A module for cooling a heat generating element comprising a heat receiving plate thermally connected to at least one heat generating element; a heat transfer device one end portion of which is thermally connected to the heat receiving plate and other end portion of which is thermally connected to a heat dissipating plate; a thermoelectric cooler one face of which is thermally connected to one face of the heat dissipating plate; a first heat sink thermally connected to other face of the heat dissipating plate; and a second heat sink thermally connected to other face of said thermoelectric cooler.
Fig. 2-1

(a) COP vs. Temperature difference (Th, Te)

(b) Temperature difference in TEC vs. Power introduced in TEC (W)

- 16 CFM
- 20 CFM
- 24 CFM
- 30 CFM
Fig. 2-9

Thermal resistance in a whole cooling system

- vertical fin 10mm
- vertical fin 20mm
- vertical fin 30mm
- vertical fin 40mm
- vertical fin 50mm
- without TEC
- with only TEC

Thermal resistance (°C/W) vs. power introduced in TEC (W)
MODULE FOR COOLING SEMICONDUCTOR DEVICE

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] The present application is a continuation application of U.S. patent application Ser. No. 10/985,412, filed on 11 Nov. 2004, the entire contents of which are incorporated herein by reference. The Ser. No. 10/985,412 application claimed the benefit of the date of the earlier filed Provisional Application No. 60/552,149 filed 11 Mar. 2004. Priority under 35 U.S.C. § 119(a) is also hereby claimed from Japanese Application No. 2004-221766, filed 29 July 2004, the disclosure of which is also incorporated herein by reference.

FIELD OF THE INVENTION

[0002] The present invention relates to a cooling device for cooling an element to be cooled having a high heat generating density such as semiconductor elements using a thermoelectric cooler (which is also referred to as TEC), for example a Peltier cooler.

BACKGROUND OF THE INVENTION

[0003] Recently, an electronic appliance includes high power and densely integrated components such as microprocessor therein. Since the microprocessor is densely integrated and processes computing and control at high speed, a large amount of heat is generated. Various cooling systems are proposed to cool chips which are high power and densely integrated components. A heat pipe or Peltier device is represented as one of the typical cooling systems.

[0004] The heat pipe comprises a round pipe shaped heat pipe and a flat shaped heat pipe. The flat heat pipe is favorably applied for cooling a component to be cooled of an electronic device such as a CPU, or the like due to the fact that the heat pipe can be easily attached to the component to be cooled, and the heat pipe has a large contact area.

[0005] Furthermore, the heat pipe is classified by the manner to be attached to the component to a top heat mode heat pipe in which a heat absorbing side of the heat pipe is positioned above a heat dissipating side thereof, and a bottom heat mode heat pipe in which the heat absorbing side of the heat pipe is positioned below the heat dissipating side thereof. In the bottom heat mode heat pipe, a working fluid circulates by the gravity. However, in the top heat mode heat pipe, the working fluid has to be circulated by the gravity, thus a capillary phenomenon of a wick is introduced in the heat pipe in general.

[0006] A hollow space is prepared within the heat pipe which functions as a passage for working fluid. Heat is transferred by a phase transition between vaporization and condensation as well as movement of the working fluid. The heat pipe having a sealed hollow portion in which the working fluid is phase-transited and moved so as to transfer heat is operated as follows:

[0007] In the heat absorbing side of the heat pipe, the heat generated by the component to be cooled and conducted through the material forming the container of the heat pipe is absorbed to vaporize the working fluid. The vaporized working fluid is transferred to the heat dissipating side of the heat pipe. In the heat dissipating side of the heat pipe, the vaporized working fluid is condensed to release the latent heat and returned to a fluid phase working fluid. The working fluid returned to a fluid phase circulates back to the heat absorbing side. Thus, the heat is transferred by the phase transition and movement of the working fluid.

[0008] In a gravity-type heat pipe, the working fluid returned to a liquid state by the phase transition moves (i.e., circulates) to the heat absorbing side of the heat pipe by gravity.

[0009] Furthermore, recently, since a semiconductor device processing high speed signal generates larger amount of heat, the above mentioned heat pipe does not fully cool the device. In order to cool the semiconductor device generating large amount of heat, a cooling device in which a thermoelectric cooler such as peltier device is directly attached to the semiconductor device is proposed.

[0010] In general, when two kinds of conductors A, B are connected, and a current flows at a constant temperature, the heat is generated or absorbed at a contact point of the conductors A and B, which is called as Peltier effect. A Peltier element uses the principle. More specifically, p-type thermoelectric semiconductor elements and n-type thermoelectric semiconductor elements are arranged alternately in parallel, and electrodes are placed at both ends of each of the semiconductor element. Both ends of the respective semiconductor elements and the electrodes are joined by soldering. Each of the p-type semiconductor elements and the n-type semiconductor elements, which are arranged alternately in parallel, are electrically connected in series through the corresponding electrodes.

[0011] Furthermore, an electric circuit which is formed by the electrodes, the p-type semiconductor elements, and the n-type semiconductor elements are electrically insulated from outside by a pair of electrically insulated substrates which are arranged outside of the respective electrodes. The electrodes and the electrically insulated substrates are jointed by soldering. Thus, the Peltier device has a construction in which the electric circuit formed by the electrodes, the p-type semiconductor elements, and the n-type semiconductor elements are sandwiched by two electrically insulated substrates. By the above described Peltier device, the heat at one of the electrically insulated substrates is transferred to the other electrically insulated substrate so that the one electrically insulated substrate side is cooled.

[0012] Conventionally, for example, as disclosed in Japanese Patent Provisional Publication No. 2004-071969 (cf. FIG. 2-10), it is known that the heat from the heat generating source is spread by a heat receiving-spreading device, and the low temperature side of the Peltier device is attached to the heat receiving-spreading device, thus the heat is input into the Peltier device. A copper heat sink is attached to the high temperature side of the Peltier device. More specifically, as shown in FIG. 2-11, in the conventional cooling device 100, a heat receiving-spreading device 101 is thermally connected to a heat generating source 103. A cooling face of the thermoelectric device 102 is connected to the heat receiving-spreading device 101, and a heat dissipating face of the thermoelectric device 102 is connected to a heat sink 104.

[0013] However, there are the following problems in the conventional method in which the lower temperature side of the Peltier device is attached to the heat generating source while the higher temperature side of the Peltier device is attached to the heat sink.

[0014] When the heat from the heat generating source (for example, CPU) increases, the heat absorbing of the Peltier device (TEC) is not sufficient so that the thermal resistance of
the cooling module rises. More specifically, it becomes difficult to enlarge the temperature difference between the heat sink and the cooling air, thus deteriorating the cooling efficiency. For example, although the required temperature difference for the heat generating source of 120 W is 15 degree centigrade, the temperature difference obtained by the easily available Peltier device is at the most 12 degree centigrade. It becomes difficult to sufficiently cool the heat generating source by the thermoelectric device, when the heat from the CPU is over 120 W under the condition of a spreading resistance of 0.10 K/W in the heat receiving-spreading device.

[0015] In addition, it is generally known that each component of the conventional cooling device is thermally connected by the use of a thermal grease. However, it is difficult to control a thickness of the thermal grease, leading to a large variation of the contact resistance between components. When the thickness of the grease is large, a total thermal resistance of the cooling module becomes high.

SUMMARY OF THE INVENTION

[0016] One object of the invention is to provide a heat sink for cooling a semiconductor element generating a large amount of heat, which enlarges a temperature difference between the heat sink and the cooling air to improve a cooling efficiency.

