

**MOLDABLE PELTIER THERMAL TRANSFER DEVICE
AND METHOD OF MANUFACTURING SAME**

CROSS REFERENCE TO RELATED APPLICATION

- [01] This application is related to and claims priority from earlier filed provisional patent application Serial No. 60/675,786, filed April 28, 2006, incorporated herein by reference.

BACKGROUND OF THE INVENTION

- [02] The present invention generally relates to devices for use in transferring or dissipating heat for purposes of thermal management. Moreover, the present invention relates to using such devices to cool parts and components, such as those in a computer system, so those parts do not fail over time. The present invention relates specifically to solid state heat transfer devices for these purposes.
- [03] In the prior art, there are many different types devices that can be used for thermal management, such as for cooling objects. These devices have particular application, for example, in thermal management within a computer environment. Typical thermal solutions include finned heat sinks and mechanical fans for cooling parts that run hot. However, these solutions can be expensive and inefficient.

[04] There are also a need for devices for use as sources of heat for various applications. For example, a hot plate may be used for heating a car seat or for raising the temperature of mechanical component for better operation thereof. These solutions have typically been coils with hot water therein or resistive wire that heat up when electricity is passed therethrough. However, these methods are expensive and inefficient.

[05] There have been attempts in the prior art to provide a solid state replacement for the aforementioned mechanical thermal solutions by using materials that exploit the Peltier effect. The Peltier effect is the creation of a heat difference from an electric voltage. More specifically, it occurs when a current is passed through two dissimilar metals or semiconductors, for example n-type and p-type material, that are connected to each other at two junctions, known as Peltier junctions. The current drives a transfer of heat from one junction to the other where one junction cools off while the other heats up.

[06] Referring to the circuit diagram of prior art Fig. 1, when a current I is made to flow through the circuit, heat is evolved at the upper junction (at T_2), and absorbed at the lower junction (at T_1).

The Peltier heat absorbed by the lower junction per unit time, $\dot{Q}$ is equal to:

$$[07] \quad \dot{Q} = \Pi_{AB} I = (\Pi_B - \Pi_A) I$$

[08] Where Π is the Peltier coefficient Π_{AB} of the entire thermocouple, and Π_A and Π_B are the coefficients of each material. P-type silicon typically has a positive Peltier coefficient, which is typically not above approximately 550 K while n-type silicon is typically negative.

[09] In this Peltier effect, the conductors are attempting to return to the electron equilibrium that existed before the current was applied by absorbing energy at one connector and releasing it at the other. The individual couples can be connected in series to enhance the Peltier effect. The direction of heat transfer is controlled by the polarity of the current, reversing the polarity will change the direction of transfer and thus the sign of the heat absorbed/evolved.

There have been attempts in the prior art to exploit the Peltier effect for cooling and heating purposes. For example, a Peltier cooler/heater or thermoelectric heat pumps are well known, which are solid-state active heat pumps which transfer heat from one side of the device to the other. Peltier coolers are also called TECs

(Thermo Electric Converter). These prior art solid state Peltier devices are plate-like in configuration and typically include an alternating array of P-type and N-type materials.

- [10] For example, a thermoelectric module 10, shown in Fig. 2, is an example of such a prior art Peltier device where only one P-N junction is shown for explanatory purposes. A typical thermoelectric module 10 is manufactured using two thin ceramic wafers 22, 24 with a series of N-type 12 and P-type 14 and semiconductor material, such as bismuth-telluride doped material, sandwiched between them. Electrical contacts 30 are also provided to deliver current from the power source 32. The ceramic material 22, 24 on both sides of the thermoelectric adds rigidity and the necessary electrical insulation from the heat sink 26 and the object 28 to be cooled. The N-type 12 material has an excess of electrons, while the P-type 14 material has a deficit of electrons. One N-type 12 and P-type 14 one make up a couple 34, as shown in prior art Fig. 2.

- [11] Thermoelectric couples 34 are arranged electrically in series and thermally in parallel. A thermoelectric module 10 can contain one to several hundred couples, for example. Prior art Fig. 3 shows an example of a prior art thermocouple device 10 that includes an

array of P-type material and N-type material in arranged in series. The N-type material 12 and P-type material 14 are specifically arranged in alternating rows where electrodes 16, 18 and 20 are provided in alternating fashion to connect the materials in series to create a string of N-P, P-N and N-P interfaces, and so on. In the device of Fig. 3, the electrodes 16 and 20 are positioned on the top of the plate while electrode 18 is positioned on the bottom of the plate. Typical insulative layers are not shown in Fig. 3 for clarity of illustration. This arrangement ensures that current flows from electrode 16 to 18 and then to 18. Large numbers of these plates can be stacked together with the appropriate dielectric insulative material therebetween, as described above.

