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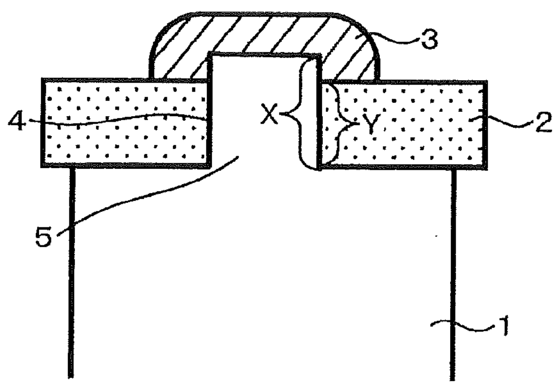
(54) Joining structures, electrical contacts, and their manufacturing means

(57) A joining structure includes plural members and an adhered and deposited layer formed by depositing powder containing metal over the plurality of members. The plural members are joined via coupling with alloying by thermal and mechanical activation between the plural members and the adhered and deposited layer. A substrate is made of a metal of high electrical conductivity. A member to be joined is formed in a cup shape and made of metal of high electrical conductivity. The adhered and deposited layer is a contact layer including fire-resistant metal or compound and metal of high electrical conductivity. One surface of the substrate and a cup-shaped opened end of the member to be joined are joined with the alloying by thermal and mechanical activation.

FIG.1



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Description

Background of the Invention

[0001] The present invention relates to joining structures, electrical contacts, and manufacturing means for electric power switches used in a vacuum circuit breaker, a vacuum insulated switch-gear, a gas insulated switch-gear, and the like.

[0002] An electric power switch that breaks an electric current in a vacuum includes a vacuum interrupter, which is a container incorporating an electrical contact and vacuum-sealed. The electrical contact is manufactured by a manufacturing process such as sintering or infiltration and is machined according to necessity. After being brazed (primarily joined) with an energization member, in a state in which the electrical contact is built in the container forming the vacuum interrupter, the container is brazed and sealed (secondarily joined) in a vacuum, whereby the electrical contact is incorporated in the vacuum interrupter. In this way, in general, in the manufacturing process for the electrical contact, the brazing step requires at least two steps including the joining with the energization member and the vacuum sealing and joining. Therefore, large costs are spent for the manufacturing of the vacuum interrupter including the electrical contacts.

[0003] If the brazing of the electrical contact and the energization member are imperfect, the electrical contact falls off during operation or a brazing-filler is vaporized by arc heating during current breaking or Joule heating during energization. As a result, electric performance is deteriorated and product reliability is deteriorated. Therefore, in the brazing, the primary brazing is required to have high reliability. Contrivance in terms of shape for obtaining a sound brazed state is made, for example, a region and a shape for keeping a proper amount of the brazing-filler are provided near a joining portion.

Brief Summary of the Invention

[0004] JP-A-2007-157666 realizes improvement of soundness of brazing by forming a brazed portion in a proper shape. However, as long as the brazing-filler is used, it is still likely that joining reliability is deteriorated by the heating vaporization of the brazing-filler. Further, since the manufacturing process for the electrical contact by the sintering or the infiltration requires a large amount of thermal energy, the manufacturing process itself for the electrical contact causes an increase in costs.

[0005] It is an object of the present invention to join members at low costs without using the brazing-filler.

[0006] According to the invention, a joining structure comprises a plurality of members, and an adhered and deposited layer through which the members are joined with each other, wherein the adhered and deposited layer is formed by powder which includes metal, is deposited onto each of the members and adheres to each of the members, and the adhered and deposited layer and each of the members are joined with each other through an alloyed junction formed between each of the members and the powder activated thermally and mechanically.

[0007] According to the invention, the members can be joined with each other at the low cost without using the brazing-filler.

Brief Description of the Several Views of the Drawings

[0008]

Fig. 1 is a sectional view of a joining structure according to the present invention;
Fig. 2 is a sectional view of another joining structure according to the present invention;
Fig. 3 is a sectional view of still another joining structure according to the present invention;
Fig. 4 is a sectional view of still another joining structure according to the present invention;
Fig. 5 is a sectional view of still another joining structure according to the present invention;
Figs. 6A and 6B are sectional views of structures of electrical contacts according to the present invention;
Figs. 7A and 7B are respectively a perspective view of a contact layer and a sectional view of the structure of another electrical contact according to the present invention;
Figs. 8A and 8B are sectional views of structures of other electrical contacts according to the present invention;
Figs. 9A and 9B are plan views of substrates used for electrical contacts according to the present invention;
Figs. 10A to 10C are sectional views of structures of electrical contacts including contact layers having plural compositions according to the present invention;
Fig. 11 is a sectional view of still another joining structure according to the present invention;
Fig. 12 is a sectional view showing the structure of a vacuum interrupter according to an embodiment 2;
Fig. 13 is a sectional view showing the structure of a vacuum circuit breaker according to an embodiment 3; and
Fig. 14 is a sectional view showing the structure of a load break switch according to the embodiment 3.

Detailed Description of the Invention

[0009] Sectional views of a joining structure according to the present invention are shown in Figs. 1 and 2. In Figs. 1 and 2, reference numeral 1 denotes a member to be joined, 2 denotes a substrate, 3 denotes an adhered and deposited layer, 4 denotes a through-hole provided in the substrate 2, and 5 denotes a protrusion provided in the member to be joined 1.

[0010] In a first structure shown in Fig. 1, the through-hole 4 of the substrate 2 and the protrusion 5 of the member to be joined 1 are fit in each other. The surface of the distal end of the protrusion 5 may be either projected further than the surface of the substrate 2 (X > Y), present on the same plane (X = Y), or further depressed than the surface of the substrate 2 (X < Y). The same applies to structures explained below. The member to be joined 1 and the substrate 2 do not have to be fit in about the axis of the member to be joined 1 shown in the figure. A portion where the member to be joined 1 and the substrate 2 are in contact with each other is referred to as a fitting portion. The adhered and deposited layer 3 is formed in the fitting portion. Powder containing metal is deposited over both members of the substrate 2 and the protrusion 5 (the member to be joined 1), whereby the adhered and deposited layer 3 can be formed in contact with the substrate 2 and the member to be joined 1, and the substrate 2 and the member to be joined 1 can be joined via coupling with alloying by thermal and mechanical activation.

[0011] In a second structure shown in Fig. 2, the substrate 2 is placed on the member to be joined 1, the through-hole 4 of the substrate 2 and a flat portion of the member to be joined 1 are overlaid, and the powder containing metal is deposited to fill the through-hole 4. Consequently, the substrate 2 and the member to be joined 1 are joined via coupling with alloying by thermal and mechanical activation of the adhered and deposited layer 3 with the substrate 2 and the member to be joined 1. A contact surface of the member to be joined 1 and the substrate 2 does not have to be flat and may be depressed to further extend the through-hole 4 downward. With these structures, it is possible to join the substrate 2 and the member to be joined 1 without using a brazing-filler or the like that has a relatively low melting point and low heat resistance. After joining the substrate 2 and the member to be joined 1, a joining state can be maintained even if the adhered and deposited layer 3 forming a protrusion portion on the surface of the substrate 2 is removed by machining or the like to planarize the surface of the substrate 2.

[0012] As shown in Fig. 3, mechanical coupling (so-called anchor effect) or a contact area can be increased between the protrusion 5 and the adhered and deposited layer 3 and firmer coupling can be obtained by increasing the surface roughness of the projecting portion of the protrusion 5 or providing very small unevenness on the projecting surface.