[0017] Another object of the invention is to provide a module for cooling a high heat generating element which reduces the heat absorbed by the thermoelectric device to have a small power consumption with low fan noise, and enables to be applied to a small system, in addition to have a wide design choice.

[0018] Inventors have intensely studied to overcome the above-described problems in the conventional devices. As a result, it has been found that when at least part of the heat transferred to the heat receiving/spreading module from the heat generating source is transferred by the heat pipe to another direction to reduce the heat passing through the thermoelectric cooler, the temperature difference in the thermoelectric cooler can be enlarged so that the power consumption in the thermoelectric cooler is reduced to improve a heat efficiency of the cooling module.

[0019] Furthermore, it has been found that when the heat transferred by the heat pipe to another direction is thermally connected with to the upper portion of the heat sink, the fan efficiency is improved and the heat efficiency of the cooling module can be improved, while a large heat sink is used as the heat sink connected to the thermoelectric cooler in the conventional device and the fan efficiency in the conventional device is about 80%.

[0020] The present invention was made on the basis of the above study results. A first embodiment of the module for cooling a semiconductor element is a module comprising a heat receiving/spreading device thermally connected to at least one heat generating element; a thermoelectric cooler thermally connected to said heat receiving/spreading device; a heat sink thermally connected to said thermoelectric cooler, and a heat pipe thermally connected to said heat receiving/spreading device to transfer a heat of said heat generating element in another direction, wherein the heat of said heat generating element is divided into at least two directions to be transferred and dissipated.

[0021] In a second embodiment of the module for cooling a semiconductor element, another heat sink is thermally connected to other end of said heat pipe to transfer a main portion of heat from said heat generating element, and to transfer a remaining portion of the heat through said thermoelectric cooler.

[0022] In a third embodiment of the module for cooling a semiconductor element, said heat sink comprises a first heat sink and a second heat sink, said first heat sink is thermally connected to said thermoelectric cooler, said second heat sink is installed above the first heat sink, other end of said heat pipe is thermally connected to said second heat sink, a main portion of heat from said heat generating element is transferred to said second heat sink by said heat pipe, and a remaining portion of the heat from said heat generating element is transferred to said first heat sink through said thermoelectric cooler.

[0023] In a fourth embodiment of the module for cooling a semiconductor element, said heat pipe comprises a U-shaped round heat pipe having a prescribed elasticity, said thermoelectric cooler and said first heat sink are arranged to be sandwiched by said second heat sink and said heat receiving/spreading device to lower a contact heat resistance.

[0024] In a fifth embodiment of the module for cooling a semiconductor element, a cooling fan is installed to said second heat sink.

[0025] In a sixth embodiment of the module for cooling a semiconductor element, a soft metal foil as a thermal interface material is arranged between said heat receiving/spreading device and said thermoelectric cooler, as well as between said thermoelectric cooler and said heat sink, respectively.

[0026] In a seventh embodiment of the module for cooling a semiconductor element, through holes are provided in corresponding prescribed positions in said heat receiving/spreading device, said thermoelectric cooler and said heat sink, respectively, and said heat receiving/spreading device, said thermoelectric cooler and said heat sink are fastened by corresponding screws.

[0027] In an eighth embodiment of the module for cooling a semiconductor element, a fastening force is controlled so as to be a constant torque.

[0028] In a ninth embodiment of the module for cooling a semiconductor element, a heat generated in said heat generating element is at least 100 W.

[0029] In a tenth embodiment of the module for cooling a semiconductor element, another heat pipe is thermally connected to said heat receiving/spreading device to transfer a heat from another heat generating element to said heat receiving/spreading device.

[0030] Furthermore, the inventors have intensely studied to overcome the above described problems in the conventional devices. As a result, it has been found that the heat absorbed by the thermoelectric device can be reduced by the following module, i.e., the heat receiving plate and the heat dissipating plate are thermally connected by a heat transfer device, then a heat sink is thermally connected to one face of the heat dissipating plate and the thermoelectric device is thermally connected to the other face of the heat dissipating plate, and in addition, another heat sink is thermally connected to a heat dissipating face of the thermoelectric device. Together with the above, a prescribed temperature difference can be obtained while maintaining small power consumption of the thermoelectric device. As a result, it is possible to downsize a heat sink and to reduce noise of the fan, leading to downsizing the module. Furthermore, it has been found that since the heat receiving plate and the heat dissipating plate are thermally connected by the heat transfer device such as a heat pipe,
cooling water pump or the like, the heat dissipating plate can be appropriately arranged, thus having a wide design choice.

[0031] The present invention was made on the basis of the above study results. An eleventh embodiment of the module for cooling a heat generating element comprises a heat receiving plate thermally connected to at least one heat generating element; a heat transfer device one end portion of which is thermally connected to said heat receiving plate and other end portion of which is thermally connected to a heat dissipating plate; a thermoelectric cooler one face of which is thermally connected to one face of said heat dissipating plate; a first heat sink thermally connected to other face of said heat dissipating plate; and a second heat sink thermally connected to other face of said thermoelectric cooler.

[0032] In a twelfth embodiment of the module for cooling a heat generating element, said heat transfer device comprises a heat pipe.

[0033] In a thirteenth embodiment of the module for cooling a heat generating element, said heat transfer device comprises a forcible circulation device to transfer heat by forcibly circulating a cooling medium.

[0034] A fourteenth embodiment of the module for cooling a heat generating element comprises a heat receiving/dissipating plate one face of one end portion of which is thermally connected to at least one heat generating element, one face of other end portion of which is thermally connected to one face of a thermoelectric cooler, other face of said other end portion of which is thermally connected to a first heat sink; and a second heat sink thermally connected to other face of said thermoelectric cooler.

[0035] In a fifteenth embodiment of the module for cooling a heat generating element, said heat dissipating plate, said thermoelectric cooler, said first heat sink and said second heat sink are arranged so as to be substantially perpendicular to said heat receiving plate.

[0036] In a sixteenth embodiment of the module for cooling a heat generating element, said heat dissipating plate, said thermoelectric cooler, said first heat sink and said second heat sink are arranged so as to be substantially parallel to said heat receiving plate.

[0037] In a seventeenth embodiment of the module for cooling a heat generating element, a third heat sink is further thermally connected to said heat receiving plate.

[0038] In an eighteenth embodiment of the module for cooling a heat generating element, said first heat sink comprises said heat dissipating plate or said heat receiving/dissipating plate and a plurality of fin plates fixed thereon by crimping.

[0039] In a nineteenth embodiment of the module for cooling a heat generating element, said second heat sink comprises a base plate and a plurality of fin plates fixed on said base plate by crimping.

[0040] In a twentieth embodiment of the module for cooling a heat generating element, said third heat sink comprises said heat receiving plate and a plurality of fin plates fixed on said heat receiving plate by crimping.

[0041] In a twenty first embodiment of the module for cooling a heat generating element, said heat transfer device is fixed to said heat receiving plate by crimping.

[0042] In a twenty second embodiment of the module for cooling a heat generating element, said heat transfer device is fixed to said heat dissipating plate by crimping.

[0043] In a twenty third embodiment of the module for cooling a heat generating element, micro-channels are provided in said heat receiving plate, a cooling fluid boiled and vaporized in said micro-channels is moved to said heat dissipating plate in a state of gas phase and returned there to fluid state, and then the cooling fluid thus returned to the fluid state circulates to said heat receiving plate by means of said forcible circulation device.

