus, composite contacts in which the two are united with each other while Cu of the second layer and Cu in the first layer mutually enter within a range from 20 μm to 100 μm from the boundary surface are manufactured. Then the first layer is used as a contact surface, and the second layer is used as a support pedestal of the first layer. A Cu plate uses pure

Cu sufficiently softened (Example 21). The temperature characteristic indicates values similar to the reference value of the example 2 (Evaluation C). Furthermore, the interruption characteristic indicates 1.1 to 1.2 times similar to the reference value of the example 2 and is qualified.

(Example 22)

[0167] As a first layer, a Cu-Cr alloy which was previously alloyed is used (Example 22). The temperature characteristic indicates values similar to the reference value of the example 2 (Evaluation C). Furthermore, the interruption characteristic indicates 1.0 times similar to the reference value of the example 2 and is qualified. Here, as for the problem of warping, it can be solved by controlling the cooling speed thereof without any trouble.

[0168] Hereinafter, the examples and comparison examples containing a predetermined amount of at least one of Bi, Te, and Sb in Cu of the first layer composed of a Cu-Cr mixture will be explained in detail. But, to show the evaluation conditions and evaluation results thereof in Figure is omitted.

(Examples 23 to 30 and Comparison examples 15 to 17)

[0169] In the aforementioned Cu-Cr mixture (the first layer), CuCrBi containing 0.01 wt% Bi in the Cu amount is prepared and is united with the second layer separately prepared, and a composite contact in which the two are united with each other while Cu of the second layer and Cu in the first layer mutually enter 40 μm from the boundary surface is manufactured. The welding separation force is measured, and it is found that the separation force is reduced to about 1/4 compared with the contact of another example having no existing Bi (improvement of the welding resistance characteristic). Namely, this example is useful in further improvement of the welding resistance characteristic (Example 23).

[0170] Similarly, CuCrBi containing 0.1 wt% Bi is prepared and is united with the second layer separately prepared and a composite contact in which the two are united with each other while Cu of the second layer and Cu in the first layer mutually enter 40 μm from the boundary surface is manufactured. It is found that the separation force is reduced to about 1/6 (improvement of the welding resistance characteristic) (Example 24).

[0171] CuCrBi containing 1 wt% Bi is prepared and is united with the second layer separately prepared and a composite contact in which the two are united with each other while Cu of the second layer and Cu in the first layer mutually enter 40 μm from the boundary surface is manufactured. It is found that the separation force is reduced to about 1/10 (improvement of the welding resistance characteristic) (Example 25).

[0172] On the other hand, CuCrBi containing 2 wt% Bi is excluded because the withstand voltage characteristic is not preferable (Comparison example 15).

[0173] In the aforementioned Cu-Cr mixture (the first layer), CuCrTe containing 0.01 wt% Te in the Cu amount is prepared and is united with the second layer separately prepared, and a composite contact in which the two are united with each other while Cu of the second layer and Cu in the first layer mutually enter 30 μm from the boundary surface is manufactured. The welding separation force is measured, and it is found that the separation force is reduced to about 1/2 compared with the contact of another example having no existing Te (improvement of the welding resistance characteristic) (Example 26).

[0174] Similarly, in the aforementioned Cu-Cr mixture (the first layer), CuCrTe containing 0.1 wt% Te in the Cu amount is prepared and is united with the second layer separately prepared, and a composite contact in which the two are united with each other while Cu of the second layer and Cu in the first layer mutually enter 30 μm from the boundary surface is manufactured. The welding separation force is measured, and it is found that the separation force is reduced to about 1/4 compared with the contact of another example having no existing Te (improvement of the welding resistance characteristic) (Example 27).

[0175] Similarly, in the aforementioned Cu-Cr mixture (the first layer), CuCrTe containing 1 wt% Te in the Cu amount is prepared and is united with the second layer separately prepared, and a composite contact in which the two are united with each other while Cu of the second layer and Cu in the first layer mutually enter 30 μm from the boundary surface is manufactured. It is found that the separation force is reduced to about 1/6 compared with the contact of another example having no existing Te (improvement of the welding resistance characteristic) (Example 28).

[0176] On the other hand, in the aforementioned Cu-Cr mixture (the first layer), CuCrTe containing 3 wt% Te in the Cu amount is prepared and is united with the second layer separately prepared, and a composite contact in which the two are united with each other while Cu of the second layer and Cu in the first layer mutually enter 40 μm from the boundary surface is manufactured. It is not preferable from the viewpoint of the withstand voltage characteristic, thereby is excluded (Comparison example 16).

[0177] In the aforementioned Cu-Cr mixture (the first layer), CuCrSb containing 0.01 wt% Sb in the Cu amount is prepared and is united with the second layer separately prepared, and a composite contact in which the two are united with each other while Cu of the second layer and Cu in the first layer mutually enter 30 μm from the boundary surface is manufactured. The welding separation force is measured, and it is found that the separation force is reduced to about 1/2 compared with the contact of another example having no existing Sb (improvement of the welding resistance characteristic) (Example 29).

[0178] In the aforementioned Cu-Cr mixture (the first layer), CuCrSb containing 1 wt% Sb in the Cu amount is prepared and is united with the second layer separately prepared, and a composite contact in which the two are united with each other while Cu of the second layer and Cu in the first layer mutually enter 30 μm from the boundary surface is manufactured. The welding separation force is measured, and it is found that the separation force is reduced to about 1/3 compared with the contact of another example having no existing Sb (improvement of the welding resistance characteristic) (Example 30).

[0179] On the other hand, in the aforementioned Cu-Cr mixture (the first layer), CuCrSb containing 1 wt% Sb in the Cu amount is prepared and is united with the second layer separately prepared, and a composite contact in which the two are united with each other while Cu of the second layer and Cu in the first layer mutually enter 40 μm from the boundary surface is manufactured. It is not preferable from the viewpoint of the withstand voltage characteristic, thereby is excluded (Comparison example 17).

[0180] From the aforementioned, containing a predetermined amount of at least one of Bi, Te, and Sb in Cu of the first layer composed of a Cu-Cr mixture is useful in further improvement of the welding resistance characteristic.

[0181] Next, by referring to Figs. 5 to 8, the examples and comparison examples when the first layer is a Cu-W mixture will be explained in detail.

(Examples 31 to 35 and Comparison examples 18 to 24)

[0182] In these examples and comparison examples, except the example 33, a Cu plate is used as Cu of the second layer. (Example 33, as Cu of the second layer, uses a Cu sintered article.)

[0183] As a representative material of the first layer, it is a target to manufacture a Cu-73% W alloy with a thickness of 1 mm, and as a representative material of the second layer a pure Cu plate with a thickness of 2 mm is used. The Cu plate is pre-heated at 500°C or higher. Cu of the Cu-W mixed powder is pre-heated at 350°C or higher and W of the Cu-W mixed powder is pre-heated at 1350°C or higher. As Cu and W for the first layer, Cu-W mixed powder (the first layer) in which W (tungsten) powder with an average particle diameter of 1 to 6 μm and Cu (copper) powder with an average particle diameter of 10 μm are uniformly mixed at a predetermined ratio (73 wt% W - Cu) is prepared. As Cu for the second layer, a Cu plate rolled to a thickness of 2 mm is prepared. Further, as steps after Cu and the Cu-W mixture are made contact with each other, in the comparison example 18, Step a is adopted, in the comparison examples 19 to 22, Step b is adopted, and in the examples 31, 32, 34 and 35, Step b is adopted. In the comparison examples 23 and 20, a predetermined thickness is left by a method for removing a part of the surface layer by a mechanical process.

[0184] In the comparison example 18, the two layers are made contact, as they were, with each other (kept loaded), and at Step a they are united with each other by mechanically pressed at a pressure of 8 t/cm^2 and the entry of Cu in the neighborhood of the boundary surface is reduced to almost 0.

[0185] In the comparison example 19, the two layers are made contact, as they were, with each other (kept loaded) and are subject to the primary heating process at 750°C at Step b, and Cu in the first layer enters the second layer by 2 to 3 μm, and Cu of the second layer enters the first layer by 3 to 5 μm.

[0186] In the comparison example 20, the two layers are made contact, as they were, with each other (kept loaded) and are subject to the primary heating process at 850°C at Step b, and Cu in the first layer enters the second layer by 15 to 17 μm, and Cu of the second layer enters the first layer by 15 to 17 μm.

[0187] In the examples 31, 32, 34 and 35, the two layers are made contact, as they were, with each other (kept loaded) and are selectively subject to the primary heating process at 900 to 1150°C at Step b, and alloying of the Cu-W mixture (the first layer) and alloying of the boundary surface between the first and second layers are realized at the same time. Thus, composite contacts in which the two layers are united with each other while Cu of the second layer and Cu in the first layer mutually enter within a range from 20 μm to 100 μm from the boundary surface are obtained. In the primary heating process, when the selected temperature is less than 900°C or more than 1150°C, the entry amount of Cu on the boundary surface between the first layer and the second layer is not within a range from 20 μm to 100 μm.

[0188] In a comparison example 21, the two layers are made contact, as they were, with each other (kept loaded) and are subject to the primary heating process at 1250°C at Step b, and alloying of the Cu-W mixture (the first layer) and alloying of the boundary surface between the first and second layers are realized at the same time. Thus, a composite contact in which Cu of the second layer and Cu in the first layer enter within a range of 100 to 110 μm from the boundary surface is obtained.

[0189] In the comparison example 22, the two layers are made contact, as they were, with each other (kept loaded) and are subject to the primary heating process at 1250°C at Step b, and alloying of the Cu-W mixture (the first layer) and alloying of the boundary surface between the first and second layers are realized at the same time. Thus, a composite contact in which Cu of the second layer and Cu in the first layer enter within a range of 110 to 115 μm from the boundary surface is obtained.

[0190] In the comparison example 23, the two layers are made contact , as they were, with each other (kept loaded), and using the composite contact manufactured in the example 32 mentioned above, one surface (the second layer) is mechanically removed and the thickness of Cu is reduced to 2 to 5 μm. The other surface (the first layer) is not mechanically processed and is kept unchanged at 30 to 35 μm.

[0191] In the comparison example 24, inversely, the first layer is mechanically removed, thus the thickness of Cu is reduced to 2 to 5 μm, and the second layer is not mechanically processed and is kept unchanged at 30 to 35 μm.

[0192] Further, the evaluation in the examples and comparison examples when the first layer is a Cu-W mixture is made such that the temperature characteristic and interruption characteristic are treated as the reference values when the entry amount of Cu from the first layer into the second layer and the entry amount of Cu from the second layer into the first layer are respectively set to 30 to 35 μm (Example 32).

