



## INSULATING OPERATING ROD AND MANUFACTURING METHOD THEREFOR

### BACKGROUND OF THE INVENTION

#### 1. Field of the Invention

The present invention relates to an insulating operating rod for an opening/closing apparatus which requires insulation and transmission of operating force in a vacuum container and a manufacturing method therefor.

#### 2. Description of the Related Art

Fig. 6 is a cross sectional view showing a conventional insulating joint disclosed in "Ceramics Joint and High-Tech Brazing" published from Industrial Technical Service.

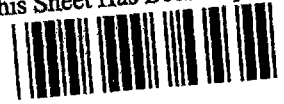
Referring to Fig. 6, reference numeral 2 represents a metallized layer, 11 represents a cylindrical ceramics, 12 represents a joint and 13 represents brazing filler metal made of Ag.

The operation will now be described. The metallized layers 2 are formed on the two surface portions at the two ends of the cylindrical ceramics 11 made of alumina. Then, a heating process is performed in hydrogen at 820°C, and then the cylindrical ceramics 11 and a kovar joint 10 are joined with the brazing filler made of Ag. Thus, the insulating joint has been obtained.

The insulating operating rod for realizing insulation and transmitting the operating force in a vacuum container is formed by joining a metal member having excellent conductivity and a metal member which is connected to an operating mechanism to the

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ceramics for realizing the insulation. Since heat treatment is performed in a vacuum when the rod is loaded into the vacuum container, a satisfactory joining characteristics are required even after heat has been added. Moreover, a joining characteristic for resisting the operating force is required. The conventional joining method shown in Fig. 6 is arranged to realize insulation and transmit the operating force in the atmosphere or gas. Thus, the joint 12 made of kovar is joined to the cylindrical ceramics 11 made of alumina with the brazing filler metal 13 made of Ag. The heating temperature raised when the vacuum container has been assembled causes the brazing filler metal to again be melted. Thus, the initial state of joining cannot be maintained. That is, the joining characteristics deteriorate. Since the joined surfaces are in parallel with the axial direction, shearing stress is exerted on the joined surfaces when tension has been applied, causing destruction to easily occur. Since costly kovar is employed to make the joint, there arises a problem in that the cost cannot be reduced.

#### SUMMARY OF THE INVENTION

To solve the above-mentioned problems, an object of the present invention is to provide an insulating operating rod for realizing insulation and transmitting the operating force in a vacuum container and formed by joining ceramics and a metal member



to each other such that the ceramics and the metal member are satisfactorily joined to each other.

According to a first aspect of the present invention, there is provided an insulating operating rod arranged to realize insulation and transmit operating force in a vacuum container and constituted by joining ceramics and a metal member to each other, the insulating operating rod comprising: an intermediate material disposed between the ceramics and the metal member and composed of a Fe-Ni alloy; a copper composite material; carbon steel; copper; or a copper alloy.

A second aspect of the present invention has the structure according to the first aspect of the invention, wherein the Fe-Ni alloy, which is the intermediate material is Fe-Ni alloy containing Ni by 20 mass% to 50 mass%; a Fe-Ni alloy containing Ni by 20 mass% to 50 mass% and Co by 3 mass% to 25 mass%; a Fe-Ni alloy containing Ni by 20 mass% to 50 mass% and Cr by 1 mass% to 12 mass%; or an Fe-Ni alloy containing Ni by 20 mass% to 50 mass% and Co by 3 mass% to 25 mass% and further containing one or two materials selected from C by 0.5 mass% to 5 mass%, Si and Mn by 0.1 mass% to 3 mass%.

A third aspect of the present invention has a structure according to the first aspect of the invention, wherein the copper composite material which is the intermediate material is in the form of a composite of Cu and Mo or W particles in a range from 40 mass% to 90 mass%; or a clad material having a triple-layered



structure in which Mo is sandwiched between two Cu layers in a quantity of 20 mass% to 80 mass%.

A fourth aspect of the present invention has a structure according to the first aspect of the invention, wherein the yield stress of the copper or the copper alloy which is the intermediate material is 4 kgf/mm<sup>2</sup> to 10 kgf/mm<sup>2</sup>.

A fifth aspect of the present invention has a structure according to any one of the first to fourth aspects of the invention, wherein the intermediate material which is provided with a through hole having ceramics engaged thereto is disposed between the ceramics and the metal member.

According to a sixth aspect of the present invention, there is provided a method of manufacturing an insulating operating rod arranged to realize insulation and transmit operating force in a vacuum container and incorporating ceramics and a metal member to each other, the method of manufacturing an insulating operating rod comprising the steps of: disposing a Fe-Ni alloy; a copper composite material; carbon steel; copper; or a copper alloy between the ceramics and the metal member to serve as the intermediate material; and joining the ceramics and the metal member to each other.