BRIEF DESCRIPTION OF DRAWINGS

[0044] FIG. 1-1 is a schematic view explaining one embodiment of the module for cooling a semiconductor element of the invention and the heat flow therein;

[0045] FIG. 1-2 is a disassembled schematic view of the module for cooling a semiconductor element of the invention;

[0046] FIG. 1-3 is a schematic view of the module for cooling a semiconductor in which components shown in FIG. 1-2 are assembled;

[0047] FIG. 1-4 is a schematic view explaining other embodiment of the module for cooling a semiconductor element of the invention and the heat flow therein;

[0048] FIG. 1-5 is a disassembled schematic view of one embodiment of the module for cooling a semiconductor element of the invention;

[0049] FIG. 1-6 is a schematic view of the module for cooling a semiconductor in which components shown in FIG. 1-5 are assembled;

[0050] FIG. 1-7 is a schematic view explaining one embodiment of the module for cooling a semiconductor element of the invention;

[0051] FIG. 1-8 is a schematic view explaining other embodiment of the module for cooling a semiconductor element of the invention;

[0052] FIG. 1-9 is a schematic view explaining other embodiment of the module for cooling a semiconductor element of the invention;

[0053] FIG. 2-1 is a graph showing a relationship between COP (heat from the heat source/TEC driving power) and temperature difference of both surfaces of TEC;

[0054] FIG. 2-2 is a schematic view of one embodiment of the module of the invention for cooling a heat generating element;

[0055] FIG. 2-3 is a schematic view showing a flow of the heat from the heat source in the module for cooling a heat generating element as shown in FIG. 2;

[0056] FIG. 2-4 is a schematic view explaining another embodiment of the module of the invention for cooling a heat generating element;

[0057] FIG. 2-5 is a schematic view explaining another embodiment of the module of the invention for cooling a heat generating element;

[0058] FIG. 2-6 is a schematic view explaining another embodiment of the module of the invention for cooling a heat generating element;

[0059] FIG. 2-7 is a schematic view explaining another embodiment of the module of the invention for cooling a heat generating element;

[0060] FIG. 2-8 is a schematic view explaining another embodiment of the module of the invention for cooling a heat generating element;

[0061] FIG. 2-9 is a graph showing a relationship between the power impressed to the TEC and heat resistance;

[0062] FIG. 2-10 is a schematic view showing a conventional module; and
FIG. 2-11 is a schematic view showing a construction of the conventional module.

**DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS**

[0064] The module for cooling a semiconductor element of the invention is described in detail with reference to the drawings.

[0065] One embodiment of the module for cooling a semiconductor element is a module comprising a heat receiving/spreading device thermally connected to at least one heat generating element; a thermoelectric cooler thermally connected to the heat receiving/spreading device; a heat sink thermally connected to the thermoelectric cooler; and a heat pipe thermally connected to the heat receiving/spreading device to transfer a heat of the heat generating element in another direction, wherein the heat of the heat generating element is divided into at least two directions to be transferred and dissipated.

[0066] FIG. 1-1 is a schematic view explaining one embodiment of the module for cooling a semiconductor element of the invention and the heat flow therein. As shown in FIG. 1-1, in the module 1 for cooling a semiconductor of the invention, the heat of the heat generating source 5 (for example, about 200 W is generated therein) is transferred to the heat receiving/spreading device 2 through the thermal interface material 8-3. One end 6a of the heat pipe 6 is thermally connected to the heat receiving/spreading device 2 to transfer the large portion (for example, 150 W) of the heat in another direction, and to transfer the remaining portion (for example, 50 W) of the heat through the thermoelectric cooler 3. The cooling face of the thermoelectric cooler 3 is thermally connected to the heat receiving/spreading device 2 through the thermal interface material 8-1. The heat sink 4 is thermally connected to the heat dissipation face of the thermoelectric cooler 3 through the thermal interface material 8-2. Another heat sink 7 is thermally connected to other end of the heat pipe 6b. Since the amount of the heat passing through the thermoelectric element 3 is reduced as described above, the thermoelectric element 3 can fully function to enlarge the temperature difference in the thermoelectric element. Thus, the temperature in the lower temperature side of the thermoelectric element is lowered, and furthermore, the temperature in the upper portion of the heat sink 7 is raised by the heat pipe 6 so that the fan efficiency is maximized to improve a cooling efficiency as the cooling module.

[0067] FIG. 1-2 is a disassembled schematic view of one of the module for cooling a semiconductor element of the invention.

[0068] As shown in FIG. 1-2, in the module 1 for cooling a semiconductor element of the invention, the heat of the heat generating source (not shown) is transferred to the heat receiving/spreading device 2. Respectively end 6a of the plurality of heat pipes 6 are thermally connected to the heat receiving/spreading device 2, and the respective end 6b of the plurality of heat pipes 6 are thermally connected to another heat sink 7. On the other hand, the cooling face of the thermoelectric element 3 is thermally connected to the heat receiving/spreading device 2, and furthermore, the heat sink 4 is thermally connected to the heat dissipating face of the thermoelectric element 3. Most of the heat is therefore transferred in the direction to another heat sink 7 by the heat pipe, and the remaining heat is transferred through the thermoelectric element 3 to the heat sink 4. The power driven fan 20 is attached to the other heat pipe to dissipate the air with the temperature raised out of the box, for example. Thus, a large portion of the heat is transferred in another direction by the heat pipe to reduce the heat passing through the thermoelectric element 3. As a result, thermoelectric element can fully function to enlarge the temperature difference. For example, the semiconductor generating the heat of about 200 W can be effectively cooled.

[0069] FIG. 1-3 is a schematic view of the module for cooling a semiconductor in which components shown in FIG. 1-2 are assembled.

[0070] As shown in FIG. 1-3, both of the heat transferred to the heat sink 4 through the heat receiving/spreading device and the thermoelectric element, and the heat transferred to another heat sink 7 by the heat pipe are forcefully dissipated out of the box by the power driven fan.

[0071] FIG. 1-4 is a schematic view explaining other embodiment of the module for cooling a semiconductor element of the invention and the heat flow therein. As shown in FIG. 1-4, the heat of the heat generating source 5 (for example, the generated heat of about 200 W) is transferred to the heat receiving/spreading device 2 through the thermal interface material 8-3 in the module 1 for cooling a semiconductor element of the invention. Then the heat is further transferred by the heat pipe 6 and the thermoelectric element 3 thermally connected to the heat receiving/spreading device 2. One end 6a of the heat pipe 6 is thermally connected to the heat receiving/spreading device 2 to transfer the most of the heat (for example, 150 W) in a different direction from the direction passing the thermoelectric cooler while the remaining of the heat (for example, 50 W) is transferred through the thermoelectric element 3.

[0072] More specifically, the heat receiving/spreading device 2 is thermally connected to the cooling face of the thermoelectric cooler through the thermal interface material 8-1, and the heat sink 4 is thermally connected to the heat dissipating face of the thermoelectric cooler 3 through the thermal interface material 8-2. The other end 6b of the heat pipe 6 is inserted and fixed into the hole formed in the upper portion of the heat dissipating fin of the heat sink 4 to be thermally connected thereto. Since the amount of the heat passing through the thermoelectric cooler 3 is reduced, the thermoelectric cooler 3 fully functions to enlarge the temperature difference therein. Furthermore, since the part of the heat of the heat generating source is directly transferred by the heat pipe to the upper portion of the heat dissipating fins, the temperature in the upper portion of the heat dissipating fins is raised to improve the fin efficiency. The number of the heat pipes extending to the upper portion of the heat dissipating fins is decided on the amount of the heat passing through the thermoelectric cooler.