[0013] As shown in Fig. 4, the surface of the member to be joined 1 in contact with the adhered and deposited layer 3 may be roughened or very small unevenness may be provided on the surface in the same manner as shown in Fig. 3. As shown in Figs. 4 and 5, when a taper or an R portion is provided in the through-hole 4 of the substrate 2, the coupling of the adhered and deposited layer 3 and the member to be joined 1 becomes firmer.

[0014] Sectional views of the structure of an electrical contact according to the present invention employing the joining structure explained above are shown in Figs. 6A and 6B and Figs. 8A and 8B. In Figs. 6A and 6B and Figs. 8A and 8B, 1 denotes a cup-shaped or bar-shaped member to be joined made of metal of high electrical conductivity, 2 denotes a substrate made of metal of high electrical conductivity, 6 denotes a contact layer containing fire-resistant metal or compound and metal of high electrical conductivity and formed of the adhered and deposited layer 3, 7 denotes a supporting member for reinforcing a space between the member to be joined 1 and the substrate 2, 8 denotes a brazing-filler placed between the supporting member 7 and the member to be joined 1 and between the supporting member 7 and the substrate 2, and 9 denotes a step for positioning provided in an overlaid portion of the member to be joined 1 and the substrate 2.

[0015] Figs. 6A and 8A respectively show electrical contacts 100 and 300 joined by the first structure shown in Fig. 1 among the joining structures explained above. Figs. 6B and 8B show electrical contacts 200 and 400 joined by the second structure shown in Fig. 2. In both cases, the adhered and deposited layer 3 also functions as the contact layer 6, whereby the joining of the member to be joined 1 and the substrate 2 and the formation of the contact layer 6 on the substrate 2 can be simultaneously attained by the joining mechanism in one step. Consequently, it is possible to manufacture the electrical contact at low costs and join contact peripheral members without using the brazing-filler.

[0016] The brazing-filler 8 placed on and under the supporting member 7 is fused in a later sealing and brazing process for a vacuum interrupter and used for brazing and fixing for the supporting member 7. Since the brazing-filler 8 is arranged in the center of the rear surface of the contact layer 6, the influence of brazing-filler vaporization involved in a temperature rise during operation is small. The brazing-filler 8 may be removed unless the fixing of the supporting member 7 is hindered. The step 9 provided in the substrate 2 may be removed unless the positioning accuracy of the substrate 2 with the member to be joined 1 is hindered. Further, in the electrical contacts 100 and 200 having the structures shown in Figs. 6A and 6B, as the shape of the through-hole 4 of the substrate 2, circular plural through-holes 4 may be equally provided in the circumferential direction as shown in the plan views of Fig. 9A. Besides, the through-holes 4 may be elongated holes along the circumference as shown in the plan view of Fig. 9B. Consequently, the dimensions of the joining portion increase, which is advantageous for improvement of joining strength and energization properties.

[0017] In the electrical contacts 300 and 400 having the structures shown in Figs. 8A and 8B, screw portions are provided in a portion where the substrate 2 and the member to be joined 1 are in contact with each other (a overlaid portion of the through-hole 4 and the protrusion 5 or the member to be joined 1 and the substrate 2) to fasten the substrate 2 and the member to be joined 1 with screws. Consequently, it is possible to prevent the substrate 2 from tilting or falling off in a process for forming the contact layer 6 explained below. Further, the electrical contacts 100 and 200 formed in the structures shown in Figs. 6A and 6B can also be formed in structures shown in Figs. 7A and 7B. Specifically, a net made of electrically conductive metal is formed as the substrate 2 and the contact layer 6 is formed on the substrate 2. When the contact layer 6 is formed, the net is placed on a rigid base, on the flat surface of which a mold release agent is applied, and powder is deposited on the net to form the contact layer 6. The outer diameter of the contact layer 6 is set smaller than the inner diameter of the cup-shaped member to be joined 1. A contact layer 1100 formed by integrating the net-like substrate 2 and the contact layer 6 is placed on the supporting member 7 on which the member to be joined 1 and the brazing-filler 8 are arranged. Powder is deposited on the outer circumference, where the net-like substrate 2 and the member to be joined 1 overlap, to fasten the substrate 2 and the member to be joined 1 (1200). In this structure, since the substrate 2 is formed in the net shape on which only a small amount of the powder is deposited, it is possible to reduce the weight of the electrical contact 1200, leading to a reduction in materials in use.

[0018] In the electrical contact according to the present invention, the metal of high electrical conductivity forming the member to be joined 1 and the substrate 2 or a part of the contact layer 6 is Cu or Ag or an alloy mainly containing Cu and Ag. Consequently, it is possible to suppress a temperature rise of the electrical contact involved in energization, prevent welding adhesion of the contact layers 6 that are in contact with each other, and secure satisfactory energization performance. The fire-resistant metal or compound forming a part of the contact layer 6 is at least one kind of Cr, Co, W, and WC. Consequently, it is possible to develop withstanding voltage properties (arc resistance), current breaking properties, and the like necessary for the electrical contact. Further, the adhered and deposited layer 3 forming the contact layer 6 is formed of powder of the fire-resistant metal or compound and metal of high electrical conductivity having a particle diameter equal to or smaller than 75 μm (hereinafter referred to as raw material powder). Consequently, it is possible to obtain the fine adhered and deposited layer 3 and efficiently deposit and fill the raw material powder around the fitting portion (Fig. 1) or on the inside of the through-hole 4 (Fig. 2). As a result, a satisfactory joining state is obtained. When the particle diameter of the raw material powder exceeds about 75 μm, the weight of powder particles increases, collision speed necessary for depositing the raw material powder is not obtained, and gaps tend to be formed among particles to be deposited. Therefore, the fine adhered and deposited layer 3 cannot be obtained.

[0019] Figs. 10A to 10C are sectional views of the structures of electrical contacts according to the present invention in which plural contact layers having different compositions are annularly arranged in the radial direction. In Figs. 10A to 10C, reference numeral 47 denotes a second contact layer having a composition different from the composition of the contact layer 6 and 48 denotes a third contact layer having a composition different from the compositions of both contact layers 6 and 47. Fig. 10A shows an electrical contact 800 in which the two kinds of contact layers 6 and 47 are annularly provided to be symmetrical with respect to the center axis. Fig. 10B shows an electrical contact 900 in which the three kinds of contact layers 6, 47, and 48 are concentrically provided to be symmetrical with respect to the center axis. Fig. 10C shows an electrical contact 1000 in which the two kinds of contact layers 6 and 47 are annularly alternately provided to be symmetrical with respect to the center axis. The electric performance of an electrical contact changes according to the composition of a contact. Therefore, it is possible to realize an electrical contact having plural functions such as breaking performance, withstanding voltage performance, and low surge properties by including plural contact layers having different compositions. The electrical contact including the contact layers having the plural compositions can be applied to the structures shown in Figs. 6A, 6B, 7B, and 8B as well. An electrical contact in which contact layers having different compositions are radially alternately arranged from the center axis to the outer circumference can also be realized.