A seventh aspect of the present invention has a structure according to the sixth aspect of the invention, wherein the carbon steel, which is the intermediate material, is joined to the



ceramics at a cooling rate which satisfies a range from 50°C/sec to 200°C/sec.

According to an eighth another aspect of the present invention, there is provided a method of manufacturing an insulating operating rod arranged to realize insulation and transmit operating force in a vacuum container and incorporating ceramics and metal, the method of manufacturing an insulating operating rod comprising the steps of: using both of a shrinkage fitting method with which one or more projections and recesses are provided for the ceramics and the metal member and heating and joining are performed and a joining method with which the joined surfaces are brazed.

The insulating operating rod according to the present invention has a structure that the intermediate material made of a Fe-Ni alloy, a copper composite material, carbon steel, copper or a copper alloy is disposed and joined between the ceramics and the metal member. Thus, stress of the joined portion caused from the difference in thermal expansion between the ceramics and the metal member can be relaxed or buffered. As a result, the joining characteristics can be improved at a low cost. Both of the shrinkage fitting method with which the projection is provided for the ceramics and a recess is provided for the metal member after which heating and joining are performed and the joining method with which the joined surfaces are brazed are employed to improve the joining characteristics.



A preferred range for the composition of the Fe-Ni alloy will now be described. The preferred Fe-Ni alloy according to the present invention is Fe-Ni alloy containing Ni by 20 mass% to 50 mass%; a Fe-Ni alloy containing Ni by 20 mass% to 50 mass% and Co by 3 mass% to 25 mass%; a Fe-Ni alloy containing Ni by 20 mass% to 50 mass% and Cr by 1 mass% to 12 mass%; or a Fe-Ni alloy containing Ni by 20 mass% to 50 mass% and Co by 3 mass% to 25 mass% and further containing one or two materials selected from C by 0.5 mass% to 5 mass%, Si and Mn by 0.1 mass% to 3 mass%. The foregoing Fe-Ni alloys may contain low-expansion metal called invar, elinvar, fernico, 42-alloy or kovar. As for the range of the thermal expansion coefficient for each of ceramics of the oxide, the nitride and the carbide must satisfy  $4 \times 10^{-6}/K$  to  $12 \times 10^{-6}/K$ . To reduce the stress caused from the difference in the thermal expansion between the insulating ceramics and the metal member, the thermal expansion coefficient of the ceramics and that of the metal member must coincide with each other. The material obtained by adding Ni, Co, Cr, C, Si and Mn to Fe to satisfy the foregoing range enables the thermal expansion coefficient of  $4 \times 10^{-6}/K$  to  $12 \times 10^{-6}/K$  to be obtained. Thus, selection of the Fe-Ni alloy having a thermal expansion characteristic which is an intermediate characteristic between that of the ceramics and that of the metal member enables the produced stress to be relaxed. As a result, the joining characteristics can be improved.



A preferred range of the composition of the copper composite material will now be described. The copper composite material according to the present invention is in the form of a composite of Cu and Mo or W particles in a range from 40 mass% and 90 mass%; or a clad material having a triple-layered structure in which Mo is sandwiched between two Cu layers in a quantity of 20 mass% to 80 mass%. The foregoing material is employed to obtain the thermal expansion coefficient of  $4 \times 10^{-6}/K$  to  $12 \times 10^{-6}/K$  which is close to the thermal expansion coefficient of the ceramics. When the copper composite material having the thermal expansion characteristic which is an intermediate characteristic between that of the ceramics and the metal member is selected, the produced stress can be relaxed. Thus, the joining characteristics can be improved. The clad material having the structure that Mo is sandwiched by Cu causes Cu to buffer the thermal stress produced between the ceramics and the metal member.

Since the carbon steel can directly be joined to the ceramics when the thermal expansion characteristic caused from transformation occurring during a cooling process is used, joining to the metal member can be facilitated. A preferred cooling rate for joining the carbon steel will now be described. Eutectoid carbon steel (0.9 % carbon) is heated to  $875^{\circ}C$  so that the structure is converted to an austenitic structure. Then, water quenching is performed to lower the material to about  $300^{\circ}C$ . In the foregoing state, volume expansion is smaller than the



volume expansion realized during the heating process. When the temperature is as it is lowered, the structure is formed into martensite. A fact is known that the volume is enlarged in the foregoing case. Joining of the carbon steel and the ceramics is performed by using a fact that the volume expansion is reduced. The reason why the preferred cooling rate is  $50^{\circ}\text{C}/\text{sec}$  to  $200^{\circ}\text{C}/\text{sec}$  will now be described. If the rate is lower than  $50^{\circ}\text{C}/\text{sec}$ , the thermal expansion is similar to that realized during the heating process. In this case, direct brazing using low expansion cannot be performed. If the rate is higher than  $200^{\circ}\text{C}/\text{sec}$ , there is a possibility that the ceramics are broken owing to thermal shock.