[0073] FIG. 1-5 is a disassembled schematic view of one embodiment of the module for cooling a semiconductor element of the invention. In the embodiment of the module for cooling a semiconductor element, the other end of the heat pipe is inserted and fixed in the heat dissipating fins of the heat sink. More specifically, respective ends of two heat pipes 6 are inserted and fixed in the heat receiving/spreading device 2. The heat receiving/spreading device 2 is thermally connected to the cooling face of the thermoelectric cooler 3 through the thermal interface material 8-1, and the base plate 4 of the heat sink is thermally connected to the heat dissipating face of the thermoelectric cooler 3 through the thermal interface material
The other end \(6b\) of the heat pipe \(6\) is inserted through the hole formed in the heat dissipating fins \(9\) of the heat sink and fixed therein.

The heat receiving/spreading device comprises a metal plate having excellent heat conductivity such as copper or a plate type heat pipe. The heat receiving/spreading device may comprises a device using a heat pipe. The thermal interface material may be made of a metal foil having a small yield stress and excellent heat conductivity such as indium.

Through holes \(301\) are formed in the four respective corners of the thermoelectric cooler, screw-holes \(201\) are formed in the corresponding position of the heat receiving/spreading device to the positions of the above through holes \(301\), and through holes \(301\) are formed in the corresponding position of the thermal interface material \(8-1\) to the positions of the above through holes \(301\). Furthermore, through holes \(802\) are formed in the corresponding positions of the thermal interface material \(8-2\) to the positions of the above through holes \(301\), and through holes \(401\) are formed in the corresponding positions of the heat sink \(4\) to the positions of the above through holes \(301\).

To fix the components of the module for cooling a semiconductor element, screws \(600\) are inserted through the through holes \(301, 301, 802, 401\) and into the screw hole \(201\), and then, the screws \(600\) are fastened so that the fastening torque is constant, thus the contact pressure of the components becomes to be a prescribed value. The relationship between the fastening torque and the pressure is expressed as follows:

\[
T = \frac{d_{f} \cdot PS \cdot \tan(\mu)}{2N}
\]

Where:
- \(T\): fastening torque \(d_{f}\): effective diameter
- \(P\): screw pitch \(\mu\): friction angle
- \(S\): thermal contact area \(P\): contact pressure
- \(N\): number of screws

Since the thermal interface materials respectively sandwiched by the thermoelectric cooler \(3\) and the heat receiving/spreading device \(2\), as well as the thermoelectric cooler \(3\) and the heat sink are made of a soft metal foil, the thermal interface materials are crushed to a specific thickness and contacted with and filled in the uneven surfaces of the components. The contact heat resistance of the respective components can be small by the above-mentioned effect of the thermal interface material, and excellent heat conductivity of the metal foil.

The metal foil may be silver foil, tin foil or the like in addition to indium foil.

FIG. 1-6 is a schematic view of the module for cooling a semiconductor element in which components shown in FIG. 1-5 are assembled.

As shown in FIG. 1-6, according to the present invention, a compact module for cooling a semiconductor element can be provided.

FIG. 1-7 is a schematic view explaining one embodiment of the module for cooling a semiconductor element of the invention.

This embodiment of the module for cooling a semiconductor element includes a first heat sink to which the heat is transferred through the thermoelectric cooler, and a second heat sink to which the heat is transferred by the heat pipe. The above-mentioned two heat sink are placed vertically and thermally isolated.

More specifically, this embodiment of the module for cooling a semiconductor element includes a heat receiving/spreading device thermally connected to at least one heat generating element, a thermoelectric cooler thermally connected to the heat receiving/spreading device, a first heat sink thermally connected to the thermoelectric cooler, a heat pipe thermally connected to the heat receiving/spreading device to transfer the heat in another direction, and a second heat sink thermally connected to the other end of the heat pipe. The second heat sink is placed above the first heat sink, the main portion of the heat from the heat generating element is transferred by the heat pipe to the second heat sink while the remaining portion of the heat from the heat generating element is transferred through the thermoelectric cooler to the first heat sink.

As shown in FIG. 1-7, the module 1 for cooling a semiconductor element includes the heat receiving/spreading device 2 thermally connected to the heat generating element, the thermoelectric cooler 3 thermally connected to the heat receiving/spreading device 2, the first heat sink 4 thermally connected to the thermoelectric cooler, and the heat pipe 6 with one end \(6a\) thermally connected to the heat receiving/spreading device 2 to transfer the heat from the heat generating element in another direction. The other end \(6b\) of the heat pipe 6 is thermally connected to the second heat sink 7.

The second heat sink 7 is placed above the first heat sink 4, and the main portion of the heat from the heat generating element is transferred by the heat pipe 6 to the second heat sink 7 while the remaining portion of the heat from the heat generating element is transferred through the thermoelectric cooler 3 to the first heat sink 4. The power driven fan is further attached on the second heat sink 2 to forcefully dissipates out of the box for example the heat transferred to the first heat sink and the second heat sink.

The first heat sink and the second heat sink are placed to be thermally isolated with about 1 mm space.

Furthermore, as shown in FIG. 1-7, the heat pipes are bent to be U shape, and the heat dissipating fins are fixed to the heat pipes. Thus prepared heat pipes with heat dissipating fins are placed above the fins attached to the high temperature side of the thermoelectric cooler. Accordingly, the module for cooling a semiconductor element can be downsized.

FIG. 1-8 is a schematic view explaining another embodiment of the module for cooling a semiconductor element of the invention. As shown in FIG. 1-8, in case that a plurality of heat generating elements exist, a protruding portion or a recessed portion 2-1 is provided with the heat receiving/spreading device 2 per se. Even in this embodiment, the other end of the heat pipe may be connected to the heat sink which is connected to the heat dissipating face of the thermoelectric cooler 3 through thermal interface material 8-2. Furthermore, the heat receiving/spreading device with a protruding or recessed portion may be applied to the module for cooling a semiconductor element with the first and second heat sinks, as explained with reference to FIG. 7.

FIG. 1-9 is a schematic view explaining other embodiment of the module for cooling a semiconductor element of the invention. In this embodiment of the module for cooling a semiconductor element, another heat pipe is ther-
mally connected to the heat receiving/spreading device to transfer the heat from another heat generating element.

[0094] As shown in FIG. 1-9, in case that the heat generating source 5-1 to be mainly cooled is positioned apart from another heat generating source 5-2 generating small heat, another heat pipe 6-2 is thermally connected to the heat receiving/spreading device 2 to transfer the heat from the other heat generating source 5-2 to the heat receiving/spreading device 2. The other heat generating source 5-2 is thermally connected to the heat receiving block through the thermal interface material 8-3, and one end of the another heat pipe is thermally connected to the heat receiving block. After the heat is transferred to the heat receiving/spreading device, various embodiment as described above may be applied thereto.

[0095] In addition, as shown in FIG. 1-2, a clip 30 may be used to fix the heat receiving/spreading device 2, the thermoelectric cooler 3, and the heat sink as thermally contacted. A prescribed notch to receive the clip may be provided with the heat dissipating fin of the heat sink.

[0096] As described above, according to the present invention, amount of the heat absorbed by the thermoelectric cooler is reduced in comparison with the conventional module, a consumption power of the thermoelectric cooler necessary for cooling is reduced, thus improving the heat efficiency of the cooling module. Furthermore, since it is not necessary to prepare new space for a tool for fixing the components, the cooling module of small size can be provided. In addition, since parts such as fixing tool except screws are not required, the number of the parts is reduced, thus enabling to provide a cooling module with easily assembled at low cost. Since the contact heat resistance between the components can be the same value, the dispersion thereof becomes small. Since the metal foil easily crushed in a thickness direction and having an excellent heat conductivity is used, the contact heat resistance can be reduced to provide a cooling module having excellent cooling efficiency. Furthermore, it is possible to make the contact pressure of the components be constant, thus enabling to provide a cooling module with small heat resistance at low cost.

