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NASA CASE NO. LAR 14964-1-CU

PRINT FIG. 1

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Serial No.: 08/215,793
03/15/94 LaRC

(NASA-Case-LAR-14964-1-CU) ELECTRICALLY CONDUCTIVE, THERMALLY INSULATING CRYOGENIC CURRENT LEADS Patent Application (NASA. Langley Research Center) 8 p

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LAR-14964-1 AWARDS ABSTRACT

ELECTRICALLY CONDUCTIVE, THERMALLY INSULATING CRYOGENIC CURRENT LEADS

The present invention relates generally to electrically conductive current leads and more particularly to thermally insulating electrically conductive current leads.

According to the present invention, a thermally insulating, electrically conductive current lead assembly consisting of a low thermal loss substrate and a series of thick film high temperature superconductive elements deposited on the substrate is provided. The substrate is a ceramic, preferably yttria-stabilized zirconia or fused silica. The high temperature superconductor may be $YBa_2Cu_3O_{7-x}$, or a superconductive compound in the Bi-Sr-Ca-Cu-O or Tl-Ca-Ba-Cu-O systems. The superconductor is deposited on the substrate using screen-printing techniques and fired at elevated temperatures (800-950°C) to densify the superconductive elements.

Novel aspects of the present invention include providing a current lead assembly which exhibits low thermal conductivity in the cryogenic region, which can withstand the operational stresses imposed on space-borne systems and which can be used to electrically connect an infrared detector to data acquisition electronics. The lead assembly is generally applicable to any cryogenic system in which heat transfer across the lead is to be minimized.

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ELECTRICALLY CONDUCTIVE, THERMALLY INSULATING CRYOGENIC CURRENT LEADS

Origin of the Invention

The invention described herein was made by an employee of the United States Government and a contract employee in the performance of work under NASA Grant Number NGT 50548 and is subject to the provisions of Public Law 96-517 (35 U.S.C. 202) in which the contractor has elected not to retain title.

Background of the Invention

1. Technical Field of the Invention

The present invention relates generally to electrically conductive current leads and more particularly to thermally insulating electrically conductive current leads.

2. Discussion of the Related Art

Current leads are an integral part of cryogenically-cooled infrared detector systems which are used by NASA for atmospheric remote sensing. In general, these infrared sensors operate more efficiently at cryogenic temperatures due to improved signal-to-noise characteristics, thus requiring liquid helium refrigeration systems for cooling. As a result, the duration of a space mission using these sensors is limited by the evaporation rate of the liquid cryogen, making all heat loads on the system critical. One non-parasitic heat load on the dewar system (i.e., not related to the dewar design and structural composition) is the electrical leads connecting the sensors to the data acquisition and storage electronics. These electronic systems are maintained at higher temperatures, resulting in a thermal gradient from 4 to 80K. The electrical connections over the temperature gradient produce a significant thermal load, accelerating the boil-off of the liquid helium cryogen and reducing the mission lifetime. This problem becomes especially critical for long duration space missions (i.e., >5 years).

Manganin (84% Cu, 12% Ni, and 4% Mn) wires are currently used for electrical connections in space-borne cryogenic systems due to their low thermal conductivity as compared to other metals and metallic alloys. However, the discovery of superconductivity above 80K in ceramic materials has provided an alternative to manganin connections. High temperature superconductors possess extremely low thermal conductivities in the cryogenic region, while maintaining sufficient electrical conductivity for detector applications, where typical currents are on the order of 1 μA. However, fine diameter wires of the high temperature superconductors have not demonstrated the required mechanical durability to withstand operational stresses imposed on space-borne systems.

It is accordingly an object of the present invention to provide a current lead assembly which exhibits low thermal conductivity in the cryogenic region.

It is a further object of the present invention to provide a current lead assembly which can withstand the operational stresses imposed on space-borne systems.

It is a further object of the present invention to provide a current lead assembly which could be used to electrically connect an infrared detector to data acquisition electronics.

It is yet another object of the present invention to accomplish the foregoing objects in a simple manner.

Additional objects and advantages of the present invention are apparent from the drawing and specification that follow.

Summary of the Invention

A thermally insulating, electrically conductive current lead assembly consists of a low thermal loss substrate; and a series of thick film high temperature superconductive elements deposited on the substrate. The substrate is a ceramic, preferably yttria-stabilized zirconia or fused silica. The high temperature superconductor may be $YBa_2Cu_3O_{7-x}$, or a superconductive compound in the Bi-Sr-Ca-Cu-O or Tl-Ca-Ba-Cu-O systems. The superconductor is deposited on the substrate using screen-printing techniques and fired at elevated temperatures (800-950°C) to densify the superconductive elements.

Brief Description of the Drawing

Fig. 1 is a schematic showing the position of the lead assembly related to the infrared detector focal plane array and the data acquisition electronics.

Detailed Description of the Invention

A unique current lead assembly is described in detail below. The lead assembly is generally applicable to any cryogenic system in which heat transfer across the lead is to be minimized.

This invention involves the use of thick film elements of high temperature superconductors deposited onto low thermal conductivity substrates as electrically conductive, thermally insulating leads for low current applications. This lead assembly consists of a series of superconductive elements screen-printed onto ceramic substrates and electrically contacted at each end. Each high temperature superconductive thick film element must exhibit low thermal conductivity, be electrically conductive at cryogenic temperatures, and be able to transport at least 1 μA of current. Suitable high temperature superconductors include $YBa_2Cu_3O_{7-x}$ with a superconductive transition temperature of 93K, compounds in the Bi-Sr-Ca-Cu-O system with transitions from 110K to 80K, and compounds in the Tl-Ca-Ba-Cu-O system with transitions from 125K to 80K. The requirements for the substrate include low thermal conductivity at cryogenic temperatures and chemical compatibility with the superconductive compound during thermal treatment (800-950°C maximum temperature). Suitable substrate materials include yttria-stabilized zirconia (YSZ) and fused silica.