Copper or the copper alloy buffers stress produced owing to the difference between the thermal expansion of the ceramics and the metal member so that satisfactory joining is performed. Preferred yield stress of copper or the copper alloy is  $4 \text{ kgf}/\text{mm}^2$  to  $10 \text{ kgf}/\text{mm}^2$ . The value  $4 \text{ kgf}/\text{mm}^2$  is determined from the yield stress of pure copper. If the yield stress is higher than  $10 \text{ kgf}/\text{mm}^2$ , the effect of buffering the stress produced in the joined portion cannot easily be obtained. Copper or the copper alloy having the yield stress satisfying the foregoing range is exemplified by oxygen free copper ( $4 \text{ kgf}/\text{mm}^2$ ), tough pitch copper ( $7 \text{ kgf}/\text{mm}^2$ ), Ag alloy containing Cu by 0.03 wt% to 0.15 wt% (annealed material,  $8 \text{ kgf}/\text{mm}^2$ ), Cr alloy containing Cu by 0.8 wt% (annealed material,  $9 \text{ kgf}/\text{mm}^2$ ) and Zr alloy containing Cu by 0.15 wt% (annealed material,  $9 \text{ kgf}/\text{mm}^2$ ). The reason why Cu



or the Cu alloy of the foregoing type is employed will now be described. When the insulating operating rod is loaded into the vacuum container, the assembly of the vacuum container is usually performed in a state in which heating to 800°C to 1000°C is performed in a vacuum. Although also metal, such as Al, Pb, In, Bi, Zn, Sn or Mg, and copper containing the foregoing metal has a yield stress not higher than 10 kgf/mm<sup>2</sup>, the foregoing low melting-point metal is formed into metal steam if the low melting-point metal is heated to 800°C to 1000°C in a vacuum. Thus, the surfaces of the vacuum container and the ceramics are contaminated, thus causing a problem to arise in that the insulating characteristic and the like deteriorate. Note that the yield stress is a value of stress with which a permanent elongation of 0.2 % of the original length occurs.

#### BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a cross sectional view showing an embodiment of an insulating operating rod according to the present invention;

Fig. 2 is a horizontal cross sectional view showing an example of a copper composite material;

Fig. 3 is a vertical cross sectional view showing an embodiment of the insulating operating rod according to the present invention;



Fig. 4 is a cross sectional view showing an embodiment of an insulating operating rod employing an active metal method according to the present invention;

Fig. 5 is a cross sectional view showing an embodiment of an insulating operating rod using both shrinkage fit and surface joining according to the present invention; and

Fig. 6 is a cross sectional view showing a conventional insulating joint.

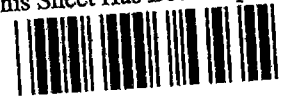
#### DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Now, a description will be given in more detail of preferred embodiments of the present invention with reference to the accompanying drawings.

(Embodiment 1)

Embodiment 1 of the present invention will now be described. Fig. 1 is a cross sectional view showing an insulating operating rod according to the present invention. Referring to Fig. 1, reference numeral 1 represents an insulating ceramics, 2 represents a metallized layer, 3 represents a plated layer, 4 represents an intermediate material, 5 represents brazing filler metal a, 6 represents a metal member and 7 represents brazing filler metal b.

Example 1 was performed such that a Fe-Ni alloy was employed as the intermediate material and a Mo-Mn method was employed to perform a joining process. The Mo-Mn metallized layer 2 having



a thickness of 30  $\mu\text{m}$  was formed on the joining surface of the insulating ceramics 1 having a diameter of 15 mm and a length of 25 mm and made of alumina. Then, the Ni-plated layer 3 having a thickness of 5  $\mu\text{m}$  was formed on the metallized layer 2 by an electrolytic method. Three types of intermediate materials 4 each having a thickness of 1 mm were employed which were Fe-42 mass% Ni, Fe-29 mass% Ni-17 mass% Co and Fe-32 mass% Ni-5 mass% Co-2 mass% Si-0.2 mass% Mn. Foil of brazing filler metal a5 having a thickness of 50  $\mu\text{m}$  and made of BNi-7 (Ni-13 % Cr-10 % P) was disposed between the intermediate material 4 and the plated insulating ceramics 1. Then, while adding a load of 1 kg, heating was performed at 950°C for 20 minutes in a vacuum so that a joined member was obtained. To join the metal member 6 having a diameter of 15 mm and a length of 25 mm and made of stainless steel (SUS304) to the upper surface of the intermediate material 4 joined to the insulating ceramics 1, the brazing filler metal b7 made of BAg-18 (Ag-30 % Cu-10 % Sn-0.025 % P) was disposed between the intermediate material 4 and the metal member 6. While a load of 1 kg was being exerted, heating was performed at 820°C for 20 minutes in a vacuum so that a joined member was obtained. A comparative material was not provided with the intermediate material 4. Moreover, the insulating ceramics 1 made of alumina and the metal member 6 made of SUS304 were heated at 950°C for 20 minutes by the Mo-Mn method by using BNi-7 in a vacuum so that joining was performed. To evaluate the joining characteristics