[0097] Furthermore, other embodiments of the module for cooling a heat generating element are described with reference to the drawings.

[0098] FIG. 2-1 is a graph showing a relationship between an operational coefficient COP (heat from the heat source/TEC driving power) and temperature difference of the both surfaces of the TEC. FIG. 2-1-A is a graph showing a theoretical value between COP and temperature difference of both surfaces of the TEC. FIG. 2-1-B is a graph showing experimental value when COP=3.

[0099] The graph showing the theoretical value between COP and temperature difference of both surfaces of the TEC is disclosed in “Extending the limits of air cooling with thermoelectrically enhanced heat sinks”, Jim Bierchenk et. al., 2004 Inter Society Conference on Thermal phenomena proceeding, pp 679–681, 2004.

[0100] As shown in FIG. 2-1-A, when the value of COP is decided, the temperature difference between the both ends of the TEC is decided, even though an amount of the generated heat varies. As shown in FIG. 2-1-B, when COP=3, the temperature difference is about 12 degree Centigrade and constant, where, CFM (Cubic Feet Per Minutes) shows a cooling air flow rate.

[0101] As described above, it is known that a thermal resistance of over all heat dissipating module is lowered by a negative thermal resistance obtained by the TEC. More specifically, the following equation is established:

\[
(\text{Thermal resistance of the heat dissipating module}) = (\text{Thermal resistance of the heat spreading/heat transfer device}) + (\text{Negative thermal resistance obtained by the TEC})
\]

[0102] As shown in FIG. 2-1, when COP (which is represented as a ratio of the heat absorbing amount of the TEC to the driving power of the TEC) is fixed to be a constant value, the temperature difference between the high temperature side and the low temperature side of the TEC becomes constant. However, when the generated heat of the CPU is increased, an absolute apparent negative thermal resistance obtained by the TEC becomes small. Thus, it becomes necessary to lower the thermal resistance of the heat spreading/heat transfer device and the thermal resistance of the heat dissipating heat sink, or it is necessary to increase the driving power of the TEC so that the over all thermal resistance of the heat dissipating module is lowered.

[0103] According to the conventional method, in order to realize a heat spreading/heat transfer device having a low thermal resistance, it is necessary to have a complex inner structure of the vaporizing portion, which is technically difficult. Furthermore, in order to realize a heat dissipating heat sink having a low thermal resistance, it is necessary to increase heat transfer area, thus the cooling module becomes larger and the weight of the module increases. In addition, in order to realize the heat sink having a low thermal resistance, it is necessary to apply a large fan so as to increase the cooling air flow rate, thus it is impossible to apply to the small scale system. On the other hand, when small size fan having a high cooling air flow rate, noise of the fan becomes large.

[0104] Furthermore, when the temperature difference in the TEC is set to be large, a large-scale power source with a larger capacity has to be used so that the consuming power of the TEC increases, thus it is difficult to apply to the small-scale system. In addition, the power source with the larger capacity needs a large cooling fan and a large heat sink to dissipate the heat of the power source per se, thus the system becomes larger. Furthermore, since the heat dissipated from the high temperature side of the TEC (which is represented by a total of the heat of the heat source and the driving power of the TEC) becomes large, a large heat sink is necessary to cool the above heat.

[0105] In the present invention, different from the above-mentioned conventional method, a heat receiving plate and a heat dissipating plate are thermally connected by a heat transfer device, a heat sink is thermally connected to one face of the heat dissipating plate and a thermoelectric cooler (TEC) is thermally connected to the other face of the heat dissipating plate, and furthermore, another heat sink is thermally connected to a heat dissipating face of the TEC. By means of the above-mentioned construction, the heat absorbed by the TEC is designed to be small.

[0106] More specifically, one of the embodiment of the module for cooling a heat generating element of the invention
comprises a heat receiving plate thermally connected to at least one heat generating element; a heat transfer device one end portion of which is thermally connected to said heat receiving plate and other end portion of which is thermally connected to a heat dissipating plate; a thermoelectric cooler one face of which is thermally connected to one face of said heat dissipating plate; a first heat sink thermally connected to other face of said heat dissipating plate; and a second heat sink thermally connected to other face of said thermoelectric cooler.

[0107] FIG. 2-2 is a schematic view showing one embodiment of the module for cooling a heat generating element of the invention. As shown in FIG. 2-2, the module for cooling a heat generating element 1 includes a heat receiving plate 3 thermally connected to a heat generating element 2 mounted on a printed board 11, a heat transfer device 4 (in this embodiment, the heat transfer device is a heat pipe) with one end portion thermally connected to the heat receiving plate and with other end portion thermally connected to the heat dissipating plate 5, a thermoelectric cooler (TEC) 6 thermally connected to one face of the heat dissipating plate 5, a first heat sink 7 thermally connected to other face of the heat dissipating plate 5, and a second heat sink thermally connected to other face of the thermoelectric cooler (TEC). The first heat sink 7 is placed on the printed board 11, and comprises a plurality of fin plates 7 fixed on the heat dissipating plate 5 by crimping. The second heat sink comprises a base plate 10 and a plurality of fin plates fixed thereon by crimping. The third heat sink also may comprises a base plate and a plurality of fin plates fixed thereon by crimping.

[0108] In the embodiment as shown in FIG. 2-2, the heat dissipating plate, the thermoelectric cooler (TEC), the first heat sink and the second heat sink are arranged so as to be substantially perpendicular to the heat receiving plate. More specifically, the heat receiving plate is arranged so as to be placed in the horizontal direction, while the heat dissipating plate, the thermoelectric cooler (TEC), the first heat sink and the second heat sink are arranged so as to be placed in the vertical direction. By means of the heat pipe, the heat can be transferred to a prescribed position apart from the heat receiving plate.

[0109] FIG. 2-3 shows a heat flow from the heat source (heat generating element) in the module for cooling a heat generating element of the invention as shown in FIG. 2-1. As shown in FIG. 2-3, the heat conducted from the heat generating element to the heat receiving plate is transferred to the heat dissipating plate by the heat pipe as indicated by the reference numeral 12. The heat transferred to the heat dissipating plate is dissipated by the first heat sink thermally connected to one face of the heat dissipating plate as indicated by the reference numeral 13. A fan (not shown) may be arranged to the first heat sink and/or the second heat sink so as to forcibly cool the heat sink. The heat absorbing face of the thermoelectric cooler (TEC) 10 is thermally connected to other face of the heat dissipating plate, and the heat is transferred to the heat dissipating face as indicated by the reference numeral 14. In this instant, the driving power is imparted to the thermoelectric cooler (TEC) as indicated by the reference numeral 16. The base plate of the second heat sink is thermally connected to the heat dissipating face of the thermoelectric cooler (TEC), and the heat is dissipated as indicated by the reference numeral 15.

[0110] For example, when the heat generated by the heat generating element is 150 W, and the COP is 2, the driving power of the TEC is 75 W, and the temperature difference between the high temperature side and the low temperature side of the TEC is 20 degree Centigrade. In the conventional module, since the first heat sink is not used, the capacity of the TEC is upgraded to obtain the desired cooling capacity (i.e., the heat dissipating is effected only in the TEC side as indicated by the reference numeral 15). Accordingly, a total of 225 W (=150 W+75 W) is dissipated. Contrary to the above, since the first heat sink is used in the present invention, the heat dissipation in the TEC side may be designed to be small. For example, the driving power of the TEC may be lowered to less than ½, i.e., 37 W. Accordingly, a total of 187 W (=150 W+37 W) is sufficient to be dissipated. This enables the down-sizing of the module in which the heat dissipating fins of the first heat sink and the second heat sink can be designed to be smaller.

