【DESCRIPTION】

【TITLE】

COOLING DEVICE OF THIN PLATE TYPE FOR PREVENTING DRY-OUT

【TECHNICAL FIELD】

The present invention relates to a thin plate-type cooling device for cooling a semiconductor integrated circuit device, etc., and more particularly to a thin plate-type cooling device capable of preventing a coolant from drying out using the phase transition of operation fluid.

【BACKGROUND ART】

As design rules decrease due to the trend towards large scale integration of semiconductor devices, and thereby the line width of electronic devices constituting semiconductor devices narrows, small-sized and high performance electronic equipment has been achieved owing to a larger number of transistors per unit area, which causes, however, that the ratio of heat emission of a semiconductor device per unit area increases. The increase of the rate of heat emission deteriorates the performance of semiconductor devices and lessens the life expectancy thereof, and eventually decreases the reliability of a system adopting semiconductor devices. Particularly in semiconductor devices, parameters are too easily affected by operation temperatures, and thereby it further deteriorates the characteristics of integrated circuits.

In response to the increase of the rate of heat emission, cooling technologies have been developed such as fin-fan, peltier, water-jet, immersion,

heat pipe type coolers, etc., which are generally known.

The fin-fan type cooler which compulsorily cools devices using fins and/or fans has been used for tens of years, but has some defects such as noise, vibration, and low cooling efficiency as compared with its large volume. Although the peltier type cooler doesn't make noise or vibration, it has a problem that it requires too many heat dissipation devices at its hot junction, needing large driving power due to its low efficiency.

The water-jet type cooler goes mainstream in cooling device research because of its excellent efficiency, but its structure is complicated due to the use of a thin film pump driven by an external power supply, and it is significantly affected by gravity, as well as a problem that it is difficult to achieve robust design when applied to personal mobile electronic equipment.

And in the cooling device using a heat pipe, since the flowing directions of gas and fluid inside a pipe are opposite each other, the gas flowing from an evaporation section towards a condensation section acts as resistance against the fluid returning from the condensation section towards the evaporation section. Accordingly, if a large amount of heat is applied to the heat pipe, the liquid into which the gas with a high velocity is to change cannot return to the evaporation section, so a dry-out phenomenon by which the coolant in the liquid state is exhausted occurs in the evaporation section. And there is a problem that its installation location is significantly restricted because the coolant gasified inside the pipe moves depending upon buoyancy and pressure difference, and

the liquefied coolant in the heat pipe depends on gravity due to the structure and size of the medium of the returning section.

In order to solve the above problem, it has been disclosed in Korea Patent Application No. 2001-52584, "A thin plate-type cooling device", by the applicant of this invention that the cooling performance of a small-sized thin plate-type cooling device is hardly affected by gravity and the coolant is naturally circulated without any external power supply. The thin plate-type cooling device disclosed includes a thin plate-shaped housing having a fluid circulation loop therein and a coolant having a phase transition characteristic, circulating the circulation loop in the housing, wherein the circulation loop in the housing includes: a coolant storage section formed on one end inside the housing for storing the coolant in the liquid state; an evaporation section including at least one first tiny channel connected to the one end of the coolant storage section, wherein the coolant in the liquid state in the first tiny channel is partly filled from the coolant storage section to a predetermined area of the first tiny channel due to the surface tension with an inner wall of the first tiny channel, the surface tension inside the first tiny channel is set more than gravity, and the coolant in the liquid state filled in the first tiny channel can be gasified by the heat absorbed from a heat source; a condensation section including at least one second tiny channel disposed away from the first tiny channel of the evaporation section as much as a predetermined distance in the longitudinal direction on a same plane for condensing the coolant in the gas state gasified and transferred

from the first tiny channel, wherein the surface tension between an inner wall of the second tiny channel and the coolant condensed is set more than gravity; a gaseous coolant transfer section disposed between the first tiny channel of the evaporation section and the second tiny channel of the condensation section; and a liquefied coolant transfer section separated from the gaseous coolant transfer section for transferring the coolant in the liquid state condensed in the condensation section towards the coolant storage section.