[0020] The joining structure and the electrical contacts explained above can be obtained by causing the raw material powder forming the adhered and deposited layer 3 to collide against the fitting portion or the overlaid portion of the substrate 2 and the member to be joined 1 at high speed by a method such as thermal spraying or explosive compaction, plastically deforming the powder, and depositing the powder with alloying by thermal and mechanical activation. In general, the fire-resistant metal or compound is relatively rigid. Therefore, even if the powder of the metal or compound is caused to collide at high speed, the powder is less easily plastically deformed. The powder is hardly deposited on a target region. However, if the powder of the fire-resistant metal or compound contains powder of relatively soft metal of high electrical conductivity, the powder is deposited while engulfing the powder of the fire-resistant metal or compound. Therefore, it is possible to obtain the contact layers 6, 47, and 48 respectively having the different components as explained above. The joining of the two members with the alloying by thermal and mechanical activation via the powder can be used for fastening of the member to be joined 1 and an energization member 49 shown in Fig. 11 as well. Specifically, in a state in which the member to be joined 1 and the energization member 49 are closely attached and placed, the member to be joined 1 and the energization member 49 can be fastened by causing the powder to collide at high speed along the edge of a contact portion of the members and forming the adhered and deposited layer 3. This can be applied to the electrical contacts shown in Figs. 6B and 7B as well.

[0021] Further, the composition of each of the contact layers 6, 47, and 48 formed by the adhered and deposited layer 3 can be changed stepwise or continuously in the thickness direction thereof (an opening and closing direction of the electrical contact). For example, when the contact layers 6, 47, and 48 are formed by thermal spraying, the composition of supplied powder is changed stepwise or continuously, whereby the contact layers have compositions gradient in the thickness direction. If the substrate 2 side is formed in a composition including a large percentage of the metal of high electrical conductivity having high adhesion with the substrate 2 and the surface sides of the contact layers 6, 47, and 48 are formed in a composition including a large percentage of the fire-resistant metal or compound, the contact layers 6, 47, and 48 excellent in adhesion with the substrate 2 and having sufficient withstanding voltage properties can be obtained.

[0022] A vacuum interrupter according to the present invention includes a pair of a fixed side contact and a movable side contact in a vacuum chamber. The vacuum interrupter includes the electrical contact according to the present invention in at least one contact. Therefore, the vacuum interrupter can develop excellent current breaking performance, withstanding voltage performance, and the like in a vacuum.

[0023] A vacuum circuit breaker according to the present invention includes, respectively in the fixed side contact and the movable side contact in the vacuum interrupter, conductor terminals connected to the outside of the vacuum interrupter and opening and closing means for driving the movable side contact. The vacuum interrupter includes the electrical contact according to the present invention. Therefore, the vacuum circuit breaker can show sufficient functions of the vacuum circuit breaker.

[0024] An electric power switch according to the present invention includes a pair of electrical contacts, one of which is the electrical contact according to the present invention, and a mechanism for feeding or breaking an electric current by bringing the pair of electrical contacts into contact with each other or separating the pair of electrical contacts. Consequently, the electric power switch can show sufficient performance of the electric power switch such as current breaking performance in an atmosphere of a vacuum, inert gas, or the air.

[0025] Best modes for carrying out the invention are explained in detail below with reference to embodiments. However, the present invention is not limited to these embodiments.

Embodiment 1

[0026] In the structures shown in Figs. 8A and 8B and Fig. 10A, the electrical contacts 300, 400, and 800 in which the contact layer 6 had compositions (analysis values) shown in Table 1 were manufactured. In all the electrical contacts 300, 400, and 800, the substrate 2 had a diameter of 54 mm and thickness of 5 mm, the inner diameter of the through-hole 4 is 12 mm, and the substrate 2 and the member to be joined 1 were made of oxygen free copper. As comparative products, electrical contacts in which the substrate 2 not including the through-hole 4 and the member to be joined 1 not including the protrusion 5 were brazed using a Cu-Mn-Ni brazing-filler were also manufactured.

[0027] First, manufacturing means for the electrical contacts 300 and 400 in this embodiment is explained. When the composition of the contact layer 6 was Cu-Cr (No. 1, No. 2, and No. 6 in Table 1), mixed powder obtained by combining Cu powder and Cr powder having a particle diameter range of 25 to 75 μm to obtain the composition of the contact layer 6 shown in Table 1 was used as the raw material powder. When the composition of the contact layer 6 was Ag-WC (No. 3 and No. 4 in Table 1), mixed powder obtained by combining Ag powder and WC powder having a particle diameter range of 0.3 to 45 μm to obtain the composition of the contact layer 6 shown in Table 1 was used as the raw material powder. In a state in which the substrate 2 and the member to be joined 1 were combined, these mixed powders were thermally sprayed to the surface of the substrate 2 using an Ar + H2 mixed gas and caused to collide against and deposited on the surface of the substrate 2. In No. 6 in which the composition of the contact layer 6 continuously changed in a range shown in Table 1, supply systems for the Cu powder and the Cr powder were separately controlled and the composition in the thickness direction of the contact layer 6 was changed stepwise or continuously from the substrate side to the surface side. After the raw material powder was deposited on the surface of the substrate 2 by thickness of about 3 mm, the substrate 2 was cut to thickness of about 2 mm by machining to obtain the electrical contacts 300 and 400 in which the total thickness of the contact layer 6 and the substrate 2 was about 5 mm.

[0028] Manufacturing means for the electrical contact 800 in this embodiment (No. 5 in Table 1) is explained. The mixed powders were used as the raw material powder. First, in a state in which the substrate 2 and the member to be joined 1 were combined, the Ag-WC mixed powder was thermally sprayed to the surface in the center of the substrate 2 using the Ar + H2 mixed gas through a shielding plate (a mask) with a hole having an inner diameter of 25 mm and caused to collide against and deposited on the surface of the substrate 2. Further, in a state in which a shielding plate (a mask) having an outer diameter of 25 mm was arranged in the center of the substrate 2, the Cu-Cr mixed powder was thermally sprayed and deposited in the same manner. Thereafter, the machining same as above was applied to obtain the electrical contact 800 including the contact layer 6 of Ag-WC on the radially inner side (about 25 mm in a diameter) and including the contact layer 47 of Cu-Cr on the radially outer side.

[0029] Manufacturing means for, among the comparative products, the electrical contacts 300 of No. 9 and No. 10 having the joining structure shown in Fig. 8A and a particle diameter range of the raw material powder different from the particle diameter range of this embodiment is explained. Mixed powder of Cu powder and Cr powder respectively having particle diameter ranges of 45 to 105 μm and 80 to 150 μm was used as the raw material powder. After the mixed powder was thermally sprayed to the surface of the substrate 2 by a method same as the method in the embodiment, the surface was cut by machining to obtain the electrical contact 300 in which the total thickness of the contact layer 6 and the substrate 2 was about 5 mm.

[0030] Subsequently, manufacturing means for, among the comparative products, electrical contacts (No. 7 and No. 8) in which the substrate 2 and the member to be joined 1 are joined by brazing is explained. Cu-Cr mixed powder and Ag-WC mixed powder same as those in No. 1 to No. 5 were used as the raw material powder. After these mixed powders were thermally sprayed to the surface of the substrate 2 without the through-hole 4 by a method same as the method for the product of the present invention, the surface was cut by machining to set the thickness of the contact layer 6 to about 2 mm. A Cu-Mn-Ni brazing-filler (having thickness of 0.1 mm) was placed between the rear surface of the substrate 2 and the flat surface (having a diameter of 12 mm) of the member to be joined 1. The substrate 2, the member to be joined 1, and the brazing-filler were heated for 10 minutes at 960°C in a vacuum of about 3×10^{-3} Pa using a vacuum heating furnace to obtain an electrical contact in which the substrate 2 having the contact layer 6 on the surface and the member to be joined 1 were brazed.