[0193] The temperature characteristic and interruption characteristic are evaluated for each composite contact. When the entry amount of Cu from the first layer into the second layer and the entry amount of Cu from the second layer into the first layer are set to almost zero, 2 to 3 μm, and 3 to 5 μm, for the reference value of the example 32, temperature rise values of 1.5 times or higher (Evaluation Z), 1.3 to 1.5 times, and 1.5 times or higher (Evaluations Y and Z) are obtained, and they are disqualified. The interruption characteristics, for the reference value of the example 32, are reduced to 0.3 times and 0.5 times and moreover in the interruption test, the first layer and second layer are separated undesirably (Comparison examples 18 and 19).

[0194] When the entry amount of Cu from the first layer into the second layer and the entry amount of Cu from the second layer into the first layer are set to 15 to 17 μm and 15 to 17 μm, for the reference value of the example 32, temperature rise values of 1.15 to 1.3 times and 1.3 to 1.5 times (Evaluations X and Y) are obtained, and they are disqualified. The interruption characteristic, for the reference value of the example 32, is reduced to 0.8 to 0.9 times, and moreover in the interruption test the first layer and second layer are separated undesirably (Comparison example 20).

[0195] When the entry amount of Cu from the first layer into the second layer is set to 20 to 25 μm and the entry amount of Cu from the second layer into the first layer is set to 20 to 25 μm (Example 31), the temperature characteristic is similar to the reference value of the example 32 (Evaluations C and D). Furthermore, the interruption characteristic indicates 0.9 to 1.0 times and is similar to the reference value of the example 32, that is, within the qualified range.

[0196] Further, the evaluation of the present invention is made such that the temperature characteristic and interruption characteristic are treated as the reference values when the entry amount of Cu from the first layer into the second layer is set to 30 to 35 μm and the entry amount of Cu from the second layer into the first layer is set to 30 to 35 μm (Example 32). Here, the temperature characteristic indicates (Evaluation C) and assumed as the reference value. Furthermore, the interruption characteristic indicates 1.0 times and assumed as the reference value.

[0197] When the entry amount of Cu from the first layer into the second layer and the entry amount of Cu from the second layer into the first layer are respectively set to 45 to 50 μm and 45 to 50 μm (Example 34), the temperature characteristic is similar to the reference value of the example 32 or more (Evaluations B and C). The interruption characteristic indicates satisfactorily 1.0 to 1.1 times.

[0198] When the entry amount of Cu from the first layer into the second layer and the entry amount of Cu from the second layer into the first layer are respectively set to 95 to 100 μm and 95 to 100 μm (Example 35), the temperature characteristic is 0.8 to 0.9 times for the reference value of the example 32 (Evaluation B). The interruption characteristic indicates satisfactorily 1.0 to 1.1 times.

[0199] However, when the entry amount of Cu from the first layer into the second layer and the entry amount of Cu from the second layer into the first layer are respectively set to 100 μm to 110 μm and 100 μm to 110 μm (Comparison example 21), or set to 110 μm to 115 μm and 110 μm to 115 μm (Comparison example 22), for the reference value of the example 32, the temperature rise values are undesirably 1.15 to 1.3 times and 1.3 to 1.5 times (Evaluations X and Y), or 1.05 to 1.15 times and 1.5 times or more (Evaluations D to Z). The interruption characteristic, for the reference value of the example 32, indicates 0.8 times to 1.0 times or 0.7 to 1.0 times and qualified values and disqualified values coexist undesirably. On each contact surface after the interruption test, composition changes and generation of internal voids due to evaporation are seen. This seems to be a cause.

[0200] When either of the entry amount of Cu from the first layer into the second layer and the entry amount of Cu from the second layer into the first layer is set to 2 to 5 μm (Comparison examples 23 and 24), the temperature characteristics indicate 1.05 to 1.15 times, 1.3 to 1.5 times, or 1.15 to 1.3 times (Evaluations D to Y, Evaluations D to X) and variations are seen. The interruption characteristics, for the reference value of the example 32, indicate 0.8 times to 1.0 times and qualified values and disqualified values coexist undesirably.

(Example 33)

[0201] In the example 33, as Cu of the second layer, a Cu sintered plate is used.

[0202] Namely, as Cu and W for the first layer, Cu-W mixed powder (the first layer) in which W powder with an average particle diameter of 1 to 6 μm and Cu powder with an average particle diameter of 10 μm are uniformly mixed at a predetermined ratio (73 wt% W - Cu) is prepared. As Cu for the second layer, a Cu sintered plate, which has a relative density of 8.0 gr/cc or more and is rolled to a thickness of 2 mm, is prepared.

[0203] On the top of the Cu sintered article (the second layer), the Cu-W mixed powder (the first layer) is placed, and the two are kept unchanged (kept loaded) and are subject to a predetermined primary heating process (1150°C) (at Step b), and Cu-W alloying of the Cu-W mixed powder (the first layer) and alloying of the boundary surface between the first and second layers are realized at the same time. Thus, a composite contact characterized in that the two (the first and second layers) are united with each other while Cu of the second layer and Cu in the first layer mutually enter within a range from 20 μm to 100 μm from the boundary surface is obtained, and the temperature characteristic and interruption characteristic are evaluated.

[0204] As a result, even if the second layer is a Cu sintered plate, the same tendency is obtained (Example 33). Further, Cu of the Cu-W mixed powder and W of the Cu-W mixed powder are heated respectively at 350°C or higher and 1350°C or higher before use.

[0205] From the aforementioned, the adaptation of the art of the present invention is also useful in a composite contact in which the Cu plate as the second layer is replaced with a Cu sintered plate.

(Examples 36 and 37 and comparison examples 25 and 26)

[0206] As Cu and W for the first layer, Cu-W mixed powder (the first layer) in which W powder with an average particle diameter of 1 to 6 μm and Cu powder with an average particle diameter of 10 μm are mixed at a predetermined ratio (25 to 95% W - Cu) is prepared. As Cu for the second layer, a Cu plate is prepared.

[0207] On the top of the Cu plate (the second layer), the Cu-W mixed powder (the first layer) is placed, and the two layers are made contact with each other, as they were, (kept loaded), are united with each other by the primary pressuring process at a pressure of 6 t/cm^2 or less, and then are subject to the primary heating process at 1150°C, and alloying of the Cu-W mixed powder (the first layer) and alloying of the boundary surface between the first and second layers are realized at the same time. Thus, a composite contact in which the two (the first and second layer) are united with each other while Cu of the second layer and Cu in the first layer mutually enter within a range from 20 μm to 100 μm from the boundary surface is obtained (Step d).

[0208] In the temperature characteristic and interruption characteristic when the entry amount of Cu from the first layer into the second layer and the entry amount of Cu from the second layer into the first layer are set respectively to 30 to 35 μm and 30 to 35 μm, Cu-W composite contacts having W amount of 25 to 95% are manufactured. An effect of controlling the entry amount of Cu from the first layer into the second layer and the entry amount of Cu from the second layer into the first layer which is a gist of the present invention is examined.

[0209] For the reference value of the example 32, in 50% W-Cu (Example 36) and 90% W-Cu (Example 37), the temperature characteristics indicate 0.8 to 0.9 times (Evaluation B) and 1.05 to 1.10 times (Evaluation D), respectively. The interruption characteristics ensure 1.1 times and 0.9 times for the reference value of the example 32, and both characteristics are satisfactory.

[0210] On the other hand, in 25% W-Cu (Comparison example 26), for the reference value of the example 32, the temperature characteristic indicates 0.8 to 0.9 times (Evaluation B) in the qualified range, though the interruption characteristic is undesirably reduced to 0.7 times, and the characteristics are disqualified as a whole. On the contact surface after interruption, remarkable surface roughness is seen (Comparison example 25).

[0211] Furthermore, in 95% W-Cu (Comparison example 26), for the reference value of the example 32, the temperature characteristic indicates 1.15 to 1.3 times (Evaluation X) and 1.3 to 1.5 times (Evaluation Y), and the interruption characteristic indicates 0.4 times for the reference value of the example 32, and is disqualified (Comparison example 26).

[0212] From the aforementioned, to the Cu-W alloy (Examples 36 and 37) in which the W amount of the first layer is 50 to 90% W (wt%), the art of the present invention is preferably adapted.

(Examples 38 and 39 and Comparison example 27)

[0213] A Cu plate (the second layer) similar to the aforementioned and a Cu-W mixed powder (the first layer) similar to the aforementioned are prepared. On the top of the Cu plate, the aforementioned Cu-W mixed powder (the first layer) is placed and the layers are united with each other by the primary pressuring process at a pressure of 6 t/cm^2 or less, (after cooling) are united with each other by the primary heating process at 950 to 1150°C, then are secondarily pressurized at a pressure of 4 t/cm^2 or more, and are united with each by the secondary heating process at 1080°C or lower (Step g).

[0214] When the average particle diameter of W in the Cu-W alloy (the first layer) is 0.1 to 1 μm (Example 38), the temperature characteristic indicates 1.05 to 1.15 times (Evaluation D)..The interruption characteristic indicates 0.9 to 1.0 times, and the two are within the qualified range.

[0215] When the average particle diameter of W is 9 to 15 μm (Example 39), the temperature characteristic indicates Evaluation C similar to that of the reference example 32, and the interruption characteristic indicates 1.1 times, and the two are within the qualified range.

[0216] On the other hand, when the average particle diameter of W is 25 to 35 μm (Comparison example 27), the temperature characteristic indicates Evaluation C similar to that of the reference example 32 and is qualified, though the interruption characteristic indicates 0.7 to 1.0 times and is disqualified. When the average particle diameter of W is larger, the interruption characteristic is varied.

[0217] From the aforementioned, to a contact in which 0.1 to 15 μm is selected as an average particle diameter of W of the first layer, the art of the present invention can be adapted usefully.

(Examples 40 to 42 and Comparison examples 28 and 29)

[0218] On the top of the Cu plate (the second layer), the aforementioned Cu-W mixed powder (the first layer) is placed, and the two layers are made contact with each other, as they were, (kept loaded), are united with each other by the primary heating process at 900 to 1150°C, and then are united with each other by the primary pressuring process at a pressure of 6 t/cm^2 or less, and Cr-W alloying of the Cu-W mixed powder (the first layer) and alloying of the boundary surface between the first and second layers are realized at the same time. Thus, a composite contact in which the two (the first and second layers) are united with each other while Cu of the second layer and Cu in the first layer mutually enter within a range from 20 μm to 100 μm from the boundary surface is obtained (Step c).

[0219] When the thicknesses of the first layer are set respectively to 0.5 to 0.6 mm, 2.5 to 3 mm, and 4.5 to 5 mm (Examples 40 to 42), the temperature characteristics satisfactorily indicate values similar to the reference value of the example 32 (Evaluations B and C). The interruption characteristics indicate 0.9 to 1.0 times similar to the reference value of the example 32 within the qualified range.