According to the thin plate-type cooling device disclosed, as the coolant circulating around the circulation loop inside the housing changes its phase between liquid and gas states, the heat of the external heat source contacting the cooling device can be dissipated using the latent heat during phase transition.

According to the thin plate-type cooling device disclosed, however, there is a possibility that the coolant in the gas state is not completely condensed in the condensation section and reaches the condensation section via the liquefied coolant transfer section and/or the coolant storage section, contained in the condensed coolant in the form of bubbles. If the bubbles contained in the coolant in the liquid state reach the evaporation section, there is concern that the dry-out phenomenon by which the coolant in the liquid state is exhausted occurs in the evaporation section.

【DISCLOSURE OF INVENTION】

In order to solve the problems above, it is an object of the present

invention to provide a thin plate-type cooling device for preventing the dry-out phenomenon in the evaporation section.

Moreover, it is another object of the present invention to provide a thin plate-type cooling device wherein its cooling efficiency is increased by improving the flow of the coolant.

In order to achieve the objects above, a thin plate-type cooling device includes a thin plate-shaped housing in which a circulation loop of a fluid is formed, and a coolant capable of changing from one state to another, circulating along the circulation loop inside the housing, wherein the circulation loop inside the housing includes an evaporation section formed on one end of the circulation loop, wherein the liquefied coolant is at least partly filled by a capillary action and the coolant filled in a liquid state is gasified by heat transferred from an external heat source, a gaseous coolant transfer section formed adjacent to the evaporation section, wherein the gasified coolant is transferred through the gaseous coolant transfer section and the gaseous coolant transfer section has at least one first cavity for containing the gaseous coolant which has not been condensed, a liquefied coolant transfer section formed adjacent to the condensation section and thermally insulated from the evaporation section, wherein the liquefied coolant is transferred towards the evaporation section, and a thermal insulation section for thermally insulating the evaporation section from at least a part of the liquefied coolant transfer section.

【BRIEF DESCRIPTION OF DRAWINGS】

Fig. 1a shows the external appearance of a thin plate-type cooling device according to a first embodiment of this invention.

Fig. 1b shows a schematic section on an X-Y plane of the thin plate-type cooling device of the first embodiment viewed in a second direction.

Fig. 2a shows a schematic sectional view taken in the first direction on the X-Y plane of the thin plate-type cooling device of the first embodiment.

Fig. 2b shows a schematic sectional view taken along the A-A' line on the Y-Z plane of the thin plate-type cooling device of the first embodiment.

Fig. 2c shows a schematic sectional view taken along the B-B' line on the Y-Z plane of the thin plate-type cooling device of the first embodiment.

Fig. 3a shows a schematic sectional view taken in the first direction on the X-Y plane of a thin plate-type cooling device of a second embodiment.

Fig. 3b shows a schematic sectional view taken along the A-A' line on the Y-Z plane of the thin plate-type cooling device of the second embodiment.

Fig. 3c shows a schematic sectional view taken along the B-B' line on the Y-Z plane of the thin plate-type cooling device of the second embodiment.

Fig. 4a shows a schematic sectional view taken in the first direction on the X-Y plane of a plate-type cooling device of a third embodiment.

Fig. 4b shows a schematic sectional view taken along the A-A' line on the Y-Z plane of the thin plate-type cooling device of the third embodiment.

Fig. 4c shows a schematic sectional view taken along the B-B' line on

the Y-Z plane of the thin plate-type cooling device of the third embodiment.

Fig. 5a shows a schematic sectional view taken in the first direction on the X-Y plane of a thin plate-type cooling device of a fourth embodiment.

Fig. 5b shows a schematic sectional view taken along the A-A' line on the Y-Z plane of the thin plate-type cooling device of the fourth embodiment.

Fig. 5c shows a schematic sectional view taken along the B-B' line on the Y-Z plane of the thin plate-type cooling device of the fourth embodiment.

Fig. 5d shows a schematic sectional view taken along the C-C' line on the Y-Z plane of the thin plate-type cooling device of the fourth embodiment.

