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 Washington, D.C.  
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NASA Case No. LEW-14162-1  
 Print Figure 1

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(NASA-Case-LEW-14162-1) HEAT TRANSFER  
 DEVICE AND METHOD OF MAKING THE SAME Patent  
 Application (NASA) 11 p CSCL 200

N91-13668

Unclas

G3/34 0320452

## AWARDS ABSTRACT

### HEAT TRANSFER DEVICE AND METHOD OF MAKING THE SAME

Gas derived graphite fibers are generated by the decomposition of an organic gas. These fibers when joined with a suitable binder are used to make a high thermal conductivity composite material.

The fibers may be intercalated. The intercalate can be halogen or halide salt, alkaline metal, or any other species which contributes to the electrical conductivity improvement of the graphite fiber. The heat transfer device may also be made of intercalated highly oriented pyrolytic graphite and machined, rather than made of fibers.

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**EMPLOYER:** NASA Lewis Research Center

**EVALUATOR:** Dr. J. Stuart Fordyce

**SERIAL NO.:** 501,893

**FILING DATE:** March 30, 1990

**HEAT TRANSFER DEVICE AND  
METHOD OF MAKING THE SAME****Origin of the Invention**

The invention described herein was made by employees of the United States Government and may be manufactured and used by or for the Government for governmental purposes without the payment  
5 of any royalties thereon or therefor.

**Technical Field**

This invention is concerned with providing an improved heat transfer device. The invention is particularly directed to a material which will transfer heat more efficiently.

10 Previous methods of transferring heat relied on high thermal conductivity materials. Some of these devices use class II A diamond which conducts heat approximately five times the rate of copper at room temperature. However, such high thermal conductivity materials, such as class II A diamond, are suitable only  
15 for short distance heat transport because of the expense of the high quality diamond. Only a short distance transport, on the order of 5mm, is practical with such materials.

Heat transfer devices of copper, aluminum, silver, and beryllium oxide have been proposed. While these materials can  
20 be used to transport heat over larger distances, their poor thermal conductivity requires high temperature gradients to transport the same power per unit area as diamond.

Heat pipes can be very effective transporters of heat with low temperature gradients. However, they rely on some active  
25 working fluid and usually have a rather limited temperature range of operation. Heat pipes are not readily constructed in arbitrarily small or complex shapes.

It is, therefor, an object of the present invention to provide a heat transfer device which conducts heat substantially better  
30 than conventional devices, yet is lightweight and strong.

Another object of the invention is to provide a heat conducting material which can be used instead of more complex heat pipes and thus, be mechanically supportive, lightweight, and have no

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active working fluid to be concerned about. However, the material would efficiently transfer heat from one place to another.

5 **Background Art**

U.S. patent No. 2,542,637 to De Poy is concerned with a method of rectifying a neutral salt heat-treating bath. A solid graphite or carbon rod is immersed in the bath to reduce metal oxides and scavenge for metals in solution. The rod may be  
10 periodically removed, cleansed, and replaced.

U.S. patent No. 4,424,145 to Sara relates to a pitch derived carbon fiber which has been boronated and intercalated with calcium. U.S. patent No. 4,435,375 to Tamura is directed to a graphite filament which has been formed by heating a  
15 purified graphite material in a plasma and then intercalated with an alkali metal.

U.S. patent No. 3,531,249 to Turkat describes pyrolytic graphite compositions which are formed by co-depositing refractory metals and graphite on a mandrel to form a filament which  
20 is in essence pyrolytic graphite. U.S. patent No. 3,294,880 which is also to Turkat describes a continuous method of manufacturing ablative and refractory materials. The invention is particularly concerned with a method and apparatus for manufacturing ablative and refractory filaments in which  
25 hydrocarbon gases are cracked in a vacuum furnace. The decomposition products are deposited on a rotating mandrel and then continuously peeled therefrom in the form of a continuous filament. U.S. patent No. 3,375,308 which is likewise issued to Turkat is concerned with the making of high purity and non-  
30 melting filaments. High temperature, high strength ablative refractory materials, such as pyrolytic graphite, are produced by vapor decomposition and hydrocarbon gas cracking techniques to provide pure crystalline refractory metals, carbides, silicides and borides in free standing shapes, coatings and in  
35 compositions to form shapes and structures for space age applications.

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### Disclosure of the Invention

Gas derived graphite fibers joined with a suitable binder are used to make a high thermal conductivity composite material device. The fiber is generated by the decomposition of an organic gas.

The fibers may or may not be intercalated. The intercalate can be a halogen or halide salt, alkaline metal, or any other species which contributes to the electrical conductivity improvement of the graphite fiber. The heat transfer device may also be made of intercalated highly oriented pyrolytic graphite and machined, rather than made of fibers.