[0220] However, when the thickness of the first layer is set to 0.1 mm or less (Comparison example 28), compared with the reference value of the example 32, the temperature characteristic indicates similar values (Evaluation B) and is qualified, though the interruption characteristic is greatly reduced to 0.4 to 0.8 times, and the characteristics are disqualified as a whole.

[0221] Furthermore, when the thickness of the first layer is set to 5.5 to 6 mm (Comparison example 29), for the reference value of the example 32, the temperature rise indicates 1.05 to 1.15 times (Evaluation D) and is within the qualified range, though the interruption characteristic indicates 0.7 to 0.9 times, and the characteristics are disqualified as a whole. When the first layer is excessively thick, it is disadvantageous to ensure a flexible contact surface .

[0222] From the aforementioned, to a contact in which 0.5 to 5 mm is selected as a thickness of the first layer, the art of the present invention can be adapted usefully.

(Examples 43 and 44 and Comparison examples 30 and 31)

[0223] When the thickness of the first layer is fixed to 1.0 mm and the thicknesses of the second layers are set respectively to 1 mm and 3 mm (Examples 43 and 44), the temperature characteristics indicate values similar to the reference value of the example 32 (Evaluation C). The interruption characteristics indicate similar values (1.0 times) and the two characteristics are similar to the reference values of the example 32 and are qualified.

[0224] However, when the thickness of the second layer is set to 0.4 mm (Comparison example 30), compared with the reference value of the example 32, the temperature characteristic indicates similar or larger values (Evaluation B and C) and is qualified, though the interruption characteristic is reduced to 0.6 to 0.8 times, and the characteristics are disqualified as a whole. Furthermore, when the thickness of the second layer is set to 6.0 mm (Comparison example 31), for the reference value of the example 32, the temperature rise indicates 1.05 to 1.15 times (Evaluation D) and is qualified, though the interruption characteristic indicates 0.8 times for the reference value of the example 32 and is disqualified.

[0225] From the aforementioned, this is useful in adaptation of the art of the present invention to a contact in which 1 to 3 mm is selected as a thickness of the second layer.

(Examples 45 and 46)

[0226] The two (the first and second layers) are just made contact (loaded) with each other, then are subject to the primary heating process (1050°C) and primary pressurizing process (6 t/cm^2 or less), and are further subject to the secondary heating process (900°C) and secondary pressurizing process (4 t/cm^2 or more), and Cu-W alloying of the Cu-W mixed powder (the first layer) and alloying of the boundary surface between the first and second layers are realized at the same time. Thus, a composite contact in which the two (the first and second layers) are united with each other while Cu of the second layer and Cu in the first layer mutually enter within a range from 20 μm to 100 μm from the boundary surface is obtained (Example 45, Step e). The temperature characteristic indicates values similar to the reference value of the example 32 (Evaluation A). Furthermore, the interruption characteristic indicates 1.2 times for the reference value of the example 32 and is qualified.

[0227] Further, with respect to the secondary heating process and secondary pressurizing process performed after the primary heating process and primary pressurizing process, only the secondary heating process may be performed or only the secondary pressurizing process may be performed.

[0228] Next, the two (the first and second layer) are just made contact with each other and then are subject to the primary heating process (1050°C) while the two are kept in the primary pressurizing contact (a weight of 2 kg/cm^2 is kept loaded), and alloying of the Cu-W mixed powder (the first layer) and alloying of the boundary surface between the first and second layers are realized at the same time. Thus, a composite contact in which the two (the first and second layers) are united with each other while Cu of the second layer and Cu in the first layer mutually enter within a range from 20 μm to 100 μm from the boundary surface is obtained (Example 46, Step f). The temperature characteristic indicates values similar to the reference value of the example 32 (Evaluations A and B). Furthermore, the interruption characteristic indicates 1.1 to 1.2 times for the reference value of the example 32 and is qualified.

(Examples 47 to 51)

[0229] As raw powder of Cu-W mixed powder (the first layer), Cu containing 0.001% Bi instead of pure Cu is prepared. For the Cu plate (the second layer), pure Cu sufficiently softened is prepared and a composite contact is manufactured under the condition at Step c (Example 47). The temperature characteristic indicates values similar to the reference value of the example 32 (Evaluation C). Furthermore, the interruption characteristic indicates 1.1 times for the reference value of the example 32 and is qualified.

[0230] As raw powder of Cu-W mixed powder (the first layer), Cu containing 0.1% Bi instead of pure Cu is prepared. For the Cu plate (the second layer), pure Cu sufficiently softened is prepared and a composite contact is manufactured under the condition at Step c (Example 48). The temperature characteristic indicates values similar to the reference value of the example 32 (Evaluation C). Furthermore, the interruption characteristic indicates 1.1 times for the reference value of the example 32 and is qualified.

[0231] As raw powder of Cu-W mixed powder (the first layer), Cu containing 1.0% Bi instead of pure Cu is prepared. For the Cu plate (the second layer), pure Cu sufficiently softened is prepared and a composite contact is manufactured under the condition at Step c (Example 49). The temperature characteristic indicates values similar to the reference value of the example 32 (Evaluation C). Furthermore, the interruption characteristic indicates 1.1 times for the reference value of the example 32 and is qualified.

[0232] As raw powder of Cu-W mixed powder (the first layer), Cu containing 0.01% Te instead of pure Cu is prepared. For the Cu plate (the second layer), pure Cu sufficiently softened is prepared and a composite contact is manufactured under the condition at Step c (Example 50). The temperature characteristic indicates values similar to the reference value of the example 32 (Evaluation C). Furthermore, the interruption characteristic indicates 1.1 times for the reference value of the example 32 and is qualified.

[0233] As raw powder of Cu-W mixed powder (the first layer), Cu containing 0.1% Sb instead of pure Cu is prepared. For the Cu plate (the second layer), pure Cu sufficiently softened is prepared and a composite contact is manufactured under the condition at Step c (Example 51). The temperature characteristic indicates values similar to the reference value of the example 32 (Evaluation C). Furthermore, the interruption characteristic indicates 1.0 times for the reference value of the example 32 and is qualified.

(Examples 52 to 54)

[0234] As raw powder of the mixed powder (the first layer), WC is prepared in place of W. For the Cu plate (the second layer), pure Cu sufficiently softened is prepared and a composite contact is manufactured under the condition at Step e (Example 52).

[0235] The temperature characteristic compared with the reference value of the example 32 is ranked Evaluation D. Furthermore, the interruption characteristic indicates 1.1 times and is qualified.

[0236] As raw powder of the mixed powder (the first layer), Mo is prepared in place of W. For the Cu plate (the second layer), pure Cu sufficiently softened is prepared and a composite contact is manufactured under the condition at Step e (Example 53).

[0237] The temperature characteristic compared with the reference value of the example 32 is ranked Evaluation C. Furthermore, the interruption characteristic indicates 1.0 times and is qualified.

[0238] As raw powder of the mixed powder (the first layer), MoC is prepared in place of W. For the Cu plate (the second layer), pure Cu sufficiently softened is prepared and a composite contact is manufactured under the condition at Step e (Example 54).

[0239] The temperature characteristic compared with the reference value of the example 32 is ranked Evaluation D. Furthermore, the interruption characteristic indicates 0.9 to 1.0 times and is qualified.

[0240] From the aforementioned, this is useful in adaptation of the art of the present invention to a composite contact in which W of the first layer is replaced with WC, Mo, or MoC.

(Examples 55 to 58)

[0241] As raw powder of the mixed powder (the first layer), Ag is prepared in place of Cu and WC is prepared in place of W. For the Cu plate (the second layer), pure Cu sufficiently softened is prepared and a composite contact is manufactured under the condition at Step e (Example 55).

[0242] The temperature characteristic compared with the reference value of the example 32 is ranked Evaluation D. Furthermore, the interruption characteristic indicates 0.9 to 1.0 times and is qualified.

[0243] As raw powder of the mixed powder (the first layer), Ag is prepared in place of Cu. For the Cu plate (the second layer), pure Cu sufficiently softened is prepared and a composite contact is manufactured under the condition at Step e (Example 56).

[0244] The temperature characteristic compared with the reference value of the example 32 is ranked Evaluation D. Furthermore, the interruption characteristic indicates 0.9 to 1.0 times and is qualified.

[0245] As raw powder of the mixed powder (the first layer), Ag is prepared in place of Cu and MoC is prepared in place of W. For the Cu plate (the second layer), pure

Cu sufficiently softened is prepared and a composite contact is manufactured under the condition at Step e (Example 57).

[0246] The temperature characteristic compared with the reference value of the example 32 is ranked Evaluation D. Furthermore, the interruption characteristic indicates 0.9 to 1.0 times and is qualified.

[0247] As raw powder of the mixed powder (the first layer), Ag is prepared in place of Cu and Mo is prepared in place of W. For the Cu plate (the second layer), pure Cu sufficiently softened is prepared and a composite contact is manufactured under the condition at Step e (Example 58).

[0248] The temperature characteristic compared with the reference value of the example 32 is ranked Evaluation D. Furthermore, the interruption characteristic indicates 0.9 to 1.0 times and is qualified.

(Modification example 1)

[0249] In the case that the thickness of the first layer is set to 0.5 mm to 3.0 mm, and the thickness of the second layer is set to 1.5 mm to 3.0 mm, and the total thickness of the first and second layers is set to 1.0 mm to 5.0 mm, alloying of the Cu-W mixture and alloying of the boundary surface between the first and second layers are realized at the same time. Thus, composite contacts in which the two are united with each other while Cu of the second layer and Cu in the first layer mutually enter within a range from 20 μm to 100 μm from the boundary surface are manufactured. Then the first layer is used as a contact surface, and the second layer is used as a support pedestal of the first layer. A Cu plate uses pure Cu sufficiently softened (Modification example 1).

[0250] The temperature characteristic indicates values similar to the reference value of the example 32 (Evaluation C). Furthermore, the interruption characteristic indicates 1.0 times similar to the reference value of the example 32 and is qualified.

[0251] As mentioned above, according to these examples, the second layer composed of Cu and the first layer composed of the Cu-Cr mixture (or the Cu-W mixture) are kept in contact with each other (kept loaded) and are united with each other by the heating process and pressurizing process under a predetermined condition, thus Cu-Cr alloying of the Cu-Cr mixture (or Cu-W alloying of the Cu-W mixture) and alloying of the boundary surface between the first and second layers are realized at the same time. Thus, a composite contact having an excellent interruption characteristic and a stable temperature characteristic can be provided in which Cu of the second layer and Cu in the first layer mutually enter within a range from 20 μm to 100 μm from the boundary surface, and both the first layer and second layer are united with each other. And, use of it, for example, as a contact of a vacuum valve as shown in Fig. 9, contributes to realization of high performance of a vacuum circuit breaker.