[0031] As explained above, it was confirmed that the formation of the contact layer 6 and the joining of the contact layer 6 with another member are simultaneously carried out and an electrical contact having structure same as that obtained by the conventional brazing method can be obtained by the joining structure and the manufacturing means according to this embodiment. The thermal spraying is used for the formation of the contact layer 6 in this embodiment. However, the same electrical contact can be obtained by another method (e.g., the explosive compaction) as long as the method is a method of causing powder to collide against and depositing the powder on the surface of the substrate 2.

[Table 1]

Division	No.	Joining structure	Raw material powder particle diameter (μm)	Contact layer composition (analysis value: wt%)		Vacuum interrupter			Remarks
				Radially inner side	Radially outer side	Interterminal resistance (μΩ)	Maximum breaking current (kA)	Chopping current (A)	
Products of invention	1	Fig. 8A	25 ~ 75	Cu-19.7Cr		12.3	33.4	7.3	
	2	Fig. 8B		Cu-20.1Cr		12.4	34.0	7.1	
	3	Fig. 8A	0.3 ~ 45	Ag 49.6WC		12.8	27.0	2.7	
	4	Fig. 8B		Ag-49.2WC		13.0	26.2	2.5	
	5	Fig. 10A	0.3 ~ 45 / 25 ~ 75	Ag-49.5WC	Cu-21.0Cr	12.7	31.8	3.2	Hybrid
	6	Fig. 8A	25 ~ 75	Cu (Substrate side) - Cu-22.4Cr (Surface side)		12.0	33.7	7.1	Gradient composition
Comparative products	7	Brazing	25 ~ 75	Cu-20.9Cr		12.6	33.5	7.3	Conventional joining method
	8	Brazing	0.3 ~ 45	Ag-49.3WC		13.4	26.6	2.6	
	9	Fig. 8A	45 ~ 105	Cu-19.3Cr		13.7	33.1	7.1	+11%
	10		80 ~ 150	Cu-18.2Cr		14.6	32.9	7.0	+19%

Embodiment 2

[0032] A vacuum interrupter functioning as a current breaking mechanism unit in a vacuum circuit breaker was manufactured using the electrical contacts 300, 400, and 800 manufactured in the embodiment 1. Fig. 12 is a sectional view showing the structure of a vacuum interrupter 500 according to this embodiment. Rated specifications are a voltage of 24 kV, an electric current of 1250 A, and a breaking current of 25 kA. In Fig. 12, a fixed side electrical contact and a variable side electrical contact of the electrical contact 300, 400, or 800 are respectively formed by contact layers 6a and 6b, substrates 2a and 2b, and members to be joined 1a and 1b. Reference numeral 10 denotes a shield provided on the inner surface of a ceramic insulating cylinder 16 to prevent scattering of metal vapor and the like during breaking, 11 denotes a movable side shield that prevents scattering of metal vapor and the like in a movable side direction, 15 denotes a movable side holder for connecting the vacuum interrupter 500 to an external conductor using a screw section, 12a and 12b respectively denote a fixed side end plate and a movable side end plate, 13 denotes a bellows for moving the movable side holder 15 up and down while keeping the inside of the vacuum interrupter 500 in a vacuum, and 14 denotes a guide for supporting a sliding portion between the movable side end plate 12b and the movable side holder 15.

[0033] The members explained above are joined in a high vacuum using a brazing-filler having a relatively low melting point. The inside of the vacuum interrupter 500 is sealed in a high vacuum. A method for the vacuum sealing and brazing is as explained below. The members were assembled in a state shown in Fig. 12. When the members were assembled, silver wax (an Ag-Cu brazing-filler) having thickness of 0.1 mm was placed in a place required to be joined. The members and the silver wax were heated for 12 minutes at 820°C in a vacuum of about 3 x 10^{-3} Pa in a vacuum heating furnace to seal the vacuum interrupter 500 while keeping the inside in a vacuum.

[0034] A result obtained by measuring electric resistance between terminals of the obtained vacuum interrupter 500 (between the member to be joined 1a and the movable side holder 15) is also shown in Table 1. The electric resistance was measured in a state in which the contact layers 6a and 6b were closed (in contact) by an own closing force generated by the vacuum in the vacuum interrupter 500. The electric resistance is a criterion for a joining state among the members included in the electrical contact 300, 400, or 800. In the electrical contact manufactured by the brazing, which is the conventional joining method, the electric resistance was 12.6 $\mu\Omega$ (No. 7) when the contact layer 6 was Cu-Cr and the electric resistance was 13.4 $\mu\Omega$ (No. 8) when the contact layer 6 was Ag-WC. In comparison, in the vacuum interrupter 500 (No. 1 to No. 4 and No. 6) in this embodiment incorporating the electrical contact 300, 400, or 800 manufactured by the joining structure shown in each of Figs. 8A and 8B, in the case of all compositions of the contact layer 6, the electric resistance was values smaller than those in No. 7 and No. 8. Since the joining structure did not include a brazing-filler layer, the resistance was small. In particular, in No. 6 including a gradient composition, the resistance was smaller than that in the case of the brazing (No. 7) by about 5%. The electrical contact 800 (No. 5) including the structure shown in Fig. 10A showed resistance between those in No. 7 and No. 8. On the other hand, in the vacuum interrupter 500 (No. 9 and No. 10) of the comparative product in which the raw material powder having a particle diameter outside the range of this embodiment was used, resistance was large compared with No. 7 by the conventional brazing method. The resistance tended to be larger as the particle diameter of the raw material powder increased. When a cross sectional tissue around a joining portion of the contact layer 6 in No. 9 and No. 10 was observed, a large number of pores were found. The pores tended to increase as the particle diameter of the raw material powder increases. Therefore, when the particle diameter of the raw material powder is larger, refinement of the contact layer 6 is insufficient, which causes an increase in the resistance. Therefore, it was confirmed that it is desirable that the particle diameter of the raw material powder is in the range of this embodiment.

[0035] As explained above, it was confirmed that the electrical contact according to this embodiment has a sound joining state without using the brazing-filler and electric performance equivalent to the conventional brazing method can be obtained.

Embodiment 3

[0036] The vacuum interrupter 500 manufactured in the embodiment 2 was incorporated in a vacuum circuit breaker 600 having structure shown in Fig. 13. The vacuum circuit breaker 600 has structure in which an operation mechanism unit is arranged on the front surface and three sets of epoxy cylinders 17 of a three-phase integral type that supports the vacuum interrupter 500 is arranged on the rear surface. The vacuum interrupter 500 is opened and closed by the operation mechanism via an insulated operation rod 18. When a circuit breaker is in a closed circuit state, an electric current flows through an upper terminal 19, the electrical contact 300, 400, or 800, a current collector 20, and a lower terminal 21. A contact force between electrodes is kept by a contact spring 22 attached to the insulated operation rod 18. The contact force between the electrodes and an electromagnetic force by a short-circuit current are kept by a supporting lever 23 and a prop 24. When a closing coil 32 is excited, from an open circuit state, a plunger 25 pushes up a roller 27 via a knocking rod 26, turns a main lever 28, and closes the electrodes. Then, the plunger 25 is held by the supporting lever 23. When the circuit breaker is in a releasable state, a release coil 29 is excited, a release lever 30 disengages the prop 24, and the main lever 28 rotates to open the electrodes. When the circuit breaker is in the open circuit state, after the electrodes are opened, a link is reset by a reset spring 31 and the prop 24 simultaneously engages. When the closing coil 32 is excited in this state, the circuit breaker changes to the closed circuit state. Reference numeral 33 denotes an exhaust cylinder.