- [12] While these prior art thermocouples may be useful in certain environments, they are only approximately 10% efficient because the joule heat and thermal backlash. Thus, in the prior art devices, a very low thermally conductive material must be used to prevent this thermal backlash. These prior art devices also suffer from the disadvantage that is it difficult and expensive to manufacture and is limited in its configuration to specific and precise alternating rows of N-type and P-type materials with precisely positioned alternating leads. Thus, the applications for such plate-like devices are limited

to such applications that can accommodate cooling devices of such a configuration. As a result, they cannot be easily formed into different shapes and configuration for using in different types of applications that require a cooling device that is not of a plate shape.

- [13] Therefore, there is a need for a Peltier type device that can be formed in any type of shape or configuration that is more efficient than prior art devices while still being able to serve as a cooling or heating device for thermal management.

SUMMARY OF THE INVENTION

- [14] The present invention preserves the advantages of prior art thermal transfer devices. In addition, it provides new advantages not found in currently available devices and overcomes many disadvantages of such currently available devices.

- [15] The invention is generally directed to the novel and unique thermal transfer device, which includes a body member having a base material of a first semiconductor material of a first type with a filler material dispersed therein of a second semiconductor material of a second type. Electrodes are attached on sides of the body member and electrical current is run therethrough to create thermal flow using the Peltier effect. As stated above, the direction of the

current flow dictates whether the device cools or heats. The device is formed by injection molding and the like and the filler is introduced into the base by, for example, extrusion or pultrusion processes.

[16] It is therefore an object of the present invention to provide a thermal transfer device that is easily moldable into any shape, size and configuration. It is an object of the present invention to provide a thermal transfer device that employs the Peltier effect and is moldable, such as by injection molding. Another object of the present invention is to provide a thermal transfer device where the thermal flow is controlled. A further object is to provide a Peltier thermal transfer device that is not limited to a plate shape and configuration.

BRIEF DESCRIPTION OF THE DRAWINGS

[17] The novel features which are characteristic of the present invention are set forth in the appended claims. However, the invention's preferred embodiments, together with further objects and attendant advantages, will be best understood by reference to the following detailed description taken in connection with the accompanying drawings in which:

- [18] Fig. 1 is a prior art circuit diagram illustrating the Peltier effect;
- [19] Fig. 2 is an elevational view of a prior art thermocouple employing the Peltier effect;
- [20] Fig. 3 is front perspective view of a prior art arrangement of multiple thermocouples arranged in series; and
- [21] Fig. 4 is a cross-sectional view of a thermocouple device in accordance with the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

- [22] The present invention solves the problems in the prior art by providing a new and unique Peltier thermocouple device that can be formed into a wide array of shapes, sizes and configuration and is more efficient than prior art Peltier thermocouple devices. The device of the present invention can be injection molded so it can be used in a wide range of thermal management applications thereby avoiding the limitation of prior art devices that are of a plate-shaped configuration.
- [23] As shown in Fig. 4, the device 100 present invention includes a base material 102 with filler 104 with electrodes 106 and 108 disposed on opposing ends thereof. In general, the device of the present invention provides a moldable base material of a first type

of semiconductor material that is filled with a second type of semiconductor material.

[24] More specifically, in accordance with the present invention, the base material 102 can be either an N-type or P-type material while the filler material is of the opposite type of the base material. For example, if the base material is selected to be an N-type material, then the filler material is selected to be P-type in nature. The materials can be any type of compatible N-type or P-type material. For example, the base and filler can be appropriately doped with bismuth to create the desired N-type and P-type semiconductor material. The filler material is preferably of a high aspect ratio (such as 5:1 or higher) to improve electrically interconnection through the body. Alternatively, the filler may be less than 5:1 in aspect ratio.

[25] In accordance with the present invention, the P-type material and N-type material can be any suitable material. Commonly used semiconducting materials can be used, such as silicon, germanium, gallium arsenide and indium phosphide. It should be understood that the present invention is in no way limited to use of these materials only. To achieve the an N-type material, a semiconductor material is doped with the appropriate element, such as antimony.

To achieve a P-type material, the semiconductor material is doped with the appropriate element, such as boron. Semiconductor materials and the doping thereof to achieve N-type and P-type materials are so well known in the art that they need not be discussed in further detail herein.

[26] The device 100 is shown to be of a block configuration for ease of illustration. However, as will be described below, the material is easily formable into different shapes and configurations because it is moldable, such as by injection molding. Across the body of the molded member, generally referred to as 110, of base material 102 and filler 104, shown in Fig. 4, electricity passes therethrough, namely through alternating filler material 104 and base material 102, namely alternating N-type and P-type material, from electrode 106 to electrode 108. Depending on the loading of the base material 102 with filler material 104, there can be dozens in not hundreds of P-N interfaces and, therefore, resultant P-N junctions than can employ the Peltier effect.