[0111] In case that the first heat sink is designed as a main heat dissipating device, and the combination of the thermoelectric cooler (TEC) and the second heat sink is designed as a sub heat dissipating device, the amount of the heat dissipation in the respective heat dissipating devices are appropriately selected, for example, the main heat dissipating device: the sub heat dissipating device=1:1.

[0112] FIG. 2-4 is a schematic view explaining another embodiment of the module for cooling a heat generating element. In this embodiment, the heat dissipating plate, the thermoelectric cooler (TEC), the first heat sink and the second heat sink are arranged so as to be substantially parallel to the heat receiving plate. More specifically, the heat receiving plate is arranged so as to be placed in the horizontal direction, while the heat dissipating plate, the thermoelectric cooler (TEC), the first heat sink and the second heat sink are arranged so as to be placed in the horizontal direction. For example, the first heat sink may be placed on the common printed board on which the heat generating element is mounted. In this embodiment, as well as the above embodiment, by means of the heat pipe, the heat can be transferred to a prescribed position apart from the heat receiving plate.

[0113] As shown in FIG. 2-4, the module for cooling a heat generating element 1 includes a heat receiving plate 3 thermally connected to a heat generating element 2 mounted on a printed board 11, a heat transfer device 4 (in this embodiment, the heat transfer device is a heat pipe) with one end portion thermally connected to the heat receiving plate and with other end portion thermally connected to the heat dissipating plate 5, a thermoelectric cooler (TEC) 6 thermally connected to one face of the heat dissipating plate 5, a first heat sink 7 thermally connected to other face of the heat dissipating plate 5, and a second heat sink thermally connected to other face of the thermoelectric cooler (TEC). The first heat sink 7 is placed on the printed board 11, and comprises a plurality of fin plates 7 fixed on the heat dissipating plate 5 by crimping. The second heat sink comprises a base plate 10 and a plurality of fin plates fixed thereon by crimping. The first heat sink also may comprises a base plate and a plurality of fin plates fixed thereon by crimping.

[0114] The heat flow from the heat source (heat generating element) in the module for cooling a heat generating element of the invention as shown in FIG. 2-4 is substantially the same as described with reference to FIG. 2-3. More specifically, the heat conducted from the heat generating element to the heat receiving plate is transferred to the heat dissipating plate by the heat pipe as indicated by the reference numeral 12. The
heat transferred to the heat dissipating plate is dissipated by the first heat sink thermally connected to one face of the heat dissipating plate as indicated by the reference numeral 13. The heat absorbing face of the thermoelectric cooler (TEC) 6 is thermally connected to other face of the heat dissipating plate, and the heat is transferred to the heat dissipating face as indicated by the reference numeral 14. In this instant, the driving power is imparted to the thermoelectric cooler (TEC) as indicated by the reference numeral 16. The base plate of the second heat sink is thermally connected to the heat dissipating face of the thermoelectric cooler (TEC), and the heat is dissipated as indicated by the reference numeral 15. The heat transferred to the first and second heat sink is dissipated in a prescribed direction by the fan(s).

[0115] FIG. 2-5 is a schematic view explaining another embodiment of the module of the invention for cooling a heat generating element. In this embodiment, a third heat sink 20 is further thermally connected to the heat receiving plate 3 in the module for cooling a heat generating element 1 described with reference to FIG. 2-4. More specifically, as shown in FIG. 2-5, a part of the heat conducted from the heat generating element 2 to the heat receiving plate is directly dissipated by the third heat sink, and the remaining heat is transferred to the heat dissipating plate 5 by the heat pipe 4. The heat transferred to the heat dissipating plate is dissipated by the first heat sink thermally connected to one face of the heat dissipating plate. The heat absorbing face of the thermoelectric cooler (TEC) 6 is thermally connected to the other face of the heat dissipating plate, and the heat is transferred to the heat dissipating face of the thermoelectric cooler (TEC). In this instant, a driving power is implied to the thermoelectric cooler (TEC). The base plate of the second heat sink is thermally connected to the heat dissipating face of the thermoelectric cooler (TEC). The respective heat transferred to the first and second heat sink is dissipated in the prescribed direction by the fan(s).

[0117] In this embodiment, the heat dissipating plate, the thermoelectric cooler (TEC), the first heat sink and the second heat sink are arranged so as to be substantially perpendicular to the heat receiving plate. More specifically, the heat receiving plate is arranged so as to be placed in the horizontal direction, while the heat dissipating plate, the thermoelectric cooler (TEC), the first heat sink and the second heat sink are arranged so as to be placed in the vertical direction.

[0118] FIG. 2-7 is a schematic view explaining another embodiment of the module of the invention for cooling a heat generating element. In this embodiment, in place of the heat pipe in the embodiment described with reference to FIG. 4, a forcible circulation device is used as the heat transfer device. The forcible circulation device transfers heat by forcibly circulating a cooling medium, and the forcible circulation device comprises, for example, a water-cooled pump and a circulation channel. More specifically, the forcible circulation device includes a circulation channel in which a cooling fluid is moved through, between the heat receiving plate 3 and the heat dissipating plate. The circulation channel is formed by a pipe or the like which is highly flexible. In case that micro channels are provided within the heat receiving plate, the cooling fluid in the micro channels are vaporized by the heat from the heat generating element to swiftly run to the heat dissipating plate in a vaporized state, and there, condensed to return to a liquid phase. The liquid phase cooling fluid is circulated by the pump back to the heat receiving plate.

[0119] In this embodiment, as described with reference to FIG. 2-3, the heat transferred to the heat dissipating plate is dissipated by the first heat sink thermally connected to one face of the heat dissipating plate. The heat absorbing face of the thermoelectric cooler (TEC) 6 is thermally connected to the other face of the heat dissipating plate, and the heat is transferred to the heat dissipating face of the thermoelectric cooler (TEC). In this instant, a driving power is implied to the thermoelectric cooler (TEC). The base plate of the second heat sink is thermally connected to the heat dissipating face of the thermoelectric cooler (TEC). The respective heat transferred to the first and second heat sink is dissipated in the prescribed direction by the fan(s).

[0120] FIG. 2-8 is a schematic view explaining another embodiment of the module of the invention for cooling a heat generating element. In this embodiment, in place of the heat pipe in the embodiment described with reference to FIG. 2-4, a heat receiving/heat dissipating plate 25 is used as the heat transfer device. More specifically, the heat receiving plate and the heat dissipating plate are integrally formed as a unit body, which is made of the material having excellent thermal conductivity. As shown in FIG. 2-8, the heat generated from the heat generating element is conducted to the heat receiving portion 25-1 of the heat receiving/heat dissipating plate, and then, the heat is transferred to the heat dissipating portion 25-2 through the material of the heat receiving/heat dissipating plate.