【BEST MODE FOR CARRYING OUT THE INVENTION】

Hereinafter, the exemplary embodiments of the present invention will now be described in detail, referring to attached drawings.

Referring to Fig. 1a, first, Fig. 1a shows the external appearance of a thin plate-type cooling device 100 according to a first embodiment of this invention. It is preferable that the external appearance of the thin plate-type cooling device 100 of this invention is approximately rectangular, and the thin plate-type cooling device 100 is formed by bonding a lower plate 100a and an upper plate 100b in each of which internal elements have been formed.

For the sake of understanding and description, it is defined that, as shown in Fig. 1a, an "X-axis direction" is the longitudinal direction (from the left to the right of the drawing) of the thin plate-type cooling device 100 of this invention, a "Y-axis direction" is the lateral direction (into the drawing) of the thin

plate-type cooling device 100, and a "Z-axis direction" is the vertical direction (from the bottom of the top of the drawing) of the thin plate-type cooling device 100. Moreover, it is also defined that a "section viewed in a first direction" is the section viewed in the negative Z-axis direction (i.e., the direction from the bottom of the top of the drawing), and a "section viewed in a second direction" is the section viewed in the positive Z-axis direction (i.e., the direction from the top of the bottom of the drawing).

Referring to Fig. 1b, Fig. 1b shows a schematic section on an X-Y plane of the thin plate-type cooling device 100 of the first embodiment viewed in the second direction. As shown in the drawing, the lower plate 100a of the thin plate-type cooling device 100 forms a circulation loop of a coolant inside an approximately rectangular housing 112 by being combined with the upper plate 100b. The coolant circulates in the arrow direction and cools an external heat source contacting the cooling device 100, using the latent heat during its phase transition between liquid and gas states.

The housing 112 can be manufactured of a material such as semiconductor, e.g. Si, Ga, etc., a novel substance-laminated material, e.g. Self Assembled Monolayer (SAM), metal and/or alloy, e.g. Cu, Al, etc. with high conductivity, ceramic, a high molecular substance, e.g. plastic, a crystalline material, e.g. diamond. Particularly, in case of a semiconductor chip as the external heat source, the housing can be made of the same material as that of the surface of the external source so as to minimize the thermal contact

resistance. In case that the thin plate-type cooling device 100 is made of semiconductor, the housing can be integrally formed as one piece with the surface material of the external source during the process of manufacturing the semiconductor chip.

Next, the coolant to be injected into the thin plate-type cooling device 100 can be selected from things capable of changing its phase between liquid and gas states due to the external heat. In this embodiment, it is preferable to use water whose latent heat and surface tension are high as the coolant, because it is desirable not to use any of a series of CFC as the coolant in consideration of environmental pollution.

In addition, since the surface tension between the coolant and an inner wall of the thin plate-type cooling device 100 varies depending upon the material of the housing, a suitable coolant should be selected. For example, any of a series of alcohol such as methanol, ethanol, etc., may be used as the coolant besides water. In case of water or alcohol as the coolant, it has an advantage that a large amount of heat can transferred because its heat capacity is large, and its contact angle by the surface tension with the inner wall of semiconductor is small, so that the current speed of the coolant becomes high. Moreover, water or alcohol as the coolant, unlike CFC, does not cause any environmental pollution even though it leaks from the thin plate-type cooling device 100 by any reason.

The selection of the coolant is merely of an optional matter for the

implementation of this invention, which does not limit the technical scope of this invention.

As shown in the drawing, the thin plate-type cooling device 100 includes an evaporation section 104 formed on one end inside the thin plate-type cooling device 100, in which the coolant in the liquid state is at least partly filled due to the capillary action and the coolant in the liquid state filled is gasified due to the heat transferred from the external heat source, a gaseous coolant transfer section 106 formed adjacent to the evaporation section 104, in which the coolant gasified is transferred in a predetermined direction due to the pressure difference, a condensation section 108 formed adjacent to the gaseous coolant transfer section 106, in which the coolant in the gas state is condensed into the liquid state, and liquefied coolant transfer sections 102 and 110 formed adjacent to the condensation section 108 and thermally insulated from the evaporation section 104, in which the coolant condensed into the liquid state is transferred towards the evaporation section 104.