[27] The base material 102 is preferably of a higher electrical resistance to ensure flow of electricity through the filler 104 dispersed therein. Thus, the Peltier effect of N-P-N-P junctions can be reproduced effectively in the composite molded device of the

present invention. Heat propagates across the body 110 of the device from the negative (-) side to the positive (+) side as in all Peltier devices. In the device of Fig. 4, as above, the direction of current flow will dictate the direction of thermal flow.

[28] Known methods of injection molding material and introducing filler therein can be used to carry out the present invention. For example, pellets of N-type base material filled with P-type material filler or P-type base material filled with N-type material filler can be introduced into an injection molding machine for introduction into an injection mold having a cavity that defines a desired net shape for the cooling device. Alternatively, semiconductor material of a first type can be introduced into an injection molding machine while semiconductor material of a second type is introduced by an extrusion or pultrusion process. These processes are so well known in the art that they need not be discussed in further detail herein.

[29] As a specific example showing the effectiveness of the present invention, a base material of Bismuth (an N-type material) was loaded about 30% with Tellurium (a P-type material) and formed into a body with the approximate dimensions of 1.5 inch long, 0.5 inch wide and 0.25 inch high. The Tellurium was not melted or

alloyed with the Bismuth. Electricity of 1 volt at 2 amps was run through the body. It was measured that the body exhibited a temperature of 10°C below ambient temperature. As a result, formed body acted as a cooler employing the Peltier effect.

[30] For example, the composition of the present invention can be formed into the configuration of a heat sink assembly where the body of the heat sink is net-shape molded into a fin or pin array where the base of the heat sink carries a first electrode while all of the tips of the pins carry a second electrode. The electrode can be affixed onto the molded assembly after molded or directly overmolded, for example.

[31] The electrode on the base of the heat sink can be placed into thermal communication with a heat generating object, such as a microprocessor that is running hot. With the proper polarity of the current through the heat sink body, the object can be cooled where the heat is drawn away from the base of the heat sink and then up through the tips of the pins for optimal thermal transfer and management. Alternatively, the polarity of current flow can be reversed to reverse thermal flow for heating, such as for a car seat.

[32] Therefore, the present invention provides a new and useful Peltier thermocouple device that can be used for thermal

management. The new device can be formed using injection molding or other forming techniques to accommodate thermal management needs that cannot be met with prior art technology. The present invention is new and unique because it provides a net-shape moldable, such as by injection molding, composite material into any desired shape where Peltier cooling or heating can be achieved.

[33] It would be appreciated by those skilled in the art that various changes and modifications can be made to the illustrated embodiments without departing from the spirit of the present invention. All such modifications and changes are intended to be covered by the appended claims.

WHAT IS CLAIMED IS:

1. A thermal transfer device, comprising:

a body member having a base material of a first semiconductor material of a first type with a filler material dispersed therein of a second semiconductor material of a second type; the body member having a first side and a second side;

a first electrode connected to the first side;

a second electrode connected to the second side;

whereby passing electrical current through the body member via the first electrode and the second electrode causes thermal flow through the body member.
2. The device of claim 1, wherein the base material is manufactured of a P-type semiconductor material.
3. The device of claim 1, wherein the base material is manufactured of an N-type semiconductor material.
4. The device of claim 1, wherein the filler material is manufactured of a P-type semiconductor material.
5. The device of claim 1, wherein the filler material is manufactured of a N-type semiconductor material.
6. The device of claim 1, wherein the filler material has an aspect ratio of 5:1 or greater.

7. A method of manufacturing a thermal transfer device, comprising the steps of:

providing a moldable base material of a first semiconductor material of a first type;

filling the base material with a filler material of a second semiconductor material of a second type;

forming the moldable base material, with filler dispersed therein, into a body member having a first side and a second side;

attaching a first electrode to the first side;

attaching a second electrode connected to the second side; and

whereby passing electrical current through the body member causes thermal flow through the body member.

8. The device of claim 7, wherein the base material is manufactured of a P-type semiconductor material.

9. The device of claim 7, wherein the base material is manufactured of an N-type semiconductor material.

10. The device of claim 7, wherein the filler material is manufactured of a P-type semiconductor material.

11. The device of claim 7, wherein the filler material is manufactured of an N-type semiconductor material.

12. The device of claim 7, wherein the filler material has an aspect ratio of 5:1 or greater.
13. The device of claim 7, wherein the base is filled with filler by pultrusion.
14. The device of claim 7, wherein the base is filled with filler by extrusion.