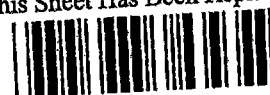
of the insulating operating rods, visual inspections and tension tests were performed so that the joining strength was measured. Results were shown in Example 1 (No. 1 to 3) in a Table 1. Sample No. 1, No. 2 and No. 3 which were examples of the present invention were free from a crack of the ceramics, separation of the joined portion and deformation. Sample No. 12 which was the comparative example encountered cracks occurred in the ceramics. As a result of the tension tests, the tensile strength of the samples according to the present invention was as follows: that of sample No. 1 was  $15 \text{ kgf/mm}^2$  and those of sample No. 2 and No. 3 were  $23 \text{ kgf/mm}^2$  or greater. As compared with the tensile strength of the comparative sample, which was  $3 \text{ kgf/mm}^2$ , the joining strength was significantly increased. Since broken portions produced owing to the tension tests were positioned in the ceramics adjacent to the joined portions, joints stronger than the strength of the ceramics were realized. In the example of the present invention, the brazing filler metal made of Ni was used to join the insulating ceramics and the intermediate material to each other, brazing filler metal made of Cu, Au or Ag may be employed.

(Embodiment 2)

Embodiment 2 was performed such that a copper composite material was employed as the intermediate material and the Mo-Mn method was employed to perform a joining process. The Mo-Mn metallized layer 2 having a thickness of  $30 \mu\text{m}$  was formed on the



joining surface of the insulating ceramics 1 having a diameter of 15 mm and a length of 25 mm and made of alumina. Then, the Ni-plated layer 3 having a thickness of 5  $\mu$ m was formed on the metallized layer 2 by the electrolytic method. Three types of intermediate materials 4 each having a thickness of 1 mm were employed which were Cu-20 mass% W, Cu-50 mass% Mo and Cu/Mo/Cu (1:2:1, 47 mass% Cu). Foil of brazing filler metal a5 having a thickness of 50  $\mu$ m and made of BNi-7 (Ni-13 % Cr-10 % P) was disposed between the intermediate material 4 and the plated insulating ceramics 1. Then, while adding a load of 1 kg, heating was performed at 950°C for 20 minutes in a vacuum so that joining was performed. To join the metal member 6 having a diameter of 15 mm and a length of 25 mm and made of stainless steel (SUS304) to the upper surface of the intermediate material 4 joined to the insulating ceramics 1, the brazing filler metal b7 made of BAg-18 (Ag-30 % Cu-10 % Sn-0.025 % P) was disposed between the intermediate material 4 and the metal member 6. While a load of 1 kg was being exerted, heating was performed at 820°C for 20 minutes in a vacuum so that a joined member was obtained. A comparative material was not provided with the intermediate material 4. Moreover, the insulating ceramics 1 made of alumina and the metal member 6 made of SUS304 were heated at 950°C for 20 minutes by the Mo-Mn method by using BNi-7 in a vacuum so that joining was performed. To evaluate the joining characteristics of the insulating operating rods, visual inspections and tension



tests were performed so that the joining strength was measured. Results were shown in Example 2 (No. 4 to 6) in a Table 1. Sample No. 4 to sample No. 6 which were examples of the present invention were free from a crack of the ceramics, separation of the joined portion and deformation. As a result of the tension tests, the tensile strength of the samples according to the present invention was 23 kgf/mm<sup>2</sup> or greater. As compared with comparative material No. 12, greater joining strength was obtained. Since broken portions produced owing to the tension tests were positioned in the ceramics adjacent to the joined portions, satisfactorily joints were obtained. In the example of the present invention, joining of the insulating ceramics 1 and the intermediate material 4 was performed by the Mo-Mn Method. As an alternative to this, an active metal method may be employed to perform the joining process which uses a brazing filler metal made of Ti-Ag-Cu, a brazing filler metal made of Zr-Ag-Cu, a brazing filler metal made of Ti-Cu. The copper composite material may be in the form of a composite of particles of Cr, WC, C, Al<sub>2</sub>O<sub>3</sub>, SiC or the like and Cu.

(Embodiment 3)

In Embodiment 2, the copper composite material was in the form of a composite of Mo or W particles with Cu and the clad material made of Cu/Mo/Cu. As shown in Fig. 2 which is a horizontal cross sectional view, an intermediate material 4 may be joined which is a copper composite material in which through



holes are formed in copper or a copper alloy 8. Moreover, ceramics 9 were heated and engaged in the through holes. The foregoing example will now be described.