[0121] In this embodiment, as described with reference to FIG. 2-3, the heat transferred to the heat dissipating portion 25-2 is dissipated by the first heat sink 7 thermally connected to one face of the heat dissipating portion. The heat absorbing face of the thermoelectric cooler (TEC) 6 is thermally connected to the other face of the heat dissipating portion, and the heat is transferred to the heat dissipating face of the thermoelectric cooler (TEC). The base plate of the second heat sink is thermally connected to the heat dissipating face of the thermoelectric cooler (TEC). The respective heat transferred to the first and second heat sink is dissipated in the prescribed direction by the fan(s).
thermoelectric cooler (TEC). In this instant, a driving power is implied to the thermoelectric cooler (TEC). The base plate of the second heat sink 8 is thermally connected to the heat dissipating face of the thermoelectric cooler (TEC). The respective heat transferred to the first and second heat sink is dissipated in the prescribed direction by fan(s).

Then, the relationship between the implied power to the TEC and thermal resistance is investigated while the condition is varied. More specifically, the various conditions are as follows: (1) the first heat sink 7 is removed from the module for cooling a heat generating element as shown in FIG. 2-4, i.e., only the TEC is attached to the heat dissipating plate and the second heat sink 8 is attached to the heat dissipating face of the TEC, (2) the length of the fins of the first heat sink is varied in the module for cooling a heat generating element as shown in FIG. 2-4, (3) the heat sink is attached to both faces of the heat dissipating plate respectively without using the TEC. The relationship between the implied power to the TEC and thermal resistance is investigated in each of the above condition. The result is shown in FIG. 2-9. As is evident from FIG. 2-9, when the TEC is not used, the thermal resistance is 0.073 (degree centigrade/W) and constant, as shown in line (1). When the first heat sink is not used, the thermal resistance becomes small as the implied power becomes larger, however, the thermal resistance is over 0.073 (degree centigrade/W) until the implied power is up to 35 W, as shown in line (2). Contrary to the above, in the module for cooling a heat generating element of the invention, the thermal resistance is largely lowered compared to the case without the TEC, even when the implied power to the TEC is 25 W, which is not affected by the variation of the length of the fins. It is noted that the thermal resistance is lowered by 0.03 (degree centigrade/W) at the most, when the length of the fins are 30 mm, and the implied power to the TEC is 25 W.

As is clear from the above, according to the module for cooling a heat generating element of the invention, the cooling efficiency is improved, while the implied power to the TEC is lowered.

The module for cooling a heat generating element of the invention is described in detail by examples.

**EXAMPLE 1**

The module for cooling a heat generating element of the invention as shown in FIG. 2-2 is prepared. More specifically, a heat receiving plate formed by a material having a high thermal conductivity such as aluminum or copper is attached to a heat generating source such as a CPU mounted on a printed board. At least one prescribed recess portion (for example, a hole) is formed in the heat receiving plate, and an end of a heat transfer device having a low thermal resistance such as a heat pipe is thermally connected to the recessed portion and fixed therein.

The other end of the heat pipe (heat transfer device) is thermally connected to a prescribed recessed portion (for example, a hole having a prescribed diameter) formed in a heat dissipating plate formed by a material having a high thermal conductivity such as aluminum or copper. The heat pipe is fixed to the above recessed portion of the heat receiving plate and the heat dissipating plate by soldering, crimping or the like.

A first heat sink formed by a material having a high thermal conductivity such as aluminum or copper is attached to one face of the heat dissipating plate. The first heat sink may comprise a plurality of fin plates soldered on the heat dissipating plate, or a plurality of fin plates fixed by crimping on the heat dissipating plate.

A heat absorbing face of the TEC is thermally connected to the other face of the heat dissipating plate. The TEC is thermally connected by using a thermal grease, by using a metal foil having a low yield stress and high thermal conductivity such as indium, or by soldering.

A second heat sink formed by a material having a high thermal conductivity such as aluminum or copper is thermally connected to a heat dissipating face of the TEC. The TEC is thermally connected to the second heat sink by using a thermal grease, by using a metal foil having a low yield stress and high thermal conductivity such as indium, or by soldering.

The module for cooling a heat generating element is further described in detail. In order to reduce the weight of the module for cooling a heat generating element, an aluminum heat receiving plate having width and length of 50 mm, times, 90 mm, and thickness of 0.7 mm is prepared. Four holes each having diameter of 6 mm are formed in the heat receiving plate, and a round heat pipe having diameter of 6 mm is inserted into the respective holes, and fixed by crimping. The crimping was carried out by pushing a metal plate jig having a thickness of 1 mm, and width of 3 mm with the power of 2000 kgf.

The heat pipe is bent at its center portion by a curvature radius of 18 mm to form a bent portion which changes the direction from horizontal to vertical (about 90 degrees change), thus the heat receiving plate and the heat dissipating plate are arranged so as to be perpendicular.

An aluminum heat dissipating plate having width and length of 80 mm, times 80 mm, and thickness of 8.5 mm is prepared. Four holes each having diameter of 6 mm are formed in the heat dissipating plate, and a round heat pipe having diameter of 6 mm is inserted into the respective holes, and fixed by crimping. Fifty two copper fin plates each having a height of 22 mm, length of 80 mm, and thickness of 0.3 mm are fixed on one face of the heat dissipating plate with a fin pitch of 1.5 mm, thus the first heat sink is attached to the heat dissipating plate.

The heat pipe and the fin plates are simultaneously fixed by crimping on the heat dissipating plate. The heat pipes are inserted into the holes, and the fin plates are inserted in the grooves respectively formed in the heat dissipating plate, and then, the vicinities of respective fin plates are deformed and fixed by the inflicted power of 2000 kgf of the fin plate crimping jig.

Four heat absorbing faces of the TEC each having width and length of 40 mm, times 40 mm, and thickness of 12 mm are attached to the other face of the heat dissipating plate through the thermal grease.

The second heat sink is prepared which comprises an aluminum base having a width and length of 80 mm, times 80 mm, and a thickness of 3 mm, and fifty second copper fin plates each having a height of 43 mm, length of 80 mm, and thickness of 0.3 mm fixed on the base plate by crimping with a fin pitch of 1.5 mm. Thus prepared second heat sink is attached to the heat dissipating faces of the TEC through the thermal grease. The second heat sink is fixed through the TEC to the heat dissipating plate by four screws.
According to the thus formed module for cooling a heat generating element of the invention, the heat flow from the heat generating source is dissipated on the first heat sink, the heat absorbed by the TEC is made smaller than that in the conventional module.

For example, in the conventional module, when the heat from the heat generating source is 150 W, the TEC has to be operated at 50 W, since it is necessary that COP is 3 for obtaining the temperature difference of 12 degree centigrade in the TEC. On the other hand, it is necessary to dissipate from the heat dissipating face the heat of 200 W which is represented by the total of the heat from the heat generating source and the driving power of the TEC. Accordingly, it is necessary to prepare and fix the heat sink which has a heat dissipating area corresponding to the upper heat.

However, since the module for cooling a heat generating element of the invention is designed so that the heat dissipates from the first heat sink of 75 W, the heat absorbed by the TEC is made to be 75 W. In this case, COP is 3 for obtaining the same temperature difference of 12 degree centigrade, it is possible to reduce the driving power of the TEC to 25 W. The heat sink attached to the heat dissipating face of the TEC therefore may be the size which corresponds to the heat dissipation of 100 W. More specifically, since it is sufficient for the heat sink to have a capability of the heat dissipation of 75 W of directly dissipated, and of 100 W of the TEC, a heat dissipating area corresponding to the heat dissipation of a total of 175 W is sufficient.

In case that a cooling air flow rate and a cooling air temperature are the same, a required heat dissipating area of a heat sink is approximately proportional to a heat dissipation of the heat sink. The heat dissipation of the heat sink in the present invention is 175 W, while the heat dissipation of the heat sink in the conventional module is 200 W, as described above. Therefore, the required heat dissipating area in the module of the invention is 88% of that of the conventional module, which is sufficient for heat dissipation, thus enabling to downsize the module for cooling a heat generating element.