The evaporation section 104, the gaseous coolant transfer section 106, the condensation section 108 and the liquefied coolant transfer sections 102 and 110 may be formed only on the lower plate 100a of the thin plate-type cooling device 100. Moreover, the upper plate 100b of the thin plate-type cooling device 100 may have only cavities on predetermined areas. The configuration of the upper plate 100b will be described later referring to Figs. 2 to 5.

The coolant inside the thin plate-type cooling device 100 forms the

circulation loop along the arrows of the drawing. That is, the coolant sequentially circulates via the evaporation section 104, the gaseous coolant transfer section 106, the condensation section 108, the liquefied coolant transfer section 110 near the condensation section, and the liquefied coolant transfer section 102 near the evaporation section.

Alternatively, the thin plate-type cooling device 100 may further include a coolant storage section (not shown) whose volume is suitable for storing a predetermined amount of the coolant in the liquid state in the liquefied coolant transfer sections 102 and 110. For example, a part of the liquefied coolant transfer section 102 near the evaporation section may be used for the coolant storage section. In addition, a plurality of coolant storage sections may be formed.

The evaporation section 104 is adjacent to one end ("exit side") of the liquefied coolant transfer section 102 near the evaporation section, and a plurality of tiny channels are formed in the evaporation section 104, so that all or a part of the tiny channels are filled with the coolant stored in the liquefied coolant transfer section 102 near the evaporation section by the capillary action. In addition, the evaporation section 104 is disposed adjacent to the external heat source (not shown), and thereby the coolant in the liquid state accumulated in the tiny channels by the heat transferred form the heat source is gasified, so it changes into the gaseous state. Accordingly, the heat from the heat source is absorbed to the coolant as much as the latent heat caused by the phase

transition of the coolant, and the heat from the heat source can be eliminated as the coolant in the gas state is condensed to dissipate the heat as described later.

It is preferable that the surface tension in the tiny channels is larger than gravity. In addition, the smaller the contact angle of the meniscus of the liquefied coolant accumulated in the tiny channels, the more it is preferable. In order to do so, it is preferable that the inner walls of the tiny channels is formed of or treated with a hydrophilic material. For example, the hydrophilic material treatment is performed by plating, coating, coloring, anodization, plasma treatment, laser treatment, etc. In addition, the surface coarseness of the inner walls of the tiny channels can be adjusted in order to improve the heat transfer efficiency.

Meanwhile, besides the tiny channels of the evaporation section 104, it is preferable that the hydrophilic treatment is performed on the surfaces of the liquefied coolant transfer sections 110 and 102 and the evaporation section 104 and the hydrophobic treatment is performed on the surfaces of the gaseous coolant transfer section 106 and the condensation section 108, so that the flow of the coolant is improved to increase the cooling efficiency.

Further, the cross-sections of the tiny channels may be circular, elliptical, rectangular, square, polygonal, etc. Particularly, the magnitude of the surface tension of the coolant can be controlled by increasing or decreasing the cross-sections of the tiny channels in the longitudinal direction thereof (i.e., the X axis direction), the transfer direction and velocity of the coolant can also be controlled by forming a plurality of grooves or nodes on the inner wall thereof.

Next, the coolant gasified in the evaporation section 104 is transferred in the opposite direction to the liquefied coolant transfer section 102 near the evaporation section, and the gaseous coolant transfer section 106 is formed adjacent to the evaporation section 104 to function as a passage through the gaseous coolant is transferred. As shown in the drawing, the gaseous coolant transfer section 106 may include a plurality of guides 118 so that the gasified coolant can be transferred in a predetermined direction (i.e., in the opposite direction to the coolant storage section 102). The guides 118 have the function of increasing the mechanical strength of the thin plate-type cooling device 100. Accordingly, the guides 118 may not be included if there is no problem in the mechanical strength.