### Brief Description of the Drawings

The objects, advantages, and novel features of the invention will be more fully apparent from the following detailed description when read in connection with the accompanying drawings in which

FIG. 1 is an elevation view showing a heat transfer device constructed in accordance with the present invention;

FIG. 2 is a section view taken along the line 2-2 in FIG. 1;

FIG. 3 is an enlarged cross-section view of one of the fibers shown in FIG. 2;

FIG. 4 is a vertical cross-section view showing an alternate embodiment of the invention;

FIG. 5 is a plan view of still another alternate embodiment of the invention; and

FIG. 6 is a vertical cross-section view taken along the line 6-6 in FIG. 5.

### Best Mode for Carrying Out the Invention

Referring now to the drawing, there is shown in FIG. 1 a heat transfer device 10 constructed in accordance with the present invention. This apparatus is used to conduct heat from heat source 12 to a heat sink 14. The source 12 and the sink 14 are constructed of highly conductive materials while the heat transfer device 10 is a graphite fiber composite composed of either intercalated or heat treated fibers.

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As best shown in FIG. 2 the heat transfer device 10 is made up of highly oriented graphite fibers 16 which may in addition have been intercalated. As shown in FIG. 3, each fiber is a  
5 coaxial layered graphite structure which is intercalated with either electron acceptor or donor intercalate species. These fibers 16 are constructed into composite material in a form suitable for the specific heat transport application.

The graphite fibers 16 are fabricated by the high temperature  
10 decomposition of an inorganic gas, such as natural gas, benzene, etc. to produce concentric layers 18 of graphite along the fiber axis. The organic gas used to generate the fiber and the conditions under which it is grown can be any number of techniques which produce highly oriented fibers.

15 These organic gas derived fibers 16 are then heated to 3000°C to further graphitize and orient them. As a result of this heating, the thermal conductivity of the fibers is increased to about three times that of copper. The high temperature heat treatment and duration can be varied.

20 The fibers 16 may also be intercalated with a suitable electron donor or acceptor material to further increase the electrical conductivity if enhancement of electrical transport is desired. Intercalation is achieved by the insertion of ions or molecules between the planes or layers 18 of graphite. This  
25 is accomplished by surrounding the fibers 16 by vapor of the intercalant at a suitable elevated temperature. The intercalant can be a halogen or halide salt, alkaline metal or any other species which contributes to the thermal conductivity improvement of the graphite fiber.

30 The pristine or intercalated graphite fibers 16 are then bundled and joined with a suitable binder 20 to produce a high thermal conductivity composite material device 10. While the binder 20 is preferably epoxy or other polymer, it is contemplated that an electrodeposited metal or low-temperature alloy  
35 could be used.

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**ALTERNATE EMBODIMENTS OF THE INVENTION**

The geometry of the high thermal conductivity composite can be varied as needed to fit specific applications. Referring now  
5 to FIG. 4 there is shown an intercalated graphite fiber composite thermal transfer device 22 that is used to cool apparatus which uses a semiconductor 24. More particularly, the heat transfer device 22 is tapered and potted into a tapered slot in a heat sink 26. It is contemplated that the heat sink 26 may be of  
10 copper or other highly conductive material. If required, a thin film electrical isolator 28 may be interposed between the semiconductor 24 and the heat sink 26.

The graphite fibers can be sputter vapor, electroless, or electrodeposited with a thin film of metal to allow electrical  
15 and/or solder bonding of the fibers to heat sinks. Such a structure is shown in FIGS. 5 and 6 wherein a semiconductor device 30 is cooled by a radial array of intercalated graphite fibers 32 which are in contact with a heat sink 34. If required, a thin film electrical isolator 36 may be interposed between the  
20 semiconductor 30 and the heat sink 34. It will be appreciated this configuration facilitates the spreading of semiconductor waste heat by utilizing the intercalated graphite fiber.

The geometry of the high thermal conductivity composite can be varied as needed to fit the specific application. In addition,  
25 tion, the heat transfer device may be simply made of intercalated highly oriented pyrolytic graphite and suitably machined rather than being made of fibers.

The intercalated graphite fiber composite material devices shown in the drawings are stronger, lighter and less expensive  
30 than other materials of the prior art. Also, these devices have the capability of transferring more heat for the same temperature differential than prior art devices.

Another important advantage of the invention is that the material operates passively. This does not require any transport  
35 of a gravitational environment.

While several embodiments of this invention have been shown and described it will be appreciated that various modifications may be made to the disclosed invention without departing from the spirit thereof or the scope of the subjoined claims.

