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(54) Superconductive current lead.

(57) A material representing a low thermal conductivity at a temperature lower than a room temperature is used for a basic member composing a superconductive current lead. The basic member is combined with an oxide system superconductive member. The basic member decreases the heat transfer from the superconductive current lead to an extreme low temperature side.

EP 0 588 461 A1

This invention relates to a superconductive current lead, and more particularly to, the improvement of a superconductive current lead connecting a superconductive machine placed in an atmosphere of an extreme low temperature to a power supply, etc. placed in an atmosphere of a room temperature.

A current lead which is used for a superconductive machine is designed to have a cross-section, such that the sum of a heat generated by the current flow through the current lead and a heat transferred from a high temperature portion to the current lead becomes minimum, and an evaporation amount of coolant such as helium, etc. becomes also minimum.

In conventional cases, a current lead is composed of copper wires. Under this circumstance, a current lead using oxide system superconductive wires each covered with Ag layer has been studied for the same purpose.

According to a current lead composed of the Ag-layered oxide system superconductive wires, however, there is a disadvantage in that a heat transfer amount is large, because the thermal conductivity of Ag is large at an extreme low temperature region which is an operation temperature region of a superconductive machine as compared to other metals, although this results in an advantage in that the stability of the superconductive wires is increased.

In this current lead, there is a further disadvantage in that Joule heat generated by eddy current and coupling current of the Ag layers is not negligible, because an electric resistance of the Ag layers becomes very small at an extreme low temperature, when AC current or transient current flows through the current lead.

Accordingly, it is an object of the invention to provide a superconductive current lead, in which a heat amount transferred from an external high temperature portion thereto is decreased.

It is a further object of the invention to provide a superconductive current lead, in which Joule heat generated by the flow of current is decreased.

It is a still further object of the invention to provide a superconductive current lead, by use of which an evaporation amount of coolant is decreased.

According to the invention, a superconductive current lead, comprises :

A predetermined number of superconductive wires ;

each of the superconductive wires, comprising :

a first member of an oxide system superconductive material ; and

a second member of a material representing a predetermind thermal conductivity at a temperature lower than a room temperature, the predetermined thermal conductivity being lower than a thermal conductivity at the room temperature.

In a material, lowering a thermal conductivity is tend to lowering an electric resistance, so that the decrease of eddy current loss or coupling current loss is realized, when AC current or transient current flows through the superconductive current lead.

In the invention, an oxide system superconductive material may be a material selected from, for instance, Y-Ba-Cu-O, Bi-Sr-Cu-O, Bi-Pb-Sr-Ca-Cu-O, Tl-Ba-Cu-O, Tl-Ba-Ca-Cu-O, Tl-Sr-Ca-Cu-O, La-Sr-Cu-O, La-Ba-Cu-O, and a material having a lower thermal conductivity at a lower temperature than a room temperature (equivalent to having a larger electric resistance) may be a material selected from, for example, an alloy including Au or Ag as a main component and at least one element of Pd, Pt, Mn, Mg, Zr, and Au, a material including a transition metal system alloy as a main component which will be oxide at a thermal treatment of a superconductive material, and an oxide system material such as alumina, MgO, $LaAlO_3$.

These latter materials may be used for a reinforcing member in a superconductive current lead, while a barrier layer of precious metal may be interposed between the oxide system superconductive material and the lower thermal conductivity material.

When Ag-Au alloy is used for a reinforcing member, a content of Au is less than 15%, perferably 1 to 10%, by atomic ratio.

A predetermined number of superconductive wires may be one or more superconductive wires.

In the accompanying drawings:-

Fig.1 is an explanatory diagram showing a superconductive current lead connecting a superconductive machine to a power supply ;

Fig.2 is a perspective view showing a superconductive current lead of a first preferred embodiment according to the invention ; and

Fig.3 is a perspective view showing a superconductive current lead of a second preferred embodiment according to the invention.

Fig. 1 shows a superconductive current lead 4 connected to a superconductive coil(machine) 3 and a current lead 5 by connectors 41 and 42, and a power supply 6 provided to apply a predetermined voltage across the superconductive coil 3 via the current lead 5 and the superconductive current lead 4, wherein the superconductive coil and current lead 3 and 4 are immersed in liquid helium 2 contained in a container 1.

Fig.2 shows a superconductive current lead 4 of a preferred embodiment according to the invention which is used in the apparatus as shown in Fig.1. The superconductive current lead 4 comprises a plurality of tape-shaped wires 7 each comprising a core 8 of an oxide system superconductive material and an alloy covering layer 9.