The condensation section 108 is the area where the gaseous coolant transferred inwards through the gaseous coolant transfer section 106 is condensed and liquefied again. In this embodiment, the condensation section 108 is formed away from the evaporation section 104 by a predetermined distance on the same plane.

Meanwhile, the condensation section 108 may include a plurality of tiny channels (not shown) similar to the tiny channels formed on the evaporation section 104. The tiny channels of the condensation section 108 may extend to the liquefied coolant transfer section 110 as described below, and further extend to the liquefied coolant transfer section 102 near the evaporation section. The tiny channels of the condensation section 108 make it easy for the gaseous

coolant to be condensed, and precipitate the completion of the coolant circulation loop by providing surface tension to transfer the coolant in the liquid state condensed towards the liquefied coolant transfer section 102 near the evaporation section.

The depth of the tiny channels of the condensation section 108 is preferably deeper than that of the tiny channels of the evaporation section 104, which is however not limited to this. In addition, the shape and change of the cross-sections, the formation of the grooves or nodes of the tiny channels of the condensation section 108 will not described in detail because they are similar to those of the tiny channels of the evaporation section 104.

Moreover, in order to increase the efficiency of the heat dissipation, a plurality of fins may be formed outside the condensation section 108 of the thin plate-type cooling device 100. The fins may have a radial shape or other shapes outside the condensation section 108. The air brought by the fan 120 touches the inner wall of the fins facing each other, so that the heat dissipation efficiency can be maximized.

Further, if the fins include micro actuators, the air surrounding the cooling device may be circulated utilizing the heat dissipated from the condensation section 108. If the fins have a tiny structure including thermoelectric conversion devices, the heat dissipated from the condensation section 108 is converted into electricity which can be used as the energy for tiny driving.

In addition, by forming the volume of the condensation section 108 to be more than the volume of the evaporation section 104, the coolant in the gas state can be easily condensed in the condensation section 108 only by the convention of the air surrounding the condensation section 108.

The liquefied coolant transfer section 110 forms a passage through which the liquefied coolant condensed in the condensation section 108 is transferred towards the liquefied coolant transfer section 102 near the evaporation section. As shown in the drawing, the liquefied coolant transfer section 110 is thermally insulated from the gaseous coolant transfer section 106, the condensation section 108 and the evaporation section 104 by a thermal insulation section 116.

The thermal insulation section 116 may be formed as partitions inside the thin plate-type cooling device 100, spaces internally sealed in the thin plate-type cooling device 100, or openings vertically penetrating the thin plate-type cooling device 100. If the thermal insulation section 116 is the spaces internally sealed in the thin plate-type cooling device 100, it may be in a vacuum state or filled with an insulation substance such as air.

As shown in the drawing, the liquefied coolant transfer section 110 is preferably symmetry along the longitudinal direction of the thin plate-type cooling device 100. The coolant circulation loop being formed symmetry along the longitudinal direction of the thin plate-type cooling device 100 is a structure which is very advantageous in dissipating heat if it has the shape of a thin plate,

i.e. its sectional length-width ratio is large, so that the cooling device 100 can radially dissipate the heat transferred from the heat source utilizing the large surface area.

This bidirectional coolant circulation loop has an advantage that even though one of the coolant circulations in the liquefied coolant transfer section 110 is not properly performed because of the effect of gravity depending upon the installation position of the cooling device 100, the other coolant circulation can be maintained.

As described above, even the liquefied coolant transfer section 110 may include tiny channels so as not to be affected by gravity, where a plurality of grooves (not shown) may be formed in the tiny channels in the direction facing the coolant storage section 102. Further, it is preferable that the sections of the tiny channels formed on the evaporation section 104 or the liquefied coolant transfer sections 110 and 102 gradually decrease from the liquefied coolant transfer section 110 contacting the condensation section 108 to the evaporation section 104 contacting the gaseous coolant transfer section 106.