6/

**ABSTRACT OF THE DISCLOSURE**

**HEAT TRANSFER DEVICE AND  
METHOD OF MAKING THE SAME**

-5 Gas derived graphite fibers are generated by the decomposition of an organic gas. These fibers when joined with a suitable binder are used to make a high thermal conductivity composite material.

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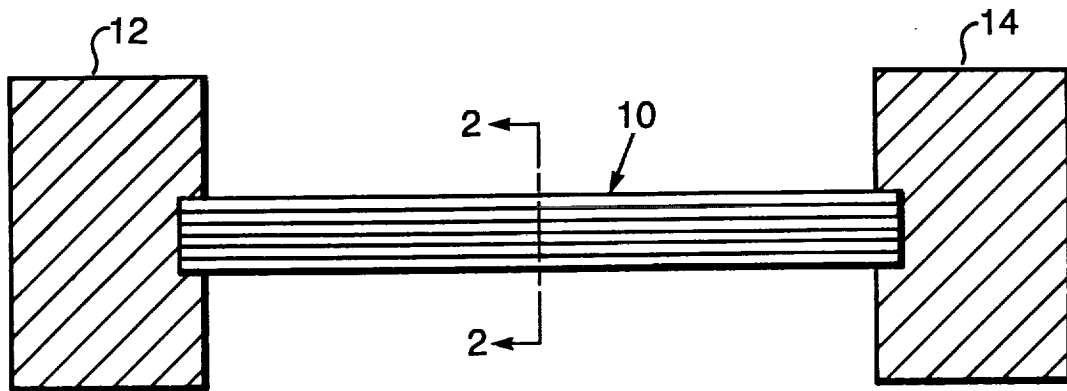