EXAMPLE 2

The module for cooling a heat generating element of the invention as shown in FIG. 2-4 is prepared. The module is substantially the same as the module for cooling a heat generating element as shown in FIG. 2-2 except that the heat receiving plate is arranged so as to be parallel to the heat dissipating plate. In FIG. 2-4, the first heat sink is placed at the lower side of the heat dissipating plate, however, the first heat sink may be placed at the upper side of the heat dissipating plate and the second heat sink may be placed at the lower side of the heat dissipating plate.

In addition, the module for cooling a heat generating element of the invention as shown in FIG. 2-5 is prepared. More specifically, the heat receiving plate is arranged so as to be parallel to the heat dissipating plate, and furthermore, the third heat sink is attached to the heat receiving plate in addition to the first heat sink and the second heat sink as described with reference to FIG. 2-4. The third heat sink comprises a plurality of fin plates having a prescribed size fixed to the heat receiving plate by crimping, or soldering. Thus, the required heat absorption of the TEC may be further lowered. Accordingly, the power consumption of the TEC may be further reduced.

In addition, the module for cooling a heat generating element of the invention as shown in FIG. 2-6 is prepared. More specifically, the heat dissipating plate is arranged so as to be vertical to the heat receiving plate, and furthermore, the third heat sink is attached to the heat receiving plate in addition to the first heat sink and the second heat sink attached to the both sides of the heat dissipating plate, as shown in FIG. 2-6. In case that a large space is available on the upper side of the heat generating source, the module as shown in FIG. 2-6 is effective. According to the module as shown in FIG. 2-6, the power consumption of the TEC is reduced, and it is possible to construct a heat sink with a small foot print.

In addition, the module for cooling a heat generating element of the invention as shown in FIG. 2-7 is prepared. More specifically, the heat receiving plate is connected to the heat dissipating plate by a highly flexible pipe, and a fluid is circulated by a pump. Although, not shown in the drawing, the third heat sink may be attached to the heat receiving plate.

The cooling module as shown in FIG. 1-3 is prepared. Aluminum plate of 44 mm times 84 mm having a thickness of 7 mm is used as the heat receiving/spreading plate in which four heat pipes each having a diameter of 6 mm are embedded. To the heat dissipating side 6 b of the heat pipe, the heat sink comprising 40 pieces of aluminum plates each having a size of 60 mm times 20 mm and thickness of 0.3 mm which are arranged with pitch of 1.5 mm is pressed into and attached thereto.

Two thermonoelectric cooler each having a size of 40 mm times 40 mm are attached to the opposite face of the heat receiving/spreading plate 2 to the face to which the heat generating source is attached. The aluminum heat sink 4 is attached to the heat dissipating face of the thermonoelectric cooler. The heat sink 4 comprises a base plate of 44 mm times 84 mm having a thickness of 3 mm and 54 pieces of aluminum fin plates having a height of 34 mm and a thickness of 0.4 mm fixed to the base plate by crimping.

The thermonoelectric cooler, the heat receiving/spreading plate and the heat sink 4 are thermally connected through the thermal grease.

A DC fan having a size of 60 mm times 60 mm is attached to the heat sink and evaluated the heat cooling efficiency thereof. As a result, the heat generating amount of the CPU was 120 W, and the power consumption of the thermonoelectric cooler was 6 W, thus it becomes clear that the heat generating element can be fully cooled. Contrary to the above, in the conventional heat sink as shown in FIG. 2-11, the heat generating amount of the CPU was 120 W, and the power consumption of the thermonoelectric cooler was 24 W. Thus, the heat sink of the invention has the same thermal efficiency as the conventional heat sink while the power consumption of the thermonoelectric cooler is remarkably reduced.

As described above, according to the present invention, since a part of the heat from the heat generating source is directly dissipated by the heat sink attached to the heat receiving plate, the heat absorbed by the TEC may be small. As a result, since it is possible to make large an absolute apparent negative thermal resistance obtained by the TEC, the thermal resistance of the module for cooling a heat generating element can be small. In addition, a desired temperature difference can be obtained while the power consumption of the TEC is maintained small. The module can be driven by a small power capability power source, and can be applied to a small scale system. Furthermore, since the power consumption can be maintained low, it can be cooled by a small sized
fan, thus enabling to be applied to a small space system. In addition, it is possible to reduce a fan-noise. Furthermore, since the heat dissipating portion (plate) is arranged appropriately, the heat dissipating portion may be arranged in a sufficient space apart from the heat generating source, in case that a sufficient space is not available near the heat generating source.

[0150] According to the present invention, it is possible to reduce the heat to be absorbed by the thermoelectric cooler (TEC), in addition to a small power consumption of the thermoelectric cooler (TEC), and a small fan noise, accordingly, thus providing a module for cooling a high heat generating element which enables to be applied to a small system, and has a wide design choice.

1. A cooling module for a heat generating element of a semiconductor element type, comprising:
   a heat receiving/spreading device thermally connected to the heat generating element;
   a thermoelectric cooler integrally formed with and thermally connected to said heat receiving/spreading device;
   a first heat sink thermally connected to said thermoelectric cooler; and
   a TEC heat path provided by said thermoelectric cooler and said first heat sink;
   a power reduction mechanism configured to reduce power consumed by said thermoelectric cooler, said power reduction mechanism being thermally connected to said heat receiving/spreading device to transfer heat of said heat generating element in another direction; and
   said power reduction mechanism comprising a heat pipe and a second heat sink thermally connected to said heat pipe, thereby forming an unconditionally divided heat path.

2. The cooling module of claim 1, wherein said first and second heat sinks are separated heat sinks.

3. The cooling module as claimed of claim 1, wherein said first and second heat sinks are integrated such that said second heat sink is stacked on said first heat sink.

4. The cooling module as claimed of claim 3, wherein said first and second heat sinks are formed by a single heat sink such that a lower part of the single heat sink constitutes said first heat sink and an upper part of the single heat sink constitutes said second heat sink.

5. The cooling module of claim 1, wherein said heat pipe comprises a U-shaped round heat pipe having a prescribed elasticity, said thermoelectric cooler and said first heat sink are arranged to be sandwiched by said second heat sink and said heat receiving/spreading device, thereby lowering a contact heat resistance.

6. The cooling module of claim 1, wherein through holes are provided in corresponding prescribed positions in said heat receiving/spreading device, said thermoelectric cooler, said first heat sink and said second heat sink, respectively, and said heat receiving/spreading device, said thermoelectric cooler, said first heat sink and said second heat sink are fastened by corresponding screws.

7. The cooling module as claimed in claim 6, wherein a fastening force of said screws is controlled so as to provide a constant torque.

8. The cooling module of claim 1, wherein-said heat generating element has a heat value of at least 100 W.

9. The cooling module of claim 1, further comprising a soft metal foil as a thermal interface material is arranged between said heat receiving/spreading device and said thermoelectric cooler, as well as between said thermoelectric cooler and said first heat sink, respectively.

10. The cooling module of claim 1, further comprising another heat pipe thermally connected to said heat receiving/spreading device to transfer heat from another heat generating element included in the heat generating element of the semiconductor element type to said heat receiving/spreading device.

11-26. (canceled)

27. The cooling module of claim 1, wherein said thermoelectric cooler is controlled such that when a heat energy of the heat generating element is less than a predetermined value, electric power consumption of the cooler is minimized whereas most of the heat energy less than the predetermined value is dissipated by means of said power reduction mechanism.

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