Meanwhile, a plurality of guides (not shown) may be formed to determine the transfer direction of the liquefied coolant at a boundary between the liquefied coolant transfer section 102 near the evaporation section and the liquefied coolant transfer section 110 and a boundary between the condensation section 108 and the liquefied coolant transfer section 110, whereby the resistance of the coolant circulation occurring because the current path of the

coolant rapidly curves can be reduced.

Meanwhile, it is preferable that the evaporation section 104 is directly attached to the heat source (not shown) not via a heat conductor to reduce the contact heat resistance, so in the embodiment the cooling device 100 is provided with fastening means 114 for fastening the cooling device 100 to the external heat source adjacent to the evaporation section 104 with bolts or rivets. The fastening means 114 may not be included because it is not relevant to the circulation of coolant.

Next, referring to Figs. 2a to 2c, the upper plate 100b of the thin plate-type cooling device 100 according to the first embodiment of this invention will be described in detail. Fig. 2a shows a schematic sectional view taken in the first direction on the X-Y plane of the thin plate-type cooling device 100 of the first embodiment, Fig. 2b shows a schematic sectional view taken along the A-A' line on the Y-Z plane of the thin plate-type cooling device 100 of the first embodiment, and Fig. 2c shows a schematic sectional view taken along the B-B' line on the Y-Z plane of the thin plate-type cooling device 100 of the first embodiment. In this embodiment, the sectional view taken in the first direction shown in Fig. 2a is the bottom view of the upper plate 100b of the thin plate-type cooling device 100.

As shown in the drawings, in this embodiment, the upper plate 100b of the thin plate-type cooling device 100 has a first cavity 124 for providing a space, where the coolant in the gas state which has not been condensed can be contained, on an area corresponding to the gaseous coolant transfer section

106 of the lower plate 100a. Moreover, the upper plate 100b may include the thermal insulation section 116 corresponding to the thermal insulation section 116 of the lower plate 100a. The upper plate 100b may be formed of the same material as that of the housing 112 of the lower plate 100a. Alternatively, the upper plate 100b may be formed of glass, etc.

Referring to Fig. 2c, the first cavity 124 is formed in order that its section is semi-oval in the direction parallel to the Y axis on the Y-Z plane. By providing the space for containing the coolant in the gas state, the first cavity 124 prevents the coolant in the gas state which has not been condensed in the condensation section 108 from being bubbles in the coolant in the liquid state.

Next, referring to Figs. 3a to 3c, the upper plate 100b of the thin plate-type cooling device 100 according to a second embodiment of this invention will be described in detail. Fig. 3a shows a schematic sectional view taken in the first direction on the X-Y plane of the thin plate-type cooling device 100 of the second embodiment, Fig. 3b shows a schematic sectional view taken along the A-A' line on the Y-Z plane of the thin plate-type cooling device 100 of the second embodiment, and Fig. 3c shows a schematic sectional view taken along the B-B' line on the Y-Z plane of the thin plate-type cooling device 100 of the second embodiment. In this embodiment, the sectional view taken in the first direction shown in Fig. 3a is the bottom view of the upper plate 100b of the thin plate-type cooling device 100.

As shown in the drawings, in this embodiment, the upper plate 100b of

the thin plate-type cooling device 100 has a plurality of first cavities 124 on areas corresponding to the gaseous coolant transfer section 106 of the lower plate 100a, where the plurality of first cavities 124 respectively correspond to a plurality of transfer paths of gaseous coolant formed by the second guides 118 of the gaseous coolant transfer section 106 and each of them has a semi-oval section on the Y-Z plane. As compared with the first cavity 124 of the first embodiment, the first cavities 124 of the second embodiment have the same functions or shapes as that of the first embodiment, except that they are separated to correspond to the second guides 118 of the lower plate 100a.

Next, referring to Figs. 4a to 4c, the upper plate 100b of the thin plate-type cooling device 100 according to a third embodiment of this invention will be described in detail. Fig. 4a shows a schematic sectional view taken in the first direction on the X-Y plane of the thin plate-type cooling device 100 of the third embodiment, Fig. 4b shows a schematic sectional view taken along the A-A' line on the Y-Z plane of the thin plate-type cooling device 100 of the third embodiment, and Fig. 4c shows a schematic sectional view taken along the B-B' line on the Y-Z plane of the thin plate-type cooling device 100 of the third embodiment. In this embodiment, the sectional view taken in the first direction shown in Fig. 4a is the bottom view of the upper plate 100b of the thin plate-type cooling device 100.