[0037] The vacuum interrupter 500 incorporating the electrical contacts 300, 400, and 800 manufactured in the embodiment 1 is incorporated in the vacuum circuit breaker 600. The vacuum circuit breaker 600 is served for a breaking test in this state. A result obtained by measuring a maximum breaking current and a chopping current is also shown in Table 1. In this embodiment, in No. 1 to No. 4 and No. 6, compared with No. 7 and No. 8 respectively including the contact layers 6 of Cu-Cr and Ag-WC joined by the conventional brazing, it was confirmed that both of the maximum breaking current and the chopping current have equivalent values and the vacuum circuit breaker 600 has practical performance. In No. 5 including the contact layers 6 and 47 having plural compositions, values of the maximum breaking current and the chopping current indicate intermediate values of No. 7 and No. 8. It was confirmed that the vacuum circuit breaker 600 has electric characteristics including both breaking performance and low surge properties.

[0038] Subsequently, the vacuum interrupter 500 manufactured in the embodiment 2 is mounted on a vacuum insulated electric power switches other than the vacuum circuit breaker 600. Fig. 14 shows a load break switch 700 mounted with the vacuum interrupter 500 manufactured in the embodiment 2.

[0039] In the load break switch, a plurality of the vacuum interrupters 500 equivalent to main circuit switching units are housed in an outer vacuum chamber 34 sealed in a vacuum. The outer vacuum chamber 34 includes an upper plate material 35, a lower plate material 36, and a side plate material 37. The peripheries (the edges) of the plate materials are joined by welding. The plate materials are set together with an equipment body.

[0040] Upper through-holes 38 are formed in the upper plate material 35. Annular insulative upper bases 39 are fixed to the edges of the upper through-holes 38 to cover the upper through-holes 38. Columnar movable side electrode rods 46b are inserted in circular space sections, which are formed in the centers of the upper bases 39, to be capable of reciprocatingly moving (moving up and down). In other words, the upper through-holes 38 are closed by the upper bases 39 and the movable side electrode rods 46b.

[0041] Axis direction ends (upper sides) of the movable side electrode rods 46b are coupled to a controller (an electromagnetic controller) set on the outside of the outer vacuum chamber 34. Outer bellows 40 are arranged on the lower side of the upper plate material 35 along the edges of the upper through-holes 38 to be capable of reciprocatingly moving (moving up and down). One end sides in the axis direction of the outer bellows 40 are fixed to the lower side of the upper plate material 35. The other end sides in the axis direction of the outer bellows 40 are attached to the radially outer circumferential surfaces of the movable side electrode rods 46b. In other words, to form the outer vacuum chamber 34 in a closed structure, the outer bellows 40 are arranged at the edges of the upper through-holes 38 along the axis direction of the movable side electrode rods 46b. An exhaust pipe (not shown in the figure) is coupled to the upper plate material 35. The outer vacuum chamber 34 is evacuated via the exhaust pipe.

[0042] On the other hand, lower through-holes 41 are formed in the lower plate material 36. Insulative bushings 42 are fixed to the edges of the lower through-holes 41 to cover the lower through-holes 41. Annular insulative lower bases 43 are fixed to the bottoms of the insulative bushings 42. Columnar fixed side electrode rods 46a are inserted in circular space sections in the centers of the lower bases 43. In other words, the lower through-holes 41 formed in the lower plate material 36 are respectively closed by the insulative bushings 42, the lower bases 43, and the fixed side electrode rods 46a. One end sides (lower sides) in the axis direction of the fixed side electrode rods 46a are coupled to a cable (a distribution line) arranged on the outside of the outer vacuum chamber 34.

[0043] The vacuum interrupter 500 equivalent to the main circuit switch unit of the load break switch is housed on the inside of the outer vacuum chamber 34. The movable side electrode rods 46b are coupled to one another via a flexible conductor 44 having two curved sections. The flexible conductor 44 is formed by alternately laminating plural copper plates and plural stainless steel plates functioning as electrically conductive plate materials having two curved sections in the axis direction. Through-holes 45 are formed in the flexible conductor 44. The movable side electrode rods 46b are inserted into the through-holes 45 and coupled to one another.

[0044] As explained above, the vacuum interrupter according to the present invention manufactured in the embodiment 2 can be applied to load break switches for a vacuum circuit breaker and a pad-mount transformer and can also be applied to various vacuum insulated electric power switches such as a switch gear besides the load break switches.

[0045] The above embodiments of the invention as well as the appended claims and figures show multiple characterizing features of the invention in specific combinations. The skilled person will easily be able to consider further combinations or sub-combinations of these features in order to adapt the invention as defined in the claims to his specific needs.

Claims

1. A joining structure comprising a plurality of members (1, 2), and an adhered and deposited layer (3) through which

the members (1, 2) are joined with each other,
wherein the adhered and deposited layer (3) is formed by powder which includes metal, is deposited onto each of the members and adheres to each of the members, and the adhered and deposited layer (3) and each of the members (1, 2) are joined with each other through an alloyed junction formed between each of the members (1, 2) and the powder activated thermally and mechanically.

2. The joining structure according to claim 1, wherein one (2) of the members (1, 2) is a substrate including a through-hole (4), and another one (1) of the members (1, 2) is an element to be joined through its protrusion fitted in the through-hole (4).

3. The joining structure according to claim 1, wherein one (2) of the members (1, 2) is a substrate including a through-hole (4), and another one (1) of the members (1, 2) is an element to be joined through the adhered and deposited layer (3) formed to fill the through-hole (4).

4. An electrical contact comprising the joining structure according to claim 2 or claim 3, wherein each of the substrate (2) and the element (1) to be joined is made of a metal of high electrical conductivity, the element to be joined is cup-shaped, the adhered and deposited layer (3, 6) includes a fire-resistant metal or compound and a metal of high electrical conductivity to form a contact layer, and a surface of the substrate (2) and an open end of the cap-shaped element (1) to be joined are joined with each other through the adhered and deposited layer (3, 6).

5. An electrical contact comprising the joining structure according to claim 2 or claim 3, wherein each of the substrate (2) and the element (1) to be joined is made of a metal of high electrical conductivity, the element to be joined is bar-shaped, the adhered and deposited layer (3, 6) includes a fire-resistant metal or compound and a metal of high electrical conductivity to form a contact layer, and a surface of the substrate (2) and an end of the bar-shaped element (1) to be joined are joined with each other through the adhered and deposited layer (3, 6).

6. The electrical contact according to claim 4 or claim 5, wherein the metal of high electrical conductivity includes at least one of Cu, Ag and an alloy of Cu and Ag, and the fire-resistant metal or compound includes at least one of Cr, Co, W and WC.

7. The electrical contact according to any one of claims 4-6, wherein the powder forming the contact layer (6) includes powder of the fire-resistant metal or compound and powder of the metal of high electrical conductivity, and a particle diameter of each of the powder of the fire-resistant metal or compound and the powder of the metal of high electrical conductivity is not more than 75 μm.

8. The electrical contact according to any one of claims 4-7, wherein the contact layer (6) is partitioned into annular portions which are concentrically arranged to be juxtaposed radially and are different from each other in composition.

9. The electrical contact according to any one of claims 4-8, wherein a composition of the contact layer varies in its thickness direction stepwise or linearly.

10. A method for producing the electrical contact according to any one of claims 4-9, wherein powder of the fire-resistant metal or compound and powder of the metal of high electrical conductivity are made collide against the protrusion or into the through-hole (4) with high speed so that the powder forming the adhered and deposited layer (3, 6) are plastically deformed to be mechanically activated when forming the alloyed junction.

11. A vacuum interrupter comprising the electrical contact according to any one of claims 4-9 as at least one of a movable contact and a fixed contact as a contact pair in a vacuum chamber of the vacuum interrupter.