Claims

1. A composite contact, comprising:

a first layer composed of a Cu-Cr mixture wherein powder or granular Cr with an average particle diameter of 0.1 to 150 μm and powder or granular Cu with an average particle diameter of 0.1 to 150 μm are mixed at a rate of 15 to 60 wt% of Cr and the remainder of Cu; and
a second layer composed of Cu;
said first layer and said second layer being united with each other while Cu of said first layer enters said second layer within a range from 20 μm to 100 μm from a boundary surface between said first layer and said second layer and Cu in said second layer enters said first layer within a range from 20 μm to 100 μm from said boundary surface.

2. A vacuum switch provided with a vacuum valve comprising: said composite contacts according to claim 1.

3. A method for manufacturing a composite contact, comprising the steps of:

step for preparing a first layer composed of a Cu-Cr mixture wherein powder or granular Cr with an average particle diameter of 0.1 to 150 μm and powder or granular Cu with an average particle diameter of 0.1 to 150 μm are mixed at a rate of 15 to 60 wt% of Cr and the remainder of Cu;
step for preparing a second layer composed of Cu;
step for placing said first layer to contact with said second layer; and
step for primary heating said second layer and said first layer contacted with said second layer at a temperature of 900 to 1150°C, thereby to realize alloying of said Cu-Cr mixture in said first layer and alloying of said boundary surface between said first and second layers at the same time and to unite said first layer and said second layer.

4. A method for manufacturing a composite contact, comprising the steps of:

step for preparing a first layer composed of a Cu-Cr mixture wherein powder or granular Cr with an average particle diameter of 0.1 to 150 μm and powder or granular Cu with an average particle diameter of 0.1 to 150 μm are mixed at a rate of 15 to 60 wt% of Cr and the remainder of Cu;
step for preparing a second layer composed of

Cu;

step for placing said first layer to contact with said second layer;

step for primary pressurizing said first layer and said second layer at a pressure of 6 t/cm^2 or less to united with each other; and

step for primary heating said second layer and said first layer at a temperature of 900 to 1150°C after said first layer and said second layer are united with each other by said primary pressurizing step, thereby to realize alloying of said Cu-Cr mixture in said first layer and alloying of said boundary surface between said first and second layers at the same time.

5. A method for manufacturing a composite contact, comprising the steps of:

step for preparing a first layer composed of a Cu-Cr mixture wherein powder or granular Cr with an average particle diameter of 0.1 to 150 μm and powder or granular Cu with an average particle diameter of 0.1 to 150 μm are mixed at a rate of 15 to 60 wt% of Cr and the remainder of Cu;

step for preparing a second layer composed of Cu;

step for placing said first layer to contact with said second layer; and

step for primary heating said second layer and said first layer contacted with said second layer at a temperature of 900 to 1150°C, thereby to realize alloying of said Cu-Cr mixture in said first layer and alloying of said boundary surface between said first and second layers at the same time to unite said first layer and said second layer; and

step for primary pressurizing said first layer and said second layer at a pressure of 6 t/cm^2 or less after said first layer and said second layer are heated by said primary heating step.

6. A method for manufacturing a composite contact, comprising the steps of:

step for preparing a first layer composed of a Cu-Cr mixture wherein powder or granular Cr with an average particle diameter of 0.1 to 150 μm and powder or granular Cu with an average particle diameter of 0.1 to 150 μm are mixed at a rate of 15 to 60 wt% of Cr and the remainder of Cu;

step for preparing a second layer composed of Cu;

step for placing said first layer to contact with said second layer; and

step for primary pressurizing said first layer and said second layer at a pressure of 6 t/cm^2 or less; and

step for primary heating said second layer and said first layer contacted with said second layer at a temperature of 900 to 1150°C while said first and second layers are kept pressurized in said primary pressurizing step, thereby to realize alloying of said Cu-Cr mixture in said first layer and alloying of said boundary surface between said first and second layers at the same time to unite said first layer and said second layer in said primary pressurizing step.

7. A method for manufacturing a composite contact, comprising the steps of:

step for preparing a first layer composed of a Cu-Cr mixture wherein powder or granular Cr with an average particle diameter of 0.1 to 150 μm and powder or granular Cu with an average particle diameter of 0.1 to 150 μm are mixed at a rate of 15 to 60 wt% of Cr and the remainder of Cu;

step for preparing a second layer composed of Cu;

step for placing said first layer to contact with said second layer; and

step for primary processing at least one of following steps,

step for primary heating said second layer and said first layer contacted with said second layer at a temperature of 900 to 1150°C, thereby to realize alloying of said Cu-Cr mixture in said first layer and alloying of said boundary surface between said first and second layers at the same time to unite said first layer and said second layer, and

step for primary pressurizing said first layer and said second layer at a pressure of 6 t/cm^2 or less to unite said first layer and said second layer; and

step for secondary processing at least one of following steps after said primary processing step,

step for secondary heating said first layer and said second layer at 1080°C or lower, and

step for secondary pressurizing said first layer and said second layer at a pressure of 4 t/cm^2 or more.

8. The composite contact according to Claim 1, wherein:

Cu of said second layer after said first layer and said second layer are united with each other is a Cu plate or a Cu sintered article practically having a relative density of Cu.

9. The composite contact according to Claim 1 or Claim

8, wherein:

Cu of said first layer after said first layer and said second layer are united with each other comprises at least one selected from the group consisting of Cr, Al, Si, and Fe by an amount of 0.5 wt% or less.

10. The composite contact according to Claim 1, Claim 8 or Claim 9, wherein:

a thickness of said first layer is set between 0.5 mm and 3.0 mm;
a thickness of said second layer is set between 0.5 mm and 3.0 mm;
a total thickness of said first layer and said second layer is set between 1.0 mm and 5.0 mm; and
said first layer is a contact surface, and said second layer is a support pedestal of said first layer.

11. The composite contact according to any one of Claims 1 and 8 to 10, wherein:

Cu of said first layer composed of said Cu-Cr mixture comprises at least one selected from the group consisting of Bi, Te, and Sb by amount of 0.001 to 1 wt%.

12. The composite contact according to Claim 1, Claim 8 or Claim 11, wherein:

said powder or granular Cr with an average particle diameter of 0.1 to 150 μm is replaced with any of powder or granular W, carbide of W, Mo, and carbide of Mo with an average particle diameter of 0.1 to 15 μm; and,
said Cu-Cr mixture is replaced with any of a Cu-W mixture, a mixture of Cu and carbide of W, a mixture of Cu and Mo, and a mixture of Cu and carbide of Mo, wherein any of powder or granular W, carbide of W, Mo, and carbide of Mo with an average particle diameter of 0.1 to 15 μm and powder or granular Cu with an average particle diameter 0.1 to 15 μm are mixed at a rate of 50 to 90 wt% of any of W, carbide of W, Mo, and carbide of Mo and the remainder of Cu.

13. The composite contact according to Claim 12, wherein:

a part of or all of Cu in said first layer is replaced with Ag.

14. The composite contact according to Claim 12 or Claim 13, wherein:

a thickness of said first layer is set between 0.5 mm and 5.0 mm;
a thickness of said second layer is set between 1.0 mm and 3.0 mm;
a total thickness of said first layer and said second layer is set between 1.5 mm and 7.0 mm; and
said first layer is a contact surface, and said second layer is a support pedestal of said first layer.

Patentansprüche

1. Verbundwerkstoff-Kontaktelement, umfassend:

eine erste Schicht, die aus einem Cu-Cr-Gemisch besteht, in dem pulverförmiges oder körniges Cr mit einem mittleren Teilchendurchmesser von 0,1 bis 150 μm und pulverförmiges oder körniges Cu mit einem mittleren Teilchendurchmesser von 0,1 bis 150 μm mit einem Anteil an Cr von 15 bis 60 Gew.-% und dem Rest aus Cu gemischt sind; und
eine zweite Schicht, die aus Cu besteht;

wobei die erste Schicht und die zweite Schicht miteinander verbunden sind, wobei das Cu der ersten Schicht in die zweite Schicht innerhalb eines Bereichs von 20 μm bis 100 μm ausgehend von der Grenzfläche zwischen der ersten Schicht und der zweiten Schicht eindringt und das Cu in der zweiten Schicht in die erste Schicht innerhalb eines Bereichs von 20 μm bis 100 μm ausgehend von der Grenzfläche eindringt.

2. Vakuumschalter, der mit einem Vakuumventil ausgestattet ist, der die Verbundwerkstoff-Kontaktelemente nach Anspruch 1 umfasst.

3. Verfahren zur Herstellung eines Verbundwerkstoff-Kontaktelements, das die folgenden Stufen umfasst:

eine Stufe zur Herstellung einer ersten Schicht, die aus einem Cu-Cr-Gemisch besteht, in dem pulverförmiges oder körniges Cr mit einem mittleren Teilchendurchmesser von 0,1 bis 150 μm und pulverförmiges oder körniges Cu mit einem mittleren Teilchendurchmesser von 0,1 bis 150 μm mit einem Anteil an Cr von 15 bis 60 Gew.-% und dem Rest aus Cu gemischt sind;
eine Stufe zur Herstellung einer zweiten Schicht, die aus Cu besteht;
eine Stufe zur Platzierung der ersten Schicht in Kontakt mit der zweiten Schicht; und
eine Stufe zu einem primären Erhitzen der zweiten Schicht und der mit der zweiten Schicht in Kontakt stehenden ersten Schicht bei einer Temperatur von 900 bis 1150 °C, um dadurch ein Legieren des Cu-Cr-Gemischs in der ersten

Schicht und ein Legieren der Grenzfläche zwischen der ersten und zweiten Schicht zur gleichen Zeit durchzuführen und die erste Schicht und die zweite Schicht zu verbinden.

4. Verfahren zur Herstellung eines Verbundwerkstoff-Kontaktelements, das die folgenden Stufen umfasst:

eine Stufe zur Herstellung einer ersten Schicht, die aus einem Cu-Cr-Gemisch besteht, in dem pulverförmiges oder körniges Cr mit einem mittleren Teilchendurchmesser von 0,1 bis 150 μm und pulverförmiges oder körniges Cu mit einem mittleren Teilchendurchmesser von 0,1 bis 150 μm mit einem Anteil an Cr von 15 bis 60 Gew.-% und dem Rest aus Cu gemischt sind;
eine Stufe zur Herstellung einer zweiten Schicht, die aus Cu besteht;
eine Stufe zur Platzierung der ersten Schicht in Kontakt mit der zweiten Schicht;
eine Stufe für ein primäres Unterdrucksetzen der ersten Schicht und der zweiten Schicht unter einen Druck von 6 t/cm^2 oder weniger, um diese miteinander zu verbinden; und
eine Stufe zu einem primären Erhitzen der zweiten Schicht und ersten Schicht bei einer Temperatur von 900 bis 1150 °C, nachdem die erste Schicht und die zweite Schicht durch die Stufe des primären Unterdrucksetzens miteinander verbunden sind, um dadurch ein Legieren des Cu-Cr-Gemischs in der ersten Schicht und ein Legieren der Grenzfläche zwischen der ersten und der zweiten Schicht zur gleichen Zeit durchzuführen.