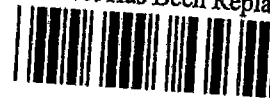
The heated and engaged copper composite material was obtained by forming seven through holes each having a diameter of 5.000 mm in oxygen free copper 8 having a diameter of 30 mm and a length of 10 mm. Moreover, alumina ceramics having a diameter of 5.002 mm and a length of 10 mm were heated and engaged at 1000°C so that the volume ratio of the ceramics was made to be 20 %. Then, the intermediate material 4 made of the copper composite material was disposed between the insulating ceramics 1 having a diameter of 30 mm and a length of 25 mm and made of alumina and the metal member 6 having a diameter of 30 mm and a length of 25 mm and made of stainless steel (SUS304). Moreover, foil made of brazing filler metal made of active metal which was Cu-28 wt% Ti was disposed between the insulating ceramics 1 made of alumina and the intermediate material 4 and between the metal member 6 and the intermediate material 4. While a load of 1 kg was being exerted, heating was performed at 950°C for 20 minutes in a vacuum so that a joined member was obtained. Fig. 3 is a vertical cross sectional view showing the insulating operating rod. To evaluate the joining characteristics of the foregoing insulating operating rod, the visual inspection and the tension test were performed to measure the joining strength. A result of the foregoing tests were shown in No. 7 of Example 3 shown



in Table 1. Also the foregoing example resulted in a satisfactory joining characteristics and exhibited tensile strength of 23 kgf/mm<sup>2</sup> or greater.

(Embodiment 4)

Embodiment 4 is an example in which a low thermal expansion characteristic realized when the cooling rate of carbon steel was used to directly join the ceramics and the carbon steel. Foil made of brazing filler metal 8 made of active metal which was Cu-28 wt% Ti was disposed between the insulating ceramics 1 having a diameter of 15 mm and a length of 25 mm and made of zirconia and the intermediate material 4 made of carbon steel (S45C) having a diameter of 15 mm and a thickness of 1 mm. While a load of 1 kg was being exerted, heating was performed at 950°C for 20 minutes in a vacuum. To realize a cooling rate of 50 C°/sec or higher, the materials were moved into a cooling tank so that joining was performed. To join the metal member 6 having a diameter of 15 mm and a length of 25 mm and made of stainless steel (SUS304) to the upper surface of the intermediate material 4 made of carbon steel joined to the insulating ceramics 1 made of zirconia, the brazing filler metal b7 made of BAg-18 (Ag-30 % Cu-10 % Sn-0.025 % P) was disposed between the intermediate material 4 and the metal member 6. While a load of 1 kg was being exerted, heating was performed at 820°C for 20 minutes in a vacuum so that a joined member was obtained. Fig. 4 is a cross sectional view showing the insulating operating rod according to the present invention



and employing the active metal method. A comparative material was obtained by performing cooling at 50 C°/sec or lower to join the insulating ceramics 1 made of zirconia and the intermediate material 4 to each other.

To evaluate the joining characteristics of the insulating operating rods, visual inspections and tension tests were performed so that the joining strength was measured. Results were shown in Example 4 (No. 8) in a Table 1. The example of the present invention was free from a crack of the ceramics, separation of the joined portion and deformation. Thus, satisfactorily joining was realized. As a result of the tension tests, the tensile strength of the samples according to the present invention was 23 kgf/mm<sup>2</sup> or greater. Since broken portions produced owing to the tension tests were positioned in the ceramics adjacent to the joined portions, satisfactorily joints were obtained. Comparative sample No. 13 obtained by making the cooling speed to be 50°C/sec or lower encountered separation of the joined portion. As a result, joining of the carbon steel serving as the intermediate material was enabled so that joining to the metal member was facilitated. Although the carbon steel was employed to serve as the intermediate material, a similar effect can be obtained when the carbon steel is used as the metal member so as to directly be joined to the insulating ceramics. As an alternative to the active metal method, the Mo-Mn method may be employed as the joining method.



(Embodiment 5)

In Embodiment 5, copper or a copper alloy having yield stress of  $4 \text{ kgf/mm}^2$  to  $10 \text{ kgf/mm}^2$  and serving as the intermediate material was disposed between the insulating ceramics 1 and the metal member 6. The Mo-Mn method was employed to perform joining. A metallized layer 2 having a thickness of  $30 \text{ }\mu\text{m}$  and made of Mo-Mn was formed on a joining surface of the insulating ceramics 1 having a diameter of 15 mm, a length of 25 mm and made of alumina. Then, the electrolytic method was employed to form the Ni-plated layer 3 having a thickness of  $5 \text{ }\mu\text{m}$  on the metallized layer 2. Then, two types of materials which were oxygen free copper plate (C1020) having a thickness of 0.5 mm and Cu-0.8 wt% Cr were employed as the intermediate material 4. Then, brazing filler metal a5 having a thickness of  $50 \text{ }\mu\text{m}$  and made of BNi-7 was disposed between the intermediate material and the plated ceramics. While a load of 1 kg was being exerted, heating was performed at  $950^\circ\text{C}$  for 20 minutes in a vacuum so that joining was performed. To join the metal member 6 having a diameter of 15 mm and a length of 25 mm and made of stainless steel (SUS304) to the upper surface of the intermediate material 4 joined to the insulating ceramics 1, brazing filler metal b7 made of BAg-18 (Ag-30 % Cu-10 % Sn-0.025 % P) was disposed between the intermediate material 4 and the metal member 6. While a load of 1 kg was being exerted, heating was performed at  $820^\circ\text{C}$  for 20 minutes in a vacuum so that a joined member was obtained. Comparative materials were