In the first example of the first preferred embodiment, the core 8 is of an oxide system superconductive material(Tl-Pb-Sr-Ba-Ca-Cu-O) including 1223 phase of Tl and Pb single layer system as a main component, and the alloy covering layer 9 is of Au-5 atomic % Pb alloy, wherein each superconducting tape is 2.4 mm in width, 1.4 mm in thickness, and 3.3 mm^2 in cross-sectional area. The superconductive current lead 4 thus fabricated is immersed in the liquid helium 2 having a temperature of 77k, wherein a superconductive critical current of approximately 100A is obtained. When current flows through the leads 4 and 5, it is determined that a heat transferred to the liquid helium 2 is approximately 0.05 mW per a current of 1A in accordance with the estimation of an evaporation amount of the liquid helium 2. In accordance with the result, it is confirmed that this superconductive current lead 4 has a property having a very small heat transfer. This is resulted from the structure that the alloy covering layer 9 having a low thermal conductivity at a low temperature is used, so that a heat transferred through the alloy covering layer 9 is decreased.

In case where AC current of 60 Hz flows through the superconductive current lead 4, it is measured that a heat of approximately 1mW per a current of 1A is transferred to the liquid helium 2. This result confirms that the superconductive current lead 4 is a conductor having a property of a very small thermal loss. This is resulted from the structure that the alloy covering layer 9 has a large electric resistance, so that eddy current loss and coupling current loss of the conductor are decreased.

In the second example of the first preferred embodiment, a superconductive current lead 4 having the same size as that in the first example is fabricated to include a core 8 of an oxide system superconductive material (Bi-Sr-Ca-Cu-O) of Bi12212 system and an alloy covering layer 9 of Ag-3 atomic % Au alloy.

A critical current of this superconductive current lead 4 immersed in the liquid helium 2 at a temperature of 4.2K is 10^5 A/cm^2 which is the same value as a value obtained in case where pure Ag is used for a covering material. At the same time, a resistivity which is as high as 0.7 to 1.2 $\mu\Omega \cdot$ cm is obtained to represent a significant change as compared to the case where pure Ag is used at an extreme low temperature region for a covering material.

In relation to the resistivity of the alloy covering layer 9, a thermal conductivity of the superconductive current lead 4 become smaller than that of common current lead of phosphorus-deoxidized copper. Consequently, the superconductive current lead 4 can be used with an eddy current loss of one percent as compared to that in the case where pure Ag is used for a covering layer.

In regard to electric resistance of the connectors 42 and 41, the resistance value is not only decreased, but also stabilized in the elapse of time.

In the first and second examples of the preferred embodiment, the thermal conductivity (W/m·k) of the alloy covering layer 9 is shown in a below table relative to a temperature along with that of a pure Ag covering layer.

TEMPERATURE (k)	FIRST EXAMPLE	SECOND EXAMPLE	PURE Ag
260	500	160	590
77	170	51	530
20	75	10	25,000

Fig. 3 shows a superconductive current lead of a second preferred embodiment according to the invention. The superconductive current lead comprises a basic member 10 of alumina, a thin layer 11 of Ag and an oxide system superconductive layer 12. The alumina basic member 10 may be replaced by an Ag-Au alloy basic member.

As described above, a material representing a lower thermal conductivity at a temperature lower than a room temperature is used for a basic member in the invention, so that a heat transferring through the basic member to coolant is not only decreased, but a heat of the lead generated by the flow of current is also decreased, thereby decreasing the consumption of the coolant and a load of a refrigerator.

A plurality of leads shown in Fig. 3 can be stacked in a similar way to the wires shown in Fig. 2.

Claims

1. A superconductive current lead comprising one or more superconductive wires the or each wire including

a first member of an oxide system superconductive material; and a second member of a material having a thermal conductivity at a temperature lower than room temperature which is lower than its thermal conductivity at room temperature.

2. A superconductive current lead according to claim 1, wherein the second member is an alloy including one of Au and Ag as a main component and at least one of Pd, Pt, Mn, Mg, Zr and Au.

3. A superconductive current lead according to claim 1 or claim 2, wherein the first member is covered with the second member to provide the superconductive wire; and the predetermined number of superconductive wires are stacked.

4. A superconductive current lead according to claim 1 or claim 2, wherein the first member is layered on one surface of the second member to provide the superconductive wire; and the predetermined number of superconductive wires are stacked.