High temperature superconductive compounds exhibit low thermal conductivity in the cryogenic region. Although ceramic materials are typically insulators at high temperatures, some ceramics exhibit high thermal conductivity as the temperature approaches absolute zero (e.g., alumina and magnesia). The combination of low thermal conductivity and high electrical conductivity exhibited by the high temperature superconductors make them ideal candidates for thermally insulating electrical connections designed to reduce heat loads on cryogenic systems.

The thermal conductivity of the substrate material onto which the superconductive elements are deposited is also critical in determining the total heat load on the system. Substrate thicknesses on the order of 0.15 to 0.25 mm or greater may be required for mechanical durability, resulting in a much greater thermal load contribution for the substrate due to the increased area as compared to the superconductor. Materials such as YSZ and fused silica possess extremely low thermal conductivities, making them ideal candidates for use with thick film superconductors in this application.

To illustrate the thermal savings estimated for a cryogenic system employing high temperature superconductive electrical lead assemblies, a thermal model was calculated. Manganin (84% Cu, 12% Ni, and 4% Mn) wires, which are currently employed in several aerospace systems, were used as a reference. Additionally, preliminary design criteria for SAFIRE (Spectroscopy of the Atmosphere using Far Infrared Emissions) were used to set the device parameters including the temperature gradient (4-80K), wire diameter (40AWG), and connection length (15 cm). The heat flow calculated for a single manganin wire over the temperature gradient was 16.6mW. As an example, a superconductive lead assembly using the $Bi_2Sr_2Ca_2\ Cu_3O_x$ (Tc= 110K) superconductive compound 16 screen-printed onto a fused silica substrate 14 exhibited a heat flow 20 of only 3.4mW or approximately 20% of the heat load induced by the manganin connection. The model showed that the use of superconductive leads over the currently employed manganin wires in cryogenic detector systems such as SAFIRE would decrease the heat load placed on the dewar system 12 by the electronic systems 18 by 60-80%, depending on the superconductor/substrate combination used.

Although our invention has been illustrated and described with reference to the preferred embodiment thereof, we wish to have it understood that it is in no way limited to the details of such embodiment, but is capable of numerous modifications for many mechanisms, and is capable of numerous modifications within the scope of the appended claims.

ELECTRICALLY CONDUCTIVE, THERMALLY INSULATING CURRENT LEADS

Abstract of the Disclosure

An electrically conductive, thermally insulating current lead assembly has been developed for cryogenic systems. This lead assembly consists of thick film elements of high temperature superconductive materials deposited onto a low thermal conductivity substrate. The superconductor elements provide current transport but minimize heat transfer. The substrate provides the mechanical durability necessary for cryogenic and other environments.

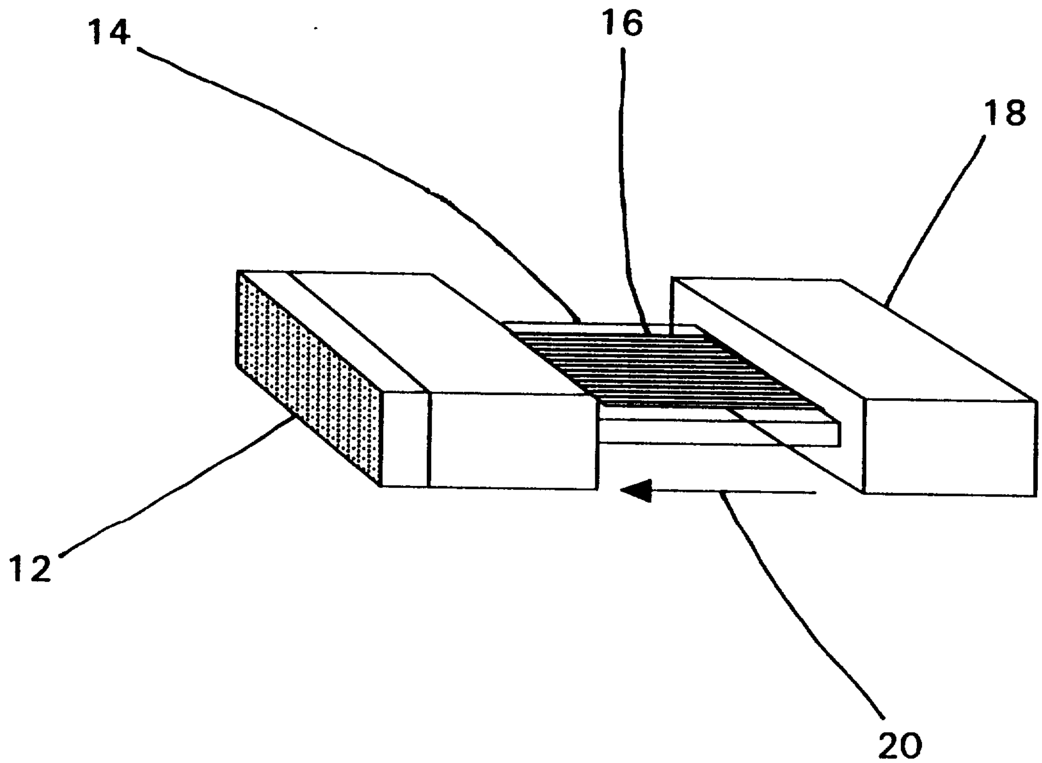

Fig. 1