5. Verfahren zur Herstellung eines Verbundwerkstoff-Kontaktelements, das die folgenden Stufen umfasst:

eine Stufe zur Herstellung einer ersten Schicht, die aus einem Cu-Cr-Gemisch besteht, in dem pulverförmiges oder körniges Cr mit einem mittleren Teilchendurchmesser von 0,1 bis 150 μm und pulverförmiges oder körniges Cu mit einem mittleren Teilchendurchmesser von 0,1 bis 150 μm mit einem Anteil an Cr von 15 bis 60 Gew.-% und dem Rest aus Cu gemischt sind;
eine Stufe zur Herstellung einer zweiten Schicht, die aus Cu besteht;
eine Stufe zur Platzierung der ersten Schicht in Kontakt mit der zweiten Schicht; und
eine Stufe zu einem primären Erhitzen der zweiten Schicht und der mit der zweiten Schicht in Kontakt stehenden ersten Schicht bei einer Temperatur von 900 bis 1150 °C, um dadurch ein Legieren des Cu-Cr-Gemischs in der ersten Schicht und ein Legieren der Grenzfläche zwischen der ersten und zweiten Schicht zur gleichen Zeit durchzuführen und die erste Schicht und die zweite Schicht zu verbinden; und
eine Stufe für ein primäres Unterdrucksetzen der ersten Schicht und der zweiten Schicht unter einen Druck von 6 t/cm^2 oder weniger, nachdem die erste Schicht und die zweite Schicht durch die Stufe des primären Erhitzens erhitzt wurden.

6. Verfahren zur Herstellung eines Verbundwerkstoff-Kontaktelements, das die folgenden Stufen umfasst:

eine Stufe zur Herstellung einer ersten Schicht, die aus einem Cu-Cr-Gemisch besteht, in dem pulverförmiges oder körniges Cr mit einem mittleren Teilchendurchmesser von 0,1 bis 150 μm und pulverförmiges oder körniges Cu mit einem mittleren Teilchendurchmesser von 0,1 bis 150 μm mit einem Anteil an Cr von 15 bis 60 Gew.-% und dem Rest aus Cu gemischt sind;
eine Stufe zur Herstellung einer zweiten Schicht, die aus Cu besteht;
eine Stufe zur Platzierung der ersten Schicht in Kontakt mit der zweiten Schicht; und
eine Stufe für ein primäres Unterdrucksetzen der ersten Schicht und der zweiten Schicht unter einen Druck von 6 t/cm^2 oder weniger; und
eine Stufe zu einem primären Erhitzen der zweiten Schicht und der mit der zweiten Schicht in Kontakt stehenden ersten Schicht bei einer Temperatur von 900 bis 1150 °C, während die erste und die zweite Schicht in der Stufe des primären Unterdrucksetzens unter Druck gehalten werden, wodurch ein Legieren des Cu-Cr-Gemischs in der ersten Schicht und ein Legieren der Grenzfläche zwischen der ersten und der zweiten Schicht zur gleichen Zeit zur Verbindung der ersten Schicht und der zweiten Schicht in der Stufe des primären Unterdrucksetzens durchgeführt werden.

7. Verfahren zur Herstellung eines Verbundwerkstoff-Kontaktelements, das die folgenden Stufen umfasst:

eine Stufe zur Herstellung einer ersten Schicht, die aus einem Cu-Cr-Gemisch besteht, in dem pulverförmiges oder körniges Cr mit einem mittleren Teilchendurchmesser von 0,1 bis 150 μm und pulverförmiges oder körniges Cu mit einem mittleren Teilchendurchmesser von 0,1 bis 150 μm mit einem Anteil an Cr von 15 bis 60 Gew.-% und dem Rest aus Cu gemischt sind;
eine Stufe zur Herstellung einer zweiten Schicht, die aus Cu besteht;
eine Stufe zur Platzierung der ersten Schicht in Kontakt mit der zweiten Schicht; und
eine Stufe zu einer primären Behandlung durch mindestens eine der im Folgenden angegebenen Stufen,
eine Stufe zu einem primären Erhitzen der zwei-

ten Schicht und der mit der zweiten Schicht in Kontakt stehenden ersten Schicht bei einer Temperatur von 900 bis 1150 °C, wobei ein Legieren des Cu-Cr-Gemischs in der ersten Schicht und ein Legieren der Grenzfläche zwischen der ersten und der zweiten Schicht zur gleichen Zeit zur Verbindung der ersten Schicht und der zweiten Schicht durchgeführt werden, und

eine Stufe für ein primäres Unterdrucksetzen der ersten Schicht und der zweiten Schicht unter einen Druck von 6 t/cm^2 oder weniger zur Verbindung der ersten Schicht und der zweiten Schicht; und

eine Stufe zu einer sekundären Behandlung durch mindestens eine der im Folgenden angegebenen Stufen nach der Stufe der primären Behandlung,

eine Stufe zu einem sekundären Erhitzen der ersten Schicht und der zweiten Schicht bei 1080 °C oder niedriger, und

eine Stufe für ein sekundäres Unterdrucksetzen der ersten Schicht und der zweiten Schicht unter einen Druck von 4 t/cm^2 oder mehr.

8. Verbundwerkstoff-Kontaktelement nach Anspruch 1, wobei:

das Cu der zweiten Schicht, nachdem die erste Schicht und die zweite Schicht miteinander verbunden wurden, eine Cu-Platte oder ein Cu-Sintergegenstand mit praktisch der relativen Dichte von Cu ist.

9. Verbundwerkstoff-Kontaktelement nach Anspruch 1 oder Anspruch 8, wobei das Cu der ersten Schicht, nachdem die erste Schicht und die zweite Schicht miteinander verbunden wurden, mindestens ein Element, das aus der Gruppe von Cr, Al, Si und Fe ausgewählt ist, in einer Menge von 0,5 Gew.-% oder weniger umfasst.

10. Verbundwerkstoff-Kontaktelement nach Anspruch 1, Anspruch 8 oder Anspruch 9, wobei:

die Dicke der ersten Schicht zwischen 0,5 mm und 3,0 mm eingestellt ist;

die Dicke der zweiten Schicht zwischen 0,5 mm und 3,0 mm eingestellt ist;

die Gesamtdicke der ersten Schicht und der zweiten Schicht zwischen 1,0 mm und 5,0 mm eingestellt ist; und

die erste Schicht eine Kontaktelementoberfläche ist und die zweite Schicht ein Trägersockel der ersten Schicht ist.

11. Verbundwerkstoff-Kontaktelement nach einem der Ansprüche 1 und 8 bis 10, wobei:

das Cu der ersten Schicht, die aus dem Cu-Cr-Gemisch besteht, mindestens ein Element, das aus der Gruppe von Bi, Te und Sb ausgewählt ist, in einer Menge von 0,001 bis 1 Gew.-% umfasst.

12. Verbundwerkstoff-Kontaktelement nach Anspruch 1, Anspruch 8 oder Anspruch 11, wobei:

das pulverförmige oder körnige Cr mit einem mittleren Teilchendurchmesser von 0,1 bis 150 µm durch pulverförmiges oder körniges W, ein Carbid von W, Mo oder ein Carbid von Mo mit einem mittleren Teilchendurchmesser von 0,1 bis 15 µm ersetzt ist; und

das Cu-Cr-Gemisch durch ein Cu-W-Gemisch, ein Gemisch von Cu und einem Carbid von W, ein Gemisch von Cu und Mo oder ein Gemisch von Cu und ein Carbid von Mo ersetzt ist, wobei ein pulverförmiges oder körniges W, ein Carbid von W, Mo oder ein Carbid von Mo mit einem mittleren Teilchendurchmesser von 0,1 bis 15 µm und pulverförmiges oder körniges Cu mit einem mittleren Teilchendurchmesser von 0,1 bis 15 µm mit einem Anteil an W, einem Carbid von W, Mo oder einem Carbid von Mo von 50 bis 90 Gew.-% und dem Rest aus Cu gemischt sind.

13. Verbundwerkstoff-Kontaktelement nach Anspruch 12, wobei:

ein Teil des Cu in der ersten Schicht oder die Gesamtmenge des Cu in der ersten Schicht durch Ag ersetzt ist.

14. Verbundwerkstoff-Kontaktelement nach Anspruch 12 oder Anspruch 13, wobei:

die Dicke der ersten Schicht zwischen 0,5 mm und 5,0 mm eingestellt ist;

die Dicke der zweiten Schicht zwischen 1,0 mm und 3,0 mm eingestellt ist;

die Gesamtdicke der ersten Schicht und der zweiten Schicht zwischen 1,5 mm und 7,0 mm eingestellt ist; und

die erste Schicht eine Kontaktoberfläche ist und die zweite Schicht ein Trägersockel der ersten Schicht ist.

Revendications

1. Contact composite comprenant :

une première couche composée d'un mélange Cu-Cr où Cr pulvérulent ou granulaire ayant un diamètre de particule moyen de 0,1 à 150 µm et Cu pulvérulent ou granulaire ayant un diamè-

tre de particule moyen de 0,1 à 150 μm sont mélangés à raison de 15 à 60 % en poids de Cr et le reste de Cu ; et
une seconde couche composée de Cu ;
ladite première couche et ladite seconde couche étant réunies entre elles tandis que Cu de ladite première couche pénètre dans ladite seconde couche dans une plage de 20 μm à 100 μm depuis une surface limite entre ladite première couche et ladite seconde couche et Cu dans ladite seconde couche pénètre dans ladite première couche dans une plage de 20 μm à 100 μm depuis ladite surface limite.

2. Interrupteur à vide muni d'une valve à vide comprenant :

lesdits contacts composites selon la revendication 1.

3. Procédé de fabrication d'un contact composite comprenant les étapes de :

une étape pour préparer une première couche composée d'un mélange Cu-Cr où Cr pulvérulent ou granulaire ayant un diamètre de particule moyen de 0,1 à 150 μm et Cu pulvérulent ou granulaire ayant un diamètre de particule moyen de 0,1 à 150 μm sont mélangés à raison de 15 à 60 % en poids de Cr et le reste de Cu ;
une étape pour préparer une seconde couche composée de Cu ;
une étape pour placer ladite première couche en contact avec ladite seconde couche ; et
une étape pour le chauffage primaire de ladite seconde couche et de ladite première couche en contact avec ladite seconde couche à une température de 900 à 1 150°C, pour réaliser un alliage dudit mélange Cu-Cr dans la première couche et un alliage de ladite surface limite entre lesdites première et seconde couches en même temps et pour réunir ladite première couche et ladite seconde couche.