12. A vacuum circuit breaker comprising the vacuum interrupter according to claim 11, an electrically conductive terminal arranged at an outside of the vacuum interrupter and electrically connected to each of the movable contact and the fixed contact in the vacuum interrupter, and an opening and closing means for driving the movable contact.

13. An electric power switch comprising the electrical contact according to any one of claims 4-9 as at least one of contacts as a contact pair, and a mechanism for making the contacts of the contact pair contact each other and be separated from each other in one of vacuumed condition, an inert gas and the atmosphere so that an electric current is turned on and off.

FIG.1

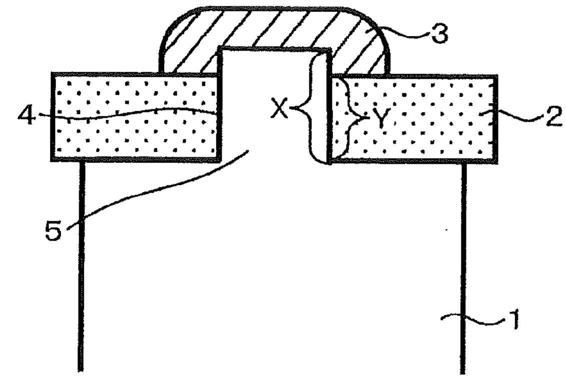

FIG.2

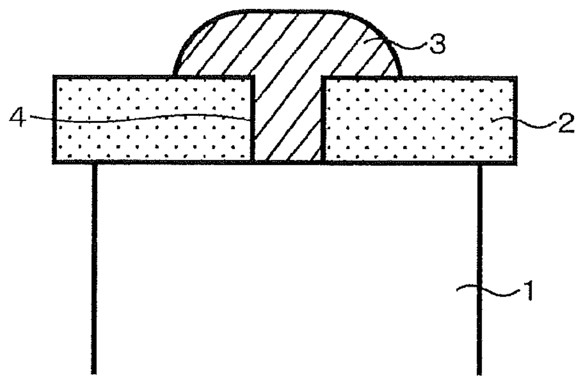

FIG.3

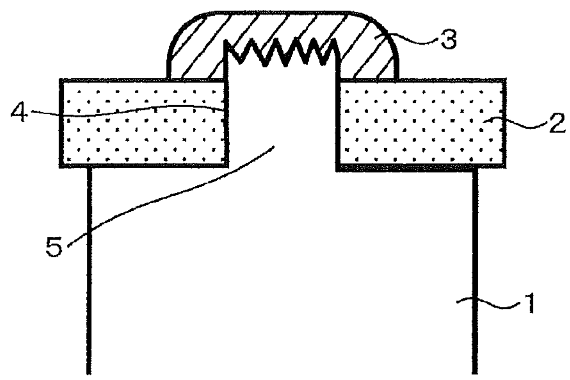

FIG.4