As shown in the drawings, the upper plate 100b of the thin plate-type cooling device 100 in the third embodiment further includes a plurality of second

cavities 126 formed on areas corresponding to the condensation section 108 of the lower plate 100a. That is, the upper plate 100b includes the plurality of the first cavities 124 formed on areas corresponding to the gaseous coolant transfer section 106 of the lower plate 100a and the plurality of second cavities 126 formed on areas corresponding to the condensation section 108 of the lower plate 100a, where the first and second cavities 124 and 126 are respectively connected to each other.

Moreover, as shown in the drawing, it is preferable that the width of each of the second cavities 126 becomes narrow as it proceeds to the area corresponding to the liquefied coolant transfer section 110. Accordingly, when the lower plate 100a and the upper plate 100b are bound, the sections of the second cavities 126 become small as they proceed to the liquefied coolant transfer section 110 and the surface tension to the liquefied coolant becomes large, so the coolant in the gas state which has not been condensed in the condensation section 108 can return to the first cavity 124 on the area corresponding to the gaseous coolant transfer section 106. Accordingly, since the coolant in the gas state is contained in the coolant in the liquid state in the form of bubbles, it is possible to prevent the coolant in the gas state from reaching the evaporation section 104 more efficiently.

Next, referring to Figs. 5a to 4d, the upper plate 100b of the thin plate-type cooling device 100 according to a fourth embodiment of this invention will be described in detail. Fig. 5a shows a schematic sectional view taken in the first

direction on the X-Y plane of the thin plate-type cooling device 100 of the fourth embodiment, Fig. 5b shows a schematic sectional view taken along the A-A' line on the Y-Z plane of the thin plate-type cooling device 100 of the fourth embodiment, Fig. 5c shows a schematic sectional view taken along the B-B' line on the Y-Z plane of the thin plate-type cooling device 100 of the fourth embodiment, and Fig. 5d shows a schematic sectional view taken along the C-C' line on the Y-Z plane of the thin plate-type cooling device 100 of the fourth embodiment. In this embodiment, the sectional view taken in the first direction shown in Fig. 5a is the bottom view of the upper plate 100b of the thin plate-type cooling device 100.

As shown in the drawings, the upper plate 100b of the thin plate-type cooling device 100 in the third embodiment further includes a plurality of third cavities 128 formed on areas corresponding to the liquefied coolant transfer section 110 of the lower plate 100a. It is preferable that each of third cavities 128 has a semi-oval shape. Moreover, the plurality of third cavities 128 may be formed in a plurality of rows along the liquefied coolant transfer section 110.

In this embodiment, when the coolant in the gas state which has not been condensed in the condensation section 108 is transferred to the liquefied coolant transfer section 110 in the formed of bubbles contained in the coolant in the liquid state, it can be captured by the plurality of third cavities 128. Accordingly, it is possible to prevent the coolant in the gas state from reaching the evaporation section 104 in the formed of bubbles contained in the coolant in

the liquid state far more efficiently.

The cooling device 100 of this invention described above can be manufactured by various methods widely known such as a MEMS (Micro Electro Mechanical System) method or a SAM (Self Assembled Monolayer) method using a semiconductor device manufacturing process. Referring to Figs.1b and 2a, the manufacturing method will be described briefly.

That is, the surface of the lower plate 100a of the thin plate-type cooling device 100 is etched to form the coolant storage section 102, the first tiny channels 120 of the evaporation section 104, the first guides 122 of the condensation section 108, the second guides 118 of the gaseous coolant transfer section 106, and the liquefied coolant transfer section 110.

Then, as described above, the surface of the lower plate 100b is etched to form the cavities 124, 126 and/or 128 and/or the thermal insulation section 116.