4. Procédé de fabrication d'un contact composite comprenant les étapes de :

une étape pour préparer une première couche composée d'un mélange Cu-Cr où Cr pulvérulent ou granulaire ayant un diamètre de particule moyen de 0,1 à 150 μm et Cu pulvérulent ou granulaire ayant un diamètre de particule moyen de 0,1 à 150 μm sont mélangés à raison de 15 à 60 % en poids de Cr et le reste de Cu ;
une étape pour préparer une seconde couche composée de Cu ;
une étape pour placer ladite première couche en contact avec ladite seconde couche ;
une étape pour la compression primaire de ladite première couche et de ladite seconde couche à une pression de 6 t/cm^2 ou moins pour les réunir entre elles ; et
une étape pour le chauffage primaire de ladite seconde couche et de ladite première couche à une température de 900 à 1 150°C après que ladite première couche et ladite seconde couche sont réunies entre elles par ladite étape de compression primaire, pour réaliser un alliage dudit mélange Cu-Cr dans ladite première couche et un alliage de ladite surface limite entre lesdites première et seconde couches en même temps.

5. Procédé de fabrication d'un contact composite comprenant les étapes de :

une étape pour préparer une première couche composée d'un mélange Cu-Cr où Cr pulvérulent ou granulaire ayant un diamètre de particule moyen de 0,1 à 150 μm et Cu pulvérulent ou granulaire ayant un diamètre de particule moyen de 0,1 à 150 μm sont mélangés à raison de 15 à 60 % en poids de Cr et le reste de Cu ;
une étape pour préparer une seconde couche composée de Cu ;
une étape pour placer ladite première couche en contact avec ladite seconde couche ; et
une étape pour le chauffage primaire de ladite seconde couche et de ladite première couche en contact avec ladite seconde couche à une température de 900 à 1 150°C, pour réaliser un alliage dudit mélange Cu-Cr dans ladite première couche et un alliage de ladite surface limite entre lesdites première et seconde couches en même temps pour réunir ladite première couche et ladite seconde couche ; et
une étape pour la compression primaire de ladite première couche et de ladite seconde couche à une pression de 6 t/cm^2 ou moins après que ladite première couche et ladite seconde couche sont chauffées par ladite étape de chauffage primaire.

6. Procédé de fabrication d'un contact composite comprenant les étapes de :

une étape pour préparer une première couche composée d'un mélange Cu-Cr où Cr pulvérulent ou granulaire ayant un diamètre de particule moyen de 0,1 à 150 μm et Cu pulvérulent ou granulaire ayant un diamètre de particule moyen de 0,1 à 150 μm sont mélangés à raison de 15 à 60 % en poids de Cr et le reste de Cu ;
une étape pour préparer une seconde couche composée de Cu ;
une étape pour placer ladite première couche en contact avec ladite seconde couche ; et

une étape pour la compression primaire de ladite première couche et de ladite seconde couche à une pression de 6 t/cm^2 ou moins ; et
une étape pour le chauffage primaire de ladite seconde couche et de ladite première couche en contact avec ladite seconde couche à une température de 900 à 1 150°C tandis que lesdites première et seconde couches sont maintenues sous pression dans ladite étape de compression primaire, pour réaliser un alliage dudit mélange Cu-Cr dans ladite première couche et un alliage de ladite surface limite entre lesdites première et seconde couches en même temps pour réunir ladite première couche et ladite seconde couche dans ladite étape de compression primaire.

7. Procédé de fabrication d'un contact composite comprenant les étapes de :

une étape pour préparer une première couche composée d'un mélange Cu-Cr où Cr pulvérulent ou granulaire ayant un diamètre de particule moyen de 0,1 à 150 μm et Cu pulvérulent ou granulaire ayant un diamètre de particule moyen de 0,1 à 150 μm sont mélangés à raison de 15 à 60 % en poids de Cr et le reste de Cu ;
une étape pour préparer une seconde couche composée de Cu ;
une étape pour placer ladite première couche en contact avec ladite seconde couche ; et
une étape pour le traitement primaire d'au moins l'une des étapes suivantes,
une étape pour le chauffage primaire de ladite seconde couche et de ladite première couche en contact avec ladite seconde couche à une température de 900 à 1 150°C, pour réaliser un alliage dudit mélange Cu-Cr dans la première couche et un alliage de ladite surface limite entre lesdites première et seconde couches en même temps pour réunir ladite première couche et ladite seconde couche ; et
une étape pour la compression primaire de ladite première couche et de ladite seconde couche à une pression de 6 t/cm^2 ou moins pour réunir ladite première couche et ladite seconde couche ; et
une étape pour le traitement secondaire d'au moins l'une des étapes suivantes après ladite étape de traitement primaire,
une étape pour le chauffage secondaire de ladite première couche et de ladite seconde couche à 1 080°C ou moins, et
une étape pour la compression secondaire de ladite première couche et de ladite seconde couche à une pression de 4 t/cm^2 ou plus.

8. Contact composite selon la revendication 1 où :

Cu de ladite seconde couche après que ladite première couche et ladite seconde couche sont réunies entre elles est une plaque de Cu ou un article fritté en Cu ayant pratiquement une densité relative de Cu.

9. Contact composite selon la revendication 1 ou la revendication 8 où :

Cu de ladite première couche après que ladite première couche et ladite seconde couche sont réunies entre elles comprend au moins l'un choisi dans le groupe consistant en Cr, Al, Si et Fe en une quantité de 0,5 % en poids ou moins.

10. Contact composite selon la revendication 1, la revendication 8 ou la revendication 9 où

une épaisseur de ladite première couche est fixée entre 0,5 mm et 3,0 mm ;
une épaisseur de ladite seconde couche est fixée entre 0,5 mm et 3,0 mm ;
une épaisseur totale de ladite première couche et de ladite seconde couche est fixée entre 1,0 mm et 5,0 mm ; et
ladite première couche est une surface de contact et ladite seconde couche est un socle de support de ladite première couche.

11. Contact composite selon l'une quelconque des revendications 1 et 8 à 10 où :

Cu de ladite première couche composée dudit mélange Cu-Cr comprend au moins l'un choisi dans le groupe consistant en Bi, Te et Sb en une quantité de 0,001 à 1 % en poids.

12. Contact composite selon la revendication 1, la revendication 8 ou la revendication 11 où :

ledit Cr pulvérulent ou granulaire ayant un diamètre de particule moyen de 0,1 à 150 μm est remplacé par l'un quelconque de W pulvérulent ou granulaire, un carbure de W, Mo et un carbure de Mo ayant un diamètre de particule moyen de 0,1 à 15 μm ; et
ledit mélange Cu-Cr a été remplacé par l'un quelconque d'un mélange Cu-W, un mélange de Cu et d'un carbure de W, un mélange de Cu et Mo, et un mélange de Cu et d'un carbure de Mo, où l'un quelconque de W pulvérulent ou granulaire, un carbure de W, Mo et un carbure de Mo ayant un diamètre de particule moyen de 0,1 à 15 μm et de Cu pulvérulent ou granulaire ayant un diamètre de particule moyen de 0,1 à 15 μm sont mélangés à raison de 50 à 90 % en poids de l'un quelconque de W, un carbure de W, Mo et un carbure de Mo et le reste de Cu.

13. Contact composite selon la revendication 12 où :

une partie ou la totalité de Cu dans ladite première couche est remplacée par Ag.

14. Contact composite selon la revendication 12 ou la revendication 13 où :

une épaisseur de ladite première couche est fixée entre 0,5 mm et 5,0 mm ;
une épaisseur de ladite seconde couche est fixée entre 1,0 mm et 3,0 mm ;
une épaisseur totale de ladite première couche et de ladite seconde couche est fixée entre 1,5 mm et 7,0 mm ; et
ladite première couche est une surface de contact et ladite seconde couche est un socle de support de ladite première couche.

FIG. 1

Condition / Example / Comparison example	Claim condition of present invention: Entry distance from boundary surface (μm)		Reference (auxiliary condition): Content of 1st layer			Content of 2nd layer		Remarks
	Entry distance of Cu of first layer into second layer	Entry distance of Cu of second layer into first layer	Material of first layer (wt%)	Particle diameter of Cr (μm)	Thickness of first layer (mm)	Material of second layer (wt%)	Thickness of second layer (mm)	Manufacturing method (condition) of composite contact (Step after Cu and Cu-Cr mixture make contact with each other)
Comparison example 1	Almost 0	Almost 0	Cu-25Cr	44~105	1.0	100% Cu plate	2.0	(Step a)
Comparison example 2	2 ~ 5	3 ~ 5	Ditto	Ditto	Ditto	Ditto	Ditto	(Step b)
Comparison example 3	15 ~ 17	15 ~ 17	Ditto	Ditto	Ditto	Ditto	Ditto	Ditto
Example 1	20 ~ 25	20 ~ 25	Ditto	Ditto	Ditto	Ditto	Ditto	Ditto
Example 2	30 ~ 35	30 ~ 35	Ditto	Ditto	Ditto	Ditto	Ditto	Ditto
Example 3	Ditto	Ditto	Ditto	Ditto	Ditto	100% sintered article	Ditto	Ditto
Example 4	45 ~ 50	45 ~ 50	Ditto	Ditto	Ditto	100% Cu plate	Ditto	Ditto
Example 5	95 ~ 100	95 ~ 100	Ditto	Ditto	Ditto	Ditto	Ditto	Ditto
Comparison example 4	100 ~ 110	100 ~ 110	Ditto	Ditto	Ditto	Ditto	Ditto	Ditto
Comparison example 5	110 ~ 120	110 ~ 120	Ditto	Ditto	Ditto	Ditto	Ditto	Ditto
Comparison example 6	2 ~ 5	30 ~35	Ditto	Ditto	Ditto	Ditto	Ditto	After step b, removal of a part of surface of second layer
Comparison example 7	30 ~ 35	2 ~ 5	Ditto	Ditto	Ditto	Ditto	Ditto	After step b, removal of a part of surface of first layer
Comparison example 8	30 ~ 35	30 ~ 35	Cu-5Cr	Ditto	Ditto	Ditto	Ditto	(Step d)
Example 6	Ditto	Ditto	Cu-15Cr	Ditto	Ditto	Ditto	Ditto	Ditto
Example 7	Ditto	Ditto	Cu-60Cr	Ditto	Ditto	Ditto	Ditto	Ditto
Comparison example 9	Ditto	Ditto	Cu-90Cr	Ditto	Ditto	Ditto	Ditto	Ditto
Example 8	Ditto	Ditto	Cu-25Cr	0.5 ~ 44	Ditto	Ditto	Ditto	(Step g)
Example 9	Ditto	Ditto	Ditto	105 ~ 150	Ditto	Ditto	Ditto	Ditto
Comparison example 10	Ditto	Ditto	Ditto	150 ~ 300	Ditto	Ditto	Ditto	Ditto