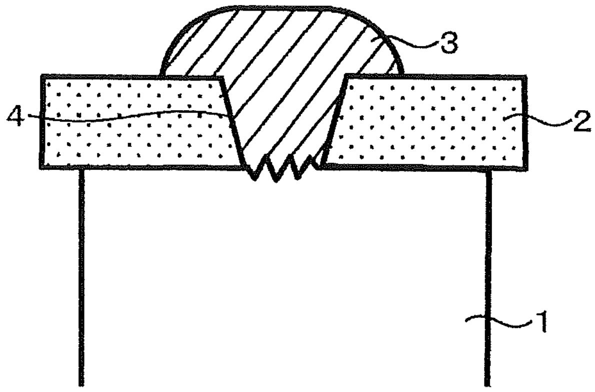

FIG.5

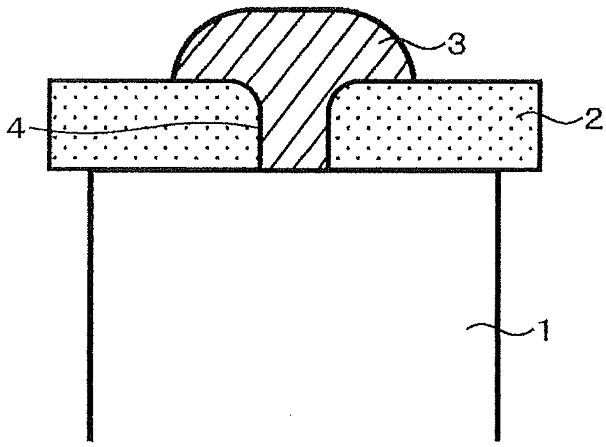

FIG.6A

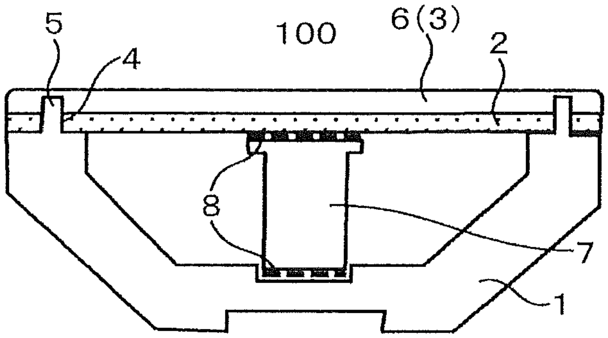

FIG.6B

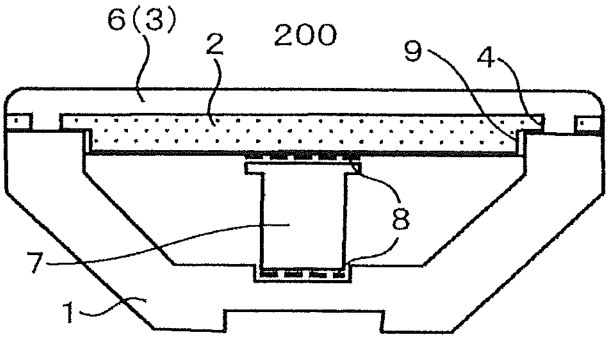

FIG.7A

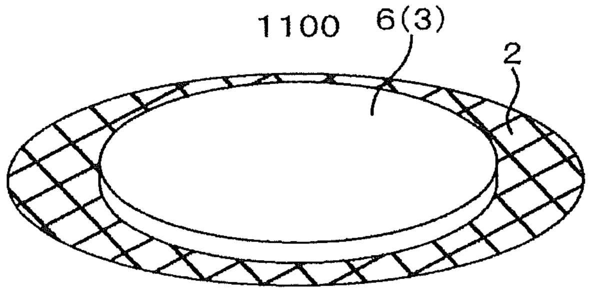

FIG.7B

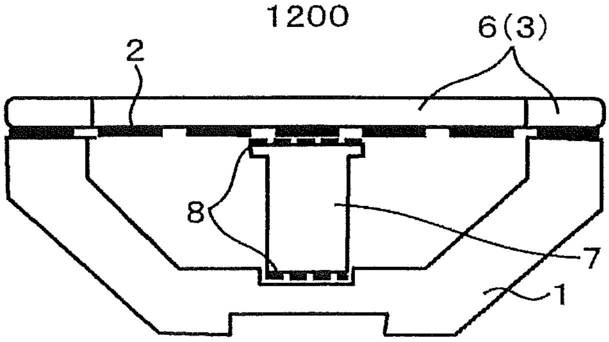

FIG.8A

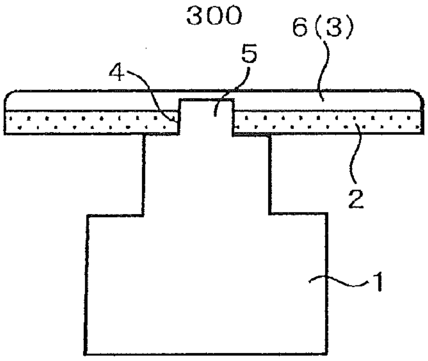

FIG.8B

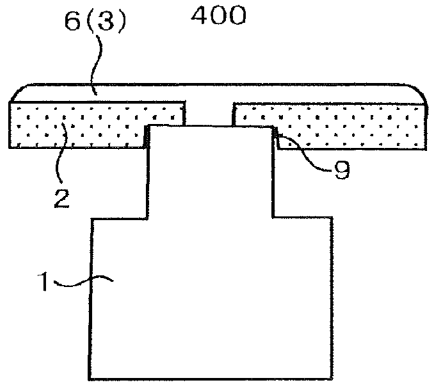

FIG.9A

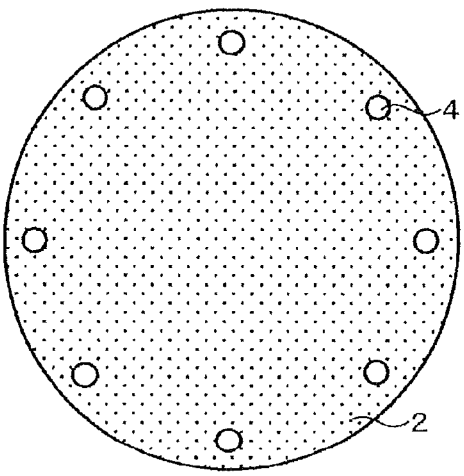

FIG.9B

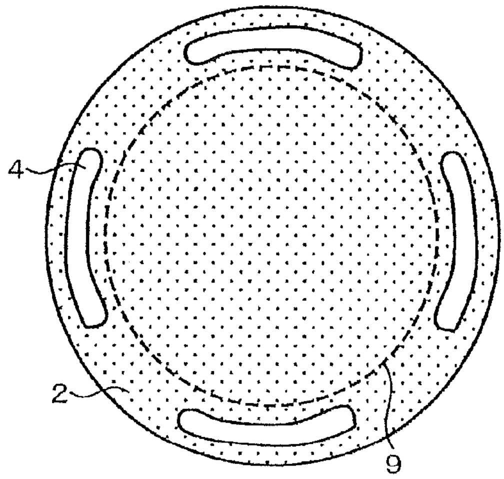

FIG.10A

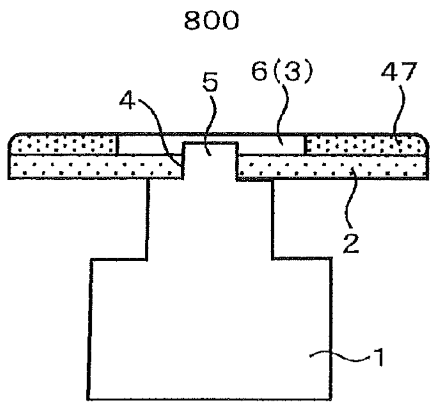

FIG.10B

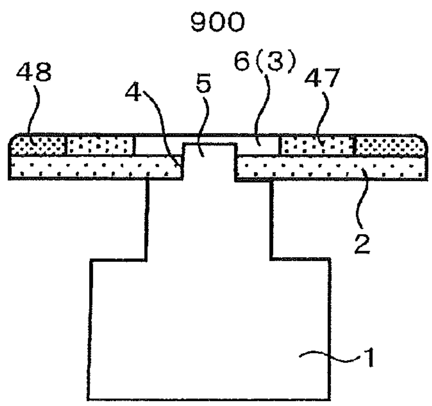

FIG.10C

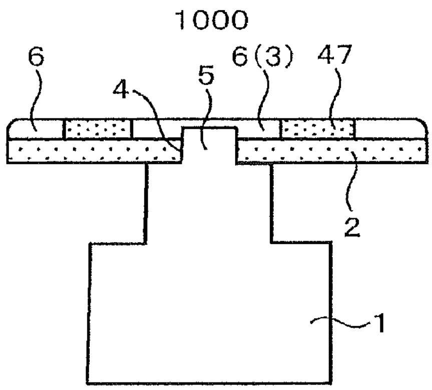

FIG.11

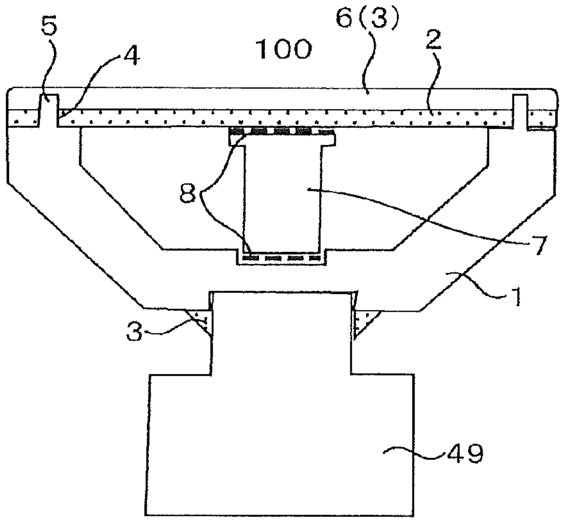
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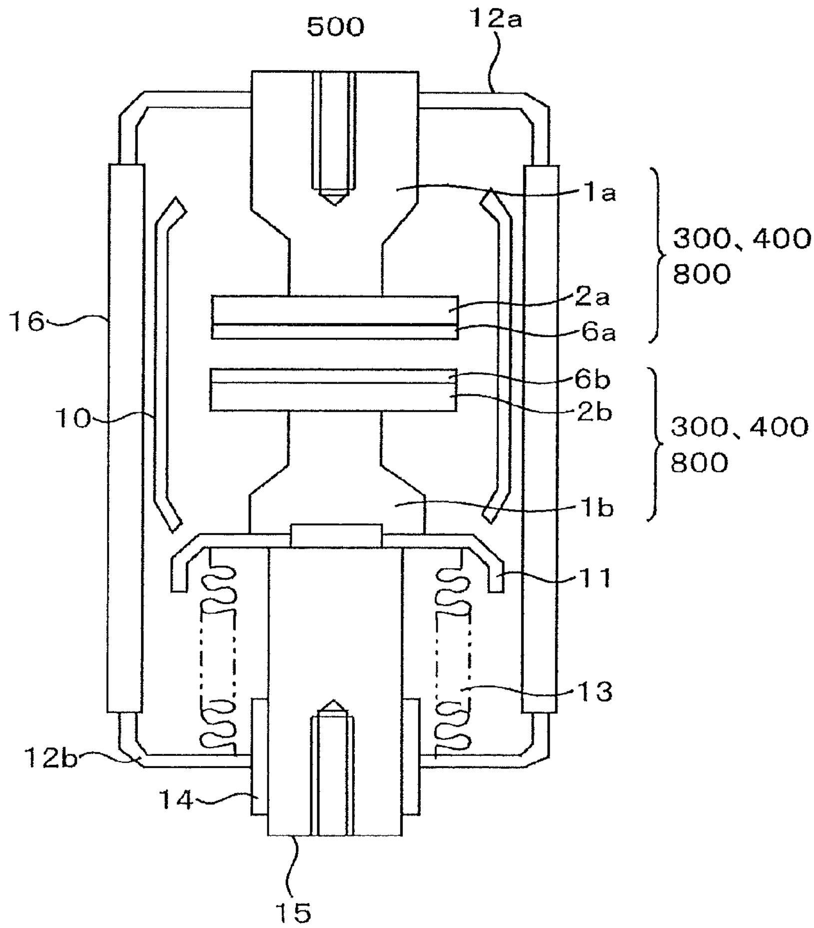
FIG.12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12b
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FIG.13