After the lower plate 100a and the upper plate 100b where the above structures have been formed are attached to each other, an anodic bonding may be performed by applying a voltage to them, so that they can be unified. Then, the pressure is reduced to make the circulation loop be in the vacuum state through a coolant insertion hole (not shown) formed to be connected to the coolant storage section 102, a predetermined amount of coolant is inserted into it, and the coolant insertion hole is sealed.

Although the present invention has been described by way of exemplary

embodiments, it should be understood that those skilled in the art might make many changes and substitutions without departing from the spirit and the scope of the present invention which is defined only by the appended claims. For example, in the configuration of the first embodiment, the cavity corresponding to the condensation section 108 may be replaced by the cavity of the third embodiment, or the cavity corresponding to the liquefied coolant transfer section 110 may be replaced by the cavity of the fourth embodiment. Moreover, alternatively, an area except the areas the upper plate 100b on which the cavities are formed may also have the same structure as that of the lower plate 100a.

【INDUSTRIAL APPLICABILITY】

According to present invention, by forming one or more cavities having a predetermined shape on the gaseous coolant transfer section, the condensation section and/or the liquefied coolant transfer section in the thin plate-type cooling device, the coolant in the gas state which has not been condensed in the condensation section can be contained or captured, so it is possible to prevent the dry-out phenomenon caused because the coolant in the gas state stays in the channels to the evaporation section and the liquefied coolant cannot be sufficiently supplied.

In addition, according to present invention, by changing the depth, width or shape of the channels to adjust the surface tension of the coolant in the liquid state, the coolant in the liquid state is rushed to the evaporation section without

external power, so it is possible to prevent the dry-out phenomenon in the evaporation section and to sufficiently supply the coolant in the liquid state to the evaporation section all the time.

In addition, according to present invention, surface treatment is partly performed on the lower and upper channels, so the flow of the coolant is improved and the cooling efficiency is increased.

[CLAIMS]

1. A thin plate-type cooling device comprising:

a thin plate-shaped housing in which a circulation loop of a fluid is formed; and

a coolant capable of changing from one state to another, circulating along said circulation loop inside said housing,

wherein said circulation loop inside said housing comprises:

an evaporation section formed on one end of said circulation loop, wherein said liquefied coolant is at least partly filled by a capillary action and said coolant filled in a liquid state is gasified by heat transferred from an external heat source;

a gaseous coolant transfer section formed adjacent to said evaporation section, wherein said gasified coolant is transferred through said gaseous coolant transfer section and said gaseous coolant transfer section has at least one first cavity for containing said gaseous coolant which has not been condensed;

a liquefied coolant transfer section formed adjacent to said condensation section and thermally insulated from said evaporation section, wherein said liquefied coolant is transferred towards said evaporation section; and

a thermal insulation section for thermally insulating said evaporation section from at least a part of said liquefied coolant transfer section.

2. A thin plate-type cooling device as claimed in claim 1, wherein at least a part of said liquefied coolant transfer section comprises a liquefied coolant storage section for storing said coolant in the liquid state.

3. A thin plate-type cooling device as claimed in claim 2, wherein at least a part of said liquefied coolant transfer section comprises a plurality of liquefied coolant storage sections.

4. A thin plate-type cooling device as claimed in claim 2, wherein said liquefied coolant storage section comprises a tiny channel of which surface tension is set to be more than gravity.

5. A thin plate-type cooling device as claimed in claim 1, wherein a cross-section of a tiny channel of said evaporation section and/or said liquefied coolant transfer section becomes small from said liquefied coolant transfer section contacting said condensation section to said evaporation section contacting said gaseous coolant transfer section.

6. A thin plate-type cooling device as claimed in claim 1, wherein said condensation section has at least one second cavity.

7. A thin plate-type cooling device as claimed in claim 1, wherein said liquefied coolant transfer section has at least one third cavity.

8. A thin plate-type cooling device as claimed in claim 1, wherein hydrophilic treatment is performed on surfaces of said liquefied coolant transfer section and said evaporation section, and hydrophobic treatment is performed on surfaces of said gaseous coolant transfer section and said condensation

section.