FIG. 1

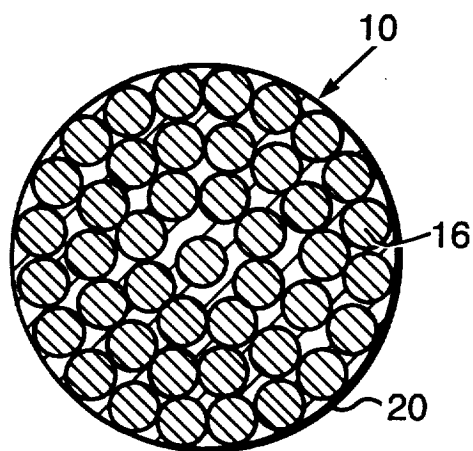


FIG. 2

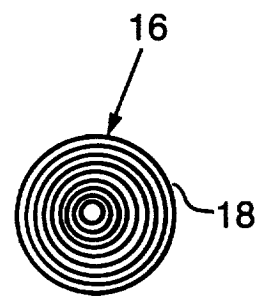


FIG. 3

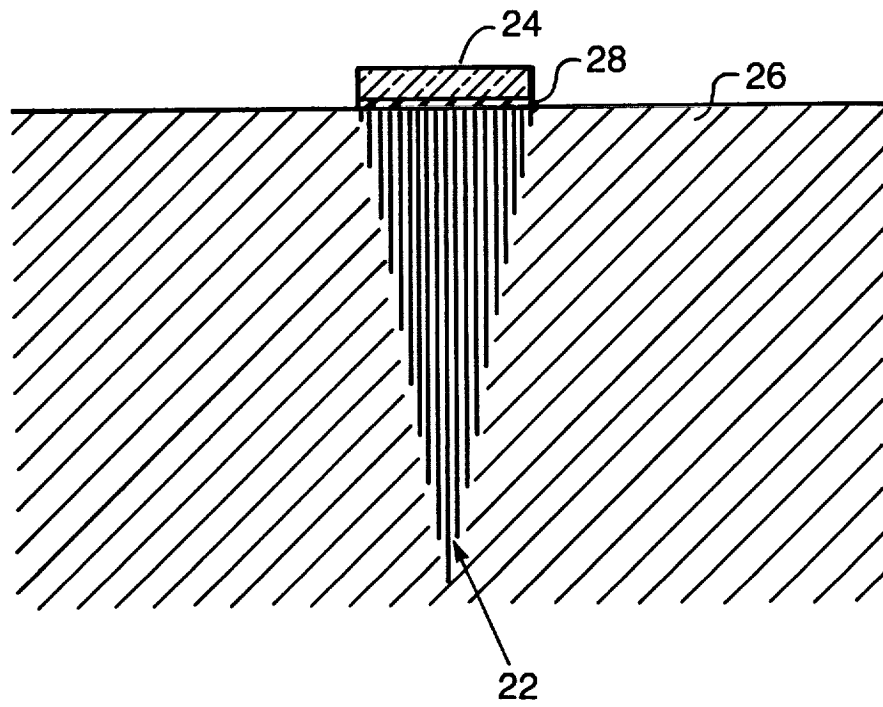


FIG. 4

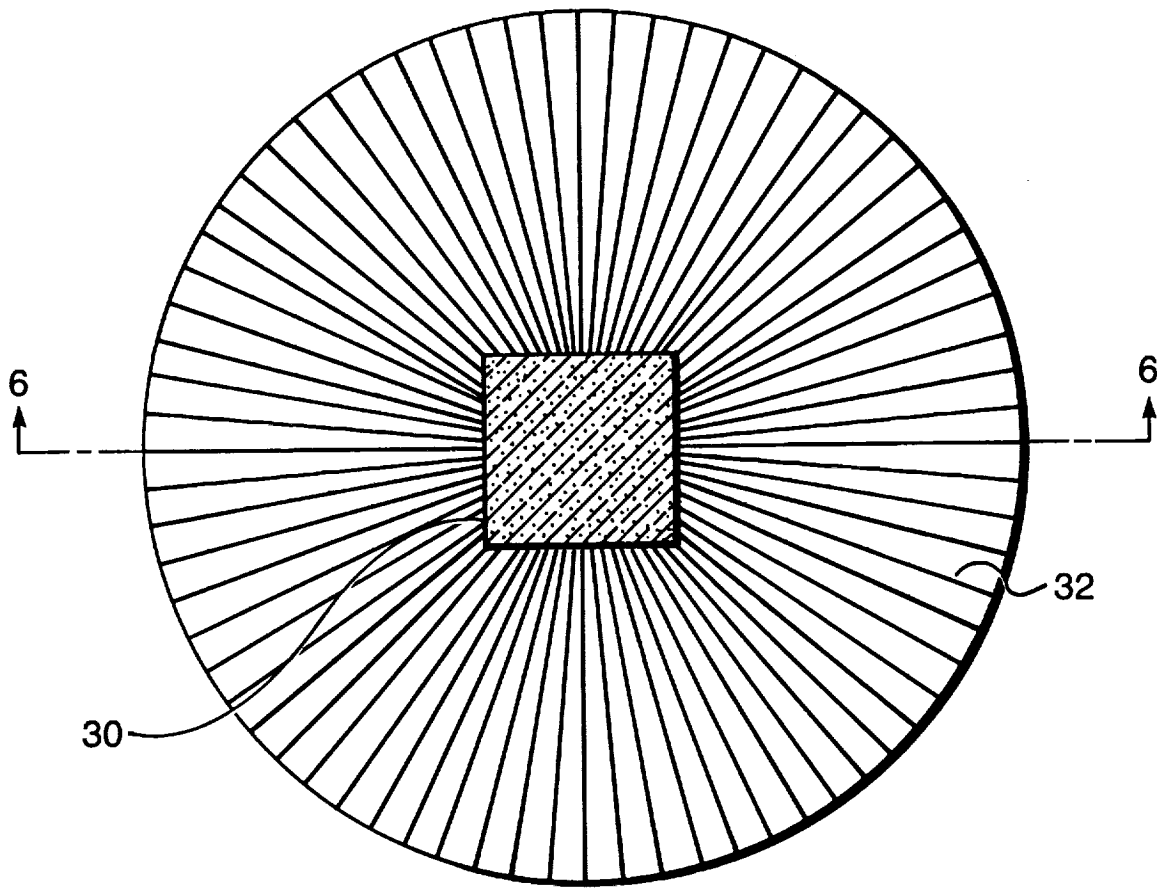


FIG. 5

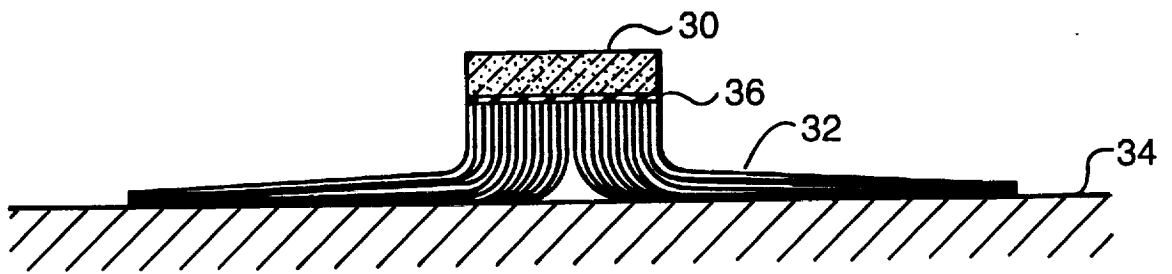


FIG. 6