FIG. 2

Condition / Example / Comparison example	Temperature characteristic	Interruption characteristic	Other characteristics	Remarks
	Relative mngnification for embodiment 2 Evaluation A: Less than 0.8; B: 0.8~0.9; C: 0.9~1.05; D: 1.05 ~ under 1.15 Evaluation X: 1.15~1.3; Y: 1.3~1.5; Z: 1.5 or more	Relative value when interruption limit is measured while increasing current almost by 1kA. (Interruption limit value of Eembodiment 2 is 1.0)	Status of first layer and second layer, temperature characteristic and interruption characteristic, after interruption test.	Overall decision O : Good × : Inferior
Comparison example 1	Z	0.3	In interruption test, separated from boudary surface of first and second layers	×
Comparison example 2	Y ~ Z	0.5	Ditto	×
Comparison example 3	X ~ Y	0.8 ~ 0.9	Ditto	×
Example 1	C ~ D	0.9 ~ 1.0	Temperature characteristic and interruption characteristic qulified	O
Example 2	C (reference)	1.0 (reference)	Ditto	O
Example 3	D	0.9	Ditto	O
Example 4	B ~ C	1.0 ~ 1.1	Ditto	O
Example 5	B	1.0 ~ 1.1	Ditto	O
Comparison example 4	X ~ Y	0.8 ~ 1.0	Large composition changes caused on contact surface after interruption test	×
Comparison example 5	D ~ Z	0.7 ~ 1.0	Large composition changes caused on contact surface after interruption test	×
Comparison example 6	D ~ Y	0.8 ~ 1.0	Variations in temperature rise value	×
Comparison example 7	D ~ X	0.8 ~ 1.0	Ditto	×
Comparison example 8	B	0.7	Great roughness of contact surface after interception test. Interruption characteristic reduced	×
Example 6	B	0.9	Temperature characteristic and interruption characteristic qulified	O
Example 7	C	0.9	Ditto	O
Comparison example 9	X ~ Y	0.4	Temperature rise value very large. Interruption characteristic reduced greatly	×
Example 8	D	0.9 ~ 1.0	Temperature characteristic and interruption characteristic qulified	O
Example 9	C	1.1	Ditto	O
Comparison example 10	C	0.7 ~ 1.0	Variations caused in interruption characteristic	×

FIG. 3

Condition / Example / Comparison example	Claim condition of present invention: Entry distance from boundary surface (μm)		Reference (auxiliary condition): Content of 1st layer			Content of 2nd layer		Remarks
	Entry distance of Cu of first layer into second layer	Entry distance of Cu of second layer into first layer	Material of first layer (wt%)	Particle diameter of Cr (μm)	Thickness of first layer (mm)	Material of second layer (wt%)	Thickness of second layer (mm)	Manufacturing method (condition) of composite contact (Step after Cu and Cu-Cr mixture make contact with each other)
Comparison example 11	30 ~ 35	30 ~ 35	Cu-25Cr	44~105	0.1 or less	100% Cu plate	2.0	(Step c) For examination of thickness of 1st layer
Example 10	Ditto	Ditto	Ditto	Ditto	0.5	Ditto	Ditto	Ditto Ditto
Example 11	Ditto	Ditto	Ditto	Ditto	1 ~ 2	Ditto	Ditto	Ditto Ditto
Example 12	Ditto	Ditto	Ditto	Ditto	3.0	Ditto	Ditto	Ditto Ditto
Comparison example 12	Ditto	Ditto	Ditto	Ditto	5 ~ 6	Ditto	Ditto	Ditto Ditto
Comparison example 13	Ditto	Ditto	Ditto	Ditto	1.0	Ditto	0.3	For examination of thickness of second layer
Example 13	Ditto	Ditto	Ditto	Ditto	Ditto	Ditto	0.5	Ditto
Example 14	Ditto	Ditto	Ditto	Ditto	Ditto	Ditto	3.0	Ditto
Comparison example 14	Ditto	Ditto	Ditto	Ditto	Ditto	Ditto	6.0	Ditto
Example 15	Ditto	Ditto	Ditto	Ditto	Ditto	Ditto	2.0	(Step e)
Example 16	Ditto	Ditto	Ditto	Ditto	Ditto	Ditto	Ditto	(Step f)
Example 17	Ditto	Ditto	Ditto	Ditto	Ditto	Ditto	Ditto	0.35%Cr - Cu
Example 18	Ditto	Ditto	Ditto	Ditto	Ditto	Ditto	Ditto	0.5%Al - Cu
Example 19	Ditto	Ditto	Ditto	Ditto	Ditto	Ditto	Ditto	0.5%Si - Cu
Example 20	Ditto	Ditto	Ditto	Ditto	Ditto	Ditto	Ditto	0.5%Fe - Cu
Example 21	Ditto	Ditto	Ditto	Ditto	Ditto	Ditto	Ditto	
Example 22	Ditto	Ditto	Ditto	Ditto	Ditto	Ditto	Ditto	For first layer, previously alloyed Cu-Cr is used

FIG. 4

Condition Ex-ample / Compar-ison example	Temperature characteristic Relative magnification for embodiment 2 Evaluation A: Less than 0.8; B: 0.8~0.9; C: 0.9~1.05; D: 1.05 ~ under 1.15 Evaluation X: 1.15~1.3; Y: 1.3~1.5; Z: 1.5 or more	Interruption characteristic Relative value when interruption limit is measured while increasing current almost by 1kA. (Interruption limit value of Eembodiment 2 is 1.0)	Other perperties etc. Status of first layer and second layer, temperature characteristic and interruption characteristic, after interruption test.	Remarks Overall decision ○ : Good × : Inferior
Comparison example 11	B	0.5 ~ 0.7	In interruption test, second layer exposed on contact surface	×
Example 10	B ~ C	0.9	Temperature characteristic and interruption characteristic qualified	○
Example 11	C	1.0	Ditto	○
Example 12	C	1.0	Ditto	○
Comparison example 12	D	0.8	Disadvantageous in ensuring flexible contact surface	×
Comparison example 13	B ~ C	0.6 ~ 0.8	In interruption test, contact surface deformed	×
Example 13	C	1.0	Ditto	○
Example 14	C	1.0	Ditto	○
Comparison example 14	D	0.8	Disadvantageous in ensuring flexible contact surface	×
Example 15	A	1.2	Temperature characteristic and interruption characteristic qualified	○
Example 16	A ~ B	1.1 ~1.2	Ditto	○
Example 17	C	1.1	Ditto	○
Example 18	C	1.1	Ditto	○
Example 19	C	1.1	Ditto	○
Example 20	C	1.1	Ditto	○
Example 21	C	1.1 ~ 1.2	Ditto	○
Example 22	C	1	Both characteristics qualified. Warp problem is solved by controlling the cooling speed.	○

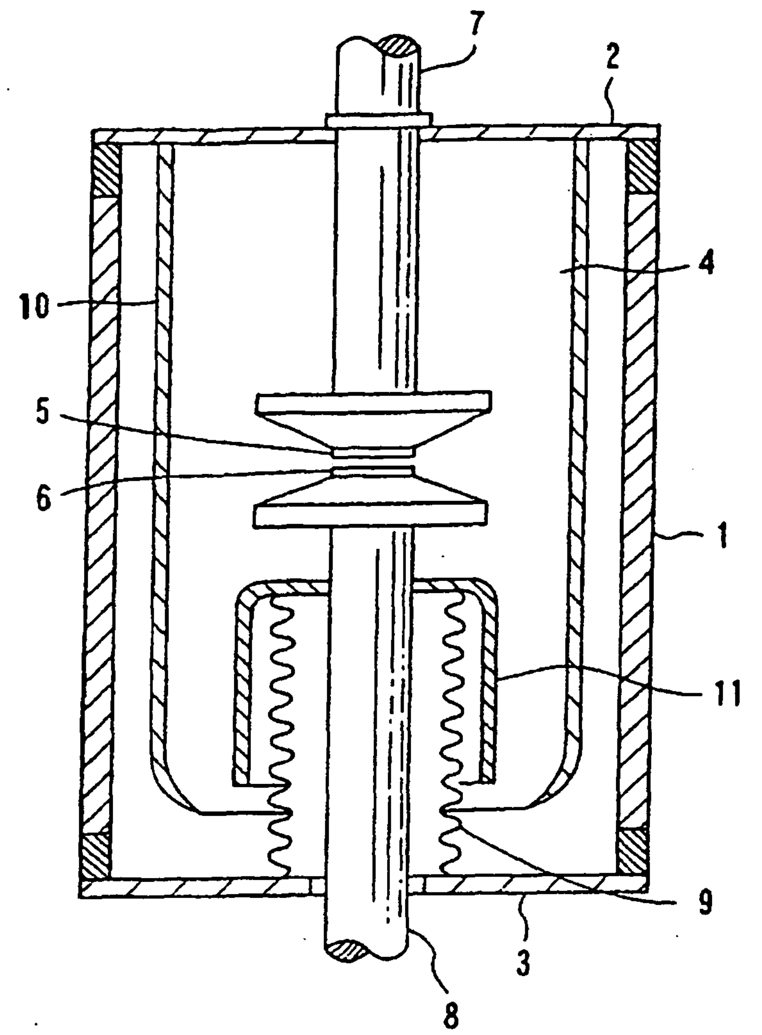
Condition / Example / Comparison example	Claim condition of present invention — Entry distance from boundary surface (μm): Entry distance of Cu of first layer into second layer	Claim condition of present invention — Entry distance from boundary surface (μm): Entry distance of Cu of second layer into first layer	Reference (auxiliary condition) — Content of 1st layer: Material of first layer (wt%)	Reference (auxiliary condition) — Content of 1st layer: Particle diameter of W (μm)	Reference (auxiliary condition) — Content of 1st layer: Thickness of first layer (mm)	Reference (auxiliary condition) — Content of 2nd layer: Material of second layer (wt%)	Reference (auxiliary condition) — Content of 2nd layer: Thickness of second layer (mm)	Remarks: Manufacturing method (condition) of compositr contact (Step after Cu and Cu-W mixture make contact with each other)
Comparison example 18	Almost 0	Almost 0	Cu-73W	W particle diameter 1~6	1.0	100% Cu plate	2.0	(Step a)
Comparison example 19	2 ~ 3	3 ~ 5	Ditto	Ditto	Ditto	Ditto	Ditto	(Step b)
Comparison example 20	15 ~ 17	15 ~ 17	Ditto	Ditto	Ditto	Ditto	Ditto	Ditto
Example 31	20 ~ 25	20 ~ 25	Ditto	Ditto	Ditto	Ditto	Ditto	Ditto
Example 32	30 ~ 35	30 ~ 35	Ditto	Ditto	Ditto	Ditto	Ditto	Ditto
Example 33	Ditto	Ditto	Ditto	Ditto	Ditto	100% sintered article	Ditto	Ditto
Example 34	45 ~ 50	45 ~ 50	Ditto	Ditto	Ditto	100% Cu plate	Ditto	Ditto
Example 35	95 ~ 100	95 ~ 100	Ditto	Ditto	Ditto	Ditto	Ditto	Ditto
Comparison example 21	100 ~ 110	100 ~ 110	Ditto	Ditto	Ditto	Ditto	Ditto	Ditto
Comparison example 22	110 ~ 115	110 ~ 115	Ditto	Ditto	Ditto	Ditto	Ditto	Ditto
Comparison example 23	2 ~ 5	30 ~ 35	Ditto	Ditto	Ditto	Ditto	Ditto	After step b, removal of a part of surface of second layer
Comparison example 24	30 ~ 35	2 ~ 5	Ditto	Ditto	Ditto	Ditto	Ditto	After step b, removal of a part of surface of first layer
Comparison example 25	30 ~ 35	30 ~ 35	Cu-25W	Ditto	Ditto	Ditto	Ditto	(Step d)
Example 36	Ditto	Ditto	Cu-50W	Ditto	Ditto	Ditto	Ditto	Ditto
Example 37	Ditto	Ditto	Cu-90W	Ditto	Ditto	Ditto	Ditto	Ditto
Comparison example 26	Ditto	Ditto	Cu-95W	Ditto	Ditto	Ditto	Ditto	Ditto
Example 38	Ditto	Ditto	Cu-73W	0.1 ~ 1	Ditto	Ditto	Ditto	(Step g)
Example 39	Ditto	Ditto	Ditto	9 ~ 15	Ditto	Ditto	Ditto	Ditto
Comparison example 27	Ditto	Ditto	Ditto	25 ~ 35	Ditto	Ditto	Ditto	Ditto
Comparison example 28	Ditto	Ditto	Ditto	1 ~ 3	0.1 or less	Ditto	2.0	(Step c) For examination of thickness of 1st layer
Example 40	Ditto	Ditto	Ditto	Ditto	0.5 ~ 0.6	Ditto	Ditto	Ditto Ditto
Example 41	Ditto	Ditto	Ditto	Ditto	2.5 ~ 3	Ditto	Ditto	Ditto Ditto
Example 42	Ditto	Ditto	Ditto	Ditto	4.5 ~ 5	Ditto	Ditto	Ditto Ditto
Comparison example 29	Ditto	Ditto	Ditto	Ditto	5.5 ~ 6	Ditto	Ditto	Ditto Ditto