5. A superconductive current lead according to any one of the preceding claims, wherein the superconductive wire is a tape-shaped wire.

6. A superconductive current lead according to claim 2, wherein the second member is Ag-Au alloy including Au of less than 15 atomic %.

7. A superconductive current lead according to claim 6, wherein the second member is Ag-Au alloy including Au of 1 to 10 atomic %.

8. A superconductive current lead according to claim 1, wherein each of the superconductive wires is a tape shaped wire, in which the first member is covered with the second member, the second member being an Ag-Au alloy including Au of 1 to 10 atomic %.

FIG. 1

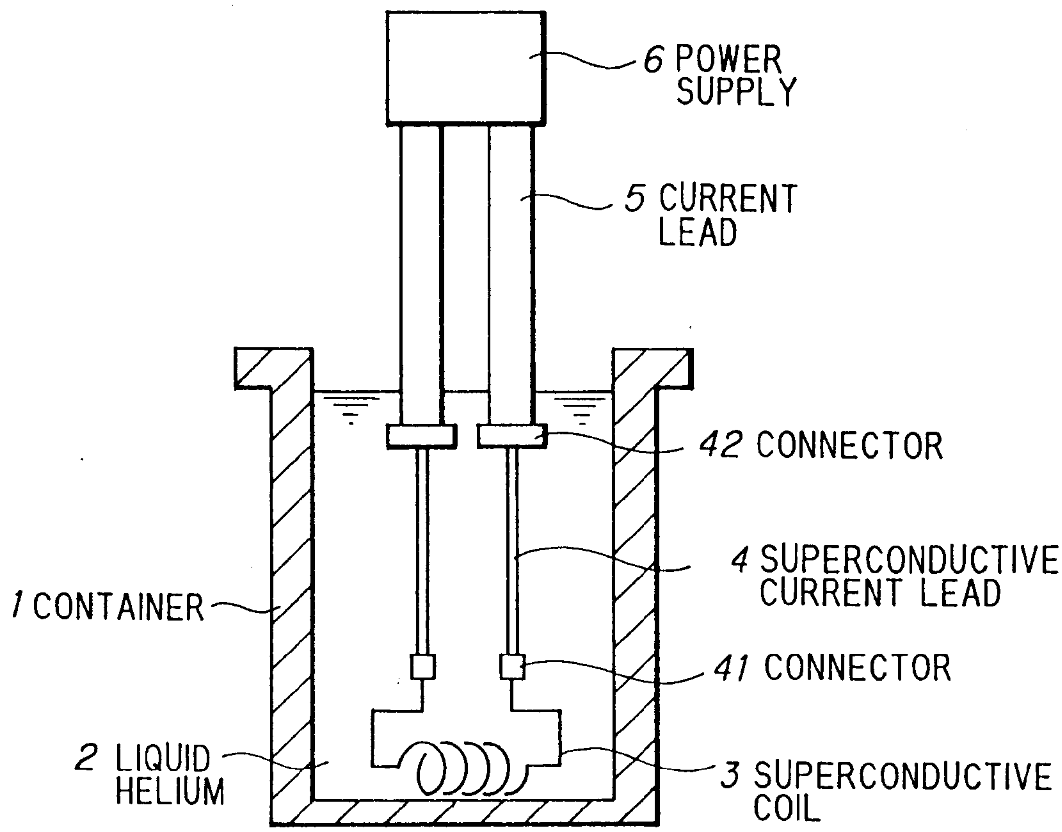

6 POWER SUPPLY
5 CURRENT LEAD
42 CONNECTOR
4 SUPERCONDUCTIVE CURRENT LEAD
1 CONTAINER
41 CONNECTOR
2 LIQUID HELIUM
3 SUPERCONDUCTIVE COIL