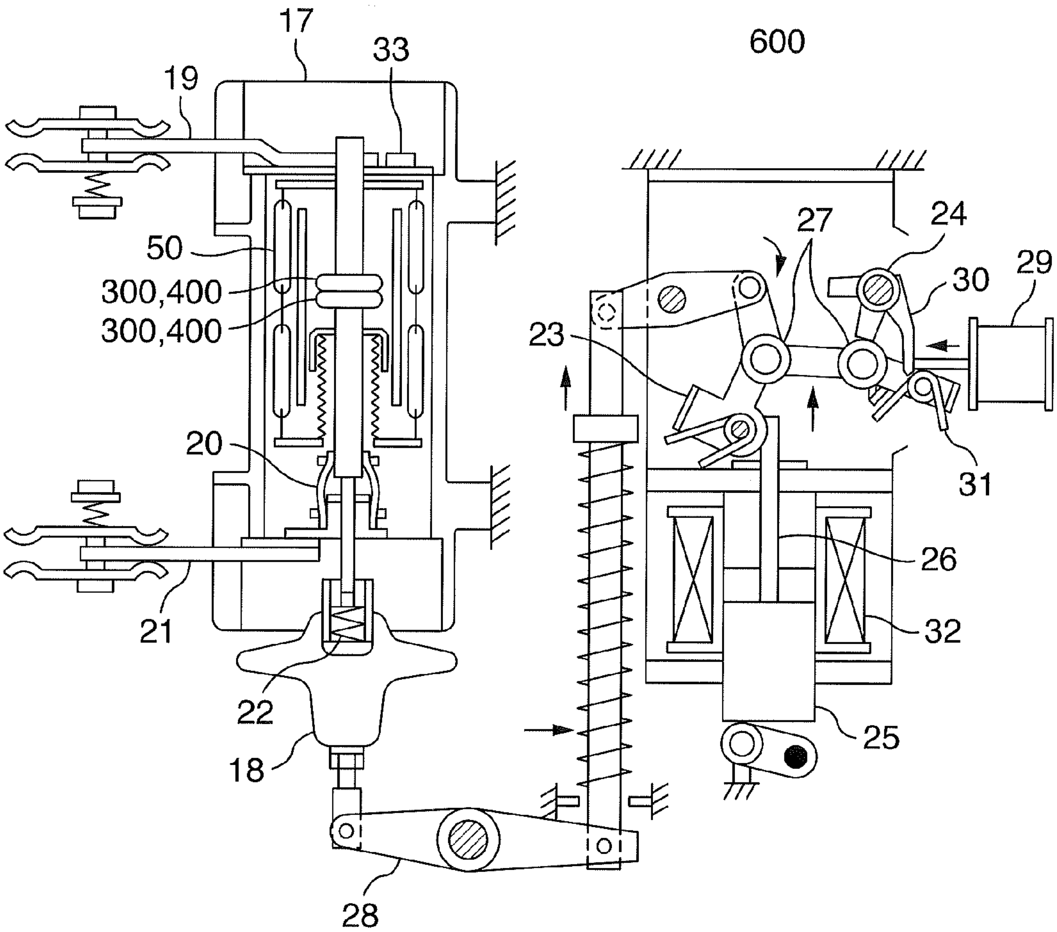
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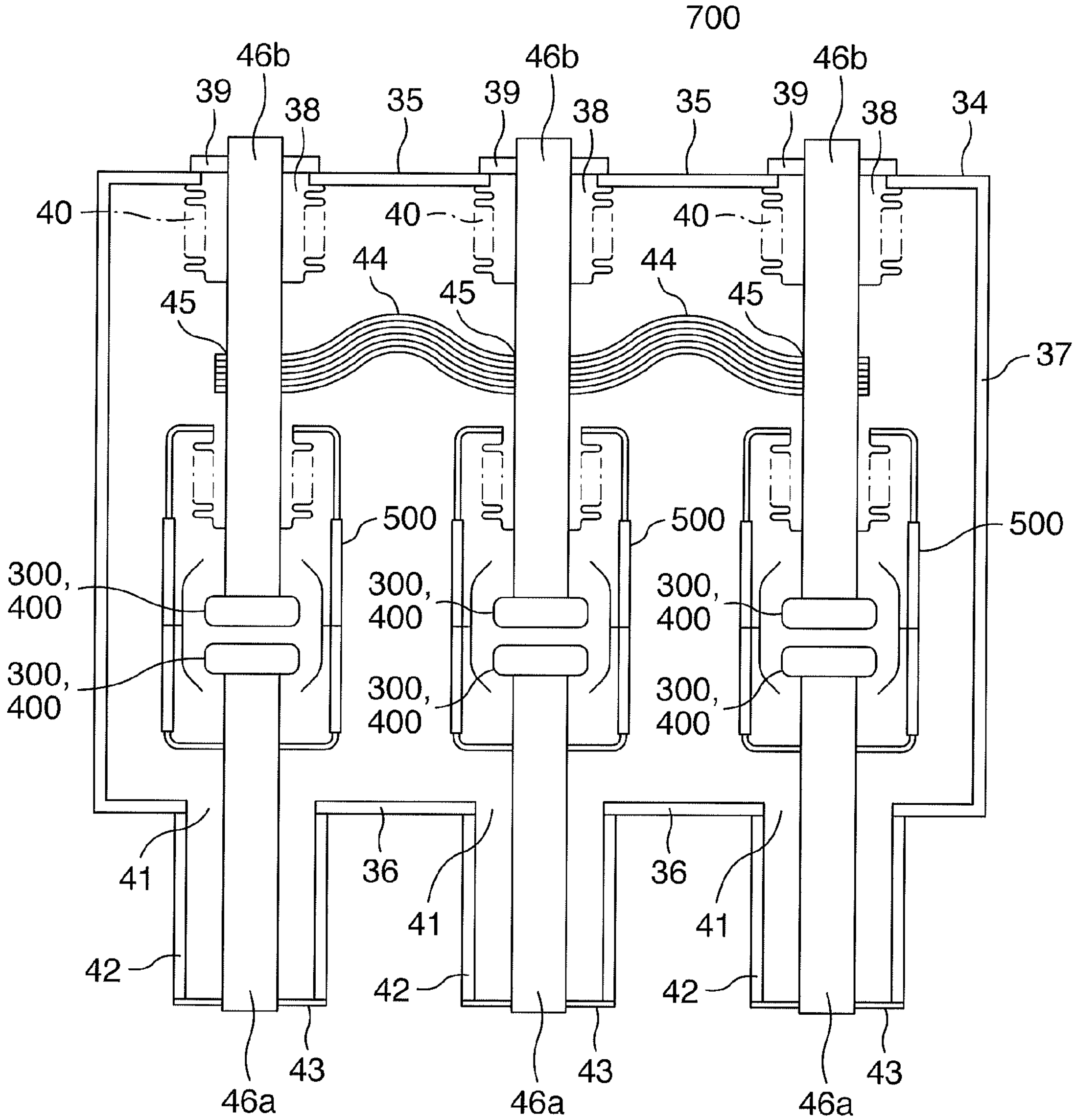
FIG.14



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Patent documents cited in the description

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