obtained by using SUS304 to join the metal member 6. Then, the Mo-Mn method was employed to perform heating at 950°C for 20 minutes in a vacuum by using BNi-7 so that a joined member was obtained. Another comparative material was obtained by using Cu-30 wt% Ni having yield stress of 17.5 kgf/mm<sup>2</sup> and serving as the intermediate material. Samples No. 9 and No. 10 which were examples of the present invention were free from a crack of the ceramics and separation and deformation of the joined portion. As a result of the tension test, the sample according to the present invention had tensile strength of 23 kgf/mm<sup>2</sup> or greater. As compared with Comparative Examples No. 12 and No. 14, greater joining strength was obtained. Since broken portions were positioned in the ceramics adjacent to the joined portions, satisfactory joining was performed. Although this example employed the Mo-Mn method to join the insulating ceramics 1 and the intermediate material 4 to each other, the active metal method may be employed which uses brazing filler metal made of Ti-Ag-Cu, brazing filler metal made of Zr-Ag-Cu or brazing filler metal made of Ti-Cu.

(Embodiment 6)

In this example, both of a shrinkage fitting method using the difference in the thermal expansion between the ceramics and metal and a surface joining method using brazing filler metal for performing joining are employed. Fig. 5 is a vertical cross sectional view showing an insulating operating rod according to



the present invention. Reference numeral 1 represents insulating ceramics in the form of a projection, 6 represents a metal member having a joining portion formed into a recess shape and 8 represents brazing filler metal made of active metal.

The alumina insulating ceramics 1 having an outer diameter of 20 mm and a length of 60 mm, incorporating a joining portion having the projection, the diameter of which was 14.001 mm and the height of which was 5 mm and the metal member 6 having an outer diameter of 20 mm and a length of 30 mm, incorporating a joining portion having the recess, the diameter of which was 14.000 mm and a depth of 5 mm and made of SUS304 were prepared. Then, the joining portions of the insulating ceramics 1 and the metal member 6 were abutted against each other. Then, brazing filler metal 10 made of active metal which was Cu-28 wt% Ti was disposed between surfaces perpendicular to the axial direction. While a load of 1 kg was being exerted, heating was performed at 950°C for 20 minutes in a vacuum so that joining and brazing were simultaneously performed. As a result, a joined member was obtained. A comparative material was obtained by preparing cylindrical insulating ceramics 1 and the metal member 6 having the dimensions similar to those of the examples were prepared and joining was performed by a similar joining method.

Results of the tension tests of the insulating operating rod according to the present invention are shown in No. 11 of Embodiment 6. The present invention resulted in tensile strength



of 23 kgf/mm<sup>2</sup> or greater. The tensile strength of the comparative example No. 15 was 7.5 kgf/mm<sup>2</sup>. The broken joined member was observed. The present invention resulted in that breakage took place in the ceramics and, therefore, strong joining was performed. Comparative Example No. 15 encountered breakage in the interface between the ceramics and the brazing filler metal. As a result, the comparative example had the tensile strength inferior to that of the example of the present invention. The present invention which used both of joining using the shrinkage fitting method and the surface joining using the brazing resulted satisfactorily. Although the foregoing examples have been described about the structure in which one projection was provided for the ceramics and one recess was provided for the metal member, two or more projections and recesses may be provided to join members having large joining areas.