FIG. 2

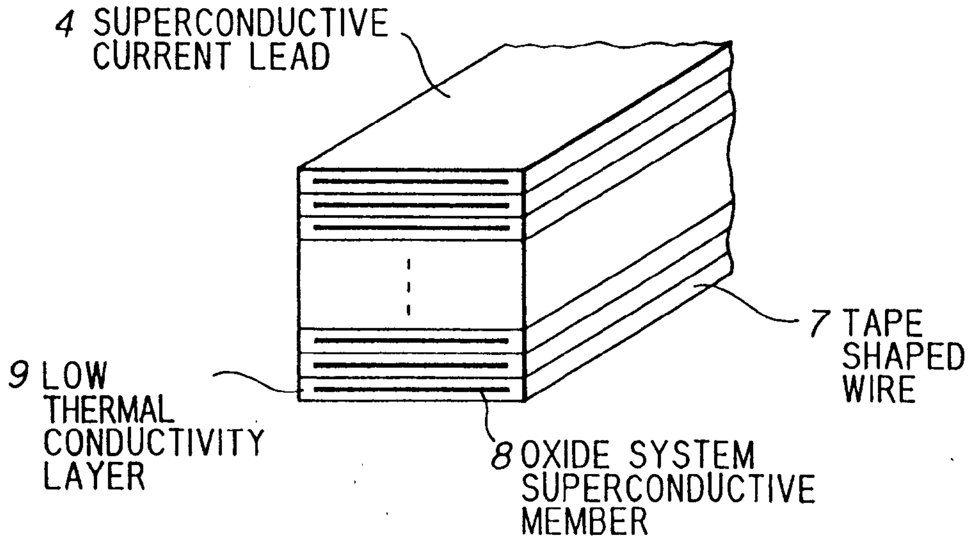
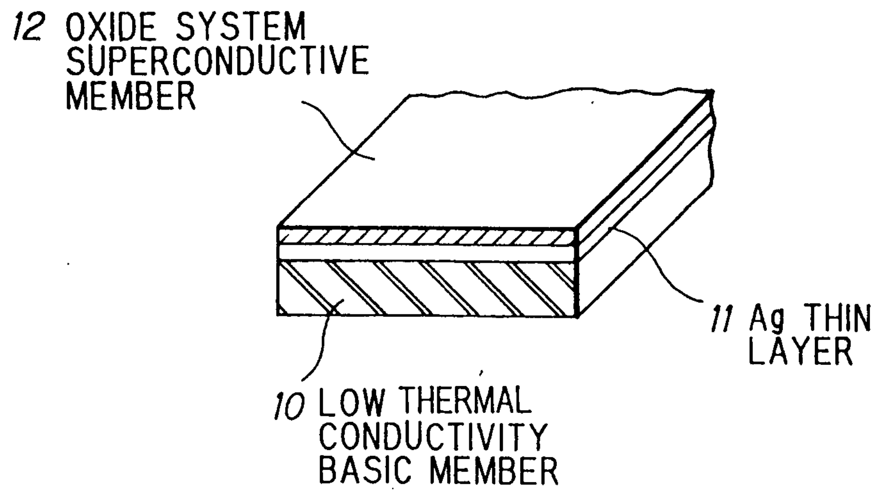

4 SUPERCONDUCTIVE CURRENT LEAD
7 TAPE SHAPED WIRE
9 LOW THERMAL CONDUCTIVITY LAYER
8 OXIDE SYSTEM SUPERCONDUCTIVE MEMBER

FIG.3


12 OXIDE SYSTEM SUPERCONDUCTIVE MEMBER
11 Ag THIN LAYER
10 LOW THERMAL CONDUCTIVITY BASIC MEMBER

European Patent Office

EUROPEAN SEARCH REPORT

Application Number

EP 93301815.2

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
X;Y	JP - A - 4-155 715 (FURUKAWA) * Claim; page 2, last quater, line 19 - page 3, first quater, line 10; figs. 1-4 * & DATABASE WPIL, no. 92-230 887, DERWENT PUBLICATIONS LTD., London, GB JP-A-4-155 715 --	1,2,5-8;3,4	H 01 B 12/00 H 01 R 4/68
Y	EP - A - 0 428 993 (SUMITOMO) * Abstract; claims; figs. 1-3 * --	3,4	
Y	JP - A - 3-276 521 (AGENCY) * Claim; fig. * & PATENT ABSTRACTS OF JAPAN, unexamined applications, E field, vol. 16, no. 95, March 09, 1992, page 135 E 1175 + 3-276 521 + --	4	
A	US - A - 5 075 285 (FLÜKIGER) * Claims; table * --	1,2	
A	EP - A - 0 409 150 (SUMITOMO) * Claims; figs. 1-7 * ----	1	

TECHNICAL FIELDS SEARCHED (Int. Cl.5)

H 01 B 12/00
H 01 R 4/00
H 01 L 39/00

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
VIENNA	15-11-1993	KUTZELNIGG

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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L : document cited for other reasons

& : member of the same patent family, corresponding document