Condition / Example / Comparison example	Temperature characteristic	Interruption characteristic	Other characteristics	Remarks
	Relative magnification for Embodiment 32 Evaluation: A: Less than 0.8; B: 0.8~0.9; C: 0.9~1.05; D: 1.05 ~ under 1.15 Evaluation: X: 1.15~1.3; Y: 1.3~1.5; Z: 1.5 or more	Relative value when interruption limit is measured while increasing current almost by 1kA. (Interruption limit value of Eembodiment 32 is 1.0)	Status of first layer and second layer, temperature characteristic and interruption characteristic, after interruption test.	Overall decision O : Good × : Inferior
Comparison example 18	Z	0.3	In interruption test, separated from boundary surface of first and second layers	×
Comparison example 19	Y ~ Z	0.5	Ditto	×
Comparison example 20	X ~ Y	0.8 ~ 0.9	Ditto	×
Example 31	C ~ D	0.9 ~ 1.0	Temperature characteristic and interruption characteristic qualified	O
Example 32	C (reference)	1.0 (reference)	Ditto	O
Example 33	D	0.9	Ditto	O
Example 34	B ~ C	1.0 ~ 1.1	Ditto	O
Example 35	B	1.0 ~ 1.1	Ditto	O
Comparison example 21	X ~ Y	0.8 ~ 1.0	Large composition changes caused on contact surface after interruption test	×
Comparison example 22	D ~ Z	0.7 ~ 1.0	Large composition changes caused on contact surface after interruption test	×
Comparison example 23	D ~ Y	0.8 ~ 1.0	Variation in temperature rise value	×
Comparison example 24	D ~ X	0.8 ~ 1.0	Ditto	×
Comparison example 25	B	0.7	Greart roughness of contact surface after interruption test. Interruption characteristic reduced	×
Example 36	B	1.1	Temperature characteristic and interruption characteristic qualified	O
Example 37	D	0.9	Ditto	O
Comparison example 26	X ~ Y	0.4	Temperature rise value very large. Interruption characteristic reduced greatly	×
Example 38	D	0.9 ~ 1.0	Temperature characteristic and interruption characteristic qualified	O
Example 39	C	1.1	Ditto	O
Comparison example 27	C	0.7 ~ 1.0	Variations caused in interruption characteristic	×
Comparison example 28	B	0.7 ~ 0.8	In interruption test, second layer exposed on contact surface	×
Example 40	B ~ C	0.9	Temperature characteristic and interruption characteristic qualified	O
Example 41	B ~ C	1.0	Ditto	O
Example 42	B ~ C	1.0	Ditto	O
Comparison example 29	D	0.7 ~ 0.9	Disadvantageous in ensuring flexible contact surface	×

Condition: Example / Comparison example	Claim condition of present invention — Entry distance from boundary surface (μm): Entry distance of Cu of first layer into second layer	Entry distance of Cu of second layer into first layer	Reference (auxiliary condition) — Content of 1st layer: Material of 1st layer (wt%) (In embodiments 52 to 54, WC, Mo, and MoC in place of W, in Embodiment 55 to 58, Ag in place of Cu)	Particle diameter of W (μm)	Thickness of 1st layer (mm)	Content of 2nd layer: Material of 2nd layer (wt%)	Thickness of 2nd layer (mm)	Remarks: The manufacturing method (condition) of composite contact (Step after Cu and Cu-W mixture make contact with each other)	(Only in Embodiments 47 to 51, Bi, Te, and Sb added)
Comparison example 30	30 ~ 35	30 ~ 35	Cu-73W	1 ~ 3	1.0	100% Cu plate	0.4	(Step c)	For examination of thickness of 2nd layer
Example 43	Ditto	Ditto	Ditto	Ditto	Ditto	Ditto	1.0	Ditto	Ditto
Example 44	Ditto	Ditto	Ditto	Ditto	Ditto	Ditto	3.0	Ditto	Ditto
Comparison example 31	Ditto	Ditto	Ditto	Ditto	Ditto	Ditto	6.0	Ditto	Ditto
Example 45	Ditto	Ditto	Ditto	Ditto	Ditto	Ditto	2.0	(Step e)	
Example 46	Ditto	Ditto	Ditto	Ditto	Ditto	Ditto	Ditto	(Step f)	
Example 47	Ditto	Ditto	Ditto	Ditto	Ditto	Ditto	Ditto	(Step c)	Bi amount in first layer : 0.001%
Example 48	Ditto	Ditto	Ditto	Ditto	Ditto	Ditto	Ditto	Ditto	Bi amount in first layer : 0.1%
Example 49	Ditto	Ditto	Ditto	Ditto	Ditto	Ditto	Ditto	Ditto	Bi amount in first layer : 1.0%
Example 50	Ditto	Ditto	Ditto	Ditto	Ditto	Ditto	Ditto	Ditto	Te amount in first layer : 0.01%
Example 51	Ditto	Ditto	Ditto	Ditto	Ditto	Ditto	Ditto	Ditto	Sb amount in first layer : 0.1%
Example 52	Ditto	Ditto	65WC in place of W	Ditto	Ditto	Ditto	Ditto	(Step e)	
Example 53	Ditto	Ditto	65Mo in place of W	Ditto	Ditto	Ditto	Ditto	Ditto	
Example 54	Ditto	Ditto	65MoC in place of W	Ditto	Ditto	Ditto	Ditto	Ditto	
Example 55	Ditto	Ditto	Ag-40WC	Ditto	Ditto	Ditto	Ditto	Ditto	
Example 56	Ditto	Ditto	Ag-40W	Ditto	Ditto	Ditto	Ditto	Ditto	
Example 57	Ditto	Ditto	Ag-40MoC	Ditto	Ditto	Ditto	Ditto	Ditto	
Example 58	Ditto	Ditto	Ag-40Mo	Ditto	Ditto	Ditto	Ditto	Ditto	

FIG. 8

Condition (Example / Comparison example)	Temperature characteristic: Relative magnification for Embodiment 32 (Evaluation A: Less than 0.8; B: 0.8~0.9; C: 0.9~1.05; D: 1.05 ~ under 1.15; Evaluation X: 1.15~1.3; Y: 1.3~1.5; Z: 1.5 or more)	Interruption characteristic: Relative value when interruption limit is measured whille increasing current almost by 1kA. (Interruption limit value of Eembodiment 32 is 1.0)	Other characteristics: Status of first layer and second layer, temperature characteristic and interruption characteristic, after interruption test.	Remarks: Overall decision (O : Good, x : Inferior)
Comparison example 30	B ~ C	0.6 ~ 0.8	In interruption test, contact surface deformed	x
Example 43	C	1.0	Ditto	O
Example 44	C	1.0	Ditto	O
Comparison example 31	D	0.8	Disadvantageous in ensuring flexible contact surface	x
Example 45	A	1.2	Temperature characteristic and interruption charactersitic qualified	O
Example 46	A ~ B	1.1 ~ 1.2	Ditto	O
Example 47	C	1.1	Ditto Welding resistance imroved	O
Example 48	C	1.1	Ditto Welding resistance imroved	O
Example 49	C	1.1	Ditto Ditto	O
Example 50	C	1.1	Ditto Ditto	O
Example 51	C	1.0	Ditto Ditto	O
Example 52	D	1.1	Both characteristics qualified	O
Example 53	C	1.0	Ditto	O
Example 54	D	0.9 ~ 1.0	Ditto	O
Example 55	D	0.9 ~ 1.0	Ditto	O
Example 56	D	0.9 ~ 1.0	Ditto	O
Example 57	D	0.9 ~ 1.0	Ditto	O
Example 58	D	0.9 ~ 1.0	Ditto	O



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