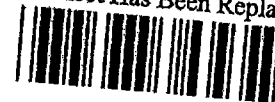


TABLE 1

| Examples            | NO. | Material of Insulating Operating Rod |          |              |                                                         |                                                             |
|---------------------|-----|--------------------------------------|----------|--------------|---------------------------------------------------------|-------------------------------------------------------------|
|                     |     | Intermediate Material                | Ceramics | Metal Member | Material for Joining Intermediate Material and Ceramics | Material for Joining Intermediate Material and Metal Member |
| 1 Present Invention | 1   | Fe-42Ni                              | Alumina  | SUS304       | Ni-13Cr-10P                                             | AG-30Cu-10Sn-0.025P                                         |
|                     | 2   | Fe-29Ni-17Co                         | Ditto    | Ditto        | Ditto                                                   | Ditto                                                       |
|                     | 3   | Fe-32Ni-5Co-3C-2Si-0.2Mn             | Ditto    | Ditto        | Ditto                                                   | Ditto                                                       |
| 2 Present Invention | 4   | Cu-20W                               | Ditto    | Ditto        | Ditto                                                   | Ditto                                                       |
|                     | 5   | Cu-50Mo                              | Ditto    | Ditto        | Ditto                                                   | Ditto                                                       |
|                     | 6   | Cu/Mo/Cu (1:2:1)                     | Ditto    | Ditto        | Ditto                                                   | Ditto                                                       |
| 3 Present Invention | 7   | Composite Material                   | Ditto    | Ditto        | Cu-28Ti                                                 | Cu-28Ti                                                     |
| 4 Present Invention | 8   | S45C                                 | Zirconia | Ditto        | Ditto                                                   | Ag-30Cu-10Sn-0.025P                                         |
| 5 Present Invention | 9   | Oxygen free copper                   | Alumina  | Ditto        | Ni-13Cr-10P                                             | Ditto                                                       |
|                     | 10  | Cu-0.8Cr                             | Ditto    | Ditto        | Ditto                                                   | Ditto                                                       |
| 6 Present Invention | 11  | -                                    | Ditto    | Ditto        | -                                                       | Cu-28Ti                                                     |
| Comparative Example | 12  | Not provided                         | Ditto    | Ditto        | -                                                       | Ni-13Cr-10P                                                 |
|                     | 13  | S45C                                 | Zirconia | Ditto        | Cu-28Ti                                                 | AG-30Cu-10Sn-0.025P                                         |
|                     | 14  | Cu-30Ni                              | Alumina  | Ditto        | Ni-13Cr-10P                                             | Ditto                                                       |
|                     | 15  | Not provided                         | Ditto    | Ditto        | -                                                       | Cu-28ti                                                     |



| Example             |                   | NO. | State After Brazing | Joining Strength (kgf/mm <sup>2</sup> ) | Remarks                                          |
|---------------------|-------------------|-----|---------------------|-----------------------------------------|--------------------------------------------------|
| 1                   | Present Invention | 1   | Excellent           | 15                                      |                                                  |
|                     |                   | 2   | Ditto               | 23 or greater                           |                                                  |
|                     |                   | 3   | Ditto               | Ditto                                   |                                                  |
| 2                   | Present Invention | 4   | Ditto               | Ditto                                   |                                                  |
|                     |                   | 5   | Ditto               | Ditto                                   |                                                  |
|                     |                   | 6   | Ditto               | Ditto                                   |                                                  |
| 3                   | Present Invention | 7   | Ditto               | Ditto                                   | Cooling rate 50°C/second or higher               |
| 4                   | Present Invention | 8   | Ditto               | Ditto                                   |                                                  |
| 5                   | Present Invention | 9   | Ditto               | Ditto                                   |                                                  |
|                     |                   | 10  | Ditto               | Ditto                                   |                                                  |
| 6                   | Present Invention | 11  | Ditto               | Ditto                                   | Both shrinkage fit and surface brazing were used |
| Comparative Example |                   | 12  | Cracks occurred     | 3                                       |                                                  |
|                     |                   | 13  | Separation occurred | -                                       | Cooling rate 50°C/second or higher               |
|                     |                   | 14  | Cracks occurred     | 5                                       |                                                  |
|                     |                   | 15  | Excellent           | 7.5                                     |                                                  |



According to the first aspect of the present invention, there is provided the insulating operating rod arranged to realize insulation and transmit operating force in a vacuum container and constituted by joining ceramics and a metal member to each other, the insulating operating rod comprising: an intermediate material disposed between the ceramics and the metal member and composed of a Fe-Ni alloy; a copper composite material; carbon steel; copper; or a copper alloy. Therefore, stress caused from the difference in the thermal expansion can be reduced and buffered. As a result, the insulating operating rod exhibiting an excellent joining characteristics can be obtained.

According to the second aspect of the present invention, there is provided the insulating operating rod having the structure that the Fe-Ni alloy, which is the intermediate material is Fe-Ni alloy containing Ni by 20 mass% to 50 mass%; a Fe-Ni alloy containing Ni by 20 mass% to 50 mass% and Co by 3 mass% to 25 mass%; a Fe-Ni alloy containing Ni by 20 mass% to 50 mass% and Cr by 1 mass% to 12 mass%; or a Fe-Ni alloy containing Ni by 20 mass% to 50 mass% and Co by 3 mass% to 25 mass% and further containing one or two materials selected from C by 0.5 mass% to 5 mass%, Si and Mn by 0.1 mass% to 3 mass%. Therefore, the insulating operating rod having a furthermore satisfactory joining characteristics can be obtained.

According to the third aspect of the present invention, there is provided the insulating operating rod having the



structure that the copper composite material which is the intermediate material is in the form of a composite of Cu and Mo or W particles in a range from 40 mass% and 90 mass%; or a clad material having a triple-layered structure in which Mo is sandwiched between two Cu layers in a quantity of 20 mass% to 80 mass%. Therefore, the insulating operating rod having a furthermore satisfactory joining characteristics can be obtained.

According to the fourth aspect of the present invention, there is provided the insulating operating rod having the structure that the yield stress of the copper or a copper alloy which is the intermediate material is  $4 \text{ kgf/mm}^2$  to  $10 \text{ kgf/mm}^2$ . Therefore, the insulating operating rod having a furthermore satisfactory joining characteristics can be obtained.

According to the fifth aspect of the present invention, there is provided the insulating operating rod having the structure that the intermediate material which is provided with a through hole having ceramics engaged thereto is disposed between the ceramics and the metal member. Therefore, the insulating operating rod having a furthermore satisfactory joining characteristics can be obtained.

According to the sixth aspect of the present invention, there is provided the method of manufacturing an insulating operating rod arranged to realize insulation and transmit operating force in a vacuum container and incorporating ceramics



and a metal member to each other, the method of manufacturing an insulating operating rod comprising the steps of: disposing a Fe-Ni alloy; a copper composite material; carbon steel; copper; or a copper alloy between the ceramics and the metal member to serve as the intermediate material; and joining the ceramics and the metal member to each other. Therefore, stress caused from the difference in the thermal expansion can be reduced and buffered. Thus, the insulating operating rod having a satisfactory joining characteristics can be obtained.

According to the seventh aspect of the present invention, there is provided the method of manufacturing an insulating operating rod having the structure that the carbon steel, which is the intermediate material, is joined to the ceramics at a cooling rate which satisfies a range from 50°C/sec to 200°C/sec. Therefore, the insulating operating rod having a satisfactory joining characteristics can be obtained.

According to the eighth aspect of the present invention, there is provided the method of manufacturing an insulating operating rod arranged to realize insulation and transmit operating force in a vacuum container and incorporating ceramics and metal, the method of manufacturing an insulating operating rod comprising the steps of: using both of a shrinkage fitting method with which one or more projections and recesses are provided for the ceramics and the metal member and heating and joining are performed and a joining method with which the joined

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surfaces are brazed. Therefore, the joining force can be enlarged and, thus, the insulating operating rod exhibiting an excellent joining characteristics can be obtained.

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WHAT IS CLAIMED IS:

1. An insulating operating rod arranged to realize insulation and transmit operating force in a vacuum container, comprising:

a ceramics member;

a metal member to which said ceramics member are joined;

an intermediate member disposed between said ceramics member and said metal member, and made of one of a Fe-Ni alloy, a copper composite material, carbon steel, copper and a copper alloy.

2. The insulating operating rod according to claim 1, wherein the Fe-Ni alloy, which is said intermediate member, is Fe-Ni alloy containing Ni by 20 to 50 mass%; a Fe-Ni alloy containing Ni by 20 to 50 mass% and Co by 3 to 25 mass%; a Fe-Ni alloy containing Ni by 20 to 50 mass% and Cr by 1 to 12 mass%; or a Fe-Ni alloy containing Ni by 20 to 50 mass% and Co by 3 to 25 mass% and further containing one or two materials selected from C by 0.5 to 5 mass%, Si and Mn by 0.1 to 3 mass%.

3. The insulating operating rod according to claim 1, wherein the copper composite material which is the intermediate member is in the form of a composite of Cu and Mo or W particles in a range from 40 to 90 mass%; or a clad material having a triple-layered structure in which Mo is sandwiched between two Cu layers in a quantity of 20 to 80 mass%.





4. The insulating operating rod according to claim 1, wherein the yield stress of the copper or a copper alloy which is said intermediate material is 4 to 10 kgf/mm<sup>2</sup>.

5. The insulating operating rod according to any one of claims 1 to 4, wherein said intermediate member which is provided with a through hole having ceramics engaged thereto is disposed between said ceramics member and said metal member.

6. A method of manufacturing an insulating operating rod arranged to realize insulation and transmit operating force in a vacuum container and incorporating ceramics and a metal member to each other, said method of manufacturing an insulating operating rod comprising the steps of:

disposing one of an Fe-Ni alloy, a copper composite material, carbon steel, copper and a copper alloy between said ceramics member and said metal member to serve as said intermediate member; and

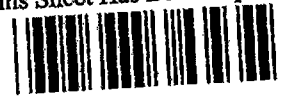
joining said ceramics member and said metal member to each other.

7. The method of manufacturing an insulating operating rod according to claim 6, wherein the carbon steel, which is said intermediate member, is joined to said ceramics member at a cooling rate satisfying a range from 50°C/sec to 200°C/sec.

8. A method of manufacturing an insulating operating rod arranged to realize insulation and transmit operating force in a vacuum container and incorporating ceramics and metal, said



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method of manufacturing an insulating operating rod comprising the steps of:

using both of a shrinkage fitting method with which one or more projections and recesses are provided for said ceramics and said metal member and heating and joining are performed and a joining method with which the joined surfaces are brazed.



\* C L M S \*